

5. Are persons who are totally deaf (i.e. those who have no hearing that contributes to communication) currently allowed to drive commercial motor vehicles in your country?

Yes Yes, if special requirements are met No

Special Requirements:

a If yes, is any information available on the existing number of deaf truck drivers licensed in your country?

-Yes Number Licensed _____
 no
 Don't Know

6. Are persons who have an average hearing loss of 40 dB or more (but are not deaf) currently allowed to drive. commercial motor vehicles in your country?

Yes yes, if special requirements are met **no**

Special Requirements:

a If yes, is any information available on the existing number of hearing impaired truck drivers licensed in your country?

yes Number Licensed _____
 no
 Don't Know

7. Are the hearing levels of new applicants or existing drivers tested in your country?

-new applicants? **yes** **no** Don't Know
-existing drivers? **Yes** **no** Don't Know

a. If hearing levels are tested, what methods are used to screen for hearing **loss**?

(1) Audiometric Testing? Yes _____ N o -

(2) Forced Whisper? Yes _____ N o -

(3) Another Test? Yes _____ **no** _____

Please describe this test? _____

b. If yes, and the test shows that an existing driver has developed some degree of hearing impairment, what happens to their driving privileges?

_____ It is revoked _____ No Change _____ Other

Other: _____

8. Will there be any change in the hearing regulations governing commercial motor vehicle drivers in the future?

_____ **yes** ' N o _____ Don't Know

If yes, what changes are planned and when?

9. Are there any regulations regarding truck drivers with the following disorders?

	excluded from driving	permitted under special conditions	No Regulations
Epilepsy?	_____	_____	_____
Heart Disease?	_____	_____	_____
Drug Use?	_____	_____	_____
Alcoholism?	_____	_____	_____

C. Hearing Standards Employed by Private Trucking Firms

After speaking with the State licensing agencies to identify those states that license the deaf and hearing-impaired for intrastate CMV operation, it was possible to contact trucking firms, both small and large, throughout the United States to examine the hearing regulations in use by these companies for intrastate drivers.

Five medium-sized and five large trucking firms were randomly selected from the Official Motor Carrier Directory (1991 edition). Company size was based on the number of tractors it owned, with the medium-sized companies averaging 281 tractors, and the large 'companies averaging 2,413 tractors. Each company operated in interstate commerce and intrastate commerce within those states that permitted the deaf and hearing-impaired to be licensed. The director of personnel or safety in each company was contacted by telephone and questioned regarding the company's policies for hiring drivers with hearing loss. Questions included: if the company had any regulations regarding hearing standards and CMV operation; whether deaf or hearing-impaired were employed by the company; and, if so, was there information on the number employed and their driving records.

All ten companies' stated that every driver must pass the Federal DOT medical requirements to be hired. Even those companies that reported operating in intrastate commerce in a state that licensed the deaf and hearing-impaired stated that all employees were subject to the Federal guidelines. Furthermore, through general conversation, the representatives pointed out that most freight shipped by these companies has the potential to be transported across State lines. Thus, in order to avoid possible problems, all employees were treated as interstate drivers. One director of safety went on to say that it is a case of "litigation fear." The handicapped employee poses "an unreasonable risk, even if he is a great employee . . . and we are gun shy to make exceptions to the [Federal] law . . . it is self-preservation."

Two firms remarked that they had employees with some degree of hearing impairment. The level of hearing impairment present, though, did not exceed the threshold outlined in 49 CFR 391.41. One company employed two drivers who developed hearing loss after many years of driving. The first driver was impaired in only one ear and had been accident-free for the previous two years. No information was available for the second driver. In the case of the second company, the director knew of three to four employees who required hearing aids to drive. Driving history information was available for two of these drivers. Driver 'A' had had no accidents or violations in the previous 5 years. Driver 'B' had been free of accidents and violations since 1988. at which time he received his third speeding violation.

The inference to be gained from this small survey is that, notwithstanding the hearing standards and regulations set forth by the states regarding licensing for the deaf and hard-of-hearing, large and medium-sized private trucking firms will not hire these drivers unless they meet the Federal standards. It appears that drivers who do not meet the Federal standards most likely will drive independently or with very small, local trucking companies.

D. Hearing Regulations in Other Industries

How do other industries view the role of hearing in safe job performance, and what regulations exist regarding it? In some occupations, hearing plays no role in adequate job performance. In others, some level of hearing could be important for safe job execution. An overview of the hearing requirements in effect in three occupational areas with ties to transportation, aviation, railroad, and military service, is provided below. All three require specific levels of hearing for job operation. Other industries may require hearing for job performance, but it is difficult to gather information from other industries because rules and regulations regarding hearing are set by individual companies rather than by the Federal government. The rules in effect most likely differ by industry, as specific tasks differ by industry.

Aviation

The Federal Aviation Administration (FAA) has specific requirements for the level of hearing necessary for selected aviation occupations. These regulations differ by occupation and the extent of participation in public transportation. Hearing standards are, by design, included with other medical standards deemed necessary for safe job performance. All pilots, flight engineers, flight navigators, and certain air-traffic control operators (14 CFR, part 67) must take medical examination and obtain a qualifying medical certificate. Types of medical certificate required for each job category are listed below (Table 3-S); they vary from a first-class certificate to a third-class certificate. The hearing requirements necessary for each class of certificate are described below.

First-class medical certificate An applicant must have the ability to: (1) hear a whispered voice at a distance of at least 20 feet with each ear separately or (2) demonstrate a hearing acuity of at least 50% of normal in each ear throughout the effective speech and radio range as shown by a standard audiometer (14 CFR 67.13).

Second-class medical certificate An applicant must be able to hear a whispered voice at 8 feet with each ear separately (14 CFR 67.15).

Third-class medical certificate An applicant must be able to hear a whispered voice at 3 feet (14 CFR 67.17).

Table 3-5. Hearing Requirements for Selected Aviation-Related Occupations

Rule	Occupation	Medical Certificate Required
14 CFR 61.83	student/recreational pilots	at least a third-class certificate
14 CFR 61.103	private pilots	at least a third-class certificate
14 CFR 61.123	commercial pilots	at least a second-class certificate
14 CFR 61.151	airline transport pilots	a first-class certificate
14 CFR 63.31	flight engineers	at least a second-class certificate
14 CFR 63.51	flight navigators	at least a second-class certificate
14 CFR 65.33	air-traffic control operators ¹	a second-class certificate

¹ Except for persons employed by the FAA, a employed in the military or on active military duty.

