Assessment of Potential Benefits and Costs of Revising Brake Inspection Procedures and Certifying Brake Technicians

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16. Abstract:
As a result of a fatal truck-bus accident in May 2001, the National Transportation Safety Board (NTSB) issued recommendations to the U.S. Department of Transportation's Federal Motor Carrier Safety Administration (FMCSA).

This project was designed to address NTSB's concerns and to assist the FMCSA in: (1) estimating the time and level of training required for commercial motor vehicle (CMV) drivers to conduct pre-trip inspections of sufficient depth to discover defects or deficiencies that were not corrected by a certified brake technician, and (2) estimating the potential benefits and costs of implementing the NTSB's recommendation to establish Federal testing and certification requirements for persons who inspect CMV brakes.

The work performed for the study involved conducting a literature review, collecting data, and interviewing and collecting information and data from stakeholders. All information obtained was examined and fed into safety and economic models to determine the potential benefits and costs that could be expected from implementation of the NTSB recommendations.

An assessment of the driver training and pre-trip inspection recommendation failed to produce net benefits under any of the scenarios considered. The driver training and pre-trip inspection recommendation produced benefit-cost ratios ranging from 0.07 (50 percent ratio of effectiveness, 200-mile average trip) to 0.55 (80 percent program effectiveness, 400-mile average trip).

The brake inspector and certification recommendation, on the other hand, produced large net benefits, with benefit-cost ratios exceeding 12.65 in all scenarios considered in this study. The BCRs ranged from a low of 12.65 (50 percent program effectiveness, 200-mile average trip) to 29.27 (90 percent program effectiveness, 400-mile average trip).

From this analysis, it appears that implementing the NTSB recommendation on certification of brake inspectors would create net benefits (benefits exceeding costs) and should be pursued. However, the NTSB recommendation on pre-trip brake inspections performed by drivers does not appear to be worthy of implementation.

17. Key Words:
Air Brakes, Brake Inspection, Brake Maintenance, Brake Technician Training and Certification, Commercial Motor Vehicle

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LIST OF ABBREVIATIONS AND ACRONYMS

ASE	(National Institute for) Automotive Service Excellence
ATA	American Trucking Associations
ATRI	American Transportation Research Institute
BCA	benefit-cost analysis
BCR	benefit-cost ratio
BLS	Bureau of Labor Statistics
BTS	Bureau of Transportation Statistics
CASE	Continuing Automotive Service Education
CFR	Code of Federal Regulations
CMV	commercial motor vehicle
CVSA	Commercial Vehicle Safety Alliance
DOT	Department of Transportation
FACT	Fatal Accident Complaint Team
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMCSR	Federal Motor Carrier Safety Regulation
FTA	Federal Transit Administration
GES	General Estimation System
IVBSS	Integrated Vehicle Based Safety System
NHTSA	National Highway Traffic Safety Administration
LTCCS	Large Truck Crash Causation Study
MCMIS	Motor Carrier Management Information System
MCSAP	Motor Carrier Safety Assistance Program
M/H	medium/heavy (duty vehicles)
NAS	North American Standard
NASS	National Automotive Sampling System
NATEF	National Automotive Technicians Education Foundation
NTS	National Transportation Statistics
NTSB	National Transportation Safety Board
OES	Occupational Employment Services
OMB	Office of Management and Budget
OOA	out of adjustment
OOS	out of service
TIFA	Trucks Involved in Fatal Accidents
TMC	Technology and Maintenance Council
UMTRI	University of Michigan Transportation Research Institute
VIUS	Vehicle Inventory and Use Survey

EXECUTIVE SUMMARY

As a result of a fatal truck-bus accident in May 2001, the National Transportation Safety Board (NTSB) issued several recommendations to the U.S. Department of Transportation's (DOT's) Federal Motor Carrier Safety Administration (FMCSA) based on their findings that the probable cause of the accident was the truck driver's inability to stop the tractor semitrailer due to the reduced braking efficiency of the truck's brakes, which had been poorly maintained and inadequately inspected.

Two of the NTSB's recommendations to FMCSA concerned brake maintenance and inspection. The recommendations were to require (1) minimum pre-trip inspection procedures for determining brake adjustment and (2) certification after testing as a prerequisite for qualification and specify, at a minimum, formal training in brake maintenance and inspection.

This project was designed to address NTSB's concerns and to assist the FMCSA in:

1. Estimating the time and level of training required for commercial motor vehicle (CMV) drivers to conduct pre-trip inspections of sufficient depth to discover defects or deficiencies that were not corrected by a certified brake technician.

2. Estimating the potential benefits and costs of implementing the NTSB's recommendation to establish Federal testing and certification requirements for persons who inspect CMV brakes.

Battelle assembled and led a project team that included the American Transportation Research Institute (ATRI), the Commercial Vehicle Safety Alliance (CVSA), and the Technology and Maintenance Council (TMC) of the American Trucking Associations. The work performed for the study involved conducting a literature review, collecting data, and interviewing and collecting information and data from stakeholders. All information obtained was examined and fed into safety and economic models to determine the potential benefits and costs that could be expected from implementation of the NTSB recommendations.
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The benefits associated with the NTSB recommendations are those related to safety as measured by the prevention of crashes involving CMVs, the avoidance of the monetary costs for these CMV crashes, the reduced number of out-of-service (OOS) brake violations, and reduced levels of fines associated with violations resulting from brakes being out of adjustment (OOA).

The NTSB recommendations would generate training costs, inspection costs, testing and certification costs, and administrative costs associated with recordkeeping and retention. Training would be required of bus and truck drivers responsible for performing pre-trip inspections. Brake inspectors would train in preparation for the testing and certification process called for in the NTSB recommendations. Training costs would include the costs associated with preparing training materials, compensating trainers, and labor replacement costs. The driver training and brake inspector certification requirements would also result in costs associated with registration and testing fees. Finally, pre-trip inspections would take drivers away from revenue-generating activities and thus would result in additional labor costs. In each case, these costs would be borne by the motor carrier industry.

The most significant costs are those incurred during pre-trip inspections, which total roughly $4.9 to $9.9 billion over the 10-year time horizon (2005 to 2014). Though each inspection would require only 2 minutes per axle, the costs of this requirement are significant because they would require billions of inspections to be performed over the next 10 years. The cost range is due to varying the assumption regarding the average distance per trip between 200 and 400 miles. Costs are higher if shorter trips are assumed because that would indicate a higher number of inspections. Training, testing, and certification collectively represent the next highest cost item, totaling $5.4 billion over the 10-year analysis timeframe. Administrative costs are relatively low, estimated at $316.7 million over 10 years. The costs associated with NTSB Recommendation 1 include driver training, pre-trip inspection costs and administrative/record-keeping costs, and were estimated at $10.1 – $15.1 billion over the 10-year analysis time horizon. NTSB Recommendation 2 costs include those tied to brake technician training, testing, certification, and related administrative/record-keeping costs. Over the 2005-2014 time period, these costs were projected to total $573.5 million. Thus, the costs associated with the first NTSB recommendation were estimated to comprise between 94.6 and 96.3 percent of the total costs of the two NTSB recommendations.

The benefits associated with the NTSB recommendations are those related to safety as measured by the prevention of crashes involving CMVs, the avoidance of the monetary costs for these CMV crashes, the reduced number of OOS brake violations, and reduced levels of fines associated with violations resulting from brakes being out of adjustment (OOA). Overall, estimated benefits are higher than projected costs over the 10-year time horizon in the base case analysis when low-end cost assumptions are used, with discounted benefits (using a 7 percent discount rate) totaling $14.5 billion ($19.6 billion in nominal benefits), compared to $10.7 billion in costs. When the high-end assumption regarding the number of inspections is used, estimated costs grow to $15.6 billion and exceed estimated benefits by $1.1 billion. Thus, net benefits are estimated at ($1.1) to $3.8 billion. These numbers correspond with benefit-cost ratios (BCRs) of 0.93 and 1.36. These results demonstrated nearly no sensitivity to variations in discount rates. At a 10 percent discount rate, the BCR ranges between 0.92 and 1.35 and varies from 0.93 and 1.37 when a 4 percent discount rate is applied. The lack of discount rate sensitivity occurs because benefits and costs are realized relatively evenly over the 10-year time horizon, with the exception of relatively higher training costs in Year 1. These figures are summarized in Table ES-1. A BCR is equal to the present value of benefits divided by the present value of costs. Thus, a BCR in excess of 1.0 demonstrates positive economic returns to society. When BCRs exceed 1.0, society experiences net benefits from the regulation (net present value of benefits = present value of benefits – present value of costs). Under the high-end estimate concerning the costs associated with pre-trip inspections (200-mile average trip), the NTSB recommendations produce net benefits with BCRs in excess of 1.0. Under the low-end estimate (400-mile average trip), the recommendations fail to produce net benefits when the program effectiveness drops below 76 percent (i.e., the BCR is below 1.0).

Benefits are allocated between the two NTSB recommendations, with a range of 70 to 90 percent of the benefits attributed to the brake inspector certification recommendation and only 10 to 30 percent attributed to the driver pre-trip inspection recommendation, based on input obtained during this study. In addition, a base assumption of program effectiveness of 70 percent was varied from 50 to 90 percent. Higher percentages of program effectiveness indicate that the NTSB recommendations would have a greater effect on either avoiding or mitigating brake-related CMV crashes.

The driver training and pre-trip inspection recommendation fails to produce net benefits under any of the scenarios considered in Table ES-1. The driver training and pre-trip inspection recommendation produced BCRs ranging from 0.07 (50 percent ratio of effectiveness, 200-mile average trip) to 0.55 (80 percent program effectiveness, 400-mile average trip).

The brake inspector and certification recommendation, on the other hand, produced large net benefits, with BCRs exceeding 12.65 in all scenarios considered in this study. The BCRs range from a low of 12.65 (50 percent program effectiveness, 200-mile average trip) to 29.27 (90 percent program effectiveness, 400-mile average trip).

Table ES-1. Benefit-cost Analysis Findings (Alternative Scenarios)

	Benefit-cost Ratios		
Program Effectiveness	**Driver Training/ Pre-trip Inspections**	**Brake Inspector Training and Certification**	**Both Driver and Brake Inspector NTSB Recommendations**
50%	0.07-0.31	12.65-16.26	0.66-0.97
60%	0.08-0.37	15.18-19.51	0.80-1.17
70%	0.10-0.43	17.71-22.77	0.93-1.36
80%	0.11-0.49	20.24-26.02	1.06-1.56
90%	0.12-0.55	22.77-29.27	1.19-1.75

From this analysis, it appears that implementing the NTSB recommendation on certification of brake inspectors would create net benefits (benefits exceeding costs) and should be pursued. However, the NTSB recommendation on pre-trip brake inspections performed by drivers does not appear to be worthy of implementation.

1. INTRODUCTION

1.1 Project Description

As a result of a fatal truck-bus accident in May 2001, the National Transportation Safety Board (NTSB) issued several recommendations to the U.S. Department of Transportation's (DOT's) Federal Motor Carrier Safety Administration (FMCSA) based on their findings that the probable cause of the accident was the truck driver's inability to stop the tractor semitrailer due to the reduced braking efficiency of the truck's brakes, which had been poorly maintained and inadequately inspected.

Two of the NTSB's recommendations to FMCSA concerned brake maintenance and inspection. They are:

> **Safety Recommendation H-02-15:** Revise 49 *Code of Federal Regulations* 396.13, Driver Inspection, to require minimum pre-trip inspection procedures for determining brake adjustment.
>
> **Safety Recommendation H-02-18:** Revise 49 *Code of Federal Regulations* 396.25, Qualifications of Brake Inspectors, to require certification after testing as a prerequisite for qualification and specify, at a minimum, formal training in brake maintenance and inspection.

This project, *Assessment of Potential Benefits and Costs of Revising Brake Inspection Procedures and Certifying Brake Technicians*, was designed to address NTSB's concerns and to assist FMCSA in:

1. Estimating the potential benefits and costs of implementing the NTSB's recommendation to establish Federal testing and certification requirements for persons who maintain or repair commercial motor vehicle (CMV) brakes.

2. Estimating the time and level of training required for CMV drivers to conduct pre-trip inspections of sufficient depth to discover defects or deficiencies that were not corrected by a certified brake technician.

1.2 Project Methodology

Battelle assembled and led a project team that included the American Transportation Research Institute (ATRI), the Commercial Vehicle Safety Alliance (CVSA), and the Technology and Maintenance Council (TMC) of the American Trucking Associations. The work performed for the study involved conducting a literature review, collecting data, and interviewing and collecting information and data from stakeholders. All information obtained was examined and fed into safety and economic models to determine the benefits and costs that could be expected from implementation of the NTSB recommendations.

1.2.1 Literature Search and Data Gathering

The literature search for this project focused on gathering data and sources related to brake condition, maintenance, training and certification of technicians and inspection of brake systems by both technicians and drivers as contributing factors related to CMV brake problems including crashes and out-of-service (OOS) conditions. The literature search was also designed to review books, documents, and data on the need for brake training for drivers and technicians, specific training programs, and techniques for economic analysis.

1.2.2 Stakeholder Interviews–Brake Condition and Maintenance as Crash Factors

In an attempt to corroborate and/or gather information not available in the literature quantifying the extent to which brake condition and maintenance could be related to CMV crashes, survey/interview questions were developed. It was expected that individuals responsible for preventing losses, reducing or assessing the risks of motor carriers, or involved in determining the cause of crashes might be in possession of such unpublished information, and willing to share it with the project research team. A list of questions was e-mailed in advance to a previously developed list of potential respondents, and the subsequent surveys were administered by phone or by return of the e-mail questionnaire. Follow-up phone calls were required in some cases to clarify any ambiguities. In addition, the TMC was able to compile data from its membership to augment the external surveys. The results of the surveys were compiled and fed into the benefits analysis portion of this study.

1.2.3 Stakeholder Interviews–Training, Testing, and Certification Programs

A similar activity sought to corroborate and/or gather additional information on current training, testing, and certification programs as well as the recommended structure for future training, should the NTSB recommendations be implemented. The targeted groups for this effort were motor carriers, training schools, certification entities, association member companies, and insurance companies. As with the first round of stakeholder interviews, these interviews were conducted with the help of e-mailed questions to the respondents that facilitated their responses. The collected information was augmented with data obtained internally from the project team members that represented large groups of stakeholders.

1.2.4 Safety Analyses

The data and information obtained in the earlier stages of the project were used to develop the safety and economic models needed to determine the potential benefit-cost ratio (BCR) for implementing the NTSB recommendations. The primary benefits are the safety impacts of crash prevention, avoidance of high crash costs, and avoidance of costs resulting from OOS brake violations due to the improved manner in which brakes are tested and maintained on commercial motor vehicles. The primary costs include the costs of driver and brake technician training, per trip driver inspection costs, and the costs associated with brake inspector testing and certification.

2. LITERATURE SEARCH AND DATA GATHERING

2.1 Overview

The literature search for this project focused on gathering data and sources related to brake condition, maintenance, training, and certification of technicians and inspection of brake systems by both technicians and drivers, as contributing factors related to CMV brake problems including crashes and OOS conditions. The literature search was also designed to review books, documents, and data on the need for driver/technician brake training, specific training programs, and techniques for economic analysis. The information provided in this report has been organized into four sections, based on each information source's primary focus. Topical areas covered in the literature search included the following:

- Data and studies on crashes and OOS violations that could be prevented or mitigated,
- The need for better driver/brake technician training and inspection,
- Existing brake training and certification programs, and
- Economic analysis techniques.

Each topical area was examined to uncover those sources that were directly applicable to the brake project. These references were then summarized and analyzed to evaluate their usefulness in assessing the status of brake-related crashes; OOS violation rates; training programs for drivers performing brake inspections, repair, and maintenance; and their suitability for use in the benefit-cost analysis. Finally, the references were examined for those most applicable for benefit-cost analysis of the brake project related cost data.

Two key uses of the material surveyed in the literature review were to:

1. Form the basis for estimating the number of crashes that could potentially be prevented through improved brake maintenance and inspection practices reflecting the implementation of the NTSB recommendations described in Section 1.1 of this report.

2. Estimate the number of OOS violations that could be prevented by implementation of the enhanced maintenance and inspection practices

The most important references used in the preparation of the project analyses are described in this section. Other sources of data and information are summarized and included in the annotated bibliography found in Appendix B.

The project's methodology to identify the percentage of truck crashes that could be prevented or mitigated by improved brake inspection practices was to examine each of the relevant sources and select the most effective CMV crash and inspection data for determining which crashes could be prevented or mitigated and which negative brake inspection results could be avoided from (1) improved inspection practices and training for CMV drivers and (2) improved training and a certification system for those maintaining CMV brake systems. Some of these data would also feed into the calculation of the fraction of vehicles that experienced a certain type of brake-related crash that could be prevented or mitigated through the implementation of an enhanced brake system. Not only were the type of brake problems associated with a crash valuable, information concerning the likelihood that the crash was caused by the brake problem was vital. That is, where the crash type involving a CMV could identify the crash as having been brake related or not brake related. For example, if a CMV that was experiencing brake problems were hit by another vehicle from behind, it is unlikely that the brake problems would have contributed to the crash.

2.2 Estimating Prevention and Mitigation of Crashes and OOS Violations

During the literature review, several databases were examined in detail to estimate the number of CMVs where crashes would potentially be caused by brake-related problems. These included the Trucks Involved in Fatal Accidents (TIFA), Hazmat Accident, Fatal Accident Complaint Team (FACT), and LTCC databases.

The TIFA data were received from UMTRI for 1993 through 2000 and covered more than 30,000 fatal truck crashes (University of Michigan, 2005). TIFA uses the Fatality Analysis Reporting System (FARS) as the source for identifying the fatal crashes. TIFA reports data included in FARS but then supplements FARS with their own data that are gathered from police accident reports and telephone calls to carriers, police, and other involved parties such as tow truck drivers. In most cases, these data provide additional detail for the user. For example, FARS provides data on collision type and although “rear-end crash” is one type of collision, there is no means to differentiate between a crash where the truck crashed into another vehicle or another vehicle crashed into the truck. In the TIFA data, the inclusion of “crash type” variables enables the identification of those trucks that struck the rear of another vehicle.

