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EFFECT OF COMMERCIAL VEHICLE SYSTEMATIC PREVENTIVE MAINTENANCE ON SPECIFIC CAUSES OF ACCIDENTS

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16. Abstract The purpose of this program was to determine the effect of proper commercial vehicle inspection and maintenance procedures on safety and to document the need for improved or modified inspection and maintenance requirements as stated in the Federal Motor Carrier Safety Regulations.

Sources of data for this study included the current technical literature, existing accident and population data, surveys of regulatory personnel and agencies, meetings with trucking industry personnel concerned with inspection and maintenance, and collection of supplemental accident information.

Based on our data analysis we conclude that there is an identifiable relationship between good inspection and maintenance practices and a reduction in defect-related accidents; in addition, the better maintenance practices are usually associated with the larger firms (who view their actions in this regard as largely of economic benefit) and the poorer maintenance practices are associated with the smaller firms or individuals (who do not or are not willing to commit the resources, financial or otherwise, to perform adequate maintenance and inspection).

Based on our data analysis and observations, we recommend that the Bureau formalize the current practices of the better motor carrier with respect to vehicle inspection and expand the enforcement and education activities of the Bureau.

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I. INTRODUCTION

Since January, 1974, the Highway Safety Research Institute has been engaged in a study of the "Effect of Commercial Vehicle Systematic Preventive Maintenance on Specific Causes of Accidents." This final report presents the relevant findings, describes the methodology used, and summarizes the content of the available literature specific to the problem of preventive maintenance programs and their effect on accidents involving large commercial vehicles. Specific recommendations are made to the Bureau of Motor Carrier Safety as a focal point for the Bureau to use in beginning the process of revising Section 396 (Inspection and Maintenance) of the Federal Motor Carrier Safety Rules and Regulations [FMCSR].

The study had three objectives:

1. Determine the extent to which accident causation is influenced by preventive maintenance.
2. Evaluate, in the light of that information, the effectiveness of the inspection and maintenance requirements of the [F]MCSR.
3. Develop recommendations, as appropriate, to improve the effectiveness of [F]MCSR.

To meet these objectives, four tasks were specified in the contract:

<u>Task A -- Literature Review</u>

1. Review extant data and studies and assess the effectiveness of State Periodic Motor Vehicle Inspection (PMVI) systems as they relate to the safety of commercial vehicle operations.

2. Review relavant data to determine whether significant data relating accidents to compliance with the inspection and maintenance requirements of the MCSR can be discerned.

Task B -- Research Plan

Establish the methodology to evaluate the effectiveness of preventive maintenance on reducing commercial vehicle accidents.

Task C -- Accident Review

1. Through an evaluation of accident data available from the Bureau and other sources, evaluate the total effect of periodic preventive maintenance on accident causation. The evaluation shall include, but not be limited to, statistically significant inferences drawn from large numbers of accidents and inferences drawn from in-depth accident investigations from various sources.

2. Conduct interviews with the following types of individuals:

   a. "Experts" in the field of commercial vehicle operation and fleet safety.

   b. Maintenance personnel.

   c. Administrators of State PMVI programs.

   d. Prominent persons holding the opinion that PMVI is of only limited effectiveness.

3. Compare detailed summaries of "expert" opinion obtained in Item C-2 (above) with data found from both the literature search and the accident study phases.

Task D -- Evaluation of MCSR Requirements

1. In the light of the information gained in Tasks A, B, and C, evaluate the effectiveness of present requirements.

2. Recommend improvements in inspection and maintenance regulations designed to improve safety and promote commercial vehicle safety performance. These recommendations shall take into consideration the nature of the industry regulated, costs and benefits, and the practicality of implementing such recommendations. These recommendations, as such, shall not be in the form of specifically worded regulations but shall be stated in general terms.

This constitutes the final report on the project. The literature review (Task A) was begun early in the program, and is included in this report as Appendix A. The technical literature concerning the effectiveness of various motor vehicle inspection activities, and the trade literature which treats primarily method for improving inspection and maintenance, are reviewed and discussed. In addition, a brief section reviews the jurisdiction of the Bureau of Motor Carrier Safety in setting the stage for discussions and comments about possible changes in rulemaking.

The research plan (Task B) was the subject of an interim report, but pertinent portions of that report have been updated and are given in Chapter III. This outlines the methodology of the study.

The accident review (Task C) included the acquisition of a number of sets of accident data, as well as numerous meetings with industry and government personnel regarding maintenance practice and accident involvement. The data acquisition procedures, and the bulk of the analyses of the data, are provided in Chapter V.

The evaluation of the [F]MCSR requirements (Task D) is reported in connection with the summary and conclusions section of the report in Chapter II. This chapter begins with a brief summary, followed by a set of conclusions, recommendations, and a discussion of these.

The sense of the report may be gained by a reading of the first three sections, although the serious reader should ultimately read both the literature review (Appendix A) and the data and analysis section (Chapter V).

II. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. Introduction

This program was initiated by the Bureau of Motor Carrier Safety to determine the effect of proper commercial vehicle inspection and maintenance procedures on safety, and to document the need for improved or modified inspection and maintenance requirements in the Motor Carrier Safety Regulations. In response to FHWA Request for Proposal #259 The University of Michigan Highway Safety Research Institute undertook to review the literature in this field, acquire and analyze accident and other data, compare this derived information with the current regulations, and to report findings and recommendations to the sponsor.

B. Summary

Sources of data for this study included the current technical literature, existing accident and population records, surveys of regulatory personnel and agencies, surveys of trucking industry personnel concerned with inspection and maintenance, and collection of supplemental accident information. Existing recent accident data, both police-reported and carrier-reported, were examined. Supplementary data were compiled by interviews of drivers involved in vehicle defect-related accidents, as well as by a comparison of this accident data with data on accidents without noted defects. Interview guidelines were developed and applied to a specifically defined sample of motor carriers in three states representing a variety of geographical and operating characteristics to determine differences in inspection and maintenance practices throughout the industry. BMCS field personnel, trucking industry executives, and state periodic motor vehicle inspection administrators were interviewed to determine their views of the relationship between inspection and maintenance and accidents, and to use them as a sounding board for ideas generated during this study.

The interview and supplementary accident data were transformed into digital form for computer analysis, and statistical analyses of these were conducted. The analyses conclude that there is an identifiable relationship between good inspection and maintenance practices and a reduction in defect-related accidents, with the more effective maintenance practices usually associated with the larger firms who view their actions in this regard as largely of economic benefit. The poorer maintenance practices are more likely to be associated with smaller firms or individual owners who do not or are not willing to commit the resources (financial or otherwise) to perform adequate maintenance and inspection. Only 16% of the small fleets surveyed required a written pre-trip inspection whereas 59% of the large fleets required such a detailed inspection procedure. Of the vehicles involved in accidents, 37% of the drivers of such vehicles from small fleets reported using a written pre-trip inspection, whereas 51% of the drivers associated with large fleets used the written pre-trip inspection.

The principal defects identified as accident-causing in this study are those likely to be visually detectable--namely tires, brakes, lights, and wheels. The single most important factor in minimizing the incidence of defect-related commercial vehicle accidents is the detection of the defect. We conclude that the most important detection mechanism lies within the driver himself, although more formal garage periodic inspection also plays a useful role.

C. Conclusions

Description of Vehicle Defect Involvement in Truck Accidents

More than 6% of the truck accident involvements reported to police agencies in one large state noted vehicle defects as a causative factor in the collision. This is as opposed to a 2% value for passenger cars in the same data. Trucks 10 years of age and older averaged about 10% for the same statistic; trucks less than three years old averaged about 4%. Defect-involved truck accidents were most likely to produce property damage only, and to be single vehicle accidents. But there were numerous injury and some fatal accidents reported too.

The most numerous defects reported were of brakes, tires, and wheel failures--about 70% of all defect accident cases. Note that all of these are failures in relatively visible components of the vehicles.

Maintenance Practice in the Trucking Industry

The maintenance practices as used by the trucking industry can be divided into three types of systems: sophisticated, adequate, and breakdown. The companies employing a sophisticated or adequate system inspect and perform maintenance activities (lubrication, etc. and repairs) on a periodic basis--recognizing the economic benefits resulting from keeping the rolling stock serviceable. Their overall attempts are to reduce vehicle breakdowns and out-of-service conditions.

The breakdown maintenance system is in reality a repair system which is invoked only upon failure or breakdown of the vehicle while in service.

The differences which exist between the sophisticated and adequate systems of maintenance are largely in the areas of record keeping and potential malfunction detection. An adequate system will employ procedures which detect defects on a day to day basis and prevent most breakdowns. Records will be manual and allow for analysis of overall operating costs.

A sophisticated maintenance system will employ advanced detection procedures using either vehicle inspection and component analysis methods or computer records of component use and replacement or both.

Relationship Between Maintenance Practice and Defect-Related Accidents

We conclude, on the basis of the studies conducted in this program, that inspection and repair does reduce the incidence of defect-related truck accidents. The several kinds of inspection activities--daily driver inspections before and after a trip, periodic garage inspections conducted by or for the owner, initial inspections (e.g., at time of initial use by carrier, change to a new service, etc.), and a state-operated periodic motor vehicle inspection--all have some ability to keep an improved group of vehicles on the highways. Their importance is probably in the order noted here, and they are discussed separately below.

Our analysis of interviews of accident-involved drivers in Texas indicates that those drivers who conduct a careful pre-trip inspection are less likely to become involved in a vehicle-defect accident. This pre-trip inspection by the driver is most important because it is the last opportunity to check the visible defects before proceeding onto the road. There is evidence that a written inspection report prior to the trip is more effective than a non-written one. The drivers who conducted a written pre-trip inspection detected defects and were also the ones not involved in the defect related crashes (see Analysis of Motor Carrier Characteristics).

In many of the trucking companies that were visited, the maintenance people asserted that they repaired promptly when they were notified of a problem. They rely heavily on driver post-trip written reports as indicators of the maintenance required. We conclude that post-trip driver reports also result in better vehicle condition on the road, and therefore fewer vehicle defect accidents.

Many trucking companies conduct garage inspections at periodic intervals--ranging from a minor inspection at an oil change to a major inspection at an overhaul. These inspections serve to discover problems not easily identified by the driver's visual check, and indeed to maintain and repair in advance of the development of a problem. Among the larger companies interviewed this periodic garage inspection was viewed largely as an economic advantage--preventing breakdowns and associated loss of revenue. While all breakdowns do not result in collisions, some do, and there is thus some safety benefit attributed to this periodic inspection.

Most of the people we talked to agreed that state-operated periodic motor vehicle inspection activities were of limited utility in maintaining large commercial vehicles--largely because the intervals between inspections are much longer than the wear-out period of many of the components. State operated PMVI is of the greatest value in controlling operators with minimal or shoddy maintenance practices.

Enforcement

The enforcement practices of the MBCS field personnel using the MCS-63 inspection form are quite useful in identifying grossly defective vehicles, and in following up with a record system at the local or regional level.

The data from these forms ultimately reside in Washington, but are of little value in characterizing the extent of defects in truck operations throughout the country because of biases in the selection of vehicles at the local level. In the present study it would have been of great value to have a precise sample of truck vehicle population to permit an estimate of the condition of commercial vehicles across such factors as cargo type, company size, etc. In our study we were forced generally to rely only on data available from accident reports.

Education and Communication

The trucking operations subject to BMCS regulation are widely varied--ranging from a single truck independent operator to a 2000-truck fleet. Maintenance practice ranges from very sophisticated operations to what is generally termed "breakdown maintenance." Understanding of the rules and regulations of the Bureau ranges from very good to minimal. In general the poorer maintenance practices and the poorer understanding are associated with the smaller and private companies--the occasional interstate trucker. As noted above, the smaller companies have more defect-related crashes, probably a fact related at least in part to their maintenance practices. They need information about all of these things--when they are subject to regulation and how they might maintain their vehicles most effectively--in an easy to understand form.

D. Recommendations

1. The most important single recommendation resulting from this study is that a vehicle should receive a thorough pre-trip inspection. The ultimate responsibility for such an inspection should rest with the driver, but it could, of course, be accomplished by driving through a checklane or by a careful walkaround with a checklist. The result of this inspection should be a written record, carried in the vehicle, and capable of being audited (by BMCS).

2. The post-trip inspection report is already a part of the regulations. It serves as a communications device to effect repairs. In its present form it is generally viewed as a means of reporting defects observed during the trip, but perhaps it should be strengthened to include the same sort of walkaround as the pre-trip inspection.

3. Evidence of inspection and maintenance activities, currently required to be kept (generally at the principal place of business), should be carried in the vehicle either as a complete record or as a synopsis. This could be in a form similar to the driver's log.

4. The MCS-63 form has been revised to provide computer codes. We recommend that the BMCS develop a management program based on data available from the collection of these forms which will:

a. Prepare reports of enforcement activity by region and for the U.S. generally.

b. Prepare reports on types of vehicle defects by several independent variables, such as vehicle make, model, year, time of year, region, etc.

c. Prepare reports and notifications to companies and manufacturers on frequent defects.

d. Prepare activity reports for field management personnel.

5. Such data (in number 4 above) would be of much more value if a set of data could be collected on an unbiased sample of the truck population periodically in addition to the normal enforcement operations.

6. Develop or foster the development of educational materials for BMCS field personnel and for trucking companies on the necessity and economic benefits of periodic inspection and maintenance with a goal of obtaining self-compliance within the industry.

7. In order to communicate with the smaller firms, instructional materials could be provided at truck stops, weigh stations, or included in state licensing examinations (for those states with classified driver's licenses). Such materials should be aimed at increasing the awareness of the BMCS regulations and the knowledge of sound safety practices such as the kinds of defects which cause accidents and the need for pre-trip inspections. While such educational materials do exist in the trade literature, it is evident that there is a need for wider distribution of this knowledge.

E. Discussion

To alleviate defects from the vehicle population there need to exist three factors--all of equal importance. These factors are:

1. Detection of Defect
2. Communication to Responsible Party
3. Repair

A fourth could be added: reporting to the detector that repair has been effected.

The factors of communication to the responsible party and repair are well-established procedures in the regulated trucking industry as well as in many private sectors. The Vehicle Condition Report (VCR) is a federal requirement and well established. A maintenance program, besides being a requirement, is also good business. Assuming that most VCR's are properly and adequately filled out, the maintenance staff is notified of the defect and repairs it. In the words of one supervisor: "If we know about it, we fix it." Given this current system and its reliability to repair properly, the reporting back of repairs completed is not necessary.

It should be noted, however, that not all defects are properly repaired the first time around--partly due to poor notification and to some extent sloppy work--and the fact of repairing a defect can cause other defects--or the act of performing maintenance can cause component degradation to the point where it becomes a defect. These problems are of minor consequence, however, when compared to the overall problem of a lack of vehicle inspection.

The problem--as detailed in the conclusions--is thus one of detection. A good detection system completes the triad of requirements for decreasing the number of vehicle defects.

There are two types of vehicle defects, those which are visible and those which require disassembly of components to detect.

The vast majority of the defects fall into the visibly detectable range. Of the defect-related crashes involving large trucks (and buses) reported by the National Transportation Safety Board in recent years, only one was traceable to a defective component detectable only by disassembly. This crash and defect was a result of improper component replacement during normal maintenance.

Since the vast majority of defects are visible or audible (air leaks) one has to look or listen to detect them. These are problems like air leaks, chafed hoses, broken or missing lights, broken springs, worn or missing brakes, etc., which are detectable during the course of safety roadside checks without disassembling any part of the vehicle. Simple tools such as a tire gauge or tire iron can detect tire inflation problems--without much added effort.

Several companies report that after instituting a good pre-trip inspection program they have had not one defect-related crash (Fleetowner, 1975 Annual Maintenance Awards).

Thus, a simple twofold program will go a long way toward reducing vehicle defects:

1. Make a written pre-trip vehicle inspection mandatory.

2. Educate drivers and other inspectors as to what to look for during an inspection.

In our opinion--based on the data contained in this report and anecdotal and observational evidence collected during the project--an adequate program of inspection and maintenance should include the following as a minimum (some of which are currently required).

I. INSPECTION

A. At time of initial use by the carrier (either at purchase, lease, or trip lease times) to verify that the vehicle is defect-free, meets all applicable standards and is in good working order.

B. Daily--before and after each trip. Safety-related defects discovered at this time should be cause for immediate repair. Equipment defects should be noted for repair at the earliest convenience. The VCR should be a post-trip inspection.

C. Periodically--the period defined by the use but probably in conjunction with periodic maintenance.

D. Tear down--at the time of a major vehicle maintenance activity such as an overhaul. A detailed and exhaustive inspection should be performed.

II. MAINTENANCE

Periodic--as is now practiced by the industry at times related to the service and intensity of use of the vehicle.

III. RECORDS

A. As a minimum record of all inspection, maintenance and repair activities by kept in a suitable form in a central location.

B. Evidence of periodic maintenance, initial inspection, daily inspection, periodic inspection, and tear down inspection be carried on the vehicle at all times. In addition, the intervals should also be noted. Additional vehicle information could also be a part of this record.

C. That the Bureau develop suitable forms to serve as guides and as minimum requirements for use by those regulated.

Currently the driver is required to carry and furnish evidence of his fitness to drive and have it updated. Therefore, why not require evidence of the fitness of the vehicle?

As aids to the enforcement process, two additional tools would seem to be most helpful: (1) development of management reports based on the MCS-63 data, and (2) periodic use of the random sampling plan for roadside vehicle selection described by Morrison and Seiff (1971). This plan was used once by the Bureau.

Development of a data analysis package would allow management to keep better checks on the MCS-63 enforcement-related activities and allow for feedback to the investigator of his production and enforcement activity. Such information can be useful in planning his future activities. Such data would permit the development of reports on the enforcement activities by region as well as for the country. Tabulation of types of vehicle defects, types of carriers and service accumulating defects, particular vehicle makes or combinations having defects, etc. could be prepared on a periodic and timely basis. Such reports would serve both as general information and as notification to carrier, manufacturer, etc. of frequently occurring defects.

The use of the random sampling plan on a periodic basis would permit description of the general vehicle population in terms of defects and provide a basis for comparison between the investigator selected population and the general population.

Data from the MCS-63 report could also be used very effectively as the basis for timely review and dissemination of educational material by the Bureau.

Educational activities sponsored by the Bureau are perhaps the most important of all its roles, because, through education, the work load of the Bureau in the regulation and enforcement areas can be lessened and the safe, efficient operation of the carriers heightened.

Since not enough enforcers of the regulations could possibly be hired, self-enforcement must be relied upon. Also, the fostering of good business practices within the industry will in general upgrade the operation of the carrier's maintenance activities.

Based in part on the data generated by the MCS-63 reports, educational materials, programs, brochures, etc. need to be continuously developed and distributed widely. Such program and materials would also serve as the basis for presentations made by the Bureau staff. Distribution of these materials could be made through: weigh stations as handouts; regional workshops and guest speakers; posters and materials at truck stops; mailings to various groups, etc.

However, it is not enough to simply draft, reproduce, and distribute such materials. They need to be prepared in a format which are--among other graphic considerations--easy to read and comprehend while retaining (accurately) the basic message.

Currently a copy of the FMCSR is delivered to any person found to be: (1) not in compliance with its rules, and (2) not aware of their existence. While this serves a legal requirement, it is doubtful that a person of ordinary educational achievement could comprehend the document. Portions of Section 396 of these rules and regulations were subjected to a readability evaluation using a computer adaptation of the readability evaluation technique devised by Flesch.* Portions of text are analyzed and given a score reflecting the relative difficulty of the text when compared to the reading capabilities of the general population. Examples are given on page 17 showing the sections evaluated and the scores. The Index shows the percent of the population who could read the material. This is then translated into a grade level equivalent. Note that the higher the index, the lower the grade level meaning that more people with a lower average educational level could read the material.

The Bureau should give priority to the continuation of the development of readable material concerning the rules and regulations in a form usable by the driver. Such a booklet need not include all the nuances of the law, but instead provide the reader with a ready reference to the practical applications (with examples) of the rules and regulations.

To facilitate an understanding among the industry of who is regulated by BMCS, the Bureau needs to develop an easy-to-understand rule on who is subject to the FMCSR, and disseminate it via the channels mentioned above. While the actual rules of subjectivity to the FMCSR are complicated, a simple rule covering many situations might result in over-compliance by those who otherwise would be exempt. However, if the rules and regulations are truly reflective of good business practice, then they should impose no additional burdens and in fact enhance the operation of the trucking company.

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*Flesch, R. The Art of Readable Writing. New York: Harper and Brothers, 1949.

FMCSR SECTION	TEXT	INDEX (*Percent*)*	GRADE LEVEL
396.1 (a)	Except as provided in paragraphs (b) and (c) of this section, every motor carrier, its officers, drivers, agents, representatives, and employees directly concerned with the inspection or maintenance of motor vehicles shall comply and be conversant with the rules in this part.	19.18	17.6
(b)	The rules in this part do not apply to a driver or a vehicle wholly engaged in exempt intracity operations as defined in this chapter.	46.10	13.6
(c)	The rules in this part do not apply to a motor carrier or driver wholly engaged in transporting mail under contract with the U.S. Postal Service in motor vehicles which have a manufacturers gross vehicle weight rating of 1000 pounds or less.	37.27	14.9
396.4	No motor carrier shall permit or require a driver to drive any motor vehicle revealed by inspection or operation to be in such condition that its operation would be hazardous or likely to result in a breakdown of the vehicle nor shall any driver drive any motor vehicle which by reason of its mechanical condition is so imminently hazardous to operate as to be likely to cause an accident or a breakdown of the vehicle.	-11.42 (0.0)	22.2
396.4 contd.	If while any motor vehicle is being operated on a highway, it is discovered to be in such unsafe condition, it shall be continued in operation only to the nearest place where repairs can safely be effected, and even such operations shall be conducted only if it be less hazardous to the public than permitting the vehicle to remain on the highway.	7.45	19.4
	OVERALL	19.00	17.6

*The percent of the adult population in the U.S. who can readily understand this material.

Grade 12 = High School Graduate; Grade 16 = College Graduate.

Example of FMCSR Text Showing the Readability Analysis Results.

Lastly, the Bureau needs to strengthen its image in the minds of the trucking population, because much confusion exists over which agency has safety regulations--ICC or BMCS--and where one can obtain additional information. A continued program of public contact and easily available and understandable materials will foster a knowledge of BMCS and how it can and does help the industry.

III. METHODOLOGY OF THE STUDY

A. Background

The relationship between preventive maintenance and crashes is a complicated one which can be best understood by asking a series of questions that approach the problem in a step-by-step fashion. These questions are:

1. What are the determinants of preventive maintenance practice?
2. How do preventive maintenance procedures affect the frequency and duration of particular failures?
3. How do particular failures affect the performance of the vehicle in terms of controllability, stopping distance, etc.?
4. How does altered-vehicle-performance interact with driver actions and road and traffic conditions to produce accidents?

Figure 1 conceptualizes the relationships of factors influencing vehicle performance the interaction of vehicle performance, driver action, and driving environment on crashes.

Preventive Maintenance (PM) is used throughout this report to mean those maintenance activities which are performed on a periodic basis prior to and to prevent component failure.

Periodic Inspection means the examining (looking at) and testing of vehicles and components for the purpose of detecting faults, malfunctions and failure.

Periodic Motor Vehicle Inspection (PMVI) is an inspection program conducted periodically by a governmental authority.

