Results of tbc workshop are summarized, by issue (visual function, testing procedure, diagnosis of other visual impairments and disorders), and presented as follows:

- **Visual Function**

  Visual Acuity—The majority of the panelists agreed that there was no compelling reason to change the binocular visual acuity standard from the current 20/40. Two panelists called for a stricter 20/25 binocular acuity standard with reasons relating to cab vibration effects and personal opinion. The monocularity issue was debated at some length. Most panelists agreed that the available research results linking driver safety to lowered acuity in one eye were sufficient to change the current standard to allow monocular drivers or drivers with vision that is substantially worse in one eye. However, a consensus on the issue of monocularity was difficult to achieve because of the diversity of opinion on the panel.

  Visual Fields—The majority of panelists agreed that some measure designed to screen for visual field defects was important for safety. Some panelists held the view that more rigorous testing, including the vertical meridian as a minimum, would be necessary to make the visual field screening effective. However, doubt was expressed about whether the commercial vision equipment currently available could be adapted to that purpose. The compromise position that was reached specified improved test equipment and procedures for testing along the horizontal meridian. Testing on the vertical meridian was not recommended at this time but was suggested for future consideration. Most of the panelists felt that screening along the horizontal meridian would be sufficient to detect for gross visual field disorders.

  Color Vision—The majority of panelists agreed that there was inconclusive evidence that congenital red-green color-defective individuals were not safe drivers. Evidence to the contrary was cited. Standardization of traffic signal colors and the presence of other environmental cues have virtually eliminated most difficulties for the color-deficient individual. In addition, the current standard does not adequately specify how to test color vision for compliance with the standard. An efficient screening for red-green color-deficiency would be expected to eliminate 8 percent of all males who currently operate CMVs. It should be noted that some panelists felt strongly that eliminating a color vision standard would be very controversial, regardless of the lack of empirical evidence supporting it.

- **Testing Procedures**—Most panelists agreed that the testing procedures for measuring acuity and visual fields needed to be more comprehensive. Visual acuity optotypes, background illumination, and target luminance should follow the 'Recommended Standard Procedures for the Clinical Measurement and Specification of Visual Acuity," as published by the Committee on Vision, National Academy of Sciences (1980). Specifying visual field target size and luminance was recommended, and the need for a test procedure that would provide a repeatable and accurate measure of field limits in the horizontal meridian was discussed.

- **Reporting Visual Impairments and Disorder**—It was generally agreed that the examining physician needs to report visual disorders and impairments, but these should not be the basis for disqualification. A definitive list of conditions was not developed at the workshop. However, panelists were able to recommend what conditions should be included in the list in a post-workshop follow-up survey.

. Special Concerns Raised at the Workshop—A primary issue discussed at the workshop was whether current and alternative approaches would ever be able to determine visual criteria levels that would separate “good' from “bad' drivers. It was questioned whether large sample database studies could provide an objective basis. Suggested alternative objective approaches were simulation of worse-case scenarios and “ride-along” observations of real-world driving, The basic factor to be considered was the practical limitations for using such approaches.

PROPOSED REVISIONS TO THE STANDARD

The proposed revisions and recommendations to the current vision standard for CMV operators were based on findings from the literature review (Synthesis of the Literature in Appendix A), results of the Delphi approach, point-of-view papers from the panel of vision and industry experts, opinions and comments from workshop panelists and participants, and post-workshop follow-up opinions from panelists.

Revisions (ii boldface) were suggested for the visual requirements section of the Federal Standard (CFR 49, 391.41(b)(10), 1985 Physical Qualification for Drivers) and the testing procedures (CFR 49, 391.43 (Head-Eyes), Medical Examination; Certificate of Physical Examination).

VISUAL ACUITY

The current visual acuity standard is recommended This recommendation is based on a lack of evidence or method for objective judgment that an acuity criterion-other than that already established and agreed upon by the majority of panelists and other vision experts-could be selected for CMV operators.

> "Has distant visual acuity of at least 20/40 in each eye. without corrective lenses or visual acuity separately corrected to 20/40 or better with corrective lenses, distant binocular acuity of at least 20/40 in both eyes with or without corrective leases."

The testing procedure for visual acuity should be revised extensively and include type and size of target, contrast type, size, contrast and luminance of target are described, as well as background luminance and testing procedure.

> "**The recommended procedure for testing visual acuity is based on the standard procedures** recommended for clinical measurement as reported by the Committee on Vision of the National **Academy of** Sciences (1980). The standard optotype is the Landolt ring. However, **other** equivalent optotypes, such **as the** Sloan letters as a **group,** are acceptable. Logarithmic sizing should **be used** (i.e., successively larger sizes **should be 126 times** larger than the **preceding** size). Optotype letters **should be** black **on. white background with** a **minimum** contrast **of** 0.85 and a luminance range **for the white background of** 85 **to** 120 cd/m^2. **Under these** conditions, **acuity should be defined as the** smallest **size at** which **7 out of 10 (or 6 out of 8) letters** are **correctly** identified **at** a given distance. **Effective** viewing distance **should** not **be less** than **4 meters.** Regardless **of** viewing distance, acuity **should be** specified in **terms of a** fraction **with 20 as the** numerator and **the** smallest type **that could be** read **at 20 feet** as **the** denominator **(Le.,** 20/20, **or** 20/40). **Although** the Snellen chart departs **from tbe** standard in several **ways, it Is acceptable** if no practical means **of following** the recommended procedure is available. If the applicant wears corrective leases, these should be worn while applicant's visual acuity is beii tested, If appropriate, indicate on the Medical Examiner's Certificate by checking the box, 'Qualified only when wearing corrective lenses'."

(Specifications for reporting acuity and corrective lens status have not been revised.)

VISUAL FIELDS

The current field-of-vision standard was incorrect. The recommended standard should state:

"... field of vision of at least 120 degrees in each eye measured separately in the horizontal meridian,".

The normal, healthy eye actually has a range of 140 degrees in the horizontal visual field. The recommendation is slightly lower than 140 degrees in each eye to allow room for normal variation with age and for errors in accuracy of testing or equipment calibration. It was deemed unnecessary to specify a binocular field since problems in binocularity important to driving will be identified through the acuity test. No empirical evidence was found to justify 120 degrees as the minimum criterion. However, past medical recommendations and consensus on views identified at the workshop provided support for this recommendation.

Recommendations have. also included a description of how to test the visual fields standard.

"The recommended procedure for testing visual fields requires equipment that is able to present a round, luminous stimulus of 0.15 to 025 degrees in angular extent on a low photopic background of 1 to 10 cd/m^2. Stimulus luminance should be 50 to 100 cd/m^2 and duration should be in the range of 100 to 200 msec. Subject fixation should be verifiable. Multiple presentation in random sequence under monocular test conditions must be possible. This will normally require separate test stimulus positions for determining temporal and nasal field limits. Testing must be monocular with one eye blocked. The test procedure should present the nasal and temporal (70 degrees to 80 degrees temporal and 50 degrees to 40 degrees nasal) a minimum of 3 times each in random alternating sequence. Responses are best recorded automatically. If the applicant wears corrective lenses, these are not required to be worn while applicant's visual fields are being checked."

COLOR VISION

The color vision standard presents a special problem because nearly 8 percent of male drivers will have a congenital red-green deficiency if tested appropriately. As stated previously, empirical evidence indicates that such individuals are no less safe to operate any type of motor vehicle than those. with normal color vision. Nevertheless, the consensus view of the workshop panelists is that some form of color standard should be retained, but formal color testing should not be required. In place of formal testing, the medical examiner will determine subjectively that an individual can safely operate in the driving environment. This color information will be extracted by asking if the driver can respond "safely and effectively" to standard traffic signals and devices displaying colors. Individuals with color deficiency will be able to answer on the basis of color, shape, and position. The intent is not to exclude drivers with congenital red-green deficiency, and otherwise normal vision, on the basis of color discrimination alone.

The recommendation is a slight variation from the current standard and specifies that there is no specific color vision test required:

"... and the ability to respond safely and effectively to colors of traffic signals and devices showing standard red, green, and amber. No test for color vision is required.'

VISUAL DISORDERS AND IMPAIRMENTS

Visual and ocular disorders that the physician should note were discussed at the workshop and evaluated again by panelists in a post-workshop survey. It was determined that a portion of the current disorders should be eliminated and other disorders should be added. The following visual disorders and impairments were selected as important (recommended additions in boldface):

- **aphakia**
- cataract
- **corneal scar**
- **exophthalmos**
- **glaucoma**
- macular **degeneration**
- **ocular** muscle imbalance
- **ptosis**
- **retinopathy, and**
- **strabismus** uncorrected by corrective leases.

In addition, "any other condition deemed important" should be added.

COMPLETE STANDARD

If all recommendations are accepted as visual standards for CMV operators, they could be incorporated in the Code of Federal Regulations as follows:

391.41 Physical qualifications for drivers.

(b) A person is physically qualified to drive a motor vehicle if that person . . .

(10) Has distant visual acuity of at least 20/40 in each eye without corrective leases or visual acuity separately corrected to 20/40 or better with corrective lenses, distant binocular acuity of at least 20/40 in both eyes with or without corrective lenses, field of vision of at least 120 degrees in each eye measured separately in the horizontal meridian, and the ability to respond safely and

effectively to colors of traffic signals and devices showing standard red, green, and amber. No test for color vision is required.

391.43 Medical examination; certificate of physical examination.

(a) Except as provided in paragraph (b) of this section, the medical examination shall be performed by a licensed doctor of medicine or osteopathy.

(b) A licensed optometrist may perform as much of the medical examination as pertains to visual acuity, field of vision and the ability to respond appropriately to traffic signals and devices as specified in paragraph (10) of 391.41(b).

(c) The medical examination shall be performed, and its results shall be recorded, substantially in accordance with the following instructions and examination form.

