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A Rationale for Establishing the Period of Validity for CVSA Truck Inspection Decals

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16. Abstract

Commercial vehicle inspections are conducted by state enforcement personnel under the Motor Carrier Safety Assistance Program (MCSAP) for the purpose of removing defective trucks from the road. Vehicles passing a North American Standard Inspection - Level I receive a CVSA (Commercial Vehicle Safety Alliance) decal, valid for a period of three months. Vehicles with decals are generally excluded from further inspections during this period on the presumption that they are less likely to have an out-of-service (O/S) violation. The objectives of this study were to find information to determine whether vehicles operating under a valid decal are less likely to have O/S violations, and to quantify the probabilities of violation as a basis for evaluating the appropriateness of the 3-month period of validity.

Data from a 1990 inspection program in Ohio showed that vehicles with valid decals have lower violation rates than those without valid decals. Data from a National Transportation Safety Board inspection study of 5-axle tractor-semitrailers were analyzed to determine how violation rates vary with period of validity of the decal. These data provided a basis for evaluating the effect of validity period on productivity of inspection programs. Finally, truck maintenance data from a national truck fleet were examined to determine how truck component failure rates compare with violation rates.

It was concluded that the 3-month decal discriminates vehicles that have a reduced probability of O/S violation, and that using the decal as a basis for excluding vehicles from routine inspections enhances the productivity of the MCSAP program in getting defective vehicles off the roads. Reducing the period of validity was found to be counter-productive in that it would bring trucks with much lower violation rates into the inspection stream displacing trucks with high rates. As a consequence, a reduction in the period of validity is not advised.

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INTRODUCTION

BACKGROUND

The Commercial Vehicle Safety Alliance (CVSA) grew out of the Commercial Vehicle Safety Alliance of Western States formed in 1980 as an arrangement among the states of California, Idaho, Oregon, and Washington to promote interstate cooperation and a more efficient motor carrier safety inspection system. A main objective of CVSA is to reduce delays caused by duplicative inspections of interstate vehicles in each state. Today, 48 states (Hawaii and South Dakota excluded) and 10 Canadian provinces are members.

The CVSA is independent of the Federal Government, although the Federal Highway Administration (FHWA) coordinates closely with the CVSA in a major outreach effort and provides funding for the inspection via the Motor Carrier Safety Assistance Program (MCSAP). CVSA states and provinces use common truck inspection standards and out-of-service criteria developed in cooperation with the US Department of Transportation (USDOT). Members affix and recognize common inspection decals to trucks that have passed an inspection. The decals are valid for three months. The quarter in which the inspection took place is indicated by the color of the decal, and the month in the quarter is indicated by clipping a corner of the decal, as shown in Figure 1. Vehicles that pass a CVSA North American Standard Inspection, as evidenced by a valid decal, are not precluded from inspection in other jurisdictions, but can usually pass through member states and provinces without further inspection.

State inspection teams vary in size and capability. A majority of states train some members of the state police or highway patrol to be certified inspectors. Nationally, 1,080,744 inspections were reported[1] in 1989 [1][2] on a budget of $47 million. Currently it is estimated that about 5% of the vehicles on the road at any time have a current CVSA inspection decal [2].

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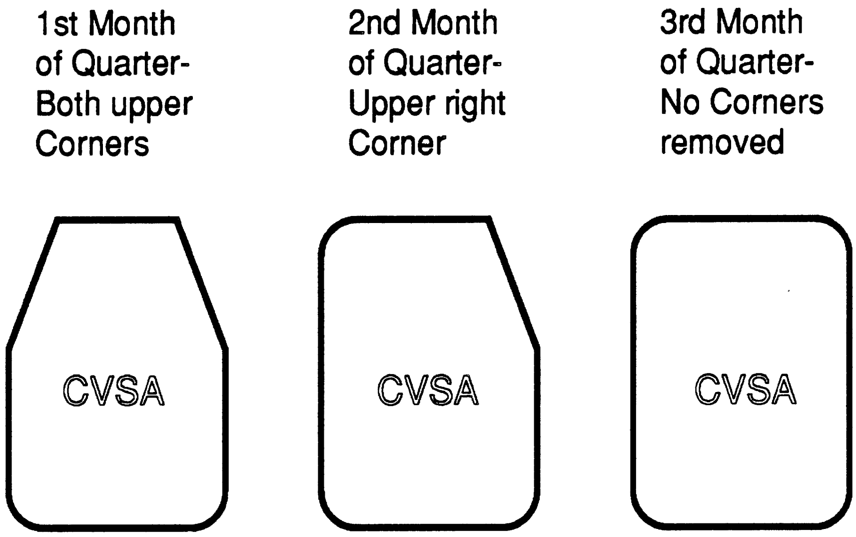
1 The actual number of inspections is higher than the reported because 4 states were not included in the 1989 reports.

2 Numbers in brackets indicate references at end of the main report.



1st Quarter	International Green
2nd Quarter	International Yellow
3rd Quarter	International Orange
4th Quarter	International White

Fig. 1 The CVSA Decal

PROBLEM AND APPROACH

Recently the appropriateness of the 3-month period of validity for the decal has been brought into question. At issue is whether there is a logical basis for establishing an appropriate period of validity, and if so, what that period should be. In response to this concern The University of Michigan Transportation Research Institute (UMTRI), under a grant from the Michigan Department of State Police, Office of Highway Safety Planning, conducted a study to determine whether the necessary information and rationale could be established as a basis for setting the period of validity for the decal.

The approach taken to the problem makes the a priori assumption that roadside inspections are conducted to ensure that safety-critical systems on trucks are in good working condition when operated on the public highway system [3]. This follows from the argument that with the privilege of using the public highways goes an operator's responsibility to maintain the truck in proper working order so as to minimize risk to other highway users.

A second assumption made is that state and provincial resources are insufficient to provide 100 percent inspection monitoring of trucks at frequent intervals. Therefore CVSA inspections should be viewed as an enforcement activity intended to provide incentive to truck operators to maintain the vehicles in safe condition. The incentive is the inconvenience, economic loss, and risk of fines that may accompany a truck being placed out-of-service (O/S) at an inspection.

The study was conceived as having two parallel tracks. The first track involved a search for information on the deterioration rate of truck components, which when combined with truck travel information should provide a picture of the probability of an out-of-service failure as a function of time since the last inspection. The second track involved the search for empirical information and data relating the increase in O/S violations on trucks as a function of time since last inspection.

In order to keep the study tractable, the emphasis is placed on class 7 and 8 trucks (those with a gross combination weight rating of 33,000 lb or more) and those equipment items that would render the vehicle out-of-service. The straight trucks, tractor semitrailers, and multi-trailer combinations occupying the class 7 and 8 weight ranges are seen as posing the major issues relative to the period of validity of the CVSA decal because their mileage rate is high and they constitute the primary truck category involved in interstate transportation. They are also at the focus of the national issues in truck safety.

Associated with the period-of-validity question is the concern that truck drivers may "hide" behind a CVSA inspection decal. That is, since the decal reduces the probability of an enforcement inspection, drivers may abuse the driving regulations—time-on-duty regulations, cargo securement, and others—in a truck with a valid decal. Although these are legitimate concerns, the status of compliance to these regulations may change on an hourly basis and cannot be linked to any inspection decal. The decal, which is affixed to the vehicle, indicates that the vehicle, its cargo, and driver were in compliance at the time of an inspection. At any later time, the driver and cargo are likely to be different; therefore, the decal can be directly linked only to the vehicle. Consequently, the study has been limited to vehicle defects only, excluding driver and cargo securement issues.

Issues relating to monitoring driver and cargo compliance should be addressed separately from those of the decal. Under current CVSA procedures an inspection of the driver, vehicle, and cargo is waived if the vehicle has a valid decal. Since compliance of the driver and cargo are unrelated to the presence of a vehicle-mounted decal, an inspecting officer should waive inspection of a vehicle with a valid decal, but be free (at his discretion) to inspect driver and cargo when warranted.

ORGANIZATION OF THE REPORT

The main portion of this report summarizes the analyses and conclusions drawn from an in-depth examination of many sources for information relevant to this issue. Detailed information serving as the basis of the analyses is presented in the appendices.

In the main report, Chapter 2 presents a brief overview of the trucking industry laying out the picture of current practices with regard to truck safety inspections, how and where different types of trucks are used, and what is known about the relationship of vehicle defects to accident experience. This information is intended to provide a setting for a critical review of the function of the CVSA decal and the knowledge of its effectiveness at serving the intended purpose. In Chapter 3 these issues are examined in light of the very limited data available to assess the effectiveness of the decal, particularly with regard to how its effectiveness is linked to the period of validity. Analyses of two studies, one from the State of Ohio and one by the National Transportation Safety Board, provide empirical data by which the period of validity can be assessed.

As an alternate approach to the problem, truck maintenance data are examined in Chapter 4 to determine the extent to which conclusions from the empirical data of Chapter 3 align with expectations from component failure rates. Maintenance experience from a large fleet is analyzed to determine mean-time-to-failure of safety-related subsystems allowing prediction of failure rates in the general truck population.

Finally, Chapter 5 presents the conclusions and recommendations that emerge from the work.

OVERVIEW OF THE TRUCKING INDUSTRY

As an aid to understanding the decal's function and period of validity in the setting of the modern trucking industry, it is beneficial to understand the inspection practices currently applied to trucks, how the trucks are used, and how their accident experience relates to defects that would be discovered in inspections. This chapter provides an overview of these aspects of the trucking industry.

TRUCK INSPECTION PRACTICES

It is well recognized that motor vehicles that are operated at high speeds need to be inspected periodically to ensure that safety-critical subsystems are functioning properly. The trucks commonly seen on the public highways are subject to inspections at several levels, the specific requirements depend on the use of the truck. Typical practices are as follows.

Driver Inspection

It is common practice in the trucking industry for the driver to take responsibility for at least a low-level inspection of every truck before driving it. Federal Motor Carrier Safety Regulations [4] require the driver of a commercial vehicle to:

a) inspect each vehicle before driving (Section 396.13),

b) be satisfied that designated parts and accessories are in good working order (Section 392.7), and

c) prepare a report at the end of each working day on the condition of each vehicle operated (Section 396.11).

The designated parts and accessories to be inspected by the driver include:

Parking (hand) brakes	Windshield wipers
Service brakes, including trailer connections	Rear vision mirrors
Steering mechanism	Coupling devices
Lighting devices and reflectors	Wheels and rims
Tires	Emergency equipment
Horns	

This type of inspection is routinely performed as a pre-trip exercise in the form of a "walk-around" inspection. In the process of walking around the vehicle the driver is expected to check each of the above items by visual examination or by operating the subsystem. Thus the driver will make sure that tires are inflated, brakes are operational, lights work, no parts are missing or broken, etc.

Maintenance Inspections

Every operator of a commercial truck, of necessity, must have periodic preventive maintenance performed on each vehicle. At those times the vehicle will receive at least a casual inspection by the mechanic performing maintenance. Inasmuch as there are no universal standards for mechanic inspections during preventive maintenance, the quality of inspections may be expected to vary with practices of individual fleets.

FHWA Annual Inspection

Effective July 1, 1990, Federal Motor Carrier Safety Regulations, Part 396.17 [4], require an annual inspection of every commercial motor vehicle. The inspection must be performed by a qualified inspector and documentation must be carried on the vehicle certifying that it has passed inspection within the previous 12 month period. Inspectors may be qualified employees of the motor carrier, a qualified agent hired by the motor carrier, or State or FHWA inspectors. In general, the inspection procedures are similar to the CVSA inspection described below, although the criteria for passing are more stringent and effectively allow no defects.

CVSA Inspection

A primary mission of the CVSA has been the development of uniform methods for inspecting commercial vehicles, and uniform criteria for placing a vehicle out-of-service. Specifically, the statement of purpose reads "To establish policies and procedural guidelines for driver-vehicle inspections and to establish out-of-service criteria for drivers and vehicles." [3] The CVSA authority derives from the Federal Highway Administration regulations contained in 49 CFR 350 established pursuant to Section 402 of the Surface Transportation Assistance Act of 1982, and reauthorized by the Commercial Motor Vehicle Safety Act of 1986.

Among the five levels of inspection defined by CVSA, Level I is the most comprehensive, and provides for a detailed inspection of the vehicle(s), driver, and cargo. Level I inspections are conducted at a prepared roadside site, for example at a weigh station parking area. Depending on individual state practices vehicles may be selected randomly. If the flow of traffic is such that the inspector has a choice of several vehicles, the one which has an obvious out-of-service defect or which, by its general condition, appears most likely to be defective will be selected. A vehicle displaying a currently valid safety inspection decal of the CVSA is to be passed through the inspection point without delay unless a defect is observed or heard. At certain times a random inspection procedure will be used, in which case vehicle selection is random, regardless of the presence of a CVSA decal.

The inspection involves careful scrutiny of the vehicle and driver looking for defects. Although the inspection encompasses many vehicle subsystems, particular attention is given to those components that are safety critical. Certain defects that may affect safe operation of the vehicle are considered a basis for declaring the vehicle out-of-service and the vehicle must be parked until towed or repaired. The safety-critical subsystems identified on the inspection form are:

Steering	Suspensions
Brakes	Frames
Lights	Couplers
Tires and wheels	Cargo securement
Fuel system	Headerboards
Exhaust system	Rear end protection

If no defects are found a decal is affixed to each vehicle in the combination. If O/S violations are observed on a vehicle, it is declared out of service and is marked by an O/S sticker. If defects are observed in safety critical subsystems, none of which are O/S violations, the equipment is not placed out of service, but will not receive a CVSA decal.

Every vehicle in service eventually develops failures of O/S severity. Once a failure occurs there are three possible courses of action:

1) The truck driver will take action to have it repaired at the earliest convenience. For most trucks which operate on a one-day or one-shift basis the repair will be done at the end of the shift. Thus (with the exception of debilitating failures) the vehicle will operate for a maximum of about 8 hours in a defective state.

2) The failure may not be evident to the driver and will not be detected until the truck is given a close inspection. The close inspection adequate to detect many failures may not occur until the truck is brought in for maintenance. In this case the vehicle may run for many days with the defect present.

3) The failure that occurs is not perceived as a failure by the driver or fleet personnel, although it is failed by CVSA O/S standards. In this case, the vehicle will continue to operate with the failure until it is detected in a CVSA inspection.

Clearly the CVSA objective of getting unsafe vehicles off the road focuses on the last two categories which represent defective vehicles being operated on a prolonged basis. It is estimated that approximately 27% of the trucks on the road have defects which qualify as O/S violations. The estimate derives from the 1989 MCSAP inspection data [1] which found O/S failures among 41% of the vehicles selected for inspection. The 41% figure overestimates the actual number of vehicles in the truck population with failures because of the bias in the selection process which attempts to pick out vehicles most likely (by appearance or other evidence) to have problems. Data from the State of Michigan (see Appendix C) show that vehicles selected randomly at a weigh scale inspection site have only about 2/3 as many violations (19% when randomly selected versus 29% when purposefully selected). Discounting the 41% MCSAP figure by this ratio gives an estimate of 27% of the truck population in violation at any time.

TRUCK USAGE

Highway trucks and tractor-trailers transport over 700 billion ton-miles of cargo in the nation each year [5]. This is accomplished by an estimated 3.1 million vehicles nominally comprised of 70% straight trucks and 30% tractor-trailers (see Appendix F). In total, trucks accumulate 55 billion miles of travel each year distributed among the truck configurations as shown in Table 1.

Table 1.

Annual Mileage by Truck Type

Configuration	Percentage of heavy trucks	Annual mileage (%)
Tractor-semitrailers	30%	65%
Doubles and triples		4
Tractors (bobtail)		1
Straight trucks	70%	28%
Straight trucks with trailers		2

Tractor-trailers average 41,000 miles per year compared to 8250 miles for a straight trucks (see Appendix A). The types of roads on which these miles are accumulated differ with the type of truck configuration as shown in Table 2.

Table 2.

Mileage Distribution by Road Type

Configuration	Limited Access	Other
Tractor-semitrailers	80%	51%
Doubles and triples	6	2
Tractors (bobtail)	1	1
Straight trucks	12	43
Straight trucks with trailers	1	2

On a nationwide basis, these statistics indicate that on limited access highways where a large percentage of CVSA inspections are performed, 87% of the heavy trucks passing by will be tractor-trailer combinations, even though they represent only 30% of the truck population. On non-limited access highways (primary and secondary roads) tractor-trailers will represent 53% of the population. Although this would suggest that random selection of vehicles in the traffic stream would result in selection of tractor-trailers in greater proportion than their fraction of the truck population, nevertheless, they are being selected in proportion to their mileage and safety exposure on the road. This is the basis for the general focus on tractor-semitrailer combinations in this report.

The reader is referred to Appendices A and F for a more in-depth discussion of these statistics.

RELATIONSHIP OF ACCIDENTS TO VEHICLE DEFECTS

In the United States each year there are about 4500 accidents involving heavy trucks resulting in 980 fatalities [6]. This corresponds to one accident per 11 million miles and one fatality every 50 million truck miles. While the accident frequency for trucks is much lower than that for passenger cars, their larger size and greater potential to cause injury and death warrant special attention to their safe operation.

The objective of the CVSA inspection program, to "remove potentially unsafe drivers and imminently hazardous vehicles from the Nation's highways," assumes that vehicle defects may cause accidents which carry risk of injuries, loss of life and property, and release of hazardous materials. The existence of this cause-effect relationship is important to evaluate the effectiveness of the period of validity for the CVSA decal. If, indeed, vehicle defects lead to accidents, then inspection activities that reduce the number of defective vehicles on the road will reduce accidents. If, however, it is only an associative relationship—e.g., vehicles that have defects are associated with drivers who are more accident prone—forcing the vehicle to be maintained will not reduce the frequency of accidents.

The currently available aggregate accident statistics are inadequate to provide a direct answer as to whether vehicles with valid CVSA decals are less frequently involved in accidents. This deficiency arises because accident reporting procedures do not include coding to indicate whether the involved heavy vehicle(s) have valid decals at the time of the accident. The addition of this information to future revisions of accident reporting forms would provide a valuable resource for evaluating effectiveness of the CVSA inspection program.

There have been specific studies (see Appendix B) that attempt to relate accident causation to vehicle defects based on post-accident examinations of vehicles, although it should be recognized that these are not without controversy. For one thing, component defects noted in such examinations are not necessarily the cause of the accident. They may have existed before the accident without being a causative factor, or the component may have failed as a result of the accident. Table 3 summarizes some of the percentages of commercial vehicle accidents in which various investigators have attributed vehicle defects to be a causative factor:

Table 3.

Accident Percentages Attributed to Vehicle Defects

Investigator	Accident proportion attributed to defect
Volkowicz [7]	12%
Volkowicz [7] - Ontario Provincial Police	7%
McDole and O'Day [8] - Vehicles 10 years or older	10%
McDole and O'Day [8] - Vehicles less than 3 years old	4%
Oregon Public Utilities Commission [9]	13%
Pennsylvania Department of Transportation [10]	13%
Eicher, Robinson and Toth [11]	6.4%

In a few other studies, investigators have attempted to quantify the proportion of accidents caused by failures of specific subsystems on trucks. The data available in this area is sparse and limited to only the brake and tire subsystems. Table 4 summarizes the findings from these studies.

Table 4.

Accident Percentages Attributed to Specific Defects

Vehicle subsystem	Investigator	Accident proportion attributed to defects
Brakes	Pennsylvania Department of Transportation [10]	3.5%
	Data from White and Miller [12]	3.9%
Tires	Pennsylvania Department of Transportation [10]	1%
	Biotechnology [13]	2%
	University of Michigan [14]	0.9%

The above statistics are seen in perspective only when it is realized that of all trucks in accidents a significant percentage have defects according to the CVSA criteria. In a previous section of this report it was estimated that 27% of the trucks on the road have O/S violations. Stein and Jones [15] reported that in all crashes involving tractor-trailers in Oregon, 41% had defects severe enough to be an O/S violation.

The controversy in these statistics arises from questions relating to experimental methodology, particularly the difficult issue of attributing an accident to one cause when most accidents involve the coincidence of a number of factors. The strongest evidence, of course, would be to conclude that a given accident would not have happened if the defect had not been present. As many experienced reconstructionists would agree, this can be difficult to prove.

Even conceding that there could be some error in the quantitative statistics, the percentages reported above are large enough that it is reasonable to conclude that vehicle defects make some small, but significant, contributions to truck accidents. On that basis, one must conclude that enforcement efforts that remove defective trucks from the road will reduce accidents, and in that context the <u>CVSA decal has value if it identifies vehicles with lower probability of defects</u>.

The inference that vehicle defects do cause accidents aligns with the opinions of experts polled on this question. Boise State University [16] is conducting an evaluation of the Idaho MCSAP program which includes a Delphi study [17] of experts opinions (state inspection staff, FHWA personnel, and safety researchers) on the "severity" of each of 400 vehicle and driver safety inspection violations. Severity was defined as the likelihood of a violation contributing to an accident. Combining this with inspection results on the most frequent violations provides the following picture of the relative severity of the most frequent vehicle defects.

Table 5.
Severity of Most Frequent Vehicle Defects

Severe Violations	Moderately Severe Violations	Low Severity Violations
All steering	Brake adjustment	Head lamps
Brake inoperative	Signal/hazard lights	Clearance lights
Tire fabric exposed	Brake drum cracked	Stop lamps
Frame cracked	Suspension	No lamps
Windshield wipers	Tire tread	Windshield
Wheel-rim cracked		

A separate and informal survey of people involved in truck safety issues was conducted in conjunction with this project to get their opinions on the likelihood of failure of vehicle components, and their assessment of the safety risk of the failure. Similar results were obtained. Namely, brakes, tires and lights were identified as the components most likely to fail and most likely to present a safety risk. Although wheels, couplers, and steering systems were perceived to carry some safety risk, they were viewed as less likely to fail.

VIOLATION RATES SINCE LAST INSPECTION

In the preceding discussion it has been established that the primary value the CVSA inspection decal can have is to identify trucks with lower incidence of defects in safety-critical vehicle systems. If that is true, then inspection officers, faced with the reality that resources are too limited to inspect all trucks, can concentrate on vehicles without decals with the confidence that they will be most productive in removing defective trucks from the road. To prove that the decal has this value, it is necessary to find data which demonstrate that trucks with a valid decal are less likely to have O/S defects.

Such data are not routinely available. However, in the course of the study, two sources that contained portions of the desired information were found—statistics acquired in a recent National Transportation Safety Board (NTSB) investigation of truck brake system condition, and inspection information acquired in the State of Ohio.

OHIO SAFETY INSPECTION DATA

In the course of normal roadside inspections the State of Ohio began noting the presence of a valid CVSA decal on heavy vehicles in April 1990. Data for the first two months of that program (April and May), covering approximately 25,000 commercial vehicles, were made available for analysis in this project. The data presented in detail in Appendix D are summarized in the table below.

Table 7.

Violation Statistics for the Ohio Study

	Valid CVSA Decal?		
Inspection results	Yes	No	Total
O/S Violations	0.6%	18.2%	18.8%
No O/S violations	4.8%	76.4%	81.2%
Total	5.4%	94.6%	100%

Of the vehicles inspected 5.4% had a valid CVSA decal and only 0.6% of these failed the inspection. Thus vehicles with a valid decal had a failure rate of 12%. By comparison, for vehicles without a valid decal the Ohio study obtained a failure rate of 19% (18.2/94.6). The comparison is shown visually in Figure 3. The 19% figure is somewhat lower than the 26% O/S violation rate obtained in Ohio inspections in the previous year [1]. Nevertheless, the Ohio data support the conclusion that decals with a 3-month period of validity are effective in sorting out trucks with a reduced probability of O/S violations.

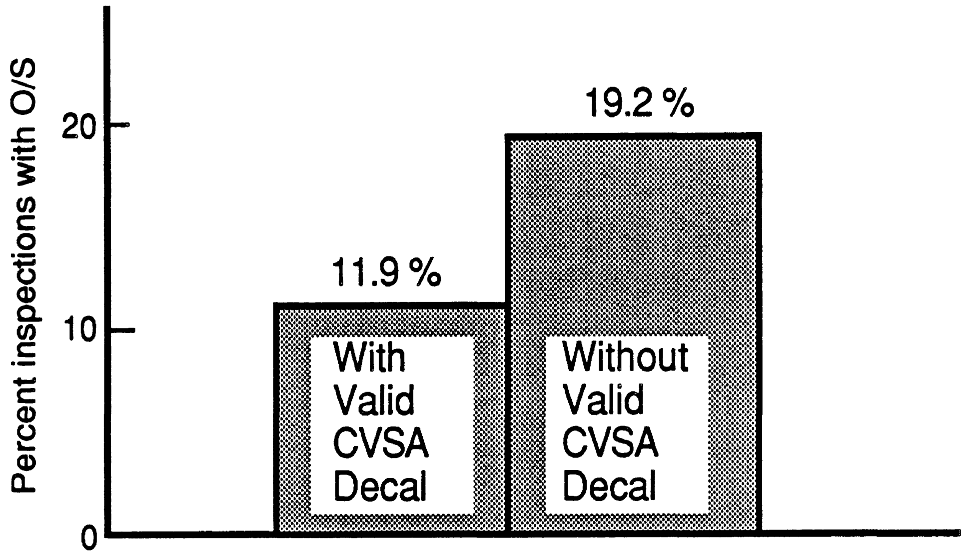


Fig. 3 Inspection results from the State of Ohio (1989)

NTSB BRAKE INSPECTION STUDY

In 1990 the NTSB initiated a Heavy Truck Inspection Project [18] intended to obtain definitive information on the condition of brake systems on 5-axle tractor-semitrailers operating on the interstate road system. The study involved roadside inspections of combination vehicles selected on a random basis at sites in Florida, Pennsylvania, Illinois, Texas, and Oregon. At each site a minimum of 150 vehicles were inspected during daylight hours on Tuesdays, Wednesdays, and Thursdays. Emphasis was placed on very careful and critical inspection procedures. Among the information collected the inspectors noted whether vehicles had a CVSA decal and, if so, the month of issue.

The Board graciously shared early results from the inspections for analysis in this project. In particular, the data were analyzed to discover whether the incidence of defects was correlated with the time interval since the last CVSA inspection. A total of 284 of the vehicles examined in the study had a CVSA decal. These were divided into subsets identified by the age of the decal (i.e., the number of months since the last CVSA inspection). Then for each subset the percentage of vehicles found to be with and without O/S brake violations was computed. Table 8 summarizes the results from this analysis.

Table 8.

O/S Brake Violations versus Time (NTSB Data)

	Age of CVSA Decal (months)											
Percentages	1	2	3	4	5	6	7	8	9	10	11	12
– With O/S violations	33	28	44	45	38	38	50	83	57	69	60	50
– Without O/S viol.	66	72	56	55	62	62	50	17	43	31	40	50

The row entitled "With O/S violations" shows a general trend of increasing frequency of violation with the age of the decal. In the first month or two, the NTSB found O/S violations on approximately one-third of the vehicles, but as the age increased to a year the violation rate went up to over 50%. The trends are somewhat obscured by the high degree of variability from month to month because of the relatively small number of trucks in each cell. For many of the months there were fewer than 10 vehicles with CVSA decals in the data base. Hence the condition of one or two vehicles could drastically affect the percentages shown.

The underlying trends are more clearly revealed by compiling the data cumulatively. That is, the percentage of vehicles without O/S violations is computed for all vehicles with a decal less than or equal to a given age. The results in this form then show what violation frequency would be expected with any hypothetical period of validity for a decal. Table 9 shows the results from the NTSB data compiled as violations percentages as a function of hypothetical period of validity for the decal.

Table 9.

Cumulative O/S Brake Violations versus Time (NTSB Data)

	Hypothetical Period of Validity for the Decal (months)											
Percentages	1	2	3	4	5	6	7	8	9	10	11	12
– With O/S violations	33	31	37	39	38	38	40	41	42	43	44	44
– Without O/S viol.	67	69	63	61	62	62	60	59	58	57	56	56

In interpreting the results from the NTSB study, it should be observed that even though NTSB inspectors used CVSA inspection criteria, at the 1-month point they found O/S violations on one-third of the vehicles that had CVSA decals. Some of these violations are due to component failures subsequent to the inspection at which the decal was issued. The remainder reflect a difference in the rigor of the procedures used by the NTSB special inspection team and the routine MCSAP inspections. The NTSB study resulted in a brake O/S violation rate of 52%[1] for vehicles with no decal compared to a 22% national average for the MCSAP program. (According to 1989 MCSAP program statistics [1], 41% of the trucks and tractor-trailers inspected have O/S violations. 54.6% of these—22% of the total—are due to brake system failures.) This would suggest that 30% (52% - 22%) of the brake O/S failures reported by NTSB were due to inspection team differences and should be deducted from the statistics to normalize the results for purposes of estimating the failure experience appropriate to routine MCSAP-reported inspections. (While the difference in overall O/S violations rates between NTSB and MCSAP inspections raises some questions, it is not the subject of this study.)

1 An additional 2 percent of the trucks were discovered to have O/S violations of other systems when the brakes were inspected.

With the 30% deduction to adjust the data to MCSAP practices, the picture of brake system failure rate versus period of validity takes the form shown in Figure 3. This plot was obtained by subtracting 30% from the O/S violation percentages as a function of time shown in Table 9. In the absence of a mathematical model of how the failure rates should increase with period of validity, a smooth curve was fitted to the graph as an approximation of the relationship. This is a reasonable approximation for the portion of the data shown, although the relationship line must eventually level out and approach the 22% limit of vehicles with no decal in an asymptotic fashion.

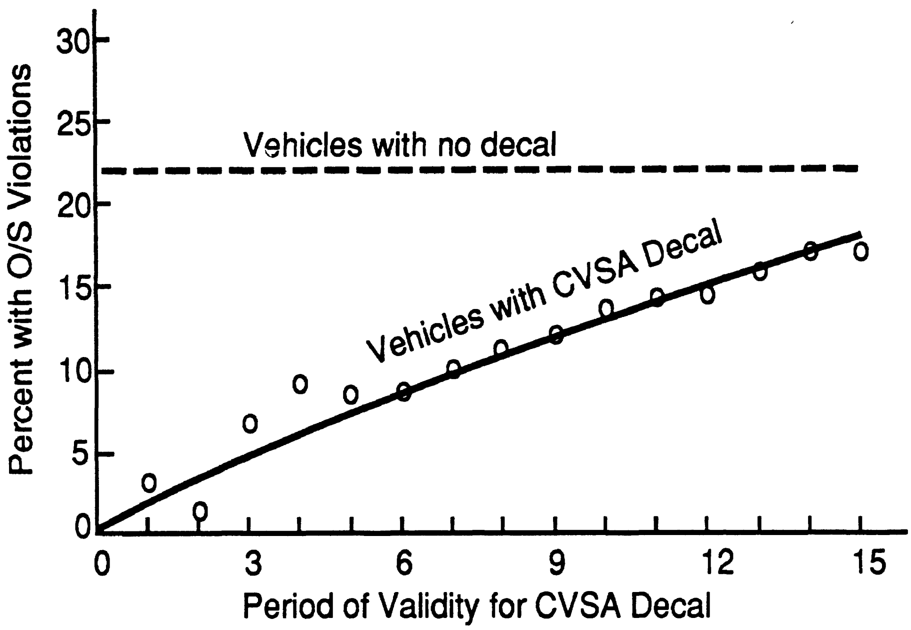


Fig. 3 O/S brake failure rates as a function of time (from NTSB data)

Inasmuch as these data reflect only brake violations which are about half of the total O/S violations reported in the MCSAP program, the rates should be doubled to estimate the overall O/S violation rate that would be experienced by state inspectors. This is reflected in the replot of the data in Figure 4.

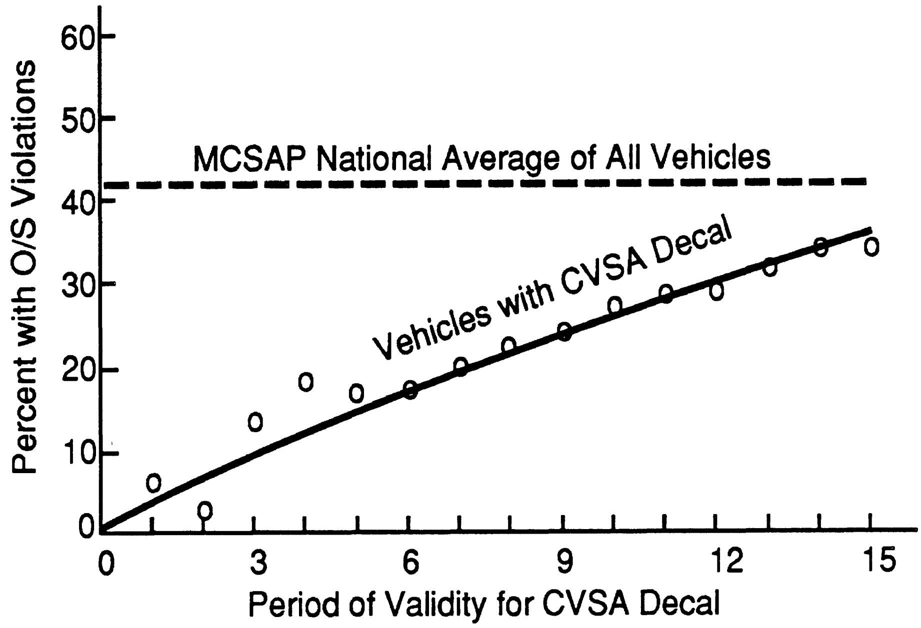


Fig. 4 Estimated O/S failure rates as a function of time

Immediately after an inspection the failure rate should be zero. Thereafter, failures accrue such that in the first few months a few percent in the population of trucks just inspected will develop O/S failures. With a 3-month period of validity, roughly 10% of the trucks with valid decals will develop failures that would place them out-of-service if inspected. Since the overall population includes trucks for which the time since last inspection ranges from 0 to 3 months, the average "age" of the decal would be 1-1/2 months. The 10% O/S rate obtained from this interpretation of the NTSB inspection program compares well with the 12% found in the Ohio study described earlier.