Maintenance represents those activities associated with adjusting, repairing, and replenishing a vehicle to keep it functioning.

Repair is the process of fixing a component or vehicle once it has failed.

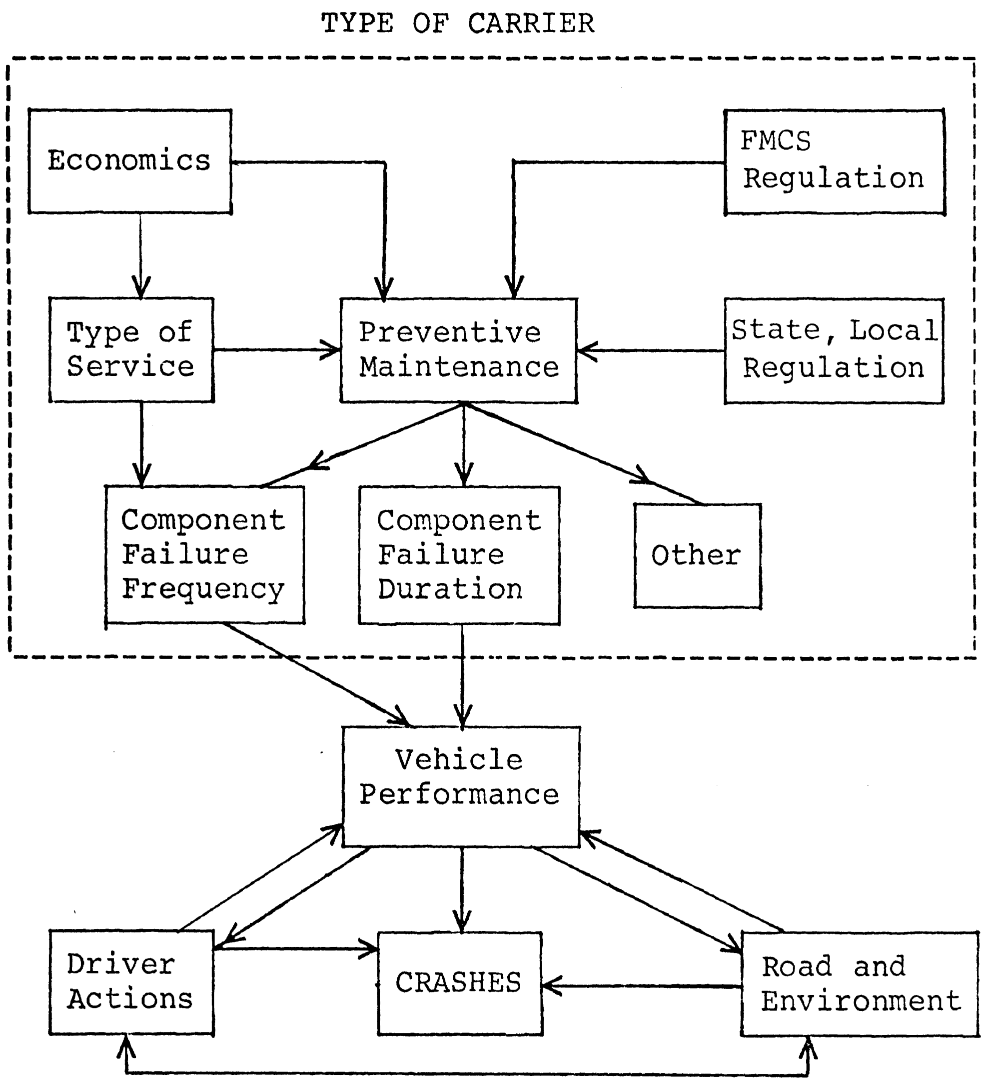


FIGURE 1.--General Program Concept.

Preventive maintenance practice is affected by four major elements as conceptualized in Figure 1: (1) Federal Motor Carrier Safety Regulations (FMCSR); (2) other regulations (state, local, etc.); (3) type of service; and (4) economic circumstances of the carrier. Extensive effort has been made to establish the specific relationships among these elements. As an overall organizing concept in this study, type of carrier is used since this closely associated with all four factors.

Preventive maintenance can have two influences on component failures. First, a systematic program can prolong the life of particular vehicle components, thus reducing the on-road incidence of failures. Second, the inspection associated with a program serves to detect failures, minimizing the time over which component failures present a hazard. This process has been extensively considered in the literature on both a theoretical and a practical basis (Creswell, et al., 1974; O'Day, 1968; Treat, 1973). The major work in this project was to try to identify how actual practice relates to recommended practices.

The relationship of degraded or failed components (i.e., components which function in a less safe or efficient manner than when new or which have ceased to function entirely) and vehicle performance is not fully understood, although some engineering analyses of the problem have been attempted. This area serves much more fundamental research, but the present effort has been confined to using current understanding to diagnose the likely effect of a particular maintenance practice on the more obvious defects.

The final question of the influence of altered vehicle performance (due to degraded or failed components) on crash causation is important. First, accident data has been examined to determine types of crashes and types of vehicles in which defects are reported. From this, the types of degraded-components performance most likely to have contributed to the particular type of crash are established. Second, crash data has been reviewed to determine whether types of carriers that display important differences in preventive maintenance practice are characterized by consistent differences in their crash involvement.

These questions can be summarized into two principal research problems. The problems are: (1) to describe how preventive maintenance practices vary across carriers which are subject to different economic and regulatory situations, and (2) to determine from accident and maintenance data if different types of carriers have different degrees of involvement in defect-related crashes.

B. Research Plan

The research plan as required by the contract is detailed here and illustrated in Figure 2. Five major data sources were used in studying the problem. They are:

1. The current literature.
2. Existing accident, inspection, and population data.
3. Surveys of regulatory personnel and agencies.
4. Surveys of persons associated with the trucking industry.
5. Collection of supplemental accident information.

Data from each source were collected and analyzed under Task C of the project. Of the information sources in Task C, the industry survey and the collection of supplemental accident information received the most effort. Then, in Task D, the analyses of Task C were used to identify specific accident problems and to formulate specific recommendations for maintenance practices to deal with the problems.

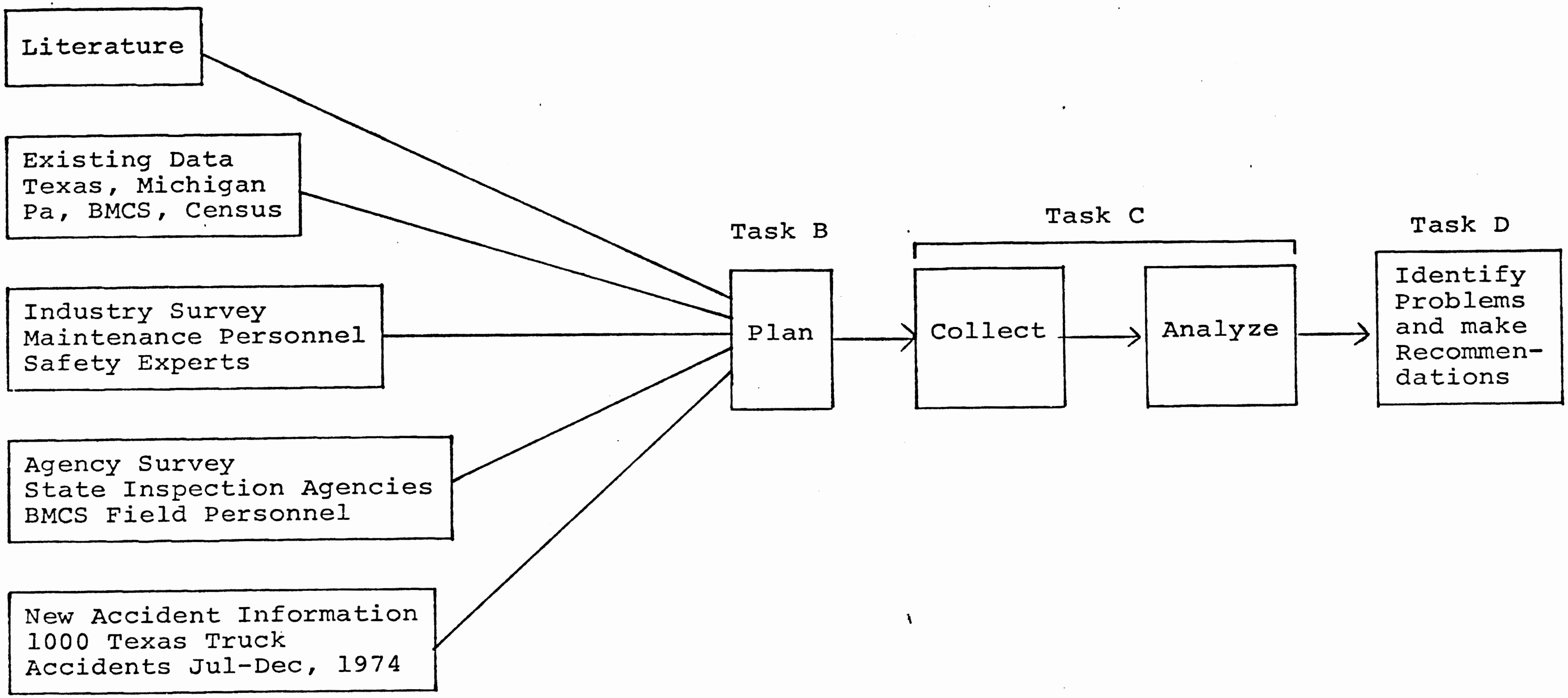


Figure 2. Information Flow

The industry survey was divided into two major parts: carrier maintenance personnel and safety experts. The larger survey effort was made up of personal interviews of maintenance personnel to determine how maintenance practices vary among carrier classifications. Between 25 and 50 carriers were contacted in each of three metropolitan regions: Dallas, Texas; Detroit, Michigan; and Pittsburgh, Pennsylvania. These areas were selected to represent large trucking centers located in states where good accident information was available. The three states also possess the advantage of representing different state motor vehicle inspection approaches, annual in Texas, semi-annual in Pennsylvania, and a checklane system in Michigan.

Supplemental accident data were collected from the State of Texas. Information on approximately 400 crashes occurring between July 1 and September 31, 1974, and involving large trucks, was collected by a combination of telephone interview and mail contact. This information was merged with the current accident reports from Texas, which are among the most comprehensive police-level accident reports available. The supplemental data were used to identify the type of carrier, to establish the type of service, and to verify the information stated on the police reports.

For both sampling and analytical purposes type of carrier is the major conceptual variable. Carriers were classified according to five major groups, which are indicated in Figure 3. Within each group, carriers were also classified by fleet size. In addition to the primary groups, sufficient information on each carrier was obtained to allow analysis of other characteristics, such as exact regulatory status and alternative fleet size, service, and commodity classifications. The authorized group includes common and contract carriers. The private carriers and the "exempt carriers" are defined according to common industry and government practice.

Carrier Type*	Carrier Fleet Size **	Maintenance Personnel Interviews	Supplementary Accident Data	Other Sources
Authorized (common or contract)	Large--21 or more units (10,000 GVWT)	Explicit identification and classification	Explicit identification and classification	Use of proxies like Vehicle Type, In-state vs. Out state Identification
Private				
"Exempt"				
Local Cartage	Small--20 or fewer units (10,000 GVWT)			
Local Service				

* Sufficient information collected to permit commodity or other classifications.

** Data were collected in finer categories to allow alternative fleet size classifications.

FIGURE 3.--Data Structure

The extent of their coverage by the FMCSR was determined from the interviews. Local cartage involves both operations of authorized carriers in commercial zones and other forms of local transportation service. The final group, local service, is similar to local cartage except that the nature of the service mission differs. Service vehicles (or fleets) are those in which the operation is primarily for the transportation of personnel and equipment, such as wreckers and utility company service trucks, rather than for transportation of cargo. These latter two groups are not, in general, subject to the FMCSR. This study attempts to contrast the maintenance practice and accident experience of the several groups to determine how they are affected by the relative impact of the FMCSR.

To recapitulate, we have hypothesized several factors which may affect preventive maintenance practice. From our present understanding these factors appear most closely associated with the type of carrier and the type of service. The major thrust of the research was then directed toward establishing these relationships between carrier/service type, maintenance practice, and accident experience. Having done this, we drew upon this information and the insights gained from both the literature and expert opinion in order to suggest potentially useful and empirically verifiable modifications to present practices.

C. Overview of Tasks C and D

The remaining effort in the contract was divided into two major tasks, which were designated Tasks C and D in the original work statement. Task C, "Accident Review," was divided into five major sub-tasks; Task D, "Recommendations," was handled as a single entity and was operated partially in parallel with the latter portions of Task C. Each major activity is discussed in the paragraphs that follow.

Task C, "Accident Review," was divided into four subtasks: C-1, Present Data Sources; C-2, Industry Surveys; C-3, Agency Surveys; and C-4, Supplementary Accident Data Collection.

C-1. Present Data Sources

This sub-task involved the analysis of several sources of data available on the problem. The data sources include: police reported large truck accidents for the states of Michigan, Pennsylvania, and Texas; carrier accident reports to BMCS; BMCS "road check" inspection reports; and the 1972 U.S. Bureau of the Census Truck Inventory and Use Survey. These accident data sources were analyzed to determine the accident patterns and the distribution of the types of defects in the accidents.

C-2. Industry Surveys

This sub-task had two principal activities:

a. The first was a meeting with carrier maintenance personnel. Between 25 and 50 carriers were contacted in each of the cities of Detroit, Michigan; Dallas, Texas; and Pittsburgh, Pennsylvania. Carriers were selected on the basis of a stratified random sample of vehicle registrations. Stratification criteria followed the plan indicated in the Background section of this study. Prior to the collection of actual information, a three week pre-test was conducted on the proposed format. Data were generated in a personal meeting conducted by an HSRI staff member. This was preceded by appropriate telephone and/or letter contact to inform the carrier of the general nature of the inquiry. Prior to contacting carriers, BMCS regional directors were briefed on the nature of activity in their region.

b. The second major activity was meeting with experts in the field of truck safety. Experts included persons associated with trucking such as representatives of industry organizations, trade publications, educational organizations, and individuals who are both supportive of and critical of Periodic Motor Vehicle Inspection.

C-3. Agency Surveys

This sub-task involved contacts with two groups of individuals.

a. The first group contacted was composed of BMCS field personnel in the Baltimore, Chicago, and Fort Worth regions. Such contacts were arranged through the BMCS Regional Directors and held in conjunction with regular meetings of personnel in the region. Meetings were held in conjunction with the initial phases of Task D. They were in the form of "round table" discussions and informal individual discussions designed to obtain the field personnel's reactions to specific findings, to receive their input on recommendations as well as to learn more about their role in BMCS. The general content of such contacts was submitted to the BMCS contract manager for approval. The replies of individual field representatives are not included in this report, as the respondents had been assured anonymity in order to encourage candor among the respondents.

b. The second group to be contacted was the state motor vehicle inspection administrators. This was accomplished by attending the session of the AAMVA committee on Engineering and Inspection.

C-4. Supplemental Accident Data Acquisition

This effort resulted in supplemental accident information on approximately 4500 large truck accidents occurring in the state of Texas from July 1 to September 31, 1974. These accidents included all truck defect related accidents as reported by the police agencies (approximately 300), as well as a representative sample of non-defect related accidents. Accident reports were obtained from the Texas Department of Public Safety in hard copy form. From these reports, the name and address of the driver and/or carrier were obtained. The involved individual(s) were then contacted by telephone or letter. The information collected was used primarily to determine the type of carrier and service in which the vehicle was engaged at the time of the accident. Secondary information included verification of the factual information on the accident report form. The respondents were also queried on the involvement or possible involvement of defects in the accident.

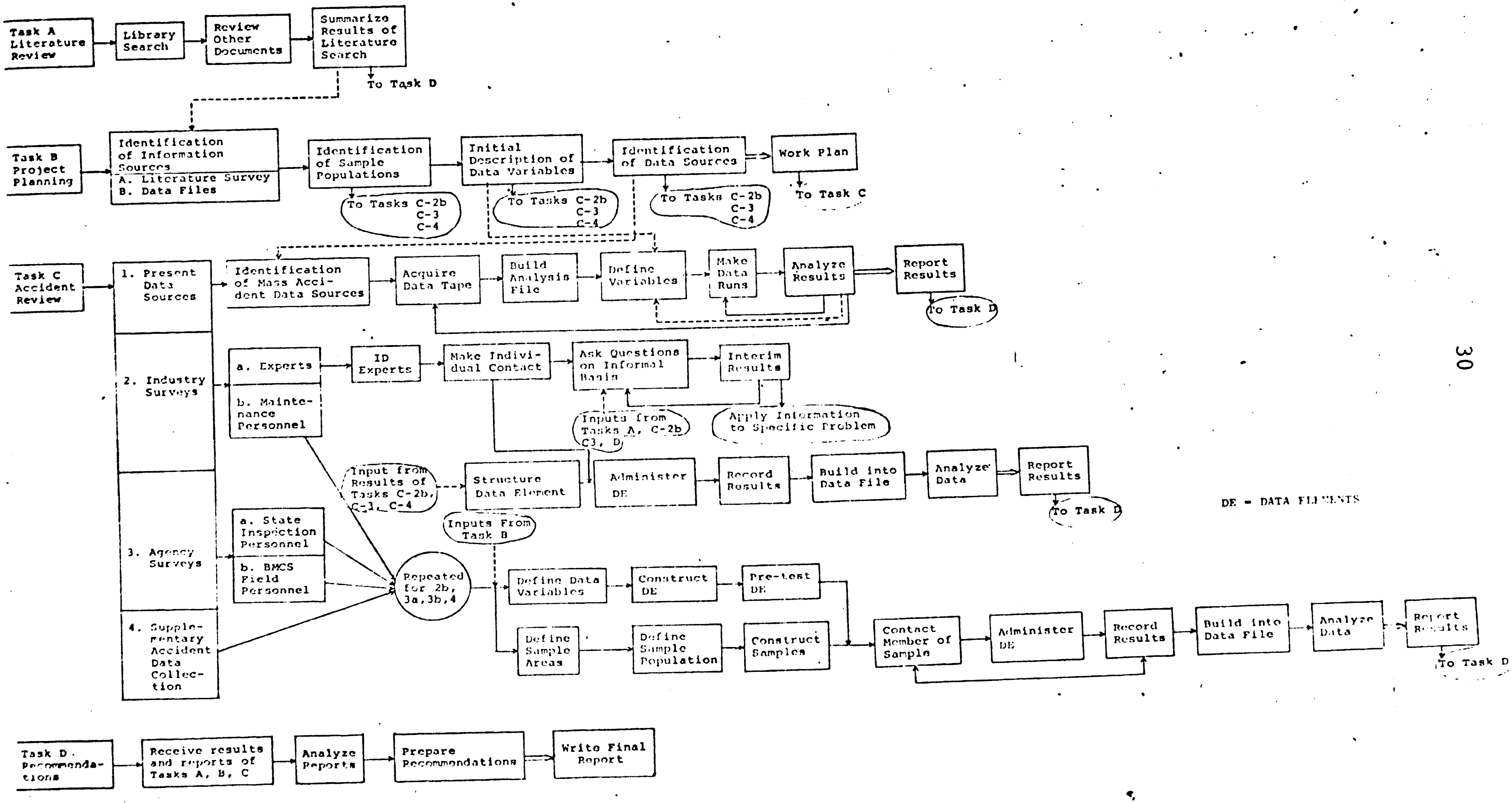
D. Recommendations

The major focus of the task is to provide suggestions, which are based on solid evidence, for possible modifications of the FMCSR. The expert interview portion of Task C was operated in close conjunction with this effort in order to establish both the feasibility and the general applicability of the recommended changes. In addition, specific areas of further research have been delineated, and ideas for continued monitoring of the FMCSR's effectiveness are proposed.

E. Project Flow Chart

To understand the interrelationship of all tasks, a flow chart is presented depicting the major project activities. This chart which follows, serves as a basis for the in-depth discussions of each task.

FLOW CHART



Task A Literature Review
Library Search
Review Other Documents
Summarize Results of Literature Search
To Task D
Task B Project Planning
Identification of Information Sources A. Literature Survey B. Data Files
Identification of Sample Populations
Initial Description of Data Variables
Identification of Data Sources
Work Plan
To Task C
To Tasks C-2b C-3 C-4
To Tasks C-2b C-3 C-4
To Tasks C-2b C-3 C-4
Task C Accident Review
1. Present Data Sources
Identification of Mass Accident Data Sources
Acquire Data Tape
Build Analysis File
Define Variables
Make Data Runs
Analyze Results
Report Results
To Task D
2. Industry Surveys
a. Experts
b. Maintenance Personnel
ID Experts
Make Individual Contact
Ask Questions on Informal Basis
Interim Results
Inputs from Tasks A, C-2b C3, D
Apply Information to Specific Problem
Input from Results of Tasks C-2b, C-3, C-4
Structure Data Element
Administer DE
Record Results
Build into Data File
Analyze Data
Report Results
To Task D
DE = DATA ELEMENTS
3. Agency Surveys
a. State Inspection Personnel
b. BMCS Field Personnel
Inputs From Task B
Repeated for 2b, 3a,3b,4
4. Supplementary Accident Data Collection
Define Data Variables
Construct DE
Pre-test DE
Define Sample Areas
Define Sample Population
Construct Samples
Contact Member of Sample
Administer DE
Record Results
Build into Data File
Analyze Data
Report Results
To Task D
Task D Recommendations
Receive results and reports of Tasks A, B, C
Analyze Reports
Prepare Recommendations
Write Final Report

IV. PROCEDURES AND RESULTS

A. Mass Data

As a first step in identifying the magnitude and general characteristics of the involvement of vehicle defects in commercial vehicle traffic accidents, searches were made of several sets of "mass" accident data. Both police-reported information and carrier-reported information were used. The accidents involving commercial vehicles with defects were compared with those involving commercial vehicles without defects, and where possible the maintenance practices of each group were considered.

Data on maintenance history were not included in the police and carrier-reported accident data, so information relative to that had to be inferred from other reported factors. It was possible to identify certain characteristics of the vehicles that could then be related to maintenance information obtained from other sources.

Data from the state of Texas served for a part of this study. Approximately 35,000 large-truck accident involvements are reported in Texas each year--including both straight trucks and tractor-trailers. For the calendar year 1973 about 6.4% of these vehicles were reported by the police to have had vehicle defects in connection with their accident. Defects are reported in nine categories, eight of which are displayed in Figure 4 by their proportion of all defects. (Windshield wiper defects were less than 1/2% overall and are not shown on this plot.) Brakes predominate, with tires and lost wheels nearly tied for second place.