Head-Eyes

The recommended procedure for testing visual acuity is based on the standard procedures recommended for clinical measurement as reported by the Committee on Vision of the National Academy of Sciences (1980). The standard optotype is tbe Landolt ring. However, other equivalent optotypes, such as the Sloan letters as a group, are acceptabk. Logarithmic sizing should be used (i.e., successively larger sizes should be 136 times larger than the preceding size). Optotype letters should be black on a white background of 85 to 120 cd/m^2. Under these conditions, acuity should be defined as the smallest size at which 7 out of 10 (or 6 out of 8) letters are correctly identified at a given distance. Effective viewing distance should not be less tbaa 4 meters. Regardless of viewing distance, acuity should be specified in terms of a fraction with 20 as the numerator and the smallest type that could be read at 20 feet as the denominator (Le., 20/20 or 20/40). Although tba Snellen chart departs from tbe standard in several ways, it is acceptable if no practical means of following the recommended procedure is available. If the applicant wears corrective lenses, these should be worn while applicant's visual acuity is being tested If appropriate, indicate on the Medical Examiner's Certificate by checking the box, "Qualified only when wearing corrective lenses." The recommended procedure for tasting visual fields requires equipment that Is able to present a round, luminous stimulus of 0.15 to 025 degrees la angular extent on a low photopic background of 1 to 10 cd/m^2. Stimulus luminance should be 50 to 100 cd/m^2 and duration should be in tba range of 100 to 200 msec. Subject fixation should be verifiable. Multiple presentation in random sequence under monocular test conditions must be possible. This will normally require separate test stimulus positions for determining temporal and nasal fkld limits. Testing must be monocular dtb one eye black& The test procedure should present the nasal and temporal limits (70 degrees to 80 degrees temporal and 50 degrees to 40 degrees nasal) a minimum of 3 times each in a random alternating sequence. Responses are best recorded automatically. If tbe applkaat wears corrective lenses, these are not required to be worn while applicant's visual fields are beiag checked.

Note aphakia, cataract, corneal scar, exophthalmos, glaucoma, macular degeneration, ocular muscle imbalance, ptosis, retinopathy, strabismus uncorrected by corrective lenses, and aay other conditions deemed important. Individuals with no vision in one eye or vision below standards in one eye as specified la paragraph (1) of 391.41(b) an? disqualified to operate commercial motor vehicles under existing Federal Motor Carrier Safety Regulations. If the driver habitually wears contact leases, or intends to do so while driving, there should be sufficient evidence to indicate that the individual has good tolerance and is well adapted to their use. The use of contact lenses should be noted on the record.

PHYSICAL EXAMINATION

General appearance ...

Vision: For distance:

Visual Acuity:
Right 20/_____ Left 20/_____
___ Without corrective lenses
___ With corrective lenses if worn
Binocular 20/_____
___ Without corrective lenses
___ With corrective lenses if worn
Horizontal field of vision (in degrees)
Right _____ Left _____
Appropriate Response to Traffic Signals/Devices:
Evidence of disease or injury:
Right _____ Left _____

DISCUSSION

This report reviews the important issue of providing empirical support for the visual test criteria as set forth in the CMV vision standard and evaluates progress in developing new methods of vision testing. Although much new material on driver safety and vision has accumulated since the last comprehensive revision of the CMV vision standard in 1970, the new data were found to provide almost the same level of empirical support as had existed previously. This finding continues to require reliance on an informed consensus to evaluate changes to vision test criteria, wording, and recommended procedures of the standard. New tests are currently being developed, and several discussed below show promise of improving on present techniques. However, no single new test or combination of tests was found to provide a level of information sufficiently superior to currently utilized techniques to warrant inclusion in the CMV standard at this time.

NEW AREAS OF VISION TESTING

Recent advances in technology and current research in visual assessment have supported the development of new methods and equipment for testing visual performance. Many of these newly emerging vision testing techniques have been scrutinized for inclusion in driver license applicant testing and renewal programs. Some of the more important of these visual tests are contrast sensitivity, tow-contrast acuity, glare sensitivity and recovery, automated visual field testing, dynamic visual acuity, and useful field of view (UFOV). To date, none of these advances has had a major impact on routine vision screening of the kind appropriate for testiog CMV drivers. In general, the thrust of research in this area has been to add coverage for factors neglected in the more traditional acuity, visual fields, and color tests. For example, contrast sensitivity measures the abiity to resolve spatial detail, as does acuity, but does so at minimum contrast. Glare recovery measures acuity under conditions of an interfering light source. Low-contrast acuity presents a standard acuity test under lower light conditions. Full-field static perimetry measures threshold sensitivity at a large number of visual field locations. One of the most promising of the new approaches is that of combining nonvisual with visual factors as is done in the UFOV test.

Contrast sensitivity testing has been a prominent emerging visual assessment technology for almost two decades. Contrast sensitivity measures the abiity of the visual system to detect variation in adjacent light and dark regions as a function of spatial frequency of how closely spaced the neighboring regions are. Hi spatial frequencies are closely spaced while low spatial frequencies are widely spaced. Contrast sensitivity measurements demonstrate that the ability to see targets of low spatial frequency is statistically independent of the abiity to see high spatial frequency targets such as those presented in visual acuity testing. This measure provides a more complete picture of the performance of the visual system than does visual acuity alone. From an administrative standpoint, commercial vision screeners are available to measure minimum testing ranges of contrast sensitivity in a relatively brief period of time (4-5 minutes).[31] However, full ranges of contrast sensitivity testing require more time and adequate space for viewing. Schieber[37] pointed out other shortcomings of contrast sensitivity testing, including difficulty in specifying the criterion level that clearly separates the abnormal contrast sensitivity function score from the normal score, difficulty in determining the number of measures of contrast sensitivity necessary to make the test accurate enough for USC in screening and questionable reliability of contrast sensitivity measurements to diagnose visual conditions such as cataracts and glaucoma, as claimed by the manufacturers. More research appears necessary to validate the relationship between contrast sensitivity measurements and visual performance necessary **for** driving before recommendations can be made for incorporating contrast sensitivity testing into any type of vision standard or screening procedure for licensing of automobile or commercial vehicle operators.

Low-contrast acuity testing also appears promising for visual assessment. It can provide information about visual disability similar to that provided by contrast sensitivity. Low-contrast optotypes arc substituted for the high-contrast letters normally employed in the acuity test. Proponents of the low-contrast acuity test claim that it rivals the contrast sensitivity function measures in terms of its abiity for making clinical diagnoses of visual disorders such as cataracts, glaucoma, diabetic retinopathy, age-related retinopathy, and ocular hypertension. Low-contrast acuity testing is easy to admiitcr and score. In addition, the low-contrast optotypes could bc easily retrofitted into many of the vision screeners already in use by driver-licensing authorities.

Disadvantages of low-contrast acuity testing include the inability to temporarily modulate test stimuli (i.e., add a motion component) and the difficulty of automating a task that has a limited number of response alternatives (i.e., the 26 letters of the alphabet). Some of these disadvantages can bc overcome. However, the most critical problem is the lack of research showing the relationship of low-contrast acuity scores to visual performance needed for safe driving.(37) This lack of experience with low-contrast acuity testing in the driving context prevents its incorporation into the draft recommendations.

Glare sensitivity testing has emerged as a new vision testing technology that could benefit driver vision screening programs. Glare is a problem for all drivers, but is of special concern for older drivers and can be potentially hazardous for those wearing contact lenses. Testing in this area has the potential for detecting significant but correctable vision problems. The aged arc increasingly more likely to develop cataractous or precataractous ocular opacities that produce marked deficits in the abiity to see under transient-illumination or high-illumination conditions (e.g., opposing headlamps during nighttime driving, high-mast roadway lighting, driving toward the brightly illuminated sky at dawn or dusk). Similarly, contact lens wearers may suffer from excessive sensitivity to glare resulting from the complications of contact lens wear, possibly related to worn or damaged contact lenses or to corneal inflammation secondary to contact lens wear.(37) These conditions are susceptible to treatment. CMV drivers who wear contacts and have glare problems could benefit from such testing. Some commercial glare sensitivity testing equipment is available and these tests can be administered in a small amount of time. However, no empirical evidence glare sensitivity performance with measures of driving performance has been repotted Acceptable levels of glare for driver safety have not been determined. This lack of generally accepted procedures and a consensus on cutoff criteria appropriate for CMV driver safety prevent including glare sensitivity testing from being included in recommendations for CMV visual requirements at this time.

Automated visual field testing has been proposed in recent years as a technology that could be used to greatly increase the sensitivity and validity of visual field testing in CMV driver licensing. Automated perimetry provides light detection threshold measurements at regularly spaced intervals throughout the visual field and has found a substantial clinical role in detection **of** retinal, optic nerve, and cortical disorders. Its automated feature improves upon the manual Goldmann type of visual field testing that has provided the clinical standard These tests provide a vastly better assessment of visual field performance than the commercial screeners used by many state licensing agencies, which test only a few points along the horizontal field axis. However, the procedure takes up to 30 minutes to complete for both eyes and is tiring to the patient. Johnson and Keltner[29] have evaluated the relationship between the visual field deficits as measured by automated perimetry and driving performance, as well as the feasibility of using the device for mass driver screening. They report that drivers with visual field loss in both eyes have a traffic accident and conviction rate twice as high as that of age- and sex-matched observers and of patients with constricted visual fields as the result of retinitis pigmentosa. For this study, a reduced resting protocol was used so that the total testing time for a full-field static assessment in one eye would take less than 5 minutes. However, the high cost of equipment and the inability to incorporate other visual tests (such as visual acuity) in the same equipment make this technology impractical for inclusion in the CMV vision standard at this time.

Dynamic visual acuity testing has consistently shown promise for use in driver licensing vision testing but has failed to gain general application. Bailey and Sheedy[34] state that even though studies have shown dynamic visual acuity to be more strongly related to accident rate than other visual attributes, the correlation is not strong enough to justify its inclusion as a vision standard The considerable amount of research devoted to dynamic visual acuity has not led to acceptance of standardized testing procedures by eyecare professionals or to incorporation of acuity testing into commercial vision screening equipment. As with glare and contrast sensitivity, the lack of wide acceptance and the difficulty of setting valid and defensible cutoff criteria for CMV drivers make this test impractical for inclusion in the CMV vision standard at this time.

The concept of testing for a useful field of view (UFOV) combines attentional factors with visual field measurements. The rationale behind this approach is that it is not the visual field that counts most for safety. It is rather the level of useful information that can be extracted from a given field configuration. In the UFOV test, the observer must discriminate the test object from similar test objects and report its position in terms of a limited number of locations in the field of view. The basis of discrimination can be varied. The UFOV test appears to depend on the earliest, preattentive (parallel-pr-ing) stage of visual attention. It tests a subject's ability to capture and direct attention to highly salient visual events, a skill which seems crucial for effective driving, especially for CMV drivers who require exaggerated lead times for hazard recognition. The UFOV test incorporates measures of divided attention, selective attention, and speed of visual information processing to arrive at an overall measure of attentional capacity. This approach is thought to represent more realistically the real-world situation in which visual judgments essential to driving safety must be made.