These data can be used to help determine the type of truck crashes that could have been avoided if brakes were functioning properly. Clearly, these data must be used in conjunction with other data such as FMCSA’s Motor Carrier Management Information System (MCMIS) inspection data that show the percentage of trucks on the road with serious brake-malfunction problems.

TIFA data also include an identification of truck crashes known to be associated with various mechanical defects. These include brakes but unfortunately due to sporadic and inconsistent inspections at crash scenes, the data were not very thorough. For the purposes of this brake project, the utility of the TIFA data demonstrated that brake problems as a contributor to fatal truck crashes were strongly linked to accident type. That is, if the truck crashed into the rear of another vehicle, identified brake problems were more likely to be a causative factor in the crash than if another vehicle crashed into the back of the truck. However, the utility of these data for the brake project was somewhat limited because the post-crash inspections lacked the consistency required.

Another source of crash data is the FACT file. The FACT file was analyzed by UMTRI and investigated by the project team as a possible source of data (Blower, 2002). The program investigated every fatal accident in Michigan since 1996 that involved a commercial motor vehicle and at least one death. The investigation includes analysis of the driver, motor carrier, accident scene, sequence of events, role of the truck, and an inspection to determine the compliance of the driver and vehicle with motor vehicle regulations.

At the time of Blower's analysis of the FACT data, 442 trucks were included in the analysis representing crashes from 1996 to February 2001. Of these, data from a North American Standard (NAS) Level 1 inspection were available for 354 of them. A violation was found for either the truck or the driver in 65.8 percent of these inspections. Over 34 percent (121) of the vehicles had at least one brake violation. Mechanical defects including those related to brakes and other vehicle components were common. Fifty-five percent of the trucks had at least one mechanical violation and 28.5 percent had at least one OOS condition.

This rate of violations and OOS for all causes is consistent with trucks routinely inspected under Michigan's Motor Carrier Safety Assistance Program (MCSAP) program. In the three-year period ending in June 2001, 21,322 trucks were subject to a Level 1 inspection. Of these, 31.8 percent were placed out of service.

The FACT data show that accident type (i.e., crash type) combined with the presence of brake problems can indicate the likelihood that a particular crash was caused by brake problems. For example, in a rear-end accident in which a CMV crashes into the rear or side of another vehicle and a brake problem already exists in the CMV, there is a good chance that the brake problem contributed to the crash. On the other hand, when another vehicle crashes into the rear of a CMV, even if the truck's brakes have an identified mechanical flaw, there is little likelihood that the CMV brake problem contributed to the crash since even brakes in perfect condition would not have helped to avoid the crash. Fifty-nine of the trucks were involved in rear-end collisions. Of these, 22 (37.3 percent) had a brake-related violation. This analysis indicates that 5.0 percent (22 of 442) of trucks involved in fatal crashes had brake-related problems that may have contributed to the crash. Note that this is close to the violation rate for brakes for all FACT trucks. For those trucks that struck another vehicle, the overall brake violation rate was 50 percent. Only 27.3 percent of the trucks struck in the rear had a brake-related violation. As expected, a far higher percentage of trucks that struck another vehicle from behind had brake problems when compared with those trucks that were struck from behind. Those truck crashes with demonstrated truck brake problems and where the truck struck another vehicle from behind have a high likelihood that faulty brakes were a contributing factor. Attempts to obtain raw FACT data from the Michigan State Police were unsuccessful. However, even if the data could have been obtained, their applicability for this project was limited because of the small population size, only involving fatal accidents within one State.

The project team also investigated utilizing Battelle's Hazmat Accident Database that was created by a Battelle team under a project for FMCSA (Battelle, 2005). The project's purpose was to obtain additional data and information on hazardous materials (hazmat) crashes that could be used to provide added information for safety analyses. The database uses the MCMIS crash file for 2002 and selects all trucks involved in hazmat crashes. From the approximately 2,000 crashes, half were selected to be enhanced through use of Police Accident Reports (PAR) and contact with motor carriers. The data for each of the approximately 1,000 hazmat crashes for which additional data were collected provide such information as accident type and cause. These data could be used to help identify those hazmat trucks that could have crashed because of a brake malfunction. In-depth data analysis showed that the identification of brake-related problems, although providing some valuable information, was insufficient for the brake project because inspections were often not thorough enough. Furthermore, the population surveyed included only hazardous material trucks and the project team believed that they would not be representative of all CMVs.

The literature survey data also included two very important sources of data that produced estimates used to feed into the benefit-cost analysis. These were the FMCSA's Large Truck Crash Causation Study (LTCCS) and the MCMIS OOS inspection data. The LTCCS is a compilation of inspection data gathered through intensive field inspection and data collection at post-accident scenes (FMCSA, 2005). There are currently data for 1,070 truck crashes (includes some data collected for trucks during a pilot study). This study has produced a considerable quantity of valuable data for people interested in large truck crashes. The LTCCS is a three-year study conducted by the National Highway Traffic Safety Administration (NHTSA) and FMCSA. The study was conducted within the National Automotive Sampling System (NASS), a nationally representative sample involving the General Estimation System (GES). GES is an annual representation of crashes from 60 sites – called Primary Sampling Units (PSUs) – throughout the United States. NASS was chosen because it provides nationally representative data chosen from police accident reports. The data were collected through response by NASS truck researchers and CVSA Level 1-certified State truck inspectors. Inspections were conducted on large trucks involved in the selected crashes.

The LTCCS data files include data for four types of truck brake problems related to a particular crash. These four types are brake failure, brake inoperable, brakes OOA, and brakes deficient. The LTCCS show that brake problems exist in about 30 percent (321 out of 1,070) of the inspections conducted for the study. The brake problems are described in more detail in Section 5.2.

The LTCCS includes detailed descriptions of accident type. These data enabled the project team to correlate those CMVs with identified brake problems with the accident types that could potentially be caused by brake problems. Therefore, the data facilitated the estimation of the percentage of crashes that could have been avoided or mitigated if brake malfunctions were prevented through more efficient inspection and preventive maintenance programs. The Battelle Team concluded that the percentage of trucks with brake violations would best be determined from LTCCS data. Similarly, the accident types that had associated brake problems and would have been avoided or mitigated with an improved brake program were also derived from the LTCCS data. Analysis of the data indicated that approximately seven percent of all CMV crashes could either be avoided or mitigated if the enhanced brake program recommended by NTSB (see Section 1.1) were in place. Section 5 of this report explains how the estimated number of crashes that would be avoided or mitigated was calculated.

The FMCSA Inspection File contains data from State and Federal inspection actions involving motor carriers, shippers of hazardous materials, and transporters of hazardous materials operating in the United States. State personnel under the Motor Carrier Safety Assistance

Program (MCSAP) conducted the majority of the inspections at the roadside. Federal and State field enforcement staff perform inspections on interstate and intrastate motor carriers and shippers and transporters of hazardous materials. Violations of the Federal Motor Carrier Safety Regulations may result in a vehicle and/or driver being placed OOS. Inspectors use CVSA-developed criteria and CMVs are placed OOS if a defect or deficiency is so severe that it presents an imminent hazard. The data collected from inspection activity are collected and stored in the FMCSA MCMIS Inspection Data File. The file also contains a limited quantity of "post-crash" inspection data derived from selective inspections at crash scenes. The roadside inspection data also include the type of OOS violation attributed to a particular CMV, including brake problems. Therefore, the data could be used as an effective baseline for estimating the number of brake problems that could be prevented if the enhanced brake training, certification, and inspection programs were implemented. The OOS data for brake violations in the FMCSA Inspection File also provide a reliable baseline for estimating the number of OOS violations that would be avoided once a new program is implemented. Therefore, this data feeds directly into the benefit-cost analysis.

The number of truck crashes was obtained from the 2002 data included in the 2004 edition of FMCSA's Large Truck Crash Facts (FMCSA, 2004). The data in this reference have been derived from several data sources including FARS, GES, MCMIS Crash File, and Highway Statistics. These data were used to provide a baseline for estimating the percentage of annual CMV crashes that might have been prevented if more effective brake maintenance, training, certification, and inspection procedures were in place. The Large Truck Crash Facts shows that approximately 416,000 crashes occurred in 2002.

OOS brake violation statistics were essential for the brake project in order to be able to estimate the number of OOS violations that could be avoided by the implementation of the more effective brake training, certification, and inspection program. Operation Air Brake provides a detailed summary of data for the years 1998 to 2004 that tabulates the number of OOS brake violations found in inspections of a sample of CMVs (CVSA, 2004). Both the CVSA and the Canadian Council of Motor Transport Administrators sponsor the annual Operation Air Brake campaign, which collects data in both countries. The program emphasizes reducing the number of brake-related violations. During 1998 to 2004, Operation Air Brake checked 66,941 units. Of these, 11,360 (16.97 percent) have had an OOS brake condition. Seventy-six motor coaches were checked in 2004. Of these, 20 (26 percent) had an OOS brake condition. These percentages of OOS brake violations were not utilized to estimate OOS violations that could potentially be avoided with improved training, certification, and inspection because the smaller, targeted and intensive sampling resulted in a violation rate considerably higher than that in the FMCSA Inspection File (FMCSA, 2005a), which shows a brake problem-related OOS rate of 9.8 percent. The purpose and implementation of the Operation Air Brake program differs systematically from the regular roadside inspection program, thus, the results of the two types of inspections are not directly comparable. Section 5 of this report includes additional analysis concerning OOS brake violations.

2.3 Need for Better Driver/Brake Technician Training and Inspection

The following subsection describes data sources, papers, reports, and books that were consulted during Battelle's analysis of driver/technician training protocols for the preparation of the brake project to describe the need for enhanced driver/technician training, certification, and inspection programs.

A survey was conducted in 2003 as part of Operation Air Brake, which is intended to reduce the number of brake-related violations, and the results are described in Report of Driver Survey: Air Brake Adjustment Knowledge (VanderZwaag, 2003). The survey results emphasize the gap that exists between the amount of knowledge drivers should have about air brake adjustment and their actual knowledge. The 4,055 driver surveys collected indicated widespread misunderstanding of the importance of brake adjustment and the correct method of brake adjustment for their vehicles. The survey asked drivers to identify the four conditions necessary to properly inspect brake adjustment.[*] Fewer than five percent (192 of 4,055 drivers) were able to correctly identify all four of the conditions. The survey results indicate that professional drivers have a poor understanding of the fundamentals of brake adjustment and how to inspect brakes to ensure that brakes are in proper adjustment. Driver lack of knowledge concerning air brake adjustment concepts and inspection would seem to contribute to brake malfunctions during truck operation. While the VanderZwaag report cannot be used to estimate the number or percentage of crashes attributable to correctable brake defects, it does underscore the need for improved driver training in the area of brake inspection and maintenance.

Research results have clearly demonstrated that improved safety practices result in reduced crashes for trucking companies. A 1992 paper investigated crash results for 233 trucking firms given a safety rating of 'unsatisfactory' in earlier Federal inspections (Moses and Savage, 1992). Faced with re-inspection, these 233 firms tended to improve their safety practices and consequently operated more safely. The estimated effect of the second inspection for these carriers was to reduce their overall crash rate by 10.4 percent. It is clear that enhanced brake inspections would likely result in measurable safety improvements. However, since the inspections only affected a small portion of the industry, the improvement in safety could not be quantified in terms of a lower number of crashes or lower crash rates for the total truck population. Furthermore, the research is somewhat dated because the compliance review process has changed. In addition, unfit carriers are shut down if they do not improve their safety performance within a limited time period (45 days for passenger and hazmat carriers; 60 days for non-hazmat property carriers).

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[*] The four conditions necessary to properly inspect brake adjustment are:

(1) 90 to 100 psi (621 to 690 kPa) in the air reservoirs
(2) engine shut off
(3) spring brakes released
(4) service brakes fully applied

The impact of two FMCSA safety programs on CMV safety reinforces the conventional wisdom that the implementation of vehicle inspection and safety compliance programs can result in safety improvements and prevent both fatalities and injuries. The report on FMCSA safety program effectiveness documents the methodology and results from an improved model to measure the effectiveness of two safety programs sponsored by FMCSA (Volpe, 2004). These programs, roadside inspections and on-site compliance reviews were evaluated with respect to their impact on reducing crashes, injuries, and fatalities. The improved model was applied to three years of inspections and reviews—2001, 2002, and 2003—and calculated the reduction in crashes, injuries, and fatalities by State for each year. Results indicated that the programs resulted in significant reductions in crashes, fatalities, and injuries. For example, in 2003, the State roadside inspection program alone resulted in reducing crashes by more than 12,600, and prevented more than 9,600 injuries and 530 fatalities. This report showed that, overall, increased inspections resulted in improved safety. These results are likely to apply to increased inspections that would be implemented if the NTSB brake-related recommendations were followed.

2.4 Training and Certification Programs

The following subsection describes references that were used during Battelle's analysis of training programs and materials.

One important source for training programs is the manual *Practical Airbrakes* (VanderZwaag 2001). This is a comprehensive manual designed to give drivers the knowledge and understanding needed to operate airbrakes in a CMV. The manual includes overall descriptions of the braking system as well as details about the major subsystem components such as the supply subsystem, the service brake subsystem, and the trailer brake subsystem. Separate chapters are included on inspecting airbrake system components and testing the airbrake system. A highly valuable chapter describes inspecting airbrake adjustment. The project team used the manual as a useful reference when considering the cost and effort associated with developing brake training materials.

The *Technician Certification Program Guidelines* was another source used to provide recommended practice for the maintenance shop manager, training manager, and/or human resources manager for use in planning, designing, and implementing a technician development program that encourages professional development through technical certification (TMC/ATA, 2004). A certification program may be developed internally or may be based on existing national certification or local licensing programs. The paper recommends that the components described in the guideline should be considered during the development of such a program. The primary goal of a motor carrier technician certification program is professional development of the technical skills and knowledge required for competent performance of the motor carrier technician.

If adopted by the industry, the Battelle Team believes the guidelines should result in improved preventive maintenance and repair programs that, because they include brakes, could help to reduce the number of crashes resulting from brake malfunctions.

The *Air Brake Handbook* proved to be another valuable source of information for developing brake-related training programs (Bendix, 2000). The handbook provides instruction and data sheets on most air brake system components. A valuable section of the handbook discusses the "fundamentals of brakes" and includes discussion of the physics of braking, how various components of air brakes operate, and a section on brake maintenance. The handbook would be a valuable resource for providing background information for inspectors and drivers and, for technicians, as a guide for troubleshooting problems. The brake maintenance section lists specific precautions designed to protect air brakes that should be followed when working around a vehicle.

Finally, another valuable resource was a report* that documented the findings of a peer exchange team that examined best practices for CMV safety (U.S. DOT, 1998). The report reflects these best practices in seven States and several trucking companies. The report contains some recommendations that are relevant to the brake project. For example, in the section on handbooks and manuals, five major recommendations are made as to how these sources should be designed, prepared, and distributed. Some of these recommendations are including publications written in easily understood language focusing on the most relevant materials for the driver, ensuring the material's design provides a well organized and useable format, providing for a mechanism that publications reach all who need them, and using the Internet as an alternate to supplying printed materials. A section on training provides descriptions of the diverse training programs available in the various States surveyed. Some of the information was found to be dated, and it would be valuable to update this peer-exchange reference guide.

2.5 Economic Analysis

The following subsection briefly describes the three references that were most important for the economic analysis of the cost and benefits of the proposed brake training, certification, and inspection program. These cost data were used to estimate the savings achieved from avoiding or mitigating crashes. Although the data provide a reliable overview of crash costs, they lack the specificity to differentiate costs related to certain crash types such as cases in which a truck strikes another vehicle or the truck is struck by a vehicle from behind.

The report entitled *Economic Cost of Motor Vehicle Crashes* constitutes one of the major sources of crash cost information in the United States. The report estimated the economic cost of all motor vehicle crashes in the United States in 2000 at $230.6 billion (Blincoe, L. et al, 2000). This study monetized the costs associated with 41,821 fatalities, 5.3 million non-fatal injuries, and 28 million damaged vehicles. The study also included a number of cost elements: (a) productivity losses, (b) property damage, (c) medical costs, (d) rehabilitation costs, (e) travel delay, (f) legal and court costs, (g) emergency services, (h) insurance administration costs, and (i) costs to employers. The costs included those associated with both police-reported and unreported crashes. The crash costs are stratified by severity according to the Abbreviated Injury Scale. This study examines crash costs associated with all vehicles, including both automobiles

* *Educational and Technical Assistance to CMV Drivers and Motor Carriers: Peer Exchange* by the Upper Great Plains Transportation Institute.

and heavy trucks. The average crash cost when all vehicles are included is $14,102 (2002 dollars).

The report entitled *Revised Costs of Large Truck- and Bus-Involved Crashes*, prepared by the Pacific Research Institute for FMCSA, documents the costs associated with large truck- and bus-involved crashes and provides a good source for estimating the comprehensive costs of truck and bus crashes (FMCSA, 2002). More specifically, the report estimates the dollar value cost per crash, victim injured, or fatality incurred because of large truck- and bus-involved crashes. The cost elements examined in the study include the following: medical-related (e.g., hospital, rehabilitation), emergency services, property damage, lost productivity (e.g., crash investigation, lost wages, recruiting and training replacement workers), and lost quality of life (e.g., pain and suffering). The costs associated with crashes are differentiated based on crash severity, ranging from no injury to fatality, and by vehicle class, including straight trucks, truck-tractor combinations, and buses. The cost of police-reported crashes involving large trucks with a gross weight rating in excess of 10,000 pounds averaged $59,153 (2000 dollars). The cost of police-reported crashes involving buses averaged $32,548. These costs are reported from a societal perspective.