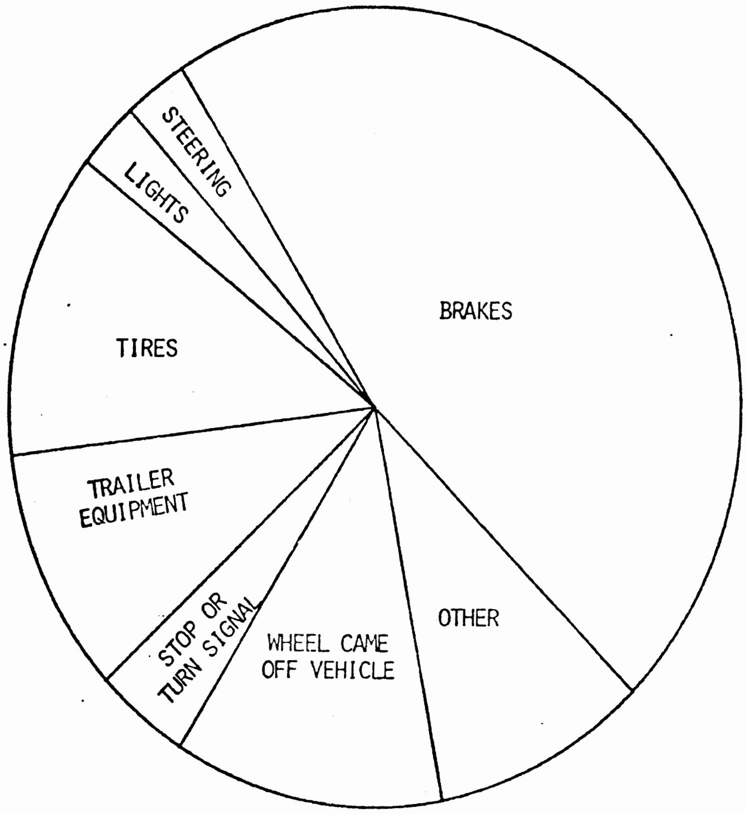


FIGURE 4.--Texas: All Large Trucks in Accidents in 1973 with Vehicle Defects (6.4% of all Trucks Involved in Accidents).

In the digital files which were analyzed there is little detail about the mechanism of the indicated failure. In order to provide a feel for this the notes from 56 "defect" accidents are transcribed from the police reports and are presented in Table 1.

TABLE 1.--Excerpts from Truck Defect Accident Reports--Texas, 1973.

1. Vehicle #1 [Semi] reportedly had brake failure.
2. Vehicle #1 [72,000# semi carrying sod] lost left rear dual wheels, crossed over roadway.
3. Vehicle #2 [Garbage Truck] was turning into rest area when brakes failed.
4. Vehicle #2 [Semi] failed to stop at stop sign. Police officer checked box on accident report "defective brakes;" driver subsequently reported that "brakes were weak.

TABLE 1 (contd.)

5. [Semi] driver stated he had no brakes and struck railroad bridge.

6. [Tractor only--Bobtail] Unit #1 approaching curve was unable to stop, due to loss of brake fluid, and drove through the barricade.

7. Vehicle was traveling east on east freeway when passenger side outer rear tire blew out causing vehicle to swerve all over freeway and turning vehicle on its side and causing load to come through top of vehicle.

8. Vehicle was traveling east, lost control when hose broke filling his cab with steam, and collided left side to guardrail on center median, then collided front to guardrail on right guardrail.

9. [Beverage Truck] brakes went out and were not sufficient to stop the vehicle he was operating and he collided into the back of #2.

10. Right rear broke off and hit bottom of other vehicle--mechanical failure, defective wheel [Dump Truck].

11. Driver was changing gears when trailers broke away from tractor. Damage was to dollies and front bottom of front trailer. Investigation found a faulty fifth wheel lock cause of accident.

12. [Semi] Trailer lights were not working but emergency flashers were (truck struck from behind).

13. Vehicle struck light pole producing minor damage; driver stated "his brakes failed."

14. Vehicle [semi] was traveling north on route at an excessive rate of speed when left front tire blew out and vehicle crossed center stripe and left opposite side of road.

15. Both vehicles were westbound on ____. Vehicle #1 [semi] was attempting to pass vehicle #2 [semi]. Vehicle #1 blew a right front tire, causing driver to lose control and swerve into the rear of the trailer of #2. #1 then continued into the ditch, turned onto its left side and burned. The driver of #1 was trapped inside the cab of his truck. Both the truck and trailer burned completely. [Not clear from report who reported the failure.]

16. Unit #1 was heading E. on ____ and was exiting off on an exit and front left tire blew out and unit struck guardrails and went off roadway [semi].

TABLE 1 (contd.)

17. Vehicle was southbound when it appeared that brake lines broke on trailer and started whipping from side to side and jack-knifed after crossing road and coming back to northbound lanes. Driver later stated that the truck had just had the brakes altered, and he felt that either the brakes or bearings failed.

18. Vehicle had defective brakes [stakebed straight truck]. Driver stated he knew the brakes were bad but thought they would hold up for the 2 miles he was going to take the vehicle--blew the master cylinder.

19. While car was passing semi, the left front tire and rim blew off the tractor and struck the car on the left side. The car then hit the bridge railing.

20. Vehicle [semi/tanker] attempted to stop for stop sign but was unable to stop. Driver said brakes on trailer were bad.

Brake defects range from complete loss (or complete lockup) to "weak brakes." Note that in several cases the officer concluded that there was a brake defect because the truck could not stop in time--and there is thus an entry in the "defect" category for such events.

The tire defects are primarily blowouts, but it is often possible to conclude that the blown tire might have been the result rather than the cause of the accident.

Defects generally put in the "other" category are most often related to load integrity--broken tie-down straps, for example. Several different kinds of "trailer" defects are noted. Lighting defects range from nonworking lights to those covered by mud. In the descriptive statistics which follow, it is likely that the frequency of tire and brake defects may be somewhat overstated (in the light of the detail of Table 1); in contrast, lost wheels may be somewhat underrepresented, since only those which caused other damage seem to be reported here.

Further Analysis of the Texas Files

Dividing the truck population into its two major components--straight trucks and semis--brakes constituted the majority of defects for both, but are more frequent for the straight trucks. This may well be because the environment for straight trucks is more urban, and brakes (as evidenced by Table 1) show up mostly in striking stopped vehicles from behind ... a characteristic of urban collisions. For total defects, both truck types exhibit about the same frequency. These distributions are shown in Figure 5 and Figure 6.

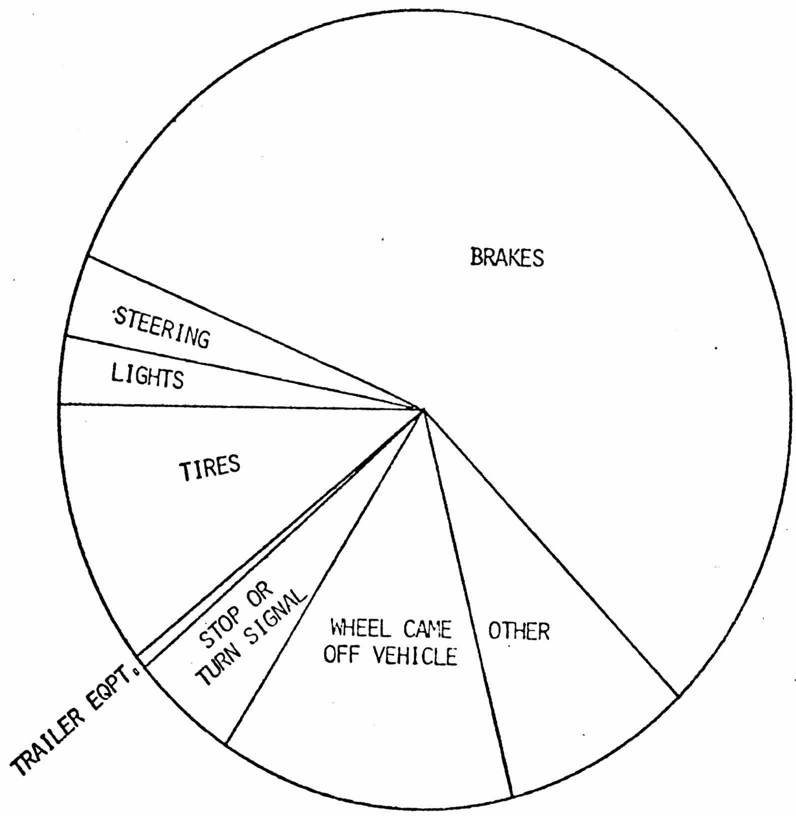


FIGURE 5.--Defect Distribution: Straight Trucks Involved in Accidents in Texas in 1973 (6.1% of all Reported Straight Truck Involvements Noted a Defect).

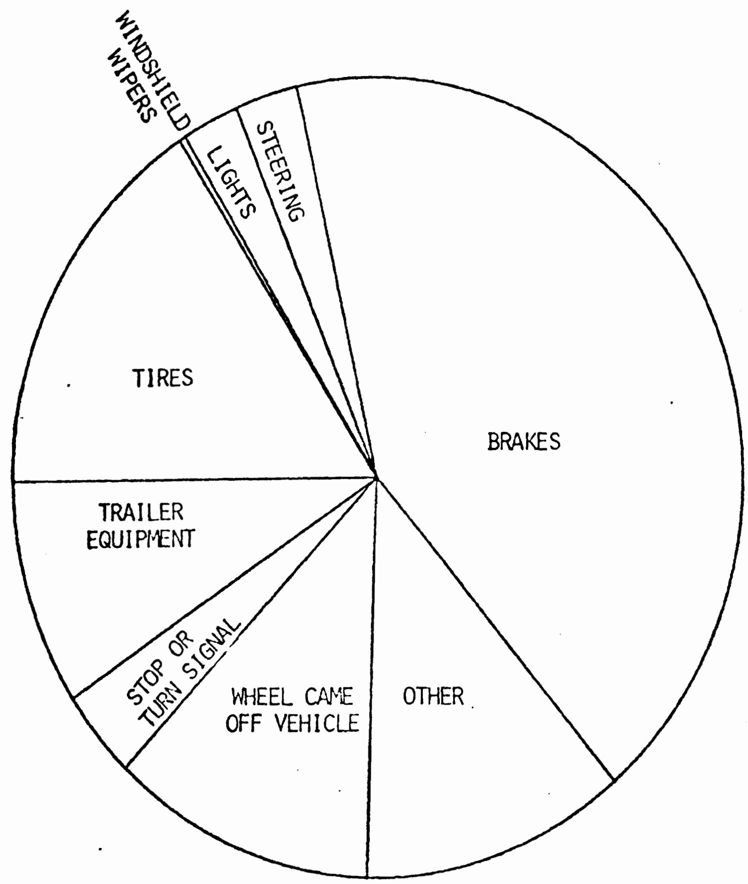


FIGURE 6.--Defect Distribution: Semi Trucks Involved in Accidents in Texas in 1973 (6.0% of All Reported Semi Truck Involvements Noted a Defect).

Urban and rural involvements are shown in Figures 7 and 8. In these diagrams the urban group is taken from crashes occurring in cities of over 250,000 population, the rural group from crashes in unincorporated areas--data from smaller cities being dropped from this presentation.

Single- and two-vehicle accidents are shown in Figures 9 and 10. Note the dominance of brake defects, particularly in the two-vehicle cases.

Overall defects are a strong function of the age of the truck. The average percentage of defects in accidents (about 6%) ranges from 10% (for model year 1965 and older) to about 4% (for 1972-1973 models), as shown in Figure 11. However, the three principal defects--brakes, tires, and lost wheels--show three quite different distributions with

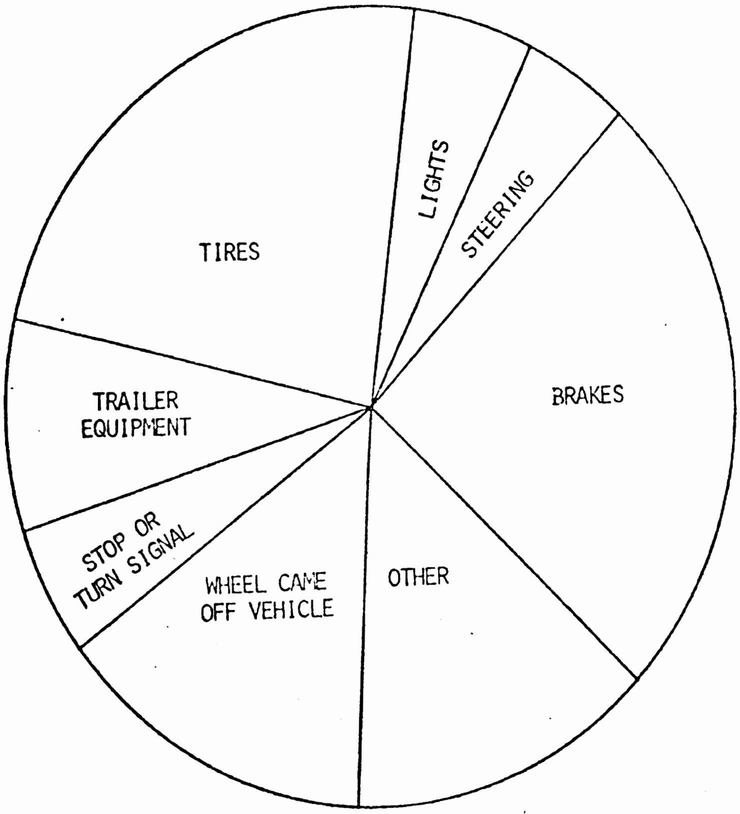


FIGURE 7.--Defect Distribution: Trucks in Rural Accidents, Texas 1973 (9.6% of Rural Truck Involvements Noted Vehicle Defects).

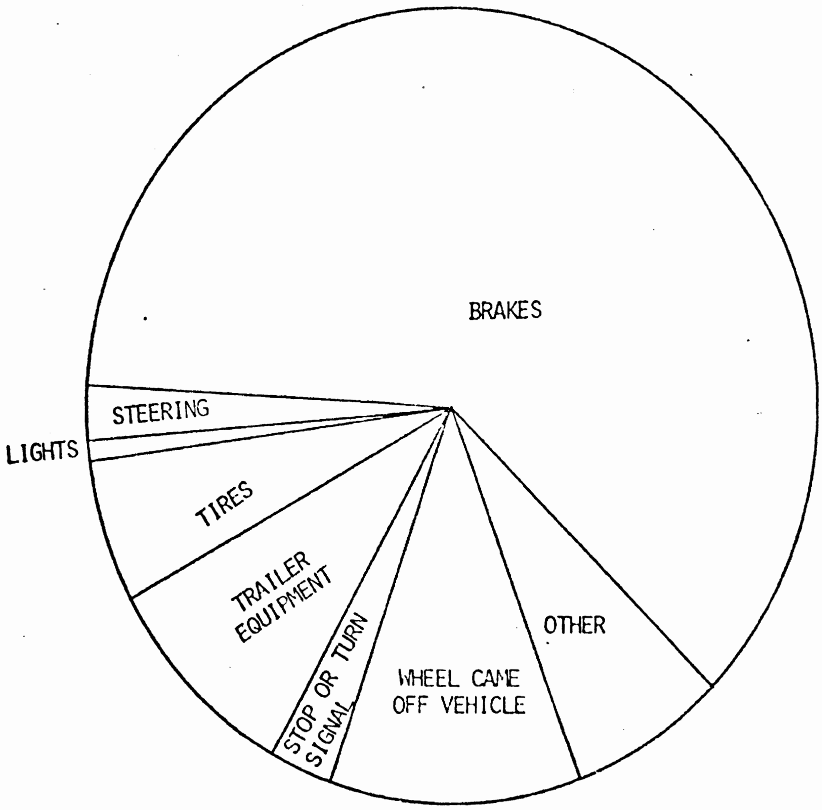


FIGURE 8.--Defect Distribution: Trucks in Large City (Urban) Accidents, Texas 1973 (4.6% of Urban Accidents Noted Vehicle Defects).

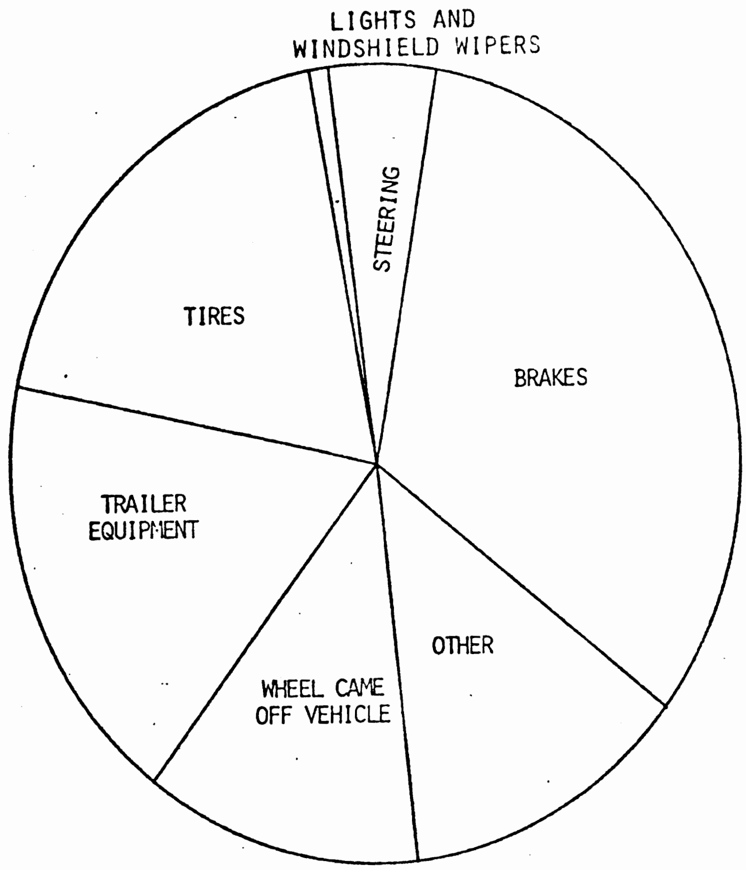


FIGURE 9.--Defect Distribution: Trucks in Single-Vehicle Accidents, 1973 Texas (13.8% of Single-Vehicle Truck Accidents Noted a Defect).

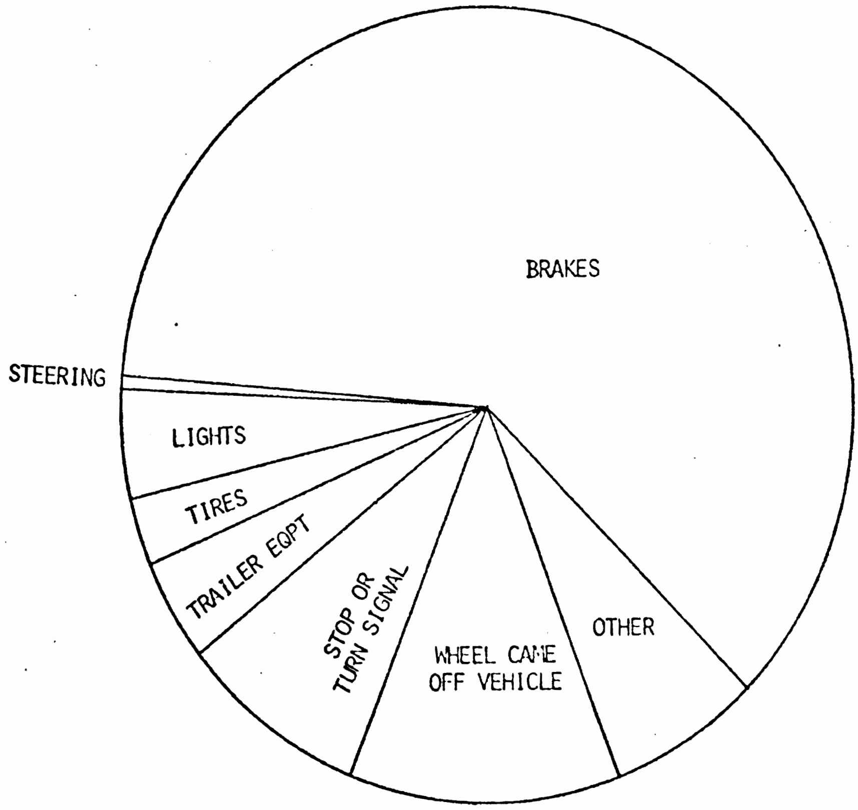


FIGURE 10.--Defect Distribution: Trucks in Two-Vehicle Accidents, Texas 1973 (4% of Two-Vehicle Truck Accidents Noted a Vehicle Defect).