Correlations of UFOV test results (38) with measures of driving safety are reportedly as high as r=0.55, which is considerably higher than reported for tasks dependent only on primary visual processing. The emerging evidence suggests further research to develop assessment approaches incorporating attentional as well as purely sensory visual capabilities. This area of investigation is expected to have a strong impact on revising standards for driver qualifications. However, several problems remain before this test can be considered for inclusion in the CMV vision standard. Even a correlation as high as r=0.55, as reported for the UFOV task, would not be sufficient to overcome the problem of a high false-positive rate, which is a problem for every vision test applied to the task of discriminating safe from unsafe drivers. Second, although equipment is currently beii developed to allow use of the UFOV test in a rapid screening context, specific criterion levels for "good" versus 'poor" UFOV levels relative to driver safety have not been dearly established In addition, the nature of this task is substantially different from the one currently included in the CMV vision standard, and present experience is insufficient to judge the likelihood of practical acceptance by both testing agencies and the CMV industry

This area of research is perhaps the most promising of those reviewed The experience with UFOV testing and other techniques that combine visual testing with behavioral assessment shows that progress can be and has been made. That the current tests need improvement is not in question. The lack of progress in devising highly predictive tests that rely solely on visual performance criteria points out the need to include more than vision in screening for unsafe drivers.

ENFORCEMENT PROCEDURES

The basis for enforcement of the current CMV vision standard is the required medical exam. At present, the general care physician must perform or verify the specitic visual tests for acuity, visual fields, and color perception, then note the list of ocular abnormalities. Physicians are not selected, trained, or certified in any way to perform these tasks as required for CMV driver testing, unless they have sought training voluntarily. An inescapable consequence of this arrangement is that testing will not be carried out on a satisfactorily uniform level. Several factors contribute to this situation: (1) free selection of an examining physician by a driver or employer, (2) uneven training and experience on the part of the physicians, and (3) nonstandard or inadequate equipment available to the examiner. These issues could be addressed individually, and in some states this approach will be the preferred course for strengthening enforcement of the vision standard. However, a more practical, effective, and efficient approach in many of the most populous states may be to encourage the state licensing authority to adopt vision standards in conformance with the Federal standard and to test drivers on the state level for the class of vehicle defined as commercial at the Federal level Many states are already in conformance with the Federal vision standards, or could be with minor changes to either their vision requirements or their vehicle class definitions. Moreover, the states that are in conformance are among the more industrialized and populated states and have a large proportion of the interstate commercial drivers. AU states require a vision exam for license application and have a visual acuity screening standard. However, only 72 percent of the states conduct periodic vision screening, which would be necessary for conformance to the CMV regulation. In addition, some states have different vision testing requirements by license class (e.g.. passenger vehicle, intrastate truck, school bus), but most states would have to institute a commercial classification that included vehicles defined under the Federal regulation. An advantage and incentive for adopting this approach would be that drivers in states where the vision standard is met would be exempt from the vision part of the medical exam.

If the state enforcement option is not feasible for political, economic, or other reasons, licensed ophthalmologists or optometrists, specifically trained and knowledgeable on the Federal CMV vision standard, should administer the vision exam. It is most likely that the general practitioners and physicians who are not routinely familiar with the standards would not have the vision equipment necessary to administer the testing requirements and may be reluctant to disqualify CMV drivers. This reluctance may be based on an unwillingness to adhere to the requirements of the vision standard or because this action might jeopardize a tong-term relationship with the patient and/or family.

Recommendations concerning enforcement are as follows: (1) Wherever feasible, have the vision part of the medical exam performed by an eye care specialist, either an ophthalmologist or optometrist; (2) Encourage state driver testing authorities to adopt both the Federal Vision Standard and the Federal definition of CMV drivers as a minimum for intrastate licensing and repeat testing, (3) when states are in conformance with the Federal standards, grant exemption on the vision part of the medical exam to that state's CMV drivers.

For documentation and proof of visual fitness, the medical examiner's certificate (medical card) should reflect that the visual tests and eye exam were conducted by a licensed ophthalmologist or optometrist. Date of examination, name of examiner, medical license number, certificate of qualification to test CMV vision standard license number, address of office and examiner's signature should be included as well. Requirements for carrying the medical card on the person and keeping a copy of the medical certificate in the vehicle should be left as specified in the current standard.

NEW APPROACH FOR PROVIDING EMPIRICAL SUPPORT

The reason for the apparent failure, even of large-scale correlational studies of vision scores and measures of driver safety, to provide empirical evidence useful in support of the vision standard does not reflect a lack of intense or directed effort. On the contrary, these studies were comprehensive and still failed to fmd definitive empirical results. This leads to the conclusion that the problem cannot be solved by broad-based correlational studies of their relationship to primary visually mediated performance. The fundamental reason is the extensive overlap of the vision test scores of safe and unsafe drivers coupled with the fact that most potential drivers with poor vision are already screened off the road by vision tests and cannot contribute to the statistical base. Vision is only one component of driver safety.

On the other hand, it is clear tbat some level of reduced vision is unsafe. Can other means be used to establish empirically meaningful limits? Two possibilities were discussed at the workshop. The first is to study worst-case simulated scenarios and the second is to employ a ride-along method for gathering real-world data on driving performance and mishaps. The worst-case simulation method might employ a full-scale driving course that presents simulated hazards and emergency situations of varying degrees of difficulty and at extremely high encounter rates compared to the real-world situation. This approach would produce driving errors, as data for measurement, at a rate high enough to be. statistically useful for evaluating drivers with normal and less than normal vision. These data might provide a basis for setting minimum vision standards for given situations on the course. This approach would be extremely expensive and still present the problem of validating the course situations with real-world needs for safety. To some extent, this problem could be addressed by comparing scores of normal and below-normal vision drivers. Compared to worst-case simulation, the ride-along technique has the advantage of providing real-world data. However, a prohibitive amount of observer time would be required to accumulate meaningful data on the rare serious accidents that are the major safety concern (not to mention the danger to the observer). Data on more routine mistakes and mishaps would again suffer from the problem of establishing relevance to the incidence of more serious accidents.

An increasingly feasible technical alternative to either of the approaches just described is computer simulation of the driving task. This approach would have the advantage of presenting scenarios of varying type and degree of difficulty at the discretion of the researcher, and would present no danger, either to the driver or to the observer. Cost would be significant in the development phase, but would be much less than a real simulation at every level. The major problem is the degree of realism that could be achieved. Technology in the area of graphics presentation is improving rapidly and ik cost is decreasing. If the problems of relating simulator performance to real-world safety considerations can be adequately addressed, this technology would appear to offer the greatest promise of providing additional support for the CMV vision standard.

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APPENDIX A

SYNTHESIS OF THE LITERATURE

This synthesis of the literature (originally the Task A Report) comprises the history of the vision standard, the intrastate vision standards, international standards guidelines of professional and government organizations, and evaluation of empirical evidence.

HISTORY OF THE VISION STANDARD

In the late 1930s, the Federal Government began regulating the vision standards for drivers of CMVs in interstate commerce. (These regulations have appeared in the Federal Register (FR) and tbe Code of Federal Regulations (CFR).) Since that time, the standard has been changed steadily in the direction of requiring more stringent visual capability. The vision standard for drivers of interstate trucks was specified originally in a general standard for medical fitness. The standard was very general and stated the following:

> "Good eyesight in both eyes (either without glasses or by correction with glasses), including adequate perception of red and green colors" (Federal Register, 1923(c), c.1938).[1]

By 1939, the standard was modified to contain specific minimum requirements for visual acuity, visual fields, and color vision:

> "Visual acuity (either without glasses or by correction with glasses) of at least 20/40 (Snellen) in one eye, and 20/100 (Snellen) in the other eye; form field of not less than 45 degrees in all meridians from the point of fixation; ability to distinguish red, green, and yellow" (4, Federal Register, 2295, 1.22, June 7, 1939).[2]

Historical documentation confirms that the standard remained the same through 1944 (9, Federal Register, 192.2(b), 1944).[3] It wasn't until 1964 that the standard was changed to include more stringent requirements in visual acuity and visual field. The minimum requirement for visual acuity now became: "... at least 20/40 (Snellen) in each eye . . . . In addition, the visual field requirement was restated to include only the horizontal meridian: . . . . form field of vision in the horizontal meridian shall not be less than a total of 140 degrees.' The visual field specification does not require that each eye be tested separately, but appears to imply with the word 'total" that binocular coverage should add up to at least 140 degrees. The abiity to distinguish color requirements (red, green, and yellow) did not change. The standard now stated that drivers requiring correction by glasses "...shall wear properly prescribed glasses at all times when driving. (29, Federal Register, 8420, 191.2(b), July 3, 1964).[4]

The standard was retied again in 1970 to include the words 'distant" and "binocular" in specifying visual acuity. The standard now stated that a driver must have'... distant visual acuity of at least 20/40 (Snellen) in each eye...' and "...distant binocular acuity of at least 20/40 (Snellen) in both eyes with or without corrective leases." However, the field of vision standard was now changed to "... at least 70 degrees in the horizontal meridian in each eye...," which is markedly different from the 1964 standard requirement, "... not be less than a total of 140 degrees...' in the horizontal meridian. The intent of this 1970 revision to the visual field requirement is not dear. It appears that part of the intent of the 1970 revision was to restate the requirement in terms of monocular testing, which is the normal medical practice. However, the extensive overlapping of binocular fields means that a binocular specification cannot simply be divided by two to arrive at a monocular specification. It is certainly not reasonable to assume that the purpose of the 1970 standard was to make the visual field requirement much less stringent than even the 1939 specification. It is also not certain that a simple error was committed and that the monocular field was supposed to be 140 degrees. Because of this ambiguity in the statement of the standard, which is still current, a reevaluation of the wording and intent of the visual fields specification is necessary. Additionally, the 1970 color requirement was revised to specify traffic control devices and their colors. The wording changed from "abiity to distinguish colors red, green, and yellow" to "ability to recognize the colors of traffic signals and devices showing stand&d red, green, and amber" (35, Federal Register, 6463, 391.41 (b)(10), April 22, 1970).[5]

Also in 1970, two separately dated changes were made to the requirement for drivers with prescription lenses. First, dated in April of 1970, the requirement for spectacles was relocated from the vision specification to Section: 392.2 (a) Spectacles to be worn." The new regulation was stated as follows:

> "A driver whose visual acuity meets any of the minimum requirements of section 391.41 of this subchapter only when he wears corrective lenses shall wear properly prescribed spectacles at all times while he is driving" (35, Federal Register, 6466, 3929 (a), April 22,1970).[6]

Secondly, dated in November of 1970, the title of the spectacle section was changed to "Corrective lenses to be worn" in order to cover the wearing of contact lenses. The regulation now included a provision that a driver could wear prescribed contact lenses instead of prescribed spectacles. The provision also required the driver to 'have a spare lens or set of lenses on his person" when driving.