In a similar fashion, with a 6-month period of validity the O/S failures among the truck population with decals would be about 18%, and at 12 months the figure would be 30%.

Viewed with this interpretation, the data make it possible to quantify the potential advantage to productivity of the CVSA inspection program from use of any selected period of validity for the decal. For that purpose a nominally linear relationship of violations to period of validity (as shown in the figure) will be assumed. Productivity can be quantified by considering the number of vehicles that must be inspected to find and remove from the road a truck with defects of that severity. With a 1-month period of validity approximately

3.5% of the trucks under decal coverage would have an O/S violation, thus about 30 vehicles would have to be inspected on average to find one with an O/S violation. With the 3-month period of validity these data give an estimate of 10% of the trucks with decals having O/S violations. At this rate 10 trucks would have to be inspected to find a violation. With increasing periods the number of trucks continues to drop as shown in Figure 5.

In a situation where only a limited number of trucks can be inspected, as is the case with the MCSAP program, there are clear advantages to using a 3-month period of validity as opposed to a shorter period. The current inspection program, with its 41% national average of O/S violations, nets one out-of-service vehicle for every 2.5 inspections. The 3-month decal excludes vehicles from inspection that have less than a 1 in 10 likelihood of violation. Trucks enter the stream of candidates for inspection only when they have a 10% probability of violation. If the period of validity were made shorter, say 1-month, vehicles that had only a 1 in 30 likelihood of violation would be added to the inspection load. Vehicles would be entering the inspection stream with only a 3.5% probability, displacing vehicles from the general population that have a 41% probability.

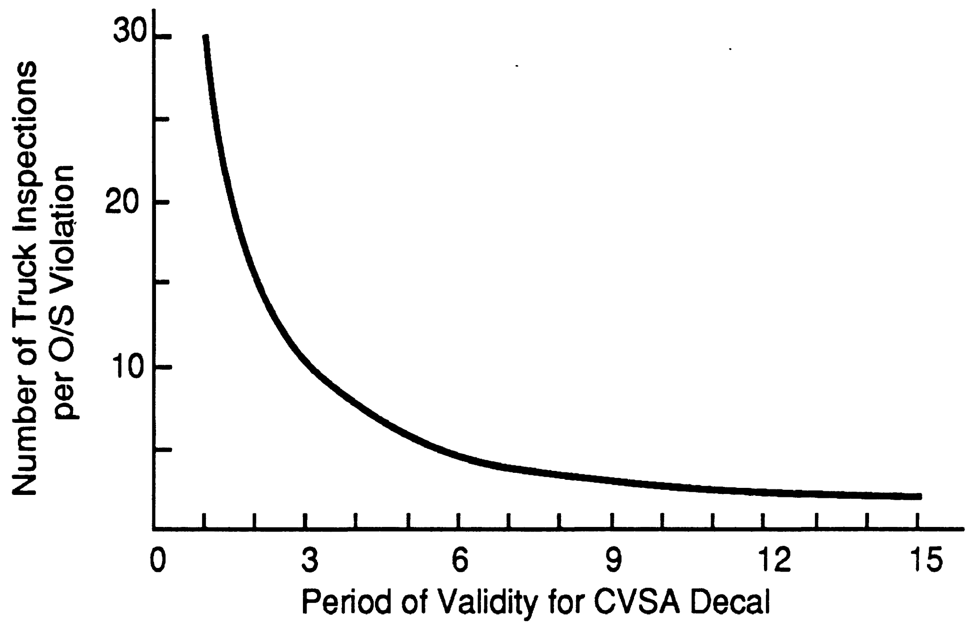


Fig. 5 Number of truck inspections required to find one O/S vehicle

An alternate way of characterizing the productivity is obtained by considering the consequences of inspecting trucks with recently expired decals. With a 1-month period of validity, out of every 100 trucks inspected only 3.5 would have O/S conditions compared to 10 with the 3-month period. In this sense the 3-month period is 3 times as productive as a 1-month period.

Although these data would indicate some increase in productivity by going to a longer period of validity, the gains are not quite as dramatic due to the diminishing slope of the relationship shown in Figure 5. Considering the sparse amount of data that was available for this analysis and the associated uncertainty in the statistics, a more robust data base should be collected and a more comprehensive optimization analysis performed before any change is made.

Finally, the reader should note that there is an element of conservativeness in the treatment applied to the data above. A nearly linear curve was used to characterize the relationship of O/S violations to period of validity in the early months (in Figure 4) on the assumption that the data scatter around the curve was the consequence of the statistical scatter in the data. There is, however, the possibility that failure rates are low with the 1- and 2-month periods but rise quickly at the 3-month point. If this is an actual effect, the benefits of the 3-month decal over that of 1- or 2-months would be much larger than described.

TRUCK COMPONENT FAILURE RATES

A second perspective on appropriate periods of validity for inspection decals is obtained by considering the probabilities of truck component failures as a function of time. The underlying question being addressed is—What are the failure rates of safety-related truck systems, and what implications do these statistics have with regard to the period for which a CVSA decal should be valid?

In this effort a large national truck fleet cooperated by providing detailed information on the maintenance program for a fleet of tractors, semitrailers and dolly converters. The data were such as to allow compilation of statistics on frequency of repair of most truck subsystems, excluding tires. Detailed discussion of the data and analysis are presented in Appendix E. The objective in this chapter is to summarize the analysis and conclusions.

OVERVIEW OF FLEET DATA

The ideal data for this exercise would contain detailed information on the lifetimes of individual components of vehicles of various types, as well as the history of the vehicle's operational environment. Less optimal data were obtained; however, they included the number of failures (repairs and replacements) and time between failures for 15 major component systems for the fleet sufficient for building a picture of truck system failure rates. The data covered the following systems on 712 tractors, 5096 semitrailers, and 800 converter dollies.

- Air system
- Headlights
- Turn Signals
- Stop/tail lights
- 5th Wheel
- Chassis
- Wheels
- Trailer pintle hook
- Brake lining/drum
- Brake adjustment
- Suspension
- Exhaust
- Steering
- Fuel tank
- Fuel lines

From this information it was possible to compile:

- Average failure rates for the systems,
- Survivor curves for individual systems,
- Probabilities of failure for the systems, and
- A general failure model.

A maintenance incident was defined as any event where maintenance (whether scheduled or unscheduled) takes place. At the raw data stage there was no distinction between maintenance items that would constitute O/S violations and those that would not. Tables 10, 11, and 12 below provide the estimates for the maintenance demands for tractors, semitrailers, and converter dollies normalized to the national average mileage for vehicles of each type. For the tractor data the maintenance incidents were reduced by the ratio of annual mileage of the average tractor (41,280 miles/year) to that of the fleet tractors (a factor of 0.27). There is no definitive data on semitrailer mileage per year, but a general rule of thumb is that there are twice as many semitrailers as tractors. Therefore average annual semitrailer mileage was estimated at half of that for tractors (i.e., 20,000 miles/year) resulting in a normalization factor of 0.66 for semitrailer data. Average annual dolly mileage was also estimated at 20,000 miles/year resulting in a normalization factor of 0.22.

There are several immediate and significant observations from this data. First, trailers and dollies have much lower overall maintenance needs than tractors, undoubtedly because of their reduced complexity. Nevertheless, based on Michigan data (Appendix C), trailers are in violation as often as tractors, probably reflecting less rigorous maintenance programs on trailers in many fleets.

Secondly, the two largest maintenance items are brakes and lights. Lights were rated by experts (see Table 5) as a low severity violation. On tractors and trailers they are a primary maintenance item, although on dollies with fewer lights the maintenance required is minimal. Even so, lights are a less frequent source of violation (16.2% in the 1989 MCSAP program versus 54.6% for brakes). The probable cause for this is that it is easier for a driver to detect defective lights than brakes.

Table 10.

Summary of Tractor Maintenance Requirements

System	Incidents/unit/yr	% of All Incidents	No. of Incidents
Air System	1.91	27.61%	Brake
Brake Adjustment	0.21	3.10	Related
Brake Linings & Drums	0.47	6.85	2.59
Headlights	0.74	10.70	Lighting
Stop/Tail Lights	1.20	17.37	Related
Turn Signals	0.80	11.55	2.74
Wheels	0.11	1.55	
Chassis Frame	0.11	1.64	
Exhaust	0.37	5.33	
Fuel Lines	0.22	3.19	
Fuel Tanks	0.08	1.13	Other
Steering	0.18	2.56	1.58
Suspensions	0.34	4.94	
5th Wheel	0.17	2.46	
Trailer Pintle Hook	0.00	0.0	
TOTAL	6.91	100%	6.91

Table 11.

Summary of Semitrailer Maintenance Requirements

System	Incidents/unit/yr	% of All Incidents	No. of Incidents
Air System	0.11	21.15%	Brake
Brake Adjustment	0.02	3.21	Related
Brake Linings & Drums	0.02	3.15	0.15
Stop/Tail Lights	0.32	59.02	Lighting Related
Turn Signals	0.03	6.01	0.35
Wheels	0.001	0.30	
Chassis Frame	0.00	0.01	
Suspensions	0.005	0.95	Other
5th Wheel	0.00	0.08	0.04
Trailer Pintle Hook	0.03	6.20	
TOTAL	0.54	100%	0.54

Table 12.

Summary of Dolly Maintenence Requirements

System	Incidents/unit/yr	% of All Incidents	No. of Incidents
Air System	0.65	61.62%	Brake
Brake Adjustment	0.07	1.47	Related
Brake Linings & Drums	0.12	11.37	0.79
Stop/Tail Lights	0.14	13.19	Related
Turn Signals	0.06	5.24	0.20
Wheels	0.006	0.60	
Chassis Frame	0.008	0.72	
Suspensions	0.005	0.44	Other
5th Wheel	0.05	5.12	0.07
Trailer Pintle Hook	0.003	0.23	
TOTAL	1.06	100%	1.06

Brakes were identified as a severe violation by the experts, with a strong likelihood of contributing to an accident. They are a relatively high maintenance item on every vehicle type and are the major source of violations in MCSAP inspections. The data shown from this fleet probably underestimate the average maintenance effort required on brake systems because the fleet uses automatic slack adjusters exclusively. On vehicles with manual slack adjusters at least several more maintenance incidents would be likely each year for brake adjustment purposes. As a rough estimate a brake adjustment is warranted every 12,000 miles of use (more frequently on local delivery vehicles and less frequently on over the highway vehicles); so, tractors could see 3 to 4 more maintenance incidents of the brake system per year and trailers and dollies 2 to 3.

No fleet data on tire maintenance were available. Tires represent approximately 10% of the O/S violations observed in MCSAP inspections each year. As a rule of thumb tread wears out at approximately 100,000 miles equating to a 2- to 3-year life on tractors and about 5 years on semitrailers and dollies. Depending on maintenance practices of a fleet (whether they replace tires individually, by sets, or by axles) one or more maintenance incidents could be added each year for tires.

PREDICTED PROBABILITIES OF FAILURE

Based on the fleet data, curves were generated for components of tractors, semitrailers, and dollies in Appendix E from which the probability of need for repair could be estimated as a function of time since last repair. Every repair incident on a vehicle is not in response to an O/S level failure, thus only a fraction of the repairs correspond to O/S failures. No hard data are available to determine the exact fraction so judgement must be used. Discussions with knowledgeable fleet personnel have produced estimates of 10% to 50%. A factor of 1/3 was used in developing the predictions below. This is slightly above the midrange of the estimates, but being slightly higher compensates, to some extent, for the fact that some brake adjustment and tire maintenance data were not included in the data base. Ultimately, the probabilities rise and fall with choice of this factor, but the general trends remain.

Using the survivor curves adjusted for the 1/3 factor the following probabilities for O/S failures were calculated for tractors, semitrailers, and dollies.

Table 13.

Probabilities of O/S failures

	Time since last repair (months)									
Vehicle Type	1	2	3	4	5	6	7	8	9	10
Tractors	0.22	0.42	0.60	0.77	0.92	1	1	1	1	1
Semitrailers	0.08	0.15	0.21	0.26	0.30	0.34	0.37	0.39	0.41	0.43
Dollies	0.07	0.13	0.19	0.24	0.29	0.33	0.36	0.40	0.43	0.45

Taking tractors as an example, the table indicates that within the first month after an inspection or repair (i.e., a point at which the vehicle was determined to have no defects) the average tractor will have a 22% chance of developing an O/S failure in use. Over two months the probability grows to 42% and so on. At six months one failure will occur on average.

Since inspections deal with combinations of vehicles the data from the above table were recombined in Table 14 to represent the most common vehicle combinations. Inasmuch as there was no separate data for straight trucks, it has been assumed that trucks are the same as tractors with regard to maintenance needs. This is not an unreasonable assumption because they are generically similar vehicles. The tractor-semitrailer combination represents the total probabilities for a tractor and a semitrailer. A doubles combination totals the probabilities for a tractor, dolly, and two semitrailers. A triples combination will have slightly higher probabilities, but is not included here because of its limited usage throughout the country.

Table 14.

Failure Probabilities for Various Vehicle Combinations

	Time since last repair (months)									
Combination	1	2	3	4	5	6	7	8	9	10
Trucks	0.22	0.42	0.60	0.77	0.92	1	1	1	1	1
Tractor-Semitrailers	0.29	0.57	0.80	1	1	1	1	1	1	1
Doubles	0.44	0.84	1	1	1	1	1	1	1	1

The data above (discussed in more detail in Appendix E) provide a rare glimpse of the system failure rates on over-the-highway truck combinations. It is clear from the data, and particularly well illustrated by the survivor curves in the Appendix, that components can fail at any time. Immediately after an inspection or maintenance operation ascertaining that a system has no defects, the probability of failure begins to grow as the vehicle is put back into service. Even though initially small, the probability is not zero. Therefore, passing an inspection does not guarantee that a vehicle will be defect free once usage is resumed. This observation is relevant to the interpretation that should be applied to the CVSA decal. The decal cannot and should not be viewed either by enforcement agencies or the general public as a certification that a vehicle is free of an O/S violation. *The inspection only provides assurance that the probability of a defect is lower on an inspected vehicle than on vehicles that have not been inspected.*

A second important point is that as defects accrue with use of a vehicle the occurrence of an O/S failure eventually becomes a certainty. In the data of Table 14 the probability of an O/S failure occurrence reaches unity within three to six months after an inspection. In most cases the defect will be corrected promptly by the user. The Ohio and NTSB inspection data indicate that around 10 to 12% of the vehicles accumulating violations during the 3-month period of validity are not repaired, so the results in Table 14 imply that the great majority of O/S failures are repaired promptly by the owner.

It is those cases in which repairs are not made that are the primary target of MCSAP inspection programs. This further supports the appropriateness of the 3-month period of validity for the CVSA decal. In effect the vehicle has a 3-month grace period following an inspection. During that time the probability of an O/S failure occurring grows. Thereafter it becomes a candidate for inspection to ensure that the owner is motivated to be vigilant in providing necessary maintenance to keep the vehicle in a safe operating condition.

CONCLUSIONS AND RECOMMENDATIONS

Commercial vehicles passing a North American Standard Inspection - Level I receive a CVSA decal, valid for a period of three months, which generally excludes them from further inspections during this period. The question addressed in this research is whether the 3-month period of validity is appropriate.

Commercial vehicle inspections are conducted by state enforcement personnel under the MCSAP program for the purpose of removing from the road trucks with defects that could affect their safe operation. The purpose of the CVSA decal affixed to vehicles that pass inspection is to identify those that are expected to have lower probability of having an O/S violation. This is especially important when it is recognized that MSCAP resources are insufficient to allow inspection of all trucks on the road on a frequent basis. Currently, approximately 1,080,000 MCSAP inspections are reported each year throughout the nation in a population of over 3 million trucks. Only about 5% have a valid CVSA decal at any one time.

At a roadside inspection operation the presence of a decal is intended to identify those vehicles less likely to have a defect and to allow the enforcement personnel to concentrate inspection efforts on vehicles that are most likely to be defective. To prove that the 3-month decal serves the intended purpose, a search was made for data by which to compare the O/S violation rates on trucks with and without valid CVSA decals.

In general not much data exist of the type needed. In a 1990 inspection program in Ohio trucks with valid CVSA decals included in the inspection sample were identified. Of the vehicles with the valid decals, 12% were found to have O/S violations in contrast to 19% among the general population without a valid decal. Inasmuch as the inspection program covered approximately 25,000 vehicles, the statistical confidence that the decal does distinguish vehicles with lower inspection failure rates is quite good.

In the same time frame the National Transportation Safety Board conducted a study of brake conditions on 5-axle tractor-semitrailers operating on the interstate highway system. The study involved random inspections of vehicles at sites in five states. Among the information collected the inspectors noted whether the vehicles had a CVSA decal, and if so, the month of issue. These data were analyzed and adjusted to estimate the probability of O/S violations that would be present on vehicles with valid decals when the period of validity of the decal is varied. The data predict that with the current 3-month period of validity approximately 10% of the vehicles operating under a valid decal have O/S violations. This contrasts with the national average 41% O/S violation rate in MCSAP inspections among vehicles without a valid decal. Thus the 3-month decal discriminates vehicles that have a violation rate of only 25% of the non-decal vehicle population. On this basis it can be concluded that *excluding vehicles with a 3-month decal from routine MCSAP inspections enhances the productivity of the MCSAP program* with regard to removing as many defective vehicles from the public roads as possible.

The NTSB data were also analyzed to determine the potential benefits of reducing the period of validity of the decal to less than the current 3-month period. Although the sample of trucks with recent decals is small, the data do support the logical expectation that there are fewer violations on trucks with "younger" decals. For example, the data indicate that only about 3% violations would be expected on trucks with valid decals, if the period of validity was one month. However, if the period is reduced it would bring trucks with much lower violation rates into the inspection stream, thus displacing trucks with higher rates. As a consequence, *reducing the period of validity of the decal would be counter-productive and is not advisable.*

Finally, looking at failure rates of truck components from analysis of fleet maintenance data a similar picture emerges. Using a repair incident as a surrogate for inspection to identify a time when a vehicle system is free of defects, it is seen that the probability of failure grows with time as the vehicle is used. Quite typically, the probability of a failure approaches unity soon after three months from the date of repair. Because the probability of failure is lower during the first three months, the vehicle is a less desirable candidate for MCSAP inspection during that time. Thereafter with the probability that a failure has occurred, it becomes a candidate for inspection to ensure that the owner is motivated and conscientious in providing the maintenance necessary to keep it operating safely.

Based on the above observations and conclusions the following recommendations are offered from this study:

1) The CVSA should continue to use the 3-month period of validity for its decal.

2) Decal status and age should be recorded in random inspection programs to build a better data base for quantifying the violation rate among trucks with valid decals, expired decals, and no decals. These data will be of value to CVSA in the future for monitoring the general condition of trucks on the road, for establishing practices for selecting trucks at inspections, and for setting policy with regard to the period of validity for the decal.

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APPENDIX A

POPULATION OF TRUCKS AND TRAVEL STATISTICS

The objective of this appendix is to characterize the vehicles engaged in interstate transportation that are the primary targets of roadside safety inspections. Most inspections are conducted on rural interstate roads since these roads generally have more suitable inspection facilities and the truck traffic volume is high. Accordingly, the truck vehicle mileage on the rural limited access is estimated for various vehicle types. These estimates and the knowledge of the number of vehicle inspections in the U.S. in one year are used to estimate the probability of a vehicle from a particular category being stopped for a roadside safety inspection.

The data source for the statistics on the truck population and travel patterns is the National Truck Trip Information Survey (NTTIS) for 1985-1986 [A-1][1] . The detailed description of the sample used in the development of the distribution of the truck population can be found in the endnotes to this appendix.

The large trucks under consideration in this study were classified by their gross vehicle weight rating (GVWR) and by the type of power unit. The GVWR classes were GVWR 3-6 and GVWR 7-8. They are referred to as Medium and Heavy classes, respectively, in the following discussion. The power units are straight truck and tractor.

It is estimated that there are almost 3,091,000 large trucks in the United States. Table A-1 shows the distribution of the large truck population in the U.S. by weight class and type of power unit. More than 70% of these are straight trucks. Furthermore, about half of the entire fleet of large U.S. trucks are straight trucks of the medium weight category (GVWR 3-6).

Table A-1

U.S. Large Truck Population by Power Unit and Weight Class

POWER UNIT	WEIGHT CLASS		
TYPE	MEDIUM	HEAVY	TOTAL
STRAIGHT	1,551,864 (50.21)*	624,360 (20.20)	2,176,223 (70.41)
TRACTOR	50,909 (1.65)	863,821 (27.95)	914,729 (29.59)
TOTAL	1,602,773 (51.85)	1,488,180 (48.15)	3,090,953 (100.00)

* Total %

Source 1985-1987 NTTIS, see Appendix F, Table F-1

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[1] Numbers in brackets indicate references at end of this appendix.

However, as shown on Table A-2, tractors accumulate nearly 68% of all the large truck mileage, while straight trucks account for only 32%. As can be seen from the table, most of the tractor mileage is accumulated by the heavy (GVWR 7-8) tractor combinations (66.5%).

Table A-2

Annual Millions of Miles Traveled by Large Trucks in the U.S. by Power Unit and Weight Class

POWER UNIT	WEIGHT CLASS		
TYPE	MEDIUM	HEAVY	TOTAL
STRAIGHT	9,529	8,434	17,964
	(17.10)*	(15.14)	(32.24)
TRACTOR	721	37,040	37,761
	(1.29)	(66.47)	(67.76)
TOTAL	1.891	11,156	13,043
	(18.39)	(81.61)	(100.00)

* Total %
Source 1985-1987 NTTIS, see Appendix F, Table F-2

The heavy tractor-powered vehicles average almost 43,000 miles per year. In contrast, straight trucks of both weight classes and medium weight tractor-powered vehicles travel considerably less in a year. The average annual mileage of large trucks is shown in Table A-3.

Table A-3

Average Annual Mileage of U.S. Large Trucks by Power Unit and Weight Class

POWER UNIT	WEIGHT CLASS		
TYPE	MEDIUM	HEAVY	TOTAL
STRAIGHT	6,141	13,509	8,255
TRACTOR	14,158	42,879	41,281
TOTAL	6,395	30,557	18,028

Source 1985-1987 NTTIS, see Appendix F, Table F-3

Table A-4 shows the distribution of the vehicle mileage of the large trucks by road class. Slightly less than half of all the large truck mileage is accumulated on limited access roads and most of this is attributed to heavy vehicles (GVWR 7-8).

Table A-4

Annual Millions of Miles Traveled by Large Trucks in the U.S. by Road and Weight Class

ROAD CLASS	WEIGHT CLASS MEDIUM	HEAVY	TOTAL
LIMITED ACCESS	1,689 (3.26)*	22,794 (44.00)	24,483 (47.26)
OTHER ROADS	7,647 (14.76)	19,671 (37.97)	27,318 (52.74)
TOTAL	9,335 (18.02)	42,466 (81.98)	51,801 (100.00)

* Total %

Source 1985-1987 NTTIS, see Appendix F, Table F-4

Table A-5 shows the distribution of vehicle travel on limited access roads by the type of truck configuration. Tractor combinations account for 87% of the vehicle mileage on the limited access roads, while straight trucks account for only 13% of this mileage with only 1.3% of the straight trucks mileage accumulated by straight trucks pulling trailers.

The most prevalent large truck on limited access roads is a tractor with one trailer. These account for 80% of the large truck traffic on limited access roads. Tractors with 2 or 3 trailers account for 6% of this mileage, and tractors with no trailers account for less than 2%.

Table A-5

Annual Millions of Miles Traveled on Limited Access Roads by Various Large Truck Configurations

TRUCK TYPE	MVMT	PERCENT
Straight Trucks Alone	2,879	11.77
Straight Trucks with 1 or 2 Trailers	319	1.30
All Straight Trucks	3,198	13.08
Tractors Alone (Bobtails)	307	1.26
Tractor with 1 Trailer	19,492	79.72
Tractor with 2 or 3 Trailers	1,454	5.94
All Tractors	21,253	86.92
All Large Trucks	24,451	100.00

Source 1985-1987 NTTIS, see Appendix F, Table F-5

Table A-6

Annual Millions of Miles Traveled on Limited Access Roads by Large Trucks in the U.S. by Power Unit and Land Use

POWER UNIT TYPE	LAND USE RURAL	URBAN	TOTAL
STRAIGHT	1,165	2,081	3,246
	(4.76)*	(8.50)	(13.26)
TRACTOR	13,935	7,305	21,240
	(56.91)	(29.83)	(86.74)
TOTAL	15,100	9,386	24,486
	(61.67)	(38.33)	(100.00)

* Total %

Source 1985-1987 NTTIS, see Appendix F, Table F-7

Table A-6 shows that 62% of the large truck travel in the United States on the limited-access roads is in rural areas and 38% is in urban areas. The table also shows that tractor-powered vehicles account for 87% of the mileage on the rural limited access roads, while straight trucks account for 13% of this mileage.

When the distribution of the annual vehicle mileage of large trucks on rural limited-access roads is examined by power unit and weight class (Table A-7), it is clear that most of the large truck mileage on the rural limited access roads (92%) is attributed to heavy (GVWR 7-8), tractor-powered vehicles.

Table A-7

Annual Millions of Miles Traveled by Large Trucks on Limited Access Rural by Power Unit and Weight Class

POWER UNIT TYPE	WEIGHT CLASS MEDIUM	HEAVY	TOTAL
STRAIGHT	451	714	1,165
	(2.99)*	(4.73)	(7.71)
TRACTOR	102	13,833	13,935
	(0.68)	(91.61)	(92.29)
TOTAL	553	14,546	13,047
	(3.66)	(96.34)	(100.00)

* Total %

Source 1985-1987 NTTIS, see Appendix F, Table F-9

MCSAP reports that there were 1,080,774 roadside safety inspections in 1989 in the U.S. [A-2]. In estimating the average number of times a vehicle of a particular category is inspected, it will be assumed that all roadside inspections are carried out on rural limited-access roads and that the vehicles are selected in proportion to their vehicle-mileage on these roads.

The proportion of vehicles by power unit and weight category is given in Table A-7. The total number of vehicles in each category is given in Table A-1. These, together with the total number of inspections, are used to estimate the average number of inspections per vehicle per year. Table A-8 shows the results of this calculation.

Table A-8

Estimates of Number of MCSAP Roadside Inspection per Year by Weight Class and Power Unit

POWER UNIT	WEIGHT CLASS		
TYPE	MEDIUM	HEAVY	TOTAL
STRAIGHT	0.021	0.082	0.038
TRACTOR	0.144	1.144	1.090
TOTAL	0.025	0.700	0.350

The average number of inspections for a large truck is .35 times a year or about once every 3 years. The values in the table reflect the usage of rural limited access roads. Although there are many more straight trucks in the vehicle population of the U.S. than there are tractors, their lower usage of the roads by which the inspections are made results in an average inspection rate of .038 inspections per vehicle per year. Tractor-powered vehicles, especially the heavy ones (GVWR 7-8), which account for most of the truck traffic on rural limited access roads, have an inspection rate of slightly more than one per vehicle per year.

References

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A-2. Motor Carrier Safety Assistance Program, Program Activity Overview - Fiscal Year 1989. Federal Highway Administration, Office of Motor Carrier Field Operations, State Programs Division, Washington, D.C., 1990.

APPENDIX B

CONTRIBUTION OF VEHICLE DEFECTS TO ACCIDENT OCCURRENCE

Introduction

Review of truck population statistics indicates that are approximately 3.1 million large trucks in the United States. They travel 51.8 billion vehicle miles annually and carry about one quarter of the intercity freight moved in the country. In one year they are involved in about 4,500 accidents resulting in 980 fatalities [B-1][1] . This corresponds to about .086 accidents per million vehicle miles and .02 fatalities per million vehicle miles.

Truck Safety Inspection programs are based on the premise that if vehicle safety defects can be identified and corrected, an accident may be avoided. It then follows that inspection programs should focus on those components where a failure is likely to contribute to an accident. While this premise is most likely true, the questions of how many accidents are caused by specific vehicle defects are still unanswered.

There have been many attempts to relate accident causation to specific vehicle defects. Such studies are usually based on data derived from post-accident examinations of vehicles. Component defects noted in such examinations are not necessarily the cause of the accident. They may be the cause. However, the defect may have existed before the accident and did not contribute to it, or the component may have failed as a result of the accident itself. Even incidents such as down-grade run-aways cannot be attributed, with certainty, to brake failure due to a brake defect. The run-away could also result of the driver's inability to control the vehicle, thus causing the brake to overheat and fail.

Faced with the difficulties of obtaining unchallangeable results from quantitative analysis of accident data, but still needing to know which components are likely to fail and cause accidents, researchers have also turned to qualitative approaches to address the questions, such as collecting opinions of experts in the field as to seriousness of specific vehicle component failures.

In this Appendix the literature on vehicle defects and accidents is reviewed and two qualitative studies on the frequency and seriousness of vehicle component failures are summarized and compared.

Quantitative Studies

Most studies found in the literature report that vehicle defects contribute from 7% to 13% of accidents involving heavy vehicles.

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[1] Numbers in brackets indicate references at end of this appendix.

In a 1986 paper on commercial vehicle accidents Volkowicz reports that in a study of 140 commercial vehicle accidents investigated in the Metropolitan area of Toronto, 12% could be attributed to vehicle defects [B-2]. Volkowich further reports that The Ontario Provincial Police attribute only 7% of commercial vehicle accidents to mechanical failure. He speculates that the discrepancy is due to the fact that vehicle defects may go unnoticed in minor accidents. Volkowicz further reports that a roadside inspection in Ontario of 11387 commercial vehicles found 11.9 % of them to be mechanically unsafe. He concludes that mechanical failure is a significant but not large cause of commercial vehicle accidents.

In a study of systematic preventive maintenance on commercial vehicles, McDole and O'Day ([B-3] found that in their sample, defects were causative factors in 10% of accidents involving trucks 10 years old or older and in 4% of accidents involving trucks less than 3 years old.

The Oregon Public Utilities Commission [B-4] and the Pennsylvania Department of Transportation [B-5] both report that 13% of the truck accidents in their respective states are associated with vehicle defects.

In a paper published in 1982, Eicher, Robinson, and Toth [B-6] report that 6.4 % of truck accidents are caused by vehicle defects.

Only one study found in the literature reported a higher rate of vehicle defects associated with truck accidents. Stein and Jones [B-7] conclude that in tractor-trailer crashes examined in Oregon, 41% of accident-involved trucks had defects severe enough to be out-of-service (O/S) violations in MCSAP roadside safety inspections. Whether the defects contributed to the accidents, or if defects were mentioned on the associated accident reports, is not clear.

Specific Components

Analysis of almost 4000 large truck accidents in Pennsylvania [B-5] by Pennsylvania DOT concluded that 3.5% were caused by brake system failures and 1% were caused by tire blowouts.

Of 259 accidents reported by trucking firms, in a study of FMSS No. 121 configured vehicles versus non-121 configured vehicles, 3.9% were reported to be caused by mechanical failure of brakes [B-8].

In a 1976 study of large truck front tire failures, Biotechnology [B-9] examined accident files of over 25,000 commercial vehicle accidents and concluded that front tire failures are associated with less than 2% of all truck accidents.

It should be noted that since most of the data were supplied through police accident reports or BMCS accident reports, which depend on the driver and brief examinations of the site for most of the data, it can be assumed that tire failure was observed in the accident, but was not necessarily the causative factor.

Another study of large truck accidents involving tire failure carried out by the University of Michigan Highway Safety [B-10] examined data on 244,439 truck accidents of all types. Tire related accidents totaled 2203 or 0.9% and resulted in 71 fatalities and 932 injuries. About 2/3 of all the tire related accidents resulted from tire failure on steering axles. The study reports that truck accidents involving tire failure are relatively rare and are almost always single-vehicle involvements.

The HSRI study reports that a truck accident involving truck-tire failure occurs about once in every 10 million to 17 million truck-miles. Further, only about one truck tire failure in 1300 to 2200 of such failures results in an accident. The study cautioned that accidents are often blamed on tire failure, when in fact tire failure is not the cause. They quote a passenger car study where drivers blamed flat tires 2.5 more times than was justified.

Qualitative Studies

It is clear from the summary of quantitative studies of vehicle defects and accidents that it is extremely difficult to isolate the causative relationship between vehicle defects and accidents from the type of data that can be collected. On the other hand, controlled experiments designed to isolate the accident causal relationship are extremely difficult to carry out.

Faced with the difficulties of obtaining unchallangeable results from quantitative analysis of accident data, but still needing to know which components are likely to fail and cause accidents, some researchers have turned to qualitative approaches to address the questions. Such approaches include Delphi panels, surveys of experts, and other expert systems.

Two qualitative studies are summarized in this appendix. One is from ongoing research conducted at Boise State University and the other was carried out as part of this research.

Boise State Study

An ongoing evaluation of the Idaho MCSAP conducted at Boise State University in Idaho [B-11] is attempting to determine the frequency and severity of truck-inspection violations and relate the safety conditions of the trucks to MCSAP activities.

Of particular interest to our effort is the part of the study where the severity of specific safety inspection violations is determined. Long and Edmonson assembled a panel of truck safety inspection experts in Idaho (state inspection staff, state DOT staff, FHWA personnel, safety researchers). Long and Edmonson are conducting similar studies in Oregon and Michigan but the results from these were not available for this study. Using the Delphi technique, the severity of each of 400 vehicle and driver safety inspection violations were determined.

Severity was defined as the likelihood of a violation contributing to an accident. The Delphi panel assigned severity codes on a seven-point scale with a score of seven being a violation most likely to cause an accident or increase the severity of an accident. A score of one would indicate that there was no likelihood of the particular violation causing an accident.

The Delphi exercise to obtain the experts' opinions regarding the severity of the violations was performed. Next, the researchers obtained commercial vehicle safety inspection data from the state and classified the most frequent violations by the severity categories. The severity categories were: high (6 and 7), moderate (4 and 5), and low (1, 2, and 3). Inspection data for 2 years was examined.

The following list gives the vehicle violations by severity from the Idaho Delphi panel.