FIGURE 11
PERCENT OF VEHICLES (TRUCK)
INVOLVED IN ACCIDENTS IN TEXAS IN 1973
FOR WHICH DEFECTS WERE NOTED
ON THE POLICE REPORT

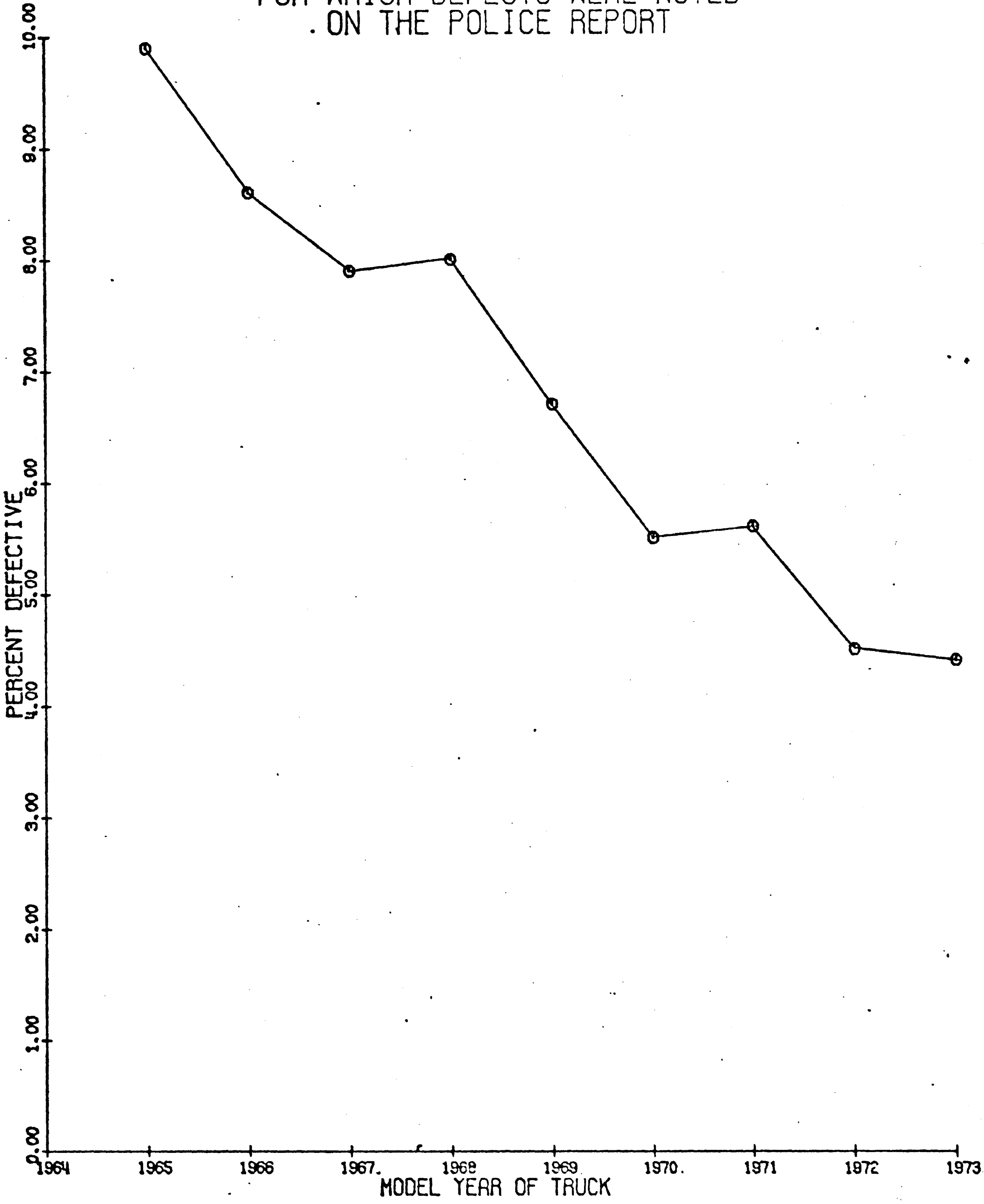
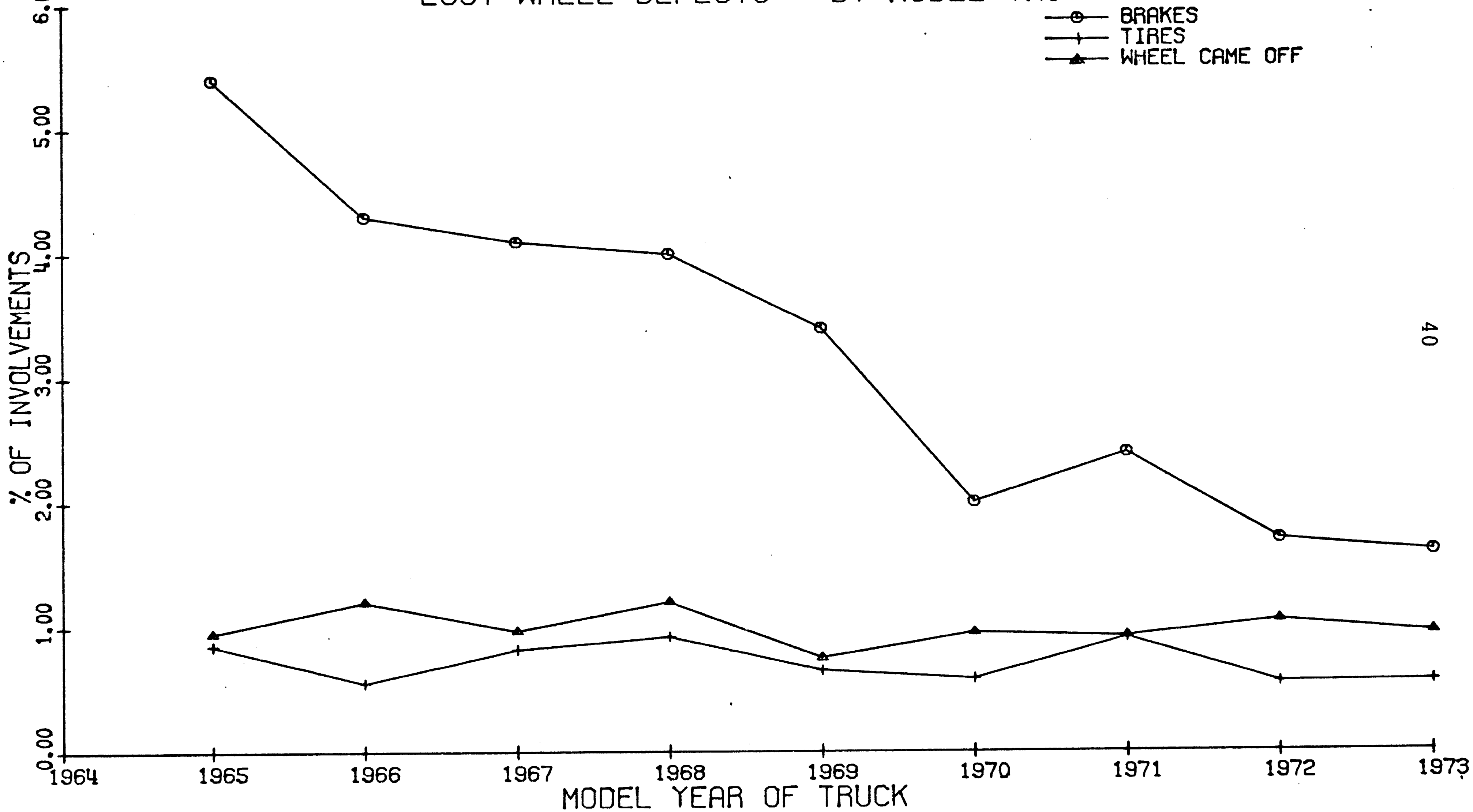


FIGURE 12

PERCENT OF ALL TRUCK INVOLVEMENTS IN TEXAS 1973 WITH BRAKE, TIRE, OR LOST WHEEL DEFECTS - BY MODEL YR.



age as depicted in Figure 12. Tires exhibit a slight rise for newer trucks, perhaps because newer vehicles are likely to be assigned to long-haul service. Brakes on trucks older than three years dominate the age data. Lost wheels hover around 1%, except for the two most recent model years, when they drop to nearly 0.5%.

Figure 13 shows the distribution of the percentage of defects reported by month for the Texas data showing a summer peak and a winter low. BMCS data show a similar distribution.

Analysis of BMCS-1972 Files

BMCS data yield more definite indication of vehicle type and cargo. Figure 14 shows the major body styles, and only the truck pulling a house trailer is far different from the average. (The Texas data discussed above indicate that about 2/3 of the defects for "trucks pulling house trailers" are associated with the trailer.) Lost wheels are the second most frequent defect, with brakes being third for this category.

A slightly different breakdown in Figure 15--the distribution by cargo classification--also shows the incidence of defects for trucks pulling house trailers, furniture, "other" combustibles, metal products, and machinery, and food and beverages being above the average. Paper products, auto carriers, and empties are on the low side.

Figure 16 shows a slight overrepresentation of the group of flammable liquids, explosives, and corrosives and toxic substances--possibly a reporting artifact because of the consequences of accidents associated with these cargoes.

Accident severity is displayed in Figure 17, with property damage only accidents showing the greatest proportion of vehicle defects, fatals the least.

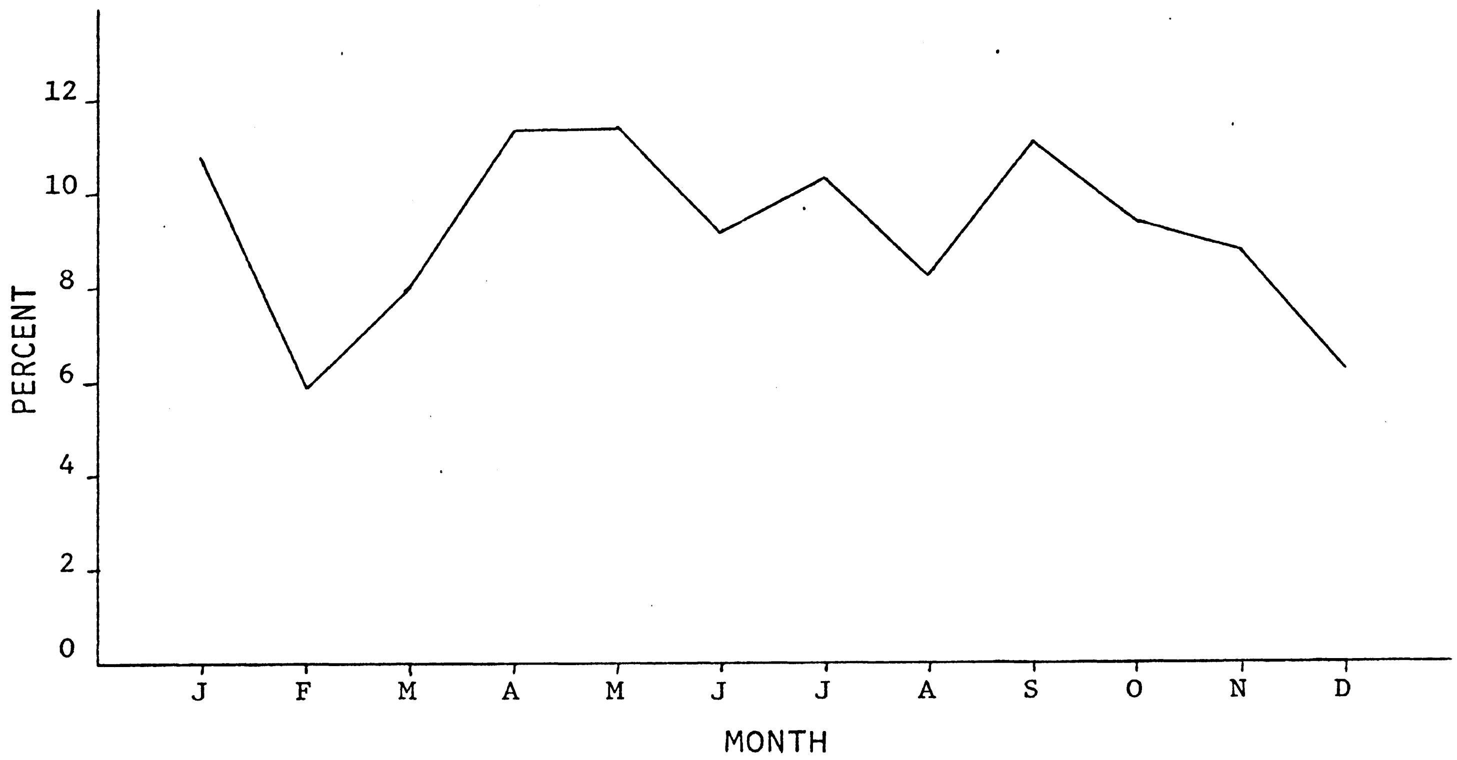


FIGURE 13.--Distribution of [Truck] Vehicle Defects Reported by Month for Texas, 1972.

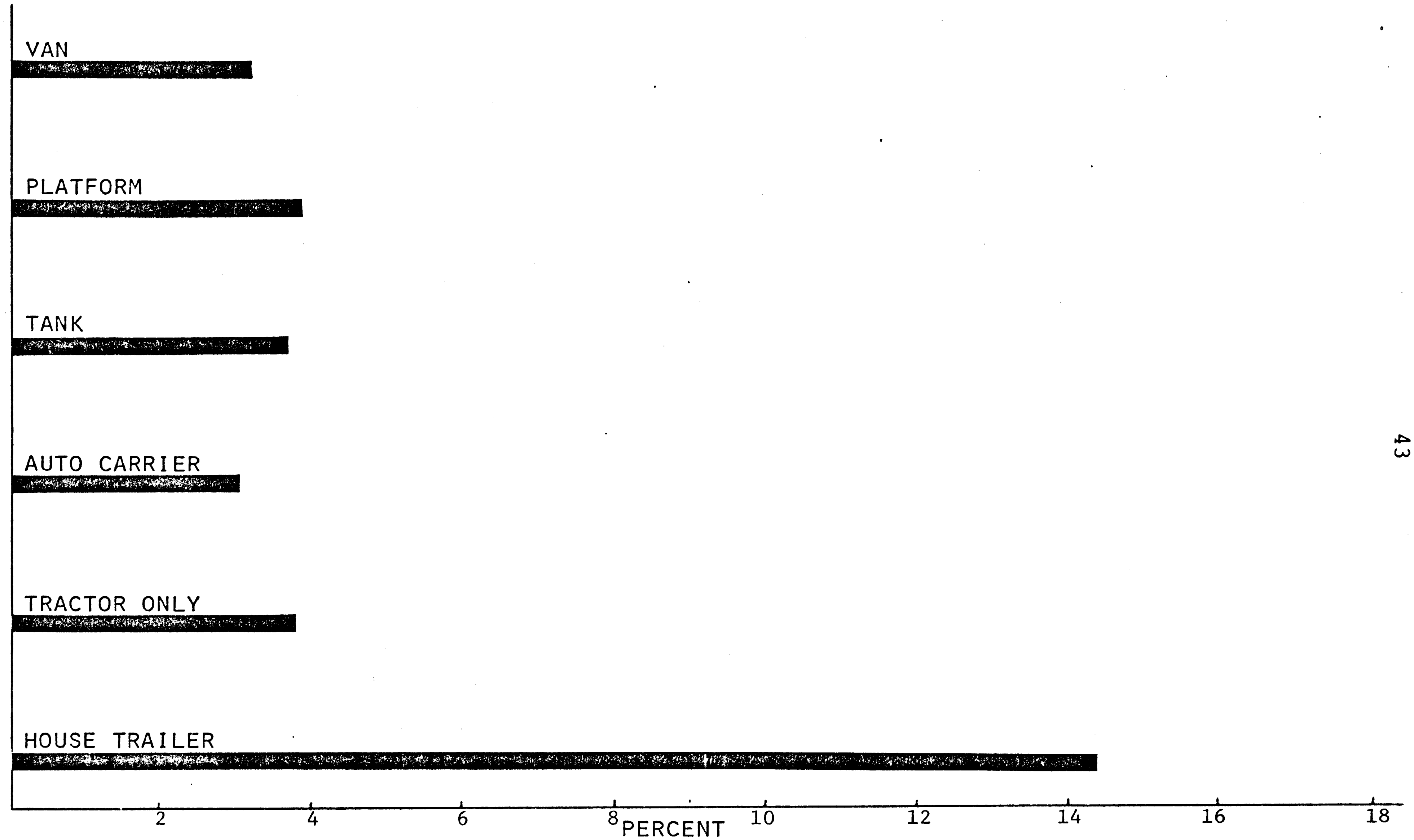


FIGURE 14.--Percent Defective Vehicles, Trucks--BMCS, 1972 by Type of Body.

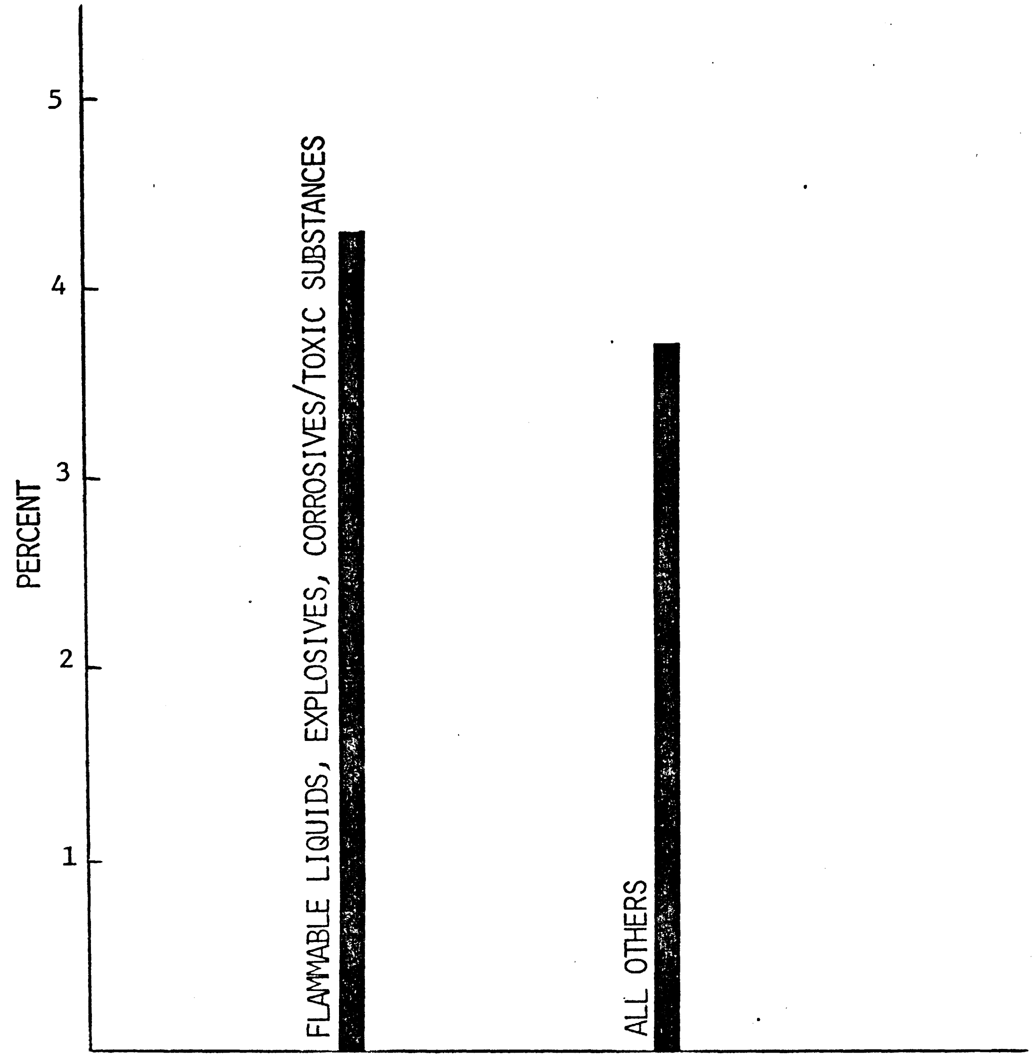


FIGURE 16.--Percent Vehicles in Accidents with Defects--BMCS, 1972 by Cargo Type.

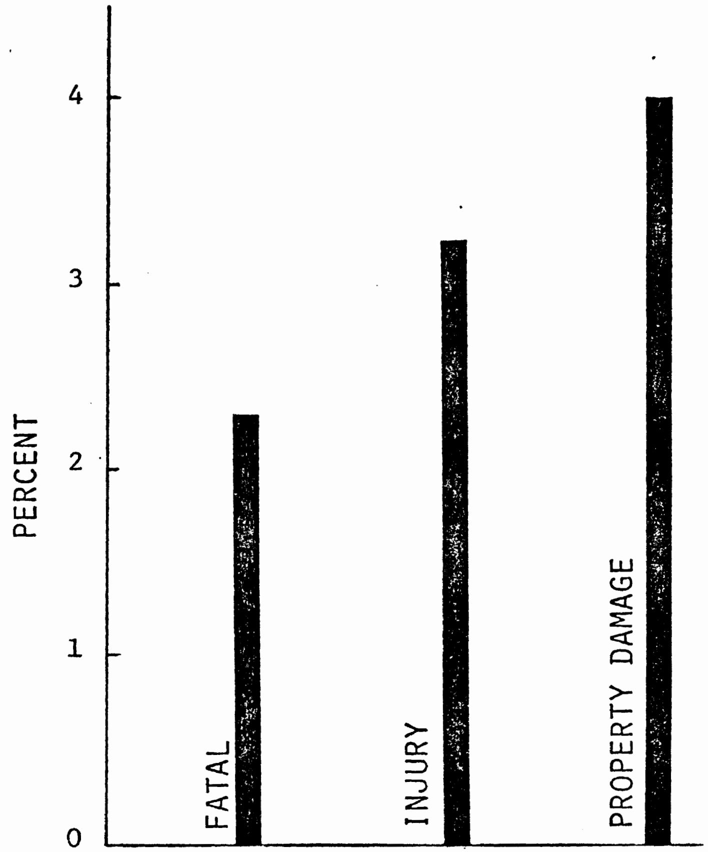


FIGURE 17.--Percent of All Truck Accidents with Reported Defects--BMCS, 1972 by Severity of Accident.

Conclusions from the Mass Data

From the police- and carrier-reported accident data, it is clear that defects in accident involved trucks are associated with older vehicles, with trucks hauling house trailers, and with young drivers. The most frequent single defect category is that of brakes, but tires and wheels combined constitute a substantial part of the problem.

Trucks carrying steel, machinery, furniture, and some explosives-flammables-corrosives are overrepresented in the defective-vehicle accident population. For some reason, summer and fall are the periods of the year most likely to produce "vehicle defect" truck accidents.

As noted above, it would have been useful if the accident reports had indicated directly the type or degree of maintenance practiced by both the company and the driver. With a few anecdotal exceptions (e.g., the driver who claimed that the "mechanic didn't put the lugs on too tight") this was not the case. The mass data, supplemented by a reading of police reports, do serve to characterize the problem of isolating vehicle defects in accidents. We note particularly that the majority of these defects can be listed under the three categories--brakes, tires, and wheels--and that all of these are potentially subject to improvement by some sort of inspection process.

This mass data analysis was a preliminary step in understanding the problem, and the information derived was used as background in developing the driver and carrier interview procedures. Other than that, reference will be made to this mass data again in the conclusions section of this report.

B. Data Sources

Data acquisition activities for four general groups were undertaken as informal data and opinion gathering exercises. These four data acquisition activities are listed below and then individually discussed. All were completed as Task C projects and are keyed to the work plan as follows:

Task C2: Industry Data Source

a. Experts
b. Motor Carrier Maintenance Personnel

Task C3: Agency Data Source

a. State Inspection Personnel
b. BMCS Field Personnel

Task C4: Supplementary Accident Data

For purposes of ready reference, the data acquisition activity conducted under Task C2b is referred to as the Motor Carrier Source and the data acquisition activity under Task C4 is referred to as the Driver Source.

Industry Data Source

Task C2a: Experts

Informal contacts were established across a broad spectrum of the trucking industry and related organizations to serve a twofold purpose. These purposes were: (1) to investigate and explore the many phases of trucking operations and maintenance, and (2) to provide an audience from which to receive feedback for new ideas in inspection rules and regulations. Major trucking organization meetings and regional meetings were attended, and individual fleet owners and operators were contacted. Major trucking organization meetings attended included Fleet Week, 1974, RCC Maintenance Meeting, SAE National Truck Committee Meeting, AAMVA Vehicle Inspection Committee Annual Meeting, Tri State Trucking Association (Pennsylvania), and the Pennsylvania State Safety

Commission Annual Meeting (Pittsburgh). At each of these meetings, sub-group sessions were attended and conversations with delegates initiated as a means of gaining information about the processes and problems of the industry.

At each of the BMCS regional offices visited, conversations were conducted with the field staff--as experts in inspection and enforcement--and several different types of carriers and their personnel were visited--to contact and investigate different types of carriers in terms of maintenance practice as perceived by the field staff.

The Motor Carrier Maintenance Personnel data source brought us into contact with a diversity of carrier types and operational personnel, most of whom were eager to express opinions.

Contacts were made with the BMCS Washington office and with the American Trucking Association (ATA) particularly in the area of their vehicle maintenance reporting systems program.

Contacts were made also with private industry in both the supplier and manufacturer area.

Based on the comments received from these experts the following can be concluded:

1. Vehicle inspection and maintenance is just plain good business practice. If the (Federal) regulations were not present, those who have a sophisticated business sense would do it anyway.

2. Frequency of inspection and maintenance is a function of the type of business and type of service. Most maintenance persons were looking for ways to extend the intervals without incurring an operational penalty.

3. The maintenance staff is willing to fix it, if they know about it.*

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*Drivers, on the other hand, as noted in Appendix A (pg. 98) sometimes complain that maintenance personnel are not so responsive.

4. State PMVI programs have very little effect on vehicle condition for those operators who subscribe to and practice regular periodic maintenance and inspection.

5. The person who is most likely to have a defective piece of equipment is the one who does not have the financial resources and/or committment to maintain the vehicle or who is unwilling to allocate sufficient funds to conduct an organized program of maintenance.

6. All manner and type of services, products, and information are available--free and otherwise--to assist in establishing and continuing a vehicle maintenance program. Oil companies, product suppliers, and the trade literature have developed example forms and record systems for operating such programs. In many instances these forms and systems are available for a nominal charge (or fee). Additionally, consultant services and entire record systems are available from firms specifically engaged in the business of sypplying complete maintenance and record systems on a fee or contractual basis.