The most current printing of the standard[7] in the Code of Federal Regulations (49, CFR, 391.41 (b) (10), October 1, 1985) has not changed since November of 1970 and is described in the following paragraphs.

As part of the effort to update the vision standards, the Federal Highway Administration, Office of Motor Carriers (FHWA OMC) is addressing the correction of the possible error in the 70-degree horizontal meridian field.[8]

The Code of Federal Regulations, Subpart E-Physical Qualifications and Examinations Sections 391.41 to 391.49[9] specifies medical standards required to be met by operators of CMVs in interstate commerce (see Appendix C). The commercial driver must be medically examined at least every 2 years and, while on duty, a driver must have a certificate showing that he or she has passed the required examination. The required examination encompasses the general health of the individual as well as setting specific standards for vision and audition. It also precludes individuals from driving if they have certain medical conditions such as specific heart conditions and, important for vision, diabetes mellitus which must be controlled by insulin.

The visual requirements for CMV drivers are included in Section 391.41 [7] and are stated as follows:

> "Has distant visual acuity of at least 20/40 (Snellen) in each eye without corrective lenses or visual acuity separately corrected to 20/40 (Snellen) or better with corrective lenses, distant binocular acuity of at least 20/40 (Snellen) in both eyes with or without corrective lenses, Geld of vision of at least 70 degrees in the horizontal meridian in each eye, and the abiity to recognize the colors of traffic signals and devices showing standard red, green, and amber" (49, CFR, 391.41(b)(10), 1985).

In addition, Section 391.43[9] states that the medical examination can be performed by a licensed doctor of medicine or osteopathy, and a licensed optometrist can perform as much of the medical examination as pertains to visual acuity, field of vision, and the abiity to recognize colors as specified in CFR 49 paragraph (10) of 391.41(b). Few instructions for performing and recording the physical examination are given, but instructions regarding specification of visual acuity, prohibition against monocular vision, contact leas tolerance, and certain common eye conditions are as follows:

> "When other than the Snellen chart is used, the results of such test must be expressed in values comparable to the standard Snellen test. If the applicant wears corrective lenses, these should be worn while applicant's visual acuity is beii tested. If appropriate, indicate on the Medical Examiner's Certificate by checking the box,

'Qualified only when wearing corrective lenses.' In recording distance vision use 20 feet as normal. Report all vision as a fraction with 20 as numerator and the smallest type read at 20 feet as denominator. Note ptosis, discharge, visual fields, ocular muscle imbalance, color blindness, corneal scar, exophthalmos, or strabismus uncorrected by corrective leases. Monocular drivers are not qualified to operate commercial motor vehicles under existing Federal Motor Carrier Safety Regulations. If the driver habitually wears contact lenses, or intends to do so while driving, there should be sufficient evidence to indicate that he bas good tolerance and is well adapted to their use. The use of contact leases should be noted on the record' (49, CFR 391.43, 1985).

As described above a problem exists in the statement of the visual field requirement. The standards, as published in the Federal Register[5] since 1970, states that a 70-degree field of view is the minimum requirement for each eye. The Federal Highway Administration has taken the position that the visual field standard should specify that 140 degrees of visual field is required in each eye. However, the evolution of the visual field specification appears to leave some doubt as to what the actual specification of horizontal field extent should be. The later section, listing international visual standards, indicates that there is no obvious consensus on visual Geld requirement, with 5 countries or provinces of the 15 listed not specifying a standard, 5 not providing a specific number (stating only the visual field should be normal or full), and the 5 remaining countries specifying numbers between 120 and 150 degrees for each monocular field and 170 degrees for a binocular field.

The color vision requirement of the 1970 CMV vision standard also presents the problem of beii unenforceable on a practical basis. The requirement now states that a driver must be able "... to recognize the colors of traffic signals and devices showing standard red, green, and amber.' As stated, this requirement does not specify relevant stimulus parameters, such as stimulus size, stimulus luminance, and wavelength composition or chromaticity that are critical in determining whether different classes of color-defective observers will be able to pass the test. To a certain extent, the wavelength composition of the stimulus is inferred by the phrase "...showing standard red, green, and amber." Presumably, the *standard' referred to is that set by the National Bureau of Standards (NBS),[10] which specifies the colors of traffic control signals in the United States.

Specific reference to the NBS or an interpretation of the color standard for the purpose of color testing would clear up that part of the stimulus problem related to chromaticity specification. However, an even more difficult problem would remain which relates to the visual angle of subtense of the test color and the intent of the CMV vision standard in restricting color-defective individuals from driving. This problem arises because the ability of red-green color-defective individuals varies significantly with the angle of stimulus subtense.[11,12] For large angular subtense (larger than 5 to 8 degrees, depending on the observer), even red-green dichromats can recognize the difference between red, green, and yellow spectral lights. These same observers are totally unable to distinguish colors in this spectral range for small lights subtending 2 degrees or less. Thus dichromats will typically "pass" a color test which presents large enough stimuli that are well saturated and reasonably bright, but will fail any classic test of red-green color vision such as pseudoisochromatic plates (colored dots of one color that show a number or pattern within colored dots of another color) or small field spectral color matching (anomaloscope testing).

If it is the intent of the color requirement of the CMV standard to exclude red-green color-defectives from driving (and this is doubtful for reasons stated above), then color testing methods most be respecified to accomplish this goal. Simply presenting colored circles printed on paper or viewing colored lights from a distance that will produce a large field of view will not screen out red-green color-defectives. In practice, individuals in this category are not being denied CMV licenses under current enforcement conditions. In fact, there seems to be no evidence that would warrant the exclusion of this class of drivers from the road

INTRASTATE VISION STANDARDS

Recommendations provided in tbis project may be partially based on the administrative ability of the states to manage vision screening programs for commercial drivers. Vision standards and testing procedures for acquiring and maintaining a license to operate a commercial vehicle intrastate were obtained from National Highway Traffic Administration (NHTSA) Guidelines for Motor Vehicle Administrators, State and Provincial Licensing Systems-Comparative Data[13] and contact with administrators from state licensing bureaus. Table A.1 compares the state vision standards for intrastate CMV drivers.

Practically every state administers a vision test for individuals applying for any type of motor vehicle license. Vision standards vary slightly from state to state, but every state that conducts visual screening has a visual acuity requirement for intrastate commercial vehicle licensing. Other visual requirements vary considerably in different states, with many states requiring visual fields testing, and several requiring color testing. Some states even have. a stereopsis requirement.

For the most part, state visual standards for intrastate commercial driver licensing are less stringent than the Federal standard for interstate commercial driver licensing. For example, even though a binocular (best corrected) visual acuity requirement of 20/40 is the standard in almost SO percent of the states, less than 10 percent of the states deny a license for monocularity. In addition, approximately 38 and 36 percent of the states have a visual field standard for each eye and both eyes, respectively. These standards range from 70, 90, and 140 degrees in each eye to 70, 110, 120, 140, and 180 degrees in both eyes. Nearly 24 percent of the states have a color perception standard and for most states the standards are for red, green, and amber. In addition, 12 percent of the states have a stereopsis standard

Periodic vision screening is administered in 72 percent of the states. Discussions with licensing bureau administrators in nine of the larger populated states (CA, FL, MI, NJ, NY, NC, PA, TX, and VA) indicated that periodic vision testing varies. Reports indicated that thee states require vision retesting every 2 years, five states require every 4 years, and one state requires every 5 years.

Table Al. Comparison of State Vision Requirements for CMV Operators

STATES	VISUAL ACUITY		VISUAL FIELD		COLOR	OTHER	RETEST
	Monoc	Binoc	Monoc	Binoc			
Alabama		20/70	No	No	No	No	No
Alaska		20/40	No	No	No	No	Periodic
Arizona		20/40	No	No	No	No	Periodic
Arkansas		20/50	NS	NS	NS	NS	NS
California		20/40	70,70	NS	R,G,A	NS	Periodic
Colorado		20/40	Yes	Yes	Yes	ST	Periodic
Connecticut		20/40	Yes	Yes	Yes	ST	No
Delaware		20/40	No	No	No	No	Periodic
Florida		20/70	No	No	No	No	Periodic
Georgia		20/60	140,140	140	No	No	Periodic
Hawaii		20/40	70,70	140	R,G,A	ST,EC	Periodic
Idaho		20/40	NS	NS	NS	NS	Periodic
Illinois		20/40	70,70	140	NS	NS	Periodic
Indiana		20/50	No	No	No	NS	Periodic
Iowa		20/70	No	No	No	NS	Periodic
Kansas		20/40	NS	NS	NS	NS	Periodic
Kentucky		20/45 PV	No	No	No	No	No
Louisiana		20/40	No	No	No	No	Periodic
Maine		20/40	NS	NS	NS	NS	No
Maryland		20/40	140,140	140	No	No	Periodic
Massachusetts		M/M	90,90	120	Yes	No	Periodic
Michigan		20/40	70,70	140	NS	NS	Periodic
Minnesota		20/40	NS	NS	NS	NS	Periodic
Mississippi		20/40	90,90	180	No	ST	No
Missouri		20/40	55,55	No	No	No	Periodic
Montana		20/40	75,75	No	Yes	ST	Periodic

Table A.1 Comparison of State Vision Requirements for CMV Operators (Cont'd.)