Severe Violations

- All Steering
- Total Brake System
- Brake inoperative
- Tire fabric Exposed
- Frame Cracked
- Frame Rubbing
- Locking Pins
- Windshield Wipers
- Wheel-Rim Cracked
- Flat Tire
- Rear View Mirror

Moderately Severe Violations

- Brake Adjustment
- Brake Drum Cracked
- Brake hose
- Brake lining
- Vacuum System
- Tow Trailer Brake
- Signal/Hazard lights (Turn Signals)
- Tail Lamps
- Suspension
- Spring Broken or Loose
- Tire tread
- Fifth Wheel
- Coupling Device
- Horn
- Speedometer
- Engine Start

All other vehicle violations are in the low severity category.

The following list gives the most frequently occurring vehicle safety violations by severity category for 1986 and 1987 from Idaho.

Frequent Severe Violations

All Steering
Brake inoperative
Tire fabric Exposed
Frame Cracked
Windshield Wipers
Wheel-Rim Cracked

Frequent Moderately Severe Violations

Brake Adjustment
Signal/Hazard lights
Brake Drum Cracked
Suspension
Tire tread

Frequent Low Severity Violations

Head Lamps
Clearance Lamps (To indicate extreme width or height)
Stop Lamps
No lamps
Windshield

UMTRI Survey of Experts

As part of this study, truck safety experts attending a meeting in Washington, DC in November, 1989 were asked to give their opinions on the likelihood of failure of vehicle components and to also give their assessment of the safety risk of the failure. Figure B-1 shows the survey form.

A 5-point semantic differential scale was used. There were five respondents. The average and standard deviation of their scores was calculated. The results were summarized in categories of Low (<2), Low/Moderate (2-3), Moderate (3-3.5), Moderate+ (3.5-4), High (4-5). The standard deviation was examined to see if the experts agreed or disagreed. A standard deviation below 1 was considered as agreement, over 1 as disagreement.

Table B-1 gives the results of the study.

Name: ______________________________ Date: __________________

Organization: ______________________________ Phone No: ______________

UMTRI Truck Safety Inspection Survey

The frequency and effort warranted in performing safety inspections of truck components depends both on the relative likelihood that the component might malfunction or fail on the road, and the safety risk that will result.

The University of Michigan Transportation Research Institute is conducting a study in which it is of interest to identify which truck components need frequent inspection to ensure safe operations. We would like your opinions as to which components are most likely to malfunction/fail, and which are most important to safety. Please record your opinions on the form below for each component using the 1 - 5 scale shown.

Rating Scale

1	2	3	4	5
Low		Moderate		High

	LIKELIHOOD OF	
	Failure	Safety Risk
BRAKES		
Adjustment	______	______
Lining Wear	______	______
Pressure loss or leaks	______	______
Low air warning	______	______
Parking brake	______	______
LIGHTS		
Headlights	______	______
Tail/stop lamps	______	______
Turn signals	______	______
STEERING	______	______
TIRES	______	______
WHEELS/LUGS/RIMS	______	______
SUSPENSIONS	______	______
COUPLING DEVICES	______	______
FRAMES	______	______
EXHAUST	______	______
FUEL SYSTEMS	______	______
HEADERBOARDS	______	______
REAR END PROTECTION	______	______

Fig. B-1 UMTRI Survey Form

Table B-1

Summary of Truck Safety Inspection Survey

Component	Likelihood of Failure	Safety Risk
BRAKES		
Adjustment	High	High
Lining	Moderate	Moderate+
Pressure	Moderate+	Moderate
Low Air Warning	Moderate	Low
Parking Brake	Moderate	Low
TIRES	Moderate	High
LIGHTS		
Headlights	Moderate+	Low/Moderate*
Tail/Stop	High	Low/Moderate*
Turn Signals	Moderate	Low/Moderate*
STEERING	Low/Moderate	Moderate
WHEELS/LUGS/RIMS	Low/Moderate	Moderate
SUSPENSION	Low/Moderate	Low/Moderate
COUPLING DEVICES	Low/Moderate	Moderate
EXHAUST	Low/Moderate	Low/Moderate
REAR END PROTECTION	Low/Moderate	Low/Moderate
FRAME	Low	Low/Moderate
FUEL	Low	Low/Moderate
HEADER	Low	Low

* Disagreement

There was agreement on the relative ratings on the likelihood of failure on all the components. The safety risk of failed lights was the only item on which there was disagreement among the experts. Closer examination of the responses showed that the representatives of the trucking industry felt that the risk was low and the FHWA experts felt that the risk was moderately high to high.

The following list gives the components which received a rating of moderate or higher on both likelihood of failure and safety risk .

- BRAKES
  - Adjustment
  - Lining
  - Pressure
- TIRES
- LIGHTS
  - Headlights
  - Tail/Stop
  - Turn Signals

The following components were considered to be a moderate safety risk but have a low to moderate likelihood of failure.

- WHEELS/LUGS/RIMS
- COUPLING
- STEERING

Results from Qualitative Studies

Justification of Comparison - The first consideration is to determine whether such a comparison is meaningful and valid. Are the groups comparable in size and composition? Will differences in composition of groups bias the results so that comparison is meaningless? Are the questions asked comparable?

Composition - The Idaho Delphi panel consisted of 9 experts and 2 researchers from Boise State University, who led the discussions. There were 6 panel members from the Idaho State Police, 2 from the OMCS of FHWA and the FHWA Region State Program Manager.

The 5 experts whose opinions are aggregated in the UMTRI survey consisted of 2 experts from CVSA, 1 from OMCS of the FHWA, 1 MVMA, and 1 from ATA.

Both groups are relatively small. The Delphi panel includes a number of persons from the Idaho state police, who carry out the commercial vehicle safety inspection program. The UMTRI panel includes 2 persons from the CVSA. The UMTRI panel has representatives of the trucking industry, while the Delphi panel does not. Both panels have representatives from FHWA.

Thus, while the compositions are not exactly the same, both groups consist of persons knowledgeable in the topic. The Delphi panel has more people involved in inspections, while the UMTRI panel has representatives of the trucking industry.

The Questions Asked - The Boise State study gives severity of violations, which is comparable to the safety risk on the UMTRI survey. The most frequent violations by level of severity on the Boise State study are comparable to a combination of a high likelihood of failure (thus frequent) and a comparable safety risk.

Comparison of results - The following list gives the components that were identified as high and medium severity violations by the Idaho Delphi panel and moderate to high safety risks by the UMTRI survey respondent:

- Brake systems
  - Total brake system
  - Adjustment
  - Lining
- Vacuum system (Pressure)
- Steering
- Tires
- Coupling Devices

The following list gives the components that were found to have the most frequent violations in the Idaho inspection data for 1986 and 1987 and were assigned a high likelihood of failure by the UMTRI survey respondents.

- Brakes
  - Brake adjustment
  - Brake pressure
- Tires
- Lights
  - Head lights
  - Stop lights
  - Turn signals

There was agreement that the following components failed frequently and were a high or moderate safety risk:

- Brakes
  - Adjustment
  - Brake pressure (inoperative)
- Tires

There was agreement between the two studies that lights failed frequently but were considered a moderate risk for turn signals and a low risk for headlights and tail lights.

Both analyses identify failure of brake systems and tires as likely events with a high safety risk. Both analyses identify failure of lights as likely events, with relatively low to moderate safety risks.

References

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B-9 "Large Truck Front Tire Accidents." Biotechnology, Inc., Report prepared for the FHWA, Nov. 30, 1976.

B-10 Dunlap, D. F., Large Truck Accidents Involving Tire Failure. University of Michigan Highway Safety Research Institute, February 1974.

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APPENDIX C

ROADSIDE SAFETY INSPECTIONS AND OUT-OF-SERVICE VIOLATIONS

Introduction

This appendix first looks at the national overview of commercial vehicle safety inspections. The distribution of MCSAP inspections, out -of-service actions and violations in 1989 by state are presented. Then the inspection records for one state are examined more closely. The records for the commercial vehicle inspections for Michigan from 1988 and 1989 are summarized and tested for seasonal effects. Records from Michigan's random inspections are compared against records from the routine inspections. Vehicle violations by component are compared across vehicle types.

National Overview

The Motor Carrier Safety Assistance Program (MCSAP) provides grants to States and eligible territories to carry out motor carrier safety enforcement activities, which include roadside commercial vehicle inspections.

In 1989 MCSAP supported activities in 45 states and 3 territories. Participating states submit information on inspections to the MCSAP in Quarterly Reports. In most cases the reports are prepared directly from the computerized Motor Carrier Safety Information Network, SAFETYNET, in place at the state.

It should be noted that there are some problems with the national data. SAFETYNET is relatively new and some states are having problems inputting all their information onto the system. Furthermore, FHWA Office of Motor Carriers (OMC) believes that there are inconsistencies in what states are actually reporting on their quarterly reports. OMC is currently addressing the problems and hopes to have consistent and complete data in the near future. Meanwhile, this is the most complete information about commercial vehicle inspections available at this time.

In 1989 there was a total of 1,080,774 full North American Standard Inspections (CVSA Level I) [C-1][1] . As a result of these inspections, 438,729 (40.6%) of the vehicles inspected were placed out-of-service (O/S). The average number of vehicle violations per O/S inspection was 2.18.

Table C-1 details the inspection statistics by state. The table shows the number of inspections reported by each state, the number of violations, the number of vehicles placed out-of-service and the percent of all vehicles inspected that are placed out-of-service.

[1] Numbers in brackets indicate references at end of this appendix.

Table C-1
Summary of FY 1989 Commercial Vehicle Inspections

State	No. of Inspections	Total violations In O/S Inspect.	Total vehicles Classified O/S	% Inspections With O/S Result	No. of violations Per O/S Inspect.
CT	16808	14990	9032	53.74	1.66
MA	14669	8166	4651	31.71	1.76
ME	6947	12916	3602	51.85	3.59
NH	6699	5657	2511	37.48	2.25
NJ	23311	16254	9448	40.53	1.72
NY	51700	0	21805	42.18	
PR	1017	2375	901	88.59	2.64
RI	4213	5277	2272	53.93	2.32
VT	729	250	120	16.46	2.08
DE	2868	2715	1490	51.95	1.82
MD	20189	23330	10278	50.91	2.27
PA	33185	34302	17722	53.40	1.94
VA	10027	11460	5206	51.92	2.20
WV	9296	7400	4209	45.28	1.76
AL	9910	15875	6963	70.26	2.28
GA	32109	29023	12581	39.18	2.31
KY	77745	76007	27715	35.65	2.74
MS	10603	12852	4286	40.42	3.00
NC	57416	26044	17861	31.11	1.46
SC	13831	23634	7181	51.92	3.29
TN	120917	131536	53340	44.11	2.47
IL	52308	18769	10432	19.94	1.80
IN	39569	36952	16817	42.50	2.20
MI	51255	32210	13968	27.25	2.31
MN	25148	18594	8041	31.97	2.31
OH	100352	44787	25836	25.75	1.73
WI	13936	14804	6822	48.95	2.17
AR	13771	15918	8231	59.77	1.93
LA	17107	12529	8378	48.97	1.50
NM	2819	0	1602	56.83	
OK	1935	3609	1877	97.00	1.92
IA	19444	14361	9336	48.01	1.54
KS	12871	9032	5785	44.95	1.56
MO	45473	72777	26017	57.21	2.80
NE	9912	8426	4886	49.29	1.72
CO	33301	45633	14070	42.25	3.24
MT	4560	3964	2390	52.41	1.66
ND	3621	2981	1494	41.26	2.00
UT	10366	10621	4556	43.95	2.33
AS	738	389	229	31.03	1.70
AZ	6416	6187	4410	68.73	1.40
CA	31253	20934	13640	43.64	1.53
GU	3202	1295	737	23.02	1.76
HI	3688	1653	1293	35.06	1.28
NV	4772	5650	2666	55.87	2.12
ID	8912	3413	2033	22.81	1.68
OR	15459	10779	6209	40.16	1.74
WA	25397	27375	13799	54.33	1.98
TOTAL	1080774	903705	438728	40.59	2.18

Derived from MCSAP Program Activity Overview - FY 1989, FHWA, Office of Motor Carrier Field Operations, State Programs Division

Table C-2 shows the breakdown of the vehicle out-of-service defects by state. Table C-3 shows the same breakdown by percentages. It can be seen that brake system defects are the largest contributor to vehicle violations followed by lights and tires.

Figure C-1 summarizes the overall distribution of vehicle defects in vehicles that were placed out-of-service. Brake defects account for 54.6% of the violations, lights for 16.2%, and tires for 9.5%.

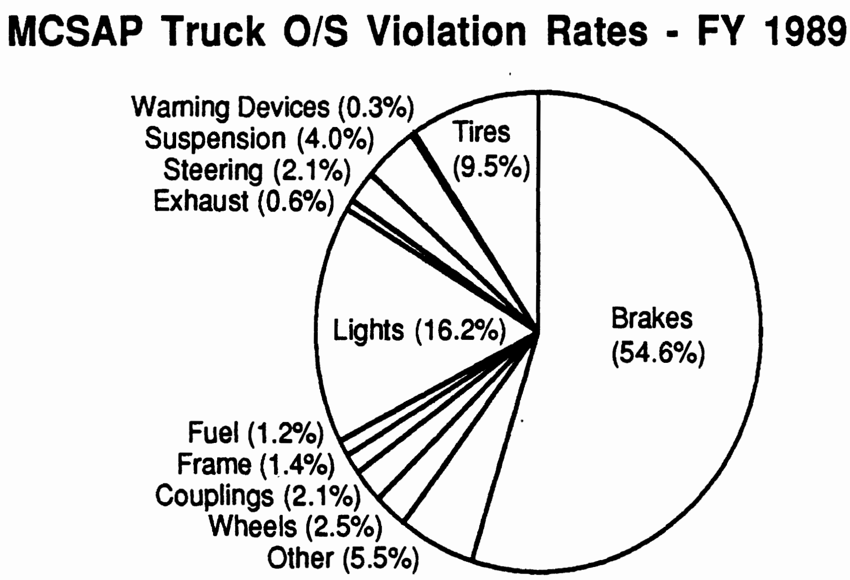


Fig. C-1 Distribution of Violations in MCSAP Truck Inspections

Table C-2

Truck Vehicle Out-of-Service Violations by Component from MCSAP Quarterly Report Summary for FY 1989

State	Total Trucks O/S	Total O/S Viol.	Brakes	Coupl. Sys.	Exh. Sys.	Fuel Sys.	Frame	Lights	Steer. Mech.	Susp-ension	Tires	Warn. Dev.	Wheels, Studs, Clamps etc.	Other Defects
CT	9032	14990	8873	160	212	235	110	2287	721	453	1435	6	171	327
MA	4651	8166	5134	41	20	104	100	1283	482	232	530	6	36	198
ME	3602	12916	9985	143	39	54	215	762	425	473	658	7	109	46
NH	2511	5657	3745	11	22	44	2	1028	203	61	389	1	16	135
NJ	9448	16254	8075	66	146	247	116	4120	138	547	2121	44	150	484
NY	21805	0	0	0	0	0	0	0	0	0	0	0	0	0
PR	901	2375	434	72	3	45	6	921	2	327	433	0	9	123
RI	2272	5277	3702	38	4	51	11	844	27	83	430	0	43	4
VT	120	250	173	3	0	5	1	32	9	12	4	1	4	6
DE	1490	2715	1185	97	5	31	54	452	104	130	252	86	122	197
MD	10278	23330	7392	803	185	424	139	1725	911	626	1516	506	120	8983
PA	17722	34302	22252	79	39	425	354	4184	344	995	3616	6	206	1802
VA	5206	11460	7279	117	27	104	108	1696	621	467	849	0	94	98
WV	4209	7400	4579	161	7	46	46	1018	237	313	551	0	110	332
AL	6963	15875	6245	338	103	357	416	4524	308	251	2131	29	390	783
GA	12581	29023	17098	762	272	166	228	4806	332	536	3488	4	617	714
KY	27715	76007	59596	483	39	457	284	9889	355	1003	2834	22	574	471
MS	4286	12852	7777	429	34	144	273	1711	70	329	861	66	362	796
NC	17861	26044	10434	259	37	278	268	9280	290	577	3463	0	555	603
SC	7181	23634	15051	645	110	78	97	4211	72	186	1655	6	288	1235
TN	53340	131536	73857	3704	493	894	2749	15319	1171	6759	13270	1301	3144	8875
IL	10432	18769	8330	232	84	200	344	4619	255	452	2270	1	484	1498
IN	16817	36952	21974	630	188	540	535	4798	1100	1504	4203	23	333	1124
MI	13968	32210	11073	787	174	334	273	10015	1182	1189	5577	9	310	1287
MN	8041	18594	8086	317	59	165	547	4826	506	1444	1571	73	396	604
OH	25836	44787	11664	2084	139	805	799	10759	889	2555	9216	50	1764	4603
WI	6822	14804	7514	241	8	107	160	3638	143	672	1733	3	207	378
AR	8231	15918	7769	560	168	141	650	2361	3	868	1649	40	734	975
LA	8378	12529	7343	185	32	72	63	2537	77	204	1176	18	423	399
NM	1602	0	0	0	0	0	0	0	0	0	0	0	0	0
OK	1877	3609	1809	110	57	40	86	793	47	72	367	2	176	50
IA	9336	14361	8874	95	33	89	169	2732	67	627	1153	0	295	227
KS	5785	9032	5102	115	40	231	43	1430	52	213	747	3	251	805
MO	26018	72777	39830	746	124	948	579	9849	3491	5406	5418	25	4833	1528
NE	4886	8426	5405	322	41	113	153	890	121	350	438	11	322	260
CO	14070	45633	29076	760	635	582	537	4225	407	1804	2946	6	676	3979
MT	2390	3964	2188	84	1	38	34	484	9	172	323	2	379	250
ND	1494	2981	1970	121	2	22	126	370	13	76	149	4	79	49
UT	4556	10621	5707	413	325	168	239	1171	484	353	819	13	364	565
AS	229	389	137	21	2	15	9	94	12	11	38	14	25	11
AZ	4410	6187	1945	107	114	362	103	1440	90	131	1020	16	568	291
CA	13640	20934	10354	825	108	415	457	2670	1383	1837	1248	72	987	578
GU	737	1295	396	0	0	4	1	544	2	2	144	31	27	104
HI	1293	1653	978	3	5	12	28	157	140	31	197	8	38	56
NV	2666	5650	2405	190	108	119	206	805	468	407	459	7	233	243
ID	2033	3413	1577	120	144	51	90	457	157	165	248	14	284	106
OR	6209	10779	5312	536	29	234	292	1749	362	493	807	6	808	151
WA	13799	27375	13845	572	767	500	715	2473	1073	1147	1288	69	844	4082
TOT	4387728	903705	493529	18587	5184	10536	12815	145978	19355	36545	85690	2611	22960	49915

SOURCE: MCSAP Program Activity Overview - FY 1989, FHWA, Office of Motor Carrier Field Operations, State Programs Division

Table C-3

Distribution of Truck Vehicle Out-of-Service Defects (%) from MCSAP Quarterly Report Summary for FY 1989

State	Brakes	Coupl. Sys.	Exh. Sys.	Fuel Sys.	Frame	Lights	Steer. Mech.	Susp- ension	Tires	Warn. Dev.	Wheels, Studs, Clamps Etc.	Other Defects
CT	59.2	1.1	1.4	1.6	.7	15.3	4.8	3.0	9.6		1.1	2.2
MA	62.9	.5	.2	1.3	1.2	15.7	5.9	2.8	6.5	.1	.4	2.4
ME	77.3	1.1	.3	.4	1.7	5.9	3.3	3.7	5.1	.1	.8	.4
NH	66.2	.2	.4	.8		18.2	3.6	1.1	6.9	.3		2.4
NJ	49.7	.4	.9	1.5	.7	25.3	.8	3.4	13.0	.3	.9	3.0
NY	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PR	18.3	3.0	.1	1.9	.3	38.8	.1	13.8	18.2		.4	5.2
RI	70.2	.7	.1	1.0	.2	16.0	.5	1.6	8.1	.8		.8
VT	69.2	1.2		2.0	.4	12.8	3.6	4.8	1.6	.4	1.6	2.4
DE	43.6	3.6	.2	1.1	2.0	16.6	3.8	4.8	9.3	3.2	4.5	7.3
MD	31.7	3.4	.8	1.8	.6	7.4	3.9	2.7	6.5	2.2	.5	38.5
PA	64.9	.2	.1	1.2	1.0	12.2	1.0	2.9	10.5		.6	5.3
VA	63.5	1.0	.2	.9	.9	14.8	5.4	4.1	7.4		.8	.9
WV	61.9	2.2	.1	.6	.6	13.8	3.2	4.2	7.4		1.5	4.5
AL	39.3	2.1	.6	2.2	2.6	28.5	1.9	1.6	13.4	.2	2.5	4.9
GA	58.9	2.6	.9	.6	.8	16.6	1.1	1.8	12.0		2.1	2.5
KY	78.4	.6	.1	.6	.4	13.0	.5	1.3	3.7		.8	.6
MS	60.5	3.3	.3	1.1	2.1	13.3	.5	2.6	6.7	.5	2.8	6.2
NC	40.1	1.0	.1	1.1	1.0	35.6	1.1	2.2	13.3		2.1	2.3
SC	63.7	2.7	.5	.3	.4	17.8	.3	.8	7.0		1.2	5.2
TN	56.1	2.8	.4	.7	2.1	11.6	.9	5.1	10.1	1.0	2.4	6.7
IL	44.4	1.2	.4	1.1	1.8	24.6	1.4	2.4	12.1		2.6	8.0
IN	59.5	1.7	.5	1.5	1.4	13.0	3.0	4.1	11.4	.1	.9	3.0
MI	43.4	2.4	.5	1.0	.8	31.1	3.7	3.7	17.3		1.0	4.0
MN	43.5	1.7	.3	.9	2.9	26.0	2.7	7.8	8.4	.4	2.1	3.2
OH	26.0	4.7	.3	1.8	1.8	24.0	2.0	5.7	20.6	.1	3.9	9.1
WI	50.8	1.6	.1	.7	1.1	24.6	1.0	4.5	11.7		1.4	2.6
AR	48.8	3.5	1.1	.9	4.1	14.8		5.5	10.4	.3	4.6	6.1
LA	58.6	1.5	.3	.6	.5	20.2	.6	1.6	9.4	.1	3.4	3.2
NM	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
OK	50.1	3.0	1.6	1.1	2.4	22.0	1.3	2.0	10.2	.1	4.9	1.4
IA	61.8	.7	.2	.6	1.2	19.0	.5	4.4	8.0		2.1	1.6
KS	56.5	1.3	.4	2.6	.5	15.8	.6	2.4	8.3		2.8	8.9
MO	54.7	1.0	.2	1.3	.8	13.5	4.8	7.4	7.4		6.6	2.1
NE	64.1	3.8	.5	1.3	1.8	10.6	1.4	4.2	5.2	.1	3.8	3.1
CO	63.7	1.7	1.4	1.3	1.2	9.3	.9	4.0	6.5		1.5	8.7
MT	55.2	2.1		1.0	.9	12.2	.2	4.3	8.1	.1	9.6	6.3
ND	66.1	4.1	.1	.7	4.2	12.4	.4	2.5	5.0	.1	2.7	1.6
UT	53.7	3.9	3.1	1.6	2.3	11.0	4.6	3.3	7.7	.1	3.4	5.3
AS	35.2	5.4	.5	3.9	2.3	24.2	3.1	2.8	9.8	3.6	6.4	2.8
AZ	31.4	1.7	1.8	5.9	1.7	23.3	1.5	2.1	16.5	.3	9.2	4.7
CA	49.5	3.9	.5	2.0	2.2	12.8	6.6	8.8	6.0	.3	4.7	2.8
GU	30.6			3.4	.1	42.0	.2	.2	11.1	2.4	2.1	8.0
HI	59.2	.2	.3	.7	1.7	9.5	8.5	1.9	11.9	.5	2.3	3.4
NV	42.6	3.4	1.9	2.1	3.6	14.2	8.3	7.2	8.1	.1	4.1	4.3
ID	46.2	3.5	4.2	1.5	2.6	13.4	4.6	4.8	7.3	.4	8.3	3.1
OR	49.3	5.0	.3	2.2	2.7	16.2	3.4	4.6	7.5	.1	7.5	1.4
WA	50.6	2.1	2.8	1.8	2.6	9.0	3.9	4.2	4.7	.3	3.1	14.9
AV	54.6	2.1	.6	1.2	1.4	16.2	2.1	4.0	9.5	.3	2.5	5.5

SOURCE: MCSAP Program Activity Overview - FY 1989, FHWA, Office of Motor Carrier Field Operations, State Programs Division

Michigan Inspections

Records for the commercial vehicle inspections conducted in Michigan for 1988 and 1989 were obtained from the Michigan State Police. There was a total of 104,000 inspections. The records were examined for differences by season, between random and regular inspections, and for patterns of vehicle defects by vehicle type.

Table C-4 shows the distribution by calendar quarters of the approximately 104,000 vehicle inspections made in Michigan in 1988 and 1989. No variation was identified by calendar quarters. The percent of vehicles placed out-of-service is approximately constant and the number of violations per O/S inspection does not change. If it is assumed that calendar quarters correspond to seasons, then it can be concluded that there is no seasonal effect in the patterns of vehicle violations in the inspections.

Vehicles chosen for inspection are not selected randomly from a stream of vehicles but are selected by the inspectors based on their experience. A comparison of regular inspection against random inspection records was made to see what differences could be found.

Table C-4

Michigan Roadside Safety Inspections for 1988 and 1989
Calendar Quarter

	No. of Inspections	Total veh. viol. In O/S Inspect.	Total vehicles Classified O/S	% Inspections With O/S Result	No. of veh. viol. per O/S Inspect.
1988					
Jan-Mar	14180	8598	4030	29	2.1
Apr-Jun	16042	9967	4631	29	2.2
Jul-Sep	12797	8193	3957	31	2.3
Oct-Dec	11658	7285	3230	28	2.2
TOTAL	54677	34043	15848	29	2.2
1989					
Jan-Mar	12919	7606	3675	28	2.1
Apr-Jun	13369	8290	3719	28	2.2
Jul-Sep	11345	8620	3560	31	2.4
Oct-Dec	11204	8796	3613	32	2.4
TOTAL	48837	33312	14567	30	2.4

Table C-5 shows the comparison of the total number of inspections against the total number of random inspections. The percent of vehicles placed O/S in the regular inspections is 29%, while only 19% of the randomly inspected vehicles are placed O/S. The number of violations per O/S inspection in the random inspections is also lower—1.7 violations as compared to 2.3 violations in the regular inspections. It appears that the inspectors do indeed select vehicles in worse conditions than average for inspection.

Table C-5

Comparison of All Michigan Inspections against Random Inspections for 1988 and 1989

YEAR	Number of Inspections	Total veh. viol. In O/S Inspect.	Number of veh. Classified O/S	% Inspections With O/S Result	Veh. violations per O/S Inspect.
1988					
All	54677	34043	15848	28.98	2.20
Random	2806	880	514	18.32	1.70
1989					
All	48837	33312	14567	29.83	2.40
Random	1040	427	235	22.60	1.80
TOTAL					
All	103514	67355	30415	29.38	2.21
Random	3846	1307	749	19.47	1.74

Next vehicle violations by vehicle type in both the regular and random inspections were explored. There was a sufficient number of records for truck tractors, semi-trailers, and straight trucks for this analysis. Table C-6 shows the distribution of vehicle defects for truck tractors found in the regular inspections. Table C-7 shows the truck tractor defects in the random sample.

Table C-8 lists all the defects that accounted for more than 5% of the violations for truck tractors that were placed O/S in both the regular and random inspections.

Table C-8
Problem Components in Truck-tractors

		Regular	Random
Brake system	Low Air Warning	19.7%	22.8%
	Front Brakes	17.1%	1.3%
	Air Hose Leaks	7.5%	6.1%
	Brakes	8.5%	6.0%
Tires		8.5%	6.0%
Tail/Stop Lamps		8.3%	8.8%
Coupling Devices		7.0%	5.7%

Table C-6

1988 and 1989 Michigan Inspections - Truck Tractor

95,676* INSPECTIONS
16,259** VIOLATIONS IN INSPECTIONS WHERE VEHICLE WAS PLACED O/S
146,866** TOTAL VIOLATIONS

VIOLATION	Total number of violations	% of total violations	Total number of violations in inspection where vehicle was O/S	% of total violations
HEATER/DEFROSTER	194	.13%	0	.00%
HORN/SPEEDOMETER	3132	2.13%	0	.00%
CAB FLOOR	120	.08%	0	.00%
WIRING	706	.48%	0	.00%
FIRE EXTINGUISHER	9144	6.23%	0	.00%
WARNING DEVICES/FLAG	4498	3.06%	0	.00%
BRAKE APPLIED /PRESSURE	803	.55%	641	3.94%
LOW AIR WARNING	4266	2.90%	3208	19.73%
PARKING BRAKE	329	.22%	105	.65%
GLASS	8167	5.56%	54	.33%
WINDSHIELD WPR/WASH	13098	8.92%	62	.38%
HEADLIGHTS	9853	6.71%	329	2.02%
FRONT TURN SIGNALS	4892	3.33%	0	.00%
CLEAR ID LIGHTS	13263	9.03%	0	.00%
STREERING TIRES	1237	.84%	320	1.97%
FRONT WHEELS/LUGS/RIMS	444	.30%	45	.28%
STEERING COMPONENTS	4693	3.20%	1235	7.60%
FRONT BRAKES	6120	4.17%	2776	17.07%
REARVIEW MIRRORS	162	.11%	0	.00%
FUEL SYSTEMS	1041	.71%	432	2.66%
BATTERY INSALL	927	.63%	0	.00%
EXHAUST SYSTEM	6891	4.69%	207	1.27%
AIR HOSES/LEAKS	9313	6.34%	1220	7.50%
TIRES	5763	3.92%	1379	8.48%
WHEELS/LUGS/RIMS	939	.64%	114	.70%
BRAKES	8008	5.45%	2168	13.33%
SUSPENSION	2822	1.92%	577	3.55%
FRAMES	404	.28%	79	.49%
COUPLING DEVICES	4792	3.26%	1140	7.01%
REAR TURN SIGNALS	4034	2.75%	622	3.83%
TAIL/STOP LAMPS	12694	8.64%	1342	8.25%
MUD FLAPS	3108	2.12%	0	.00%
REAR END PROTECTION	38	.03%	0	.00%
CARGO SECUREMENT	400	.27%	130	.80%
TARPING REQUIRED	57	.04%	0	.00%
OTHER VIOLATIONS	4631	3.15%	2	.01%

The inspection records for a particular vehicle type include all the units in the train if one of the units is the specified vehicle type.

* Number of inspections where one unit was a truck tractor
** Total number of violations recorded for the power unit

Table C-7

1988 and 1989 Michigan Inspections - Truck Tractor, Random

3,112* INSPECTIONS, 663 VEHICLES PLACED O/S
456* VIOLATIONS IN INSPECTIONS WHERE VEHICLES WAS PLACED OOS
4,677** TOTAL VIOLATIONS

VIOLATION	Total number of violations	% of total violations	Total number of violations in inspection where vehicle was O/S	% of total violations
HEATER/DEFROSTER	7	.15%	0	.00%
HORN/SPEEDOMETER	90	1.92%	0	.00%
CAB FLOOR	1	.02%	0	.00%
WIRING	25	.53%	0	.00%
FIRE EXTINGUISHER	326	6.97%	0	.00%
WARNING DEVICES/FLAG	114	2.44%	0	.00%
BRAKE APPLIED /PRESSURE	17	.36%	10	2.19%
LOW AIR WARNING	143	3.06%	104	22.81%
PARKING BRAKE	10	.21%	3	.66%
GLASS	219	4.68%	0	.00%
WINDSHIELD WPR/WASH	441	9.43%	4	.88%
HEADLIGHTS	260	5.56%	2	.44%
FRONT TURN SIGNALS	175	3.74%	0	.00%
CLEAR ID LIGHTS	401	8.57%	0	.00%
STREERING TIRES	33	.71%	6	1.32%
FRONT WHEELS/LUGS/RIMS	9	.19%	0	.00%
STEERING COMPONENTS	180	3.85%	30	6.58%
FRONT BRAKES	230	4.92%	97	21.27%
REARVIEW MIRRORS	2	.04%	0	.00%
FUEL SYSTEMS	29	.62%	13	2.85%
BATTERY INSALL	23	.49%	0	.00%
EXHAUST SYSTEM	208	4.45%	0	.00%
AIR HOSES/LEAKS	275	5.88%	28	6.14%
TIRES	143	3.06%	27	5.92%
WHEELS/LUGS/RIMS	23	.49%	5	1.10%
BRAKES	217	4.64%	37	8.11%
SUSPENSION	78	1.67%	29	6.36%
FRAMES	10	.21%	0	.00%
COUPLING DEVICES	187	4.00%	26	5.70%
REAR TURN SIGNALS	150	3.21%	10	2.19%
TAIL/STOP LAMPS	529	11.31%	40	8.77%
MUD FLAPS	72	1.54%	0	.00%
REAR END PROTECTION	0	.00%	0	.00%
CARGO SECUREMENT	3	.06%	0	.00%
TARPING REQUIRED	0	.00%	0	.00%
OTHER VIOLATIONS	133	2.84%	0	.00%

The inspection records for a particular vehicle type include all the units in the train if one of the units is the specified vehicle type.

* Number of inspections where one unit was a truck tractor
**Total number of violations recorded for the power unit

The components that accounted for most of the violations are brake system, tires, tail/stop lamps, and coupling devices. It is interesting to note that the pattern of vehicle defects in the truck tractors placed O/S is very similar in the regular and random inspections. This implies that, while a greater portion of vehicles selected for regular inspections are found to have defects severe enough to place them out-of-service, the pattern of vehicle defects in those vehicles in the random sample that have defects is the same as in the population.

Table C-9 gives the distribution of vehicle defects for straight trucks for the regular inspections. Table C-10 shows the same distribution for the random sample.