Interestingly, the American Medical Association (Engleberg 19862) has recommended new standards for hearing in the aviation industry. In its opinion, the forced-whisper test is “antiquated, non-objective, and not at all related to the requirements of hearing in the cockpit environment.” It recommends that hearing standards for all certificate holders should be based in part on audiometric testing.

In reality, though, hearing impairment among pilots is not a major factor in the denial of commercial and airline transport licenses.. Waivers are granted to pilots who fail the forced-whisper or pure-tone screening test if they can demonstrate that the hearing Impairment does not affect performance in the cockpit during a flight test. The large majority of the affected pilots tested in flight have passed and been granted a medical waiver (Hark, personal communication).

Railroad

The railroad industry has recently instituted a new rule regarding the hearing requirements of train engineers; 49 CFR 249.43 states that locomotive engineers should have some degree of hearing The level of hearing required is similar to that for CMV drivers Engineers should meet or exceed the following thresholds: (1) by an audiometric test, there should be no average hearing loss in the better ear greater than 40 db at 500, 1,000, and 2,000 Hz, with or without use of a hearing aid and (2) a person should perceive a forced whisper in the better ear at not less than 5 feet, with or without the use of a hearing aid. However, waivers to these standards may be granted. Under the final rule published by the Federal Railroad Administration (FRA 1991), “railroads have the discretion to make individual medical judgments if a person can demonstrate

² Engelberg, A. L., Gibbons, H. L., & Doege, T. C. (1986). A Review of the Medical Standards for Civilian Airmen, Synopsis of a Two-Year Study. *J Amer Med Assoc*, 255(12), 1589-1599.

³ **Federal Railroad Administration (1991,19 June). 49 CFR Part 240: Qualifications for Locomotive Engineers; Final Rule. Federal Register, pp. 28228-28246.**

that they can compensate for their diminished acuity.” Certain conditions may also be imposed by the medical officer of a railroad company.

This new rule is a change from the previous rule under which no particular level of hearing was required. One of the reasons stated for the change was a recent spate of attention-grabbing crashes involving alcohol and/or drug-impaired engineers. The Federal Railroad Administration thus felt the need to impose standards upon locomotive operators for public safety purposes.

Army

The Department of the Army has medical fitness standards that an individual must meet both at enlistment and for retention (31 CFR 571.2). Necessary hearing threshold levels are classified as follows (Fitzpatrick 1988);

H1 An audiometric average that cannot exceed 25 db with no individual level greater **than 30** db at 500, 1,000, and 2,000 Hz. The threshold at 4,000 Hz cannot exceed 45 db.

H2 (1) For both ears, an audiometric average that cannot exceed 30 db with no individual frequency level greater than 35 db at 500, 1,000, and 2,000 Hz. The threshold at 4,000 Hz cannot exceed 55 db, or (2) For the better ear, the threshold cannot exceed **30** dB at 500 Hz, 25 db at 1,000 Hz, 25 db at 2,000 Hz, and 35 db at 4,000 Hz. The worse ear can have any configuration.

H3 Includes levels exceeding H2 and speech reception threshold which cannot exceed **30** db HL in the better ear with the use of an hearing aid.

Summary

It appears that other transportation industries regard hearing to be important for safe and efficient operation. Although information is not available, it is likely that sufficient hearing may be a safety requirement in other industries, such as construction (particularly with regard to high-rise buildings) and public protection (police and fire). There remain no data, however, to evaluate the risk, if any, that individuals with hearing impairment may pose in the airline, railroad or other industries.

⁴ **Fitzpatrick**, D.T. (1988). An Analysis of Noise-Induced Hearing Loss in Army Helicopter Pilots. *Aviation, Space, and Environmental Medicine*, 59, 927-942.

IV. RISK ASSESSMENT

Introduction

Recent legislation enacted to increase work opportunities for individuals with disabilities” raises an old debate over the safety of their employment. Employment opportunities in commercial transport for those with certain health conditions have traditionally been restricted out of public safety concerns. Health conditions such as diabetes, cardiovascular disease, epilepsy, hearing loss, and psychiatric disorders have been viewed as potential risk factors for motor vehicle crashes. Yet, the contribution of these factors to the development of such events remains relatively unknown. There are few data available to describe the safety risks associated with medical conditions.

The issue facing regulators, employers, and the public is whether the benefits of employing individuals with disabilities outweigh the risks. Social benefits include the improved economic and psychological well-being employment provides to affected persons. Risks include more accidents, with attendant injury and economic consequences, and the additional costs of maintaining a monitoring program for those with medical impairments. Additionally, in the Americans With Disabilities Act, employers do face liability for refusing a position to a properly qualified person with a medical condition.

At present, persons with psychiatric disorders, insulin-treated diabetes, epilepsy, and other disorders are excluded from operating commercial motor vehicles in interstate activity (49 CFR 391.41). The primary motivation behind these regulations was the view that unnecessary commercial vehicle crashes could be prevented. With any change in regulation comes the concern that the number of CMV crashes will increase.

Medical conditions are thought to influence the development of accidents in four ways (Figure 4-1): (1) sudden loss of consciousness, (2) impairment in that inhibits the recognition of threats or the ability to react to them, (3) impairment in judgment, and (4) functional limitations caused by impaired motor ability (Guidelines for Motor Vehicle Administrators 1980). A sudden loss of consciousness may, for example, result from seizures in persons with epilepsy and from hypoglycemic episodes and in persons with diabetes. Perceptual impairment may arise from a vision or hearing deficiency. Alterations in judgment may occur in a number of psychiatric disorders. Impaired motor ability may result from an amputation, stroke, or severe arthritis. The medical condition may lead to an accident directly, or through a secondary condition (Figure 4-2).

How does one determine if the licensing of individuals with health impairments is safe? The essential data required for any analysis are those which describe the link between medical factors and accidents. Several case reports have shown that medical conditions among truck drivers have led to road crashes (Christian 1972, Sturner 1983, Cockram 1986, NTSB 1986, Grattan 1968). Case reports, though, tell us very little about what the relative risk for crashes in a population of impaired drivers might be.