STATES	VISUAL ACUITY		VISUAL FIELD		COLOR	OTHER	RETEST
	Monoc	Binoc	Monoc	Binoc			
Nebraska		20/40	70,70	140	Yes	No	Periodic
Nevada		20/40	No	No	No	No	Periodic
New Hampshire		20/40	NS	NS	NS	NS	Periodic
New Jersey		20/40	70,70	No	R,G,A	No	NS
New Mexico		20/40	NS	NS	NS	NS	Periodic
New York		20/40	NS	NS	NS	NS	Periodic
North Carolina		20/50	No	70	Yes	No	Periodic
North Dakota		20/40	70,70	140	No	No	Periodic
Ohio		20/40	70,70	No	No	No	Periodic
Oklahoma		20/40	No	No	No	No	No
Oregon		20/40	No	110	No	No	No
Pennsylvania	No	20/40	No	140	No	No	No
Rhode Island		20/40	60,60	120	Yes	No	Periodic
South Carolina		PV	NS	NS	NS	NS	Periodic
South Dakota		20/40	No	No	No	No	Periodic
Tennessee		20/40	No	No	No	No	No
Texas		20/50	No	No	No	No	Periodic
Utah		20/40	NS	NS	Yes	ST	Periodic
Vermont		20/40 PV	NS	NS	NS	NS	No
Virginia		20/40	100,100	100	No	NS	Periodic
Washington		20/40	No	140	R,G,A	No	Periodic
West Virginia		20/40	No	No	No	No	No
Wisconsin		20/40	70,70	140	No	No	Periodic
Wyoming		20/40	No	No	No	No	Periodic

Key to Table 1: Visual acuity is expressed in Snellen notation; visual field is given in degrees along the horizontal meridian; color abbreviations: R = red, G = green, A = amber, Y = yellow, and B = blue; abbreviations for other conditions: AK = aphakia, DP = diplopia, EY = eye coordination, HM = high myopia, NB = night blindness, NG = nystagmus, and ST = stereopsis (absence of); NS = standard not specified; No = no standard; PV = default to private vehicle standard.

INTERNATIONAL VISION STANDARDS

The United States vision standard for CMV drivers has evolved over a period of more than 50 years to meet the perceived requirements of American roads. During this same period, similar standards have been evolving in other industrialized countries, but not necessarily in driving environments comparable to those found in the United States. It is impossible to know the extent to which the standards in the industrialized countries have influenced each other during their evolution. Certainly, it is reasonable to assume that some transfer of information has occurred, especially among English-speaking countries and countries of the European community. However, regardless of the history of how this information was spread, a survey comparing specific vision standards for drivers of CMVs in the industrialized countries can shed some light on the limits of vision thought to be reasonable by different national organizations. The results of this survey are presented next.

Current information on foreign vision standards of CMV drivers was obtained through correspondence with international standards, medical, and commerce organizations in January and February of 1991. In addition, vision standards for countries in the European Common Market were obtained from the British Association of Optometrists[14] and from a 1985 review article by Charman.[15] Table A.2 provides a summary of international vision standards for a selection of industrialized countries considered to be representative of the spectrum of response. Standards for visual acuity, visual fields, color vision, other conditions, and retesting are listed in tbe table.

Review of the foreign vision standards for CMVs revealed a wide disparity among the countries that offered information on visual standards. Visual acuity for each eye is specified with most countries requiring more than the current 20/40 Federal requirement. Only a few countries have binocular acuity requirements that are more stringent than the Federal 20/40 requirement. For visual fields, most countries state that the drivers have "normal" fields or "full" fields. Only 4 of 15 countries specified the visual field range for each eye (e.g., 120, 125, and 150 degrees). Most of the countries do not have a requirement for color, 2 of 15 did specify requirements for red, green, blue, amber, and yellow. Vision standards for CMV drivers vary significantly from country to country. Nine of 15 countries have other visual requirements, such as stereopsis, and will deny licensure for visual disorders and impairments such as aphakia, ametropia, diplopia, myopia, night blindness, and nystagmus. Eight of 15 countries reported that they require periodic checks for vision. The time between rechecks ranges from annually to every 2, 3, or 5 years. Some countries do not start periodic vision programs until drivers reach certain ages (e.g., 50, 60, or 65).

Table A.2. Summary of International Vision Standards for CMV Operators

COUNTRY/ Province	VISUAL ACUITY Monoc	VISUAL ACUITY Binoc	VISUAL FIELD Monoc	VISUAL FIELD Binoc	COLOR	OTHER	RETEST
Australia / Queensland	20/30 20/30	NS	NS	170	R,A,G	Deny Aphakes	NS
South	20/30 20/40	NS	Normal + 45	NS	NS	Deny Aphakes	3 yrs
West	20/30 20/60	20/30	NS	NS	NS	NS	NS
Victoria	20/40 20/40	NS	NS	NS	NS	NS	3 yrs >60, 1 yr
Belgium	20/40 20/65	NS	125 125	NS	Deny Protanope	Deny NB,NG, DP	3 yrs
Canada /Ontario	20/30 20/50	NS	120 120	NS	NS	NS	3 yrs >65, 1 yr
Denmark	20/40 20/80	NS	NS	NS	NS	NS	NS
Italy	20/27 20/50	NS	Normal Normal	NS	Normal	Normal Stereop	NS
Japan	20/40 20/40	20/25	NS	NS	R,Y,B	Normal Stereop	NS
Netherlands	20/25 20/40	20/25	150 150	NS	NS	Deny NB,DP	>50, 5 yrs
Sweden	20/25 20/50	NS	Normal Normal	NS	NS	NS	2 yrs
Switzerland	20/20 20/25	NS	Normal	NS	NS	Deny NB,ST,HM	5 yrs >50, 3 yrs
United Kingdom	20/30 20/40	NS	Full Full	NS	NS	Deny DP,HM,AP	NS
West Germany	20/20 20/25	NS	NS	NS	NS	NS	NS
EEC	20/27 20/40	NS	No Field Loss	NS	NS	Deny DP,NB	Periodic

Key to Table 2: Visual acuity is expressed in Snellen notation; visual field is given in degrees along the horizontal meridian; color abbreviations: R = red, G = green, A= amber, Y = yellow, and B = blue: abbreviations for other conditions: AK= aphakia, DP = diplopia, HM = high myopia, NB = night blindness, NG = nystagmus, and ST = stereopsis (absence of); NS = standard not specified

GUIDELINES OF PROFESSIONAL AND GOVERNMENT ORGANIZATIONS

This section presents vision recommendations for CMV operators by the American Medical Association (AMA) and the U.S. Department of Transportation, National Highway Traffic Safety Administration, and American Association of Motor Vehicle Administrators (USDOT, NHTSA, and AAMVA).

VISION RECOMMENDATIONS OF THE AMA

The task of enforcing the Federal vision standard for operators of CMVs falls primarily to medical doctors who have a minimal amount of training in methods for visual testing. The AMA has historically participated in setting the Federal vision standards and bas provided guidelines[16] for vision testing to its members. The guidelines published in 1986 differ from the Federal vision standard in excluding high-power spectacle lenses (10 diopters or greater) and in requiring visual acuity in each eye of 20/25 or better compared to 20/40 for the CMV standard. In addition, other visual disorders are discussed, including stereopsis, nighttime vision, diplopia, and oscillopsia, but specific recommendations for excluding drivers with these conditions are avoided.

Class I drivers are qualified to operate any vehicle, including large, heavy articulated trucks and vehicles, and trucks transporting hazardous materials, such as fuel, chemicals, explosives, and radioactive substances. Excerpts from the AMA vision recommendations for Class I drivers only are given below:

- Central Visual Acuity–Central visual acuity should be assessed at a standard distance of 20 feet with optimal refractive correction. The assessments should *exclude* the use of extremely high-power spectacle lenses in the range off 10 diopters (D), binoculars, telescopes or low-vision-aid spectacles or compound magnifying systems, because such leases distort and reduce the visual fields of the wearer. In all instances, the driver's acuity should be demonstrated promptly.

  It is recommended that drivers in Class I have central visual acuity of 20/25 or better in each eye with or without conventional spectacle correction. Spectacle correction of 10 D or more in either eye should be disqualifying. A driver may be tested with contact lenses if he or she can wear them all day.

- Field of Vision–The Goldmann 30-centimeter radius bowl perimeter has become the **reference** standard for testing visual fields since its introduction in 1945. However, less cumbersome and less expensive equipment may be wed . . . .

In testing fields of vision, the examiner may use confrontation testing with eye-to-eye fixation by examiner and examine. The examiner measures awareness of a cotton-tip applicator or a moving finger at the periphery and compares it with his or her own visual fields, which must be normal.

Alternate methods of testing utilize the American Automobile Association's table model field-of-vision tester, which is 20 inches in diameter and encompasses approximately 220 degrees horizontally; the Titmus push-button perimeter arc, adapted to the top surface of a Titmus vision tester, the simple hand-held Schweigger and Spiller rotating arc perimeters; and the hand-held C Perimeter. For screening purposes, the testing is confined to the horizontal arc and utilizes a 3-millimeter white target against a 330-millimeter radius are or a Goldmann perimeter using the III 4e target.

For Class I drivers, each eye is tested separately while the other eye is obscured by an opaque occluder, preferably one that is tied around the head The patient's spectacles or contact lenses should be worn during the visual field examination. Each eye should have visual field recognition throughout an arc of 140 degrees or more. Individuals wearing spectacles with lenses exceeding 10 D or utilizing heavy spectacle frames generally cannot meet this standard

- Color Vision–The completely color-blind or achromatic individual usually has poor central visual acuity and also may have visual field loss. The widespread modification of adding yellow to red and adding blue to green traffic signals has reduced the problem of red-green visual confusion, even in persons with significant deficiencies of red or green sensitivity.

Class I drivers should be able to distinguish the basic traffic control colors, red, green, and amber, with each eye separately.

- Stereopsis–Stereopsis is almost exclusively a function of near vision and it is tested by near-range equipment, such as a Verhoeff stereopter, the Wirt-Titmus double-printed polaroid vectograms, or random dot stereograms. Distance depth perception in driving does not relate. to near-range stereopsis and it can be satisfactorily tested only with a road driving test. Testing of this function is not required to determine a driver's medical qualifications.

- Nighttime Vision–Nighttime or mesopic visual functions...are classified as (1) night vision or central acuity under reduced illumination; (2) glare tolerance or central acuity against a standardized glare light source; and (3) glare recovery time, as expressed in seconds necessary to regain satisfactory night vision after exposure to disabling glare. Economical and reliable testing procedures are not generally available and results often are not reproducible.