Table C-11 lists the components that contributed to more than 5% of all the vehicle violations in the straight trucks that were placed O/S. It can be seen from the table that the rear turn signals and tail/stop lights are a problem in the general population of straight trucks since they appear in both samples. The contribution of steering defects is also similar in both samples.

It appears that the tires in the general population of straight trucks are not as significant a problem as they are in the vehicles selected for inspection. From this one can speculate that the condition of the tires may be a criterion used by inspectors to select the straight trucks to be inspected.

The parking brake and low air warning appear to be problems in straight trucks. However, the brakes were more of a problem in the inspector-selected sample than in the random sample.

Table C-11
Problem Components in Straight Trucks

		Regular	Random
Brake System	Low Air Warning	6.4%	6.0%
	Parking Brake	8.8%	19.8%
	Brakes	7.2%	(4.0%)
Tires		10.6%	(3.3%)
Lights	Rear Turn Signals	13.9%	17.2%
	Tail/Stop Lamps	22.2%	22.5%
Steering Components		7.1%	6.6%

Table C-9

1988 and 1989 Michigan Inspections - Straight Trucks

26,280* INSPECTIONS, 7,749 VEHICLES PLACED O/S
13,360** VIOLATIONS IN INSPECTIONS WHERE VEHICLE WAS PLACED O/S
103,338**TOTAL VIOLATIONS

VIOLATION	Total number of violations	% of total violations	Total number of violations in inspection where vehicle was O/S	% of total violations
HEATER/DEFROSTER	188	.18%	0	.00%
HORN/SPEEDOMETER	3541	3.43%	0	.00%
CAB FLOOR	514	.50%	0	.00%
WIRING	164	.16%	0	.00%
FIRE EXTINGUISHER	7074	6.85%	0	.00%
WARNING DEVICES/FLAG	7611	7.37%	0	.00%
BRAKE APPLIED /PRESSURE	264	.26%	209	1.56%
LOW AIR WARNING	1326	1.28%	920	6.89%
PARKING BRAKE	2409	2.33%	908	6.80%
GLASS	4351	4.21%	58	.43%
WINDSHIELD WPR/WASH	4961	4.80%	39	.29%
HEADLIGHTS	5094	4.93%	197	1.47%
FRONT TURN SIGNALS	4152	4.02%	0	.00%
CLEAR ID LIGHTS	15468	14.97%	0	.00%
STREERING TIRES	1432	1.39%	500	3.74%
FRONT WHEELS/LUGS/RIMS	380	.37%	56	.42%
STEERING COMPONENTS	2832	2.74%	945	7.07%
FRONT BRAKES	779	.75%	366	2.74%
REARVIEW MIRRORS	264	.26%	0	.00%
FUEL SYSTEMS	540	.52%	207	1.55%
BATTERY INSALL	644	.62%	0	.00%
EXHAUST SYSTEM	1540	1.49%	141	1.06%
AIR HOSES/LEAKS	892	.86%	263	1.97%
TIRES	5556	5.38%	1410	10.55%
WHEELS/LUGS/RIMS	998	.97%	110	.82%
BRAKES	2417	2.34%	956	7.16%
SUSPENSION	1833	1.77%	411	3.08%
FRAMES	298	.29%	45	.34%
COUPLING DEVICES	173	.17%	54	.40%
REAR TURN SIGNALS	4939	4.78%	1861	13.93%
TAIL/STOP LAMPS	11645	11.27%	2967	22.21%
MUD FLAPS	2294	2.22%	0	.00%
REAR END PROTECTION	360	.35%	0	.00%
CARGO SECUREMENT	2004	1.94%	728	5.45%
TARPING REQUIRED	298	.29%	0	.00%
OTHER VIOLATIONS	4137	4.00%	0	.00%

The inspection records for a particular vehicle type include all the units in the train if one of the units is the specified vehicle type.

* Number of inspections where one unit was a straight truck
**Total number of violations recorded for the first unit

Table C-10

1988 and 1989 Michigan Inspections - Straight Trucks, Random

720* INSPECTIONS, 115 VEHICLES PLACED O/S
151* VIOLATIONS IN INSPECTIONS WHERE VEHICLES WAS PLACED O/S
1,681** TOTAL VIOLATIONS

VIOLATION	Total number of violations	% of total violations	Total number of violations in inspection where vehicle was O/S	% of total violations
HEATER/DEFROSTER	7	.42%	0	.00%
HORN/SPEEDOMETER	49	2.91%	0	.00%
CAB FLOOR	7	.42%	0	.00%
WIRING	1	.06%	0	.00%
FIRE EXTINGUISHER	148	8.80%	0	.00%
WARNING DEVICES/FLAG	104	6.19%	0	.00%
BRAKE APPLIED /PRESSURE	2	.12%	2	1.32%
LOW AIR WARNING	17	1.01%	9	5.96%
PARKING BRAKE	81	4.82%	30	19.87%
GLASS	89	5.29%	1	.66%
WINDSHIELD WPR/WASH	79	4.70%	0	.00%
HEADLIGHTS	56	3.33%	2	1.32%
FRONT TURN SIGNALS	70	4.16%	0	.00%
CLEAR ID LIGHTS	374	22.25%	0	.00%
STREERING TIRES	15	.89%	3	1.99%
FRONT WHEELS/LUGS/RIMS	5	.30%	0	.00%
STEERING COMPONENTS	56	3.33%	10	6.62%
FRONT BRAKES	11	.65%	4	2.65%
REARVIEW MIRRORS	4	.24%	0	.00%
FUEL SYSTEMS	6	.36%	4	2.65%
BATTERY INSALL	10	.59%	0	.00%
EXHAUST SYSTEM	27	1.61%	0	.00%
AIR HOSES/LEAKS	6	.36%	2	1.32%
TIRES	51	3.03%	5	3.31%
WHEELS/LUGS/RIMS	7	.42%	1	.66%
BRAKES	28	1.67%	6	3.97%
SUSPENSION	34	2.02%	7	4.64%
FRAMES	7	.42%	0	.00%
COUPLING DEVICES	1	.06%	0	.00%
REAR TURN SIGNALS	71	4.22%	26	17.22%
TAIL/STOP LAMPS	171	10.17%	34	22.52%
MUD FLAPS	9	.54%	0	.00%
REAR END PROTECTION	2	.12%	0	.00%
CARGO SECUREMENT	19	1.13%	5	3.31%
TARPING REQUIRED	1	.06%	0	.00%
OTHER VIOLATIONS	66	3.93%	0	.00%

The inspection records for a particular vehicle type include all the units in the train if one of the units is the specified vehicle type.

* Number of inspections where one unit was a straight truck
**Total number of violations recorded for the first unit

Table C-12 shows the distribution of vehicle defects for semi-trailers in the regular inspections. Table C-13 shows the distribution for the random sample.

Table C-12

1988 and 1989 Michigan - Semi-trailers

74,369* INSPECTIONS, 22,397 VEHICLES PLACED O/S
134,619** TOTAL VIOLATIONS IN INSPECTIONS

VIOLATION	Total number of violations	% of total violations	Total number of violations in inspection where vehicle was O/S	% of total violations
COUPLING DEVICES	966	.72%	275	.88%
HEADERBOARDS	531	.39%	233	.74%
MRKR/CLEAR LIGHTS	20944	15.56%	0	.00%
TIRES	25104	18.65%	6951	22.14%
WHEELS/LUGS/RIMS	2812	2.09%	257	.82%
BRAKES	24411	18.13%	7156	22.79%
AIR HOSES/LEAKS	7040	5.23%	945	3.01%
FRAMES	1826	1.36%	376	1.20%
SUSPENSION	4088	3.04%	1218	3.88%
WIRING	338	.25%	0	.00%
TURN SIGNALS	9406	6.99%	4903	15.62%
TAIL/STOP LAMPS	23470	17.43%	8051	25.64%
MUD FLAPS	4344	3.23%	0	.00%
REAR END PROTECTION	436	.32%	0	.00%
CARGO SECUREMENT	2553	1.90%	1004	3.20%
TARPING REQUIRED	177	.13%	0	.00%
OTHER VIOL	6165	4.58%	1	.00%

Since the inspection records for a particular vehicle type include all the units in the train, it is assumed that in semi-trailer inspection records, the first towed unit is the semi-trailer.

* Number of inspections where at least on unit was a semi-trailer
** Total number of violations recorded for first vehicle in tow

Table C-13

1988 and 1989 Michigan Inspections - Semi-trailers, Random

3026* INSPECTIONS, 626 VEHICLES PLACED O/S
635** TOTAL VIOLATIONS IN INSPECTIONS WHERE VEHICLE WAS O/S

VIOLATION	Total number of violations	% of total violations	Total number of violations in inspection where vehicle was O/S	% of total violations
COUPLING DEVICES	24	.66%	4	.63%
HEADERBOARDS	14	.39%	7	1.10%
MRKR/CLEAR LIGHTS	661	18.19%	0	.00%
TIRES	608	16.73%	117	18.43%
WHEELS/LUGS/RIMS	92	2.53%	2	.31%
BRAKES	732	20.14%	138	21.73%
AIR HOSES/LEAKS	270	7.43%	21	3.31%
FRAMES	26	.72%	9	1.42%
SUSPENSION	80	2.20%	17	2.68%
WIRING	3	.08%	0	.00%
TURN SIGNALS	277	7.62%	109	17.17%
TAIL/STOP LAMPS	603	16.59%	201	31.65%
MUD FLAPS	71	1.95%	0	.00%
REAR END PROTECTION	12	.33%	0	.00%
CARGO SECUREMENT	24	.66%	10	1.57%
TARPING REQUIRED	1	.03%	0	.00%
OTHER VIOL	136	3.74%	0	.00%

Since the inspection records for a particular vehicle type include all the units in the train, it is assumed that in semi-trailer inspection records, the first towed unit is the semi-trailer.

* Number of inspections where at least on unit was a semi-trailer
** Total number of violations recorded for first vehicle in tow

Table C-14 lists those components that account for more than 5% of the vehicle violations in both the regular and random inspections. It can be seen that the brakes, tires, and lights are problems in the regular sample as well as in the random sample.

Table C-14

Problem Components for Semi-trailers

		Regular	Random
Brakes		22.8%	21.7%
Tires		22.1%	18.4%
Lights	Turn Signals	15.6%	17.2%
	Tail/Stop Lamps	25.6%	31.6%

Conclusions

Nationally about 40% of the commercial vehicles inspected at MCSAP roadside safety inspections have vehicle defects serious enough to place the vehicle out-of-service. Defects in the brake system account for 54.6% of the violations, tires for 9.5%, and lights for 11.2%.

More detailed examination of the roadside safety inspection records from Michigan showed patterns of defects similar to those identified in the national data. Again, the components with the most violations were brake systems, tires, and lights.

Examination of the records by vehicle type showed that certain vehicle types had additional components that consistently showed up in the out-of-service violations. Coupling device defects accounted for more than 5% of the vehicle violations on the truck-tractors that were placed out-of-service as did steering component defects on straight trucks.

Similar patterns of vehicle defects were found in the regular sample of vehicles selected by inspectors and in the random sample. The only large exception to this was that the random sample of straight trucks had far fewer tire defects that did the regular sample. This implies that the condition of the tires may be a criterion used by inspectors in selecting straight trucks for inspection.

When the total random sample was compared against the regular sample of inspections it was found that only 19% of the vehicles from the random sample were placed O/S. In the regular sample this percentage was 29%. The number of violations per O/S inspection in the random inspections is also lower, 1.7 violations as compared to 2.3 violations in the regular inspections. It appears that the inspectors do indeed select vehicles in worse conditions than average for inspection.

This together with the patterns of vehicle defects in the regular and random samples implies that while a greater portion of vehicles selected for regular inspections are found to have defects severe enough to render them out-of-service, the pattern of vehicle defects in those vehicles in the random sample that have defects is the same as in the population.

No seasonal effects were found in the patterns of violations.

References

C-1 Motor Carrier Safety Assistance Program, Program Activity Overview - Fiscal Year 1989. Federal Highway Administration, Office of Motor Carrier Field Operations, State Programs Division, Washington, D.C., 1990.

APPENDIX D

O/S VIOLATIONS AS A FUNCTION OF TIME SINCE LAST CVSA DECAL

Introduction

One of the key questions in this investigation is that of the period of validity of the CVSA Decal. The knowledge of the relationship between the age of the CVSA decal and inspection results could provide valuable input into the selection of the specific period of validity for the CVSA decal.

This appendix documents our exploration into the question of how the inspection results of the roadside safety inspections vary with time since the issue of the last CVSA decal.

Data

A large number of observations of safety inspection results and the time since the issue of a CVSA decal are preferred sources of data for this exploration. No existing information of this type was found. However, two data sources that contained portions of the desired information were identified.

The first was from roadside safety inspections conducted by the State of Ohio, where the absence or presence of a valid CVSA decal was recorded. The presence of a valid decal implies that the vehicle passed a CVSA inspection sometime within the last 3 months. Analysis of these data would allow us to test for significant differences between the inspection results of vehicles which passed a roadside safety inspections within the last 3 months and all other heavy vehicles.

The second data set was made available to us by the National Transportation Safety Board from its current study of heavy vehicle brakes. The study involved the collection of detailed brake information from of a random sample of 5-axle vehicles in five states. Among the information collected was the presence of a CVSA decal and its date of issue and the presence of O/S violations. Since the inspection team was critically examining the brake system, most of the O/S violations will be for the brake system. However, any other observed O/S conditions were also noted.

Analysis of these data would provide a relationship between brake inspection results and time since last inspection. Since violations in the brake systems account for 55% of all O/S violations (See Appendix B), it is conjectured that these results will be similar to those derived from analysis of O/S violations for all vehicle systems.

Analysis of the Ohio Safety Inspection Data

The Public Utilities Commission of Ohio provided us with information on approximately 25,000 vehicle inspections from April and May, 1990. The data consisted of the number of vehicles by vehicle type with and without CVSA decals, the number in each vehicle and decal category that were placed out of service, and the total number of violations and O/S violations for each of the major vehicle components for each vehicle and decal type.

Table D-1 shows the distribution of the inspection records from Ohio. About 5% of the inspected vehicles had valid CVSA decals, indicating that they had successfully passed a CVSA inspection within the last 3 months. Of these vehicles, 12% had vehicle violations severe enough to render them out-of-service. However, 19% of the vehicles without the CVSA decals were placed out of service.

Table D-1

Distribution of the Ohio Inspection Records

MONTH	No. of vehicles Inspected	Vehicles with CVSA decal	Vehicles with No CVSA decal	No. of O/S Vehicles with CVSA decal	No. of O/S Vehicles with No CVSA decal
APRIL	11541	593 (5.1%)	10948 (94.9%)	66 (11.1%)*	2052 (18.7%)**
MAY	14254	809 (5.7%)	13445 (94.3%)	101 (12.5%)	2653 (19.7%)
TOTAL	25795	1402 (5.4%)	24393 (94.6%)	167 (11.9%)	4705 (19.3%)

* % of all vehicles with CVSA decals
** % of all vehicles without CVSA decals

The first question asked was—Is there a difference between inspection results of vehicles with valid CVSA decals and those without?

Table D-2 shows the contingency tables of the entire sample by month. These tables were used to test for independence between the presence of a valid CVSA decal and the roadside safety inspection result.

The results indicate (at alpha =.0001 for both months) that the two are not independent. This means that there is an association between the presence of a valid CVSA decal and the inspection result. Those vehicles with a valid decal have significantly fewer inspections with O/S results than do the vehicles without valid CVSA decals.

Table D-2

Tests for Independence between Presence of CVSA Decal and Inspection Results, Total Ohio Sample

APRIL, 1990

INSPECTION RESULT	VALID CVSA DECAL PRESENT ON INSPECTED VEHICLE Yes	No	ROW TOTAL
O/S	66	2052	2118
NOT O/S	527	8896	9423
TOTAL	593	10948	11541

NULL HYP. - Inspection result independent of presence of valid decal

$\chi^2 = 21.1 > \chi^2$ (DF =1, ALPHA =.00001). Therefore, reject null hypothesis.

MAY, 1990

INSPECTION RESULT	VALID CVSA DECAL PRESENT ON INSPECTED VEHICLE Yes	No	ROW TOTAL
O/S	101	2635	2736
NOT O/S	708	10810	11518
TOTAL	809	13445	14254

NULL HYP. - Inspection result independent of presence of valid decal

$\chi^2 = 24.9 > \chi^2$ (DF =1, ALPHA =.00001). Therefore, reject null hypothesis.

Table D-3 shows the distribution of violations by component for all vehicle inspections for April and May. It can be seen from the table that brake systems, lighting, and tires are the components that have the largest number of violations.

Table D-3

Ohio Commercial Inspections from April and May, 1990

APRIL, 1990
VALID CVSA DECAL - 593 VEHICLES - 66 PLACED O/S
NO VALID CVSA DECAL - 10,948 VEHICLES - 2,052 PLACED O/S

	Vehicles with valid CVSA decals		Vehicles without valid CVSA decals	
Violation	Total no. of Violations	No. of O/S Violations	Total no. of Violations	No. of O/S Violations
BRAKES	152	70	2456	1133
COUPLING DEVICES	12	5	146	40
EXHAUST SYSTEM	8	0	80	7
FUEL SYSTEM	3	1	62	46
FRAME	1	0	87	33
LIGHTING	173	16	3530	495
STEERING	6	4	103	49
SUSPENSION	12	3	298	139
TIRES	54	13	1296	396
WARNING DEVICES	13	0	258	28
WHEELS	20	4	226	44
ALL OTHERS	101	2	1601	88

MAY, 1990
VALID CVSA DECAL - 809 VEHICLES - 101 PLACED O/S
NO VALID CVSA DECAL - 13,445 VEHICLES - 2,635 PLACED O/S

	Vehicles with valid CVSA decals		Vehicles without valid CVSA decals	
Violation	Total no. of Violations	No. of O/S Violations	Total no. of Violations	No. of O/S Violations
BRAKES	258	144	3327	1604
COUPLING DEVICES	20	10	144	40
EXHAUST SYSTEM	7	2	114	17
FUEL SYSTEM	9	4	45	21
FRAME	1	0	130	53
LIGHTING	205	8	4047	573
STEERING	17	12	161	63
SUSPENSION	46	13	344	151
TIRES	69	11	1629	468
WARNING DEVICES	7	0	148	1
WHEELS	20	7	262	69
ALL OTHERS	134	10	1711	106

The next question asked is—Is there a pattern to the violations for the vehicles with and without valid CVSA decals by vehicle type? The next set of tables give the inspection results for each vehicle type. Table D-4 shows the inspection results for straight trucks; Table D-5 for semi-trailers; Tables D-6 for truck-tractors, Tables D-7 for full trailer and Table D-8 for converter dollies.

Table D-4

Comparison of Inspection Results of Vehicles With and Without Valid CVSA Decals - Ohio, 1990 - Straight Trucks

APRIL, 1990
VALID CVSA DECAL - 29 VEHICLES - 3 PLACED O/S
NO VALID CVSA DECAL - 744 VEHICLES - 172 PLACED O/S

Violation	Vehicles with valid CVSA decals: Total no. of Violations	Vehicles with valid CVSA decals: No. of O/S Violations	Vehicles without valid CVSA decals: Total no. of Violations	Vehicles without valid CVSA decals: No. of O/S Violations
BRAKES	7	5	131	82
COUPLING DEVICES	0	0	1	1
EXHAUST SYSTEM	0	0	7	0
FUEL SYSTEM	0	0	9	8
FRAME	0	0	4	0
LIGHTING	31	2	498	69
STEERING	3	3	28	20
SUSPENSION	0	0	17	0
TIRES	10	0	101	25
WARNING DEVICES	2	0	63	0
WHEELS	2	0	14	2
ALL OTHERS	10	0	271	15

MAY, 1990
VALID CVSA DECAL - 29 VEHICLES - 4 PLACED O/S
NO VALID CVSA DECAL - 856 VEHICLES - 200 PLACED O/S

Violation	Vehicles with valid CVSA decals: Total no. of Violations	Vehicles with valid CVSA decals: No. of O/S Violations	Vehicles without valid CVSA decals: Total no. of Violations	Vehicles without valid CVSA decals: No. of O/S Violations
BRAKES	3	2	132	96
COUPLING DEVICES	0	0	0	0
EXHAUST SYSTEM	1	1	13	5
FUEL SYSTEM	1	1	20	15
FRAME	0	0	3	1
LIGHTING	17	0	557	60
STEERING	1	0	39	28
SUSPENSION	1	0	28	8
TIRES	0	0	102	42
WARNING DEVICES	3	0	64	0
WHEELS	0	0	12	4
ALL OTHERS	11	1	325	18

Table D-5

Comparison of Inspection Results of Vehicles With and Without Valid CVSA Decals - Ohio, 1990 - Semi-trailers

APRIL, 1990
VALID CVSA DECAL - 105 VEHICLES - 19 PLACED O/S
NO VALID CVSA DECAL - 5185 VEHICLES - 1094 PLACED O/S

	Vehicles with valid CVSA decals		Vehicles without valid CVSA decals	
Violation	Total no. of Violations	No. of O/S Violations	Total no. of Violations	No. of O/S Violations
BRAKES	31	11	1217	494
COUPLING DEVICES	0	0	13	2
EXHAUST SYSTEM	0	0	1	0
FUEL SYSTEM	0	0	1	1
FRAME	1	0	69	28
LIGHTING	59	12	2223	401
STEERING	0	0	0	0
SUSPENSION	1	1	173	97
TIRES	15	6	877	276
WARNING DEVICES	0	0	135	28
WHEELS	6	0	135	28
ALL OTHERS	2	0	121	9

MAY, 1990
VALID CVSA DECAL - 133 VEHICLES - 13 PLACED O/S
NO VALID CVSA DECAL - 6377 VEHICLES - 1395 PLACED O/S

	Vehicles with valid CVSA decals		Vehicles without valid CVSA decals	
Violation	Total no. of Violations	No. of O/S Violations	Total no. of Violations	No. of O/S Violations
BRAKES	41	17	1691	728
COUPLING DEVICES	0	0	9	1
EXHAUST SYSTEM	0	0	0	0
FUEL SYSTEM	0	0	0	0
FRAME	0	0	101	45
LIGHTING	66	7	2470	485
STEERING	0	0	0	0
SUSPENSION	1	1	190	105
TIRES	25	2	1118	324
WARNING DEVICES	0	0	0	0
WHEELS	8	0	150	44
ALL OTHERS	5	1	125	11

Table D-6

Comparison of Inspection Results of Vehicles With and Without Valid CVSA Decals - Ohio, 1990 - Truck Tractors

APRIL
VALID CVSA DECAL - 458 VEHICLES - 3 PLACED O/S
NO VALID CVSA DECAL - 4907 VEHICLES - 770 PLACED O/S

	Vehicles with valid CVSA decals		Vehicles without valid CVSA decals	
Violation	Total no. of Violations	No. of O/S Violations	Total no. of Violations	No. of O/S Violations
BRAKES	114	54	1094	553
COUPLING DEVICES	12	5	130	37
EXHAUST SYSTEM	8	0	72	7
FUEL SYSTEM	3	1	52	37
FRAME	0	0	14	5
LIGHTING	83	2	779	20
STEERING	3	1	75	29
SUSPENSION	11	2	108	42
TIRES	29	7	310	93
WARNING DEVICES	11	0	59	0
WHEELS	12	4	76	14
ALL OTHERS	89	2	1206	63

MAY, 1990
VALID CVSA DECAL - 647 VEHICLES - 84 PLACED O/S
NO VALID CVSA DECAL - 6061 VEHICLES - 1023 PLACED O/S

	Vehicles with valid CVSA decals		Vehicles without valid CVSA decals	
Violation	Total no. of Violations	No. of O/S Violations	Total no. of Violations	No. of O/S Violations
BRAKES	214	125	1457	769
COUPLING DEVICES	20	10	135	39
EXHAUST SYSTEM	6	1	101	12
FUEL SYSTEM	8	3	25	6
FRAME	1	0	25	6
LIGHTING	122	1	971	25
STEERING	16	12	122	35
SUSPENSION	16	12	122	35
TIRES	44	9	395	100
WARNING DEVICES	14	0	84	1
WHEELS	12	7	99	21
ALL OTHERS	118	8	1254	77

Table D-7

Comparison of Inspection Results of Vehicles With and Without Valid CVSA Decals - Ohio, 1990 - Full Trailers

APRIL, 1990
VALID CVSA DECAL - 1 VEHICLES - 0 PLACED O/S
NO VALID CVSA DECAL - 88 VEHICLES - 9 PLACED O/S

	Vehicles with valid CVSA decals		Vehicles without valid CVSA decals	
Violation	Total no. of Violations	No. of O/S Violations	Total no. of Violations	No. of O/S Violations
BRAKES	0	0	9	3
COUPLING DEVICES	0	0	2	0
EXHAUST SYSTEM	0	0	0	0
FUEL SYSTEM	0	0	0	0
FRAME	0	0	0	0
LIGHTING	0	0	25	4
STEERING	0	0	0	0
SUSPENSION	0	0	0	0
TIRES	0	0	7	1
WARNING DEVICES	0	0	0	0
WHEELS	0	0	1	0
ALL OTHERS	0	0	2	1

MAY, 1990
VALID CVSA DECAL - 0 VEHICLES - 0 PLACED O/S
NO VALID CVSA DECAL -130 VEHICLES - 16 PLACED O/S

	Vehicles with valid CVSA decals		Vehicles without valid CVSA decals	
Violation	Total no. of Violations	No. of O/S Violations	Total no. of Violations	No. of O/S Violations
BRAKES	0	0	42	10
COUPLING DEVICES	0	0	0	0
EXHAUST SYSTEM	0	0	0	0
FUEL SYSTEM	0	0	0	0
FRAME	0	0	1	1
LIGHTING	0	0	49	3
STEERING	0	0	0	0
SUSPENSION	0	0	4	3
TIRES	0	0	14	2
WARNING DEVICES	0	0	0	0
WHEELS	0	0	1	0
ALL OTHERS	0	0	6	0

Table D-8

Comparison of Inspection Results of Vehicles With and Without Valid CVSA Decals - Ohio, 1990 - Converter Dollies

APRIL, 1990
VALID CVSA DECAL - 0 VEHICLES - 0 PLACED O/S
NO VALID CVSA DECAL - 24 VEHICLES - 3 PLACED O/S

	Vehicles with valid CVSA decals		Vehicles without valid CVSA decals	
Violation	Total no. of Violations	No. of O/S Violations	Total no. of Violations	No. of O/S Violations
BRAKES	0	0	5	1
COUPLING DEVICES	0	0	0	0
EXHAUST SYSTEM	0	0	0	0
FUEL SYSTEM	0	0	0	0
FRAME	0	0	0	0
LIGHTING	0	0	1	1
STEERING	0	0	0	0
SUSPENSION	0	0	0	0
TIRES	0	0	1	1
WARNING DEVICES	0	0	0	0
WHEELS	0	0	0	0
ALL OTHERS	0	0	1	0

MAY, 1990
VALID CVSA DECAL - 0 VEHICLES - 0 PLACED O/S
NO VALID CVSA DECAL - 21 VEHICLES - 1 PLACED O/S

	Vehicles with valid CVSA decals		Vehicles without valid CVSA decals	
Violation	Total no. of Violations	No. of O/S Violations	Total no. of Violations	No. of O/S Violations
BRAKES	0	0	5	1
COUPLING DEVICES	0	0	0	0
EXHAUST SYSTEM	0	0	0	0
FUEL SYSTEM	0	0	0	0
FRAME	0	0	0	0
LIGHTING	0	0	0	0
STEERING	0	0	0	0
SUSPENSION	0	0	0	0
TIRES	0	0	0	0
WARNING DEVICES	0	0	0	0
WHEELS	0	0	0	0
ALL OTHERS	0	0	1	0

The patterns of vehicle violations for each vehicle type were examined and compared between the groups of vehicles with valid CVSA decals and those without the decals. Those components which registered the most O/S vehicle violations were listed for each vehicle and decal category. Tables D-9 and D-10 list these "problem" components for each case under consideration.

Table D-9

The Problem Components (April)

VEHICLE TYPE	VALID CVSA DECALS	NO VALID CVSA DECAL
STRAIGHT TRUCK	BRAKES LIGHTING STEERING TIRES*	BRAKES LIGHTING STEERING TIRES
SEMI-TRAILER	BRAKES LIGHTING TIRES	BRAKES LIGHTING TIRES SUSPENSION WARNING DEVICES WHEELS
TRUCK-TRACTOR	BRAKES LIGHTING TIRES COUPLING DEVICES WHEELS	BRAKES LIGHTING TIRES COUPLING DEVICES FUEL SYSTEM STEERING SUSPENSION WHEELS
FULL-TRAILER	**	BRAKES LIGHTING
CONVERTER DOLLIES	**	BRAKES

* There was a large number of violations but no O/S violations.

** Less than 2 vehicles with a valid CVSA decal in this category.

Table D-10

May Problem Components

VEHICLE TYPE	VALID CVSA DECALS	NO VALID CVSA DECAL
STRAIGHT TRUCK	BRAKES LIGHTING TIRES	BRAKES LIGHTING TIRES STEERING SUSPENSION FUEL SYSTEM
SEMI-TRAILER	BRAKES LIGHTING TIRES	BRAKES LIGHTING TIRES SUSPENSION FRAME WHEELS
TRUCK-TRACTOR	BRAKES LIGHTING TIRES COUPLING DEVICES STEERING SUSPENSION WHEELS	BRAKES LIGHTING TIRES COUPLING DEVICES STEERING SUSPENSION WHEELS
FULL-TRAILER	*	BRAKES LIGHTING TIRES SUSPENSION
CONVERTER DOLLIES	*	BRAKES

* Less than 2 vehicles with a valid CVSA decal in this category.

The Pattern

A definite pattern can be identified from the examination of these tables. In almost every case the problem components include brakes, lighting, and tires. This holds for both the vehicles with valid CVSA decals and the vehicles without the valid decals. The vehicles without valid decals typically have other problem components. For truck-tractors, coupling devices and wheels appear as problem components for both groups in both months.

There were fewer than two full-trailers and converter dollies with valid CVSA decals inspected in April and in May. The problem components for those vehicles inspected in these categories were again brakes, and in the case of the truck-tractors, lighting.

Brakes, lighting, and tires appear to be the major problem components for all vehicles, including those with valid CVSA decals. An examination of patterns of violations indicates that the vehicles with CVSA decals that do not pass inspection generally have problems with lighting, tires, and/or brakes. These components are also problems for vehicles without valid CVSA decals. However, this set of vehicles has problems with other components also.

Analysis of NTSB Heavy Truck Brake Study Data

The NTSB has been studying the conditions of brakes on 5-axle vehicles. Their study involved inspecting a random sample of heavy vehicles in five states. They collected detailed information on the condition of the sample vehicle's brakes, determined the braking efficiency, and noted whether the vehicle had out-of-service violations. The team was concerned with the brake system and brake violations. However, if other serious defects were observed, they were also noted. The team recorded the presence of CVSA Inspection decals and the date of existing decals for each vehicle.

The Sample

Table D-11 shows the distribution of the total NTSB sample, by state, whether or not a decal was present, and the number of O/S vehicles in each category. There were 910 vehicles in the sample. Of these 50% were found to have brake violations severe enough to render the vehicle out-of-service and 2% had other readily observable O/S defects.

Approximately a third (31%) of the vehicles had a CVSA decal. Of these, 47.5% had violations severe enough to be classified out-of-service. For vehicles without any CVSA decals this percentage was 54%.

As in the analysis of the Ohio data, the first question addressed was—Is there a difference between the inspection results for those vehicles with CVSA decals and those vehicles without the decals? However, it should be noted that in this case the CVSA decals refers to decals of any age, not just valid decals.

Table D-11

Sample from NTSB Heavy Truck Brake Inspection Study

State	Sample	Vehicles with CVSA decal	Vehicles with No CVSA decal	No. of O/S vehicles with CVSA decal	No. of O/S vehicles with No CVSA decal
FLORIDA	185	36 (19.5%)	149 (80.5%)	25 (69.4%)	87 (58.4%)
ILLINOIS	197	49 (24.9%)	148 (75.1%)	24 (48.9%)	92 (62.2%)
OREGON	148	113 (76.4%)	35 (23.6%)	53 (46.9%)	17 (48.6%)
PENNSYLVANIA	220	52 (23.6%)	168 (76.4%)	21 (40.4%)	66 (39.3%)
TEXAS	160	34 (21.3%)	126 (78.7%)	12 (35.3%)	77 (61.1%)
TOTAL	910	284 (31.2%)	626 (68.8%)	135 (47.5%)	339 (54.1%)

Table D-12 shows the contingency table for the total sample, testing the independence of the inspection results and the presence of the CVSA decal. The analysis shows that at a significance level of .05 there is a no relationship between the presence of a CVSA decal and the inspection results. However, if we set the significance level at .1, a relationship between inspection results and the presence of a CVSA decal is indicated. The significance level represents the probability of a Type 1 error, i.e., rejecting a hypothesis when, in fact, it is true. However, decreases in Type 1 errors are balanced by increases in the probability of Type 2 errors, or the chance of accepting a hypothesis when in fact it is false.

Thus, the question of independence between the inspection results and the presence of a decal merits further scrutiny.

Table D-12

Testing for Relationship between Inspection Results and Presence of CVSA Decal in NTSB Data

TOTAL SAMPLE

	CVSA Decal Yes	CVSA Decal No	TOTAL
O/S	135	339	474
NOT O/S	149	287	436
TOTAL	284	626	910

$\chi^2 = 3.41 > 2.706$, the critical χ^2 value for DF=1 and $\alpha = .1$

$\chi^2 < 3.841$, the critical χ^2 value for DF=1 and $\alpha = .05$

Therefore, investigate further.

Tables D-13 through D-17 repeat the same contingency table analysis for each state. In each state, except Texas, the inspection results were found to be independent of the presence or absence of the CVSA decal at significance levels of 0.1. In the Texas case, the hypothesis of independence could not be rejected at a significance level of $\alpha = .05$.