Figure 4-1. Medical Conditions and Their Possible Effects on Driving Ability

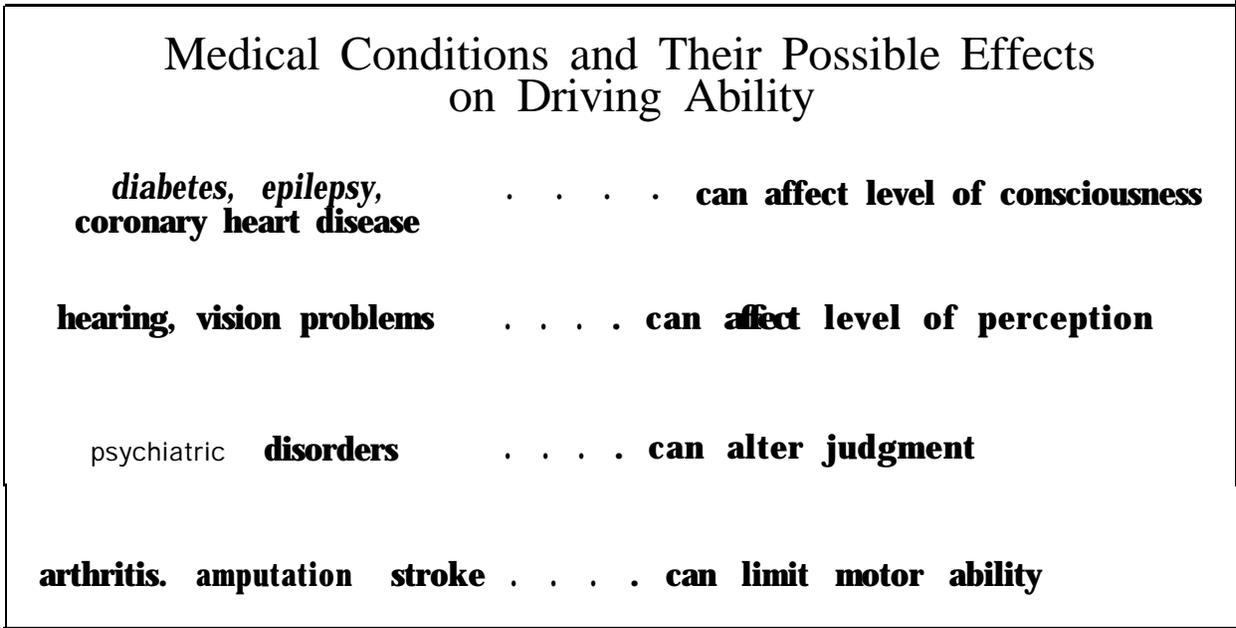
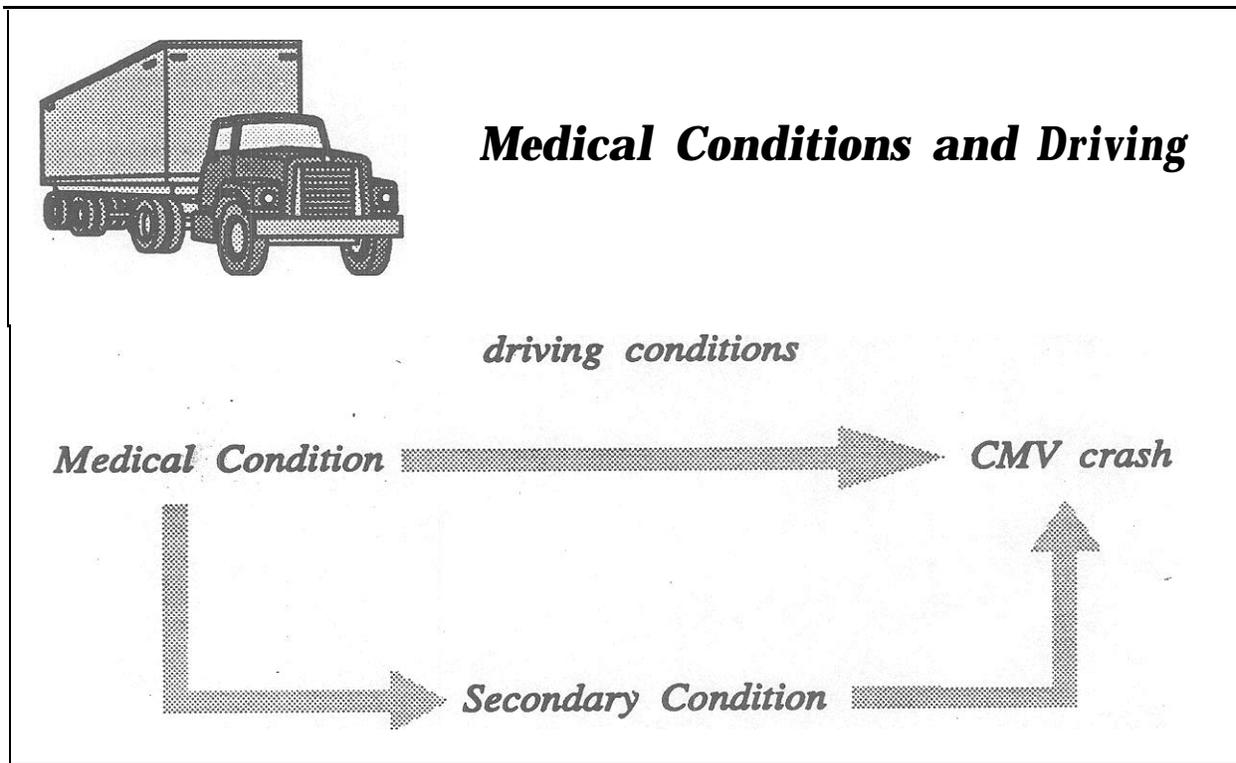


Figure 4-2. Medical Conditions and Driving



Surveying the driving records of medically impaired CMV operators is not generally possible due to employment restrictions. Given the lack of direct data, an alternative approach might be to examine indirect or secondary data. Conducting a risk analysis may be the most likely strategy given the regulatory nature of the issue. Risk analyses use the best possible data from the scientific literature to generate estimates in scenarios where direct information is not available (NRC 1983, HHS 1986). These risk projections are then provided to decision makers who are responsible for deciding if the risks are acceptable and manageable. By integrating the best possible data that can be brought to bear on a specific question concerning regulation, the risk assessment approach maximizes both the individuals' rights and public safety.