The report entitled *Economic Burden of Traffic Crashes on Employers* found that traffic crashes occurring on the job resulted in 2,100 fatalities and 353,000 injuries annually during the 1998-2000 timeframe (NHTSA 2003). Further, job-related vehicle crashes accounted for nearly 6.5 percent of all crash injuries. The study estimated the economic burden of traffic crashes on employers, including health-related fringe benefits costs, employer health care costs, sick leave, life and disability insurance for employees involved in crashes, and wage-risk premiums. These cost elements amounted to nearly $60 billion in annual costs to employers in the United States during the 1998-2000 time horizon. This study estimated costs to employers by State. The costs to employers in California and New York were highest, topping $3.5 billion in each State. It also examined the costs associated with crashes involving an alcohol-impaired driver and passengers that are not using restraining devices. Finally, the study broke down cost by industry, estimating the highest costs in the land transportation, construction, mining, and agriculture sectors. The average cost per crash to employers was estimated at $16,471 in direct costs (2000 dollars) and $24,536 in total costs, including the wage-risk premium (a premium paid in the workplace to compensate employees accepting risk due to potentially dangerous working conditions).

From these reports, the Pacific Institute study was deemed most relevant because it comprehensively examines a broad range of costs associated with crashes involving buses and trucks weighing in excess of 10,000 pounds. The Pacific Institute report examines costs from a societal perspective. For example, this study includes costs associated with emergency response and the decline in quality of life experienced by drivers and their dependents following crashes involving serious injuries and fatalities. Both of these cost items are not borne directly by industry. Therefore, these costs can be used to examine the economic value of the brake inspection program on society but cannot be used to determine how the program would affect the industry's bottom line.

3. STAKEHOLDER INTERVIEWS–BRAKE CONDITION AND MAINTENANCE AS CRASH FACTORS

3.1 Approach

As described in Section 2, published literature was sought concerning brake condition and brake maintenance as contributing factors in CMV crashes. Since availability of this type of information in the open literature was expected to be limited, a parallel effort involving interviewing of personal data sources was undertaken. The intent of these interviews was two-fold: (1) to gather data unavailable from the literature search or database analysis and (2) to corroborate the limited information that was available. The information from the surveys was then used in the economic and safety analyses.

Potential interviewees included individuals and organizations on or known to the project team, which included the CVSA, TMC, and FMCSA. Fleet and insurance contacts were provided by CVSA as well as through prior personal knowledge. Crash investigators were previously known to members of the research team. The final list of interviewees was reviewed and approved by FMCSA. Several potential interviewees indicated they were unable to respond, but referred the project team to other individuals. Survey questions were tailored to three groups of such individuals, consisting of (1) trucking or bus fleet safety representatives, (2) insurance industry representatives, and (3) crash investigators. Furthermore, during the course of the data collection, it became apparent that some of the initially proposed sources were unable to provide adequate answers to the questions. In some cases, this was because the interviewee did not have or could not obtain the requested data and in others the data could not be released due to corporate restrictions. Substitute sources were approached in these cases.

The questions were sent via e-mail in advance to allow the respondent time to gather the data, and propose a time for the interview phone call. Due to scheduling conflicts, coordination of phone interviews within the desired time frame was sometimes difficult. Therefore, the respondents were sent follow-up e-mails and left voice messages asking them to fill in the answers and e-mail them back. This was to encourage completion of the survey questions with minimum burden on the respondents' time. Once the responses were received, it was much easier for the project team to follow up with phone calls only when required for clarification. Ultimately, nine interviews were conducted, involving a range of commercial motor carrier (both truck and bus) and insurance industry representatives. Persons who conduct crash investigations (or supervise those that do) and professional accident investigators also contributed to the data, through e-mail reply to questionnaires. In these cases, for which the gathering of no new data was required, the respondent estimated a range of percentages of crashes in which brake system malfunction or failure were factors. General information on the respondents is summarized in Table 3-1.

Table 3-1. Respondent Profile

Respondent	Category	Power Units	Trailers	Comments
1	Motor Carrier (truck)	>8,000	>32,000	Many drivers are union drivers.
2	Motor Carrier (truck)	>1,000 Tractors, >8,000 Single Units	10K-15K	Trailers not domiciled. The number reported are those traveling through region for which respondent was responsible.
3	Motor Carrier (truck)	~1,000	~1,700	Mostly carry hazmat, so probably better than average safety record. Prefer not to have drivers do brake adjustments.
4	Motor Carrier (truck)	400-500	400-500	Drivers are owner-operators
5	Motor Carrier (truck)	>8,000	>13,000	Drivers are owner-operators
6	Motor Carrier (motor coach)	>1,900	Not Applicable	
7	Insurance Provider	Not provided	Not provided	
8	Insurance Provider	Not provided	Not provided	
9	Insurance Provider	Not provided	Not provided	Number of vehicles unknown, but one of top 3 CMV insurers in North America.
Estimates only	Crash Investigators (3)	Not applicable	Not applicable	

3.2 Stakeholder Input Regarding Brake-related CMV Crashes

The responses are presented according to topic, with a tabulated summary, followed by a discussion of each group's response.

3.2.1 Brake-related Crashes

Respondents were asked about the percentage of crashes in which brake system malfunction or failure was a factor. This question was answered by the fleets based on their data from 2004, and as estimated values based over several years for the insurance industry respondents and crash investigators. A summary of their responses to this question is shown in Table 3-2.

Table 3-2. Estimates of the Percentage of Brake-related Crashes

Motor Carrier Fleet Safety Representatives	Insurance Industry Representatives	Crash Investigators and Enforcement/Inspection Officers
0 to less than 1 percent	Five to 10 percent	25 to 60 percent

This range of responses was surprisingly broad, with the motor carriers attributing either zero or "less than one percent" of their DOT-reportable crashes to brakes. The very low motor carrier response likely reflects the fact that the responding fleets are safe fleets with good maintenance practices. Indeed, that they participate in CVSA and were willing to share their data is an indication of their confidence in their safety record and maintenance practices. Not that they had zero crashes, as the number of DOT-reportable crashes ranged from the low 20s to over 300, depending on the fleet. Rather, they indicated with some assurance that none of their crashes involved brake system malfunction or failure. In response to a specific question, the fleets all indicated that if brakes were a contributing factor, their investigation was sufficiently detailed that they would have identified this as such.

In comparison, the insurance industry respondents estimated that the range of DOT-reportable crashes in which brake system malfunction or failure was a cause or factor was from 5 to 10 percent. This somewhat higher range is likely due to the fact that the fleets this group of respondents insures covers a range of different maintenance and safety practices, and likely have a range of safety ratings. The project team's sense is that the range reported by the insurance industry respondents is representative of the actual number, given that they deal with a wide variety of fleets, in size and maintenance. The specifics of their customers were not shared with the project team.

In contrast to these relatively low ranges, the crash investigators indicated that from 25 up to 60 percent of the crashes they had investigated could be attributed to brake system malfunction or failure. However, these numbers were admittedly high. These individuals investigate a large number of serious injury and fatal crashes annually, and are considered brake failure analysis specialists. As such, they may be called in to look at a non-representative group of crashes in which brake failure is suspected a priori. Nevertheless, their comments have provided additional insight into the question at hand. One respondent said:

"We investigate over 50 CMV serious injury/fatal collisions per year and have done so for almost 20 years. As brake failure analysis is one of my specialties, my percentages of brake defects to accident cause may be higher than most. However, based on my experience, about 80 percent of the time when I am called in, I find brake defects and improper brake equipment that was not recorded by the investigating law enforcement agency. In my opinion this is a combination of:

1) *Lack of training to examine CMV brake systems*
2) *Lack of understanding of calculating brake force relative to CMV vehicle dynamics*

3) *Limited enforcement power related to FMCSR*
4) *Limited resources – availability of DOT/CVSA inspectors*
5) *Limited availability of specialized test equipment to examine damaged air brake systems (not usually available to typical law enforcement personnel)"*

For those crash investigators and testing specialists that have brake testing equipment, such as performance-based brake testers (PBBTs), at their disposal, assuming that the post-crash vehicle is capable of being tested on a PBBT, brake problems may be found at a higher rate than those from a visual inspection. Thus, the recommendations of the NTSB to certify inspectors and have drivers trained and perform pre-trip inspections of brake systems including but not limited to stroke measurements for s-cam type air brakes, without the use of similar brake force measuring equipment, would not likely provide the same benefit as if such equipment were used in maintenance and pre-trip inspections. It also should be noted that PBBTs used in the maintenance shop, or as a required part of an annual inspection, would be of increased benefit for brake types where stroke cannot be measured, such as hydraulically actuated, electric, or air-disc brakes.

One enforcement officer, while unable to provide numerical responses to our questions, did suggest that the NTSB recommendation regarding drivers' pre-trip inspection should possibly have referenced 49 CFR 392.7, since 49 CFR 396.13 relates more to the driver duties for reviewing the last daily vehicle inspection report. This recommendation has no bearing on the benefit-cost analysis, although if driver training were recommended, it would likely be applicable to both these regulations.

3.2.2 Preventable Brake-related Crashes

Respondents were also asked about the percentage of crashes that brake system maintenance or inspection could have prevented or decreased their severity. For this question, the range of responses was narrower than the first, with the fleets' estimates increasing and the investigators' decreasing, as seen in Table 3-3.

Table 3-3. Estimates of the Percentage of Preventable Brake-related Crashes

Motor Carrier Fleet Safety Representatives	Insurance Industry Representatives	Crash Investigators and Enforcement/Inspection Officers
Less than 1 to 16 percent	Eight to 15 percent	15 to 40 percent

Although the range is narrower for this question, the relative ranking of respondents' answers was the same, with the fleets being the lowest and the crash investigators being the highest. There was overlap this time between the fleets and insurance companies, showing that at least some fleets felt improved brake maintenance and/or training would be beneficial in improving braking, thus preventing or decreasing the severity of crashes, as compared with their view that few crashes were the result of brake malfunction or failure.

The fact that the crash investigators' estimate was lower for this question than the previous question dealing with malfunction or failure led to a follow-up question, to which they indicated their belief that, while inspection of brakes could help decrease the number of crashes, it would not be as effective as brake performance measurement, in which malfunctions or hidden defects would be identified.

3.2.3 Additional Comments from Motor Carriers

At the close of the phone interviews, motor carrier fleet safety representatives were also asked if they had any data concerning improvements in safety or OOS statistics that they could relate directly to a specific new or improved maintenance, inspection, or training program. Although no quantitative data were provided, one respondent indicated he noticed "an improvement" with changes in maintenance and training, and another indicated a reduction in OOS rates after consolidating safety and compliance functions for five subsidiary carriers.

3.2.4 Values to be used in Economic Analysis

Although a wide range of answers were obtained from the personnel interviews, the project team applied their engineering judgment to the responses in order to identify a range of values to be used in the economic analysis. First, for each of the three groups surveyed, the range of values was consistent within each group for the two different brake-related aspects of the surveys: (1) the percentages of crashes that could be attributed to brake system malfunction or failure and (2) the percentage of crashes for which brake maintenance or inspection could have prevented or decreased their severity. To obtain the range of values to be used in the economic analysis, the lowest estimates (from the fleets) were regarded as both coming from fleets with relatively good safety ratings and also likely to be conservative. Similarly, the highest estimates (from the crash investigators) were regarded as coming from a non-representative subset of vehicles, and likely to be overestimates. The CMV insurance industry representatives were felt to have the best overall data with no reason for bias, therefore more likely to encompass an accurate and appropriate range to be used. Given these factors, for the percentage of crashes that could have been prevented or had their severity decreased from better brake inspection, <u>we recommend using from 5 to 10 percent for a conservative estimate</u> and <u>from 5 to 20 percent for a less-conservative estimate</u>. These ranges cover the overlap range of the fleets and insurance industry representatives, and the less-conservative estimate also includes the low end from the crash investigators.

4. STAKEHOLDER INTERVIEWS–TRAINING, TESTING, AND CERTIFICATION PROGRAMS

4.1 Approach

The next phase of the project involved conducting interviews with up to nine entities concerning (a) training and certification for drivers, brake inspectors, and technicians and (b) the management of the process, along with safety and economic analysis. The intent of these interviews was to gather data unavailable from the literature search or database analysis and to gather information that was available from a sampling of fleets, schools, certification entities, association member companies, and insurance companies.

Nine interviews were conducted, involving commercial motor carriers (both truck and bus), a technician training school, a testing and certification organization, and insurance industry representation. This document summarizes the interviews and the information gathered.

Potential interviewees included individuals known to the project team. Motor carrier and insurance contacts were provided by CVSA as well as through prior personal knowledge. The final list of interviewees was reviewed and approved by FMCSA. Several potential interviewees indicated they were unable to respond, but referred the project team to other individuals. Survey questions were tailored to three groups of such individuals, consisting of (1) trucking or bus motor carrier safety representatives, (2) insurance industry representatives, and (3) driver/technician schools and testing/certification organizations. Further, during the course of the data collection, it became apparent that some of the initially proposed sources were unable to provide adequate answers to the questions. Substitute sources were approached in these cases.

The specific information sought from the respondents was forwarded to them in advance of the interview to allow the respondent time to gather the data. For some respondents, scheduling conflicts made it difficult to coordinate phone interviews within the desired period and they provided written responses. The project team then followed up with these individuals to clarify their responses or to obtain additional information.

Ultimately, nine interviews were conducted, involving a range of commercial motor carriers (both truck and bus), insurance industry representatives, a school for brake technicians, and a testing and certification organization. General information on the respondents is summarized in Table 4-1.

Table 4-1. Respondent Profile

Respondent	Category	Power Units	Trailers	Comments
1	Motor carrier (truck)	8,586	13,606	
2	Motor carrier (truck)	289	Not provided	
3	Motor carrier (truck)	658	1,100	
4	Motor carrier (bus)	700	Not applicable	
5	Association (motor carrier)	12 to 10,000*	Not provided	Number of motor carriers in response is unknown
6	Association (motor carrier)	12 to 4,900* median: 166	30 to 14,000* median: 318	Brake inspector data represents 12 motor carriers; driver inspection data represents 45 motor carriers
7	School for technicians	Not applicable	Not applicable	
8	Testing and certification organization	Not applicable	Not applicable	
9	Insurance provider	Not available	26,510	Represents 85 motor carriers

* These figures indicate the range of power units and trailers operated by the motor carriers members represented in each association's response.

Several of the respondents represented constituencies of many organizations and they were able to provide data for a cross-section of their membership, thereby increasing the effective number of entities for which data were obtained. Overall, the motor carriers represented included a wide range of operations, including tanker/hazardous materials, refrigerated, specialized, retail, and private. Both truckload (TL) and less-than-truckload (LTL) carriers were represented.

To better understand the relevance of the data obtained from the respondents, a brief summary of the characteristics of the carriers represented in the collected data is presented.

Brake inspectors have an average of 12.8 years of experience, according to the carriers. The insurance representative provided an estimate of 10 years of experience. Carriers reported that an average of 58 percent of their brake inspectors have completed a formal training program rather than on-the-job training or an apprentice program (with estimates ranging from 20 to 100 percent). The insurance representative put that figure at only 20 percent.

Carrier respondents varied among the number of power units they operated. Some had fewer than 20, while others had more than 5,000; the median number of power units was 200. Of these, carriers estimated that 9.1 percent were older than October 20, 1994, when automatic brake adjusters and push stroke indicators were required on certain air brake systems. The absence of the devices may make it more difficult for certain brake inspections to be conducted by a driver. The insurance representative placed the average motor carrier size that they insure at 85 power units, with only 3 percent older than October 20, 1994.

Trailer fleets ranged from 30 to 14,000, with a median of 396. Of these, carriers estimated that 22.2 percent of them were older than October 20, 1994, when automatic brake adjusters and brake adjustment indicators were required to be installed on certain air brake systems. As for power units, the absence of the devices may make it more difficult for certain brake inspections conducted by a driver. The insurance representative estimated his firm's average insured fleet to include about 312 trailers, with about 9 percent older than October 20, 1994.

Vehicle OOS rates for brake-related conditions were reported to be approximately 3.4 percent. This excludes one carrier that reported a rate of 39 percent but whose rate in FMCSA's SafeStat system is approximately 11 percent. The insurance representative estimated the brake-related OOS rate to be 2.3 percent. These figures were considerably lower than the Operation Air Brake data presented in Section 2.2, indicating that the respondents may have better-than-average brake inspection, repair, and maintenance programs.

Carrier annual maintenance expenditures averaged around $10,200 per power unit (ranging from $3,500 to $22,000) and $2,250 per trailer (ranging from $600 to $5,000). The total annual maintenance expenditures that were considered preventive (e.g., inspections, replacement of parts before failure) was estimated to be about 55 percent (ranging from 13 to 85 percent). The proportion of total maintenance expenditures that were brake-related was not available. The insurance representative's estimate for preventive maintenance is 18 percent (and he would not disclose annual maintenance expenditures).

4.2 Stakeholder Input Regarding the Impact, Cost and Implementation Feasibility of the NTSB Recommendations

The data gathered from the interviews related to training, testing, and certification programs are presented in three subsections: (a) driver inspection, (b) training and certification of brake inspectors, and (c) safety and economic analysis. Each addresses the responses from motor carrier, insurance, and school representatives.

4.2.1 Driver Inspection

Impact of inspection on operations

It is important to understand how stakeholders viewed the feasibility of drivers performing functional pre-trip brake inspections, and whether these inspections could be performed with the driver alone or whether a second individual was necessary. Respondents were asked to consider that a brake inspection with two people would add one minute per axle to a pre-trip inspection and that a driver conducting the inspection alone would require two additional minutes per axle for a pre-trip inspection. They were also asked to consider that one-person inspections would require the driver to use a device to apply the service brakes or to measure the free stroke. Respondents were not provided any additional details on what these inspections would entail and were provided per-axle time estimates to allow them to determine the impacts on their fleets based on the vehicle configurations that they operate. The per-axle time estimates were based on the NTSB recommendation, which focused on determining brake adjustment during pre-trip inspections. A more complete inspection might consider, in addition to brake adjustment, checking for other deficiencies, including air leaks, cracks in the linings, contaminated linings, chafed hoses, incorrect connections or splices, and holes in the chambers resulting from corrosion or other damage. Outside the cab, the driver could check the tractor protection valve. Then in the cab, he or she could check the air loss rate and low-pressure warning device.