Table D-13

Testing for Relationship between Inspection Results and Presence of CVSA Decal in NTSB Data, Florida

FLORIDA

	CVSA Decal		
	Yes	No	TOTAL
OOS	25	87	112
NOT OOS	11	62	73
TOTAL	36	149	185

$\chi^2 = 1.48 < 2.706$, the critical χ^2 value for DF=1 and $\alpha = .1$

Therefore, inspection result is independent of presence of decal.

Table D-14

Testing for Relationship between Inspection Results and Presence of CVSA Decal in NTSB Data, Illinois

ILLINOIS

	CVSA Decal		
	Yes	No	TOTAL
OOS	24	92	116
NOT OOS	25	56	81
TOTAL	49	148	197

$\chi^2 = 2.64 < 2.706$, the critical χ^2 for DF=1 and $\alpha = .1$

Therefore, inspection result is independent of presence of decal.

Table D-15

Testing for Relationship between Inspection Results and Presence of CVSA Decal in NTSB Data, Oregon

OREGON

	CVSA Decal Yes	No	TOTAL
OOS	53	17	70
NOT OOS	60	18	78
TOTAL	113	35	148

χ^2 =0.030 <2.706, the critical χ^2 for DF=1 and $\alpha = .1$

Therefore, inspection result is independent of presence of decal.

Table D-16

Testing for Relationship between Inspection Results and Presence of CVSA Decal in NTSB Data, Pennsylvania

PENNSYLVANIA

	CVSA Decal Yes	No	TOTAL
OOS	21	66	87
NOT OOS	31	102	133
TOTAL	52	168	220

χ^2 =0.020 <2.706, the critical χ^2 fpr DF=1 and $\alpha = .1$

Therefore, inspection result is independent of presence of decal.

Table D-17

Testing for Relationship between Inspection Results and Presence of CVSA Decal in NTSB Data, Texas

TEXAS

	CVSA Decal Yes	No	TOTAL
OOS	12	77	89
NOT OOS I	22	49	71
TOTAL	34	126	160

χ^2 =7.21 > 2.706, the critical χ^2 for DF=1 and $\alpha = .05$

Therefore, inspection result is not independent of presence of decal.

This indicates that there is a relationship between the inspection results and CVSA decal presence in the Texas sample and not in the samples from the other states. Closer examination of the samples showed that the Texas sample the distribution of the decal age was different than that in the other states. The Texas sample had fewer older decals than did the other states.

This implies that, if decals of all ages are considered, the presence or absence of a decal is not related to the inspection result. The analysis of the Texas sample supports the finding from the Ohio data that there is a relationship between inspection results and the presence of recent CVSA decals.

The NTSB data allows the exploration of the next question: Is the inspection result independent of the age of the CVSA decal on the vehicle?

Table D-18 shows the age distribution of the CVSA decals on those vehicles in the sample that had a decal.

Table D-18

Distribution of CVSA Decals by Age in NTSB Sample

NO. OF VEHICLES IN EACH CVSA DECAL AGE CATEGORY

	AGE OF CVSA DECAL (DAYS)														
STATE	<30	60	90	120	150	180	210	240	270	300	330	360	390	410	440
FLORIDA															
TOTAL	1	0	5	0	0	1	5	3	2	2	2	2	2	2	2
O/S	0	0	3	0	0	0	3	3	1	2	1	2	2	1	1
NOT O/S	1	0	2	0	0	1	2	0	1	0	1	0	0	1	1
ILLINOIS															
TOTAL	6	3	7	12	2	1	1	0	2	2	0	3	3	0	1
O/S	3	2	3	5	1	1	1	0	1	0	0	1	2	0	0
NOT O/S	3	1	4	7	1	0	0	0	1	2	0	2	1	0	1
OREGON															
TOTAL	11	16	17	7	10	3	7	2	1	8	1	1	1	5	1
O/S	2	3	9	5	4	1	2	1	1	7	1	1	1	4	0
NOT O/S	9	13	8	2	6	2	5	1	0	1	0	0	0	1	1
PENNSYLVANIA															
TOTAL	3	4	7	9	6	1	3	0	2	1	4	2	1	2	1
O/S	1	2	3	3	1	1	2	0	1	0	2	0	1	2	1
NOT O/S	2	2	4	6	5	0	1	0	1	1	2	2	0	0	0
TEXAS															
TOTAL	3	5	5	1	6	2	2	1	0	0	3	0	2	1	0
O/S	2	1	0	0	3	0	1	1	0	0	2	0	1	0	0
NOT O/S	1	4	5	1	3	2	1	0	0	0	1	0	1	1	0
ALL															
TOTAL	24	28	41	29	24	8	18	6	7	13	10	8	9	10	5
O/S	8	8	18	13	9	3	9	5	4	9	6	4	7	7	2
NOT O/S	16	20	23	16	15	5	9	1	3	4	4	4	2	3	3

Table D-19 shows the distribution of the portion of the sample with decals by age (in calendar quarters). Contingency table analysis was used to test for independence between the age of the CVSA decal and inspection results.

Table D-19

Distribution of CVSA Decals by Age in Calendar Quarters in the NTSB Sample

NO. OF VEHICLES IN EACH CVSA DECAL AGE CATEGORY
AGE OF CVSA DECAL (QUARTER)

	1 <90 Days	2 90-180 Days	3 180-270 Days	4 270-360 Days	5 360-440 Days	Row Total
O/S	34	25	18	19	16	112
NOT O/S	59	36	13	12	8	128
TOTAL	93	61	31	31	24	240

χ^2 Test for independence between the age of the CVSA decal and inspection result.

NULL HYP. - INSPECTION RESULT INDEPENDENT OF DECAL AGE

$\chi^2 = 12.70$ which is > than 9.488, the critical value of χ^2 (DF=4), $\alpha = .05$

REJECT NULL HYP.—Therefore, we can conclude that there is a relationship between decal age and inspection outcome.

The results indicate that the inspection results and the age of the decal are not independent. Thus, we can conclude that there is a relationship between the age of the decal and the inspection results.

Next the nature of the relationship between the age of the decal and inspection results was explored. Table D-20 gives the cumulative distribution of the sample with decals, by decal age.

Table D-20

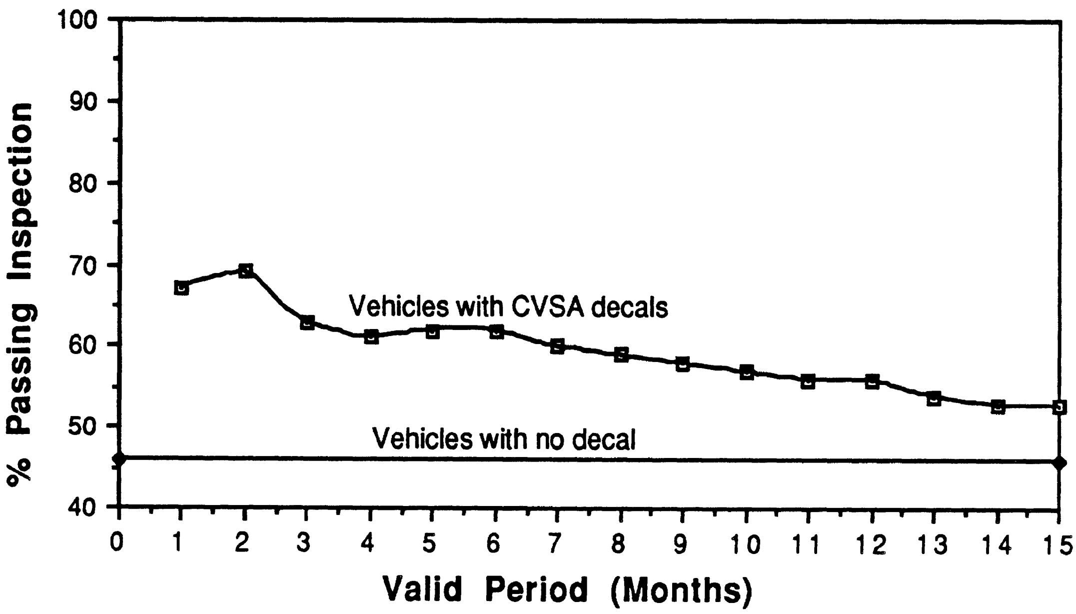
Cumulative Distribution of O/S Vehicles in NTSB Sample by Decal Age

VEHICLES IN EACH CVSA DECAL AGE CATEGORY

AGE OF CVSA DECAL (DAYS)

STATE	<30	60	90	120	150	180	210	240	270	300	330	360	390	410	440
NUMBER															
TOTAL	24	28	41	29	24	8	18	6	7	13	10	8	9	10	5
O/S	8	8	18	13	9	3	9	5	4	9	6	4	7	7	2
NOT O/S	16	20	23	16	15	5	9	1	3	4	4	4	2	3	3
CUMULATIVE															
TOTAL	24	52	93	122	146	154	172	178	185	198	208	216	225	235	240
O/S	8	16	34	47	56	59	68	73	77	86	92	96	103	110	112
%O/S	.33	.31	.37	.39	.38	.38	.40	.41	.42	.43	.44	.44	.46	.47	.47
NOT O/S	16	36	59	75	90	95	104	105	108	112	116	120	122	125	128
%NOT O/S	.67	.69	.63	.61	.62	.62	.60	.59	.58	.57	.56	.56	.54	.53	.53

Figure D-1 shows the cumulative portion of the sample that has passed inspection by the age of the decal. Note, that this allows the comparison of different decal validity periods for this sample. For example, if the decal valid period was one month (30 days), 67% of the vehicles with valid decals would pass another inspection. If the valid period was 3 months (90 days), this percentage would be 63%. As the valid period increases the inspection results of the vehicles with decals approach the inspection results of vehicles without decals.



Findings

Analysis of the NTSB data indicates that the presence of a CVSA decal (any age) is not related to the condition of the vehicles (as measured by an inspection). The presence of a decal itself is equivalent to no decal at all.

Analyses of both the Ohio and NTSB data indicate that vehicles with valid CVSA decals do better on an inspection than vehicles without a valid CVSA decal.

The analysis of the Ohio data indicates that tires, lights, and brakes are still problems on vehicles with valid CVSA decals. The problem is not, however, as great as on vehicles without the valid CVSA decals.

Analysis of the NTSB data shows that there is a definite relationship between the inspection result and the age of the CVSA decal for those vehicles that had a decal. The newer the decal, the better the performance on the CVSA inspections.

APPENDIX E

VEHICLE COMPONENT FAILURE PATTERNS FROM MAINTENANCE RECORDS

Introduction

Knowledge of the reliability of components used on highway trucks would add considerably to the development of inspection schedules. If the time distributions of mechanical or functional failures of major truck components were known, then a probabilistic model of failures which are potential O/S violations could be developed.

This appendix documents our examination of the patterns of vehicle component failure from fleet maintenance records, the development of rates and probabilities of failure of the major vehicle components and our efforts in developing a model of failure which would result in an O/S violation.

Data

The ideal data for this exercise would contain information on the lifetimes of individual components of vehicles of various types as well as the history of the vehicle's operational environment. Our search for such information was not successful. We were, however, able to obtain data on the number of failures (repairs/replacements) and time between failures for 15 major component systems from a large national fleet.

The management of the national fleet provided us with information about 712 tractors, 5096 trailers, and 800 converter dollies. The vehicles were 1984 to 1989 models, equally distributed. All vehicles are equipped with automatic slack adjusters.

The information was concerned with maintenance incidents for a set of 15 major components. A maintenance incident is defined as the event where maintenance (whether scheduled or unscheduled) takes place. The component systems were:

Brake Air System
Brake Adjustment
Brake Lining and Drum Repair/Replace
Chassis Frame
Exhaust
Fuel Lines
Fuel Tanks
Headlights
Steering
Stop/Tail Lights
Suspensions
Trailer Pintle Hook
Turn Signals
Wheels
5th Wheel

The data were aggregated for each vehicle type and component and consisted of :

- total number of maintenance incidents in one year
- the number of initial maintenance incidents in one year
- the number of repeat incidents in one year
- distribution of time between maintenance incidents

The average annual mileages for the Fleet vehicles were:

- 155,000 miles/year for a tractor
- 30,000 miles/year for a trailer
- 90,000 miles/year for a converter dolly

Methodology

The approach to the analysis of these data was to:

- Develop average failure rates for the components from the fleet data.
- Develop survivor curves for individual components. The survivor curve is a curve which shows the number of units that survive in service at given ages. It is commonly used in the determining service lives in the utility industry and in highway pavements.
- Develop probabilities of failure for the various components from the survivor curves.
- Develop a model of failure which would result in an O/S condition for various common vehicle configurations with average annual mileage.

Average Incident Rates

Tractors

Table E-1 shows the summary of the maintenance data for the 712 fleet tractors. The average number of maintenance incidents per tractor is 25.6. Of these 9 are first incidents and 16.6 are repeat incidents. The table shows that the Brake Air system is the component with the most maintenance incidents (7 per year), followed by stop/tail lights (4.5 incidents /year), turn signals (2.9 per year), and headlights (2.7 per year).

Table E-1

Maintenance Incidents for 712 Tractors in 1989

Repair Type	First Incidents	Percent Failed at least once	Repeat Incidents	Total Incidents	Incidents per unit/yr
AIR SYSTEM	706	99.16	4322	5028	7.06
BRAKE ADJUSTMENT	347	48.74	217	564	.79
BRAKE LINING AND DRUM	591	83.01	657	1248	1.75
CHASSIS FRAME	241	33.85	57	298	.42
EXHAUST	566	79.49	405	971	1.36
FUEL LINES	339	47.61	242	581	.82
FUEL TANKS	171	24.02	34	205	.29
HEADLIGHTS	641	90.03	1307	1948	2.74
STEERING	359	50.42	110	469	.66
STOP/TAIL LIGHTS	701	98.46	2463	3164	4.44
SUSPENSIONS	528	74.16	372	900	1.26
TRLR PINTLE HOOK	0	0	0	0	0
TURN SIGNALS	662	92.98	1441	2103	2.95
WHEELS	221	31.04	62	283	.40
5TH WHEEL	334	46.91	114	448	.63
TOTAL	6407		11803	18210	
AVE INCIDENTS/VEHICLE	9.00		16.58	25.58	

Trailers

Table E-2 shows the maintenance incident summary for the 5096 fleet trailers. The total number of maintenance incidents per trailer is 3.6 per year, of which 2 are first incidents and 1.5 is a repeat incident. The stop/tail lights receive the most maintenance at an average of 2.1 incidents/trailer per year.

Table E-2

Maintenance Incidents for 5096 Trailers in 1989

Repair Type	First Incidents	Percent Failed at least once	Repeat Incidents	Total Incidents	Incidents per unit/yr
AIR SYSTEM	2612	51.26	1235	3847	.75
BRAKE ADJUSTMENT	548	10.75	36	584	.11
BRAKE LINING AND DRUM	513	10.07	60	573	.11
CHASSIS FRAME	1	.02	0	1	.00
EXHAUST	1	.02	0	1	.00
FUEL LINES	0	0	0	0	0
FUEL TANKS	0	0	0	0	0
HEADLIGHTS	0	0	0	0	0
STEERING	0	0	0	0	0
STOP/TAIL LIGHTS	4525	88.80	6212	10737	2.11
SUSPENSIONS	170	3.34	3	173	.03
TRLR PINTLE HOOK	978	19.19	150	1128	.22
TURN SIGNALS	990	19.43	103	1093	.21
WHEELS	52	1.02	3	55	.01
5TH WHEEL	15	.29	0	15	.00
TOTAL	10405		7802	18207	
AVE INCIDENTS/VEHICLE	2.04		1.53	3.57	

Converter Dolly

Table E-3 shows the maintenance incident summary for the 800 converter dollies from the Fleet. These converter dollies average 7 maintenance incidents per year. Of these, approximately 3 are first incidents and 4 are repeat incidents. The brake air system is the component that receives the most maintenance at about 4 incidents per year.

Table E-3

Maintenance Incidents for 800 Converter Dollies in 1989

Repair Type	First Incidents	Percent Failed at least once	Repeat Incidents	Total Incidents	Incidents per unit/yr
AIR SYSTEM	665	83.13	2825	3490	4.36
BRAKE ADJUSTMENT	76	9.50	7	83	.10
BRAKE LINING AND DRUM	475	59.38	169	644	.81
CHASSIS FRAME	40	5	1	41	.05
EXHAUST	0	0	0	0	0
FUEL LINES	0	0	0	0	0
FUEL TANKS	0	0	0	0	0
HEADLIGHTS	0	0	0	0	0
STEERING	0	0	0	0	0
STOP/TAIL LIGHTS	444	55.50	303	747	.93
SUSPENSIONS	24	3	1	25	.03
TRLR PINTLE HOOK	13	1.63	0	13	.02
TURN SIGNALS	255	31.88	42	297	.37
WHEELS	33	4.13	1	34	.04
5TH WHEEL	229	28.63	61	290	.36
TOTAL	2254		3410	5664	
AVE INCIDENTS/VEHICLE	2.82		4.26	7.08	

Distribution of Maintenance Activity by Component

Table E-4 gives the distribution of maintenance incidents by component for the tractors. Note that almost 40% of the maintenance incidents are light related and about 38% are brake-related. All other components account for the remaining 23% of the maintenance activities.

Table E-4

Maintenance Incidents for 712 Tractors in 1989

Component	Incidents per unit/yr	% of Total Incidents	
AIR SYSTEM	7.06	27.61%	
BRAKE ADJUSTMENT	.79	3.10%	BRAKE RELATED
BRAKE LINING AND DRUM	1.75	6.85%	37.5%
HEADLIGHTS	2.74	10.70%	
STOP/TAIL LIGHTS	4.44	17.37%	LIGHT RELATED
TURN SIGNALS	2.95	11.53%	39.6%
CHASSIS FRAME	.42	1.64%	
EXHAUST	1.36	5.33%	
FUEL LINES	.82	3.19%	
FUEL TANKS	.29	1.13%	OTHER
STEERING	.66	2.58%	22.9%
SUSPENSIONS	1.26	4.94%	
TRLR PINTLE HOOK	0	.00%	
WHEELS	.40	1.56%	
5TH WHEEL	.63	2.46%	
TOTAL	25.58	100.00%	

Table E-5 shows the distribution of maintenance incidents by component for the trailers. Table E-6 shows the same distribution for the converter dollies.

Table E-5

Maintenance Incidents for 5096 Trailers in 1989

Repair Type	Incidents per unit/yr	% of Total Incidents	
AIR SYSTEM	.75	21.15%	
BRAKE ADJUSTMENT	.11	3.21%	BRAKE RELATED
BRAKE LINING AND DRUM	.11	3.15%	27.51%
STOP/TAIL LIGHTS	2.11	59.02%	LIGHT RELATED
TURN SIGNALS	.21	6.01%	65.03%
CHASSIS FRAME	.00	.01%	
EXHAUST	.00	.01%	
SUSPENSIONS	.03	.95%	OTHER
TRLR PINTLE HOOK	.22	6.20%	7.46%
WHEELS	.01	.30%	
5TH WHEEL	.00	.08%	
TOTAL	3.57	100.00%	100%

Table E-6

Maintenance Incidents for 800 Converter Dollies in 1989

Repair Type	Incidents per unit/yr	% of Total Incidents	
AIR SYSTEM	4.36	61.62%	
BRAKE ADJUSTMENT	.10	1.47%	BRAKE RELATED
BRAKE LINING AND DRUM	.81	11.37%	74.46%
STOP/TAIL LIGHTS	.93	13.19%	LIGHT RELATED
TURN SIGNALS	.37	5.24%	18.43%
CHASSIS FRAME	.05	.72%	
SUSPENSIONS	.03	.44%	OTHER
TRLR PINTLE HOOK	.02	.23%	7.11%
WHEELS	.04	.60%	
5TH WHEEL	.36	5.12%	
TOTAL	7.08	100.00%	100%

Figure E-1 compares the total number of maintenance incidents across the 3 vehicle types. Figure E-2 shows the distributions of the maintenance incidents by component for tractors, trailers, and converter dollies.

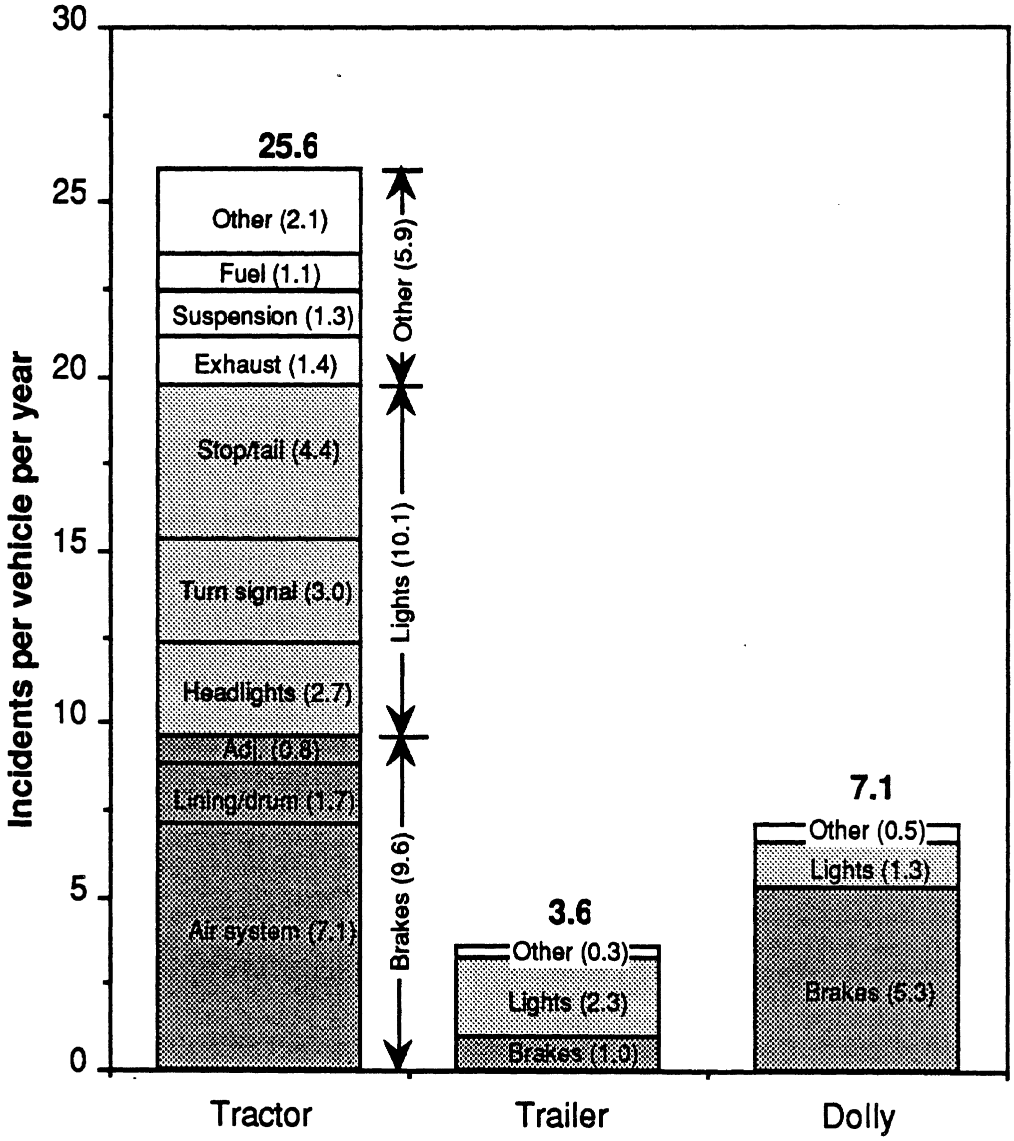


Fig. E-1 Maintenance Incidents for Fleet Vehicles

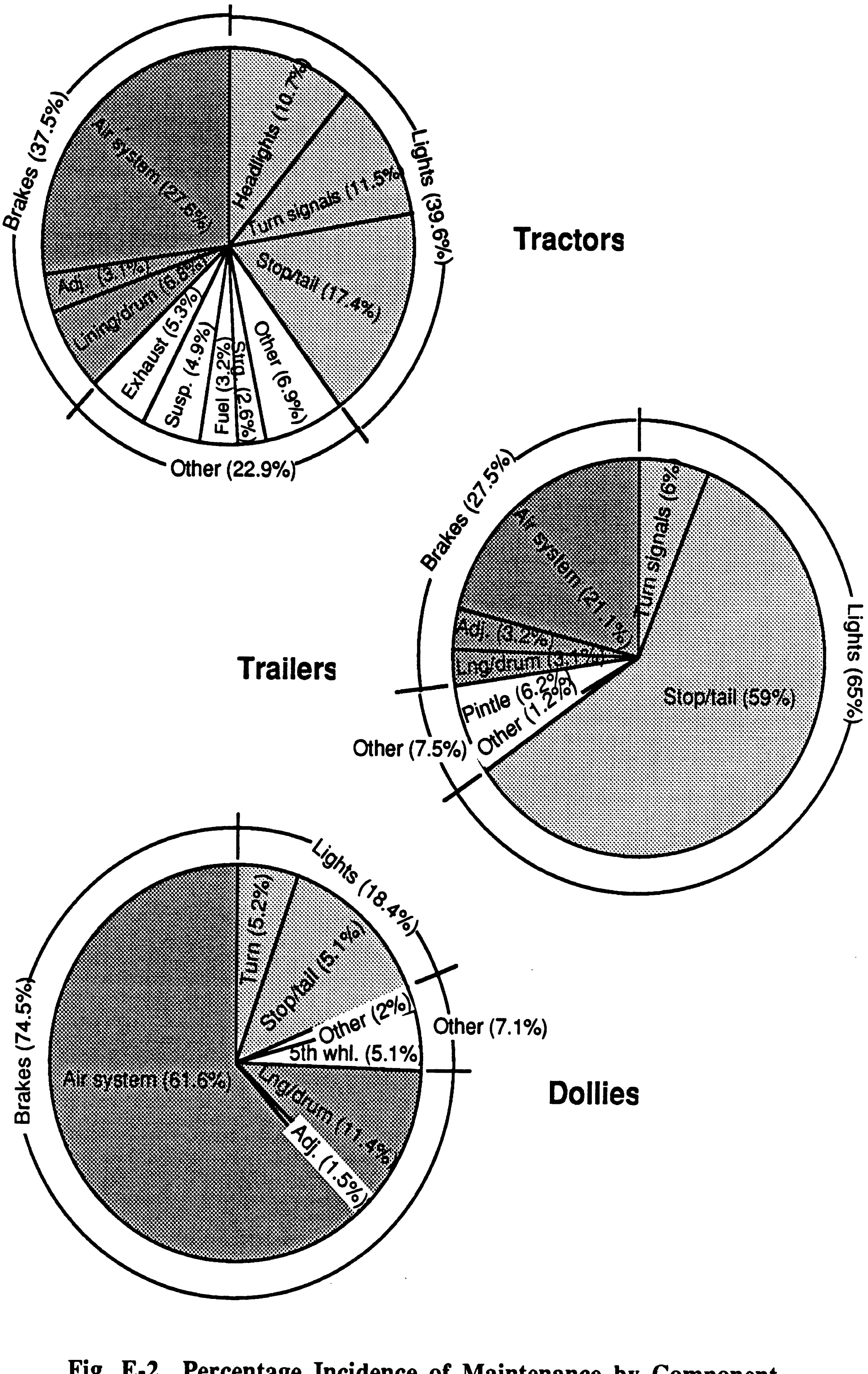


Fig. E-2 Percentage Incidence of Maintenance by Component

Relating Fleet Data to Average Vehicles

It is clear that the vehicles from the national fleet are used much more extensively than average vehicles. Since the use of vehicles contributes to the wear and deterioration of many of its components, it is reasonable to assume that the need for repairs and replacements on an average vehicle would be somewhat lower than for vehicles from the fleet. It is further assumed that the need for repairs is proportional to the mileage of the vehicle.

The average annual mileage of a Fleet tractor is 155,000 miles, while the annual mileage of an average tractor is 41,280 miles or .27 times the mileage of a tractor from the fleet. Based on the assumptions listed above, the number of maintenance incidents for an average vehicle can be estimated.

Table E-7 shows the estimated number of maintenance incidents for an average tractor. There are approximately 7 incidents per year. Of these, 2.6 are for the brake system, 2.7 are light related, and 1.6 are for everything else.

Table E-7

Estimated Maintenance Incidents for Average tractor

Repair Type	Incidents per unit/yr	% of Total Incidents	
AIR SYSTEM	1.91	27.61%	
BRAKE ADJUSTMENT	.21	3.10%	BRAKE RELATED
BRAKE LINING AND DRUM	.47	6.85%	2.59%
HEADLIGHTS	.74	10.70%	
STOP/TAIL LIGHTS	1.20	17.37%	LIGHT RELATED
TURN SIGNALS	.80	11.55%	2.74%
WHEELS	.11	1.55%	
CHASSIS FRAME	.11	1.64%	
EXHAUST	.37	5.33%	
FUEL LINES	.22	3.19%	
FUEL TANKS	.08	1.13%	OTHER
STEERING	.18	2.58%	1.58%
SUSPENSIONS	.34	4.94%	
TRLR PINTLE HOOK	0	.00%	
5TH WHEEL	.17	2.46%	
TOTAL	6.91	100.00%	6.91

Survivor Curves

Survivor curves are a way of presenting information on the distribution of lifetimes of equipment. They are commonly used in the highway engineering field, but can be applied whenever the length of useful lives of equipment or materials is of interest. Typically they are developed from longitudinal records of the life of each piece of equipment.

In our case we have information for one year in the life of a fleet of vehicles. For each component, we have the total number of repairs in a year, the number of first incidents, the number of repeat incidents, and a distribution of the time, in 20 day intervals, between repair incidents.

Let us define the time between repairs/replacements as the useful life of a component and use these time periods as the basis of a survivor curve. Since we are in effect looking at a "one year window" in the lives of the vehicles, we have information on complete lives of components only in cases where there were at least two failures of the component during the "window" period. In such cases we know the lifetime of at least one unit of the component. We also know that on vehicles where there were no first failures of the component, the useful life of the component is obviously longer that the "window" period.

Figure E-3 shows the concept of the "window." It is clear that the "window" view cannot provide the lifetime of a component that failed only once during the time of observation. However, if we assume that the lifetimes of the components come from a specific distribution, then the information about lifetimes obtained from our window is basically the same as obtained from any other "window" a little earlier or later in time. If we accept this assumption then we can develop survivor curves from the information provided.

Table E-8 gives the information from which the survivor curve for the Brake Air System for the fleet tractors was developed. The time interval in each case is 20 days for the fleet vehicles. Figure E-4 shows the survivor curve for all tractor systems. Figures E-5 and E-6 are survivor curves for trailers and converter dollies. The survivor curve can be interpreted as showing the probability of failure of the component as a function of time since the last maintenance activity on that component. The survivor curves for all the components for the fleet tractors, trailers, and converter dollies were developed from the data provided by the fleet. Those data are tabulated at the end of this appendix.