The safety impact of regulatory changes affecting CMV drivers with hearing impairments is considered below. At present, people with severe hearing loss and total deafness are excluded from driving commercial motor vehicles on an interstate basis [49 CFR 391.41(11)]. As with other medical disorders, this restriction is being examined by the Federal Highway Administration for its relevance.

The literature review presented an overview of the manner in which hearing loss may affect driving safety. It was clear in the review that the current literature does not provide sufficient evidence to either prove or disprove that hearing is required for safe driving. The safety risks related to hearing-impaired CMV operators are not known. The purpose of this paper is to use risk analysis techniques to evaluate the potential risk of allowing hearing impaired persons to be CMV drivers.

This study uses available evidence from the literature review and the examination of hearing standards in other countries and industries to quantify formally the hazards that may be associated with hearing loss in CMV operation. We seek to estimate the increased likelihood of a crash and the increased number of CMV crashes that might be expected if persons with severe hearing impairments were licensed to operate CMV in interstate activity. The risk analysis will observe the basic framework of the points presented below.

1. Identify the medical factor of interest.
2. Characterize its hazard.
3. Estimate the level of exposure to the medical factor.
4. Characterize the risk incurred from this exposure..

In the following sections, we describe the medical factor of interest regarding drivers with little or no hearing and the potential role of hearing in CMV operation. We characterize the hazard that may be related to hearing impairment, focusing on whether the danger related to hearing impairment is constant or apparent only in certain situations. Section 3 discusses the frequency of exposure to situations in which hearing may be important, and Section 4 provides the heart of the risk analysis, taking the information from the previous sections to determine whether hearing impairment does indeed increase a driver's probability of a CMV crash. Where possible, we also estimate the extent to which the risk of a crash differs between deaf drivers and drivers suffering from noise-induced hearing loss. The final section discusses policy **options** that can be used to reduce any hazard that might be attributable to hearing impairment.

1. Identify the Medical Factor of Interest

Safe driving depends upon the driver's ability to receive messages from his or her driving environment, interpret them, and adjust to them (Wagner 1962). Four senses are likely to play a role in the driver's ability to receive messages: vision, hearing, touch, and smell (Platt 1962). The medical issue of primary importance for this discussion is the ability of an individual with a hearing impairment to distinguish important sounds in the driving task. Hearing loss can affect the perception of warning stimuli and other significant sounds. Without recognizing sounds that warn of approaching vehicles or mechanical failure, a driver may have insufficient time to react to and prevent a crash.

This mechanism is different from that which is apparent for other disorders such as epilepsy, diabetes, and heart disease. In these conditions, the concern is over the development of sudden incapacity. Hearing impairment, on the other hand, is not a situation that arises suddenly. Affected drivers are constantly limited in their ability to hear. The lack of hearing is thought to affect the driving task through the inability to recognize warning signals in the driving environment and communication. Four specific areas of danger have been described in the literature.:

1. Cannot detect problems during pm-trip inspections.
2. Cannot hear mechanical problems on the vehicle.
3. Cannot hear horns, sirens, or train whistles.
4. Poor communicative abilities in the event of an emergency.

By considering these hazards within the matrix of highway safety designed by Haddon (1972), one can see (Table 4-1) that hearing impairment is most likely to have an influence on events occurring in the pre-crash phase--during vehicle inspections, for example, or during vehicle operation when the ability to hear warning sounds could prevent the onset of a crash. The impact of poor communication has been implicated: as a post-crash phenomenon.

Table 4-1. The Haddon Matrix and the Hazards Related to Hearing Loss in CMV Driving

	Human	Vehicular	Environmental
Pre-Crash (while stopped)	• non-recognition of sound due to hearing impairment	* sound as an indicator in vehicle inspection	
(while driving)	* inaudibility of sounds due to hearing impairment	mechanical malfunction	* warning sounds from sirens, horns, trains
Crash			
Post-Crash	* poor communication		

2. Characterize the Potential Hazard

To understand the potential threat related to hearing impairment, it is important to characterize, in more detail, the manner in which hearing is likely to fit into the CMV driving task. Components include knowledge of which driving-age population is likely to be affected by hearing impairment, the fashion in which they would be affected, and the environment in which the significance of hearing in driving takes place.

Background

Hearing impairment is a prevalent chronic health condition in the United States today. An estimated 21 million individuals reported some degree of hearing loss in 1987 (Schoenborn 1988).

Hearing impairment is primarily a condition of the aged. In the United States, approximately 30% of the population over 65 years of age has some type of hearing difficulty (Hotchkiss 1989, Adams 1990). Persons over 65 constitute 40% of all persons with hearing impairment (Schoenborn 1988). A significant increase in the prevalence of hearing impairment is noticed after age 45, which may be a function of NIHL. Recently, an increase in NIHL among young males (up to 15% affected) has been observed.

Hearing-impaired individuals can be identified from any of a number of different procedures, including voice tests, pure-tone audiometric tests, and by asking persons on a survey if they have difficulty hearing. The number of persons classified as hearing-impaired differs by the type of measurement undertaken. Surveys provide a crude, but inexpensive, estimate of the number with hearing impairment. Voice tests provide a more refined means to identify persons with hearing loss, but involve greater cost. A health professional usually administers the examination. Even more precise estimates are available from pure-tone threshold tests with an audiometer. Such tests provide a standardized definition of hearing impairment. Trained examiners, though, are necessary for a test with an audiometer to be useful,

What does the term "hearing impairment" actually refer to? Broadly speaking, hearing impairment can describe any hearing disability, whose severity may range from mild to profound (ASHA 1981). A broad interpretation also includes the contingents of the deaf and the hard of hearing. The level of impairment in hearing that is meaningful, though, varies by the issue in which it is applied (Office of Technology Assessment 1986).