While some carrier respondents indicated that there would not be appreciable impacts on their operations if two-person inspections were required (and actually believed that safety would be improved), most reported significant negative impacts on their operations. Among motor carriers, 24.5 percent indicated that two-person inspections would have little or no negative impact or a net positive impact on their operations. Some common themes included:

- Operational feasibility
    - Team drivers – in some cases, this would require the driver to come out of the sleeper, with significant implications due to hours of service rules.
    - Availability of second person – for many carriers, additional staff are not available during all operational periods (such as late night) when pre-trip inspections are conducted. This would require hiring additional staff just to serve this inspection function. Additional staff may not be available in remote locations.
- Cost
    - One company with 1,500 3-axle vehicles indicated it would add 16,500 hours per year (based on 220 days of operation per year).
    - Another company estimated the additional effort would require two technicians for two hours each day, seven days a week (1,456 hours per year).
    - Companies that reported total annual costs cited estimates of
        - $152,000 (10 minutes per driver per day × 45 drivers × 5 days per week × 52 weeks per year × 2 drivers per inspection ≈ 4000 hours × $38 per hour),
        - $175,200 (800 buses × 3-axles × 1 minute per axle × $12 per hour = $480 per day × 365 days per year),
        - $750,000,
        - $3.72 million (10 minutes per driver per day × 1,431 drivers × $60 per hour × 5 days per week × 52 weeks per year), and
        - $13 million (based on a minimum cost of at least $50,000 per day).

Another indicated annual costs of $3,250 per driver, but did not indicate the number of drivers.

Most carrier respondents seemed much more comfortable with the idea of drivers performing the inspections alone; however, the added cost and reduction in available driving hours was still an issue for many. Several carrier respondents still thought that a two-person inspection would provide better results and that the approach was preferred. Overall, about one-third of motor carriers indicated that one-person inspections would have little or no negative impact or a net positive impact on their operations. Representative issues included:

- Reductions in driving time due to the inspection and necessary clean-up (as the drivers would get very dirty doing the inspections) would limit available driving hours
    - One motor carrier indicated that their drivers might not be able to unload and get home at the end of their day; another stated that it would increase the likelihood that a driver could not reload or take on a second load.
    - For motor carriers that quantified the total additional time required per day, the estimates of reduced available driving time were 14, 15, 20, 25, and 30 minutes in a 14-hour period.
- Operational feasibility
    - Several respondents indicated that they were concerned about having their drivers getting dirty from crawling under a truck, particularly in adverse weather conditions such as rain or snow. While not specifically identified by any respondents, this would also apply to motor coach operators whose drivers typically wear a coat and tie. This would require additional time to change clothes or the use of a protective coverall.
- Cost
    - One company with 1,500 3-axle vehicles estimated the effort to require 33,000 hours per year, but believes the time required to be closer to 5-minutes per axle rather than 2-minutes per axle; resulting in an annual increase of 82,500 hours.
    - One motor carrier with 150 mostly 8- or 9-axle semi trailer trucks with 2 to 3 trailers estimated annual costs exceeding $300,000. Others that quoted specific costs estimated total annual increased expenditures of
        - $11,400 (15 minutes per driver per day × 45 drivers × 5 days per week × 52 weeks per year × 1 driver per inspection ≈ 3000 hours × $38 per hour),
        - $1.5 million, and
        - $13 million (based on a minimum cost of at least $50,000 per day).

    Another estimated annual costs of $6,500 per driver.

There were also some recurrent themes that apply to the overall idea of drivers examining brakes as part of their pre-trip inspections.

- Some felt that drivers were only qualified to do visual inspections and that only certified brake technicians were appropriate for physical inspections.* They stated that drivers should not be "overriding" certified technicians.† One respondent indicated that current union rules preclude drivers from performing these types of inspections.
- There was also a concern from an insurance representative that drivers, even if required to crawl under the vehicle to physically inspect brakes, would not actually do it every time, particularly during inclement weather. Driver safety concerns included the provision of protective eyewear and headgear and additional clothing for those crawling under vehicles. Increased driver injuries could be expected from this activity.
- Others felt that these inspections would increase the drivers' familiarity with brake systems, thereby improving safety. One indicated that having two-person inspections would increase safety because "two people will see more and be more aware." One person indicated that brakes could not be inspected enough and that the overall impact would be positive on his company's operations.
- A couple of carrier respondents indicated that they believed the time estimates for added inspection per axle were too low. One, mentioned above, indicated that 5 minutes for a one-person inspection was needed and the other indicated that a two-person inspection would take more than one minute per axle, as it is difficult to get to the brake chamber on their 7-axle trailers.

Training content

Some individuals contacted expressed specific ideas on what the training should include, subject to their beliefs on exactly what the driver should be required to do during a pre-trip inspection; they were not provided a list of specific inspection activities to be required.

For those that felt the driver should not be required to crawl under the vehicle, one suggestion was to have the driver view the angle of the pushrod, the thickness of the pads, and the gap between the pads and drum; however, this would apply only to certain types of brake systems.

Driver training optimums

Respondents were asked about the appropriate amount of initial and refresher training and the frequency for refresher training for drivers. This training would include conducting pre-trip inspections and being able to identify brake deficiencies that were not correctly repaired by a technician. Table 4-2 provides a summary of the carrier responses.‡

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* The reader should note that CMV enforcement officers are not certified brake technicians but are sufficiently trained and certified to perform brake inspections.

† The premise for the NTSB recommendation for brake inspections during a driver's pre-trip inspection assumes that a well-trained or equipped driver would be able to report defects independently of a brake technician.

‡ Again, some data obtained from associations interviewed represented several of their constituents.

Table 4-2. Responses on Driver Training Class Time for Brake Inspection

Initial Training	
Length	%
1 hour	2
2 hours	25
1/2 day	41
1 day	30
2 days	2
1 week	0

Refresher Training			
Length	%	Frequency	%
1 hour	7	< 1 year	8
2 hours	72	Annually	43
1/2 day	21	Biennially	28
1 day	0	3-5 years	23
2 days	0	Never	0
1 week	0		

Note that totals may not sum to 100 percent due to rounding.

The insurance representative indicated that 1/2 day was appropriate for both initial and refresher training and that refresher training should be conducted biennially. The testing organization felt that more time is needed for initial training—2 days—and that refresher training should be 1/2 day and offered every 3 to 5 years.

Anecdotally, one individual from a motor carrier mentioned that today's drivers are generally not mechanically inclined and extensive training would be necessary to impart the appropriate knowledge. This individual was not able to recommend a specific amount of training, however.

Data were also collected from carriers on the recommended class size for driver pre-trip inspection training, as shown in Table 4-3.

Table 4-3. Responses on Driver Training Class Structure

Class Size and Format	%
Individual – driver learns on his/her own	10
Individual – one-to-one instruction	31
Team – experienced senior driver with less experienced drivers	14
Groups of up to 4 drivers per instructor	17
Groups of 5 to 10 drivers per instructor	12
10 to 20 drivers per instructor	9
More than 20 drivers per instructor	7

One carrier indicated that classroom training can accommodate up to 20 students; whereas, hands-on instruction should be limited to only four or five students. The insurance representative would recommend training in groups of up to four drivers per instructor. The school indicated that training, in general, should be able to accommodate each individual's requirements and learning style.

When carriers were asked about the effort required to convert their current class size and format to the optimum (as they saw it), only 6 percent indicated that they were already using the optimum configuration. Forty-eight percent would require a little effort and 45 percent would require a considerable effort.

Based on carrier responses, drivers learn best when there is a combination of hands-on training used in conjunction with classroom instruction. Some indicated that a video could suffice for classroom instruction, provided the drivers still had an opportunity for hands-on experience. The insurance representative felt that formal one-on-one instruction followed by hands-on experience was the preferred approach among the motor carriers he insured.

Most carriers would develop additional required training for drivers in-house (79 percent). The insurance representative also indicated that in-house development was likely among his carriers. The average annual salary of driver trainers was reported to be $40,000 to $60,000 for salaried drivers and $10 to $20 per hour for drivers paid hourly.

Driver training recordkeeping is done in-house (98 percent) and slightly more than half done in-house is done manually (56 percent). Of the recordkeeping done electronically, listed systems included standard spreadsheet and database programs and custom systems. The one carrier that indicated their recordkeeping was handled by a third party cited monthly costs of $495 to cover eight drivers.

4.2.2 Training and Certification of Brake Inspectors

As highlighted by the testing and certification organization, "the scope of the technical [training] content is quite different for an individual performing brake inspections from that of the technician who must also have the requisite knowledge and skill to diagnose and repair deficiencies identified in the inspection process."

For those carriers who have technicians as employees (some do not), an average of 73 percent of the technicians were brake inspectors per 49 CFR 396.25(b). In 75 percent of motor carriers, drivers were not brake inspectors, but at least some drivers were brake inspectors in 25 percent of the motor carriers from which data were obtained. The insurance representative indicated that, for the motor carrier they insure, approximately 90 percent of the technicians are brake inspectors.

Not a single carrier would alter the number of technicians from current levels if certification of brake inspectors were required.

Brake inspector training optimums

Respondents were asked about the appropriate amount of initial and refresher training and the frequency for refresher training for brake inspectors. This training would include conducting proper inspection, maintenance, service, and repair of CMV brake systems as well as appropriate testing and certification as recommended by the NTSB. Table 4-4 provides a summary of the carrier responses.*

Table 4-4. Responses on Brake Inspector Training Class Time

Initial Training		Refresher Training			
Length	%	Length	%	Frequency	%
1 hour	0	1 hour	0	< 1 year	7
2 hours	7	2 hours	57	Annually	29
1/2 day	21	½ day	29	Biennially	36
1 day	50	1 day	7	3-5 years	29
2 days	14	2 days	7	Never	0
4 days	7	4 days	0		

Note that totals may not sum to 100 percent due to rounding.

Carriers that recommended a longer initial training class also recommended longer periods between refresher training. The insurance representative indicated that two days was appropriate for initial training of brake inspectors and that refresher training should be offered biennially as a one-day class. The testing organization representative felt that 4 days was appropriate for initial training and that 1/2-day refresher training should be offered biennially. The school felt that more than one week was necessary for initial training and that a full day of refresher training should be completed annually.

Data were also collected from carriers on the recommended class size for brake inspector training, as shown in Table 4-5.

* Again, some data obtained from associations interviewed represented several of their constituents.

Table 4-5. Responses on Brake Inspector Training Class Structure

Class Size and Format	%
Individual – technician/inspector learns on his/her own	5
Individual – one-to-one instruction	14
Team – experienced senior technician/inspector with less experienced technician/inspector	27
Groups of up to 4 technicians/inspectors per instructor	2
Groups of 5 to 10 technicians/inspectors per instructor	23
10 to 20 technicians/inspectors per instructor	9
More than 20 technicians/inspectors per instructor	0

The insurance representative indicated that on-the-job training is the best approach for training brake inspectors. A school indicated that more than 20 technicians/inspectors per instructor was the optimal learning arrangement. Most of the carrier respondents indicated that hands-on training was the most effective, with some mentioning the added benefit of video or classroom training in addition to the hand-on learning. The school stated that it was best to evenly split the time between classroom and hands-on training.

Employee training recordkeeping for brake inspectors was done primarily manually in-house (88 percent), with the remaining done electronically in-house (using either custom software or integrated commercial business applications, including those from PeopleSoft and TMW Systems Inc.). This is consistent with the response from the insurance representative indicating manual in-house recordkeeping.

Training challenges

According to the respondents, the challenges that carriers face with delivering effective training for brake inspectors include:

- Not all employees are fluent in English.
- Many brake inspectors have never familiarized themselves with the FMCSRs and the requirements in 49 CFR 393 and 396 and Appendix G to Subchapter B, Minimum Periodic Inspection Standards.
- Employee turnover.
- Fitting training into the normal work schedule, while maintaining the ability to continue operations.
- Providing defects to diagnose (i.e., components with defects for use in hands-on training).
- Wide variety of system designs.

Accreditation

Only one quarter of carriers contacted for this study indicated that they have developed a structured periodic brake inspection accreditation program for their company technicians, usually conducted annually (one respondent repeated the accreditation every three years). However, only one of these extended the program to their third-party vendors.

Just over one third of carriers contacted for this study indicated that they have developed a structured periodic brake inspection training program for their company technicians, usually conducted annually (one respondent repeated the training every two years). Two of these carriers extended their programs to their third-party vendors.

The testing and certifying organization provided some general comments that are illustrative of the key issues in the area of accreditation:

- Independent, third-party certification is an objective method of validating training, provided the assessment is defined, developed, and specified by persons knowledgeable in the subject area. This is one of the key tenets, and perhaps the greatest value of Automotive Service Excellence (ASE) certification; the test specifications, task lists, and questions are all developed by technicians and other subject matter experts with experience gained working in the field on a daily basis. These subject matter experts also establish the passing score for a given certification area. Certification by an independent, third-party entity is a recognized and accepted means of validating knowledge gained through training.
- The NATEF evaluates secondary and post-secondary medium/heavy (M/H) truck technician training programs against standards developed by the automotive industry and recommends qualifying programs for certification (accreditation) by ASE. The current Instructional Standards for M/H Truck Brake Systems include 105 hours of instruction broken down into 66 tasks that incorporate the brake inspection requirements in Appendix G to Subchapter B of the FMCSRs. Substantially meeting these instructional tasks is mandatory to achieve certification (accreditation). Additionally, an optional certification area in the NATEF standards for M/H Truck programs is Preventive Maintenance, requiring another 105 hours of instruction, including brake inspection tasks that, again, substantially meet the requirements of Appendix G to Subchapter B of the FMCSRs.
- The NATEF process has resulted in certified automotive training programs in all fifty States at the secondary and post-secondary levels. NATEF also evaluates the providers of in-service technician training programs under a program called Continuing Automotive Service Education (CASE).
- The ASE offers eight certification specialties within the M/H Truck series. Two of those certifications (T4–Brakes and T8–Preventive Maintenance Inspection) seem to fulfill or exceed the brake inspection requirements outlined in Appendix G to Subchapter B of the FMCSRs. The cost of this certification is $57, including a $32 registration fee and $25 testing fee.

4.2.3 Safety and Economic Impacts on Brake-related Crashes

Almost all carriers estimated that brake system malfunction or failure was a factor in none of their DOT-reportable CMV crashes. The only carrier reporting a non-zero figure indicated that it was less than 5 percent. However, the insurance representative also reported that the motor carriers that they insure averaged around 5 percent brake-related DOT-reportable crashes, with an average of about 10 DOT-reportable crashes per year per motor carrier. A bus motor carrier indicated that they experience about five DOT-reportable crashes per year (and operate 700 buses). The median number of DOT-reportable crashes among all motor carriers that reported a value was 15, although one motor carrier reported 131 (1,550 power units) and two motor carriers reported 239 and 250, respectively (and 8,586 and 8,000 power units, respectively). The latter motor carrier, reporting 250 crashes, was the only motor carrier that indicated a non-zero brake-related crash percentage, as stated above. The testing and certification organization, however, estimated that 10 percent of all DOT reportable crashes involve brake system malfunction or failure.

The turnover rate for brake inspectors is generally fairly low, with 64.3 percent of carriers indicating rates less than 2 percent, 14.3 percent were less than 10 percent, and the remaining 21.4 percent were in the 20 to 25 percent range. Interestingly, the insurance representative estimated the turnover rate for brake inspectors to be 30 percent. In this analysis, the brake technician turnover rate is assumed to be 15 percent.

Interviewees were asked their opinions about the safety impact of implementing the NTSB recommendations—having drivers conduct pre-trip brake inspections and certifying brake inspectors—and 56 percent indicated that there would be no positive impact, 6 percent were unsure, and 38 percent predicted a decrease in crashes. The estimates of decreased crashes ranged from less than one percent all the way up to a 100 percent decrease. The average estimated decrease from these respondents was 28 percent. The insurance representative indicated a 0.5 percent decrease in all crashes as a result of implementing the recommended rule changes.

Most felt that such a program would be beneficial, even if they did not estimate a decrease in crashes. They cited better-educated drivers and brake technicians, improved awareness of proper maintenance procedures, and lower brake repair costs. Some indicated that they were already implementing some form of the recommendations, but that other companies could benefit. The testing organization felt that while having drivers conduct pre-trip inspections would produce a benefit in terms of reduced crashes, it would be significantly more beneficial to have certified brake technicians and inspectors perform that function. They believe that "the differences in existing brake systems used on medium/heavy commercial vehicles and the technical knowledge and familiarization of these systems extends beyond the reasonable expectation for drivers." They also feel that new technology in brake systems will likely increase the amount of information necessary to perform proper brake inspections.

5. SAFETY ANALYSES

This section of the report details the findings of the economic analysis, which estimates the societal benefits and costs of implementing the NTSB recommendations. The primary benefits of the recommendations are the safety impacts of crash prevention, avoidance of high crash costs, avoidance of fines due to violations associated with brakes being OOA, and avoidance of costs resulting from OOS brake violations due to the improved manner in which brakes are tested and maintained on commercial motor vehicles. The primary costs of the recommendations include the following: the costs of driver and brake inspector training, per trip driver inspection costs, and the costs associated with brake inspector testing and certification.

Analysis of these benefit and cost items above have been quantitatively estimated over a 10-year analysis period. Since most of the costs are expected to occur on an annual basis, given that the NTSB recommendations are for an ongoing program while only the initial training costs will be borne in the first year, the examination is based on a 10-year analysis time frame, from 2005 to 2014. There are no capital costs (i.e., outlays for capital investment in equipment, buildings or property) associated with implementing the NTSB recommendation for certifying commercial motor vehicle brake technicians. A discount rate of 7 percent was used to construct the net present value estimate in the baseline scenario as prescribed in the OMB Circular A-94 (OMB, 2002). In order to examine the sensitivity of the analysis to discount rates, scenarios using discount rates of 4 and 10 percent were also examined. All benefit and cost items were combined to compute benefit-cost ratios (BCRs) as depicted in Figure 5-1. To the extent that benefits exceed costs, the BCR exceeded 1.0. BCRs of less than 1.0 indicate negative economic returns to society.