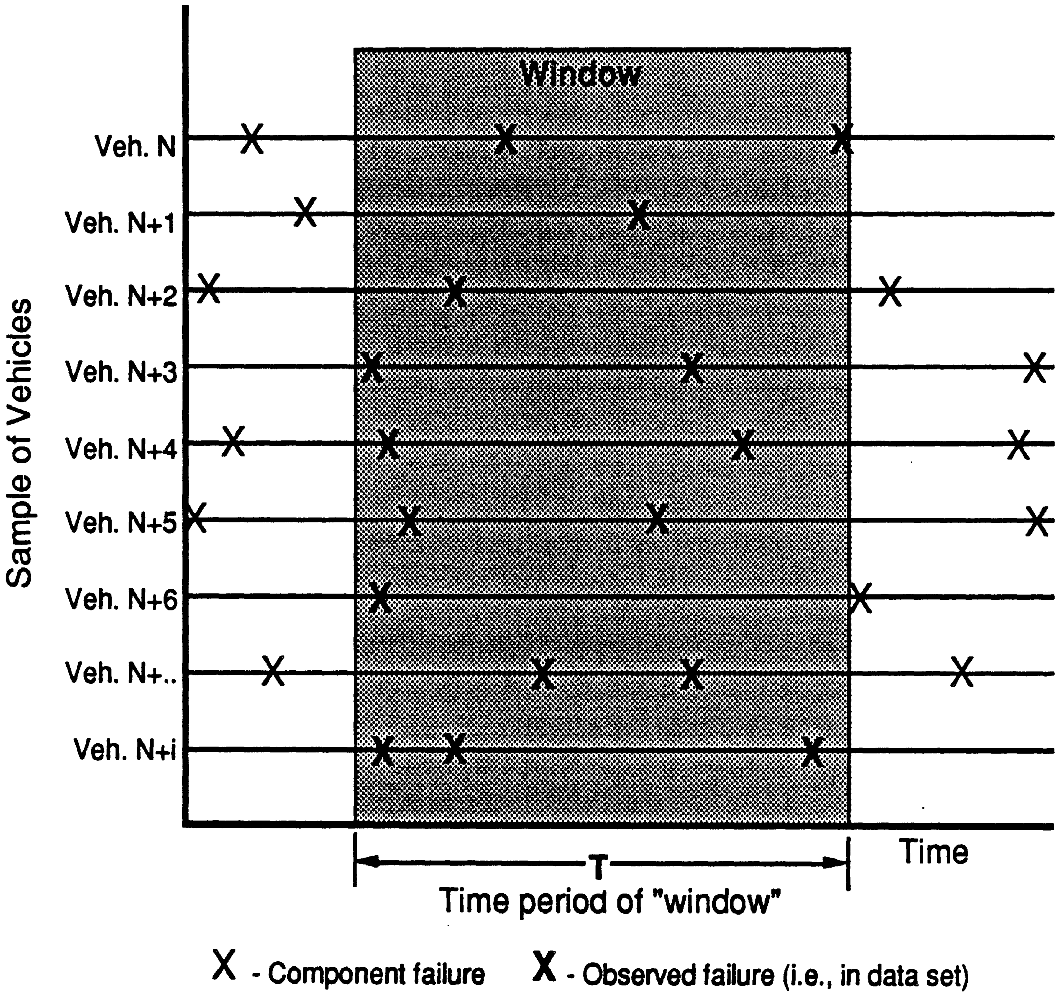


Fig. E-3 The Window Concept

Table E-8

Tractor Brake Air System

712 TRACTORS
706 HAD AT LEAST 1 BRAKE AIR SYSTEM FAILURE IN T
6 TRACTORS HAVE HAD NO FAILURES OF AIR SYSTEM

THERE HAD BEEN 4322 FAILURES OF AIR SYSTEM IN T

THUS, WE HAVE LIFETIME OF 4322 COMPONENTS AND WE KNOW THAT 6 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 4328 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum. % Failed	% Surviving
1	1646	38.03	38.03	61.97
2	948	21.90	59.93	40.07
3	662	15.30	75.23	24.77
4	439	10.14	85.37	14.63
5	217	5.01	90.39	9.61
6	145	3.35	93.74	6.26
7	101	2.33	96.07	3.93
8	62	1.43	97.50	2.50
9	35	0.81	98.31	1.69
10	31	0.72	99.03	0.97
11	13	0.30	99.33	0.67
12	8	0.18	99.51	0.49
13	6	0.14	99.65	0.35
14	2	0.05	99.70	0.30
15	5	0.12	99.81	0.19
16	2	0.05	99.86	0.14
TOTAL	4322			

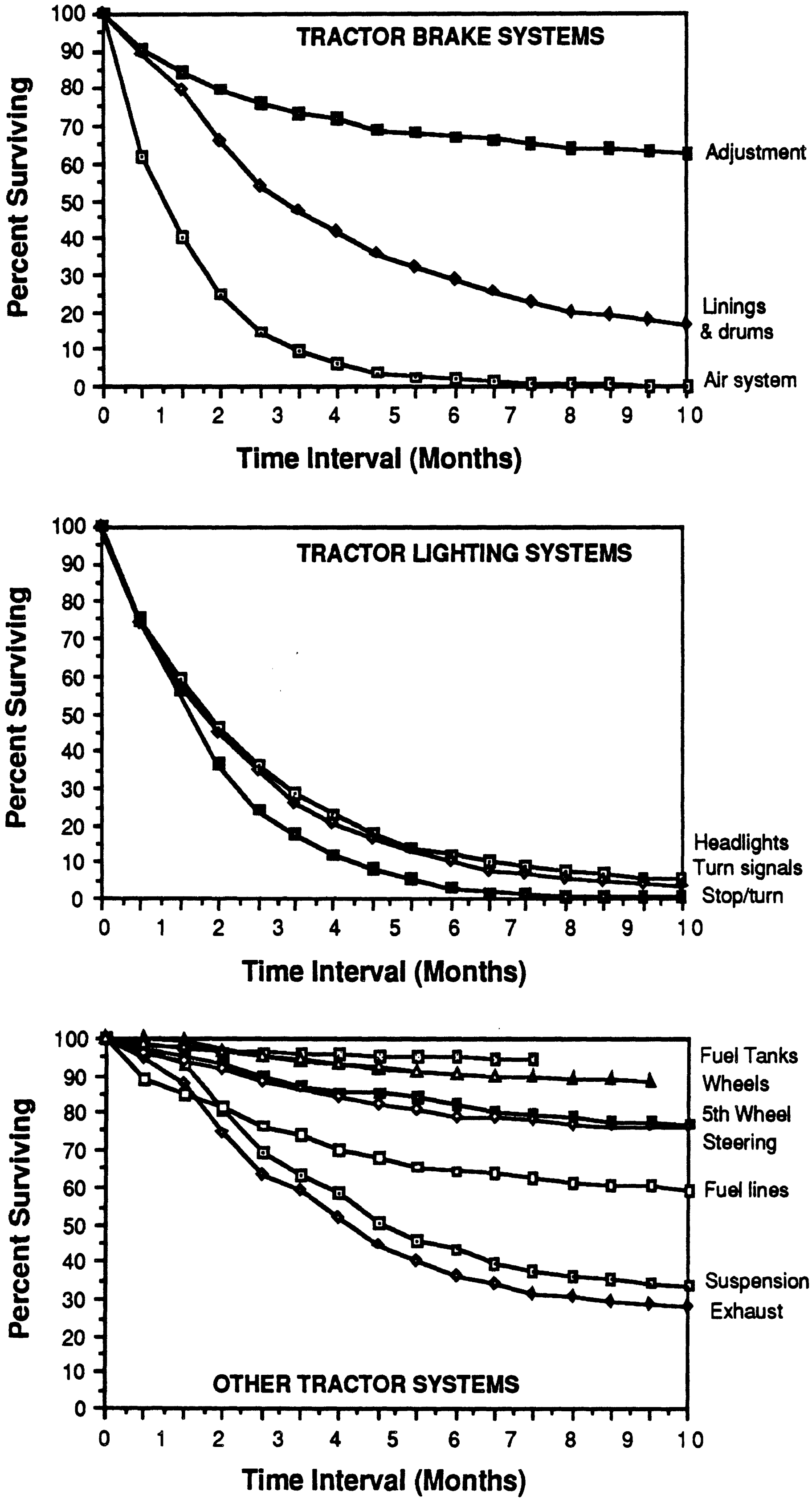


Fig. E-3 Tractor Survivor Curves

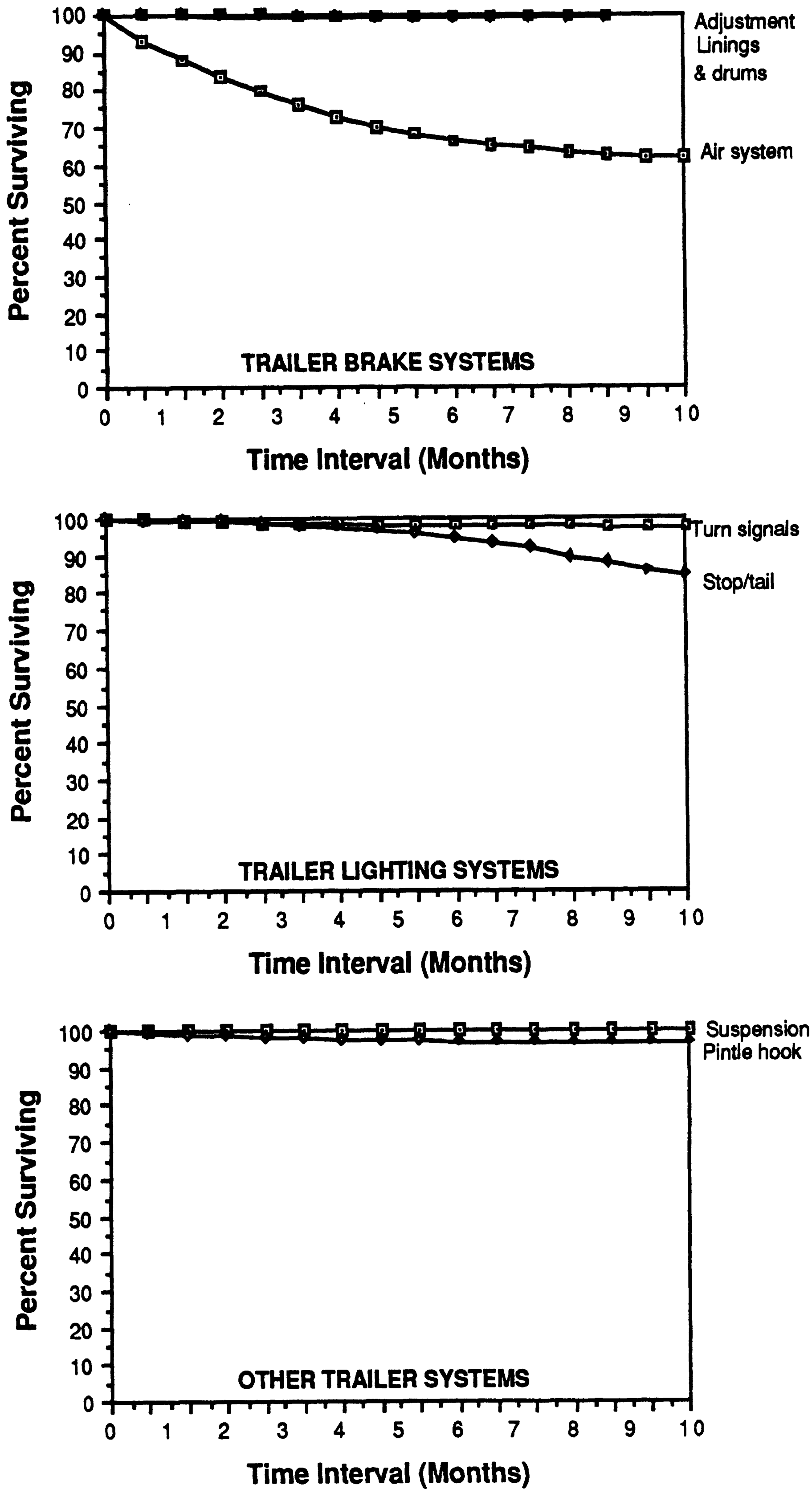


Fig. E-4 Trailer Survivor Curves

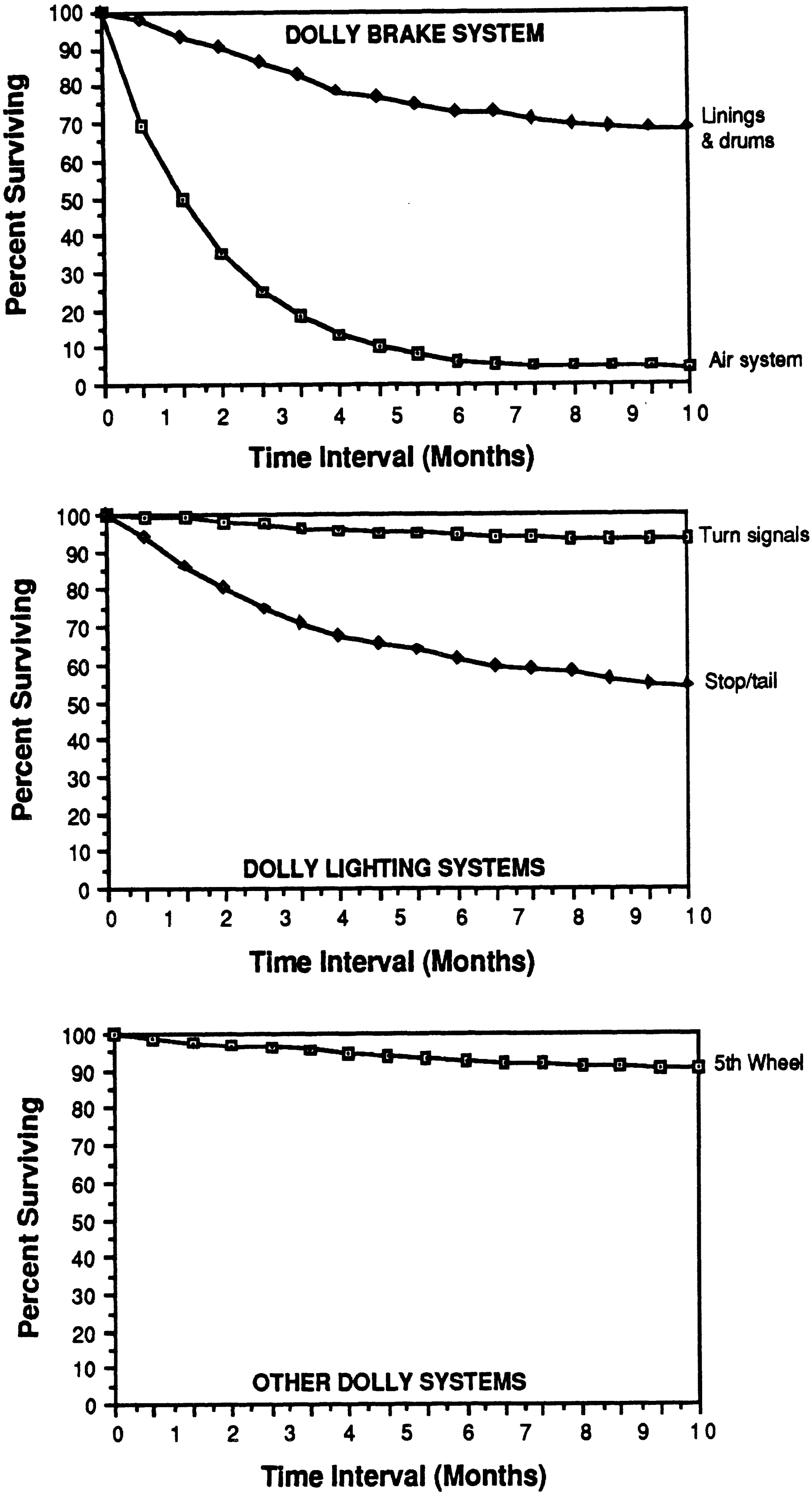


Fig. E-5 Dolly Survivor Curves

Probability of Failure of each Component

Fleet Vehicles

As mentioned above the survivor curves can be used to estimate the probability of failure of a component as a function of time since the last repair/replacement. Table E-9 summarizes the probabilities of component failure from the survivor curves and presents them as a function of time in months for the fleet tractors.

Similarly, Table E-10 summarizes the probabilities of component failure on the fleet trailers as a function of time in months. There were too few failures recorded in the data to develop survivor curves for wheels and the 5th wheel. This means that the probability of failure of these components is very low.

Table E-9

Probability of Need for Repair (Fleet Tractor)

	Time Since Last Repair (Months)									
Component	1	2	3	4	5	6	7	8	9	10
AIR SYSTEM	.490	.752	.879	.937	.968	.983	.992	.995	.997	.998
BRAKE LINING/DRUM	.157	.342	.497	.589	.663	.711	.762	.801	.817	.832
BRAKE ADJUSTMENT	.129	.206	.254	.284	.316	.330	.344	.361	.369	.373
HEADLIGHTS	.332	.534	.672	.769	.841	.880	.902	.926	.935	.945
TURN SIGNALS	.345	.554	.700	.797	.841	.895	.927	.944	.955	.963
STOP/TAIL LIGHTS	.343	.631	.788	.876	.961	.966	.982	.992	.993	.995
SUSPENSION	.055	.191	.335	.416	.520	.570	.616	.635	.651	.660
EXHAUST	.090	.255	.387	.483	.577	.636	.673	.695	.711	.718
5TH WHEEL	.040	.069	.139	.144	.153	.181	.201	.213	.223	.228
STEERING	.056	.081	.141	.159	.186	.208	.222	.228	.238	.239
FUEL TANK	.018	.035	.041	.045	.050	.054	.058			
FUEL LINES	.128	.187	.250	.298	.334	.358	.371	.388	.396	.405
CHASSIS	.003	.032	.054	.063	.078	.087	.099	.104	.107	
WHEELS	.019	.040	.056	.067	.083	.094	.100	.105	.108	.112

Table E-10

Probability of Need for Repair (Fleet Trailer)

Component	Time Since Last Repair (Months) 1	2	3	4	5	6	7	8	9	10
AIR SYSTEM	.093	.164	.222	.272	.310	.338	.353	.368	.380	.382
BRAKE LINING/DRUM	.003	.005	.007	.008	.011	.012	.012	.013	.013	
BRAKE ADJUSTMENT	.001	.003	.003	.004	.005	.006	.007	.008	.008	
TURN SIGNALS	.004	.009	.012	.015	.018	.019	.021	.022	.023	.024
STOP/TAIL LIGHTS	.232	.428	.581	.696	.774	.831	.868	.890	.903	.910
SUSPENSION	.000	.000	.000	.000	.000	.000	.001			
PINTLE HOOK	.007	.014	.019	.024	.027	.029	.031	.034	.034	.035

Table E-11 shows the probabilities of component failure on the fleet converter dollies as a function of time in months. There were too few failures recorded in the data to develop survivor curves for brake adjustments, suspension, chassis/frame, pintle hook, and wheels. This means that the probability of failure of these components is very low.

Table E-11

Probability of Need for Repair (Fleet Converter dolly)

Component	Time Since Last Repair (Months) 1	2	3	4	5	6	7	8	9	10
AIR SYSTEM	.406	.648	.785	.869	.909	.034	.949	.951	.953	.954
BRAKE LINING/DRUM	.049	.097	.156	.215	.243	.271	.284	.306	.315	.318
TURN SIGNALS	.008	.019	.032	.044	.053	.060	.065	.068	.072	.072
STOP/TAIL LIGHTS	.101	.200	.274	.323	.357	.392	.412	.423	.430	.457
5TH WHEEL	.018	.033	.043	.055	.067	.074	.083	.089	.093	.095

Average Vehicles

The annual mileage of fleet vehicles is considerably greater than that of average vehicles. However, we can infer the probabilities of failure for average vehicles if we know the ratio of the mileage of fleet and average vehicles. Recall that the time interval for the time between failure for the fleet vehicles was given in 20 day increments. Thus, the number of days that it takes an average vehicle to accumulate the same mileage as the fleet vehicle accumulates in 20 days can be determined. The time axis of the survivor curves can be scaled accordingly, and the probability of failure can be obtained from the survivor curve.

The following table compares the annual mileage for average and fleet vehicles used in this analysis:

	Annual Vehicle Mileage		
	Average	Fleet	Ratio
Tractor	41,280	155,000	.27
Trailer	20,000	30,000	.66
Converter dolly	20,000	90,000	.22

Table E-12 shows the probabilities of failure of components as a function of time (months) of a tractor with average annual mileage. Tables E-13 and E-14 show the probabilities of component failure of an average trailer and an average converter dolly.

Table E-12

Probability of Need for Repair (Average Tractor)

	Time Since Last Repair (Months)											
Component	1	2	3	4	5	6	7	8	9	10	11	12
AIR SYSTEM	.200	.350	.450	.550	.590	.700	.750	.770	.810	.850	.870	.890
BRAKE LINING/DRUM	.040	.080	.120	.160	.200	.252	.304	.356	.408	.460	.476	.492
BRAKE ADJUSTMENT	.020	.040	.080	.120	.160	.176	.192	.208	.224	.240	.250	.260
HEADLIGHTS	.100	.220	.300	.350	.410	.450	.500	.540	.590	.630	.650	.670
TURN SIGNALS	.085	.170	.250	.340	.420	.466	.512	.558	.604	.660	.690	.720
STOP/TAIL LIGHTS	.087	.174	.260	.340	.437	.520	.610	.640	.700	.755	.780	.800
SUSPENSION	.014	.029	.043	.058	.072	.118	.165	.211	.258	.304	.326	.349
EXHAUST	.025	.049	.074	.098	.123	.172	.221	.271	.320	.369	.383	.398
5TH WHEEL	.020	.030	.040	.050	.060	.070	.080	.090	.100	.109	.118	.127
STEERING	.012	.023	.035	.046	.057	.069	.081	.092	.115	.124	.132	.141
FUEL TANK	.004	.008	.012	.016	.020	.024	.028	.032	.036	.040	.044	.048
FUEL LINES	.030	.060	.090	.120	.150	.164	.179	.194	.211	.237	.253	.260
CHASSIS	.005	.010	.015	.020	.025	.031	.036	.041	.046	.051	.056	.061
WHEELS	.005	.010	.016	.021	.026	.031	.037	.042	.047	.052	.058	.063

Table E-13

Probability of Need for Repair (Average Trailer)

Component	Time Since Last Repair (Months) 1	2	3	4	5	6	7	8	9	10	11	12
AIR SYSTEM	.067	.119	.164	.204	.241	.272	.300	.320	.339	.348	.358	.368
BRAKE LINING/DRUM	.000	.002	.003	.003	.004	.004	.005	.006	.006	.006	.007	.008
BRAKE ADJUSTMENT	.002	.003	.005	.006	.007	.008	.010	.011	.012	.012	.012	.013
TURN SIGNALS	.003	.005	.009	.011	.014	.015	.017	.018	.019	.021	.022	.022
STOP/TAIL LIGHTS	.159	.306	.428	.539	.623	.696	.752	.796	.831	.858	.877	.890
SUSPENSION	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001
PINTLE HOOK	.005	.010	.014	.017	.021	.024	.026	.028	.029	.031	.032	.033

Table E-14

Probability of Need for Repair (Average Converter dolly)

Component	Time Since Last Repair (Months) 1	2	3	4	5	6	7	8	9	10	11	12
AIR SYSTEM	.135	.270	.406	.486	.567	.648	.693	.739	.785	.813	.841	.869
BRAKE LINING/DRUM	.016	.033	.049	.065	.081	.097	.117	.136	.156	.176	.195	.215
TURN SIGNALS	.003	.005	.008	.012	.015	.019	.023	.028	.032	.036	.040	.044
STOP/TAIL LIGHTS	.034	.067	.101	.134	.167	.200	.225	.249	.274	.290	.307	.323
5TH WHEEL	.006	.012	.018	.023	.028	.033	.036	.039	.043	.047	.051	.055

Probability of O/S Failure for Average Straight Trucks, Semi-Trailers, and Doubles

The probability of failure of any of a series of components can be determined by adding the probabilities of failure of each of the individual probabilities. However, these are the probabilities of any need for repair, and it is reasonable to assume that only some portion of these repairs are for potential O/S violation conditions. Discussions with maintenance experts indicate that somewhere between 10% and 50% of the incidents that we were examining were potential O/S violations.

We calculated probabilities of an O/S type failure for typical vehicle configurations by combining the probabilities of the separate vehicles that make up the combinations. A tractor was used as a surrogate for a straight truck, since we did not have information on straight trucks. A semi-trailer combination was made up from a tractor and a trailer, and a double was made up from a tractor, two trailers, and a converter dolly. Four sets of probabilities were calculated for each vehicle type reflecting a range of values for the percentage of failures that result in O/S conditions. The percentages used were 10%, 25%, 33% and 50%.

Table E-15 shows the probabilities of a potential O/S condition as a function of time in months estimated by this simple model.

Table E-15

Estimated Probability of O/S Condition as Function of Time

A. Assuming 10% of failures result in O/S violation

	MONTH						
Vehicle Configuration	1	2	3	4	5	6	7
STRAIGHT TRUCK	.065	.125	.178	.229	.275	.324	.370
SEMI-TRAILER	.088	.170	.241	.307	.366	.426	.481
DOUBLE	.131	.254	.361	.457	.543	.628	.701

B. Assuming 25% of failures result in O/S violation

	MONTH						
Vehicle Configuration	1	2	3	4	5	6	7
STRAIGHT TRUCK	.163	.313	.446	.572	.688	.811	.924
SEMI-TRAILER	.221	.424	.602	.767	.916	1	1
DOUBLE	.329	.632	.904	1	1	1	1

C. Assuming 33% of failures result in O/S violation

	MONTH						
Vehicle Configuration	1	2	3	4	5	6	7
STRAIGHT TRUCK	.216	.419	.596	.765	.919	1	1
SEMI-TRAILER	.292	.567	.804	1	1	1	1
DOUBLE	.436	.844	1	1	1	1	1

D. Assuming 50% of failures result in O/S violation

	MONTH						
Vehicle Configuration	1	2	3	4	5	6	7
STRAIGHT TRUCK	.324	.627	.893	1	1	1	1
SEMI-TRAILER	.442	.894	1	1	1	1	1
DOUBLE	.657	1	1	1	1	1	1

The results of this model show that the chances of a failure that would result in an O/S condition if not repaired increases quite rapidly with time from the time where all systems were inspected and found to be in satisfactory condition. At three months the probability that a straight truck will have experienced a potential O/S condition is somewhere between .2 and .9, depending on the portion of failures assumed to result in O/S conditions. For the semi-trailer this probability range is between .25 and certainty. The model indicates that a double configuration will have a probability between .35 and certainty of an O/S condition in 3 months.

It should be remembered that this is a simple model based on a series of assumptions that simplify reality. Tire failures were not included in our calculations because we did not have data on the distribution of tire failures. Furthermore, the vehicles we examined were all equipped with automatic slack adjusters. Consideration of these factors would increase the probabilities of O/S failures somewhat.

Nevertheless, the results are based on real maintenance data. Even when taking the assumptions under consideration the trend in the probabilities of failures is clear, supporting the three month interval as a reasonable life of an inspection decal.

Survivor Data

The basic data representing the survivor behavior of components on tractors, trailers and converter dollies are given in Tables E-16 through E-41 that follow.

Table E-16

Survivor Curve Data—Tractor Air Brake System

712 TRACTORS
706 HAD AT LEAST 1 BRAKE AIR SYSTEM FAILURE IN T
6 TRACTORS HAVE HAD NO FAILURES OF AIR SYSTEM

THERE HAD BEEN 4322 SUBSEQUENT FAILURES OF AIR SYSTEM IN T

THUS, WE HAVE LIFETIME OF 4322 COMPONENTS
AND WE KNOW THAT 6 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 4328 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	1646	38.03	38.03	61.97
2	948	21.90	59.93	40.07
3	662	15.30	75.23	24.77
4	439	10.14	85.37	14.63
5	217	5.01	90.39	9.61
6	145	3.35	93.74	6.26
7	101	2.33	96.07	3.93
8	62	1.43	97.50	2.50
9	35	0.81	98.31	1.69
10	31	0.72	99.03	0.97
11	13	0.30	99.33	0.67
12	8	0.18	99.51	0.49
13	6	0.14	99.65	0.35
14	2	0.05	99.70	0.30
15	5	0.12	99.81	0.19
16	2	0.05	99.86	0.14
TOTAL	4322			

Table E-17

Survivor Curve Data—Tractor Brake Linings and Drums

712 TRACTORS
591 TRACTORS HAD REPAIRS/RELACEMENTS OF BRAKE LININGS OR DRUMS AT LEAST ONCE DURING T
121 HAD NO REPAIRS OR REPLACEMENTS OF BRAKE LINIGS OR DRUMS DURING T
IN ALL, THERE HAVE BEEN 657 REPAIR/REPLACEMENT INCIDENTS DURING T

WE KNOW THE TIME INTERVALS BETWEEN THE FAILURES FOR THE 657 FAILURES

WE ALSO KNOW THAT AT TIME T, 121 FAILURES HAVE NOT YET OCCURRED BUT THAT THESE SHOULD OCCUR SOMETIME IN TIME > T.

THEREFORE, WE CAN DEVELOP A SURVIVOR CURVE FOR A POPULATION OF 778 UNITS OF THE PARTICULAR COMPONENT.

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	85	10.93	10.93	89.07
2	74	9.51	20.44	79.56
3	107	13.75	34.19	65.81
4	98	12.60	46.79	53.21
5	46	5.91	52.70	47.30
6	48	6.17	58.87	41.13
7	41	5.27	64.14	35.86
8	33	4.24	68.39	31.61
9	21	2.70	71.08	28.92
10	28	3.60	74.68	25.32
11	23	2.96	77.64	22.36
12	19	2.44	80.08	19.92
13	9	1.16	81.24	18.76
14	7	0.90	82.14	17.86
15	8	1.03	83.17	16.83
16	4	0.51	83.68	16.32
17	6	0.77	84.45	15.55
TOTAL	657			

Table E-18

Survivor Curve Data—Tractor Brake Adjustment

712 TRACTORS
347 HAD AT LEAST 1 BRAKE ADJUSTMENT IN T
365 TRACTORS HAVE HAD NO BRAKE ADJUSTMENTS IN T

THERE WERE 217 SUBSEQUENT BRAKE ADJUSTMENTS IN T

THUS, WE HAVE LIFETIME OF 217 BRAKE ADJUSTMENT
AND WE KNOW THAT 365 WILL BE ADJUSTED AT TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 582 ADJUSTMENT

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	57	9.79	9.79	90.21
2	36	6.19	15.98	84.02
3	27	4.64	20.61	79.39
4	20	3.44	24.05	75.95
5	16	2.75	26.80	73.20
6	9	1.55	28.35	71.65
7	16	2.75	31.10	68.90
8	6	1.03	32.13	67.87
9	5	0.86	32.99	67.01
10	4	0.69	33.67	66.33
11	9	1.55	35.22	64.78
12	5	0.86	36.08	63.92
13	3	0.52	36.59	63.41
14	3	0.52	37.11	62.89
15	1	0.17	37.28	62.72
TOTAL	217			

Table E-19

Survivor Curve Data—Tractor Headlights

712 TRACTORS
641 HAD AT LEAST 1 HEADLIGHT FAILURE IN T
71 TRACTORS HAVE HAD NO HEADLIGHT FAILURES IN T

THERE HAD BEEN 1307 SUBSEQUENT FAILURES OF HEADLIGHTS IN T

THUS, WE HAVE LIFETIME OF 1307 COMPONENTS
AND WE KNOW THAT 71 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 1378 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	351	25.47	25.48	74.52
2	213	15.46	40.94	59.06
3	171	12.41	53.35	46.65
4	138	10.01	63.36	36.64
5	107	7.76	71.13	28.87
6	79	5.73	76.86	23.14
7	72	5.22	82.08	17.92
8	56	4.06	86.15	13.85
9	25	1.81	87.96	12.04
10	22	1.60	89.56	10.44
11	18	1.31	90.86	9.14
12	24	1.74	92.61	7.39
13	7	0.51	93.11	6.89
14	12	0.87	93.99	6.01
15	7	0.51	94.49	5.51
16	2	0.15	94.64	5.36
TOTAL	1307			

Table E-20
Survivor Curve Data—Tractor Turn Signals

712 TRACTORS
662 HAD AT LEAST 1 TURN SIGNAL FAILURE IN T
50 TRACTORS HAVE HAD NO FAILURES OF TURN SIGNALS IN T

THERE HAD BEEN 1441 SUBSEQUENT FAILURES OF TURN SIGNALS IN T

THUS, WE HAVE LIFETIME OF 1441 COMPONENTS
AND WE KNOW THAT 50 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 1491 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	392	26.29	26.29	73.71
2	244	16.36	42.65	57.35
3	190	12.74	55.40	44.60
4	156	10.46	65.86	34.14
5	123	8.25	74.11	25.89
6	84	5.63	79.74	20.26
7	57	3.82	83.57	16.43
8	47	3.15	86.72	13.28
9	41	2.75	89.47	10.53
10	39	2.62	92.08	7.92
11	18	1.21	93.29	6.71
12	17	1.14	94.43	5.57
13	12	0.80	95.24	4.76
14	8	0.54	95.77	4.23
15	8	0.54	96.31	3.69
16	2	0.13	96.44	3.56
17	3	0.20	96.65	3.35
TOTAL	1441			

Table E-21
Survivor Curve Data—Tractor Stop/Tail Lights

712 TRACTORS
701 HAD AT LEAST 1 STOP/TAIL LIGHT FAILURE IN T
11 TRACTORS HAVE HAD NO STOP/TAIL LIGHT FAILURES IN T

THERE HAD BEEN 2463 SUBSEQUENT FAILURES OF STOP/TAIL LIGHTS IN T

THUS, WE HAVE LIFETIME OF 2463 COMPONENTS
AND WE KNOW THAT 11 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 2474 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	614	24.82	24.82	75.18
2	467	18.88	43.70	56.30
3	479	19.36	63.06	36.94
4	309	12.49	75.55	24.45
5	159	6.43	81.97	18.03
6	139	5.62	87.59	12.41
7	96	3.88	91.47	8.53
8	76	3.07	94.55	5.45
9	50	2.02	96.57	3.43
10	34	1.37	97.94	2.06
11	15	0.61	98.55	1.45
12	15	0.61	99.15	0.85
13	4	0.16	99.31	0.69
14	1	0.04	99.36	0.64
15	4	0.16	99.52	0.48
16	1	0.04	99.56	0.44
TOTAL	2463			

Table E-22
Survivor Curve Data—Tractor Suspension Systems

712 TRACTORS
528 HAD AT LEAST 1 SUSPENSION SYSTEM FAILURE IN T
184 TRACTORS HAVE HAD NO FAILURES OF THE SUSPENSION SYSTEM

THERE HAD BEEN 372 SUBSEQUENT FAILURES OF THE SUSPENSION SYSTEM IN T

THUS, WE HAVE LIFETIME OF 372 COMPONENTS
AND WE KNOW THAT 184 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 556 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	21	3.78	3.78	96.22
2	19	3.42	7.20	92.80
3	66	11.87	19.07	80.93
4	63	11.33	30.40	69.60
5	35	6.29	36.69	63.31
6	27	4.86	41.55	58.45
7	45	8.09	49.64	50.36
8	26	4.68	54.32	45.68
9	15	2.70	57.02	42.98
10	21	3.78	60.79	39.21
11	9	1.62	62.41	37.59
12	6	1.08	63.49	36.51
13	6	1.08	64.57	35.43
14	6	1.08	65.65	34.35
15	2	0.36	66.01	33.99
16	2	0.36	66.37	33.63
17	3	0.54	66.91	33.09
TOTAL	372			

Table E-23
Survivor Curve Data—Tractor Exhaust Systems

712 TRACTORS
566 HAD AT LEAST 1 EXHAUST SYSTEM FAILURE IN T
156 TRACTORS HAVE HAD NO FAILURES OF THE EXHAUST SYSTEM

THERE HAD BEEN 405 SUBSEQUENT FAILURES OF THE EXHAUST SYSTEM IN T

THUS, WE HAVE LIFETIME OF 405 COMPONENTS
AND WE KNOW THAT 156 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 561 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	32	5.70	5.70	94.30
2	37	6.60	12.30	87.70
3	74	13.19	25.49	74.51
4	64	11.41	36.89	63.11
5	20	3.57	40.46	59.54
6	44	7.84	48.30	51.70
7	40	7.13	55.43	44.57
8	25	4.46	59.89	40.11
9	21	3.74	63.63	36.37
10	13	2.32	65.95	34.05
11	15	2.67	68.62	31.38
12	5	0.89	69.51	30.49
13	7	1.25	70.76	29.24
14	4	0.71	71.48	28.52
15	2	0.36	71.83	28.17
16	2	0.36	72.19	27.81
TOTAL	405			