The distinction between the deaf and hard-of-hearing is an important one for any discussion of CMV operation and the impact of hearing loss. The hearing disorders of relevance for this discussion can be characterized in two distinct forms: hearing impairment (often from repeated exposure to noise) and severe hearing loss from congenital, traumatic, or medical origins resulting in deafness. The initial impact of a regulatory change on deaf drivers is likely to have its greatest effect on existing intrastate-licensed drivers. After some period of time, the impact may have its greatest effect at the younger ages when individuals (both deaf and non-deaf) are generally making a decision about driving commercial motor vehicles as a vocation. Such drivers are likely to have little or no previous experience driving commercial motor vehicles. The impact of a regulatory change on drivers with hearing impairment related to age or the long-term

exposure to noise, though, would affect a different group of individuals those at older ages with extensive experience operating commercial motor vehicles.

Clear etiologic, audiologic, and demographic differences also distinguish most individuals with hearing impairment from those who are deaf. Severe hearing loss characterized as deafness can develop from congenital, traumatic, or medical origins. Though variable, deafness has often been defined as the inability to use auditory input as a mode of communication. Others characterize deaf persons as those who are unable to use hearing as a primary channel for receiving speech even with amplification (Nowell 1985). Deafness can be diagnosed at any age, although most tend to think of persons who became deaf prior to adulthood. Estimates of its prevalence by age are lacking. Deaf persons make up about 2% of all cases of hearing impairment (Gallaudet estimates).

Other forms of hearing impairment may be associated with the aging process or exposure to noise. NIHL is caused by repeated exposure to high levels of noise, which destroys the sensory hair cells of the inner ear and causes irreparable damage. Maximum loss is usually reached after about 10 years of exposure, but the loss will continue indefinitely. This sensorineural hearing loss is different from conductive hearing loss, which is a result of problems associated with the outer or middle ear. The distinction between these two conditions can be identified on an audiogram. Some degree of hearing often remains in both conditions, such that the individual, if loud enough, can communicate through auditory input. Hearing impairments of these types are most often diagnosed after age 45.

The current FHWA regulations have been designed to disqualify all deaf drivers. Under the screening criteria for the pure-tone test and the forced-whisper test, persons with moderate levels of hearing loss or higher may also be disqualified. The number who would be eliminated, though, is not clear.

It is also not clear how (the deaf and hard of hearing) would differ with respect to the four danger areas listed above, other than the fact that persons with hearing impairment may be able to communicate better. The regulations implicitly assume that persons with significant uncorrected hearing loss and those who are deaf pose equal risks as drivers, because both groups would be unable to detect necessary warning signals. The crash risks for these two categories of individuals, though, have not been appropriately evaluated. It is possible that hearing-impaired drivers could have a lower risk than deaf drivers because they may be able to hear warnings that are sufficiently loud. On the other hand, the hard-of-hearing could have a higher crash risk because they may not have learned to compensate for their disability in the same way as deaf people.

The issues

CMV operation requires the use of four senses to some extent: vision, hearing, smell, and touch. The hazard related to the loss of hearing, though, is likely to arise primarily in situations where an auditory stimulus is the first most prominent signal to the driver in a warning or emergency situation, as shown earlier in the Haddon Matrix. The failure to attend to this stimulus may lead to a crash. As always, mitigating factors may be relevant irrespective of hearing sensitivity. One such factor, for example, is whether or not the stimulus comes within

sufficient time to enable the driver to avert a crash.. Nonetheless, available information suggests that hearing plays a small role in the driving task, often being most significant in non-routine driving situations.

Two petitions have been submitted to change the Federal regulations barring hearing impaired persons from driving CMVs. The arguments both for and against the petitions characterize succinctly the hazards that could arise from hearing impairment and the environment in which they occur. Reasoning presented by those who sought to change the rule included the following: 1) safe driving is almost all visual, and hearing plays a small role; 2) drivers with impairment can compensate for their deficiency; and 3) noise levels in trucks mask sounds and render hearing insignificant as a safety factor. Arguments presented by the FHWA included the following: 1) hearing is important to act on (a) emergency sounds, (b) improper mechanical sounds, and (c) communication; and 2) noise levels are not high in all driving situations. These arguments will be addressed in the following text.

Driving, vision, and hearing

From all indications, vision is the sense of primary importance to the driving task. Henderson and Burg (1974) found that vision makes up over 95% of the driving task from a sensory perspective. Most licensing agencies test or require testing for visual acuity, but rarely test for other sensory capabilities. Additionally, it is recognized that it is possible to drive with only the visual sense in functional order (Platt 1962).

This does not necessarily mean that hearing plays an insignificant role in driving safety. While the specific auditory requirements necessary for safe driving are not entirely known, Henderson and Burg (1973) noted that the following auditory stimuli, among others, may be important to truck driver safety: warning or attention-getting stimuli (horns, sirens, whistles) and feedback stimuli (e.g., sounds from the vehicle when in operation or stopped). The importance of hearing for driving appears to arise in rare instances, such as during emergency responses and during critical driving-phases.

In interviews with CMV operators, Henderson and Burg asked for opinions on the contribution of hearing to 1) pre-trip inspections; 2) noticing "cues" during operation (for monitoring the engine, transmission, exhaust system, drive line and tire performance); and 3) gathering information that originates outside of the truck (horns, sirens, etc). The drivers interviewed felt that hearing did provide some margin of safety in CMV operation. However, the drivers were unable to estimate the degree to which hearing would be important. While directly observing driver behavior, Henderson and Burg found that hearing did not provide input of significant value to the driving task. Sounds originating from outside the vehicle could not be heard. Because of the high noise levels in truck cabs, hearing may make its greatest contribution in off-the-road maintenance tasks that take place in a quiet environment.

Noise in trucks and its effect on hearing

Preliminary evidence suggests that it is important to reference the driving environment for CMV operators. Specifically, whether noise levels in truck cabs are sufficient to affect the ability to hear meaningful sounds for the driving task. If noise levels are sufficient to render hearing useless while driving, then the risk for hearing-related crashes due to the non-recognition of warning sounds may be lower than expected.

A review of the studies that have examined noise levels in truck cabs under operating conditions suggests that noise levels in commercial truck cabs could exceed 85 db for substantial portions of driving time (Close 1972, Tyler 1973, Ram 1980, Reif 1980, Hessel 1982). Current OSHA standards require the institution of hearing conservation programs when sounds routinely average over 85 db(A). Even studies conducted in the early 1980s reported mean noise levels over 85 dbA when driving with the windows open and radios off (Kam 1980, Reif 1980, Hessel 1982).