5.1 Background Crash Data for Benefits Assessment

This subsection establishes CMV brake data estimates for use in benefit-cost analyses. Estimates are provided for crashes prevented and mitigated through the implementation of an enhanced brake maintenance, certification, and inspection program for technicians and an enhanced brake inspection program for drivers. Estimates of the number of crashes that potentially could either be mitigated or prevented with the new program are based on a direct analysis of the LTCCS data, as well as the values provided by the motor carrier, insurance, and crash investigator interviews. Developing the predicted effectiveness of the enhanced inspection program in preventing or mitigating brake related crashes relies on engineering judgment. The study team drew on its expertise in brake function, crash analysis, and familiarity with how brakes operate in a crash environment.

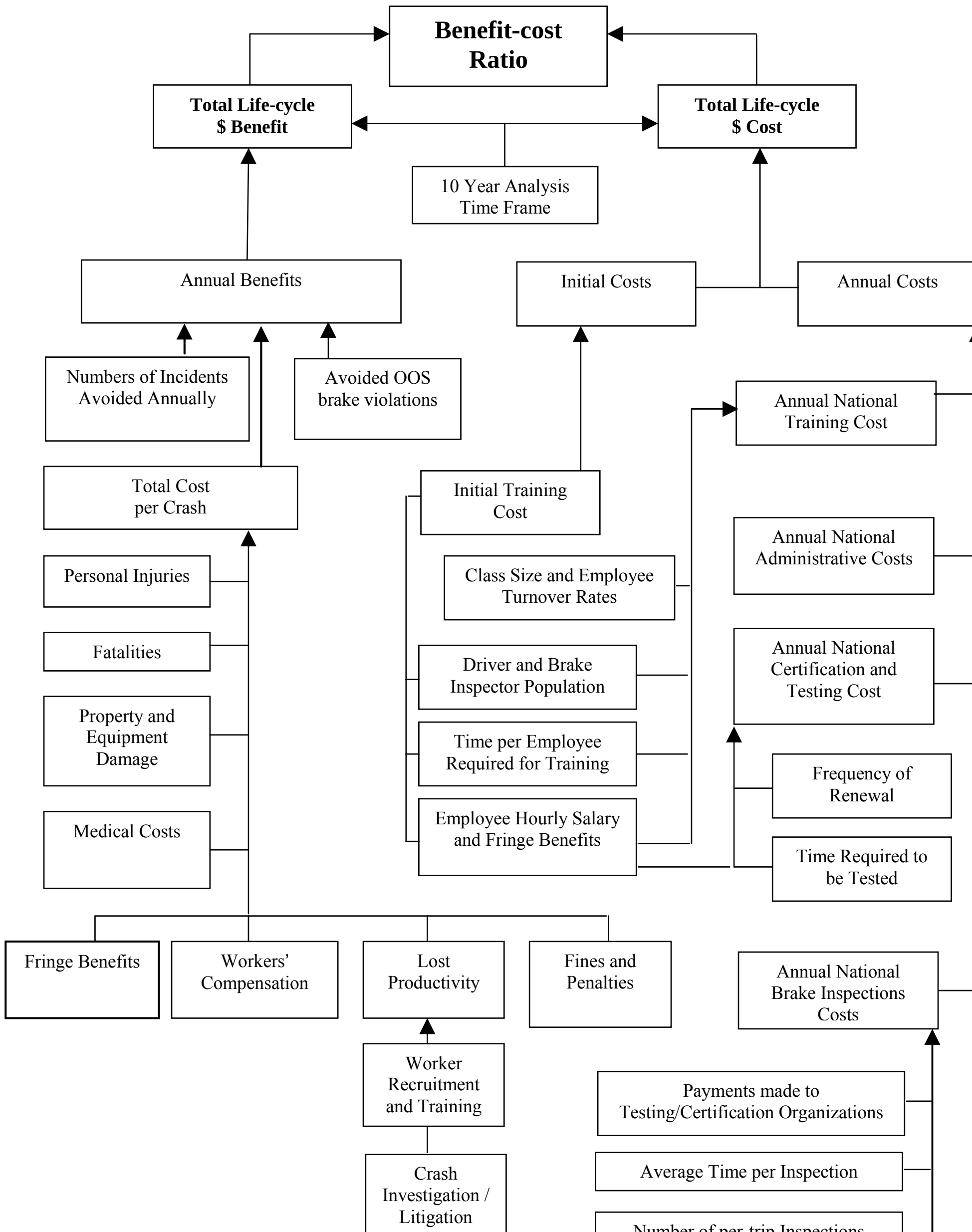

Figure 5-1. Data Elements Combined to Determine Societal Benefit-cost Ratios

5.2 Benefits Assessment

The benefits associated with the NTSB recommendations are those related to safety as measured by the prevention of crashes involving CMVs, the avoidance of the monetary costs for these CMV crashes, the reduced number of OOS brake violations, and reduced levels of fines associated with violations resulting from brakes being OOA. These benefits are explored individually in the following sections.

5.2.1 Safety Impacts

This section examines the approach used to estimate the number of CMV crashes that would be prevented if improved brake maintenance and inspection procedures were implemented and the monetary benefits associated with avoiding CMV crashes. Data used in the study, along with sources, are also cited in this section of the report.

5.2.1.1 Avoidable Truck Crashes

Studies and databases surveyed for the project were examined to determine the most appropriate sources to use for estimating the number of truck crashes that may have been caused by brake problems. Databases describing the results of post crash inspections seemed to be most appropriate. The LTCCS and the MCMIS inspection file both include the results of post crash inspections. The LTCCS data files currently include data for 1,070 trucks (includes some data collected for trucks during a pilot study). The LTCCS shows that brake problems exist in about 30 percent (321 out of 1,070) of the post-crash inspections conducted for the study. MCMIS post-crash inspection data show that brake defects or deficiencies existing prior to the crash were found in only about 8 percent of the post-crash inspections.

An examination of data included in other studies in the project literature search indicates that the percentage for brake problems included in the LTCCS data analysis provides a reasonable estimate of brake problems that may cause a crash. For example, CVSA provides a detailed summary of data from Operation Air Brake for the years 1998 to 2004. During those years, Operation Air Brake checked 66,941 trucks during roadside inspections. Of these, 11,360 (16.97 percent) have had an OOS brake condition. The percentage of brake problems found in inspections of trucks after a crash would be expected to be much higher than those found in inspections of operating vehicles. In another study, 667 crashes involving 734 large trucks (greater than 10,000 pounds) in Washington State were investigated over a two-year period. When the sample was then limited to tractor trailers (about 60 percent of the crash sample), trucks with brake defects were present in 56 percent of the crash sample. This study did not use as representative a sample as the LTCCS and, therefore, may have found a higher percentage of brake problems than the LTCCS. In other words, the Washington State study did not use a representative statistical sampling approach to selecting the crashes to include and may have over-sampled crashes involving brake defects.

Due to the thoroughness of the LTCCS and the bounding results of other studies, the LTCCS was used for this study in order to estimate the number of brake-caused crashes that would be prevented or had their severity reduced if the brake training, certification, and maintenance program based on NTSB recommendations (described in Section 1.1) were introduced. The great majority of the crashes in the study involved trucks with air brakes. About 90.1 percent of the trucks inspected in the post-crash investigations had air brakes, about 7.6 percent had hydraulic brakes and the remainder, about 2.3 percent, had unknown brake types.

The LTCCS includes data for four types of truck brake problems related to a particular crash: brake failure, brake inoperable, brakes OOA, and brakes deficient. The problems are defined as follows:

- **Out of adjustment:** If any of the brakes were measured as OOA, then this variable would be recorded as present.
- **Brakes inoperative:** This problem is present if the brakes are not working for any reason. If the brakes are inoperative because they are severely OOA, they might be recorded in the OOA category.
- **Brake system malfunction (failure):** This variable establishes whether or not the vehicle experiences a braking system malfunction (total failure such as pedal to the floor) during the pre-crash phase (may not include a malfunction due to OOA).
- **Brake system deficiency:** Braking system deficiency records any problem other than brake OOA. It includes the following: worn pads, unmatched brakes, hose connection, air pressure, brake fade, etc.

In order to assess the contribution of each of the brake problems, the data were grouped in categories because, in some cases, more than one brake problem was identified for a particular vehicle. The brake problem types were grouped in a hierarchy according to the problem considered most important, or most likely to contribute to a crash: brake failure, brake inoperative, brake system deficiency, and brakes OOA.

Brake failure accounted for 12 crashes, although an additional brake problem also existed in two of the crashes. Similarly, the 23 "brakes inoperative" problems identified for a crash were grouped as one category despite the fact that 13 of the crashes also had another brake problem associated with them. For brake system deficiency, 97 of the 121 crashes where brake deficiency was listed had only that factor. Twenty-four of the crashes also included brakes OOA as a factor. Those 24 crashes were placed in the brake system-deficiency category because of the hierarchy used in the analysis. One hundred and sixty-five crashes were characterized by brakes OOA alone.

The next step was to determine the percentage of the crashes that were unlikely to be influenced by the truck's brakes. These were the crashes where another vehicle hit the truck from behind. About 23 percent of the crashes with brake problems fall into this category. Thus, the number of crashes eligible as candidates for causing a crash is reduced by 23 percent, reducing the 321 eligible crashes to 247. The distribution of the brake problems among the 321 crashes in the LTCCS is shown in Table 5-1 along with the number of eligible crashes with identified brake problems after the "truck was hit from behind" accident type was eliminated from the total crashes.

Table 5-1. Distribution of Crashes among Brake Problem Categories in the LTCCS

Brake Problem Category	Number of Crashes	Number of Brake-related Crashes
Brake Failure	12	9
Brake Inoperative	23	18
Brake System Deficiency	121	93
Brakes Out of Adjustment	165	127
Total	321	247

Next, the role that the various brake problems play in causing a crash was determined. Although more than one brake problem was sometimes associated with a crash, for this step, causation was linked to the most serious problem in the category. Because the data in the LTCCS provided insufficient detail concerning the behavior of individual brakes and the exact nature and severity of a particular brake problem, the Battelle Team was unable to estimate precisely the role that a brake mechanical problem may have played in leading to a crash. Therefore, since the team understood that other pre-crash factors such as human error also might be in play, engineering judgment was used to estimate the number of crashes that would either be avoided or mitigated if the brake problem could have been eliminated before the crash occurred. As shown in Table 5-1, the number in each brake category found in the first column already has been reduced by subtracting the percentage of crashes where the crash type involved another vehicle striking the CMV from behind. For each of the four categories of brake problems, engineering judgment was first applied to determine the likelihood that the crash would either have been prevented or mitigated if the brake problem had been eliminated. Next, the percentage of crashes that would have fallen into each of those two categories was estimated. The discussion below describes how the particular brake crash category was allocated into either the crash-prevented or crash impacts-mitigated categories.

- **Brake system malfunction (failure):** For this brake problem category, it was estimated that all (100 percent) of the nine crashes (excluding where the truck was hit from behind) would have been prevented if the total brake failure had been prevented through proper maintenance and inspection.
- **Brakes inoperative:** For the brakes inoperative category, where the brakes are not working, it was assumed that by preventing these problems, all 18 crashes (excluding where the truck was hit by another vehicle from behind) would have either been avoided or mitigated through proper maintenance and inspection. This percentage was further assumed to be about 50 percent where the crash would have been avoided (nine crashes) and 50 percent where the crash would have been mitigated (nine crashes).
- **Brake system deficiency:** The team evaluated this category to be the third most serious of the four brake problem categories. The team applied engineering judgment to conclude, based on the nature of brake problems in this group, that about half (50

percent) of the 93 crashes in this category (47 crashes) would either be avoided or mitigated if the brake system deficiency had been prevented through proper maintenance and inspection. It was further assumed that about half of the 47 crashes would be avoided and half mitigated if brake problems had been prevented.

- **Out of adjustment:** The team estimated that about 25 percent of the crashes identified in the brake OOA category (32 out of 127 crashed) would have been prevented or mitigated if this problem had been eliminated through proper maintenance and inspection. This percentage was selected because the post-crash inspection required only one brake to be identified as OOA to be placed in this category. However, if only one brake was OOA, the stopping power of the vehicle would not have been significantly reduced, and consequently would not have been the cause of the crash. Battelle also estimated that if this braking problem were eliminated, 16 of the 32 crashes would have been avoided and 16 mitigated. A better estimate could be placed on this category if the number of axles on each vehicle and the number of OOA brakes were known; however, the LTCCS did not provide this level of detail.

Table 5-2 shows the four categories of brake problems with the number of crashes that could have been caused by brake problems and the breakdown into whether preventing the brake problem would have resulted in either avoiding a crash or reducing a crash's severity. For the purposes of this analysis, the assumption was made that if a crash were mitigated by fixing or preventing a brake problem, then the crash impacts would have been reduced by 50 percent.

Table 5-2. Examination of Brake Safety

Brake Problem Category	Number in Category	Number of Crashes Caused by Problem	Number of Crashes Avoided	Number of Crashes with Consequences Reduced by 50%
Brake Failure	9	9	9	0
Brake Inoperative	18	18	9	9
Brake System Deficiency	93	47	23	24
Brakes Out of Adjustment	127	32	16	16
Totals	247	106	57	49

In order to estimate the percentage of truck crashes that could be averted by the implementation of an enhanced training and brake maintenance program, the number of crashes shown under the "Number in Category" column in Table 5-2 must first be converted to the "Number of Crashes Caused by Problem" as shown in column 3 of the table. The next step is to convert the number of crashes caused by the problem to either "Number of Crashes Avoided" (column 4) and/or "Crashes with Consequences Reduced" (column 5). For example, in order to calculate the numbers in Table 5-2 for "Brakes Inoperative" (column 1), the project team used the assumptions found under each brake problem category and discussed above. Therefore, for "Brake Inoperative," this is considered the second most serious brake problem and all of the eligible crashes characterized by this problem and found in the "Number in Category" column were estimated to have caused crashes. Table 5-2 shows that the 18 crashes in the "Number in Category" column remain 18 in the "Number of Crashes Caused by Problem" column. The next step is to allocate the number of estimated crashes caused by the problem to either crashes avoided or crashes with the consequences reduced. Based on the discussion of brakes inoperative above, the assumption was made that if the brake problem could have been prevented or repaired before a crash, then half of the crashes would have been avoided (9 crashes) and half of the crashes would have been mitigated (9 crashes).

In order to estimate the percentage of truck crashes that would either be avoided or mitigated once an enhanced training and brake maintenance program was implemented, the project team first estimated the percentage of crashes that would have been avoided if the new program was fully effective in preventing or repairing brake malfunctions. (Bus crashes are discussed in the next section.) To calculate this number, the total number of crashes avoided, as shown in Table 5-2, was compared with the LTCCS 1,070 sample number to arrive at a percentage of all crashes that would have been avoided. The percentage of crashes that would be avoided if the brake problem could be eliminated would be 5.3 percent of all crashes. This percentage is calculated by dividing the Total Number of Crashes Avoided in Table 5-2 by the total sample number. That is, by dividing the 57 crashes avoided by the 1,070 crashes in the sample.

Second, to obtain a percentage of the total number of crashes that would be mitigated, the total number of crashes mitigated as shown in Table 5-2 was compared with the LTCCS 1,070 sample number to arrive at a percentage of all crashes that would have been mitigated. The number of crashes listed under the Total for Consequences Reduced in Table 5-2 is 49. When 49 is divided by the 1,070 LTCCS sample total, 4.6 percent of the total crashes are estimated to have their consequences mitigated. Thus, about 10 percent (9.9 percent) of all crashes could either be avoided or mitigated if the enhanced brake maintenance and training program was 100-percent effective. This percentage (10 percent) falls within the range of 1 to 40 percent estimate of crashes that could be prevented that the project team received as estimates from interviewees with brake expertise.

Finally, in order to estimate the percentage of truck crashes that either would be avoided or mitigated once an enhanced training, certification, and brake maintenance program was implemented, the Battelle Team had to estimate the effectiveness of the new program. The team assumed that the new program would unlikely be 100-percent effective. Some quality problems will always exist and shortfalls may continue to exist in training and effectiveness of maintenance and inspection programs. Although the team had no precise metrics to calculate new program effectiveness, based on their experience working with changes in vehicle maintenance and inspection programs, the team applied their best judgment to develop the assumption that the new program would experience program shortfalls in about 30 percent of the brake program activities. Thus, the new program would have an estimated effectiveness of 70 percent. Therefore, the enhanced NTSB recommended brake program (See Section 1.1) would result in either avoiding or mitigating about 7 percent (10 percent × 70 percent) of the total crashes. This number still falls within the range obtained in the survey results. Although the 70-percent program effectiveness estimate represents the project team's best assumption, the project team believes it appropriate to perform a sensitivity analysis for a range of effectiveness levels. Section 5.4, Benefit-cost Analysis, examines cost-benefit for effectiveness levels of 50, 60, 80, and 90 percent as well as at the 70-percent program effectiveness level for both crashes avoided and crashes mitigated.

Utilizing the results from the above analysis of LTCCS, about 10 percent of the 416,000 police-reported crashes found in the most recent Large Truck Crash Fact Book, 2002 data could reasonably have been caused by faulty brakes and could either be avoided or mitigated if the new brake training and maintenance program was 100 percent effective. However, when the assumed 70 percent program effectiveness is used, only 7.0 percent of all crashes would be affected. When the data are examined in more detail, 3.6 percent of all crashes would be avoided. The percentage of crashes avoided is estimated by assuming that 70 percent of the 57 shown in Table 5-2 for "Total Crashes Avoided" (about 40) would actually be avoided under the enhanced program. This percentage is about 3.6 percent of the total crashes in the LTCCS sample. To calculate the estimated number of crashes avoided, 5.3 percent is multiplied by the 416,000 police reported crashes in 2002. The resulting number, 22,161, is then multiplied by the assumed 70 percent program effectiveness rate to give 15,513 annual crashes. When rounded, this results in about 15,550 crashes avoided. A similar calculation to estimate the number of annual crashes mitigated shows that about 3 percent of the 416,000 crashes would be mitigated after the 70 percent efficiency rate is applied. This means that about 13,340 annual crashes would have their consequences reduced by half under the enhanced program.