Task C2b: Motor Carrier Maintenance Personnel

The basic research design called for two data acquisition activities to be conducted concerning periodic inspection and maintenance and defect-related accident causation. The purposes were to:

1. Describe the nature and structure of the maintenance practices and procedures within the trucking community.

2. Determine what relationships exist between periodic inspection, maintenance and accidents.

As a part of the analysis, these two data acquisition activities were linked together, using common variables to describe the effects of inspection and maintenance on defect-related accidents.

The method of gathering information about the motor carrier inspection and maintenance activities is described in this section. The method of gathering information about defect-related accidents is described under Task C4.

Three geograhpical areas in the United States were chosen to contain representative types of operational and carrier characteristics, including terrain, operating environment, cargo, type of operation, etc. These areas also had good state-level accident records and statistics, which made them attractive from an analytic point of view.

These geograhpical areas are known as Production Areas of Origin and are made up of one or more standard metropolitan statistical areas. In standard definition these areas may cross state lines. However, we have restricted our sampling to only those areas wholly contained within a state. The areas and their definitions are as follows:

PRODUCTION AREAS

DETROIT

Michigan: Detroit, Flint, Ann Arbor
(not including Toldeo)

Genesee Macomb Monroe Oakland Washtenaw Wayne	Counties = 6

PITTSBURGH

Pennsylvania: Pittsburgh
(not including Wierton, Wheeling, Stuebenville)

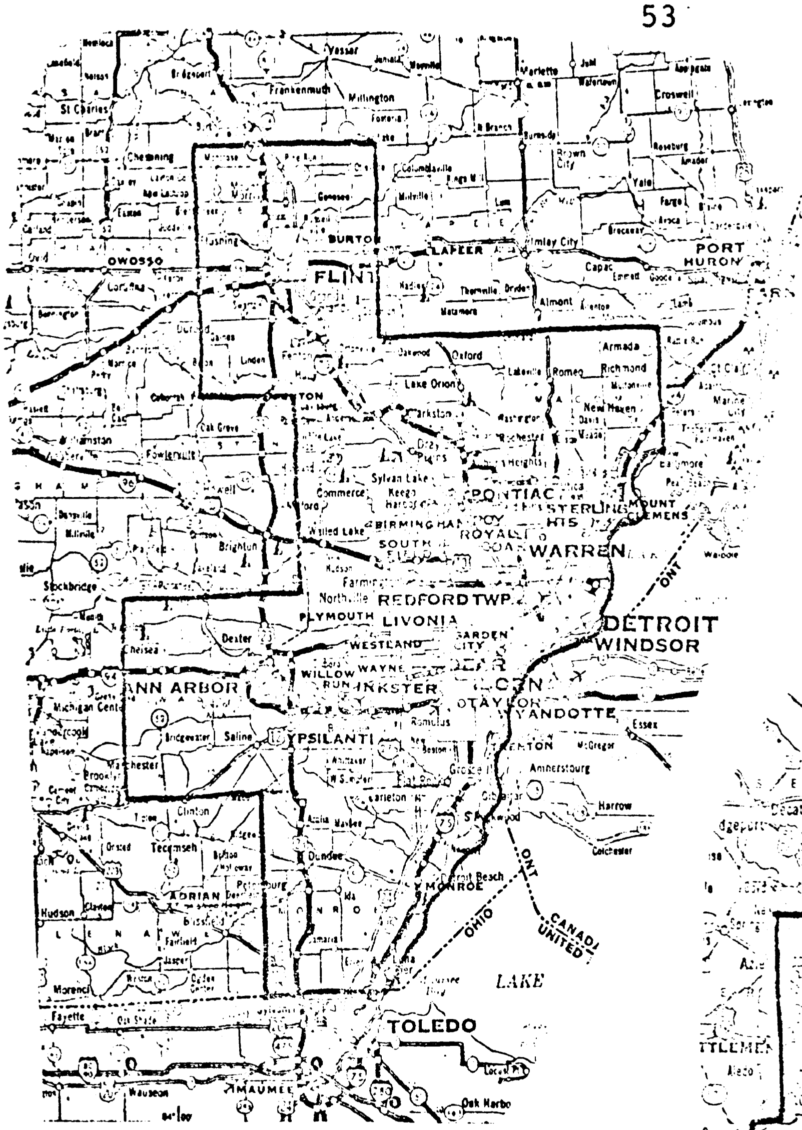
Allegheny Beaver Washington Westmoreland	Counties = 4

DALLAS, FORT WORTH

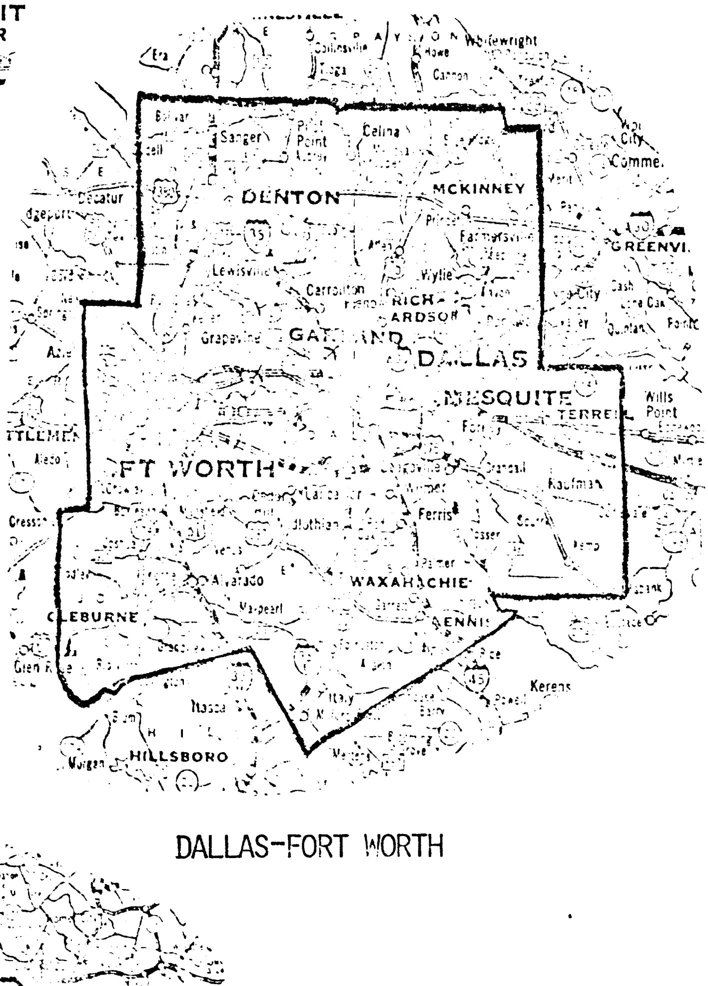
Texas: Dallas, Fort Worth

Collin Dallas Denton Ellis Johnson Kaufman Rockwall Tarrant	Counties = 8

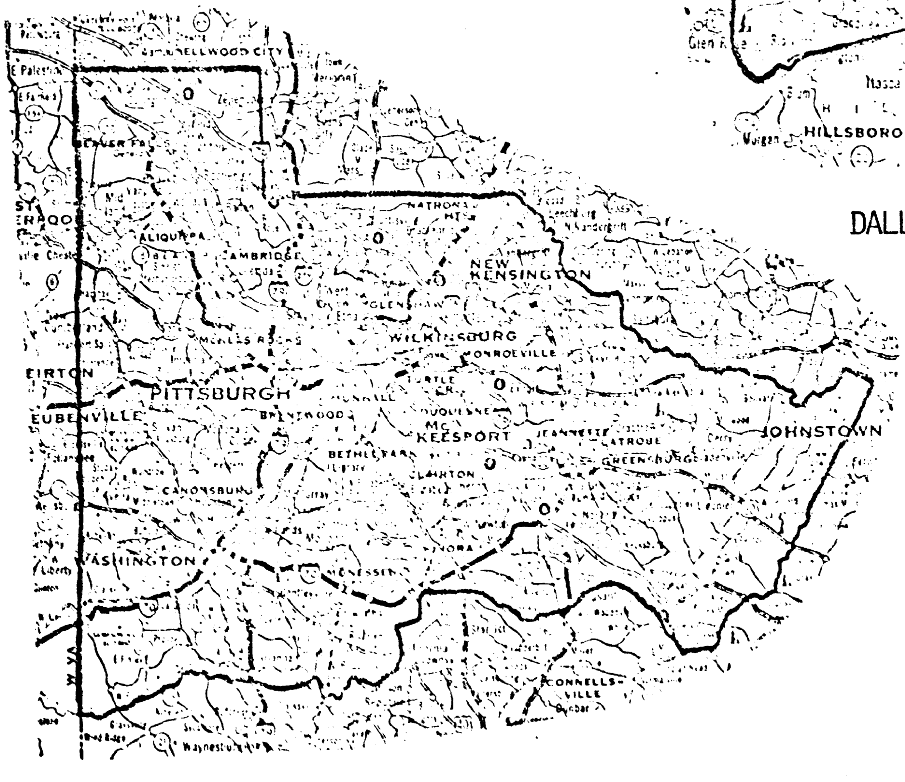
These areas are depicted on the accompanying maps.



DETROIT



DALLAS-FORT WORTH



PITTSBURGH

TABLE 2

TRUCKS IN WEIGHT GROUPS 3-8 OF TWELVE SPECIFIED BODY STYLES (1964-1973 YEAR MODELS)

SMSA-- Production Area	1973 Pop. × 10^-3	Land Area Sq. Mi.	OWNERS -- BY FLEET SIZE 1	%	2-5	%	6-10	%	11-19	%	20-49	%	50+	%		TRUCKS -- BY FLEET SIZE 1	%	2-5	%	6-10	%	11-19	%	20-49	%	50+	%	
MICHIGAN	8887.5	58216																										
Genesee	444.3	642	759	8.2	277	8.6	44	8.4	25	9.6	9	6.3	9	14.1		759	8.2	717	8.4	320	8.2	350	9.6	257	6.0	618	12.8	
Macomb	625.3	480	1489	16.1	459	14.3	58	11.1	32	12.3	10	7.0	1	1.6		1489	16.1	1210	14.2	433	11.2	454	12.4	315	7.4	99	2.1	
Monroe	118.5	557	493	5.3	132	4.1	12	2.3	5	1.9	--	--	1	1.6		493	5.3	335	3.9	84	2.2	69	1.9	---	---	99	2.1	
Oakland	907.9	867	1808	19.5	611	17.0	80	15.3	43	16.5	16	11.3	7	10.9		1808	19.5	1616	18.9	601	15.5	605	16.6	512	12.0	435	9.0	
Washtenaw	234.1	711	527	5.7	162	5.0	20	3.8	6	2.3	2	1.4	1	1.6		527	5.7	418	4.9	144	3.7	76	2.1	49	1.1	96	2.0	
Wayne	2666.8	605	4189	45.2	1580	49.1	308	59.0	150	57.5	105	73.9	45	70.9		4189	45.2	4255	49.8	2299	59.2	2098	57.4	3149	73.5	3477	72.1	
TOTAL	4996.9	3862	9265	68.8	3221	23.9	522	3.9	261	1.9	142	11.0	64	0.5	13475	9265	26.9	8551	24.8	3881	11.3	3652	10.6	4282	12.4	4824	14.0	34455
%	56%	6.6%																										
PENNSYLVANIA	11784.0	45333																										
Allegheny	1606.0	728	1961	54.1	759	60.1	140	62.2	83	71.6	60	78.9	15	68.2		1961	54.1	2085	60.8	1055	63.0	1146	71.4	1735	79.3	1130	68.1	
Beaver	208.4	440	399	11.0	103	8.2	18	8.0	12	10.3	2	2.6	--	--		399	11.0	290	8.4	130	7.8	171	10.7	74	3.4	--	--	
Washington	210.9	857	502	13.8	156	12.4	31	13.8	7	6.0	4	5.3	2	9.1		502	13.8	401	11.7	229	13.7	95	5.9	93	4.3	134	8.1	
Westmoreland	376.9	1024	763	21.0	245	19.4	36	16.0	14	12.1	10	13.2	5	22.7		763	21.0	656	19.1	261	15.6	193	12.3	285	13.0	396	23.9	
TOTAL	2401.2	3049	3625	68.0	1263	23.7	225	4.2	116	2.2	76	1.4	22	0.4	5327	3625	25.6	3432	24.2	1675	11.8	1605	11.3	2187	15.4	1660	11.7	14184
%	20%	6.7%																										
TEXAS	11196.7	267339																										
Collin	66.9	836	263	4.2	65	3.0	5	1.6	2	1.1	1	0.8	1	1.6		263	4.2	172	2.9	37	1.6	23	0.9	35	1.0	67	1.4	
Dallas	1327.3	859	3187	51.4	1182	54.6	191	59.7	112	60.5	81	68.6	48	77.4		3187	51.4	3222	55.2	1423	60.3	1573	60.9	2499	69.3	3720	79.4	
Denton	75.6	911	313	5.0	78	3.6	5	1.6	5	2.7	--	--	--	--		313	5.0	196	3.4	34	1.4	65	2.5	--	--	--	--	
Ellis	46.6	940	183	3.0	53	2.4	8	2.5	5	2.7	1	0.8	--	--		183	3.0	147	2.5	54	2.3	66	2.5	22	0.6	--	--	
Johnson	45.8	740	178	2.9	58	2.7	1	0.3	2	1.1	2	1.7	--	--		178	2.9	149	2.6	7	0.3	27	1.0	52	1.4	--	--	
Kaufman	32.4	815	196	3.2	43	2.0	6	1.9	1	0.5	--	--	--	--		196	3.2	119	2.0	43	1.8	16	0.6	--	--	--	--	
Rockwall	7.0	147	44	.7	13	.6	1	0.3	1	0.5	--	--	--	--		44	0.7	39	0.7	7	0.3	13	0.5	--	--	--	--	
Tarrant	716.3	861	1836	29.6	672	31.1	103	32.2	57	30.8	33	28.0	13	21.0		1836	29.6	1790	30.7	753	31.9	798	30.9	997	27.7	897	19.2	
TOTAL	2317.9	6109	6200	68.5	2164	23.9	320	3.5	185	2.0	118	1.3	62	0.7	9049	6200	24.5	5834	23.1	2358	9.3	2581	10.2	3605	4.3	4684	18.5	25212
TOTAL-STATES	31,866.2		10909	68.5	6648	23.9	1067	3.8	562	2.0	336	1.2	148	.5	27851	19090	25.8	11787	24.1	7914	10.7	7838	10.6	10074	13.6	11168	15.1	73901
TOTAL-AREA	9,716.2																											
PERCENT	30%																											

TABLE 3

FLEET SIZE GROUPINGS AND A CONDENSATION OF TABLE 1.

Fleet Size Group	No. of Trucks Represented by Group	Owners in Sample	% of Owners in Sample	Total Trucks in Sample	% of Total No. of Trucks	Sample Size
1	1	19,090	68%	19,090	26%	8
2	2- 5	6,648	24%	17,817	24%	8
3	6-10	1,067	4%	7,914	11%	4
4	11-19	526	2%	7,838	11%	4
5	20-49	336	1%	10,074	14%	5
6	50+	148	1%	11,168	15%	5
			100%	73,901	100%	34

Vehicle registration information for large trucks was obtained from the R.L. Polk Co., which regularly compiles vehicle registration data for all types of vehicles from all states. Trucks are divided into 8 weight groups corresponding to gross weight categories. All vehicles over 10,000 pounds gross vehicle weight (GVW) fall into weight groups 3-8. Vehicle registration data for all trucks in these weight groups was requested from Polk. Table 2 details this data.

Six groupings of fleet size were used to condense the table and provide for a meaningful structure of the industry. Table 3 shows the condensation of the Polk data. Truck registration by region are similar for each fleet group size. Therefore, the distribution of total vehicles by fleet size would be used to establish the sample size in each region. Due to budget limitations not more than approximately 100 fleets could be visited in the three regions, or about 33 per production area. Using this target figure, a sample proportional to the percent of total number of trucks was established. The results of this sample selection are shown in the far right column of Table 3. The final design sample size of 34 per area or a total of 102 was established.

The R.L. Polk Company furnished a tape of registered owner's name, address, and fleet size, and its composition was arranged so that all owners of a given fleet size were grouped together. Table 4 shows our arrangement of this data. Within each production area, candidate fleet owners by fleet group size were drawn randomly. A total of 102 names of fleets varying in size from 1 vehicle to several thousand was compiled. Since the registration list is a compilation of owners described in a given area, large companies with multiple domiciles appeared several times.

It was necessary to correct for the errors in fleet size and sample again.

Once the sample was drawn, telephone numbers were obtained for the entries and each entry queried as to type of business. Several cases of change of ownership or type of business were uncovered. These, as well as the persons for

TABLE 4

SAMPLE OF R. L. POLK DATA LISTING (HSRI's Version)

```
********************************************************************************
0002 - HSRI I.D. NUMBER

NO. OF TRUCKS(WT. CODE 3-8):  1     NO. OF TRUCKS(WT. CODE 1&2):  1     TOTAL NO. OF TRUCKS:  2

      PROD CO                             STATE CODE:26
28069 ARMADA RIDGE                       COUNTY CODE:099
ARMADA, MI 48005

          TRUCK WEIGHT CODES 3-8                          TRUCK WEIGHT CODES 1-2
MAKE  YR  BODY  WT.      MAKE  YR  BODY  WT.               MAKE  YR  BODY  WT.
 GMC  66   VAN   6                                          GMC  68   PIC   1

********************************************************************************
0003 - HSRI I.D. NUMBER

NO. OF TRUCKS(WT. CODE 3-8):  2     NO. OF TRUCKS(WT. CODE 1&2):  3     TOTAL NO. OF TRUCKS:  5

           FARM SUPPLY                    STATE CODE:26
75075 N                                  COUNTY CODE:099
ARMADA, MI 48005

          TRUCK WEIGHT CODES 3-8                          TRUCK WEIGHT CODES 1-2
MAKE  YR  BODY  WT.      MAKE  YR  BODY  WT.               MAKE  YR  BODY  WT.
 GMC  71   STK   6        CHE  65   STK   5                 GMC  73   STK   2
                                                            FOR  70   PIC   1
                                                            FOR  67   PIC   1

********************************************************************************
0004 - HSRI I.D. NUMBER

NO. OF TRUCKS(WT. CODE 3-8):  1     NO. OF TRUCKS(WT. CODE 1&2):  0     TOTAL NO. OF TRUCKS:  1

     ELECTRIC CO                          STATE CODE:26
74110 CHURCH ST                          COUNTY CODE:099
ARMADA, MI 48005

          TRUCK WEIGHT CODES 3-8                          TRUCK WEIGHT CODES 1-2
MAKE  YR  BODY  WT.      MAKE  YR  BODY  WT.               MAKE  YR  BODY  WT.
 GMC  70   STK   6

********************************************************************************
```

whom a telephone number could not be obtained, had to be replaced in the sample. This was particularly true of the small operators.

Preliminary tabulation showed that: 97% of the owners own fleets of fewer than 10 trucks; 97% of the owners also own 61% of the trucks; 3% of the owners own the other 39% of the trucks.

It should be noted here that our sampling included vehicles engaged in <u>all</u> types of operation, including interstate, intrastate, local delivery, etc. It was not possible short of a personal or telephone interview, to determine more precisely the type of business engaged in by the owner.

Our preliminary survey work showed that our fleet selection ran the gamut from owners of single trucks engaged in local delivery to the largest interstate carrier. Table 5 shows this distribution.

To provide for a systematic means of recording data from the interviews, a data guide was developed. Called the Motor Carrier Maintenance Guide, the form was organized to describe the motor carrier's operations, maintenance practices, and to solicit his opinions on accident causation. Three basic areas were designated as the major content groups:

1. Operations
2. Maintenance Practices
3. Accident Relationship

Items were developed for each content area which would best characterize the maintenance and operational characteristics of the carriers.

The data guide is organized so as to embody the above and allow for stratification by type of organization (owner-operator, broker/lease, company). Such a stratification was necessary to permit structuring the entries for the different types of organizations and personnel assignments to help elicit the best response to the items. Also included are provisions for identification and other control information. Figure 18 shows the structure of the survey Guide.

TABLE 5.--Preliminary Fleet Selection.

Group	Size	Total by Group	Total
Individual and Owner Operator		19	19
Wholesale/Retail -- Except for Food Wholesale	Small	8	
Wholesale/Retail -- Except for Food Wholesale	Medium	10	18
Intrastate and Local Trucking	Small	2	
Intrastate and Local Trucking	Medium	5	
Intrastate and Local Trucking	Large	2	9
Interstate Carrier	Medium	3	
Interstate Carrier	Large	6	9
Manufacturing	Small	2	
Manufacturing	Medium	2	4
Raw Agricultural	Small	2	2
Food Processing/Wholesale	Medium	8	
Food Processing/Wholesale	Large	4	12
Fleet Leasing	Small	1	
Fleet Leasing	Medium	4	
Fleet Leasing	Large	4	9
Construction/Contracting	Small	6	
Construction/Contracting	Medium	9	
Construction/Contracting	Large	1	16
Local Service		1	1
Bulk Transportation	Medium	1	1
Unknown		2	2
			102

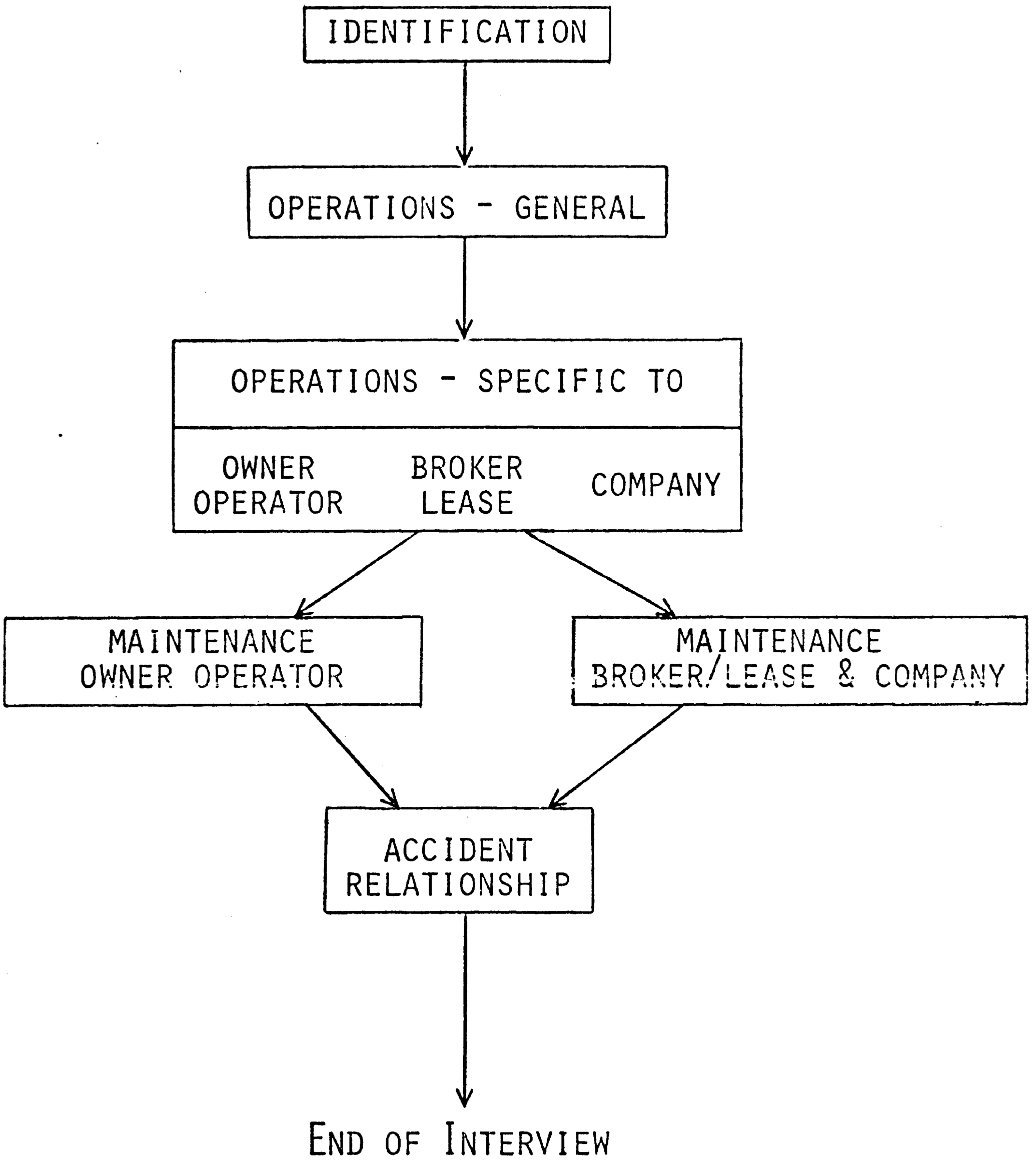


Figure 18: Structure of the Motor Carrier Maintenance Guide

Each designated trucking company was contacted by telephone and an appointment established whereby an interviewer could personally visit the prospective respondent at his place of business. Steps were taken to ensure candor among the respondents and each was given the following statement:

MOTOR CARRIER SURVEY

Introductory Statement

The Highway Safety Research Institute is conducting an inquiry of the trucking industry and of those who use large trucks in the normal course of conducting their business. The purpose is twofold: (1) to describe the nature and structure of the maintenance practices and procedures within the trucking community, and (2) to determine what relationships exist between periodic inspection, maintenance, and accidents.