Our contact with two truck manufacturers, though, found that insulation of tractor cabs has improved over the last decade, and interior noise levels may now be lower than these earlier reports suggest. A study in France (Pachiaudi 1987), for example, found mean noise levels of 81.2 dbA in a tractor cab with a radio on and windows open. Insulating the tractor to screen out engine and tire noise, though, may also screen out important emergency and warning sounds. Canada has no Federal hearing standards, in part; because of the increasing use of insulating materials in truck cabs.

Cab noise levels and masking of sound signals

It is possible, then, that the noise environment of the CMV driver or the insulation of tractor cabs may mask, or hide, the audibility of sound warnings. Such situations can mean that any driver, hearing-impaired or not, may not be able to hear important auditory signals while operating a CMV. There is evidence to support the claim that truck cab noise levels are sufficiently high that they interfere with a driver's ability to hear warning signals and vehicle malfunctions (Henderson and Burg 1973). More details are provided below.

The audibility of warning sounds in the truck cab

Warning signals as diverse as automobile horns, emergency vehicle sirens, train whistles, and railroad crossing bells have been identified as potentially important to driver safety. Several case reports, for example; note that the failure to hear train whistles led, in part, to CMV crashes with trains (NTSB 1986). Three factors affect the perceptibility of these warning sounds to a normal hearing CMV driver: the level of sound immediately outside the vehicle, the distance between the sound source and the truck when the sound is first detected, and sound attenuation.

The level of sound intensity in which the signal can be heard by the truck driver varies. For example, the faster the truck is moving, the louder the sound must be. Whether the windows are open or the radio is playing also affects sound perception. Distance is particularly important in determining a signal's usefulness to the driver. A driver must be able to hear a signal at a distance that allows him or her to react successfully. Last, it is important to note that the intensity of a warning sound dissipates over the distance it travels. The noise environment of the truck is likely to have some influence on all three factors.

Based on their investigations, Henderson and Burg (1973) concluded that 'drivers obtain very little, if any, useful information about the environment external to the truck... by means of audition.' Reports by Aurelius and Korobow (1971) and Potter (1977) concur with this assessment. All found, in general, that audible warning sounds emitted by cars, trains, and emergency vehicles were probably not adequate to warn CMV drivers, regardless of their hearing sensitivity, at any reaction distance of practical value. Automobile horns, for example, may not be heard by the driver of a large truck at distances beyond 6 to 18 feet when operating at 40 mph with the windows closed. Emergency sirens may not be heard at distances beyond 100 to 125 feet for a CMV with music playing on the radio: This may be due, in part, to the noise environment of the truck cab.

The audibility of mechanical sounds in the truck cab

There are indications that hearing may be important for monitoring proper truck functioning. Sounds from the engine, gears, brakes, and tires may provide clues about malfunctions. An auditory sign from engine noise, for example, could prompt an inspection that would prevent an accident. However, the relative value of these sounds for truck safety remains unknown. Much of what is believed about the role of hearing in the perception of vehicle malfunction is largely speculative.

No data exist that describe the degree to which hearing is required to recognize vehicle malfunctions. While not being able to hear unusual engine noises or warning buzzers could increase the risk for a crash, there are reports that suggest the hearing-impaired may still be able to recognize inappropriate vehicle functioning through vibration.

There also are no data available on the audibility of sounds that indicate a malfunction in the CMV driving environment. For those without hearing loss, it is likely that aural perception of malfunctions could be affected by noise levels in the tractor cab. This could depend on factors such as window position, use of a radio, and truck speed. However, Henderson and Burg (1973) point out that noise levels are such that truck drivers should be able to hear above interior noise levels when the truck is stopped or traveling at slow speeds in the city.

Noise levels vary by situation

Noise levels in truck cabs do vary across various situations. Many of the noise level scenarios are under the driver's control. We have already noted even higher noise levels in the cab if a radio is on or windows are down. Because most cab noise originates in the engine (Priede 1967), vehicle speed plays a role in cab noise levels. Cab noise is highest during highway driving, and lower during city driving or when a truck is at a stop (Close and Clarke 1972). The noise environment of truck cabs may also vary depending on whether the air conditioner is on or off, by the degree of soundproofing in the vehicle, and by the road surface.

Noise in trucks and its effect on CMV drivers

The noise environment may also affect the driver through TTS and NIHL. TTS (temporary threshold shift) results from short-term exposure to high levels of noise. It generally disappears within several hours if exposure is discontinued. With TTS, "normal-hearing" drivers may temporarily be unable to recognize and act on important sounds.

A number of reports have established that long-term exposure to excessive noise can lead to hearing loss (NIH 1990, Jones 1983). NIHL is permanent hearing loss. Based on the tractor cab noise levels presented earlier, CMV driving probably poses a major risk factor for NIHL. The literature clearly demonstrates that there is some degree of hearing loss among CMV drivers (Mackie 1974, Nerbonne 1975, Dufresne 1988, Backman 1983). The type of hearing loss seen in each report was consistent with that of NEIL. The best data on the prevalence of hearing loss in professional drivers are available from Finland (Backman 1983). About 13% of the drivers surveyed audiometrically had some form of hearing loss.

That truck driving can cause NIHL is of primary importance for the risk assessment, because the likely pool of people who would be affected by regulations concerning hearing and licensing would be those individuals already driving CMV's. An interior noise regulation (49 CFR 393.94) was introduced in 1973 by the DOT in order to reduce tractor cab interior noises and control the loss of hearing among truck drivers. However, no information is available on its effectiveness. The driving environment may very well still be "inadequate to protect not only the driver's hearing, but his job security as well," as Durham (1981) implies.

Vehicle inspection and the role of hearing

The noise environment, though, does not directly relate to vehicle inspection, as drivers are outside the cab for parts of the inspection procedure. Hearing may be required in the pre-trip inspection to "determine that required alarms and emergency devices automatically deactivate at the proper pressure level" (49 CFR 383.113). Henderson and Burg (1973) also stressed the importance of hearing in the pre-trip inspections with regard to checking for air leaks in the braking system or tires. However, there are no data which have assessed the importance of hearing for these tasks. It is also possible that both visual and audible warnings may exist for certain aspects of the inspection process for such devices.