(For Class I drivers)...the physician testing nighttime vision should attempt to detect morphologic and structural alterations of the eye that are known to affect it and its mesopic functions, such as corneal opacities; dystrophies or scars affecting the pupillary portion of the cornea; lens opacities, particularly those involving the pupillary or central portion of the lens; pigmentary degeneration of the retina;

optic atrophy, degeneration of the maculae; or significant arteriosclerotic, diabetic, or hypertensive retinopathy.

- Diplopia and Oscillopsia–Binocular vision and fusion are the product of highly specialized and precise neurological functions. Factors known to impair these functions are alcohol ingestion, hypoxia, and fatigue. Individuals vary greatly in their fusional capacities and in their tolerance of the impairing factors. A driver who develops diplopia soon will learn to close an eye to suppress one of the images. The occurrence. of diplopia is relatively rare, but its presence could interfere with the safe operation of a motor vehicle.

  Among the many neurological diseases that may produce diplopia is multiple sclerosis. A high proportion of patients with that condition have nystagmus of a rapid, jerky type that may cause some blurring of the visual image. Gaze palsies of supranuclear origin and conditions involving the extraocular muscles or sixth cranial nerve also can cause diplopia. Ptosis due to a condition affecting the third nerve may reduce the visual field Acute optic neuritis reduces vision on the side of the affected nerve; symptoms may clear in days or weeks but recurrences are frequent.

  To be medically qualified for a Class I . . . license, the driver should have a waiver from the examining physician based on long-standing functional adaptation.

- Transient States Affecting Vision–(The guidelines describe reasons for transient obscuring of vision, including physiological disorder, dilating pupils during eye exams, temporary monocular states, and problems with contact lenses. However, no specific recommendations are made for Class I or other class drivers.)

MSION RECOMMENDATIONS OF USDOT/NHTSA/AAMVA

The U.S. Department of Transportation and National Highway Traffic Safety Administration, in cooperation with the American Association of Motor Vehicle Administrators, published a 1980 booklet entitled 'Guidelines for Motor Vehicle Administrators; Functional Aspects of Driver Improvement-A Guide for State Medical Advisory Boards."[17] This handbook provided a set of vision recommendations for all drivers who are otherwise medically capable of operating commercial vehicles, including heavy trucks. The recommendations differ from those in the Federal vision standard but are the same as those in the AMA standard for visual acuity (i.e., 20/25 or better is required in each eye, not 20/40 as specified in the Federal standard). However, visual fields are the same as those in the Federal vision standard (i.e., 140 degrees for each eye in the horizontal field). In addition, color identification is the same as that in the Federal vision standard and AMA recommendations (i.e., abiity to distinguish red, green, and yellow/amber). The booklet provides recommendations for visual acuity, visual fields, ocular motility, color discrimination, depth perception, dark adaptation, refractive states, and strabismus (crossed eyes). The recommended requirements for Medical Category I drivers (covering commercial motor vehicles) are as follows:

- Visual A&y-Prompt central visual acuity is required to interpret traffic signs and cues at usual speeds. Central visual acuity for distance should be recorded using the Snellen notation. The individual should have the ability to coordinate use of both eyes and have conventionally corrected visual acuity in each eye of at least 20/25. Periodic reevaluation is recommended.

- Monocular Visual Acuity-Recommend that license be denied to those with monocular vision.

- Binocular Horizontal Visual Field—Each eye tested separately must have a horizontal visual field of 140 degrees or more. Periodic reevaluation is recommended

- Ocular Motility—Drivers with a history of intermittent or uncontrolled diplopia should not be licensed.

- Color Discrimination—Individuals with defective color vision may be considered. Can have some degree of color blindness, but has the abiity to discriminate red, green, and yellow traffic signals. Periodic reevaluation is recommended.

- Depth Perception—No recommendations are given.

- Dark Adaptation/Glare Tolerance—It is recommended that the overall visual behavior of individuals with cataracts, retinal abnormalities, chronic pupillary constrictions, or other known causes of glare intolerance or poor dark adaptation be carefully evaluated before such individuals arc. recommended for unrestricted licensure.

- Refractive States—Myopia (nearsightedness), hyperopia (farsightedness), and astigmatism (distorted, but constant for all viewing distance) can usually be compensated for and need not be considered as problems. Likewise, presbyopia (inability to focus clearly at near) is natural to aging and is not of licensing concern if compensated or corrected.

- Strabismus(crossed eyes)—The strabismic person should be evaluated based upon visual acuity and normal visual fields the same as a binocular person.

- Use of Telescopic Lenses—It is recommended that telescopic device applicants not be licensed except upon individual review and evaluation by a medical advisory board

EVALUATION OF EMPIRICAL EVIDENCE

Vision standards for commercial driving have evolved in parallel with those for private motor vehicles. Although the performance demands on commercial drivers considerably exceed those placed on an average private passenger vehicle operator, the recommended CMV vision standards that apply to both differ only in relatively minor ways. A typical state CMV standard rests on the specification of a minimum binocular visual acuity performance which varies from 20/70 (3 states) to 20/40 (40 states). In comparing private vehicle and CMV standards, it is noted that at least 40 states require 20/40 binocular vision for CMV drivers compared to 38 states requiring 20/40 for drivers of private vehicles. Thus, the difference between the private and commercial requirements is small and confined to a very few states. The Federal CMV vision standard farther specifies a minimum visual field in the horizontal meridian In general, the state CMV standards fall below the Federal CMV standard. Only 19 states have monocular visual field standards as required in the Federal standard Similar to acuity, states have slight variations in visual tield requirements for private vehicle operators, compared to CMV requirements. Seventeen states have monocular field standards for private vehicle drivers compared to 19 for CMV drivers. Eighteen additional states have binocular field standards for both private and CMV drivers.

The evolution of visual performance standards has been guided by a clearly perceived need to specify adequate visual capacity to assure public safety in a task obviously dependent on vision. However, this process has been able to draw little from an empirical base which was almost nonexistent at the start of the process and has encountered considerable difficulty in adding information of clear practical significance since that time. A reading of the historical data in this area leads to the conclusion that original standards were based on a consensus of expert opinion at tbat time. Major original contributors to this consensus were (1) the medically oriented fields of ophthalmology and optometry, and (2) research scientists concerned with problems of human visual psychophysics. Inter& and influence from both of these sources remain strong to the present. However, during the intervening period, a separate identifiable research and engineering community has evolved that both coordinates and conducts research in direct support of standard-making and the regulatory process. This discipline (traffic engineering and safety) is multidisciplinary in nature, drawing from the medical, engineering and scientific fields, and has presided over the accumulation of a very large base of data on problems related to safety and efficiency in virtually all matters pertaining to private, commercial, and public motor vehicle use.

DRIVING PERFORMANCE RECORD

A major research effort commenced to identify and measure the relationship among many aspects of visual performance and accessible indicators of driving safety. These studies often take the form of a *post hoc* analysis of data already accumulated through routine driver registration testing and record keeping. However, some studies have introduced innovative controlled vision testing methods into the driver testing routine, designed to obtain data on a broad scale which could then be correlated with the driving record over time. Since the early 1960s, numerous research projects have been conducted to study tbe relationship between vision test results for operators of motor vehicles and their driving performance record (i.e., accidents and violations). Most of these studies were initiated to determine what visual skills best correlate with driving performance in an attempt to recommend to state licensing agencies the most practical vision tests to admiier to license applicants and renewals. Many of tbe studies focused on vision tests tbat were easily accessible through commercial vision screening devices. However, some of the studies involved developing customized vision testing apparatus and some used clinical equipment that would be impractical for mass vision screening in a licensing bureau environment. Most of the research focused on the passenger vehicle operator; only a few investigated the visual and driving performance of the CMV operator.

A summary of the most significant research efforts in the area of vision performance of passenger vehicle operators versus their driving performance record is presented next. Then, the more limited evidence describing a relationship between visual performance of CMV operators and their driving performance record is examined. Last, the discussion focuses on aging and visual pathology as they relate to driving.

Passenger Vehicle Operator

(1) Burg Studies-One of the earliest, most comprehensive studies on the relationship between vision and the driving performance record was conducted by Burg[18-21] on more than 17,500 drivers over a 3-year period in the 1960s. Driving habits (annual mileage reported), age, and gender were reported in addition to information on their vision test performance. In Burg's studies, tbe following vision tests were examined: dynamic visual acuity (ability to perceive details of an object when there is relative motion between the observer and tbe object); static visual acuity (ability of the observer to perceive details of a stationary object); lateral visual field (extent of the observer's side vision when looking straight ahead); lateral phoria (aim of tbc eyes in the horizontal plane); low-light

recognition thresholds, glare recovery (length of time required to perceive an object after being subjected to glare); and sighting dominance (individual's preferred eye). Of the vision tests analyzed in relation to traffic convictions and accidents (reported), statistically significant correlations found between vision and the driving performance record which were nevertheless extremely weak. Burg reported that mileage and age were the most powerful predictors of traffic accidents and convictions. A later analysis of the Burg data by Hills and Burg in 1977[22] revealed a small but significant correlation between accident rates for drivers over age 54 and their static/dynamic visual tests and glare recovery tests.

Many of the research studies from the 1960s concluded that accident and violation records were only slightly predictable from visual performance measures and that factors such as age, sex, and exposure mileage were better predictors of driving records than any visual characteristics. [19,22,39]

(2) Mark I Vision Tester—In the early 1970s, the U.S. Department of Transportation was developed an interest in the results of the Burg studies. They initiated a series of investigations designed to develop a battery of vision tests that were more functionally related to driver performance and safety, and which could lead to the development of a vision testing device for use in screening driver's license applicants or renewals. In this study, Henderson and Burg[23], after reviewing prior literature and analyzing earlier data, provided a systematic analysis of the visual requirements for driving. Through use of a prototype vision testing device (MARK I), the following visual functions were regarded as important to USC in the study:

- Static visual acuity (normal illumination)
- Central angular movement
- Central movement-in-depth
- Useful peripheral vision
- Static acuity (low-level illumination)
- Field of view
- Eye movement and fixation
- Dynamic visual acuity

- Accommodation faculty
- Glare sensitivity

Over 600 license renewal operators were screened on the MARK I. Accident statistics were collected for the preceding 3 years for each operator. Results showed a moderate, consistent age-related decline for all the visual functions. Significant age-related loss in visual ability was reported for static acuity under normal and low illumination, glare, and dynamic acuity. However, the correlational analyses conducted to assess the potential predictive validity of the MARK I displayed many significant correlations in the direction of poor visual performance statistically related to a good driving record. Further analyses revealed the age factor as an extraneous variable causing this outcome. Older drivers with the experience and ability to compensate for their lost visual functions, plus their greatly reduced driving mileage, had considerably fewer accidents than their younger, better-sighted counterparts. The U.S. Department of Transportation, encouraged by some of the results of the MARK I, decided to continue its research to develop a valid vision screening device to be employed as standard equipment in a typical motor vehicle department field office.