We are interested in the total truck community--including everything from the one truck, owner/operated vehicle to the very largest interstate truck transportation corporation in the United States.

Since it is impossible for us to talk to all truck operators, you have (your firm has) been chosen to represent a particular type of trucking operations in our sample.

All answers given to questions in this meeting are strictly confidential. No items of a financial nature will be discussed. No individual responses will be shown or given to any governmental or other agency or person. Only summary statistics will be released. Also, you (your firm) will not be identified with the responses. The meeting should take less than 1 hour of your time.

Most were willing to cooperate and the number of refusals was less than 5%.

Early in the program it became evident that: (1) everyone has a maintenance program generally classifiable into one of three categories--sophisticated, adequate, or breakdown; (2) maintenance or lack of it is done for economic reasons (those who have a program do it as a part of good business practice and those who don't either don't have the financial backing to do it or the desire to allocate funds for that activity); (3) virtually all large carriers have a maintenance program.

At each meeting, time was spent discussing the nature of the maintenance activity, exploring why certain practices were followed (or not followed), touring the shop facilities (where available), and examining maintenance and inspection records. The results of these meetings and discussions are detailed on page 71.

Agency Data Source

Task C3a: Meetings with State Inspection Personnel

A meeting of the AAMVA Vehicle Inspection Committee in Detroit afforded an opportunity to meet and talk with vehicle inspection personnel from many states. The following paragraphs represent a consensus of the discussions held.

It was determined that a formal mail survey of state inspection personnel would not be in the best interest of the contract, since forming a list of responsible persons, contacting them, and obtaining responses would be time-consuming and probably yield low response. Most state vehicle inspection programs are passenger-vehicle and light-truck oriented and cover only those vehicle components which are readily visible. A few states remove wheels and examine brake linings.

Most states also have regulations requiring commercial vehicles to be regularly inspected and maintained in safe operating conditions which are enforced by the Public Service Commission (or its counterpart). All states have rules and regulations governing safe operation similar to the Federal Motor Carrier Safety Regulations (FMCSR) or have adopted the FMCSR in toto.

Most large trucking companies and many medium and small companies have inspection programs which are implemented because it is good business practice and the companies would do it anyway, regardless of state law.

In states requiring inspection, only the small trucking company operators were of the opinion that PMVI helped them keep up their vehicle.

PMVI may not be successful for large trucks because they cover many more miles--up to 10 times as many miles in a year--than a passenger vehicle. Hence, a once a year annual inspection, while adequate to catch many impending passenger vehicle defects, has little or no effect on trucks because of a much more pronounced rate of component wear, defect, failure, and replacement due to higher usage.

For the commercial vehicle which accrues its mileage in a similar fashion to a passenger vehicle, an annual inspection might be effective.

It should be noted that some states (Illinois, for example) have a law that exempts a commercial vehicle from state inspection if subject to the FMCSR. Such legislation is defeating to vehicle inspection, since it provides a loophole large enough to drive a defective truck through. Some form of federal remedial rulemaking is advised in these cases.

State PMVI does serve a purpose. It provides a service for the small, low mileage operator, and informs uninformed operators of the benefits derived from periodic inspection. The consensus of PMVI officials is, however, that PMVI has minimal effect on high mileage vehicles.

Task C3b: Data Acquisition from BMCS Field Personnel

BMCS field personnel servine the three data acquisition regions (Dallas, Detroit, Pittsburgh) were contacted and interviewed.

The purpose of these interviews were to:

1. Gain information about the Bureau activities in enforcement.

2. Examine the trucking industry from a regulatory point of view.

3. Use these field people as resource persons to better understand the role of regulation and to serve as experts in maintenance and inspection activities.

Each trip consisted of meeting with the BMCS regional supervisor, a visit to a vehicle roadside check point, visits to representative area trucking companies or other related activity, and in-depth interviews with the field personnel.

The role of the field safety investigation is multifaceted but basically one of enforcement and education. Enforcement of the FMCSR is in the forefront, in that roadside checks and audits of carrier records are an ongoing function.

The roadside checks are initiated at the investigator's discretion, while the audits are in response either to results of the roadside checks or to complaints. If, in the course of his investigation, a lack of understanding of the rules and regulations is evident, the investigator undertakes whatever educational steps he feels necessary to inform the carrier of his obligations and assist him in setting up a system for compliance with the rules.

Each regional manager and his safety investigator were asked a series of questions designed to: (1) ascertain their role in the BMCS organization, (2) obtain their view of which sections of part 396, FMCSR need improvement, and (3) gain information as to where the problems lie with respect to defect-related accidents.

The first item provided the information necessary to our understanding of the role of the field personnel.

In response to the item concerning the adequacy of part 396 and where improvements were needed, all agreed that the section (part 396), is basically adequate. While each investigator had his own pet grievance with certain sections of part 396, all felt that:

1. The record-keeping requirements need to be minimum rather than recommended.
2. They needed a means to easily verify that maintenance and inspection was being performed on the vehicle--particularly at roadside checks.
3. While regulations require inspections, they do not specify that the inspector be qualified.
4. Trip lease arrangements are not specifically covered in the vehicle inspection requirements.

All were unanimous in their opinion that the problem vehicles from an inspection and maintenance standpoint were those belonging to operators who either do not have the financial resources to adequately maintain the vehicle or who do not desire to allocate the necessary resources to maintenance. These are typically the exempt commodity carriers and the economically marginal operators.

The field personnel all felt they put in a large number of hours preparing and presenting education programs to acquaint operators with BMCS and its rules and regulations. Any help from the Headquarters office would be greatly appreciated.

From our visits with these people, we observe that:

1. Feedback from the field safety and compliance checks--usually the MCS-63 forms--would provide the safety investigators with direction as to where the problems lie and what they are.

2. Educational materials in the form of additional handout materials and basic topic outlines for presentations, speeches, etc. would be most helpful in completing the task of effective presentations to various trucking groups.

3. Due to the wide variance in operating styles and priorities observed among the teams, more central control and direction from Washington would be desirable. The computerization, development, and use of data generated by the MCS-63 form would be most helpful here.

Task C4: Supplementary Accident Data Acquisition

Arrangements were made with the State of Texas Department of Public Safety to purchase the required number of accident reports listing all large trucks involved in collisions in Texas for a 87 day period beginning July 1, 1974.

The purpose was to obtain access to a population of crash-involved drivers operating both defective and not-defective trucks involved in crashes, so that these drivers (or a sample of them) could be contacted concerning various aspects of their operation on the day they were involved in the crash. Our design called for obtaining data concerning maintenance from one source and accident involvement from another (accident reports). Unfortunately, accident reports do not list certain variables critical to our analysis--namely, type of service (inter- vs. intra-state operation), cargo, pupose of the trip. It was necessary to contact these drivers to answer certain questions concerning their operation on the day of the accident.

Beginning July 1, 1974 the state of Texas began sending copies of all large truck accident reports involving a large truck to HSRI. Based on our sampling plan, it was determined that approximately 200 defect-related accident reports would be needed. Using a defect rate of 7% (based on an analysis of the Texas mass accident data truck file), this meant that approximately 3000 reports would be needed. Owing to anticipated subject mortality and miscoding, a plan of oversampling was initiated whereby additional reports would be obtained to ensure the achievement of the 200 figure. An analysis of the first few weeks of report collection revealed an over-estimation of about 1% in the defect rate.

In all, 4377 accident reports covering crashes in which a large truck was involved were received from Texas. This covered the 11-week periods of July 1-July 22 and July 30-September 24, 1974--or 79 days. For this period, 288 reports or 6.28% of the total were labeled as referring to accidents involving trucks with a defect. The following generalizations from this data are of interest.

DISTRIBUTION OF NUMBER OF VEHICLES BY DAY OF WEEK

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	TOTAL
Typical Day	14	71	71	75	68	75	29	403
% Distribution	3.5	17.6	17.6	18.6	16.9	18.6	7.2	100%

DISTRIBUTION OF NUMBER OF DEFECT VEHICLES BY DAY OF WEEK

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	TOTAL
Typical Day	2	4	4	5	5	4	2	26
% Distribution	7.7	15.4	15.4	19.2	19.2	15.4	7.7	100%

x^2 on ratio between total distribution and defect distribution = 6.508. No significant difference -- no one day stands out.

DISTRIBUTION OF VEHICLES BY MODEL YEAR -- JULY ONLY

	Unknown	62 & Older	63	64	65	66	67	68	69	70	71	72	73	74	TOTAL
Total Vehicle Population	43	56	25	28	39	64	78	91	127	127	147	211	256	201	1,493
%	2.9	3.8	1.7	1.9	2.6	4.3	5.2	6.1	8.5	8.5	9.8	14.1	17.1	13.5	100%
Actual Defects	0	6	5	4	5	8	9	3	9	9	16	9	14	10	108
%	0	5.5	4.6	3.7	4.6	7.4	8.3	2.8	8.3	8.3	14.8	8.3	13.0	9.3	100%
Expected Defects based on Population	3.1	4.1	1.8	2.1	2.8	4.6	5.6	6.6	9.2	9.2	10.6	15.2	18.5	14.6	108

The x^2 between the distribution of expected defects and actual defects = 24.39 and is significant at the .05 level. It appears that 72-74 vehicle experience is good. With 71 and older vehicles, problems begin--namely, they are experiencing more defects than would be expected for their numbers in the population. This is confirmed in the mass data analysis as seen in Chapter IV, page 31.

For the 228 vehicle defect related accident reports, a matched pair sample was created whereby each defect report was matched with a report containing a vehicle which did not have a defect.

These matching variables were (in order of importance):

Date of Accident
Age of Vehicle (Model Year)
Geographic Region (Proximity by city and county)
Time of Day

No effort was made nor was it possible to match on body style, vehicle make, purpose of trip, or vehicle cargo. Two reasons exist for this: (1) the information was not on the accident report, and (2) a much larger sample would be required in order to accumulate enough cases for a meaningful match to be made.

All 288 defect accident cases were matched. Some cases were matched with more than one non-defect report to provide a back-up case in the event that the first match (which was the best) could not be contacted.

The matched pairs of cases were placed in a random order to avoid any bias associated with data.

Each driver of the large truck in the matched pair was to be contacted and interviewed according to the following schedule:

1. Contact the defect related driver.
2. Contact the 1st match (non-defect-related driver).
3. Contact the 2nd match if the 1st was not available.

Since the match interview was of no use if the defect driver could not be reached, the contact with the defect driver was paramount. If he could not be reached by repeated telephone attempts, his company was contacted. If they were unavailable or could not be contacted, he was sent a letter.

When contacted, the defect related driver was interviewed. If his company was contacted, the same form was used. If a mail inquiry was used, a slightly different version of the data request containing all the required information was used. Once the interview was completed the match interview process was begun, using the same steps as outlined above. If either the defect-related driver or one of the matches could not be contacted and interviewed, the case was dropped.

Two hundred fifty of the 288 defect related cases were begun, with interviews being completed with 64 pairs of cases. Substantial numbers could not be contacted--either no telephone number was available, no telephone contact could be made, or they did not return the mailed inquiry. In many instances we tracked drivers from one company to another and at times half-way across the country. At the end of this phase we were able to contact and complete discussions with 64 pairs of drivers.

C. Results of Data Acquisition

The methodology of the study called for two principal data acquisition activities to address the question of whether periodic inspection and maintenance result in fewer defect crashes. The Motor Carrier Maintenance Guide (Task C2b) described the trucking industry's operations and miantenance practices and gathered opinions on accident causation. The Supplemental Accident Data Acquisition collected additional data from crash involved drivers who were driving both defective and non-defective vehicles.

Each trucking operation and truck driver contacted was categorized on a number of characteristics--those unique to the particular method and those common to both methods.

1. CHARACTERISTICS COMMON TO BOTH METHODS

    Freight Classification
    Type of Carrier
    Type of Operation
    Operational Descriptors and Characteristics

2. MOTOR CARRIER MAINTENANCE GUIDE

    Maintenance Practices
    Fleet Size

3. SUPPLEMENTAL ACCIDENT DATA ACQUISITION
Accident Information

The information gained from both was then linked together, using the characteristics common to both methods to complete the matrix discussed in Chapter III and reproduced below.

Freight Classification	Type of Carrier	Type of Operation		Fleet Size		Maintenance Practice	Defect/ Accident Experience	Operational Descriptors and Characteristics
		Intrastate	Interstate	Large*	Small**			
General Freight or Multiple Classification	Common							
	Contract							
	Private							
Specialized	Common							
	Contract							
	Private							
Exempt Agricultural								
Local Delivery		/////	/////					
Service or Utility		/////	/////					

*50 or more units.
**Less than 50 units.

The results of this data combination are reported at the end of this chapter.

The following sections are addressed to the findings of the two methods reported separately.

Results of the Data Acquisition from the Motor Carrier Maintenance Personnel

Sixty seven (67) meetings were completed in the three geographic regions, with 30 conducted in the Detroit Production area, 19 in the Pittsburgh area, and 17 in the Dallas area. The majority of the meetings were with small and medium-size companies (for reasons previously stated). The distribution by type of organization follows:

N	Type of Organization
9	Owner/Operator
1	Broker
2	Leasing Organization
55	Trucking Company*

*Defined as any organization using large trucks in the normal course of its business.

Fleet sizes ranged from one-vehicle operators to a trucking company with 2,815 vehicles. The vehicle mix included straight trucks, trailers, and combination units. The fleets were arranged in six groups, according to the number of vehicles in the fleet.

Group	No. of Units in Group	Number of Respondents	Percent
1	1	14	20.9
2	2-5	16	23.9
3	6-10	9	13.4
4	11-19	5	7.5
5	20-49	9	13.4
6	50+	4	19.4

The carriers represented a wide range of operating authority within different types of operation.

Freight Classification	Carrier	Interstate		Intrastate	
		Large*	Small**	Large	Small
General Freight or Multiple Classification	Common	2			
	Contract	0			1
	Private	2			
Specialized	Common	1	1		2
	Contract	1			5
	Private	2	17	3	24
Exempt Agricultural		0			
Local Delivery		/////	/////		6
Service or Utility		/////	/////	1	

*50 or more units. **Less than 50 units.

This distribution can be further collapsed into inter- and intrastate operations such that 26 (31%) were engaged in interstate commerce and 41 (61%) were engaged in intrastate and local commerce.

When queried about subjectivity to the FMCSR, confusion was apparent on the part of some of the smaller carriers.* Twenty-one (21) reported they were subject to the FMCSR and 46 reported they were subject to only state regulations. We suspect a greater number of the 46 reporting they were subject to state regulations only should have been subject to FMCSR but were either unaware of their obligations or chose to ignore them. At the very least, 5 carriers were aware they were subject to FMCSR.

The commodities that these carriers trasnported collapsed into a list similar to the Carriers of Transportation list. The following table depicts the types of commodities transported.

%	Type of Cargo
1.5	Farm Products--Raw
7.5	Mining Products--Raw
0.0	Forest Products--Raw
11.9	Processed Food
0.0	Textile Products--Raw
6.0	Textile Products--Processed
25.4	Building Materials
0.0	Household Goods
1.5	Furniture
0.0	Paper Products
1.5	Chemicals
0.0	Petroleum--Raw
3.0	Petroleum--Processed
3.0	Primary Metal Products
10.4	Fabricated Metal Products
1.5	Machinery--ex. Electrical
1.5	Electrical Machinery
4.5	Transportation Equipment
7.5	Scrap, Refuse, Garbage
9.0	Mixed Cargo--LTL Freight
3.0	Other ________________
100.0%	

*The term carrier or company is meant here to be all inclusive regardless of size. Thus, the owner-operator is a company.

Twenty-four percent (24%) of the companies indicated they belonged to trade or driver assications and 52 percent indicated they subscribed to or received trucker periodicals or other maintenance publications. It should be noted that companies receiving publications or belonging to associations are primarily the larger carriers.

In response to the items concerning the types of records kept, the following responses were received.

%	Type of Record Kept
46	Driver Log
24	Pre-Trip Vehicle Condition Report
51	Post-Trip Vehicle Condition Report
43	Written Maintenance Schedule
85	Maintenance Cost Records
78	Maintenance History on Each Vehicle

Most of the larger companies kept all of the above records, except the pre-trip report. For the smaller companies, record keeping is spotty. Additionally, certain of the records are not required to be kept. Almost all companies (85%) kept maintenance cost records, but in the cases of the smaller companies it was only the repair cost receipts, often only for "tax purposes."

The means of obtaining maintenance services vary with the company but usually they are either purchased or performed by the company (self maintenance). Virtually all large companies have their own maintenance services, occasionally purchasing services for major component overhaul or when the shop is back-logged. The smaller companies--if primarily in the trucking business--perform their own minor and periodic maintenance and purchase major repairs. Non-trucking companies using trucks incidental to their business usually purchase all services, often from the dealer who sold the truck.

For the companies performing their own maintenance, they employ persons with specific responsibility for maintenance and have staffs and facilities large enough to handle the work load. Mechanics come from a variety of sources and have a low turnover rate. In most of the larger shops they are unionized and hence subject to union work rules. A few of the better shops provide training opportunities for formal mechanical training.

Regarding vehicle inspections, the following responses were obtained:

What type of visual pre-trip walk-around inspection report is used by the driver?

12%	Checklist
19%	No Checklist--but Detailed Visual
60%	Cursory Only--Visual, Non-Detailed (quick look)
8%	No Inspection
1%	Don't Know
100%	

Is any other pre-trip inspection made?

75%	No
25%	Yes
100%	

What type of post-trip inspection and report is made?

22%	Vehicle Condition Report (FMCSR)
10%	Other Written ________________
12%	No Report
54%	Report Only if Defect Noted While Driving
2%	Don't Know
100%	

Are periodic inspections made by your maintenance staff (repair service) or company?

12%	Yes--type not specified			
		54%	Visual	Sum of these = 78%
		12%	Written	
13%	No			
9%	Unknown			
100%				

What are the inspection intervals?

10%	Only as noted
80%	Periodic
10%	Unknown
100%	

Are records of inspection maintained by your company?

8%	No Inspection
27%	Visual Inspection Only
18%	Written but no Record Kept
33%	Written with Retained Record
15%	Unknown
100%	

Driver defect reports including the VCR are the means of communication between the driver and the repair shops. Responses show that maintenance personnel feel the driver reports are useful.

What is your general feeling about driver defect reports?

18%	Cannot Answer
80%	Useful
0%	A Nuisance
2%	Not Helpful
100%	

Their utility, however, is tempered by the willingness of the writer (driver) to be specific, but, given a good report, the maintenance department has a clue as to the problem.

Each maintenance person interviewed was asked to rate specific vehicle systems and components which require frequent maintenance. The following list is a compilation of their answers.

Component by Major Categories	No. of Responses Indicating Item Requires Frequent Maintenance
ENGINE: General	0
Engine Itself	15
Intake/Exhaust System	11
Fuel	5
Radiator	5
Gauges	2
BRAKES: TRACTOR, TRAILER & CONVERTER--General	1
Drums	5
Air Compressor & Controls	6
Hoses and Connections	11
Lining	4
Mechanism	2
SUSPENSION: TRACTOR, TRAILER & CONVERTER -- General	0
Springs, Shackles & Brackets	14
Shock Absorbers	4
Air Suspension	1
Axle (excluding Drive Axle)	1
Landing Gear	6
STEERING: General	3
Linkage	7
Gear Box	1
BODY/CHASSIS -- General	0
Lights:	11
adjustments/damage	2
head	1
tail	12
running and clearance	31
Cab/Trailer:	1
floor	5
windows	2
general condition of body	2
wipers	8
defroster	0
mirrors	8
fifth wheel	1
safety equipment	0
horn	1
DRIVE TRAIN: General	1
Transmission	9
Clutch	12
Drive and/or Rear Axle Assembly	1
MISCELLANEOUS:	0
Battery	11
TIRES: General	10
Wheels	4
Lugs	5
Tires-Tread and Carcass	28
Other (Electrical System--General)	1

As was expected, the clearance lights were the most frequent maintenance.

In response to:

What kind of maintenance record system do you have?

22%	None
12%	Computerized
58%	Manual
8%	Combination or Missing Data
100%	

Most reported a manual system. Those companies that have a computerized system are large. In several cases, other companies were moving in that direction and recognized the value of such a system but placed a good manual system and better inspection as higher priority needs.

The final portion of the discussion dealt with the opinions of the respondents to a variety of items dealing with several subjects, including accident causation and governmental regulations. Their responses are noted here.

The following were identified as contributors to large-truck accidents in 1972 and 1973. How frequently might these defects cause accidents? (The values are percentages.)

Contributors to Large Truck Accidents	Frequently	Sometimes	Infrequently	Don't Know	Not Applicable
Front Tire Blow-Out	18	15	42	24	
Rear Tire Blow-Out		3	70	27	
Trailer-Tire Blow-Out		2	52	30	17
Brake Failure	17	26	44	14	
Coupling Device	8	6	33	27	26
Wheel	2	14	60	26	
Lights (Front)	5	5	68	23	
Lights (Rear)	6	9	67	18	
Tow-Bar	3	5	3	20	70
Steering Failure	8	12	61	20	
Smooth Rear Tires	3	17	58	23	
Unloading Hose		3	6	20	71
Cargo Securing Chain	3	6	35	17	39

On the average, are drivers able to identify potential mechanical defects before these problems become dangerous?