Table E-24
Survivor Curve Data—Tractor 5th Wheel

712 TRACTORS
334 HAD AT LEAST 1 5TH WHEEL FAILURE IN T
378 TRACTORS HAVE HAD NO FAILURES OF THE 5TH WHEEL

THERE HAD BEEN 114 SUBSEQUENT FAILURES OF 5TH WHEELS IN T

THUS, WE HAVE LIFETIME OF 114 COMPONENTS
AND WE KNOW THAT 378 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 492 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	15	3.05	3.05	96.95
2	9	1.83	4.88	95.12
3	10	2.03	6.91	93.09
4	15	3.05	9.96	90.04
5	13	2.64	12.60	87.40
6	9	1.83	14.43	85.57
7	1	0.20	14.64	85.36
8	6	1.22	15.85	84.15
9	11	2.24	18.09	81.91
10	7	1.42	19.51	80.49
11	6	1.22	20.73	79.27
12	3	0.61	21.34	78.66
13	4	0.81	22.16	77.84
14	1	0.20	22.36	77.64
15	2	0.41	22.77	77.23
16	2	0.41	23.17	76.83
TOTAL	114			

Table E-25
Survivor Curve Data—Tractor Steering System

712 TRACTORS
359 HAD AT LEAST 1 STEERING SYSTEM FAILURE IN T
353 TRACTORS HAVE HAD NO FAILURES OF THE STEERING SYSTEM

THERE HAD BEEN 110 SUBSEQUENT FAILURES OF THE STEERING SYSTEM IN T

THUS, WE HAVE LIFETIME OF 110 COMPONENTS
AND WE KNOW THAT 353 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 463 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	20	4.32	4.63	95.37
2	9	1.94	6.57	93.43
3	7	1.51	8.09	91.91
4	16	3.46	11.54	88.46
5	8	1.73	13.27	86.73
6	12	2.59	15.86	84.14
7	9	1.94	17.80	82.20
8	7	1.51	19.32	80.68
9	7	1.51	20.83	79.17
10	2	0.43	21.26	78.74
11	3	0.65	21.91	78.09
12	4	0.86	22.77	77.23
13	3	0.65	23.42	76.58
14	1	0.22	23.64	76.36
15	1	0.22	23.85	76.15
16	1	0.22	24.07	75.93
TOTAL	110			

Table E-26
Survivor Curve Data—Tractor Fuel Tank

712 TRACTORS
171 HAD AT LEAST 1 FUEL TANK FAILURE IN T
541 TRACTORS HAVE HAD NO FAILURES OF FUEL TANK

THERE HAD BEEN 34 SUBSEQUENT FAILURES OF FUEL TANK IN T

THUS, WE HAVE LIFETIME OF 34 COMPONENTS
AND WE KNOW THAT 541 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 575 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	9	1.57	1.57	98.43
2	3	0.52	2.09	97.91
3	8	1.39	3.48	96.52
4	3	0.52	4.00	96.00
5	1	0.17	4.18	95.82
6	2	0.35	4.53	95.47
7	2	0.35	4.87	95.13
8	1	0.17	5.05	94.95
9	2	0.35	5.40	94.60
10	2	0.35	5.74	94.26
11	1	0.17	5.92	94.08
TOTAL	34			

Table E-27
Survivor Curve Data—Tractor Fuel Lines

712 TRACTORS
339 HAD AT LEAST 1 FUEL LINE FAILURE IN T
373 TRACTORS HAVE HAD NO FAILURES OF FUEL LINES

THERE HAD BEEN 222 SUBSEQUENT FAILURES OF FUEL LINES IN T

THUS, WE HAVE LIFETIME OF 222 COMPONENTS
AND WE KNOW THAT 373 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 595 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	63	10.59	10.59	89.41
2	26	4.37	14.96	85.04
3	22	3.70	18.66	81.34
4	30	5.04	23.70	76.30
5	15	2.52	26.22	73.78
6	21	3.53	29.75	70.25
7	14	2.35	32.10	67.90
8	15	2.52	34.62	65.38
9	7	1.18	35.80	64.20
10	3	0.50	36.30	63.70
11	9	1.51	37.82	62.18
12	6	1.01	38.83	61.17
13	3	0.50	39.33	60.67
14	3	0.50	39.83	60.17
15	4	0.67	40.51	59.49
16	1	0.17	40.67	59.33
TOTAL	222			

Table E-28
Survivor Curve Data—Tractor Chassis

712 TRACTORS
241 HAD AT LEAST 1 CHASSIS FAILURE IN T
471 TRACTORS HAVE HAD NO CHASSIS FAILURES IN T

THERE HAD BEEN 57 SUBSEQUENT CHASSIS FAILURES IN T

THUS, WE HAVE LIFETIME OF 57 COMPONENTS
AND WE KNOW THAT 471 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 528 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	1	0.19	0.19	99.81
2	1	0.19	0.38	99.62
3	15	2.84	3.22	96.78
4	10	1.89	5.11	94.89
5	3	0.57	5.68	94.32
6	3	0.57	6.25	93.75
7	5	0.95	7.20	92.80
8	6	1.14	8.33	91.67
9	2	0.38	8.71	91.29
10	5	0.95	9.66	90.34
11	2	0.38	10.04	89.96
12	2	0.38	10.42	89.58
13	1	0.19	10.61	89.39
14	1	0.19	10.80	89.20
TOTAL	57			

Table E-29
Survivor Curve Data—Tractor Wheels

712 TRACTORS
221 HAD AT LEAST 1 WHEEL FAILURE IN T
491 TRACTORS HAVE HAD NO FAILURES OF THE WHEELS

THERE HAD BEEN 62 SUBSEQUENT FAILURES OF WHEELS IN T

THUS, WE HAVE LIFETIME OF 62 COMPONENTS
AND WE KNOW THAT 491 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 553 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	7	1.27	1.27	98.73
2	7	1.27	2.54	97.46
3	8	1.45	3.98	96.02
4	7	1.27	5.25	94.75
5	4	0.72	5.97	94.03
6	4	0.72	6.69	93.31
7	5	0.90	7.60	92.40
8	8	1.45	9.05	90.95
9	2	0.36	9.41	90.59
10	2	0.36	9.77	90.23
11	2	0.36	10.13	89.87
12	2	0.36	10.49	89.51
13	1	0.18	10.67	89.33
14	1	0.18	10.85	89.15
15	2	0.36	11.22	88.78
TOTAL	62			

Table E-30

Survivor Curve Data—Trailer Air Brake System

5096 TRAILERS
2612 HAD AT LEAST 1 BRAKE AIR SYSTEM FAILURE IN T
2484 TRAILERS HAVE HAD NO FAILURES OF AIR SYSTEM

THERE HAD BEEN 1235 SUBSEQUENT FAILURES OF AIR SYSTEM IN T

THUS, WE HAVE LIFETIME OF 1235 COMPONENTS
AND WE KNOW THAT 2484 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 3719 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	199	6.72	6.72	93.28
2	153	5.17	11.89	88.11
3	133	4.49	16.38	83.62
4	118	3.99	20.37	79.63
5	111	3.75	24.12	75.88
6	90	3.04	27.16	72.84
7	83	2.80	29.96	70.04
8	60	2.03	31.99	68.01
9	54	1.82	33.81	66.19
10	28	0.95	34.76	65.24
11	30	1.01	35.77	64.23
12	30	1.01	36.79	63.21
13	28	0.95	37.73	62.27
14	15	0.51	38.24	61.76
15	6	0.20	38.44	61.56
16	14	0.47	38.92	61.08
TOTAL	2825			

Table E-31
Survivor Curve Data—Trailer Brake Adjustment

5096 TRAILERS
548 HAD AT LEAST 1 BRAKE ADJUSTMENT IN T
4548 TRAILERS HAVE HAD NO BRAKE ADJUSTMENT IN T

THERE HAD BEEN 36 SUBSEQUENT BRAKE ADJUSTMENT IN T

THUS, WE HAVE LIFETIME OF 36 BRAKE ADJUSTMENTS
AND WE KNOW THAT 4548 WILL BE ADJUSTED SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 4584 BRAKE ADJUSTMENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	2	0.04	0.04	99.96
2	7	0.15	0.19	99.81
3	3	0.07	0.26	99.74
4	3	0.07	0.32	99.68
5	1	0.02	0.35	99.65
6	2	0.04	0.39	99.61
7	6	0.13	0.52	99.48
8	2	0.04	0.56	99.44
9	1	0.02	0.59	.99.41
10	2	0.04	0.63	99.37
11	3	0.07	0.69	99.31
12	3	0.07	0.76	99.24
13	1	0.02	0.78	99.22
TOTAL	36			

Table E-32
Survivor Curve Data—Trailer Brake Linings and Drums

5096 TRAILERS
513 HAD AT LEAST 1 BRAKE LINING OR DRUM REPAIR IN T
4583 TRAILERS - NO BRAKE LINING OR DRUM REPAIRS IN TIME T

THERE HAD BEEN 60 SUBSEQUENT BRAKE LINING OR DRUM REPAIRS IN T

THUS, WE HAVE LIFETIME OF 60 COMPONENTS
AND WE KNOW THAT 4583 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 4643 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	10	0.21	0.21	99.79
2	5	0.11	0.32	99.68
3	9	0.19	0.51	99.49
4	4	0.09	0.59	99.41
5	7	0.15	0.74	99.26
6	4	0.09	0.83	99.17
7	9	0.19	1.02	98.98
8	3	0.06	1.09	98.91
9	3	0.06	1.15	98.85
10	2	0.04	1.19	98.81
11	1	0.02	1.21	98.79
12	2	0.04	1.26	98.74
13	1	0.02	1.28	98.72
TOTAL	60			

Table E-33
Survivor Curve Data—Trailer Suspension System

5096 TRAILERS
170 HAD AT LEAST 1 SUSPENSION SYSTEM FAILURE IN T
4926 TRAILERS HAVE HAD NO FAILURES OF SUSPENSION SYSTEM IN T

THERE HAD BEEN 3 SUBSEQUENT FAILURES OF SUSPENSION SYSTEM IN T

THUS, WE HAVE LIFETIME OF 3 COMPONENTS
AND WE KNOW THAT 4926 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 4929 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	0	0	0	1
2	0	0	0	1
3	0	0	0	1
4	2	0.04	0.04	99.96
5	0	0	0.04	99.96
6	0	0	0.04	99.96
7	0	0	0.04	99.96
8	0	0	0.04	99.96
9	0	0	0.04	99.96
10	0	0	0.04	99.96
11	1	0.02	0.06	99.94
TOTAL				

Table E-34
Survivor Curve Data—Trailer Stop/Tail Lights

5096 TRAILERS
4526 HAD AT LEAST 1 STOP/TAIL LIGHT FAILURE IN T
571 TRAILERS HAVE HAD NO FAILURES OF STOP/TAIL LIGHTS IN T

THERE HAD BEEN 6212 SUBSEQUENT FAILURES OF STOP/TAIL LIGHTS IN T

THUS, WE HAVE LIFETIME OF 6212 COMPONENTS
AND WE KNOW THAT 571 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 6783 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	1080	15.92	15.92	84.08
2	994	14.65	30.57	69.43
3	831	12.25	42.82	57.18
4	749	11.04	53.86	46.14
5	57	8.48	62.34	37.66
6	489	7.21	69.55	30.45
7	385	5.68	75.23	24.77
8	294	4.33	79.56	20.44
9	237	3.49	83.05	16.95
10	188	2.77	85.82	14.18
11	129	1.90	87.72	12.28
12	84	1.24	88.96	11.04
13	63	0.93	89.89	10.11
14	51	0.75	90.64	9.36
15	26	0.38	91.02	8.98
16	15	0.22	91.24	8.76
17	20	0.29	91.53	8.47
18	2	0.03	91.56	8.44
TOTAL	6212			

Table E-35
Survivor Curve Data—Trailer Turn Signal

5096 TRAILERS
990 HAD AT LEAST 1 TURN SIGNAL FAILURE IN T
4106 TRAILERS HAVE HAD NO FAILURES OF AIR SYSTEM

THERE HAD BEEN 103 SUBSEQUENT FAILURES OF TURN SIGNALS IN T

THUS, WE HAVE LIFETIME OF 103 COMPONENTS
AND WE KNOW THAT 4106 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 4209 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	13	0.31	0.31	99.69
2	8	0.19	0.50	99.50
3	16	0.38	0.88	99.12
4	11	0.26	1.14	98.86
5	9	0.21	1.36	98.64
6	5	0.12	1.47	98.53
7	10	0.24	1.71	98.29
8	3	0.07	1.78	98.22
9	6	0.14	1.93	98.07
10	7	0.17	2.09	97.91
11	3	0.07	2.16	97.84
12	1	0.02	2.19	97.81
13	3	0.07	2.26	97.74
14	4	0.10	2.35	97.65
15	1	0.02	2.38	97.62
16	2	0.05	2.42	97.58
17	1	0.02	2.45	97.55
TOTAL	103			

Table E-36
Survivor Curve Data—Trailer Pintle Hook

5096 TRAILERS
987 HAD AT LEAST 1 PINTLE HOOK FAILURE IN T
4118 TRAILERS HAVE HAD NO FAILURES OF PINTLE HOOK

THERE HAD BEEN 150 SUBSEQUENT FAILURES OF PINTLE HOOKS IN T

THUS, WE HAVE LIFETIME OF 150 COMPONENTS
AND WE KNOW THAT 4118 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 4268 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	21	0.49	0.49	99.51
2	21	0.49	0.98	99.02
3	18	0.42	1.40	98.60
4	14	0.33	1.73	98.27
5	16	0.37	2.11	97.89
6	12	0.28	2.39	97.61
7	8	0.19	2.58	97.42
8	8	0.19	2.76	97.24
9	5	0.12	2.88	97.12
10	8	0.19	3.07	96.93
11	5	0.12	3.18	96.82
12	7	0.16	3.35	96.65
13	2	0.05	3.40	96.60
14	3	0.07	3.47	96.53
15	1	0.02	3.49	96.51
16	1	0.02	3.51	96.49
TOTAL	150			

Table E-37
Survivor Curve Data—Converter Dolly Brake Air System

800 CONVERTER DOLLIES
665 HAD AT LEAST 1 BRAKE AIR SYSTEM FAILURE IN T
135 TRAILERS HAVE HAD NO FAILURES OF AIR SYSTEM

THERE HAD BEEN 2825 SUBSEQUENT FAILURES OF AIR SYSTEM IN T

THUS, WE HAVE LIFETIME OF 2825 COMPONENTS
AND WE KNOW THAT 135 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 2960 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	909	30.71	30.71	69.29
2	583	19.70	50.41	49.59
3	426	14.39	64.80	35.20
4	308	10.41	75.20	24.80
5	195	6.59	81.79	18.21
6	150	5.07	86.86	13.14
7	89	3.01	89.87	10.13
8	61	2.06	91.93	8.07
9	42	1.42	93.35	6.65
10	24	0.81	94.16	5.84
11	14	0.47	94.63	5.37
12	7	0.24	94.87	5.13
13	7	0.24	95.10	4.90
14	3	0.10	95.20	4.80
15	2	0.07	95.27	4.73
16	4	0.14	95.41	4.59
17	1	0.03	95.44	4.56
TOTAL	2825			

Table E-38
Survivor Curve Data—Converter Dolly Brake Linings and Drums

800 TRAILERS
475 HAD AT LEAST 1 BRAKE LINING OR DRUM REPAIR IN T
325 CONVERTER DOLLIES - NO BRAKE LINING OR DRUM REPAIRS IN TIME T

THERE HAD BEEN 169 SUBSEQUENT BRAKE LINING OR DRUM REPAIRS IN T

THUS, WE HAVE LIFETIME OF 169 COMPONENTS
AND WE KNOW THAT 325 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 494 UNITS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	14	2.83	2.83	97.17
2	20	4.05	6.88	93.12
3	14	2.83	9.71	90.29
4	21	4.25	13.96	86.04
5	16	3.24	17.20	82.80
6	21	4.25	21.45	78.55
7	9	1.82	23.28	76.72
8	10	2.02	25.30	74.70
9	9	1.82	27.12	72.88
10	3	0.61	27.73	72.27
11	7	1.42	29.15	70.85
12	7	1.42	30.56	69.44
13	4	0.81	31.37	68.63
14	1	0.20	31.57	68.43
15	1	0.20	31.78	68.22
TOTAL	157			

Table E-39
Survivor Curve Data—Converter Dolly Turn Signals

800 TRAILERS
255 HAD AT LEAST 1 TURN SIGNAL FAILURE IN T
545 CONVERTER DOLLIES HAVE HAD NO TURN SIGNAL FAILURES IN T

THERE HAD BEEN 42 SUBSEQUENT FAILURES OF TURN SIGNALS IN T

THUS, WE HAVE LIFETIME OF 42 COMPONENTS
AND WE KNOW THAT 545 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 587 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	4	0.68	0.68	99.32
2	1	0.17	0.85	99.15
3	6	1.02	1.87	98.13
4	5	0.85	2.72	97.28
5	6	1.02	3.75	96.25
6	4	0.68	4.43	95.57
7	4	0.68	5.11	94.89
8	2	0.34	5.45	94.55
9	3	0.51	5.96	94.04
10	2	0.34	6.30	93.70
11	2	0.34	6.64	93.36
12	1	0.17	6.81	93.19
13	2	0.34	7.15	92.85
14	0	0	7.15	92.85
15	0	0	7.15	92.85
16	0	0	7.15	92.85
TOTAL	42			

Table E-40
Survivor Curve Data—Converter Dolly Stop/Tail Lights

800 TRAILERS
444 HAD AT LEAST 1 STOP/TAIL LIGHT FAILURE IN T
356 TRAILERS HAVE HAD NO FAILURES OF STOP/TAIL LIGHTS IN T

THERE HAD BEEN 303 SUBSEQUENT FAILURES OF STOP/TAIL LIGHTS IN T

THUS, WE HAVE LIFETIME OF 303 COMPONENTS
AND WE KNOW THAT 356 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 659 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	42	6.37	6.37	93.63
2	49	7.44	13.81	86.19
3	41	6.22	20.03	79.97
4	36	5.46	25.49	74.51
5	25	3.79	29.28	70.72
6	20	3.03	32.32	67.68
7	16	2.43	34.75	65.25
8	12	1.82	36.57	63.43
9	17	2.58	39.15	60.85
10	10	1.52	40.66	59.34
11	7	1.06	41.73	58.27
12	4	0.61	42.33	57.67
13	9	1.37	43.70	56.30
14	10	1.52	45.22	54.78
15	3	0.46	45.67	54.33
16	2	0.30	45.98	54.02
TOTAL	303			

Table E-41
Survivor Curve Data—Converter Dolly 5th Wheel

800 TRAILERS
229 HAD AT LEAST 1 5TH WHEEL FAILURE IN T
571 CONVERTER DOLLIES HAVE HAD NO FAILURES OF 5TH WHEEL IN T

THERE HAD BEEN 61 SUBSEQUENT FAILURES OF 5TH WHEELS IN T

THUS, WE HAVE LIFETIME OF 61 COMPONENTS
AND WE KNOW THAT 571 WILL FAIL SOMETIME WHEN TIME > T

WE WILL DEVELOP SURVIVOR CURVE FROM INFO ON 632 COMPONENTS

Time Interval	No. of Failures	Percent Failed	Cum % Failed	% Surviving
1	7	1.11	1.11	98.89
2	8	1.27	2.38	97.62
3	6	0.95	3.33	96.67
4	4	0.63	3.96	96.04
5	4	0.63	4.59	95.41
6	6	0.95	5.54	94.46
7	5	0.79	6.33	93.67
8	5	0.79	7.12	92.88
9	2	0.32	7.44	92.56
10	4	0.63	8.07	91.93
11	3	0.47	8.55	91.45
12	2	0.32	8.86	91.14
13	2	0.32	9.18	90.82
14	1	0.16	9.34	90.66
15	1	0.16	9.50	90.50
16	1	0.16	9.65	90.35
TOTAL	61			

APPENDIX F

OVERALL TRUCK POPULATION AND TRAVEL STATISTICS

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The objective of this appendix is to identify the high-mileage subset of the large-truck population that is the primary target of the CVSA inspections. Most inspections are conducted on rural interstate roads since these roads generally have more suitable inspection facilities and the truck traffic volume is high. The first issue is to identify the appropriate subset of the national truck population for the focus of this analysis. Preliminary runs have been made using the NTTIS (National Truck Trip Information Survey) data to provide an overview of U.S. heavy trucks and their travel patterns.

Two dimensions along which large trucks may be classified are the GVWR (gross vehicle weight rating) and the power unit type. Table F-1 presents a breakdown of the national truck population according to the four categories of straight versus tractor and GVWR class 3-6 versus class 7 and 8. Straight trucks account for about 70% of all trucks, while tractor combinations comprise the remaining 30%. However, as indicated by Table F-2, tractors accumulate nearly 68% of annual truck mileage, while straight trucks account for only 32%. In terms of weight class, 48% of all trucks are GVWR 7-8 (Table F-1), but these trucks are responsible for 82% of annual truck mileage (Table F-2). Combining these two factors of interest, the tables indicate that while class 7 and 8 tractors make up only 28% of the national truck population, they account for 66% of the yearly miles traveled. These figures are a reflection of a much higher average annual mileage for the 7-8 tractor class, nearly 43,000 miles, as compared to the other three classes considered (Table F-3).

In terms of truck travel on limited access roads, GVWR 7-8 vehicles are responsible for 93% of this annual mileage (Table F-4), and tractors account for 87% of limited access travel (Table F-5). The proportion of travel on limited access roads varies directly with the configuration of the truck (Table F-6). Straight trucks log only 20% of their miles on limited access roads, compared to 59% for tractors. Trucks pulling trailers have more limited access travel than those without trailers, and this peaks for tractors hauling 2 or 3 trailers, with 72% of their mileage occurring on limited access roads.

Adding the rural/urban dimension to the discussion, straight trucks log 51% of their yearly mileage on rural roads, compared to 68% for tractors (Table F-7). Tractors account for 75% of all rural mileage, with straight trucks accumulating the remaining 25% (Table F-8).

Table F-9 presents figures for rural limited access travel. Tractors account for 92.3% of this mileage compared to 7.7% for straight trucks, and GVWR class 7-8 trucks log 96.3% of rural limited access miles compared to 3.7% for class 3-6 vehicles. The population of GVWR 7-8 tractors accounts for 91.6% of all rural limited access travel.

Travel patterns of trucks, in terms of land use and road class, differ according to the power unit. If total annual mileage is broken down into the four categories defined by urban versus rural and limited access versus other road types, the largest proportion of tractor travel, 38.6%, is on rural limited access roads (Table F-7). This type of travel represents the smallest proportion of straight truck mileage, accounting for only 7.4% of the yearly total. Table F-10 restricts the focus to GVWR class 7 and 8 vehicles. Despite a slight change in percentages, rural limited access travel still comprises the largest category for tractors and the smallest for straight trucks.

The next stage of the analysis focuses on average annual mileage. The objective is to identify the characteristics associated with trucks that have high average annual mileage. Straight trucks are distinguished from tractors throughout the analysis. Factors that are examined include carrier type (interstate versus intrastate, and private versus for-hire), model year (of the power unit), GVWR, and type of service (local versus over-the-road).

Average Annual Mileage by Truck Type and Use

Data from the National Truck Trip Information Survey (NTTIS) have been used to derive average annual mileage estimates for different classes of large trucks. The purpose of estimating these mileage figures is to enable the identification of characteristics associated with trucks that have high amounts of yearly travel. In the attached series of figures, the bars (or markers) in each graph represent the average annual mileage for a particular class of large truck.

Figure F-1 splits the trucks according to the type of power unit. The difference in annual mileage is dramatic, with straight trucks averaging just under 11,000 miles, while tractor combinations have a yearly average of nearly 44,000 miles.

Figure F-2 maintains the power unit split and further breaks down average annual mileage according to the GVWR class. The association between GVWR and average annual mileage differs between straight trucks and tractors. For the straight trucks, the mileage figures increase from class 5 through class 8, but the class 3 and 4 trucks have higher mileage figures than the class 5 group. This may be attributable to small sample sizes for both the class 3 and class 4 straight trucks. For the tractors, mileage increases gradually from class 4 through class 7 and then rises sharply for class 8 vehicles. While GVWR class 8 trucks have the highest average annual mileage estimates for both straights and tractors, this figure is only 19,175 miles for straights but 47,300 for tractors.

Figure F-3 shows the breakdown according to area of operation. Trucks belonging to companies that operate interstate put on more miles than intrastate trucks, but the difference is much sharper for tractors than for straight trucks. figure F-4 illustrates that for-hire trucks have higher average annual mileage than trucks operated by private companies, and this holds for both straight trucks and tractors.

Figures F-5 and F-6 combine the two factors of area of operation and operating authority. Figure F-5 illustrates a six-level breakdown of interstate/private carrier, interstate/ICC-authorized, interstate/ICC-exempt, intrastate/private carrier, intrastate/for-hire, and daily rental. The average annual mileage figures associated with these categories vary according to the power unit type. Among the straight trucks, intrastate/for hire trucks have the highest annual figures, averaging over 25,000 miles, followed by interstate/ICC-exempt, at 21,350 miles. Among the tractors, all three of the interstate categories have higher mileage estimates than the other three groups, with the interstate/ICC-exempt and interstate/ICC-authorized classes logging the most annual miles (50,741 and 50,050 miles respectively).

In a simpler classification, the average annual mileage figures are illustrated for the four classes defined by interstate versus intrastate and private versus for-hire companies in Figure F-6. Among both straight trucks and tractors, trucks belonging to intrastate/private companies average the fewest miles annually. Interstate/for-hire trucks have the highest annual mileage among tractors, while the intrastate/for-hire class has the highest figure among straight trucks.

Figure F-7 is a line graph representing average annual mileage by model year of the truck. The association between the age of the truck and the yearly miles traveled is stronger for the tractors than the straight trucks. This figure for tractors ranges from just over 28,000 miles for the 1972 and earlier models to more than 72,000 miles for the 1983 trucks. The entire range for the straight trucks is from 6,700 annual miles for the pre-1973 group to about 19,400 for the 1980 models. The three subsequent years show a decrease in average annual mileage among the straight trucks.

Trucks were also classified according to the usual type of service, with the results presented in Figures F-8 and F-9. Figure F-8 uses a three-level breakdown of local travel, short-haul (one-way trip distance of 50 to 200 miles), and long-haul (one-way trip distance of over 200 miles). In the NTTIS survey, owners were asked to estimate the percentage of annual mileage of their trucks over these three categories. In the first graph, the "local" category represents those trucks that have the greatest proportion of their mileage in the local travel category, with similar distinctions made for the short-haul and long-haul groups. Among both straights and tractors, the average annual mileage figures increase from the local group to the short-haul class to the long-haul trucks. The range for straights is from 10,200 to 24,200 miles, and for tractors from 24,200 to 65,750 miles.

Figure F-9 combines short-haul and long-haul travel in order to split trucks according to whether a greater proportion of their yearly mileage is spent in local versus over-the-road travel. The average annual mileage for the over-the-road group is twice as high as the local group among straight trucks and nearly two and a half times as high among tractors.

Figure F-10 represents tractors only and illustrates the association between cab style and average annual mileage. This figure rises from short to medium to long conventional cabs but is highest for cabovers at 52,665 miles per year.

In sum, of the factors examined, the following were found to be the most strongly associated with high average annual mileage for large trucks:

Tractor
GVWR class 8
Interstate carrier
For-hire company
Late model year
Long-haul service
Cabover

Interactions most likely exist between some of these factors that were not examined. An example would be older trucks being relegated to local service while newer ones engage in more over-the-road travel. These factors are studied in combination in the next section

Average Annual Mileage of Different Classes

The trucks were first split according to power unit (straights versus tractors) and then classified according to five dimensions simultaneously. The five dimensions that were considered are:

1. Company's area of operation – interstate vs. intrastate
2. Operating authority – private vs. for hire
3. Model Year – early models versus late models. Actual years used were 1979-84 for "late" and pre-1979 for "early".
4. GVWR – classes 3-6 versus 7-8
5. Usual travel range – local versus over-the-road

Since each of the five factors has two attributes, the resulting classification scheme has 32 categories each for straight trucks and tractor-trailers. The analysis was conducted on only 9 of the straight truck and 12 of the tractor categories, however, due to the small sample sizes of the remaining classes. Table F-11 shows the sample sizes of the truck classes selected for analysis. Categories with N < 25 were rejected and are included in the residual "other" categories. Also shown in Table F-11 are the weighted percents of each class, or the estimated proportion of the national large truck population that each of the categories represents. The 9 straight truck categories account for nearly 85% of all straight trucks, and the 12 tractor classes comprise about 83% of all tractor-trailers.

Table F-12 presents the estimated average annual mileage figures for each of the straight truck classes and Table F-13 does the same for the tractor-trailer categories. The tables show both the total annual miles as well as the mileage split according to land use and road class. This enables the identification of overall high-mileage trucks as well as those that travel heavily on particular types of roads, such as limited access roads in rural areas. The weighted percents shown in Table F-11 should be considered along with the information in Tables F-12 and F-13 so that the national representation of each truck class is kept in mind.

For example, according to Table F-11, the most common class of straight truck ationally out of the categories considered is the one described as "intrastate, private, rly model, GVWR 3-6, local travel". Nearly 35% of all straight trucks fall into this tegory. The average mileage of one of these trucks is only 6,196 miles annually, the vest of all the classes included in the analysis (Table F-12). Furthermore, only 126 of ose miles are accumulated on rural-limited access roads. The class of straight truck with both the highest average annual mileage and the greatest number of miles on rural-limited access roads is that defined as "interstate, private, late model, GVWR 7-8, over-the-road service". These trucks accumulate an average of 34,324 miles annually (Table F-12), more than triple the overall straight truck average, but they account for only 1.3% of straight trucks nationally (Table F-11).

The situation differs for the tractor-trailers. The three classes with the highest weighted percents also have the highest average annual mileage figures, as well as the greatest number of miles on rural-limited access roads. These three categories, which together account for over 39% of all tractor-trailers nationally (Table F-11), are "interstate, private, late model, GVWR 7-8, over-the-road", "interstate, for hire, early model, GVWR 7-8, over-the-road", and "interstate, for hire, late model, GVWR 7-8, over-the-road". As shown in Table F-13, the average annual mileage estimates for these three classes range from 53,873 to 69,080, and the number of rural-limited access miles is from 25,711 to 36,285.

Tables F-14 and F-15 show the percentages that each of the four land use/road class categories comprise for each of the truck classes. All of the straight truck classes are characterized by rural-limited access mileage which is less than 20% of all miles, and for several of the classes such travel accounts for only 2 or 3% of the annual mileage (Table

F-14). The tractor-trailers show more variation in the proportion of rural-limited access travel (Table F-15). The three classes previously identified as logging the greatest number of miles annually also have the greatest proportion of rural-limited access miles, with the highest reaching 52.5% of all miles traveled. The class with the lowest proportion of rural-limited access miles among the tractors is that described as "interstate, for hire, early model, GVWR 7-8, local service", at 12.9%. Only 2,780 of this category's annual 21,533 miles are driven on rural-limited access roads (Table F-13).

The analysis described in this section was carried out for two main purposes. Whereas previous analyses had produced average annual mileage estimates for different classes of large trucks, the factors were considered individually, or at most in pairs (power unit type and some other factor). The current analysis provides a much finer classification of trucks, taking into account six factors (including power unit type) simultaneously. Second, the average annual mileage figures produced here have been subdivided across four categories of land use and road type. This is of interest since inspecting stations are frequently located on rural-limited access roads, and trucks logging high mileage on such roads may be more likely targets of safety inspections. The tables included in this appendix allow for the identification of overall high-mileage trucks, those with high mileage on particular types of roads, and an estimate of how common particular classes of trucks are on a national basis.