Communication and the role of hearing

It has been argued that ability to communicate orally may affect safe CMV operation. Safety in a truck in the pre-crash, crash, and post-crash phases of the Haddon Matrix may depend on the ability to perceive and understand speech. In the pre-crash phase, a truck driver could receive a warning over a CB radio regarding upcoming road and traffic conditions. This consists of a speech signal, with no visual input. In the post-crash phase or in an emergency, it may be important for the truck driver to use both oral and aural communication. Great Britain, for example, requires that deaf applicants demonstrate some ability to communicate with other persons. This is the only hearing standard the U.K. enforces. Again, there are no studies to document how the lack of hearing affects safety through this mechanism.

Compensating for hearing impairment

There are a number of ways that people can overcome the effects of hearing impairment. With respect to the importance of communication mentioned above, one method is through written communication. In a telephone survey we conducted of State highway patrol and training departments, all respondents reported that police officers use written communication when interacting with deaf drivers. Drivers who develop hearing loss (partial or total) later in life usually learn to compensate for their loss by reading lips or listening for key words and phrases. Technologies such as text terminals provide a means for telephone communication for the deaf or hard-of-hearing.

As Evans (1991) notes in his book, Traffic Safety and the Driver, it is important to draw some distinction between driver performance (what a driver can do) and driver behavior (what a driver does do). The diminished perception of sounds among the hearing-impaired may not necessarily translate into an increased crash experience. The behavior of hearing-impaired drivers, as noted above, may compensate to some extent for their diminished perceptual performance.

Some of the literature suggests that those without hearing may be able to compensate, behaviorally, for their hearing loss while driving (Finesilver 1962, Roydhouse 1967, Schein 1968, Burg 1970). Roydhouse (1967) suggests that the visual attentiveness and road sense of deaf drivers may be more pronounced because of their lack of hearing. Woods (1978) commented that the deaf have increased sensitivity to feel and handling. Finesilver (1962) argued that deaf drivers are less subject to fatigue caused by background noise. Visual gauges, as well as audible warnings, also exist for many vehicle functions.

Certain studies also show that monocular drivers (drivers with vision in only one eye) have the same or a lower crash rate than binocular drivers (Evans 1991). Evans also cites evidence that other vision deficiencies (including static visual acuity, dynamic acuity, visual field, glare recovery, and recognition in low illumination of light) are not correlated with higher accident rates. Recall that 95% of the driving task is reported to be visual. To the extent that vision problems can be compensated for behaviorally, it is not unreasonable to assume that hearing problems can similarly be compensated for, as argued by Finesilver, Roydhouse, Woods, and others.

There are reports specific to commercial motor vehicles to support this argument. In one case, when a tire was rubbing against a piece of steel, the deaf driver involved was able to smell the burning rubber and stop the truck (Petersen 1978). In a second case, interviews with CMV drivers found that most malfunctions that create sound will also cause a vibration (Henderson and Burg 1974).

Summary

It is well established that driving tasks are primarily visual, but this does not rule out hearing as potentially important to driving safety. One unresolved issue remains the significance of auditory stimuli in the CMV driving situation. The literature suggests that any hazard which might be assigned to hearing impairment is likely to be small. The primary indication for this is the effect of noise levels in the truck cab in masking the sounds of significant impact. Recent innovations to reduce noise levels in truck cabs through soundproofing or insulation may also limit the audibility of appropriate stimuli. Auditory signals thus may have their largest impact on the driving task in situations where high background noise is not involved. The frequency of events where hearing is likely to be important to driving safety is explored in the next section. The contribution of compensatory behavior to the crash experience, though, remains unknown.

3. Estimating the Level of Exposure to Driving Situations Involving Hearing

The next issue is the exposure of CMV drivers to the situations in which hearing is thought to be relevant. An advantage when examining hearing impairment is that, unlike other medical risk factors for crashes (e.g., hypoglycemia in diabetes), hearing impairment is constant and not sporadic. While a person with poor hearing may always be under constraints, it is likely that the risk related to hearing impairment occurs only at times when hearing is necessary to avert a crash. Thus, the point of interest here is not necessarily the frequency of hearing impairment, but the frequency with which hearing is important in the driving task.

Within this context, and considering the points raised in the previous section, it would be important to consider data on the number of encounters with sirens, the number of encounters with tram whistles, the number of mechanical breakdowns while driving, the number of pre-trip inspections, and so on. In other words, the frequency with which hearing-related events occur. The risk of crashes related to hearing impairment will not exist in situations where hearing does not have a significant role in the driving task.

For example, although this has not been discussed in the literature, it would be important to consider how often a CMV is likely to encounter an emergency vehicle. Commercial motor vehicles that drive on highways the majority of time are unlikely to encounter situations where they may have to yield the right of way to emergency vehicles. This might mean that there are few opportunities for a crash between these trucks and buses and an emergency vehicle. Thus, exposure to such a driving situation would be low. On the other hand, delivery truck operators may do most of their driving in cities, where the opportunity to encounter emergency vehicles is much greater. However, there is no way to estimate the frequency with which CMVs encounter emergency vehicles.

Similarly, there is no way to estimate the frequency with which CMVs encounter railroad crossings where there is the potential for a crash with a train. Thus, for these and other possible scenarios where it has been argued that hearing might be important for driving safety, there are no data on the frequency of exposure. There are also no data on how often impaired communication increases injury or damage. Nor are there data on how often truck drivers first notice a malfunction because of a noise it produces and for what proportion of time these sounds are audible.

4. Characterize the Risk Incurred by the Exposure

The lack of data on the frequency with which drivers encounter hearing-related tasks complicates the job of determining the crash risks associated with hearing-impaired drivers (both deaf and the hard-of-hearing). Nonetheless, some epidemiologic, accident, and hearing information does exist which pertains to this evaluation. While the data are not ideal for the analysis, we attempt to describe, with a number of assumptions, the risk that may be implied for drivers with hearing loss. Important factors to consider when characterizing this risk include identifying whom the issue affects (how many drivers and what population is affected by a rule change), translating the exposure to hearing-related events into the occurrence of crashes, and evaluating the variability in the assumptions used.

Identify the number of drivers affected by a regulatory change

The number of persons with hearing impairments that could be expected to be licensed if the current regulations were liberalized is presented below. These estimates are based upon a variety of sources. Data on the prevalence of self-reported hearing impairment are available from the 1989 National Health Interview Survey (Hotckiss 1989, Adams 1990). The breakdown of this prevalence by age is shown in Table 4-2.