In order to break down benefits between the two parts of the NTSB recommendations—driver training and pre-trip inspections and brake inspector training and certification—a small number of trucking industry representatives were contacted in order to allocate the benefits between the two recommendations.* Each of the trucking industry representatives contacted stated that the vast majority of the benefits would result from the brake inspector training certification. These views were echoed at a presentation of preliminary findings.† Reasons given for the limited usefulness of driver inspections included:

- High driver turnover rates,
- Lack of knowledge concerning vehicle maintenance techniques,
- Limitations in union contracts,
- Physical constraints,
- Aversion to the liability risk, and
- Lack of willingness to crawl under vehicle.

Based on this input, a range of 10 to 30 percent of the benefits are assumed to be generated through driver training and inspection programs. The remainder, 70 to 90 percent, were attributed to the proposed brake inspector training and certification programs.

* Telephone interviews with Paul Abelson, Marc Clark, Peggy Fisher, and Bob Flesher. October 14, 2005.
† Presentation delivered to the Brake Maintenance Technical Advisory Task Force at the TMC Fall Meeting, September, 2005. Valley Forge, Pennsylvania.

5.2.1.2 Avoidable Bus Crashes

Total bus crashes are listed in National Transportation Statistics report for 2003 (BTS 2004). In 2002, there were an estimated 58,000 bus crashes. The National Transportation Statistics figure also includes transit and school buses. However, identifying the number of intercity buses subject to FMCSA rules involves identifying the number of crashes involving buses not subject to FMCSA rules and subtracting them from the total number of crashes. Transit and school buses operate in a completely different environment from intercity motor coaches and many other passenger CMVs subject to FMCSA's jurisdiction. Several sources including the American Bus Association, National Safety Council, FMCSA databases, and FARS were investigated to determine the number of intercity bus crashes alone. The project team determined that data from the Transit Bus Integrated Vehicle-Based Safety Systems (IVBSS) project provides the best available data and would be used to estimate the annual number of intercity bus crashes (FTA 2004). This project began its process to estimate intercity and intracity bus crashes by first calculating the number of transit and school bus crashes and then subtracting this number from all bus crashes. When these data are used, the annual number of intercity bus crashes is estimated at about 7,800. The assumption used for this analysis is that the same percentage of intercity bus crashes as was the case with trucks could be caused by brake problems. When the same percentage figure of crashes that could have been caused by brakes and the same estimated 70 percent program efficiency level are applied to the 7,800 crashes, about 291 crashes could have been avoided by the implementation of the enhanced NTSB recommended brake program. Similarly, about 250 crashes annually could have been mitigated if the new training, certification, and inspection programs were in place. As for truck crashes discussed in Section 5.2.1.1, the assumptions for distributing benefits between the two NTSB recommendations were also applied here. A sensitivity analysis of a range of program effectiveness levels is applied to bus crashes in Section 5.4.

5.2.1.3 Avoided Costs of CMV Crashes

The CMV crash data presented in the preceding sections are multiplied by the societal costs of such crashes to determine program benefits or, more specifically, the costs that would be avoided by reducing the number of CMV crashes. The most recent and comprehensive estimates of the societal costs of truck and bus accidents are presented in the Pacific Institute's *Revised Cost of Large Truck and Bus-Involved Crashes,* prepared for FMCSA in 2002 (Zaloshnja, 2002). The societal costs as estimated by this report associated with heavy truck crashes and bus crashes are $59,153 and $32,548, respectively.[*] These costs, which are represented in 2000 dollars, were inflated to 2005 dollars—inflated to $66,813 for large trucks and $36,763 for buses—based on growth in the Consumer Price Index. These costs comprise medical-related costs, emergency services, property and equipment damage, lost productivity (e.g., wages, fringe benefits, claims processing costs, litigation costs, crash investigation costs, recruiting and training replacement for disabled workers), and monetized quality-adjusted life years.

[*] The cost estimates presented in Zaloshnja 2002 are based on data related to police-reported crashes for trucks with gross vehicle ratings in excess of 10,000 pounds and all transit and intercity buses. Thus, the bus crash estimate is based on data collected on crashes involving both transit and intercity buses.

The number of truck- and bus-involved crashes expected to be averted with implementation of the recommendations are expanded over the 10-year time horizon using a truck motor carrier growth rate based on the American Trucking Associations' U.S. Freight Transportation Forecast to 2016 (ATA, 2005). Furthermore, the estimates of total bus crashes are expanded based on motor carrier growth as estimated based on historic growth rates of private commercial buses from 1993-2003. This data is found in *Federal Highway Statistics* in Table MV-10 (FHWA, 2004).

To construct estimates of the benefits associated with crash avoidance the total number of estimated crashes avoided due to the implementation of the NTSB recommendations—16,941 for trucks and 308 for buses in 2005—were multiplied by estimated societal costs per crash ($66,813 for trucks and $36,763 for buses). The number of avoidable truck crashes was assumed to grow by 3 percent annually based on forecast growth in the trucking industry.[*] The number of bus crashes avoided and mitigated through the implementation of the NTSB recommendations was estimated to grow by 1.9 percent annually based on historic growth rates in the number of intercity buses.[†] The dollar values estimated for crash mitigation is the product of the estimated number of mitigated crashes (14,563 for trucks and 265 for buses) and the societal costs per crash divided in half. As noted previously, we assume that mitigated crashes would generate roughly half the costs relative to those crashes that would be avoided.

Based on the aforementioned assumptions, total crash cost savings are estimated at $18.7 billion over the 10-year analysis time horizon. Of this amount, $18.5 billion or 99 percent are attributed to the reductions in large truck crashes while $176.6 million are attributed to intercity bus crashes. Discounting these values at 7 percent results in an estimated $13.8 billion in avoided costs due to enhanced safety over the 10-year (2005-2014) time horizon. These benefits are shown in Table 5-3.

5.2.2 Out-of-Service Violation Impacts

For OOS truck violations, several surveys such as Operation Airbrake could have been used to provide the basis for estimating how many OOS violations could have been prevented by the adoption of the enhanced maintenance and inspection activities. The assumption made for this analysis is that the MCMIS data for OOS brake-related violations is most appropriate because it reflects the actual inspections that a carrier was subjected to by a "qualified technician" in a year. Consequently, any reduction in OOS violations derived from the implementation of the enhanced brake maintenance and inspection activities should be estimated using the MCMIS OOS data. OOS data for 2002, 2003, and 2004 from MCMIS are shown in Table 5-4.

[*] American Trucking Association, U.S. Freight Transportation Forecast to 2008. Washington, D.C.
[†] Bureau of Transportation Statistics. National Transportation Statistics. 2004. Washington, D.C. http://www.bts.gov/publications/national_transportation_statistics/2005/html/table_bus_profile.html

Table 5-3. Benefits Associated with Avoided Crash Costs

	Truck Crashes		Bus Crashes		Truck Crash Cost Savings	Bus Crash Savings	Total Crash Cost Savings	Discounted Total Crash Cost Savings
	Avoided	Mitigated	Avoided	Mitigated				
2005	16,941	14,563	308	265	1,618,404,577	16,187,163	1,634,591,739	1,634,591,739
2006	17,446	14,997	314	270	1,666,633,033	16,498,149	1,683,131,182	1,573,019,797
2007	17,966	15,444	320	275	1,716,298,697	16,815,111	1,733,113,808	1,513,768,721
2008	18,501	15,905	326	280	1,767,444,399	17,138,161	1,784,582,560	1,456,750,955
2009	19,053	16,378	332	286	1,820,114,242	17,467,419	1,837,581,660	1,401,882,250
2010	19,620	16,867	339	291	1,874,353,646	17,803,001	1,892,156,648	1,349,081,539
2011	20,205	17,369	345	297	1,930,209,385	18,145,032	1,948,354,416	1,298,270,814
2012	20,807	17,887	352	302	1,987,729,624	18,493,633	2,006,223,257	1,249,375,015
2013	21,427	18,420	359	308	2,046,963,967	18,848,931	2,065,812,898	1,202,321,915
2014	22,066	18,969	365	314	2,107,963,493	19,211,055	2,127,174,549	1,157,042,013
Total	194,032	166,799	3,360	2,888	18,536,115,063	176,607,655	18,712,722,718	13,836,104,759

Table 5-4. Non-crash Vehicle Inspections and Number of OOS Brake Violations

Number of "non-crash" vehicle inspections performed (Levels 1,2,5)				
Vehicle Type	Year			Average
	2002	2003	2004	
Motor coach	8,917	9,717	9,846	9,493
Truck	2,118,985	2,111,454	2,196,450	2,142,246
Total	**2,127,902**	**2,121,171**	**2,206,296**	**2,151,789**

Number of "non-crash" vehicle inspections with an OOS brake violation				
Vehicle Type	Year			Average
	2002	2003	2004	
Motor coach	446	532	482	487
Truck	193,354	215,070	222,529	209,940
Total	**193,800**	**215,602**	**223,011**	**210,804**

MCMIS data for 2002 to 2004 show that for an average year, a total of 2,142,246 non-crash truck inspections were conducted. Of these inspections, brake violations represent an average of about 9.8 percent or 209,940 brake-related OOS violations per year.

If the same program efficiency of 70 percent is applied to a new brake maintenance and training program, 70 percent of the OOS violations could be prevented by the implementation of the enhanced brake maintenance and inspection activities. By adopting the new program, this calculation would result in a reduction of 146,958 brake related OOS violations annually.

For the years 2002, 2003, and 2004, MCMIS non-crash motor coach inspection data show that for an average year, 9,493 non-crash bus inspections were conducted. Of these, about 5 percent or 487 inspections resulted in an OOS brake violation in an average year. If the same 70 percent program efficiency level was applied to the bus brake-related OOS violations, 341 OOS violations would be avoided in a year by adopting the enhanced training, certification, and inspection program.

The costs associated with OOS violations are based on the assumptions that the average OOS violation results in 8.7 hours of downtime and that being placed out of service costs an average motor carrier $57 per hour.* Based on these assumptions, total savings resulting from a reduction in OOS violations as a result of the brake inspection program totals $851.2 million over the 10-year time horizon or $629.3 million in discounted present value terms.

* Interview with Dan Murray, American Trucking Research Institute, 7/23/05

5.2.3 Impacts on Citations involving Monetary Penalties

Some cost savings can be expected due to improved maintenance and driver inspections (and correction) of stroke adjustment as a result of fines not being assessed for brake OOA violations. These would be in addition to the savings for vehicles not placed OOS due to brake adjustment.

While the amount of a fine for a "stroke beyond the adjustment limit" violation varies from place to place, a check of eight jurisdictions resulted in an average fine per violation (including court costs) of roughly $100.

The number of vehicles that would see cost savings from improved maintenance and pre-trip inspection due to elimination of OOA violations is calculated based on the assumptions outlined below. The data are taken from Operation Air Brake statistics from the years 1998 through 2004, looking only at the U.S. checks and separate calculations are given for trucks and buses:

- The total number of trucks inspected: 111,053
- The total number of truck brakes checked: 866,627
- Average number of truck brakes per vehicle = 866,627/111,053 = 7.80
- The total number of truck OOS for brake adjustment = 14,412

Thus, this is a minimum of 2 × 14,412 = 28,825 brakes OOA on trucks OOS for brakes OOA. This assumes that the CVSA 20-percent rule* was applied, so at least 2 brakes per truck had to be OOA. Another method would take 20 percent of 7.80 brakes average per truck × 14,412 trucks = 22,494 brakes OOA on trucks OOS for OOA brakes.

Data compiled from Operation Air Brake statistics indicate that the total number of brakes OOA was 54,228. We assume that the total number of brakes OOA (54,228) includes those on trucks placed OOS (28,825 or 22,494, depending on which calculation you use). Therefore, the number of brakes OOA, but not resulting in OOS (i.e., those which would have been subject to a citation and fine) would be 54,228 less 28,825 (or 22,494) = 25,403 (or 31,734). We divide this number of brakes by the number of brakes per truck (in order to not be OOS, each truck would only be allowed to have only one brake OOA) and get 25,403/7.80 = 3,255 trucks (or 4,066 using the second method).

This results in 3,255/111,053 = 2.9 percent (or 3.7 percent) of the trucks inspected being subject to a fine for brakes OOA. Using this percentage of the 2.1 million inspections per year and $100 dollar average fine, and a 70 percent efficiency of the "maintenance + driver inspections," a savings of $4.4 million per year (or $5.5 million using the second calculation method) are estimated. We use the mid-point of these two estimates (3.3 percent) in the benefits calculation resulting in an estimated $4.9 million in savings in Year 1. Total savings over the 10-year time frame are estimated at $56.6 million (nominal 2005 dollars).

* CVSA OOS criteria specify that vehicles with 20 percent or more of their brakes found to be defective should be placed OOS. In terms of adjustment, defective means ¼-inch or more beyond the recommended adjustment limit.

The bus analysis follows the truck analysis:

- The total number of buses inspected: 76
- The total number of bus brakes checked: 350
- Average number of bus brakes per vehicle = 350/76 = 4.61
- The total number of bus OOS for brake adjustment = 11

Thus, this is a minimum of 2 × 11 = 22 brakes OOA on buses OOS for brakes OOA.
This assumes that the CVSA 20-percent rule was applied, so at least 2 brakes per bus had to be OOA. Another method would take 20 percent of 4.61 brakes average per bus × 11 buses = 10 brakes OOA on buses OOS for OOA brakes.

The total number of brakes OOA, as estimated based on data compiled from Operation Air Brake statistics, was 31. We assume that the total number of brakes OOA (31) includes those on buses placed OOS (22) (or 10, depending on which calculation you use). Therefore, the number of brakes OOA, but not resulting in OOS (i.e., those which would have been subject to a citation and fine) would be 31 less 22 (or 10) = 8 (or 20). These numbers do not sum to 31 due to rounding. We divide the number of brakes by the number of brakes per bus (in order to not be OOS, each bus would only be allowed to have only one brake OOA) and get 8/4.61 = 2 buses (or 4 using the second method).

This results in 2/76 = 2.3 percent (or 5.8 percent) of the buses inspected being subject to a fine for brakes OOA. Using this percentage of the 9,500 inspections per year and $100 dollar average fine, and a 70 percent efficiency of the "maintenance + driver inspections," we get a savings of $15,000 per year (or $38,500 using the second calculation method). We use the mid-point of these two estimates (4.1 percent) in the benefits calculation resulting in an estimated $27,000 in savings in Year 1. Total savings over the 10-year time frame are estimated at $310,000 (nominal 2005 dollars).

5.3 Costs Assessment

Implementing the NTSB recommendations would generate training, inspection, testing, and certification costs as well as administrative costs associated with record keeping and retention. Training would be required of bus and truck drivers responsible for performing pre-trip inspections. Brake inspectors would train in preparation for the testing and certification process called for in the NTSB recommendation. Training costs would include the costs associated with preparing training materials, compensating internal trainers, paying fees to external trainers, and labor costs for staff receiving the training. Training costs would include those required to train both new and existing drivers in initial and refresher training courses. The brake inspector certification process also would result in costs associated with registration and testing fees. Finally, pre-trip inspections would take drivers away from revenue-generating activities and would, thus, result in additional labor costs. In each case, these costs would be borne by the motor carrier industry. This section of the report examines these costs and examines the costs each would impose on industry.

5.3.1 Training, Testing, and Certification Costs

The recommendations set forth by NTSB would require a sufficient level of training in brake systems for both CMV drivers and brake inspectors. The results of the training, testing, and certification surveys suggest that the intensity of training necessary for drivers and brake inspectors would be different reflecting their particular responsibilities. Drivers would need to attain an acceptable level of knowledge to ensure for proper maintenance of CMV brake systems by conducting pre-trip inspections to identify the presence of brake deficiencies.

Initial training costs in Year 1 for driver training and for brake inspector training are made up of the costs to deliver the training, fees paid to third-party vendors, and labor replacement costs. The costs to deliver and receive the training are based on input provided from training, testing, and certification surveys regarding the duration of the training, pay for trainers, and class size. Labor data for truck and bus drivers, as well as brake inspectors, were obtained from the following sources: the National Compensation Survey (Bureau of Labor Statistics [BLS]), Occupational Employment Statistics (Bureau of Labor Statistics), American Trucking Associations Driver Compensation Survey, and Bureau of Transportation Statistics Office of Motor Carrier Information's Financial and Operating Statistics. The total number of truck drivers who would need to be trained initially was estimated by FMCSA at 7.0 million. The total number of brake inspectors used in the analysis is 456,666, and is also based on data provided by FMCSA.

Respondents indicated that an initial training course taking 4 hours would be sufficient to train drivers. Brake inspectors, however, would need a higher level of understanding to properly inspect, maintain, service, and repair CMV brake systems and to pass testing for certification as recommended by NTSB. The respondents indicated that brake inspectors would be required to undergo 8 hours of initial training and 2 hours of testing and certification.

Training costs over Years 2-10 of the 10-year analysis timeframe include the additional training needed to account for periodic refresher courses. To determine refresher training costs, assumptions were required regarding the wage of the participants, average class size, frequency, and duration of the refresher training course. Truck driver turnover rates were obtained from comments provided on an initial draft of this report at the TMC Fall Meeting in Valley Forge, PA. These comments identified turnover rates by industry segment (LTL, truckload, private). This information was combined with ATRI market share data to estimate driver turnover rates for the entire industry. Bus driver turnover rates were assumed to mirror those of truck drivers, and brake inspector turnover rates are based on BLS averages for the transportation sector and information acquired through stakeholder interviews. Interview respondents indicated that the NTSB recommendations would require truck drivers to undergo 2 hours of refresher training every year, while brake technicians would take 2 hours of refresher training every 2 years.