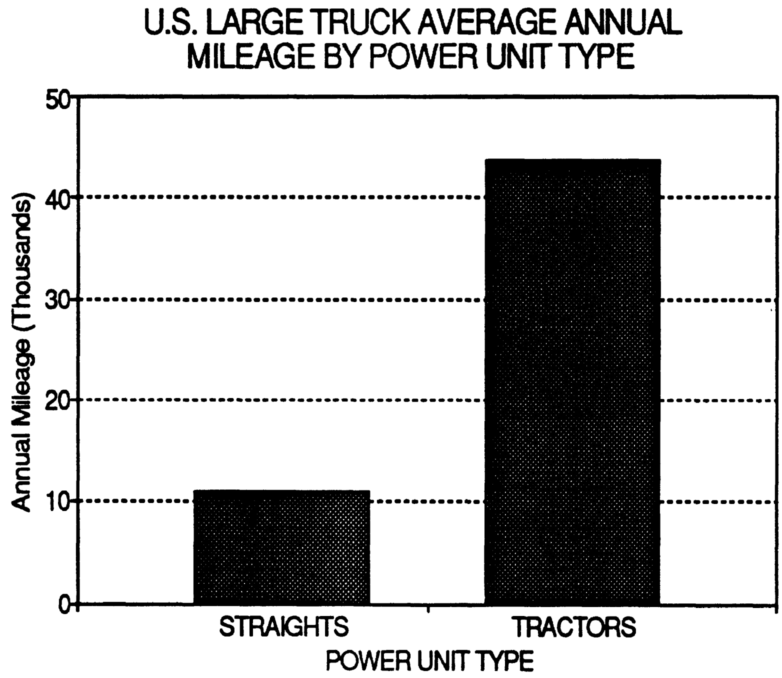


Figure F-1

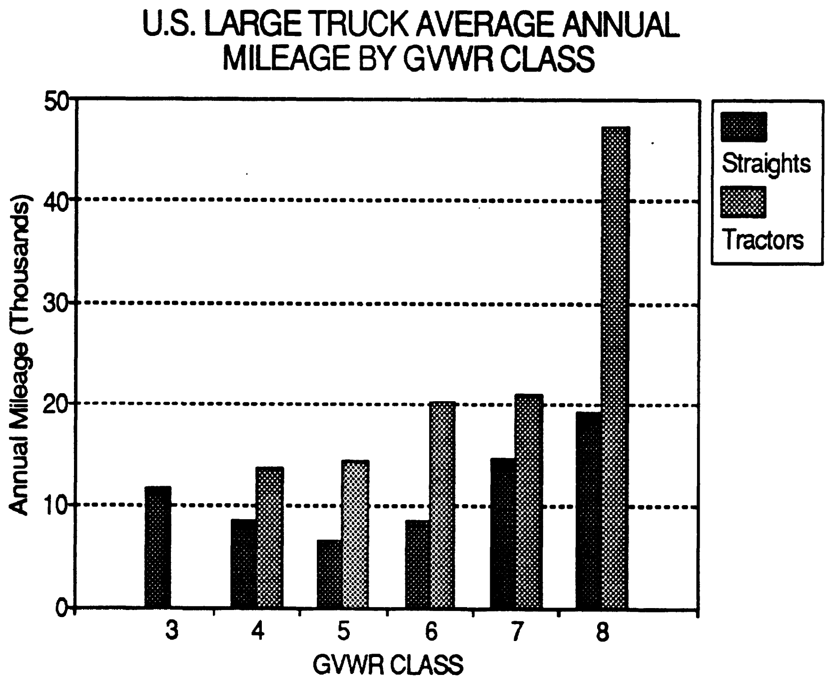
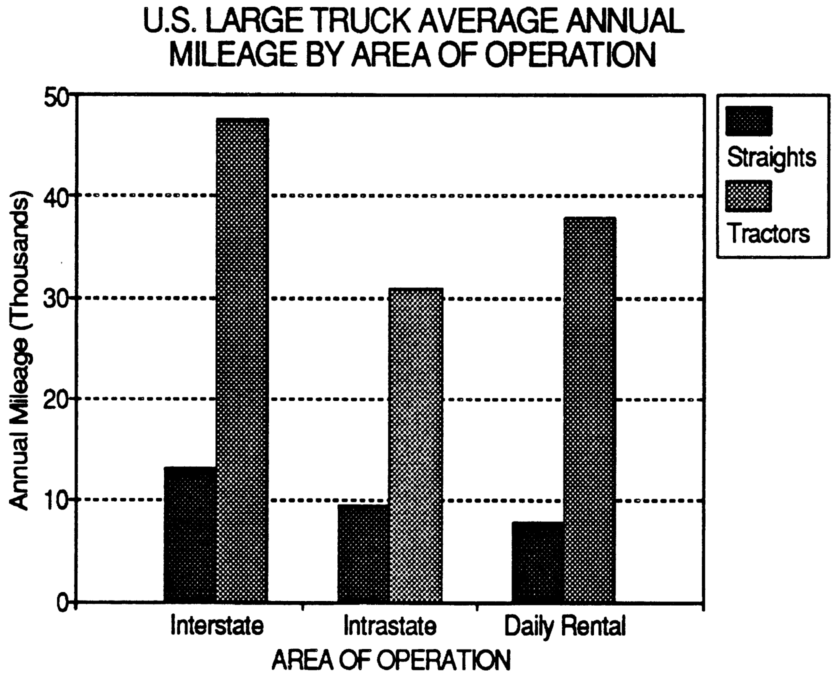


Figure F-2



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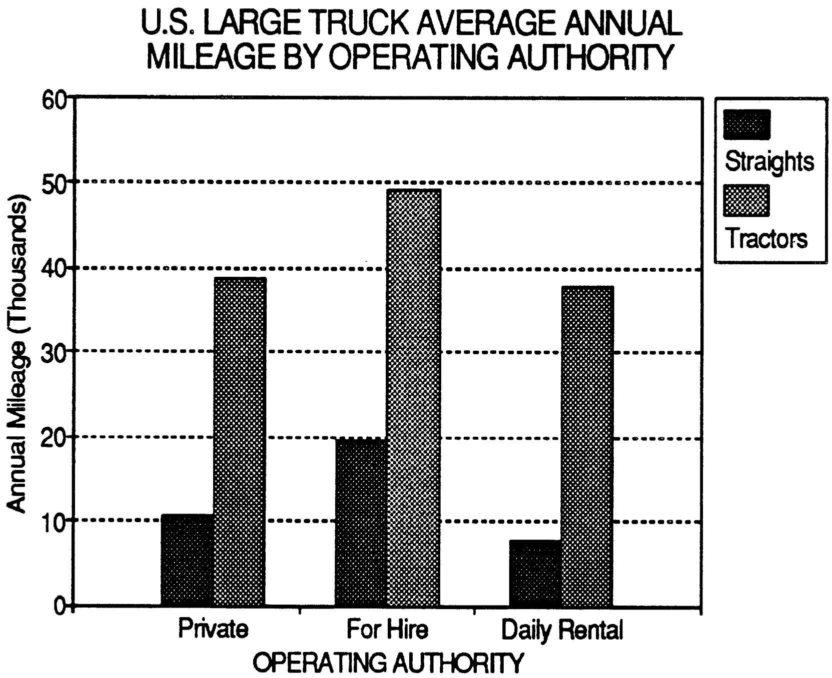

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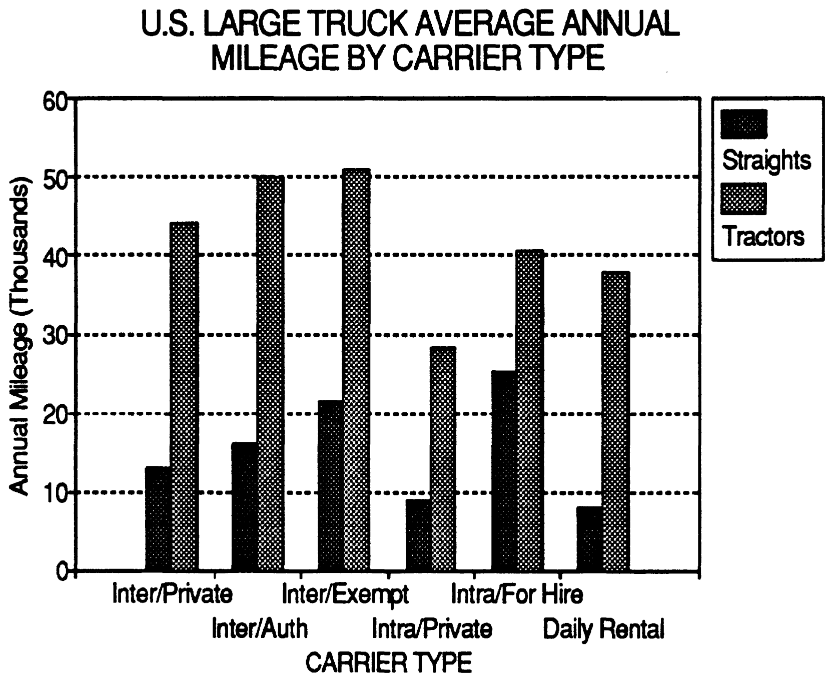

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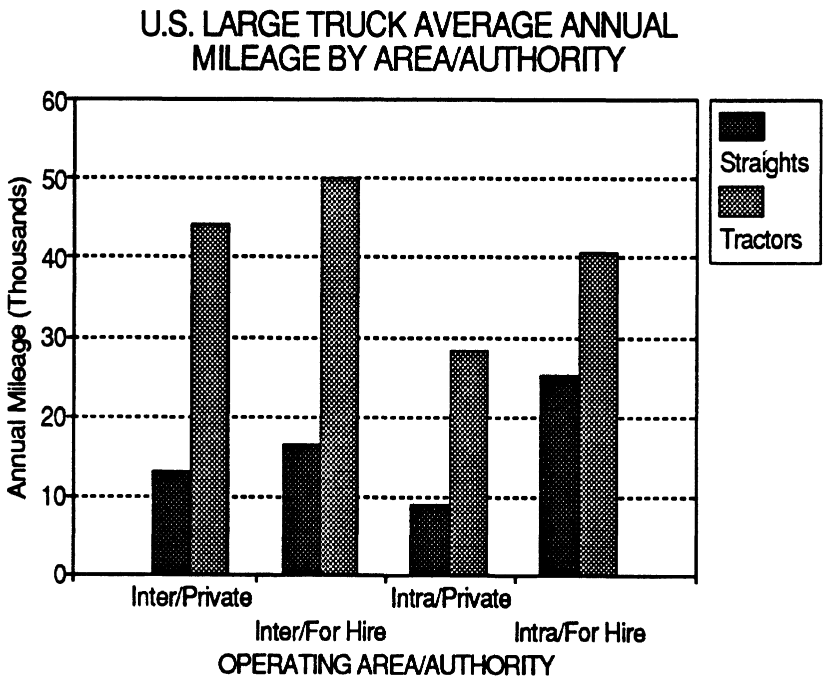

Figure F-6

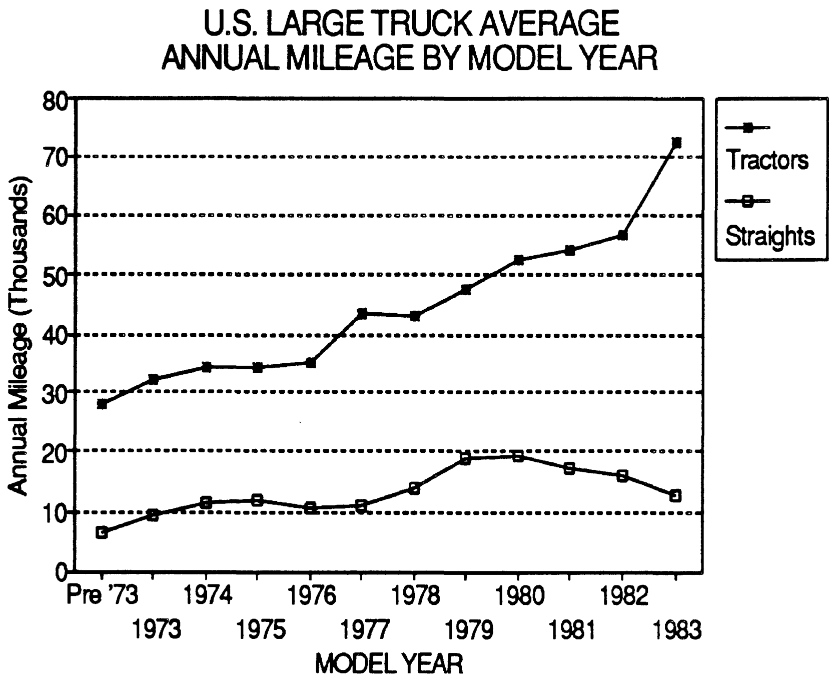

Figure F-7

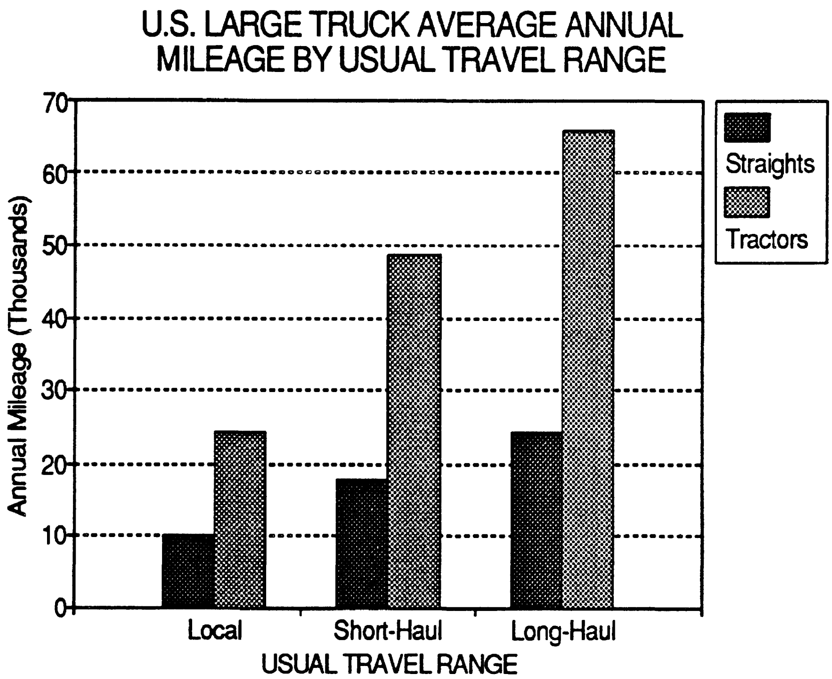

Figure F-8

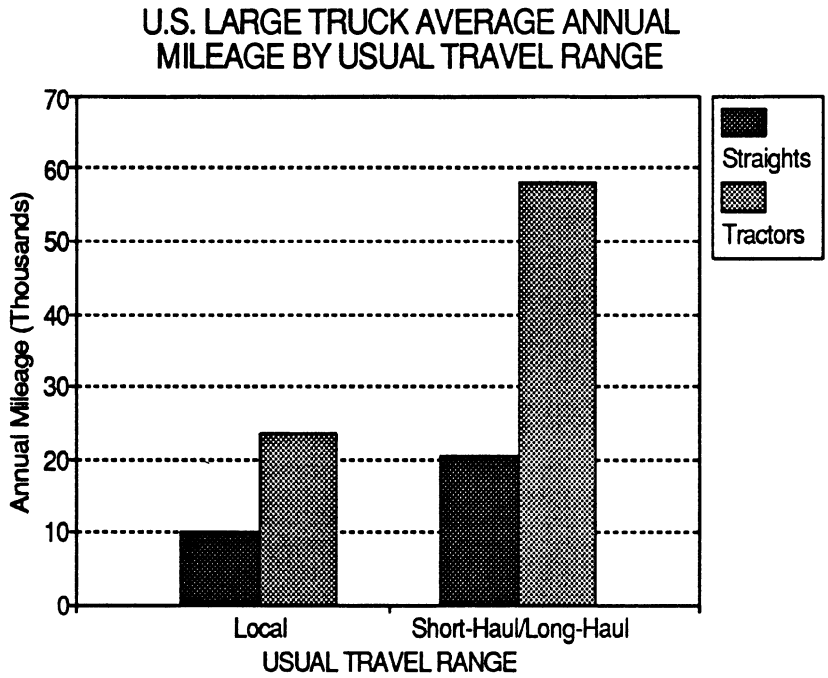

Figure F-9

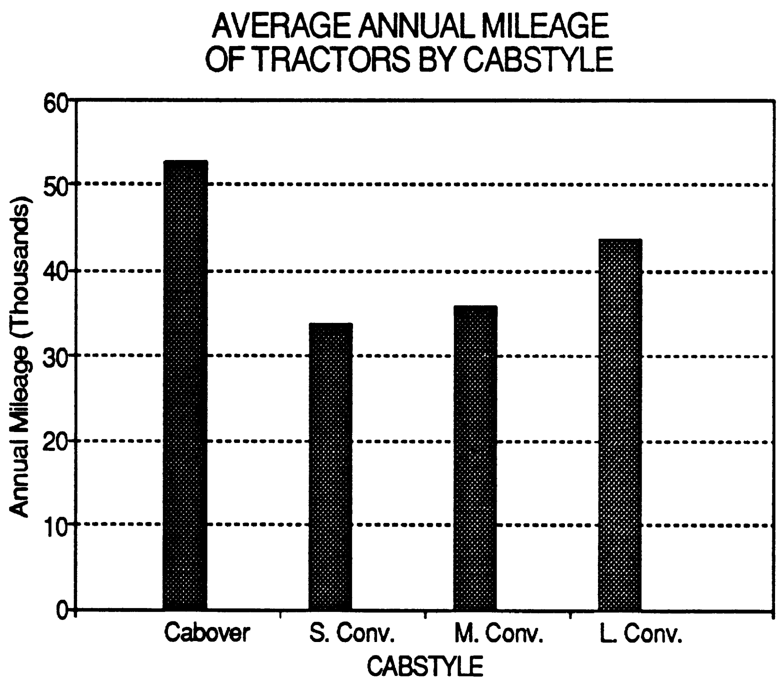

Figure F-10

TABLE F-1
U.S. Large Truck Population by Power Unit Type and Weight Class 1985–1987 NTTIS

POWER UNIT TYPE		GVWR CLASS		TOTAL
		Class 3–6	Class 7–8	
Straight	Sample N	2030	1601	3631
	Nat'l Pop. Estimate	1,551,864	624,360	2,176,223
	Column %	96.82	41.95	70.41
	Total %	50.21	20.20	70.41
Tractor	Sample N	112	2474	2586
	Nat'l Pop. Estimate	50,909	863,821	914,729
	Column %	3.18	58.05	29.59
	Total %	1.65	27.95	29.59
TOTAL	Sample N	2142	4075	6217
	Nat'l Pop. Estimate	1,602,773	1,488,180	3,090,953
	Column %	100.00	100.00	100.00
	Total %	51.85	48.15	100.00

TABLE F-2
Annual Millions of Miles Traveled by Power Unit Type and Weight Class for U.S. Heavy Trucks 1985–1987 NTTIS

POWER UNIT TYPE		GVWR CLASS		TOTAL
		Class 3–6	Class 7–8	
Straight	Sample N (trips)	1,667	3,230	4,897
	Estimated Mileage	9,529	8,434	17,964
	Column %	92.97	18.55	32.24
	Total %	17.10	15.14	32.24
Tractor	Sample N (trips)	224	7,926	8,150
	Estimated Mileage	721	37,040	37,761
	Column %	7.03	81.45	67.76
	Total %	1.29	66.47	67.76
TOTAL	Sample N (trips)	1,891	11,156	13,047
	Estimated Mileage	10,250	45,474	55,725
	Column %	100.00	100.00	100.00
	Total %	18.39	81.61	100.00

TABLE F-3
Average Annual Mileage by Power Unit Type and Weight Class
1985–1987 NTTIS

AVERAGE ANNUAL MILEAGE			
POWER UNIT TYPE	GVWR CLASS		TOTAL
	Class 3–6	Class 7–8	
Straight	6,141	13,509	8,255
Tractor	14,158	42,879	41,281
TOTAL	6,395	30,557	18,028

TABLE F-4
Annual Millions of Miles Traveled by Road Class and Weight Class for U.S. Heavy Trucks
1985–1987 NTTIS

ROAD CLASS		GVWR CLASS		TOTAL
		Class 3–6	Class 7–8	
	Sample N (trips)	1,891	11,156	13,047
Limited Access	Estimated Mileage Row % Total %	1,689 6.90 3.26	22,794 93.10 44.00	24,483 100.00 47.26
Other Roads	Estimated Mileage Row % Total %	7,647 27.99 14.76	19,671 72.01 37.97	27,318 100.00 52.74
TOTAL	Estimated Mileage Total %	9,335 18.02	42,466 81.98	51,801 100.00

TABLE F-5
Annual Millions of Miles Traveled by Road Class for Various Heavy Truck Configurations 1985–1987 NTTIS

TRUCK TYPE	ROAD CLASS				TOTAL	
	Limited Access		Other			
	Miles	Column Percent	Miles	Column Percent	Miles	Column Percent
Straight Trucks Alone	2,879	11.77%	11,801	43.29%	14,680	28.39%
Straight Trucks w/ 1–2 Trailers	319	1.30	671	2.46	990	1.91
All Straight Trucks	3,198	13.08%	12,473	45.75%	15,671	30.30%
Tractors Alone (Bobtails)	307	1.26%	279	1.02%	587	1.13%
Tractors with 1 Trailer	19,492	79.72	13,958	51.20	33,450	64.68
Tractors with 2–3 Trailers	1,454	5.94	553	2.03	2,007	3.88
All Tractors	21,253	86.92%	14,790	54.25%	36,044	69.70%
Total Trucks	24,451	100.00%	27,263	100.00%	51,714	100.00%

TABLE F-6
Annual Millions of Miles Traveled by Road Class for Various Heavy Truck Configurations 1985–1987 NTTIS

TRUCK TYPE	ROAD CLASS				TOTAL	
	Limited Access		Other			
	Miles	Row Percent	Miles	Row Percent	Miles	Row Percent
Straight Trucks Alone	2,879	19.61%	11,801	80.39%	14,680	100.0%
Straight Trucks w/ 1–2 Trailers	319	32.19	671	67.81	990	100.0
All Straight Trucks	3,198	20.41%	12,473	79.59%	15,671	100.00%
Tractors Alone (Bobtails)	307	52.42	279	47.58	587	100.0
Tractors with 1 Trailer	19,492	58.27	13,958	41.73	33,450	100.0
Tractors with 2–3 Trailers	1,454	72.42	553	27.58	2,007	100.0
All Tractors	21,253	58.97%	14,790	41.03%	36,044	100.00%
Total Trucks	24,451	47.28%	27,263	52.72%	51,714	100.0%

TABLE F-7
Annual Millions of Miles Traveled by
All Heavy Trucks according to
Land Use, Road Class, and Power Unit Type
1985–1987 NTTIS

LAND USE/ ROAD CLASS		POWER UNIT TYPE		TOTAL
		Straight	Tractor	
	Sample N (trips)	4,897	8,150	13,047
Urban/Limited	Estimated Mileage	2,081	7,305	9,387
	Column %	13.25	20.24	18.12
Urban/Other	Estimated Mileage	5,616	4,385	10,002
	Column %	35.76	12.15	19.31
Rural/Limited	Estimated Mileage	1,165	13,935	15,099
	Column %	7.42	38.60	29.15
Rural/Other	Estimated Mileage	6,842	10,474	17,316
	Column %	43.57	29.01	33.43
Urban	Estimated Mileage	7,698	11,691	19,388
	Column %	49.02	32.38	37.43
Rural	Estimated Mileage	8,007	24,409	32,415
	Column %	50.98	67.62	62.57
Limited Access	Estimated Mileage	3,246	21,240	24,486
	Column %	20.67	58.84	47.27
Other Roads	Estimated Mileage	12,458	14,859	27,318
	Column %	79.33	41.16	52.73
TOTAL	Estimated Mileage	15,704	36,099	51,804
	Column %	100.00	100.00	100.00

TABLE F-8
Annual Millions of Miles Traveled by All Heavy Trucks according to Land Use, Road Class, and Power Unit Type 1985–1987 NTTIS

LAND USE/ ROAD CLASS		POWER UNIT TYPE		TOTAL
		Straight	Tractor	
	Sample N (trips)	4,897	8,150	13,047
Urban/Limited	Estimated Mileage	2,081	7,305	9,387
	Row %	22.17	77.83	100.00
Urban/Other	Estimated Mileage	5,616	4,385	10,002
	Row %	56.15	43.85	100.00
Rural/Limited	Estimated Mileage	1,165	13,935	15,099
	Row %	7.71	92.29	100.00
Rural/Other	Estimated Mileage	6,842	10,474	17,316
	Row %	39.51	60.49	100.00
Urban	Estimated Mileage	7,698	11,691	19,388
	Row %	39.70	60.30	100.00
Rural	Estimated Mileage	8,007	24,409	32,415
	Row %	24.70	75.30	100.00
Limited Access	Estimated Mileage	3,246	21,240	24,486
	Row %	13.26	86.74	100.00
Other Roads	Estimated Mileage	12,458	14,859	27,318
	Row %	45.61	54.39	100.00
TOTAL	Estimated Mileage	15,704	36,099	51,804
	Row %	30.32	69.68	100.00

TABLE F-9
Annual Millions of Miles Traveled by Heavy Trucks on Rural Limited Access Roads by Weight Class and Power Unit Type 1985–1987 NTTIS

POWER UNIT TYPE		GVWR CLASS Class 3–6	GVWR CLASS Class 7–8	TOTAL
Straight	Sample N (trips)	1,667	3,230	4,897
	Estimated Mileage	451	714	1,165
	Row %	38.73	61.27	100.00
	Total %	2.99	4.73	7.71
Tractor	Sample N (trips)	224	7,926	8,150
	Estimated Mileage	102	13,833	13,935
	Row %	0.73	99.27	100.00
	Total %	0.68	91.61	92.29
TOTAL	Sample N (trips)	1,891	11,156	13,047
	Estimated Mileage	553	14,546	15,099
	Row %	3.66	96.34	100.00
	Total %	3.66	96.34	100.00

TABLE F-10
Annual Millions of Miles Traveled by GVWR Class 7 and 8 Trucks according to Land Use, Road Class, and Power Unit Type 1985–1987 NTTIS

LAND USE/ ROAD CLASS		POWER UNIT TYPE		TOTAL
		Straight	Tractor	
	Sample N (trips)	3,230	7,926	11,156
Urban/Limited	Estimated Mileage	1,042	7,206	8,248
	Column %	14.78	20.35	19.42
Urban/Other	Estimated Mileage	2,686	4,213	6,899
	Column %	38.10	11.90	16.25
Rural/Limited	Estimated Mileage	714	13,833	14,546
	Column %	10.12	39.06	34.25
Rural/Other	Estimated Mileage	2,608	10,163	12,772
	Column %	36.99	28.70	30.08
Urban	Estimated Mileage	3,729	11,419	15,147
	Column %	52.88	32.24	35.67
Rural	Estimated Mileage	3,322	23,996	27,318
	Column %	47.12	67.76	64.33
Limited Access	Estimated Mileage	1,756	21,038	22,794
	Column %	24.91	59.40	53.68
Other Roads	Estimated Mileage	5,295	14,377	19,671
	Column %	75.09	40.60	46.32
TOTAL	Estimated Mileage	7,051	35,415	42,465
	Column %	100.00	100.00	100.00

TABLE F-11
Sample Sizes and Weighted Percentages for Selected Classes of Large Trucks
1985–1987 NTTIS

STRAIGHT TRUCKS		
Straight Truck Category	Sample N	Weighted Percent
Inter/Priv./Early/3–6/Local	133	17.8%
Inter/Priv./Early/7–8/Local	157	6.3
Inter/Priv./Late/3–6/Local	46	4.0
Inter/Priv./Late/7–8/Local	89	2.9
Intra/Priv./Early/3–6/Local	225	34.7
Intra/Priv./Early/7–8/Local	195	8.2
Intra/Priv./Late/3–6/Local	49	4.1
Intra/Priv./Late/7–8/Local	133	5.4
Inter/Priv./Late/7–8/Haul	40	1.3
All Other Straight Trucks	252	15.4
All Straight Trucks	1,319	100.0%

TRACTOR-TRAILERS		
Tractor-Trailer Category	Sample N	Weighted Percent
Inter/Priv./Early/7–8/Local	93	6.6%
Inter/Priv./Early/7–8/Haul	136	9.2
Inter/Priv./Late/7–8/Local	66	3.8
Inter/Priv./Late/7–8/Haul	171	10.3
Inter/Hire/Early/7–8/Local	110	7.4
Inter/Hire/Early/7–8/Haul	202	13.1
Inter/Hire/Late/7–8/Local	56	3.1
Inter/Hire/Late/7–8/Haul	277	16.1
Intra/Priv./Early/7–8/Local	87	5.8
Intra/Priv./Early/7–8/Haul	37	2.4
Intra/Priv./Late/7–8/Local	59	3.2
Intra/Hire/Early/7–8/Local	38	2.1
All Other Tractors	276	16.9
All Tractors	1,608	100.0%

KEY:
Inter = Interstate   Intra = Intrastate
Priv. = Private   Hire = For Hire
Early = model years prior to 1979   Late = model years 1979–84
3–6 = GVWR classes 3–6   7–8 = GVWR classes 7–8
Local = Local service   Haul = Over-the-road service

TABLE F-12
Average Annual Mileage of Selected Classes of Straight Trucks with Mileage Split According to Land Use and Road Class 1985–1987 NTTIS

Straight Truck Category	LAND USE/ROAD CLASS				
	Rural/Limited	Rural/Other	Urban/Limited	Urban/Other	TOTAL
Inter/Priv./Early/3–6/Local	280	4,913	605	2,711	8,509
Inter/Priv./Early/7–8/Local	1,555	6,462	1,595	5,111	14,724
Inter/Priv./Late/3–6/Local	2,705	3,144	4,735	5,841	16,425
Inter/Priv./Late/7–8/Local	1,305	6,269	3,367	6,948	17,889
Intra/Priv./Early/3–6/Local	126	3,620	500	1,950	6,196
Intra/Priv./Early/7–8/Local	438	4,278	2,000	5,776	12,492
Intra/Priv./Late/3–6/Local	300	3,139	1,195	4,673	9,307
Intra/Priv./Late/7–8/Local	1,104	6,084	2,436	8,611	18,235
Inter/Priv./Late/7–8/Haul	6,734	14,031	4,781	8,778	34,324
All Other Straight Trucks	1,804	5,396	2,480	5,936	15,616
All Straight Trucks	813	4,666	1,457	4,072	11,009

KEY:
Inter = Interstate Intra = Intrastate
Priv. = Private Hire = For Hire
Early = model years prior to 1979 Late = model years 1979–84
3–6 = GVWR classes 3–6 7–8 = GVWR classes 7–8
Local = Local service Haul = Over-the-road service

TABLE F-13
Average Annual Mileage of Selected Classes of Tractor-Trailers with Mileage Split According to Land Use and Road Class
1985–1987 NTTIS

Tractor-Trailer Category	LAND USE/ROAD CLASS				
	Rural/Limited	Rural/Other	Urban/Limited	Urban/Other	TOTAL
Inter/Priv./Early/7–8/Local	3,080	7,724	3,453	4,969	19,226
Inter/Priv./Early/7–8/Haul	15,089	17,736	8,206	4,850	45,880
Inter/Priv./Late/7–8/Local	5,586	15,383	5,418	6,901	33,288
Inter/Priv./Late/7–8/Haul	28,038	18,674	13,587	6,123	66,421
Inter/Hire/Early/7–8/Local	2,780	5,950	5,248	7,555	21,533
Inter/Hire/Early/7–8/Haul	25,711	12,451	11,225	4,486	53,873
Inter/Hire/Late/7–8/Local	4,250	4,334	6,186	8,874	23,643
Inter/Hire/Late/7–8/Haul	36,285	12,889	15,413	4,493	69,080
Intra/Priv./Early/7–8/Local	3,364	11,851	3,241	4,473	22,928
Intra/Priv./Early/7–8/Haul	9,245	16,033	4,356	3,255	32,890
Intra/Priv./Late/7–8/Local	3,969	10,131	5,276	10,135	29,511
Intra/Hire/Early/7–8/Local	5,498	13,429	10,246	5,319	34,491
All Other Tractors	10,199	12,113	7,014	6,214	35,541
All Tractors	16,576	12,654	8,970	5,642	43,842

KEY:
Inter = Interstate   Intra = Intrastate
Priv. = Private   Hire = For Hire
Early = model years prior to 1979   Late = model years 1979–84
3–6 = GVWR classes 3–6   7–8 = GVWR classes 7–8
Local = Local service   Haul = Over-the-road service

TABLE F-14
Average Annual Mileage of Selected Classes of Straight Trucks with Mileage Split According to Land Use and Road Class
Row Percents
1985–1987 NTTIS

Straight Truck Category	LAND USE/ROAD CLASS				
	Rural/Limited	Rural/Other	Urban/Limited	Urban/Other	TOTAL
Inter/Priv./Early/3–6/Local	3.29%	57.74%	7.11%	31.86%	100.00%
Inter/Priv./Early/7–8/Local	10.56	43.89	10.83	34.72	100.00
Inter/Priv./Late/3–6/Local	16.47	19.14	28.83	35.56	100.00
Inter/Priv./Late/7–8/Local	7.29	35.04	18.82	38.84	100.00
Intra/Priv./Early/3–6/Local	2.04	58.43	8.06	31.47	100.00
Intra/Priv./Early/7–8/Local	3.51	34.24	16.01	46.24	100.00
Intra/Priv./Late/3–6/Local	3.22	33.73	12.84	50.21	100.00
Intra/Priv./Late/7–8/Local	6.06	33.36	13.36	47.22	100.00
Inter/Priv./Late/7–8/Haul	19.62	40.88	13.93	25.57	100.00
All Other Straight Trucks	11.55	34.55	15.88	38.01	100.00
All Straight Trucks	7.39%	42.39%	13.24%	36.99%	100.00%

KEY:
Inter = Interstate   Intra = Intrastate
Priv. = Private   Hire = For Hire
Early = model years prior to 1979   Late = model years 1979–84
3–6 = GVWR classes 3–6   7–8 = GVWR classes 7–8
Local = Local service   Haul = Over-the-road service

TABLE F-15
Average Annual Mileage of Selected Classes of Tractor-Trailers with Mileage Split According to Land Use and Road Class
Row Percents
1985–1987 NTTIS

Tractor-Trailer Category	LAND USE/ROAD CLASS				
	Rural/Limited	Rural/Other	Urban/Limited	Urban/Other	TOTAL
Inter/Priv./Early/7–8/Local	16.02%	40.18%	17.96%	25.84%	100.00%
Inter/Priv./Early/7–8/Haul	32.89	38.66	17.89	10.57	100.00
Inter/Priv./Late/7–8/Local	16.78	46.21	16.28	20.73	100.00
Inter/Priv./Late/7–8/Haul	42.21	28.11	20.46	9.22	100.00
Inter/Hire/Early/7–8/Local	12.91	27.63	24.37	35.08	100.00
Inter/Hire/Early/7–8/Haul	47.73	23.11	20.84	8.33	100.00
Inter/Hire/Late/7–8/Local	17.98	18.33	26.16	37.53	100.00
Inter/Hire/Late/7–8/Haul	52.53	18.66	22.31	6.50	100.00
Intra/Priv./Early/7–8/Local	14.67	51.69	14.13	19.51	100.00
Intra/Priv./Early/7–8/Haul	28.11	48.75	13.25	9.90	100.00
Intra/Priv./Late/7–8/Local	13.45	34.33	17.88	34.34	100.00
Intra/Hire/Early/7–8/Local	15.94	38.94	29.70	15.42	100.00
All Other Tractors	28.70	34.08	19.73	17.48	100.00
All Tractors	37.81%	28.86%	20.46%	12.87%	100.00%

KEY:
Inter = Interstate   Intra = Intrastate
Priv. = Private   Hire = For Hire
Early = model years prior to 1979   Late = model years 1979–84
3–6 = GVWR classes 3–6   7–8 = GVWR classes 7–8
Local = Local service   Haul = Over-the-road service