(3) Mark II Vision Tester-Upon developing a new device (MARK II) that was relatively compact, durable, and affordable (as well as having such features as a much shortened administrative testing time, and the entire instructions, testing, and scoring procedure computer-automated), initial testing by Shinar[24-26] performed initial testing using 890 licensed operators. The results revealed very low correlations behveen accident rate measures and visual performance. In fact, no significant correlation existed behveen vision and driving record for the 25 to 54 age group. Additional testing indicated that poor dynamic and static visual acuity under low levels of illumination was most consistently related to accidents; poor static acuity under low levels of illumination was related to nighttime accidents. There was also a relationship between central angular movement and accident involvement. In addition, none of the single vision tests was significantly associated with accident involvement for all age groups, but each test was significantly associated with accident involvement for one or more of the age groups. Results indicated that the reliability and stability of the vision test scores bad to be increased before pass/fail criteria could be analyzed. Overall results between the battery of vision tests and the driving statistics were inconclusive and really did not establish a clear-cut relationship behveen specific visual tests and the driving record.

(4) Visual Acuity-Important work, correlating visual acuity test scores of 13,700 drivers with self-reported accidents during the previous 12-month period, was carried out in the mid-1970s by Hofstetter.[27] Data were collected nationally over a period of 10 years by means of a survey taken in a variety of settings and population. Additional support was provided from the Auxiliary to the American Optometric Association, using six available commercial vision screeners. Accident rates for persons with acuity in the lower quartile of the measurements were compared to rates for persons with acuity above the median measurement. Drivers in the lower visual acuity group were found to be twice as likely to have had three accidents in the previous year as those with acuity above the median, and 50 percent more likely to have bad two accidents. No significant differences were found between the lower acuity and higher acuity drivers when only one accident was used as the criterion of comparison. This study provides evidence of a connection between poorer visual acuity and increased accident frequency. These results apply only to the very poor visual performers compared to the best in the driver cohort. Hofstetter estimated the visual acuity lower quartile cutoff for young drivers at 20/25 and for older drivers at 20/60. However, the quartile cutoffs are arbitrary and cannot be interpreted in terms of a criterion for routine driver screening.

Davison[28] reviewed literature on the relationship of vision tests to driving record in the late 1970s. 'He concluded that weak but statistically significant positive associations with the driving record could be consistently documented for dynamic visual acuity, angular movement detection, detection of movement-in-depth, and static visual acuity. The review found no statistically significant associations with driving records for the following vision tests: color vision, stereoscopic acuity, muscle imbalance, and visual fields. Davison concluded that these last four vision tests are poor predictors of accident rates and are of doubtful value in a routine driver screening environment.

In 1985, Davison[29] conducted vision tests (visual acuity, vertical/lateral muscle balance, binocular fusion, and color perception) on 1,000 motorists. These motorists were randomly stopped in and around a town in England and asked to volunteer for a vision test and provide information on driving record, vision examination history, and other demographic information. He found significant positive associations between accidents and right-eye or left-eye visual acuity and binocular acuity for all drivers and a relationship between accidents and vertical heterophoria for drivers age 55 and over. (He also found a relationship between accidents and heterophoria [binocular muscle imbalance] and accidents.)

(5) Visual Fields-The visual field test used in driver screening measures only the outermost limits of the horizontal meridian in response to a dearly super-threshold (bright) stimulus. Studies on visual Gelds in the 1970s by Council and Allen[30] did not show a significant relationship between the test results and the drivers' records. The Council and Allen study involved a very large driver cohort in which visual field measurements were compared with accident rates for 52,000 drivers. This study found that only 1 percent of drivers recorded a horizontal field of 120 degrees or less, and that the accident rate for these drivers was no higher than for those whose fields were greater than 120 degrees. Earlier studies by Danielson[31] involved a much smaller driver cohort (680 drivers) and also reported no significant relationship between horizontal and central visual fields and the accident performance record.

Evaluation of visual fields for medical purposes has advanced to the level of using computer-automated techniques to measure brightness detection thresholds for a grid of up to 80 or more locations throughout the potential field of vision. In 1980, Keltner and Johnson[32] used automated static perimetry to screen more than 500 drivers for any evidence of visual field loss. This technique found that approximately 5 percent of the motorists had significant visual field loss compared to only 1 percent found to have a noticeable deficit in the study by Council and Allen using the horizontal meridian test. In addition, Keltner and Johnson report that subjects over age 65 have four to five times the incidence of visual field deficits of younger patients. For the Keltner and Johnson study, field loss was defined as substantial depression of all or part of the peripheral visual field and/or an inability to detect two or more adjacent visual field points (scotoma). This project was extended[33] to compare the visual field loss of 10,000 volunteer drivers with accident/conviction histories. For this larger study, it was found that drivers with visual field loss in both eyes had accident and conviction rates that were twice as high as those for drivers with normal visual fields. The results were statistically significant. These authors suggest that decreased performance on a visual fields test is most likely to result from age-related decreases in retinal illumination and other acquired vision impairments which are more common in older age groups (such as glaucoma, degenerative myopia, diabetic retinopathy, and retinal detachment).

In the mid-1980s, North[34] conducted a review of studies comparing the relationship between the extent of visual field and driving performance. He reported that Johnson and Keltner's study in 1983[33] showed evidence to support the relationship between visual fields and safe driving, while the majority of other similar studies comparing accident records and visual fields performance had not. This may have been attributed to the use of nonstandard perimetric tests that had not been validated, inadequate controls over the subject's fixation, and limited testing of only two locations on the horizontal meridian of the visual field North reported that the lack of relationship found between the extent of visual field and driving performance could be due to poor study methodology and motorists with visual defects limiting their driving to favorable conditions.

(6) Glare Sensitivity–Studies on glare sensitivity were conducted in the 1970s. Henderson and Burg[23] and Shinar et al.[25] were unable to show any significant relationships. In addition, Gerstle et al.[35] were unable to show a significant correlation between glare sensitivity scores and accident type, yet reported that drivers with a glare problem modified their driving behavior (i.e., reduced night driving). Wolbarsht, in 1977,[36] tested 1,500 driver's license applicants and renewals for glare sensitivity at three veiling glare ratios (background:target) of 2:1 (high glare), 4:1 (medium glare), and 8:1 (low glare). He used a modified commercial vision screener with a customized overlying glare source of controllable intensity. The results showed no significant correlation between glare scores and driving performance, although the average glare sensitivity scores did increase with age. He recommended that drivers 50 years of age and older be periodically checked for elevated glare sensitivity because of their tendency toward elevated scores, even though his data could not be used to set glare screening criteria. He also found that monocular drivers tended to have elevated glare sensitivity.

(7) Contrast Sensitivity–A recent study[37] was completed for the Pennsylvania Department of Transportation (PennDOT), to determine the value and feasibility of periodic vision screening during license renewal. Decina et al. examined the relationship of three vision measures (static visual acuity, horizontal visual fields, and contrast sensitivity) to accident and violation records for 12,483 drivers who were unaware that they would be tested. It was discovered that drivers who failed the PennDOT visual standard or scored below "normal" on the contrast sensitivity test were at a significantly higher risk for

accidents in the two oldest age groups (66 to 76 and 76+), but not in younger groups. However, researchers found no significant relationship between poor vision performance on each of the vision tests analyzed separately and accident and violation records.

In summary, clear-cot, strong correlations between vision tests and driving records of passenger vehicle operators have been difficult to establish because of the statistical distribution of drivers (age, sex, driving environment, driving experience, driving behavior) and indeterminate causes of traffic accidents. Difficulties in trying to relate driving performance to visual capabilities have been suggested in the literature as follow:

- Vision is only one of many factors influencing driving performance,
- Some of the vision tests wed in studies do not really relate to the visual requirements of driving,
- Reliability of criteria used to measure driving performance may be low,
- Research methods may have used unrepresentative samples of the driving population, and
- Individuals with visual difficulties place self-imposed limits on their driving, thus reducing their exposure to the risk of an accident.

Commercial Motor Vehicle Operators

The literature reviewed in the preceding section relates to passenger vehicle driven. In general, the conclusions regarding the strength and existence of a statistical relationship from these studies can be applied in the context of CMV driving. However, since the demands of commercial driving are greater than those for passenger vehicle driving and the consequences of errors are greater, criteria for CMV drivers are more appropriately set based on evidence compiled in the commercial driving context. The studies tbat are reviewed next apply specifically to the CMV driver's task.

In 1973, Henderson and Burg attempted to relate CMV driving skills to the visual tests included in the Mark I Vision Tester.[23] Their goal was to establish a sound scientific basis for minimum visual standards for the Bureau of Motor Carrier Safety. The relative importance of different aspects of the driving task was established by examining the literature, interviewing truck drivers, observing truck drivers in action, and conducting a systematic examination of the driving task. These authors established a hierarchy of importance for the visual functions selected as most important. Weights were assigned to various driving behaviors and to each visual function according to its judged importance to the driving behavior. Those visual functions judged to be most important to the truck driving task and necessary to an analysis comparing visual performance and accidents and violations were:

- Static Visual Acuity,
- Dynamic Visual Acuity,
- Perception of Angular Movement,
- Perception of Movement-in-Depth,
- Visual Field,
- Movement in Depth and Steady, Saccadic, and Pursuit Fixations,
- Glare Sensitivity, and
- Angular Movement.

In the study that followed (on 236 CMV drivers), these authors reported a statistically significant relationship between poor visual performance on some tests and accident involvement. Most important among the specific measures of visual performance found to have a relationship to accidents were perception of movement and dynamic visual acuity. However, no correlation was found between static visual acuity or field of view and accident frequency for commercial drivers in this relatively small sample.