The research team assumed that driver training for companies employing 20 or more individuals would be conducted in-house. The in-house training costs are a function of training material costs ($4 per student), the hourly cost of the trainer ($34.70 per hour), training time (4 hours for initial training and 2 hours for refresher training), and average class size (17.5 students per class). The basis for each assumption is detailed in Table 5-5. Based on these assumptions, the average cost to supply the course in-house is estimated at $12 per student for initial training and $8 per student for refresher training. Because small companies lack the resources and capabilities to perform training in-house, companies with 19 or fewer employees are assumed to rely on external trainers. Based on the data collected in support of the brake technician course cost analysis presented in Table 5-6, fees paid to external trainers are estimated at $15 per student per hour. The 2002 Economic Census indicates that roughly 24.9 percent of all individuals employed in NAICS 484 Truck Transportation and 14.4 percent of all individuals employed in NAICS 4852 Interurban and Rural Bus Transportation and NAICS 4855 Charter Bus Industry are employed by companies with fewer than 20 employees (U.S. Department of Commerce 2002). Based on these assumptions, the numbers of truck and bus drivers seeking external training in the first year following implementation are estimated at 1.7 million and 3,503, respectively. External training costs are estimated at $15 per student per hour based on a scan of training schools presented in Table 5-6.

The more complex needs associated with training and certifying brake technicians is assumed to be performed completely by third-party vendors. The fees associated with external training courses for brake technicians were determined through a scan of comparable programs offered through training schools and academic institutions around the United States, as highlighted in Table 5-6. The costs associated with these training courses ranged from $45 to $250, with most in the $150-$250 range. However, these programs are generally more comprehensive and take much more time than the amount most motor carriers view as necessary to complete the training considered in this study. The list of comparable classes presented in Table 5-6 ranges from simple pre-trip inspection courses to more comprehensive brake technician courses. When normalized on a per-hour cost basis, the hourly training cost for these courses generally falls between $10 and $20. Based on these data, this analysis assumes an average training course cost of $15 per student per hour or $120 for initial brake technician training and $30 for all refresher training courses. This cost does not include the certification testing nor does it cover the labor costs associated with the time brake technicians spend in class.

Training cost estimates also account for payments to workers who replace drivers attending training. These labor replacement costs are a function of the hourly rates paid to replacement labor and the time drivers spend in class. The overtime provisions of the Fair Labor Standards Act do~~es~~ not apply to CMV drivers. Therefore, it is assumed that labor replacement costs would be paid at standard hourly rates and motor carriers would not incur overtime costs. Based on these assumptions, the labor replacement costs, which include fringe benefits, are estimated at $19.00, $19.25, and $22.69 for truck drivers, bus drivers, and brake technicians, respectively.

Table 5-5. Training Cost Assumptions

Data Requirements	Assumption	Source
1. Number of truck drivers	7.0 million in 2005	FMCSA (Gruberg 2005)
2. Number of bus drivers	24,380 in 2005	BTS, NTS
3. Number of brake inspectors	456,666 in 2005	FMCSA
4. Time required to train drivers initially	4 hours	Interviews
5. Time requirements and frequency of refresher training for drivers	2 hours every year	Interviews
6. Time required to train brake technicians initially	8 hours	Interviews
7. Time required for testing and certification process	2 hours	Interviews
8. Time requirements and frequency of refresher training for brake technicians	2 hours every 2 years	Interviews
9. Average class size	15-20 (assumed 17.5)	Interviews
10. Training materials costs	$4 per student	Interviews
11. Average salary + fringe benefits of trainer	$34.70/hr	Interviews
12. Average salary + fringe benefits of truck drivers	$19.00/hr	ATA Driver Compensation Study, Occupational Employment Statistics, BLS National Compensation Study
13. Average salary + fringe benefits of bus drivers	$19.25/hr	National Transit Database BLS Employer Costs for Employee Comparative Statistics
14. Average salary + fringe benefits of brake technicians	$22.69/hr	Bureau of Labor Statistics, Occupational Employment Statistics
15. Truck driver turnover rates	55 percent	Comments provided at TMC Fall Meeting in Valley Forge, PA concerning turnover rates by industry segment (LTL, truckload, private) combined with ATRI market share data.
16. Bus driver turnover rates	55 percent	Assumed to be same as truck drivers'
17. Brake technician turnover rates	15 percent	BLS, Transportation Sector and Interviews
18. Payments to third party trainers for brake technician courses (initial / refresher training)	$120 per student (initial) / $30 per student (refresher)	Scan of training schools
19. Registration and testing costs for brake technicians	$32 registration + $25 testing = $57 (initial); $25 testing fee for renewals	Scan of training schools
20. Share of drivers working for companies with fewer than 20 employees	24.9 percent (truck drivers), 14.4 percent (bus drivers)	2002 Economic Census - NAICS 484 (Truck) and 4852 (Bus) and 4855 (Bus)

Table 5-6. Driver and Technician Training Courses and Associated Fees

School	Class	Cost	Cost per Hour of Instruction
Advance Driver Training	Air brakes	$250	$21
Western Wyoming Community College	Commercial vehicle pre-trip inspection	$45	$12
Catawba Valley Community College	Vehicle safety inspection course	$50	$6
Central Pennsylvania Institute of Science and Technology	Mechanic inspection certification, including brake systems	$198	$11
Aspire	Brake training video and manual	$129	N/A
Fox Valley Technical College	Various diesel service mechanic and technician courses	$224	$14

Based on these assumptions, total training, testing, and certification costs are estimated at $5.4 billion over the 10-year time horizon in discounted 2005 dollars. Of that amount, $4.8 billion are attributed to the training of truck drivers, $13.3 million to training bus drivers, and $564.9 million to the training, testing, and certification of brake inspectors.

In the short-term, the availability of external training options for drivers and brake inspectors could be limited. Based on the assumptions outlined previously in this section, the NTSB recommendations considered in this report would result in 1.7 million drivers and 456,666 brake inspectors attempting to locate external training options to satisfy new training requirements. Furthermore, motor carriers across the country would require time to develop training curricula and associated materials in order to train approximately 5.3 million drivers in the first year following implementation of the NTSB recommendations.

In 2004, there were roughly 2,000 automotive service technician training programs that had been certified by the National Institute for ASE. The NATEF has also certified more than 100 schools offering M/H technician training programs. There are 700 testing centers nationwide used by ASE in the certification process. These and other training facilities could be used to satisfy the requirements outlined in the NTSB recommendations; however, there are concerns that implementing the NTSB recommendations could be difficult in terms of both the ability of external trainers to meet the demand in the short-term and the geographic distribution of trainers and training facilities.

The economic analysis presented in this report does not make any assumptions regarding the availability of training seats, nor does it examine the impact of the enhanced demand for training caused by the NTSB recommendations on the prices associated with external training classes and certification testing. In order to address industry concerns regarding the challenges associated with meeting the requirements outlined in the NTSB recommendations, FMCSA could consider an extended implementation period (e.g., 2-4 years). Extending the implementation period would ease the burden on industry by allowing motor carriers more time to develop internal training programs and enabling the training industry to expand the supply of training seats and address the issues relating to the geographic dispersion of motor carrier operations.

5.3.2 Inspection Costs

The NTSB recommendations would require that CMV drivers inspect vehicle brakes before each trip. To estimate the cost of pre-trip inspections, the research team calculated the product of the total number of axles on single-unit and combination trucks operating on U.S. highways, the average number of trips taken by heavy trucks annually in the United States, per-axle inspection time requirements, and the average wage of the truck drivers performing the inspections. This section of the report describes the methods used to determine the costs associated with pre-trip inspections and estimates total pre-trip inspection costs associated with the NTSB recommendations.

Total Number of Axles on Single-Unit and Combination Trucks

Since the interview survey respondents estimated pre-trip inspection costs on a per-axle basis (2 minutes per axle), it became necessary to determine the number of axles on single-unit and combination trucks operating in the United States. The Federal Highway Administration's (FHWA's) *Highway Statistics* presents annual data on the number of single-unit and combination trucks operating in the United States in Table VM-1 (FHWA, 2004). These values were combined with data presented in the 2002 Vehicle Inventory and Use Survey (VIUS) in order to estimate the number of axles on trucks requiring pre-trip inspections (U.S. Census Bureau, 2004). The results of this analysis are presented in Table 5-7. Note that the NTSB recommendations would not apply to vehicles weighing 10,000 pounds or less. Therefore, these vehicles were excluded from the analysis. As shown, the number of axles on single-unit and combination trucks was estimated at 16.4 million in 2003.

Table 5-7. Number of Axles on Single-unit and Combination Trucks

Truck Type	Total Number of Vehicles	Total Number of Axles
Single Unit Trucks		
2 axles	1,852,642	3,705,284
3 axles	760,670	2,282,010
Axles not specified	7,385	18,463
Combination Trucks		
3 axles	155,088	465,264
4 axles	354,487	1,417,948
5 axles or more	1,543,496	7,717,480
Axles not specified	192,014	768,055
Total	4,865,782	16,374,504

Annual Number of Trips Taken by CMVs

The 2002 Vehicle Inventory and Use Survey (VIUS) published a comparative summary of operation ranges for U.S. trucks registered in the 1997 and 2002 VIUS (U.S. Census Bureau, 2004). These estimates represent average miles per trip, as shown in Table 5-8. VIUS data indicate that roughly 50 percent of all trucks operate in an area of less than 50 miles, the average trip length for 16.8 percent of all trucks falls between 51 to 200 miles, and only about 9.5 percent of all trucks' average trip length exceeds 200 miles.

The drawback of using these percentages for the CMV brake inspection and maintenance study is that they do not represent trucking industry averages. Rather, VIUS statistics represent aggregate statistics of all types of trucks. This study, on the other hand, focuses on trucking and intercity bus industry motor carriers that are largely under-represented in VIUS data.

Table 5-8. VIUS Percentage of Trucks Based on Range of Operation

Range of Operation	1997	2002
50 miles or less	52.5	52.3
51 to 200 miles	23.9	16.8
201 miles or more	15.1	9.5
Off the road, not reported, and not applicable	8.5	20.4

Forkenbrock, in a study titled "External Costs of Intercity Truck Transportation," used an ATA database principally comprised of Class I (annual revenues in excess of $10 million) carrier data to estimate the proportion of for-hire truckload general freight trucking operations falling into three ranges of operation categories: less than 250 miles, 250 to 500 miles, and over 500 miles (Forkenbrock, 1999). These data are shown in Table 5-9. The data set used in Forkenbrock (on pages 505 to 526), had a small number of Class II carriers (annual revenues between $3 and $10 million) and almost no Class III carriers (annual revenues of less than $3 million). Due to the bias inherent in the data used in the study, the percentage of trucks traveling in excess of 500 miles per trip would not appear to apply to the overall trucking industry.

Table 5-9. Percentage of Trucks Based on Range of Operation

Range of Operation	Highway Miles Operated (thousands)	Percentage Share of Total
Less than 250 Miles	723,052	8.09%
250 - 500 Miles	1,367,380	15.30%
Over 500 Miles	6,845,397	76.61%
Total	8,935,829	100.00%

Neither of the two studies outlined previously are directly applicable to this study; however, they could represent upper and lower bounds on most likely estimates. Thus, the research team initially adopted a mid-range estimate of 300 to 400 miles per trip on average for the CMVs studied here. However, when considering that long-haul trucking operations would be required to inspect the brake systems each day prior to departure, the most miles a truck could travel between inspections would be roughly 660 (60 miles per hour multiplied by 11 hours on the road). Thus, the low-end estimate was reduced to 200 miles. When combined with annual mileage estimates on a per-truck and bus basis appearing in *Highway Statistics*, this range produces an estimate of 68 to 136 inspections per year per truck and 21 to 43 inspections per year per bus.

Inspection Costs

The annual number of axles inspected is computed as the product of the number of annual inspections (68-136 as outlined in the previous section) and the total number of axles on single-unit and combination trucks (16.4 million as documented in Table 5-7). Based on these assumptions, the total number of truck axles requiring inspection was estimated at between 1.1 and 2.2 billion in 2005. Based on truck driver salaries previously noted in the training cost analysis (Table 5-5), total estimated costs associated with performing 2-minute pre-trip inspections on each axle would result in approximately $4.9 to $9.9 billion in inspection costs over the 10-year study time horizon.

The total number of bus axles inspected annually is a function of the number of inspections outlined in the previous section of this report (21-43 annually) and the total number of bus axles (estimated at 279,790). The cost to inspect each axle is a function of the time required to inspect it (2 minutes or 1/30th of an hour) and the hourly wage plus fringe benefits of bus drivers ($19.25 as documented in Table 5-5). Based on these assumptions, total inspection costs are estimated at between $25.2 and $50.3 million over the 10-year study time horizon.

Administrative Costs

There are administrative costs borne by the motor carrier industry associated with coordinating training for drivers and brake inspectors and maintaining training and certification records. To determine the costs associated with these activities, there were several questions posed to industry regarding the costs associated with these administrative functions. Unfortunately, the interview surveys failed to produce conclusive results in this area. Thus, based on limited data and additional analysis of the administrative requirements under the NTSB recommendations, the research team estimates administrative costs at 10 minutes per driver and brake inspector trainee. The annual administrative costs are, therefore, estimated as the product of the number of annual driver and brake inspector trainees and 10 minutes salary for executive secretaries and administrative assistants, estimated in the BLS OES at $22.64, including fringe benefits. Based on these assumptions, total administrative costs are estimated at $316.7 million over the 10-year time horizon (2005 to 2014). Of this amount, $303.7 million was attributed to administering the driver training programs, with the remainder ($13.0 million) tied to brake inspector training and certification.

5.4 Benefit-cost Analysis

The incremental costs incurred by the motor carrier industry to implement the NTSB recommendations in the base case analysis (70 percent program effectiveness) are summarized in Tables 5-10 and 5-11. Benefits associated with improved safety and reduced OOS violations are also included in these tables. The most significant costs are those incurred during pre-trip inspections, which total roughly $4.9 to $9.9 billion over the 10-year time horizon (2005 to 2014). Though each inspection would require only 2 minutes per axle, the costs of this requirement are significant because they would require billions of inspections to be performed over the next 10 years. The cost range is due to varying the assumption regarding the average distance per trip between 200 and 400 miles. Training, testing, and certification collectively represent the next highest cost item, totaling $5.4 billion over the 10-year analysis timeframe. Administrative costs are relatively low at $316.7 million over 10 years.

Overall, estimated benefits are higher than projected costs over the 10-year time horizon in the base case analysis when low-end cost assumptions are used, with discounted benefits (using a 7 percent discount rate) totaling $14.5 billion ($19.6 billion in nominal benefits), compared to $10.7 billion in costs. When the high-end cost assumption regarding the number of inspections is used, estimated costs grow to $15.6 billion and exceed estimated benefits by $1.1 billion. Thus, net benefits are estimated at ($1.1) to $3.8 billion. These numbers correspond with benefit-cost ratios of .93 and 1.36. These results demonstrated nearly no sensitivity to variations in discount rates. At a 10 percent discount rate, the benefit-cost ratio ranges between .92 and 1.35 and varies from .93 and 1.07 when a 4 percent discount rate is applied. The lack of discount rate sensitivity occurs because benefits and costs are realized relatively evenly over the 10-year time horizon, with the exception of relatively higher training costs in Year 1.

Table 5-10. Benefit-cost Analysis Findings (Average Trips by CMV Assumed to be 200 miles)

Year	Benefits	Discounted Benefits	Driver Training Cost: Trucks	Driver Training Cost: Intercity Buses	Pre-Trip Inspection Costs: Trucks	Pre-Trip Inspection Costs: Intercity Buses	Inspector Training, Testing and Certification Costs	Administrative Costs	Total Discounted Cost	Net Benefits
2005	1,713,889,124	1,713,889,124	696,909,995	1,920,157	1,167,723,733	6,202,826	184,461,554	28,250,387	2,085,468,652	(371,579,528)
2006	1,764,789,808	1,649,336,269	528,587,581	1,530,354	1,123,803,801	5,908,405	35,513,159	27,665,991	1,723,009,291	(73,673,022)
2007	1,817,204,004	1,587,216,354	508,728,496	1,457,715	1,081,535,767	5,627,960	51,180,876	29,762,014	1,678,292,828	(91,076,474)
2008	1,871,176,752	1,527,437,610	489,615,519	1,388,524	1,040,857,500	5,360,826	37,932,763	29,619,836	1,604,774,969	(77,337,359)
2009	1,926,754,431	1,469,911,730	471,220,618	1,322,617	1,001,709,207	5,106,372	47,770,212	31,441,674	1,558,570,701	(88,658,971)
2010	1,983,984,801	1,414,553,744	453,516,816	1,259,838	964,033,344	4,863,996	39,189,244	31,640,612	1,494,503,849	(79,950,105)
2011	2,042,917,046	1,361,281,887	436,478,147	1,200,039	927,774,529	4,633,124	45,315,399	33,281,720	1,448,682,957	(87,401,070)
2012	2,103,601,811	1,310,017,485	420,079,622	1,143,079	892,879,465	4,413,210	39,710,098	33,749,340	1,391,974,813	(81,957,329)
2013	2,166,091,252	1,260,684,830	404,297,191	1,088,822	859,296,859	4,203,735	43,474,724	35,279,227	1,347,640,558	(86,955,728)
2014	2,230,439,077	1,213,211,075	389,107,708	1,037,141	826,977,349	4,004,203	40,384,942	36,042,290	1,297,553,632	(84,342,557)
Total	19,620,848,106	14,507,540,108	4,798,541,694	13,348,285	9,886,591,552	50,324,657	564,932,970	316,733,092	15,630,472,250	(1,122,932,142)

Table 5-11. Benefit-cost Analysis Findings (Average Trips by CMV Assumed to be 400 miles)

Year	Benefits	Discounted Benefits	Driver Training Cost: Trucks	Driver Training Cost: Intercity Buses	Pre-Trip Inspection Costs: Trucks	Pre-Trip Inspection Costs: Intercity Buses	Inspector Training, Testing and Certification Costs	Administrative Costs	Total Discounted Cost	Net Benefits
2005	1,713,889,124	1,713,889,124	696,909,995	1,920,157	583,861,866	3,101,413	184,461,554	28,250,387	1,498,505,373	215,383,751
2006	1,764,789,808	1,649,336,269	528,587,581	1,530,354	561,901,900	2,954,203	35,513,159	27,665,991	1,158,153,188	491,183,081
2007	1,817,204,004	1,587,216,354	508,728,496	1,457,715	540,767,883	2,813,980	51,180,876	29,762,014	1,134,710,965	452,505,390
2008	1,871,176,752	1,527,437,610	489,615,519	1,388,524	520,428,750	2,680,413	37,932,763	29,619,836	1,081,665,806	445,771,804
2009	1,926,754,431	1,469,911,730	471,220,618	1,322,617	500,854,604	2,553,186	47,770,212	31,441,674	1,055,162,911	414,748,819
2010	1,983,984,801	1,414,553,744	453,516,816	1,259,838	482,016,672	2,431,998	39,189,244	31,640,612	1,010,055,179	404,498,564
2011	2,042,917,046	1,361,281,887	436,478,147	1,200,039	463,887,264	2,316,562	45,315,399	33,281,720	982,479,131	378,802,757
2012	2,103,601,811	1,310,017,485	420,079,622	1,143,079	446,439,732	2,206,605	39,710,098	33,749,340	943,328,476	366,689,009
2013	2,166,091,252	1,260,684,830	404,297,191	1,088,822	429,648,430	2,101,868	43,474,724	35,279,227	915,890,261	344,794,569
2014	2,230,439,077	1,213,211,075	389,107,708	1,037,141	413,488,674	2,002,101	40,384,942	36,042,290	882,062,856	331,148,219
Total	19,620,848,106	14,507,540,108	4,798,541,694	13,348,285	4,943,295,776	25,162,329	564,932,970	316,733,092	10,662,014,145	3,845,525,963

Table 5-12 presents the findings of the benefit-cost analysis when the ratio of program effectiveness is varied between 50 and 90 percent and the benefits and costs are split between the two NTSB recommendations (driver inspection and training and brake inspector training and certification) As discussed in Section 5.2, roughly 70 to 90 percent of the benefits associated with reducing the number of crashes, fines and violations are attributed to the proposed brake inspector training and certification program. The majority of the costs, however, were attributed to the driver training and pre-trip inspection recommendation.