92%	Yes
2%	No
6%	Don't Know
100%	

Why should trucks have regular servicing?

It reduces repair costs.	Agree
It increases resale value.	Agree
It reduces down time due to failure.	Agree
It prevents down time due to the enforcement of govt. regulations.	Agree
Prevention of injury or death.	Strongly Agree
It prevents accidents.	Strongly Agree
Regular servicing is not necessary.	Disagree

Which are most likely to cause an accident?

24%	Left Front Tire Failure
6%	Right Front Tire Failure
54%	Don't Know
16%	Either

Which are most likely to fail?

16%	Tube-Type Tires
27%	Tubeless Tires
55%	Don't Know
2%	Unknown

Are vehicle failures and defects, or driver errors most frequently the cause of accidents with large trucks?

3%	Vehicle or Mechanical Failure
88%	Driver Error
9%	Both--about equal

There are a number of government agencies which are concerned with highway safety including local police, state motor vehicle administrations, and federal regulatory bodies. To what extent do these influence your firm?

Local Police	Not Influential
State Police	Influential
State Commercial Vehicle Inspectors	Influential
Federal Commercial Vehicle Inspectors	Not Influential*
Company Inspection	No Opinion

*Of those regulated by BMCS, they responded influential.

Are governmental vehicle mechanical condition regulations:

Governmental Regulations	Excessive	About Right	Too Weak	No Effect	NA
Federal	6%	65%	11%	15%	2%
State	5%	82%	14%		
Local	3%	65%	9%	15%	8%

Do governmental regulations force the firm to accept maintenance and repair costs that are excessive?

Governmental Regulations	Yes	No	No Effect	Don't Know
Federal	2%	93%	3%	2%
State	3%	95%	2%	--
Local		95%	5%	

Does the State PMVI Program affect the condition (mechanical) of your vehicles?

70% No
30% Yes -- Most of these were small intrastate carriers who were not subject to BMCS rules and regulations. The large carriers would not be affected by this anyway, since inspection is just plain good business.

Are drivers assigned to different vehicles (power units) for each trip (i.e., slip seat) or are they assigned to the same vehicle?

29% Different Vehicle (Slip Seat)
69% Same Vehicle

Most companies would like to have the same vehicle assignment since it results in better vehicle condition, but cannot justify it on economic grounds.

At the end of the discussion, HSRI's representative was asked to make several ratings of the company, based on his observation and evaluation of the company when compared to others. These results are reported here but discussed in detail at the end of this section.

Our estimate of the level of maintenance and inspection activities of organization.

Level of Maintenance & Inspection	Maintenance	Inspection
Above FMCSR Standards	28%	12%
FMCSR Standards	62%	34%
Below FMCSR Standards	10%	48%
Non Existent (None)		6%

What is the OSHA type shop rating? (HSRI's judgment of the working conditions of the area.)

12%	Excellent
43%	Good
25%	Fair
5%	Poor
8%	Unacceptable
6%	No Facility at Interview Site
100%	

What type of maintenance and inspection program does this company have?

Insp.	Maint.	
6%	5%	Sophisticated (Computer Records, etc.)
34%	48%	Adequate (Manual Records or Computer)
13%	31%	Marginal (Some Semblance of a System)

	Insp.	Maint.	
Cursory Visual	43%	15%	Maintenance Only--Fix if we find it.
No Inspection	3%	1%	Breakdown maintenance--repairs only to keep it going.

Appearance of Firm:

Condition	General Quarters	Equipment--Tractors & Trailers	Shop or Garage*
Spotless	7%	7%	4%
Clean and Tidy	43%	31%	30%
Used but not Abused	28%	53%	30%
Generally Clean but Disorganized	17%	3%	15%
Dirty but Orderly	2%	2%	15%
Dirty and Disorganized	0%	2%	4%
Neglected and Run Down	2%	2%	0%
Missing Data	2%	2%	2%

*At about 20 locations, facilities were not available for inspection.

The overwhelming conclusion based on this data and from personal discussions during the interviews is that while maintenance programs exist, adequate detection of vehicle defect is lacking. Also, the driver is in an ideal position to detect and report mechanical defects and problems, both before, during, and after a trip.

Results of the Supplemental Accident Data Acquisition

The drivers in the matched pair-sample were contacted by telephone. In addition to a detailed analysis of certain of the variables, a series of frequency counts were made of all the data entries on the form. Some of these are of interest and are reported here.

One hundred fourteen (114) cases or 57 matched pairs of drivers were contacted. Using a random sample, these 57 pairs of cases were chosen to represent the data period of 79 days. These 57 cases were distributed over 44 days of the data collection period.

The reports selected for this investigation represented accidents which occurred in 50 of the 254 counties in Texas. Of these, accident reports were drawn from 50 of the counties (20%). As might be expected, the counties containing Dallas, Fort Worth and Houston had the most accident reports selected.

Time of day of crash was evenly distributed, with 42.5% of the crashes occurring in the AM and 57.5% of the crashes occurring in the PM.

Vehicle ownership was distributed over several different kinds of owners, as tabulated below:

11%	Self--i.e. Driver or Relative
46%	Trucking Company
1%	Broker
4%	Leasor
37%	Other Business Firm
1%	Don't Know

The distribution of vehicle model year ranged from a 1950 unit to 1974 units.

Percent	Model Year
9	1950
9	1952
9	1958
9	1959
9	1961
9	1962
2.6	1963
1.8	1964
2.6	1965
2.6	1966
6.1	1968
6.1	1969
7.9	1970
19.3	1971
6.1	1972
21.1	1973
18.4	1974

Many different vehicle makes were reported.

Percent	Make
16	Chevrolet
2	Diamond T (Reo)
1	Dodge
16	Ford
16	White
11	GMC
23	International
4	Mack
9	Kenworth
4	Peterbilt

In terms of vehicle type, the majority were semi units (60%) followed by straight trucks (30%), bobtail units (5%), doubles (2%), and straight truck and trailer (3%).

These vehicles were equipped with one of the following cargo body styles.

Percent	Cargo Body Style
6	Bobtail
0	Chassis Only
5	Beverage
11	Dump
0	Fire Truck
4	Flat Bed Container
3	Flat Bed with Added Device
7	Flat Bed--Other
8	Float (Low Boy)
5	Gondola (Grain, Hopper)
1	Garbage
1	Mixer
2	Pole
25	Van--Conventional
6	Van--Refrigerated
5	Van--Furniture (Moving)
0	Van--Open Top
5	Wrecker
0	Automobile Carrier
6	Tanker--Liquid
0	Tanker--Bulk Dry
0	Cattle Rack--Livestock
0	Utility (Telephone, etc.)
0	Boom or Crane
0	Other ____________

The majority of the vehicles were carrying these types of cargo and loaded at the time of the crash (66%).

Percent of All Vehicles	Cargo
7	Farm Products--Raw
8	Mining Products--Raw
3	Forest Products--Raw
18	Processed Food
1	Textile Products--Raw
1	Textile Products--Processed
8	Building Materials
4	Household Goods
6	Furniture
4	Paper Products
4	Chemicals
0	Petroleum--Raw
4	Petroleum--Processed
1	Primary Metal Products
8	Fabricated Metal Products
4	Machinery--ex. Electrical
1	Electrical Machinery
5	Transportation Equipment
4	Scrap, Refuse, Garbage
9	Mixed Cargo--LTL Freight

Percent of All Vehicles	Cargo
9	Mixed Cargo--LTL Freight
2	Other
1	No Load
1	General Commodities
2	Bobtail

Subjectivity to the FMCSR was a question asked. The answers received were wide ranging and thought to be inaccurate in some cases. To the best of our determination, the responses are as follows:

Percent	Trip Subject to:
40	FMCSR
20	PSC (Public Service Commission)
32	No Regulation
1	Unknown
5	Should be FMCSR but responded PSC
1	Should be FMCSR but responded None
3	Should be FMCSR but was unknown by the driver

The distribution of operating authority (type of service) is shown below. These are driver responses verified to the best of our ability.

Percent	Type of Service
15	Interstate--Common Carrier
7	Interstate--Contract Carrier
12	Interstate--Private Carrier
4	Intrastate--Common Carrier
5	Intrastate--Contract Carrier
18	Intrastate--Private Carrier
2	Exempt Agricultural
31	Local Delivery
5	Service or Utility
1	Unknown

Forty-five percent (45%) of the trips were local in nature. The average distance from the origin to the point of the crash for the other 60% of the trips were 154 miles.

Eighty-nine percent (89%) of the respondents indicated that they drove this type of truck regularly, and 93% indicated that they regularly hauled this type of cargo. There were no differences between the defect and non-defect involved drivers in this respect.

Ninety percent (90%) of the drivers were driving for a trucking company or truck using company at the time of the crash. Seven percent (7%) were driving for themselves.

Fifty percent (50%) of the vehicles were in fleets of fewer than 15 vehicles. The largest fleet represented was 1,700 vehicles. Only 20% of the vehicles were in fleets of over 35 vehicles.

In response to:

Did you make an inspection of the vehicle prior to beginning the trip?

46%	Detailed Inspection
42%	Brief Look-Around
2%	No
4%	Unknown
5%	Yes, But Type Unknown

Forty-six percent (46%) of the drivers reported that they had made a detailed inspection while 93% said they had made some type of an inspection. Only 8% of the drivers stated that they had detected a mechanical problem prior to the trip. These problems were four cases of bad brakes, and one each of defective lights, front end alignment, tire failure, and general body condition.

Thirty-eight percent (38%) of the drivers said that a mechanical problem was a cause or contributor to the accident, whereas 1/2 of the vehicles were chosen because they had defects contributing to the crash. Either the defects occurred during the trip or the drivers failed to detect them during their pre-trip inspection.

These driver-stated accident causation factors and the reason determined by us (and the police) are shown below.

Driver Stated	Category	Our Reason
7%	Brakes--bad in general	26%
1%	No Lights or Defective Lights	4%
3%	Inoperative Brakes	
	Front End (Steering Axle)	1%
2%	Brake Failure following repair	
7%	Tire Failure	7%
2%	Tow Bar or Chain	2%
2%	Cargo Tie Down	5%
2%	Fifth Wheel	1%
7%	Wheel Failure	5%
6%	Brake System Failure	
2%	Body	
1%	Suspension	

The following shows the types of service represented by the driver of these accident-involved vehicles.

Operating Authority and Nature of Operations

Freight Classification	Carrier	Interstate		Intrastate	
		Large*	Small**	Large	Small
General Freight or Multiple Classification	Common	5	8	2	2
	Contract	2	1		3
	Private		5	1	
Specialized	Common	1	1		2
	Contract	1	2	2	3
	Private		9	1	15
Exempt Agricultural					3
Local Delivery			2	2	28
Service or Utility					8

*50 or more units. **Less than 50 units. Unknown 3.

Of the 114 drivers interviewed, 33% were engaged in interstate commerce and 67% were engaged in intrastate or local delivery.

Grouped according to driver-reported fleet size, we get the following:

Fleet Size No. of Units	Group	N	Percent
1	1	12	11
2-5	2	25	22
6-10	3	8	7
11-19	4	11	10
20-49	5	22	20
50+	6	17	15
	Unknown	17	15

A detailed analysis comparing intrastate and interstate carriers on several defect and non-defect criteria follows.

D. Analysis of Motor Carrier Characteristics

In order to separate the motor carriers studied in this project by characteristics of their maintenance practices, they were divided into three categories of fleet size and by their operating authority. Size is expressed as small (1-5), medium (6-19), and large (20+), and operating authoriy is given as inter- or intrastate.

The inspection, maintenance, and driver survey variables presented in the following tables were dichotomized as necessary so that an entry into the table is an indication of "good" practice. In variable 16, for example, a "yes" response to whether a pre-trip vehicle condition report is required was tabulated as a good response. The values shown in the tables represent the percentage of good responses within each of the categories described.

Table 6 shows the data for motor carrier inspection variables, and the collapsing of the categories in the last

TABLE 6

MOTOR CARRIER INSPECTION VARIABLES

Analysis Variable Number	Variable Name	Inter State Sm %	Inter State M %	Inter State L %	Intra State Sm %	Intra State M %	Intra State L %	Inter State	Intra State	Fleet Size Sm	Fleet Size Large
16	Pre trip Vehicle Condition Report	13	33	67	5	25	20	42	12	7	45
17	Post trip Vehicle Condition Report	25	83	67	23	50	90	58	46	24	77
37	Pre trip Insp. Detailed	25	33	75	13	13	40	50	20	16	59
	Quick Look	50	66	25	82	63	50	42	70	73	38
37	Pre trip Insp. Something	75	100	100	95	75	90	92	90	89	95
38	Other Pre trip Insp.	25	33	50	9	38	10	38	14	13	32
39	Vehicle Condition Report Made (FMCSR-VCR)	13	50	58	0	25	20	42	9	3	40
39	Some type of Veh. Con. Rpt.	100	100	100	68	75	100	100	78	77	100
41	Periodic Insp. made by Maint. Staff	62	80	83	59	100	100	77	78	59	89
42	Inspection Intervals - periodic	100	80	92	59	100	90	85	75	70	93
43	Insp. Records Maintained	50	67	75	14	63	80	65	41	24	77
92	Driver Defect Reports-useful	100	80	92	55	75	100	92	70	67	96
107	Driver is able to Identify mech. defects	100	100	100	86	75	90	100	85	89	95
132	Estimate of adequate inspection per FMCSR requirements	50	17	92	13	63	60	62	34	23	77
134	Company has a system of inspection	38	68	92	22	75	88	69	44	26	90
129	State PMVI Affect Cond.	62	68	58	86	75	50	61	76	80	54

four columns is of particular interest. The differences in responses by inter/intrastate do not show any dramatic differences, while a consistent pattern emerges when a comparison is made between small and large fleet sizes. In almost every variable, larger fleet size is associated with better inspection practices. It can be concluded that the greater the number of vehicles under the control of a single carrier, the better will be their inspection practices, irrespective of the kind of hauling done by the company.

The data for the motor carrier maintenance variables are shown in Table 7. As in the previous case, the size difference among carriers shows a more marked effect than does the difference in operating authority. It can be concluded that the maintenance practices of larger companies are more adequate than those of the smaller ones.

In trying to relate the information on inspection and maintenance practices to on-the-road performance, we turn to the data reported by the driver and shown in Table 8. Because of the small numbers involved, most of the variables give very little indication of difference between fleets of different size. Variable 21, however, indicating whether a detailed inspection was made prior to the trip in the accident population sampled, shows clearly the advantage of a good inspection system. In the large fleet size group, twice as many vehicles in the inspected category showed no defects as were in the defect group. For the small fleet size group, the reverse is true. Although we cannot state the reason why from these data alone, large fleets have both better inspection practices and a smaller proportion of defect associated accidents. This result is summarized in Table 9.

The effect of commercial vehicle systematic preventive maintenance on specific causes of accidents is a general effect. Namely, the presence of a maintenance and inspection system reduces the likelihood of a defect and hence an accident given two

TABLE 7

MOTOR CARRIER MAINTENANCE VARIABLES

Analysis Variable Number	Variable Name	Fleet Size & Operating Authority: Inter State Sm%	Inter State M%	Inter State L%	Intra State Sm%	Intra State M%	Intra State L%	Inter State	Intra State	Fleet Size Sm	Fleet Size Large
18	Uses Regular Written Maint. Schedule	13	33	83	9	50	90	50	39	10	86
19	Keeps Maintenance Cost Records	100	100	83	81	75	90	93	81	86	86
20	Keeps Maintenance History on each Vehicle	50	83	91	73	87	80	77	78	70	86
93	Maintenance Record System	88	100	100	50	88	100	89	71	60	100
133	Shop Rating - Good or Excellent	50	17	75	31	62	60	54	46	36	68
131	Estimate of Adequate Maintenance per FMCSR requirements	100	67	100	77	100	80	92	83	83	90
135	Company has a system of maintenance	88	83	92	73	88	60	93	78	77	77

TABLE 8

DRIVER SURVEY VARIABLES

Analysis Variable Number		Variable Name	Fleet Size & Operating Authority: Inter State Sm%	M%	L%	Intra State Sm%	M%	L%	Fleet Size Sm	Large
21		Vehicle Inspection Prior to Trip	100	100	100	93	83	75	19	87
21		Detailed Inspection Prior to Trip	57	83	74	33	31	30	37	51
22		Detected a Mech. Problem prior to trip	0	50	11	3	0	0	2	5
24		Mech. problem cause of accident? (yes) (detected by driver after accident)	28	67	21	30	31	40	27	31
27		This report used because it was for a defective vehicle	43	67	26	43	38	65	43	46
21	D*	Detailed Inspection Prior to Trip	83	50	50	39	40	30	52	36
	M		50	50	86	29	25	28	33	66
22	D	Detect a Mech. Problem prior to Trip	17	0	0	0	0	0	5	0
	M		0	100	14	5	0	0	4	9
24	D	Mech. problem cause of accident	80	25	80	69	80	67	72	67
	M		0	50	7	0	0	0	0	5
21	D	Inspection prior to trip	100	100	100	92	100	92	90	95
	M		100	100	93	88	88	100	90	95
28	D	No defect	0	0	17	0	0	0	0	5
	M		100	50	93	100	92	100	100	95

* D = Defect M = Non Defect

TABLE 9

SUMMARY OF VEHICLE DEFECTS AS A FUNCTION OF CARRIER SIZE

	SMALL	LARGE
(1) Defect	n=16 21%	n=18 24%
(2) No Defect	n=21 28%	n=21 28%

Sample Size Computation for Table 9:

		Small	Large	Missing Data
(1) Defect	Inter	3	5	4
	Intra	13	13	9
	TOTAL	16	18	13
(2) No Defect	Inter	4	14	1
	Intra	17	7	3
	TOTAL	21	21	4

112	Cases in Original Data File
- 19	Cases in Missing Group
79	Cases in Table and Missing Data
- 17	Cases of Missing Data
62	Cases in Table

important factors: (1) a good detection and reporting system, and (2) an adequate resource allocation to ensure effective repairs. (This should not be construed to mean that unlimited resources should be used in maintenance; indeed, over-maintenance can also be a cause of defects--hence, potential accidents).

Our data indicate that the larger the carrier, the less defect related crashes are likely to occur. This does not appear to be due to the physical size of the carrier per se (number of units), but to the willingness and ability of the carrier to allocate funds to provide for adequate maintenance with an effective inspection/detection system to back it up. Certain small carriers also achieve this goal by proper management and resource allocation.

APPENDIX

APPENDIX A

MOTOR VEHICLE INSPECTION: BACKGROUND AND REVIEW OF THE LITERATURE

I. INTRODUCTION

An analysis of the effectiveness of motor carrier safety regulations requires an ability to evaluate the efficacy of motor vehicle inspection in general as well as an understanding of the structure of the motor carrier industry. A substantial amount of research has gone into the former area because the field is rather complex. One of the functions of this appendix is to review the literature on vehicle maintenance and safety to help determine the methodology that is most suitable for an evaluation of the effectiveness of motor carrier safety regulations. Two alternative analytical approaches to the problem will be reviewed. The first uses a step-by-step approach to tie preventive maintenance to limiting performance characteristics. The second attempts to use expert opinion to rank the safety importance of particular components. In addition, an idea of current maintenance practices will be obtained by reviewing the trade journal literature.

Maintenance procedures of U.S. carriers vary widely from routine checks on certain vehicle components to the use of replacement theory to determine optimal replacement intervals. The basic criteria of optimality seem to be economic considerations and not safety. However, these two factors are generally not conflicting so that minimizing costs due to maintenance problems often results in greater safety.

A brief review of the monthly articles on maintenance in some of the major trade journals illustrates some of the factors that carriers are advised to consider during their routine maintenance inspection. Tires are probably the most frequently mentioned components that are discussed in these articles.

Drivers and maintenance men are often exhorted to check tire pressure--a practice which, according to one maintenance expert, is often neglected (Shea, 1972).* Tire pressure in relation to top vehicle speed and load is discussed in the literature and information about tube-type and tubeless tires is often provided. Since radial tires are becoming more popular they are often discussed, and the major theme of these discussions is that they should be compatible with other vehicle components.

Brakes are also often mentioned. A common admonition is that maintenance personnel should check for air leaks. The effect of speed on brake wear is also occasionally commented on. Lubrication is another factor commonly discussed, especially methods of increasing the lubrication intervals.

The failure of drivers to check basic components during the pre-trip inspection is often examined. The items most commonly overlooked are locking devices on trailer sliding tandems, missing or loose wheel nuts, amount of water in air tanks, tire pressure, and fifth wheel.

Another common item of discussion, especially recently during the energy crisis, is fuel consumption. The effects of such factors as speed, idling, and tire pressure on fuel consumption are some of the major points of consideration.

While all of the above factors are straightforward, most are essential to the safe operation of large trucks. If drivers are ignoring such fundamental factors as the presence of wheel nuts, much can be done to improve safety merely by stressing the importance of such factors on carriers. If drivers can be made aware of these problems, as many of the articles reviewed are attempting, then the payoff should be great.

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*Denotes a reference located in the Bibliography.

However, other problems exist. Among them is the fact that, according to a number of drivers, maintenance personnel pay no attention to many of the defects that drivers do write up. Furthermore, many drivers besides overlooking obvious defects before leaving (dispatched) their terminals, are unable to detect many less obvious defects by visual inspection.

This survey suggests that problems such as exhaust leakage or steering malfunctions are not often considered. In addition, defects such as defective windshield wipers, which are not blatant safety hazards or do not significantly increase operating costs, also seem to be neglected.

Studies conducted by the Bureau of Motor Carrier Safety demonstrate the consequences of the negligence involved in some pre-trip inspections. A controlled sampling survey conducted by the Bureau in 1970 resulted in 16.5% of the vehicles sampled being ordered out-of-service and 27.8% being classified "unsafe" (BMCS, 1971).

Road checks of selected vehicles by the BMCS indicate that the most frequently reported defects are those relating to braking systems and lighting devices. For example, in 1968, of 53,067 vehicles inspected, brake defects were reported 26,989 times and 9,678 of these reports involved out-of-service conditions. There were 26,216 lighting device defects of all types and 2,002 lighting device out-of-service defects (BMCS, undated).

The Bureau of Motor Carrier Safety has issued a truck driver's pre-trip checklist of items which should be checked before each trip. This list includes all the components mentioned above and many others (BMCS, 1972). The Bureau has also issued a pamphlet which recommends the procedure for pre-trip inspections (BMCS, 1971). Hopefully, articles such as these will improve carriers' awareness of their inspection responsibilities.

Knowledge of the structure of the motor carrier industry is essential so that a comparison can be made between accidents involving trucks that are subject to motor carrier regulation and those that are not. It is also important to know whether specific carriers are aware of the applicability of Federal Motor Carrier Safety Regulations to their operations. Because of the complexity of BMCS jurisdictional criteria, many of the smaller carriers are uncertain about whether they are subject to BMCS regulations.

The next portion of this appendix provides a background into the research on evaluation of the effectiveness of motor vehicle inspection and the defective equipment/safety problem. Particular attention will be paid to the work that has been done on the limit performance characteristics of various vehicle components and their effects on accident causation.

The last section of this appendix is devoted to a description of the legal structure of the motor carrier industry from the perspective of Federal regulation. This perspective is chosen because many of the regulations of the BMCS are based on Interstate Commerce Commission concepts and apply to the services over which ICC has jurisdiction.