Table 4-2. Prevalence of Self-Reported Hearing Loss by Age

	20-44 years	45-64 years
Percent of population with hearing impairment	4.8%	12.8%
U.S. population	99,518,000	46,498,000
Hearing impaired population	4,776,864	5,951,744

These data suggest that there are approximately 10,700,000 hearing-impaired persons of driving age. This estimate, though, does not consider the level of hearing impairment present. It is not clear how many are deaf, how many suffer from hearing impairment due to exposure to noise, or how many have hearing loss greater than 40 db HL (averaged at 500, 1,000, and 2,000 Hz).

With evidence of ~~potentially extreme noise levels in the truck~~ tractor cab, one must ask if the hearing loss experience of the CMV population would be similar to that of the general population with hearing impairment. What is of critical importance is to be able to document the prevalence (and incidence) of hearing loss among CMV drivers.

Estimates of the prevalence of hearing impairment among professional drivers are uncommon. Data on self-reported hearing loss from the 1971 and 1977 National Health Interview survey indicate that 2.9% of those engaged in the transport industry as a whole (excluding the railroads) had some level of hearing impairment. This estimate, though, includes

all transportation workers, many of whom may not work in environments with noise levels similar to those in truck cabs.

The best data available are, those from Finland, where audiometric screening was conducted on 633 professional drivers (Backman 1983). Participants included bus drivers, stock delivery drivers, truck drivers, and tank truck drivers. The occurrence of hearing defects in the frequency range of speech perception was evaluated cross-sectionally. Overall, the frequency of hearing loss increased from 8% in the youngest drivers, ages 30-34, to 17% among the oldest drivers, ages 50-54, with an overall prevalence of 13%.

We estimate the number of current CMV drivers who might be affected by hearing difficulties on the basis of these figures. As hearing loss in the Fiid study was defined as an average of 20 db HL or greater at the speech frequencies, an adjustment to the data is necessary to consider the frequency of hearing loss above 40 db HL on average. Information from the NHANES I study (Rowland 1980) permit an estimate of the proportion of people with hearing loss over 20 db HL whose impairment is in fact 40 db HL or higher. The following table shows the details behind our calculations. We estimate that about 169,000 of the existing 5.5 million CMV drivers might be expected to have hearing loss above the stated FHWA screening criteria (40 db HL).

Table 4-3. Number of CMV Drivers With Hearing [REDACTED]

	Percent with hearing defects	Number of CM-Vdrivers	% with defect above 40 db HL	# with defect above 40 db HL
21-29 yrs	@ 4%	1,107,500	27%	11,961
30-34 yrs	8%	711,500	27%	16,794
35-39 yrs	10%	792,500	29%	22,982
40-44 yrs	9%	792,500	29%	20,681
45-49 yrs	15%	557,500	33%	27,396
50-54 yrs	17%	551,500	33%	31,275
55-64 yrs	@ 20%	630,000	30%	37,800

¹ Based on Finland estimates; @ = estimated values.

² Derived from Bureau of Labor Statistics estimates of the proportion driving by age and FHWA estimates on the total population.

³ Based on NHANES I data: The proportion of persons with hearing loss greater than 20 db HL whose impairment is 40 db HL or greater.

The data from Finland can also be used to estimate the number of new (incident) cases of hearing loss occurring each year among a cohort of truck drivers. For example, between ages 30-34 and 50-54, the prevalence of hearing loss rose from 8 to 17 percent. Thus, during the 20 years between 34 and 54, nine percent of the drivers appeared to develop hearing loss: roughly a 0.45% increase each year. This figure can be translated into a crude incidence rate for the CMV drivers. Thus, the estimated number of new cases of hearing loss among CMV drivers each year between ages 34 and 54 would be 2,700,000 X 0.0045 = 12,150. This figure only notes those with hearing loss of 20 db I-IL or greater in the speech frequencies. Using an adjustment factor (0.30) from the NHANES I data (Rowland 1980), about 3,650 drivers could have their licenses decertified each year if the current regulations were strictly applied.

Our estimates, however, still indicate little about the number of deaf drivers who might be affected. Deaf drivers are not currently permitted to be licensed in interstate commerce. Predictions on the number of deaf persons who might apply for an interstate CMV license are hindered by the relative lack of national data on the prevalence of deafness.

Although not complete, some information is available on the number of deaf persons in the United States. In 1968, Schein determined that the prevalence of deaf persons in the metropolitan Washington, DC, area was close to one person in 1,000. Applying this rate to the U.S. population of driving age shows that there may be about 146,016 deaf individuals of driving age in the U.S. In 1971 and 1977, the National Health Interview Survey included a question on level of hearing impairment. Projections from this data indicate that 350,000 persons may have classified themselves as deaf in both ears in 1987 (Hotchkiss 1989). Lastly, estimates from Gallaudet University place the number of deaf individuals in the United States at 500,000. Despite being the best data available, these estimates remain quite crude.

Averaging this information (as shown in Table 4-4), we would predict about 215,000 deaf individuals of driving age. Assuming that the proportion of the deaf population being licensed to drive CMVs would be similar to that for the general population (3.85%, FHWA estimates), an estimated 8,300 deaf persons might be licensed in interstate trucking.

Table 4-4. The Deaf Population in the United States

	total population	Pop. of driving age	
Schein		146,016	X = 215,000 (0.0385) = 8278
Hotchkiss	350,000	205,450 ¹	
Gallaudet	500,000	293,500 ¹	

¹ The total population times the proportion of U.S. population of driving age (58.7%).

Many factors, though, could affect the number of deaf persons who would be licensed in interstate commerce, including discouragement from participation by peers, family, and physicians and outright discrimination by employers. The extent to which both could affect the number who might be licensed following a rule change is discussed in the next section.

Predicted ~~scope~~

Estimates of the likely distribution of hearing impairment in the existing CMV licensed population and the number of deaf drivers who might seek to be licensed are presented above. Some question, though, remains as to how many in each group would be affected by a liberal change in the current regulations. Recent surveys done as part of this contract indicate that the number of additional drivers licensed under a rule change may be substantially different from the figures presented above.

We have evidence that suggests that most existing drivers with hearing impairment do not lose their driving privileges. Our survey of private trucking firms found that very few CMV drivers failed their biannual medical examinations for reasons related to hearing impairment (48