Table 5-12. Benefit-cost Analysis Findings (Alternative Scenarios)

	Benefit-cost Ratios		
Program Effectiveness	**Driver Training/ Pre-trip Inspections**	**Brake Inspector Training and Certification**	**Both Driver and Brake Inspector NTSB Recommendations**
50%	0.07-0.31	12.65-16.26	0.66-0.97
60%	0.08-0.37	15.18-19.51	0.80-1.17
70%	0.10-0.43	17.71-22.77	0.93-1.36
80%	0.11-0.49	20.24-26.02	1.06-1.56
90%	0.12-0.55	22.77-29.27	1.19-1.75

The final step in conducting the benefit-cost analysis (BCA) is to compare the societal costs and benefits and to construct BCRs in order to quantify the extent to which benefits exceed or fall short of costs. A BCR is equal to the present value of benefits divided by the present value of costs. Thus, a BCR in excess of 1.0 demonstrates positive economic returns to society. When BCRs exceed 1.0, society experiences net benefits from the regulation (net present value of benefits = present value of benefits – present value of costs). Under the high-end estimate concerning the costs associated with pre-trip inspections (200-mile average trip), the NTSB recommendations produce net benefits with BCRs in excess of 1.0. Under the low-end estimate (400-mile average trip), the recommendations fail to produce net benefits when the program effectiveness drops below 76 percent (i.e., the BCR is below 1.0).

The driver training and pre-trip inspection recommendation fails to produce net benefits under any of the scenarios considered in Table 5-12. The driver training and pre-trip inspection recommendation produced BCRs ranging from 0.07 (50 percent ratio of effectiveness, 200-mile average trip) to 0.55 (80 percent program effectiveness, 400-mile average trip).

The brake inspector and certification recommendation, on the other hand, produced large net benefits, with BCRs exceeding 12.65 in all scenarios considered in this study. The BCRs range from a low of 12.65 (50 percent program effectiveness, 200-mile average trip) to 29.27 (90 percent program effectiveness, 400-mile average trip).

APPENDIX A. REFERENCES

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APPENDIX B. ADDITIONAL ANNOTATED REFERENCES

This appendix describes data sources, papers, reports, and books that were consulted during this study but not discussed directly in the Section 2, Literature Review. Although the annotated references were not used directly for the report preparation, they served to provide background material and information or to validate another source and indicate its applicability to the project. Material here is organized under the following categories used for the Literature Review in Section 2.

- Data and studies on crashes and OOS violations that could be prevented or mitigated,
- The need for better driver/ brake technician training and inspection,
- Existing brake training programs, and
- Economic analysis techniques.

No additional annotated references are described under economic analysis techniques.

B.1 Data and Studies for Use in Estimating Crashes and OOS Violations That Could be Prevented or Mitigated

(CPIR-B File) Smist, T.E.;Ramney, T.A., Heavy Truck Causation: Analysis of the CPIR-B File; U.S. Department of Commerce, National Technical Information Service, April 1983

The CPIR-B (Heavy Truck) accident file identifies specific factors related to heavy truck accident causation. The population of over 335 trucks includes both straight and articulated (semis) trucks but was selected by a number of different sources over a number of years. Consequently, the sample is not random or necessarily representative of the overall population of large trucks. Furthermore, the methodology concerning how the various accident categories were determined is not fully detailed. This makes it difficult for the reader to evaluate the usefulness of the data.

The analysis does provide a tabulation of component failures for those vehicles involved in the crashes. For the 335 trucks involved in the accidents, known brake failure represents 3.6 percent of the total.

(FACT Database) Shelton, Terry, "What is the Current Level of Compliance?" North American Brake Safety Conference, Toronto, Canada, September 2000

The contribution of brake defects as a contributor to truck crashes is uncertain. Some study analyses show brake defects being responsible for up to 45 percent of truck crashes and trucks involved in crashes are at least as likely to have brake defects as trucks sampled randomly. The Michigan FACT project, which included a detailed field inspection of trucks involved in fatal accidents, showed that about 31 percent of trucks involved in fatal crashes had brake defects. However, it is uncertain how often these defects actually caused the crash.

Fleischer, G.A., Philipson L.L., Statistical Analysis of Commercial Vehicle Accident Factors Volume II – Summary Report. NHTSA, Washington D.C, 1978

This report is based on an analysis of about 3,000 California State Highway Patrol accident reports for a one-year period. The statistical analysis focuses on quantitative risk analysis. The report does include a breakdown of the "inadequacy of certain functions." Braking in-lane represented 27 percent, brake and steering 15.8 percent, brake-fade 0.7 percent, brake-caused 3.3 percent for skid, and 3.3 percent for leaving lane. However, in only about 200 cases did an officer cite equipment violations.

Freund, Deborah M., Woodford, Gary R., Minor, Larry, Stopping on 18 Dimes: A Decade of Progress in Motor Vehicle Brake Safety." Proceedings of 2002 International Large Truck and Bus Safety Research and Policy Symposium, Knoxville, TN, 2002.

This article describes the changes in brake safety standards over time, the role of the FMCSA in brake safety and publishing brake regulations, and the trend in OOS brake violations identified in inspections from fiscal years 1989 through 2000. The article cites the development and adoption of automatic brake adjusters and brake adjustment indicators as being major steps forward in ensuring brake safety. Both NHTSA and FMCSA have been active in issuing rules requiring anti-lock braking systems (ABSs).

Performance-based brake testing has been supported by the FMCSA, which has published specifications for brake-testing machines purchased by States with FMCSA grants. The FMCSA also proposed regulations for pass/fail criteria to be applied to brake testers that are used in CMV inspections.

The article also examines data from roadside inspections concerning the number of OOS brake violations found during each of the fiscal years from 1989 through 2000. The data show a decrease in OOS brake conditions from 54.6 percent in 1989 to 34.3 percent in 2000. The authors attribute the improvement in reducing the number of OOS brake adjustment violations by more than 60 percent.

It may be possible to determine the reduction in crashes over the same time period and estimate the fraction of those that may be attributed to the reduction in OOS brake adjustment violations

Jones, Ian S., Stein, Howard S., Vehicle and Driver Factors in Relation to Crash Involvement of Heavy Trucks. (Insurance Institute for Highway Safety) Proceedings of Strategic Research Program and Traffic Safety on Two Continents in Gothenburg, Sweden, September, 1989. VTIrapport 351A, 1990.

Large truck (greater than 10,000 pounds) crashes on Washington interstates were investigated for a two-year period. For each large truck involved in a crash, three trucks were randomly selected for inspection at the same location and time of day as the crash but one week later. The effects of truck and driver characteristics on crashes were assessed by comparing their relative frequency among those trucks that crashed compared to the sampled trucks. The study found that trucks with defective equipment were over-involved in crashes. Trucks with brake defects had a crash risk one-and-a-half times that for trucks without brake defects.

The study involved 667 crashes involving 734 large trucks over a two-year period. The sample was then limited to tractor trailers. These represented about 60 percent of the crash sample. Seventy-seven percent of crashes involved tractor trailers had at least one defect violation compared to 66 percent of the comparison sample. Trucks with brake defects were present in 56 percent of the crash sample compared with 44 percent of the comparison sample. Thus, the relative risk for trucks with out-of-service defects (OOS) was estimated to be 1.7. Trucks with only violation defects (and not placed OOS) were 1.5 times the risk. Clearly, defective brakes on tractor trailers result in more accidents than trucks with good brakes. However, the actual increased risk for a crash must also take into account such factors as driving long hours and driver inexperience.

Kolstad, James and Harris, Claude, Air Brake Problems–New NTSB Recommendations (Sessions Summary), The Trailblazer, October 1992.

This article summarizes a conference session held in October, 1992. The participants agreed that significant brake problems are quite widespread. For example, in 1988, the NTSB investigated 189 heavy truck accidents and found significant braking problems in 32 of them according to Kolstad, a former NTSB chairman (16.9 percent). A 17-month study that began in 1989 examined the brakes on 1,520 5-axle trucks at weigh stations. More than 56 percent of the trucks (856 trucks) were taken out of service because of brake system violations. More than 46 percent of the trucks were placed out of service for OOA brake violations alone.

Kolstad commented on the significance of OOA or deficient brakes by stating that although these brakes can stop or slow a truck in a routine stop, they may be incapable of stopping a truck in an emergency braking operation.

(Operation Air Brake) Ford, David W., Brake Safety on Trucks Still a Concern; MSP Obtains Infrared Cameras, Michigan State Police Online Newsletter, Michigan.gov/msp, September 2002.

The Michigan State Police completed their annual Operation Air Brake report for 2002. The results showed that approximately 15 percent of all trucks checked during the random inspections were placed out of service for brake violations. In 2001, 16 percent of all trucks checked were placed out of service because of brake violations. This percentage of OOS brake violations can be related to crashes that could potentially be avoided with improved inspection and maintenance.

Rune, and Vaa, Truls, The Handbook of Road Safety Measures, Elsevier, Oxford, U.K., 2004.

This handbook summarizes the results of more than 1,700 road safety evaluation studies. The book includes all vehicle types and diverse studies relating to road safety measures. Subjects covered include highway engineering, traffic control, vehicle design, and driver training. Unfortunately, the section on heavy truck ABS and Disc Brakes does not include any studies that focus on heavy truck performance or, more specifically, the role of brake malfunctions in accidents. However, in another section on safety equipment on trucks and heavy vehicles, the authors state that trucks with technical defects have an accident rate that is 70 percent higher than trucks without defects. This indicates that increased inspections of semitrailer trucks should be able to reduce accidents. In a section dedicated to vehicle and garage inspections (including roadside inspections) the authors cite two studies that examine the affect of periodic inspections on heavy vehicles. These are described elsewhere in this literature review.

SafeStat 2003 Data for Preventable OOS as a Percentage of Total OOS Violations, Interpreted by Zonar Systems Corporation, 2003.

Zonar Systems prepared a graph showing the percentage of preventable OOS as a percentage of total violations. Brake violations are shown as 22.14 percent of the total.

Wilson, D.F.; Kenik, E.A.; Blau, P.J., Evaluation of Corrosion Failure in Tractor-Trailer Brake System. Oak Ridge National Lab., TN, July 2002.

This report analyzes an example of a tractor-trailer brake that failed due to corrosion. Although the report indicates that an increasingly large number of brakes on tractor trailers are failing because of corrosion, there is no attempt in the report to quantify this conclusion or to link the number of corrosion induced brake failures to crashes.

B.2 Need for Better Driver/Brake Technician Training and Inspection

Clark, B., Preventive Maintenance: The Key to Dependability, Owner Operator, Vol. 10 Issue No. 4, 1980.

Preventive maintenance for trucks is described as the best way to avoid breakdowns on the road. Preventive maintenance is defined as a series of scheduled inspections and services scheduled on a time or mileage frequency. The purpose is to prevent major problems by catching problems when they are small and by ensuring that parts are properly lubricated. Brake-lining checks are cited as an example of a type of preventive maintenance that keeps watch on lining wear and replaces it before damage is done to the drums. Model preventive maintenance/inspection forms are included with the article.

Technology & Maintenance Council's (TMC) Future Chassis (Brakes) Task Force Future Brake Position Paper (2001)—1, TMC/ATA, Future Truck Program Position Paper, Future Braking System, Equipment User Expectations, 2001.

This paper, which is the result of an effort by a TMC task force, describes future braking systems. The position paper describes the needs of motor carriers with respect to future braking systems during the next 5 to 10 years. The paper notes that the trucking industry has expressed the need for further enhancements resulting in improved product performance, maintenance, and safety. Any improvements made should be compatible with, and not adversely affect, other systems. Future braking systems should significantly reduce stopping distance which would likely reduce the number and frequency of crashes. This will result in a safer vehicle under all driving conditions. In addition, future vehicle changes, such as changes in GVW, vehicle geometry, and vehicle performance improvements, have to be considered in order to satisfy future requirements for stopping distance reduction. The paper recommends that future brake systems have enhanced diagnostics and warning capabilities including status indication for wearable components that require periodic maintenance. Furthermore, the onboard diagnostic capabilities should include maintenance scheduling and service prediction, prior to experiencing severe, unsafe vehicle conditions that would lead to out-of service or worse conditions.

Selected NTSB Reports

The NTSB crash investigations cited below represent those that are brake related. NTSB reports were consulted to gain an understanding of the types of crashes likely caused by pre-crash brake problems.

Highway Accident Report, Collision Between Truck-Tractor Semi Trailer and School Bus Near Mountainburg, Arkansas on May 31, 2001, NTSB/HAR-02/03 PB2002-916203 National Transportation Safety Board, 2002.

This report analyzes a fatal crash that occurred on May 31, 2001, near Mountainburg, Arkansas, involving a Gayle Stuart Trucking, Inc., truck-tractor semitrailer that collided with a 65-passenger school bus operated by the Mountainburg, Arkansas, Public Schools. Three school bus passengers were killed; two other passengers received serious injuries. The southbound truck-tractor semitrailer exited Interstate 540 at State Highway 282 near Mountainburg, Arkansas. The driver was unable to stop at the stop sign at the bottom of the ramp. The 79,040-pound combination unit was traveling approximately 48 mph when it entered the intersection and collided with the right side of the westbound school bus. After their investigation, the NTSB determined that the probable cause of the accident was the truck driver's inability to stop the tractor semi trailer at the stop sign at the bottom of the ramp due to the reduced braking efficiency of the truck's brakes. Furthermore, the NTSB determined that the brakes had been poorly maintained and inadequately inspected.

NTSB/HAB-01/01, Accident No.: HWY-99-FH012, March 2, 1999.

This NTSB report describes a fatal bus crash that the NTSB concluded was caused by malfunctioning brakes. An inspection determined that the steering-axle brakes were OOA and the brake drums had dark spots, typically seen on overheated drums. The drive axle brakes were also OOA to the extent that they were incapable of providing any braking force. The brakes on the auxiliary weight-bearing axle, commonly referred to as a "tag axle," were not operational because they were "cammed over." Both tag axle drums were worn beyond the manufacturer's accepted limits.

On March 2, 1999, a 1979 Motor Coach Industries MC-9, 47-passenger charter motor coach, owned and operated by Shuttle Jack, Inc., (Shuttle Jack) of Santa Fe, New Mexico, carrying 2 adults and 34 children was returning from a ski trip. The bus was descending a 14-mile mountainous roadway when about halfway down the roadway, the driver discovered that the vehicle's air brakes were no longer capable of slowing or stopping the bus. He noted that the brake air-pressure-gauge reading was between 90 and 120 pounds per square inch, which was the normal system operating pressure for this vehicle. During the next 3.5 miles, the driver made several unsuccessful attempts to bring the bus under control by pumping the air brakes, down-shifting the automatic transmission, pulling on the emergency/parking brake valve, and shutting off the engine. Eventually, the driver lost control of the bus while rounding a left-hand curve. The bus departed the right side of the roadway, crashed into a rock embankment, and then rolled onto its left side back onto the roadway. Two passengers were fatally injured and the 35 other occupants received varying degrees of injuries.

NTSB/HAB-02/14, Accident No.: HWY-98-SH-018, February 17, 1998, 4:00 p.m.

This NTSB report describes the fatal crash involving a double semitrailer and a van. The NTSB determined that the likely cause of the accident was inoperable brakes. The driver of the tractor-double semi trailer stated that she noticed traffic on Interstate Highway 405 slowing in front of her and began applying the brakes. When she applied her brakes, the air pressure for the brake system depleted rapidly. The double semitrailer crashed into the first vehicle stopped in traffic ahead, a Dodge van, and pushed it into five other vehicles. The double semitrailer and van erupted in fire. Three van occupants were fatally injured; seven others involved in the collision sustained minor injuries.

B.3 Training Programs

Ohio Commercial Drivers License Manual; Version 2.0, June 1998

The manual provides driver licensing testing information for all drivers who wish to have a CDL. The manual includes pre-trip inspection information for air brakes as well as a section describing how to use the brakes while driving in such situations as on a downhill stretch. This recent commercial driver's handbook was used as a resource for considering driver training measures for brake inspection and maintenance.