Although visual field has not been shown to correlate with driver performance in passenger vehicles, it seems unreasonable to assume that very large amounts of visual field loss are consistent with safe driving, especially in heavy commercial vehicles. Monocular drivers represent one important extreme, in exhibiting total visual field loss in one eye with relatively normal function in the other. McKnight et al.[38] studied the vision skills of monocular and binocular truck drivers. Consistent with common-sense expectation, they found that the monocular driver showed deficiencies on a number of clinical visual measures. However, no differences were found between monocular and binocular drivers in tasks of actual driving performance (information interpretation, hazard detection, visual search, lane keeping, clearance judgment, and gap judgment). The one exception, is which a deficit was seen, was with information interpretation; defined as the distance at which signs could be read during both day and night driving in a controlled road test. The binocular drivers were able to read road signs at significantly greater distances than were the monocular drivers. It is interesting to note that the performance on this measure did not correlate significantly with the clinical measure of static visual acuity. Based on the lack of significant differences obtained from the other performance measures that correlated significantly with acuity, it was concluded that an individual's style of driving was a more predictive measure of accident involvement than was his visual status.

In a more. recent attempt to correlate visual performance with accident record, Rogers, Ratz, and Janke in 1987(39) studied the driving records of visually impaired and nonimpaired heavy-vehicle operators. The purpose of the project was to determine whether the Federal vision standard can be justified based on the traffic safety record of these drivers. The records of over 16,000 heavy-vehicle operators registered by the California DMV were examined. Measures of driving performance consisted of Z-year total accidents and convictions associated with incidents involving commercially registered vehicles. Visually impaired operators were categorized into two subgroups of substandard static acuity; (1) moderately visually impaired (corrected acuity between 20/40 and 20/200 in the worse eye, 20/40 or better in the other), and (2) severely visually impaired (corrected acuity worse than 20/200 Snellen in the worse eye, 20/40 or better in the other). Nonimpaired drivers met current Federal acuity standards (corrected acuity of 20/40 or better in both eyes). Results of the analysis, adjusted for age, showed:

- Visually impaired drivers had a significantly higher incidence of total accidents and convictions and commercial-plate accidents and convictions than did the nonimpaired drivers.

- Moderately impaired drivers had a significantly higher incidence of commercial-plate accidents than did nonimpaired drivers.

- The incidence of total accidents did not significantly differ between the nonimpaired and moderately impaired drivers either before or after adjusting for age.

- Severely impaired drivers had a significantly higher incidence of commercial-plate convictions than did nonimpaired drivers.

- Nonimpaired and moderately impaired drivers did not significantly differ on commercial-plate convictions.

- Drivers licensed to operate. any combination of heavy vehicles bad a higher incidence of total accidents and convictions and commercial-plate accidents than did those licensed to operate single vehicles having three or more axles.

These findings Lad to qualified support for the current Federal standard, particularly regarding exclusion from driving of the severely impaired Less support is offered regarding the restriction of moderately visually impaired heavy-vehicle operators.

The studies reviewed previously represent a substantial accumulation of data on the relationship of vision to driver performance. No single study provides support for definitive changes to the current Federal commercial vehicle vision standard Nevertheless, it is equally apparent that changes in terms of both more and less stringent requirements in several performance areas should be carefully evaluated at this the with the minimum aim of encouraging further empirical work. Additionally, it is apparent that a large gap exists between the stated Federal standard and its uniform and effective implementation at the level of routine practical testing. Even though little evidence appears to exist to support a substantial and direct relationship between vision and driver safety, much evidence has been accumulated to support the hypothesis that vision contributes in a critical way in interaction with other factors to influence highway safety.

Normal Aging and Visual Pathology

Beyond the age of 50, the effects of aging begin to have a noticeable impact on visual performance. The aging process is not well understood, bat its effects on vision are a slow decline in performance, that is manifested as a gradual shift toward less optimal performance in the normal mean for an age group as age increases. This shift in performance has little practical impact at first; but if persons over the age of 65 are compared to those under 40, a very noticeable difference in performance is evident. It is unclear how this gradual deterioration affects driver safety. Added to this normal aging process is the increased incidence of disease-related pathology in the eye, which is the most important contributor to serious visual deficits. Driver safety is more clearly linked to disease-related decline in vision since this is likely to be more rapid and profound than the decline associated with normal aging. This section is a review of studies relating aging and disease to driver performance, with an attempt to assess the impact of these processes on commercial driver performance.

However, the impact of aging on the visual capabilities of the CMV driver is mitigated considerably by the fact that the older drivers are underrepresented on the road. Figure A.1 illustrates this point for all licensed Pennsylvania drivers. Figure A.l(A) shows the distribution of private passenger licenses (Class One), by age, for the approximately 6.7 million Class I and III licensed operators. The largest proportion of licensed driven occurs in the 20 to 40 age groups. Above this age there is a decline that levels off until about the age of 65, where a second decline occurs. The corresponding distribution for CMV drivers (Class Three) is shown in Figure A.1(B). One immediate difference is the approximately 6:1 ratio of males to females compared to the roughly 50-50 split for passenger licenses. Of greater significance to visual capabilities are the reduced proportions of licenses at the age extremes. The 20 to 30 age group is very much underrepresented compared to passenger licenses and the oldest age groups above 65 also fall off more rapidly. Nevertheless, the proportion of CMV licensed drivers over the age of 50 and up to age 65, where visual capabilities begin to decline noticeably, is still quite comparable to that of passenger car drivers. If these drivers were to participate in the actual driving task in proportion to their licenses, the problem of aging and vision could be as significant as it would be for the general driver cohort. However, other evidence, such as tbat represented by the superimposed dashed line in Figure A.1(B), points to a possible decline in older driver participation on the road in comparison to the number of licenses held. The dashed line labeled Actual Drivers represents 1989 survey data[(40)] from the Regular Common Carrier Conference Organization. These data on age are taken from truckers actually on the road during a certain period. The survey data indicate a severe reduction in the proportion of CMV drivers over the age of 50 actually on the road Further study may show that drivers with greater loss of visual capabilities are even more severely underrepresented, although this is only speculation at this time.

Many studies[(41-43)] have evaluated the driving performance of visually impaired automobile drivers—defined by the U.S. Department of Health and Human Services as persons with the inability to see newsprint with corrective lenses or with no useful vision in one or both eyes; individuals with cataracts, glaucoma, color blindness, detached retina, and other eye diseases are included. Conditions of these individuals may or may not significantly interfere with the driving function. Drivers with color blindness can usually adapt quite well to the driving task. However, visually impaired drivers with such conditions as cataracts, glaucoma, or extremely poor vision (not better than 20/200 with corrective lenses) may be a serious risk to themselves and others on the highways. These studies were conducted by state licensing agencies that have been usefulness of their medical

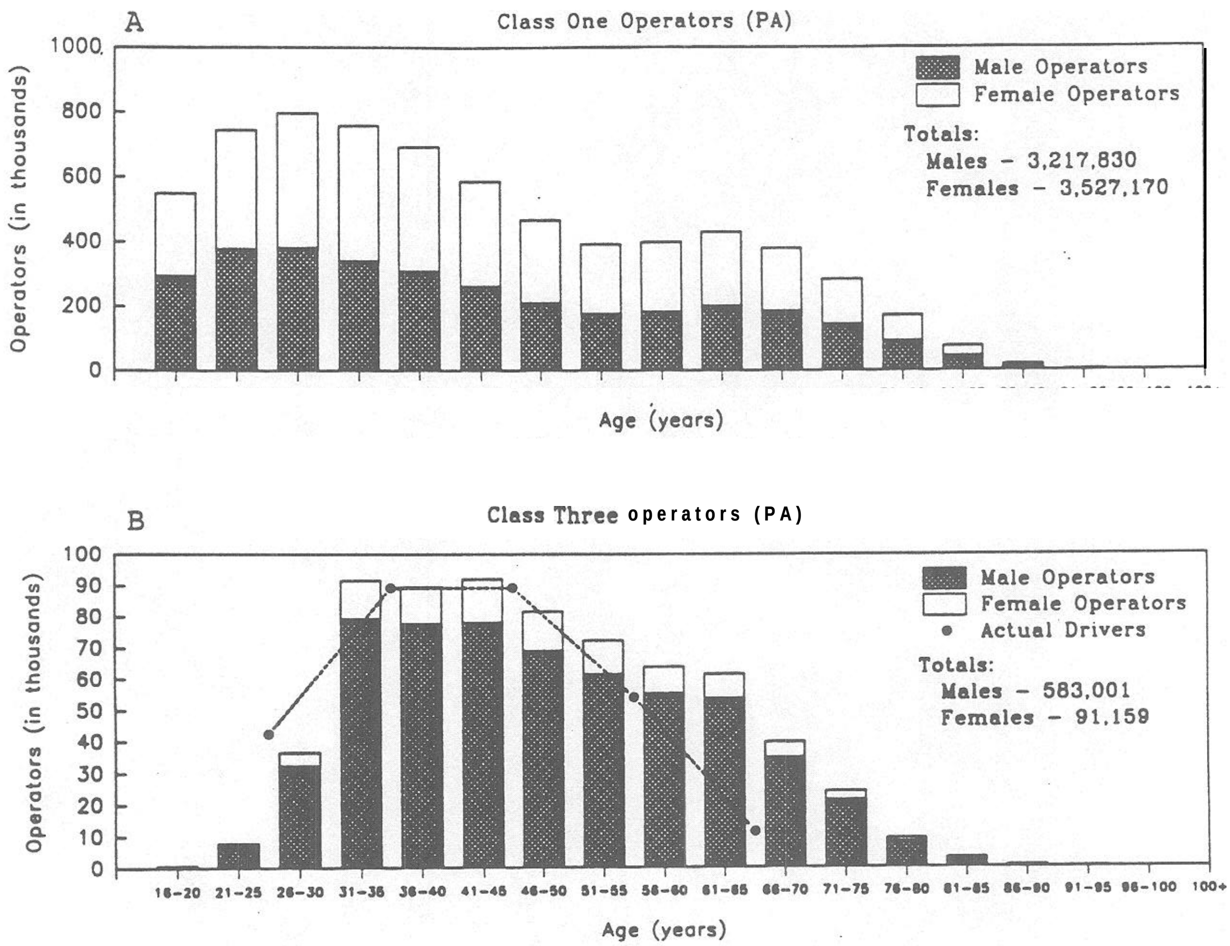

Figure A.1(A) Licensed Private Passenger Car (Class 1) and (B) Commercial and Heavy Vehicle Operators (Class 3) in Pennsylvania by Age