II. BACKGROUND: RESEARCH INTO THE EFFECTIVENESS OF MOTOR VEHICLE SAFETY REGULATIONS

Poor mechanical condition has for many years been considered a cause of a substantial number of motor vehicle accidents. Such a relation is both intuitively plausible and is supported by frequent involvement in crashes of vehicles with glaring mechanical deficiencies. Public concern has led to the enactment of various program to upgrade the quality of the vehicle population. Most prominent among these efforts have been the periodic motor vehicle inspection programs (PMVI). Most public attention has been focussed on the programs' effect on private passenger cars.

The federal government has long been involved in the area of motor carrier operations--first under the Interstate Commerce Commission and more recently under the Department of Transportation. The Bureau of Motor Carrier Safety (BMCS) has played an active role in establishing and enforcing standards of vehicle equipment and condition in the motor transportation industry. The standards have been codified in the Federal Motor Carrier Safety Regulations (FMCSR). Programs cover four major areas: field inspection of drivers and trucks moving in interstate commerce; safety surveys of carrier's operations at terminals; in-depth investigation of particular crashes; and collection and analysis of carrier reported accident data. These programs have in all likelihood served to improve the safety level of the industry (BMCS, 1972).

Until recently the relationships among maintenance activity, vehicle condition, vehicle inspection, and accident causation have received, like most other highway safety areas, scant scientific evaluation. Most programs were predicted on the intuitive concept that inspection appeared to be a good idea. Little was done to evaluate the programs' effectiveness. Since the mid-1960's, studies have been actively pursued in a number of areas: attempts to define statistical relationships between the existence of inspection programs and accident rates; empirical measurement of the effect of vehicle inspection programs on the mechanical condition of motor vehicles involved in crashes, with "clinical" examinations of vehicles involved in crashes to determine the role played by mechanical defects in accident causation; and mathematical and engineering analyses of the relationships among maintenance practice, initial vehicle quality, inspection activities, degraded component condition, and accidents.

Statistical comparisons of jurisdictions with and without periodic motor vehicle inspection programs have produced results favorable to inspection. The most commonly cited investigation is that of Buxbaum and Colton (Buxbaum, 1966) in which they analyzed age-adjusted motor vehicle mortality rates per 100,000 total population. In their initial study they found highly significant differences among inspection and non-inspection jurisdictions for non-white males in the 45 to 54 year-old age category. In the second study, such significant differences appeared for both white and non-white males in the 15 to 64 year-old age groups. Their second study also controlled for other factors like population density and mean income. However, in a re-analysis of similar data, Fuchs and Leveson, using a slightly different statistical methodology and variables more directly tied to driving experience, e.g., per capita gasoline consumption, found no statistically significant relationship between inspection and death rates (1967). Using slightly different data, i.e., mileage death rates, Recht found a statistically significant but small effect of inspection. He used the same predictor variables as Fuchs and Leveson (1967). In an earlier review of the data, Mayer and Hoult concluded that there were indications of a relationship between inspection and fatality rates, but that the picture was so clouded by the inherent variability in the data that it would be difficult to demonstrate conclusively a relationship (1963). Bintz analyzed trends in accident rates over an extended period and found that states without PMVI programs had experienced a greater reduction in crash rates than those that had periodic inspection (1966).

To find a more precise relationship between inspection and accident experience, Reinfurt and his colleagues (1971) followed the accident experience of vehicles in North Carolina as the state's inspection program was phased in. No difference was discerned in accident experience among vehicles which had and had not been inspected. A similar study for Florida is now being conducted. To test the hypothesis that older vehicles might be overinvolved in accidents due to mechanical defects, Hall and Little (1968) examined fatal and other crash experience for a large sample of accidents in three Michigan counties. They concluded that older vehicles were not significantly overinvolved. These results were challenged by Joksch on a number of empirical and methodological grounds. Joksch concluded that older vehicles were relatively overinvolved in accidents. Multi-disciplinary Accident Investigation teams sponsored by the National Highway Traffic Safety Administration have also reviewed the role of mechanical defects in crashes. A team at the Indiana University devoted painstaking effort to the problem. The Indiana investigation concluded that in 6% of the crashes a mechanical problem was the primary cause of the accident. In another 8% of the crashes defects contributed substantially to either the causation or the severity of the accident (Treat, 1973, 1973, 1971). The investigation also concluded that "at fault" vehicles in accidents had a significantly higher incidence of defects in categories of tire tread depth, brake lining thickness, wheel alignment, windshield wiper operations, and horn operation than did the general car population.

A detailed study of truck accidents by Scott (1971), which used police reports, indicated that trucks reported as being mechanically defective were significantly overinvolved in single-vehicle accidents and that trucks engaged in heavy service operations, like dump trucks and pole trucks, had substantially higher frequencies of reported defects than the general truck population. This research conclusively indicates that a small fraction of, but still substantial numbers of, crashes result from vehicle defects. Moreover, the studies suggest a frequent association between problem drivers and problem vehicles, from which it might be hypothesized that certain crashes normally attributed to driver error may have resulted from non-obvious degradations in performance, particularly of vehicle handling components. Scott postulated that such overinvolvement was more likely a function of driver characteristics and exposure factors than of differences in mechanical condition (1971). The safest conclusion that can be drawn from these studies is that they present irrefutable evidence for the extreme difficulty in drawing inferences from statistical analyses of aggregate accident data.

More directly related to the question of degraded mechanical condition and accident causation have been "clinical" or in-depth investigations of crashes. The earliest reported study of this kind was performed by a group at the Harvard Medical School, which discovered a large incidence of mechanical defects contributing to accidents that had been considered to be the result of driver errors (Harvard Medical School, undated). The published summaries of BMCS investigations of motor carrier crashes indicate a 10%-15% involvement of mechanical defects in contributing to crashes as shown in Table 1.

TABLE 1.--Reported Involvement of Mechanical Defects in Contributing to Motor Carrier Crashes as Reported from BMCS Accident Investigations.

Year	Total Crashes	Crashes Involving Mechanical Defects	Percent
1967	250	28	11.2
1968	247	38	15.0
1969	286	32	11.2
1970	221	23	10.4
1971	291	36	12.4
1972	305	32	10.5

SOURCE: Bureau of Motor Carrier Safety, Summary of Accident Investigations, 1967-1972.

A third type of study has measured the mechanical condition of vehicles against variables such as the age of the vehicle, vehicle mileage, driver economic and demographic characteristics, and the type of inspection system used. The number of studies has been small because of the high cost of a large sample of vehicles needed to describe the population adequately. The earliest study, conducted by Sherman and McCutchen at the Highway Safety Research Institute, used a sample of vehicles from the municipal inspection stations in Washington, D.C.; Cincinnati, Ohio; Memphis, Tennessee; and a sample of vehicles on the road in Ann Arbor, Michigan. Using consistent inspection criteria in each city, these investigators found substantial differences between cities with no inspection and frequent inspection. (Ann Arbor, with no inspection system, had the highest failure rate; Memphis, with the most frequent inspection, had the lowest failure rate (McCutchen and Sherman, 1968).

Another early study conducted by TRW, Inc., used data generated by diagnostic facilities around the country to describe factors which affected mechanical condition. The study found that the age/mileage relationship was the most consistent explanatory item (1968). The most ambitious investigation was conducted under NHTSA direction by Ultra-system, Inc. This study attempted to draw an unbiased, representative sample of the national vehicle population in order to establish the effect of vehicle inspection and many other factors on the vehicle's condition. The study found significant differences among inspection states taken as a whole and a non-inspection state--California. The conclusions, however, were marred by the investigator's data collection difficulties, which forced them to use extreme techniques such as recruiting volunteers through newspaper advertising and using regular diagnostic facility customers. These techniques raise questions about the sample's representativeness (Fisher, et al., 1972). Most recently, Creswell and others at HSRI evaluated a spot inspection system in Michigan. The investigation reaffirmed the consistent relationship between vehicle condition and vehicle age, vehicle mileage, owner age, and owner's economic status, but it found only a slight relationship between the spot inspection program and vehicle condition (Creswell, et al., in preparation).

In the truck area, BMCS conducted a controlled sample of vehicle condition to measure the degree of bias in their normal inspection procedures. While the study concluded that BMCS'r normal inspection was reasonably unbiased, it did reveal substantial variation in condition among regions of the country and among types of carriers (BMCS, 1971; Morrison and Seiff, 1972). From these studies, it can be concluded that periodic inspection probably has a positive influence on the condition of vehicles, that the degree of influence varies from component to component, and that the condition of vehicles is very strongly influence by their age, mileage, and owner characteristics.

Mathematical and engineering analyses have been made of the relationships among the elements of inherent component quality, usage, owner maintenance practice, inspection efforts, degraded component condition, vehicle performance, and accident causation. A substantial portion of this work has been performed by the Highway Safety Research Institute by O'Day and Creswell (1967, 1971, 1968, 1969) and by Segel, Murphy and others (1971, 1972, 1971). The first two researchers have concentrated on defining heuristic and mathematical models of the effects of owner repair practice, inherent component failure rate, and vehicle inspection on component condition. The second group has engaged in an extensive program of describing the influence of various design parameters on the handling performance of vehicles. This description has been summarized in a series of heuristic models, which provide a useful conceptual approach to the problem.

One of these models is shown in Figure 1. A convenient starting point in this model is the box labeled "Component Failure and Degradation." How often an item fails or how rapidly performance degrades is affected by a number of factors: initial quality, vehicle use under different service conditions, the general environment, and most importantly in the present context, the operator's preventive maintenance program. For example with proper lubrication, preventive maintenance can reduce wear experienced by moving parts, or

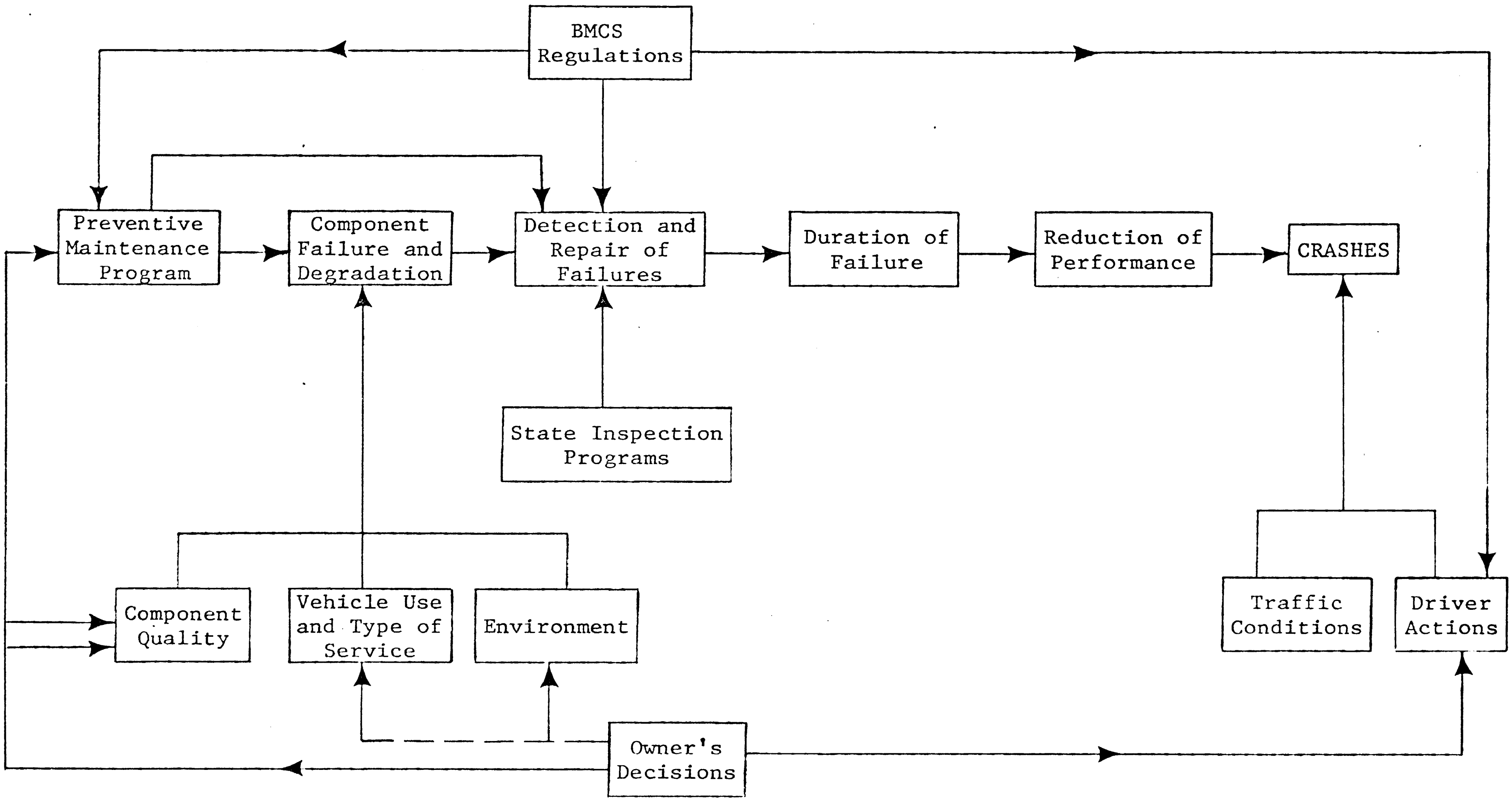

FIGURE 1.--Model Simulating Effect of Repair Practice, Inherent Component Failure Rate and Vehicle Inspection on Crashes.

close control of tire pressure can enhance tread life. The BMCS program enters the process in two ways. First by specifying minimum standards for component quality, FMCSR limits the possibilities for excessive wear produced by inadequate devices. Second, by requiring established preventive maintenance procedures, the regulations may limit the rapidity of wear. While the relation between preventive maintenance and longer component life is quite plausible, little quantitative evidence is available to define it precisely.

Given that a component has failed or degraded in performance below some acceptable level, it is still necessary for the operator to detect this condition and to repair it. Established preventive maintenance programs will help insure that defects, when they do occur, will be detected and repaired quickly. Backing up this owner-initiated detection and repair activity are the BMCS road inspections and the state periodic inspection activities. These two programs can be considered complementary. The state inspection programs require that all the vehicles in the fleet be brought to standard at some specified interval. Complementing this, the BMCS spot check program provides the operator an incentive to maintain vehicle condition between required inspections in order to avoid the losses associated with having a unit taken "out-of-service" while enroute or having other sanctions imposed. Further, the BMCS spot inspections have a direct effect of causing the repair of vehicles found defective. The combined effect of preventive maintenance, state inspection, and BMCS activities serves to determine the mean time duration of a defect on a particular vehicle and hence the proportion of vehicles in the total population that are defective.

The above relationships can be summarized by the equation (O'Day and Creswell, 1967):

$$\% \text{ Defective} = \frac{T_{repair} - I}{T_{fail} + T_{repair} - I}$$

where:

% Defective is the percent of vehicles in the total population having a particular defect;

T_{repair} is the mean time to repair a defect once it has occurred;

T_{fail} is the mean time to failure;

I is a parameter representing the frequency and efficiency of inspection.

Considering the equation, if a component fails slowly, i.e., has a long mean time to failure, and is repaired quickly, i.e., has a short mean time to repair, the effect of an inspection system, either periodic or spot, will be small. Conversely, if a component fails quickly and is repaired slowly, there is a large potential effect for inspection. These effects are illustrated in Figure 2. In the figure, the vertical axis represents the proportion of the vehicle population that is defective, and the horizontal axis is the mean time to repair, plotted with shorter times to the right. The upper two curves represent the performance of a relatively short-lived component, say headlight aim, with and without an annual state inspection program. The lower two curves indicate the behavior of a moderately long-lived component, say passenger car tail lights, again with and without inspection. In the case of the short-lived component, if the operator seldom repairs the component when it becomes defective because of some combination of difficulty in detection of the failure, expense of repair, or lack of significant effect on operating, as opposed to safety, performance, the proportion of vehicles with the component being defective is shown by point "A". Imposition of an annual state inspection system would reduce

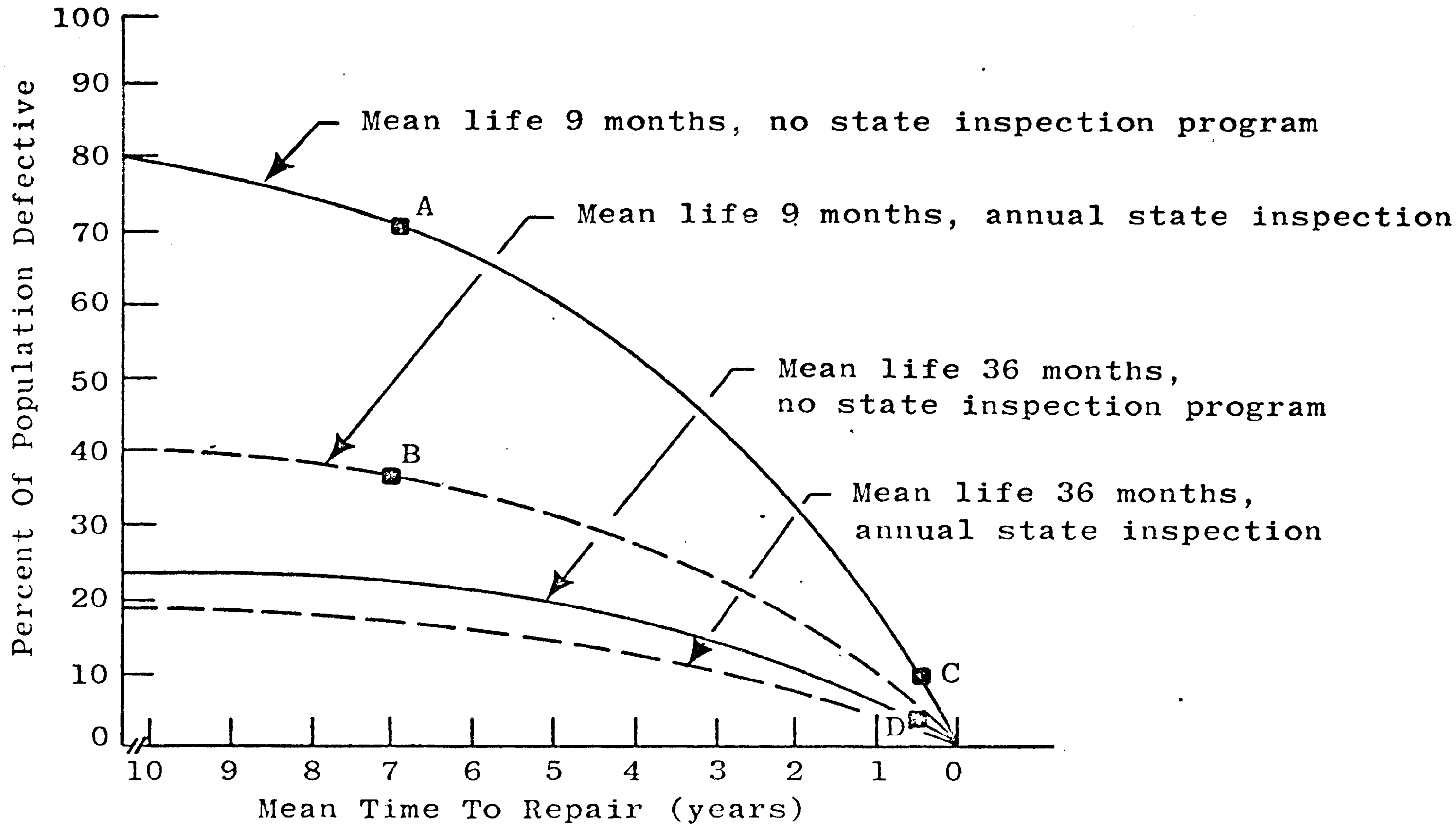

FIGURE 2.--Effect of Owner Repair Time and State Inspection Program on Outage Frequency.

outage substantially to the point marked "B". If, however, the owner instituted a meaningful preventive maintenance program, which would reduce the mean time to repair to three months, then the proportion of defective vehicles will fall to the point marked "C". On the other hand, for a long-lived component that is repaired rather quickly, imposition of a state inspection program or enhanced preventive maintenance will produce relatively small decreases in the frequency of defective vehicles on the road. This is illustrated by point "D" on the graph.

Reviewing the argument, the BMCS activities have three effects in the present model. Most importantly, by requiring and enforcing preventive maintenance programs, BMCS can have a substantial impact on the mean time to repair and an influence on the mean time to failure.

Secondarily, through enforcement procedures used by the spot inspection program, BMCS can directly reduce the number of defective vehicles in a fashion analogous to the operation of the state periodic inspection program. However, the secondary effect is probably quite small, considering the relatively small fraction of the population inspected each year. The variables then for a future study could be to discover the impact of the MCSR had on operator's preventive maintenance practice, to determine the effect of different degrees of preventive maintenance on defect occurrence, and to establish the deterrent influence of the spot inspection on poor maintenance practice.

Once a component has worn to a particular point or failed completely, the performance of the vehicle will be degraded in some fashion. The amount of degradation will depend on the type of component, the performance measure selected, and the type of performance. Type of performance can be defined as nominal or limiting. Nominal performance refers to the ability of the vehicle to perform ordinary maneuvers or other tasks under usual driving conditions, such as the typical stopping distance in traffic, and limit performance covers the most extreme condition encountered, such as full emergency braking to avoid a crash. Performance measurements can either be of system output, e.g., stopping distance, or of component related phenomena, e.g., wheel cylinder mechanical gain. System output measurements are most directly related to the safety effects of ultimate concern. Yet often it will only be possible to measure directly the effect of component wear or failure on specific phenomena, and then to relate changes in the phenomena to system output measures.

On these matters, it would be quite difficult to characterize the state-of-the-art in large commercial vehicle performance. Present knowledge varies from component system to component system and within designs for particular components. Rigorous analytical and experimental methods have been more widely adopted in recent years, and are likely to become more prevalent as increasingly strict performance standards are required. Areas affecting controlability--tires, brakes, steering, and suspension--have been heavily studies; and other component systems--headlighting, visibility, and rear lighting--have received some attention. The majority of the studies have concentrated on performance within the range of normal specifications. These investigations have been directed toward design improvements rather than determining the effect of wear and failure under present designs. In the area of wear and failure vs. performance analysis, tire tread wear and brake failures have received some attention. For tires, the onset velocity for hydroplaning is dramatically, almost exponentially, reduced as the tread wears (Clark, 1971; Doughaday and Palmer, 1970). In the area of brake performance, Murphy, Segel, and others (1971) have experimentally induced brake failures in commercial vehicles and compared the performance of the degraded system with the standard braking system. A summary of their results is shown in Table 2.

TABLE 2.--Stopping Distance for Regular and Emergency Braking Systems.

TRUCK TYPE	STOPPING DISTANCE*			
	LOADED		UNLOADED	
	Standard	Degraded	Standard	Degraded
Light	191	238	150	160
Medium	282	744	307	352
Heavy	248	2200	263	1594

*Measured in feet. Standard stopping distance measured as shortest stopping distance either with or without wheels locked. Degraded stopping distance for light and medium trucks indicates performance of service brakes with power assist disabled. Heavy truck stopping distance measured with hand brake.

In addition to examining commercial vehicle performance under a variety of conditions, the study also performed a detailed theoretical and simulation analysis of brake performance. Of several performance measurements, brake force is most closely related to stopping distance, and the authors established the following relationship:**

$$F_X = 2(p_1-p_o)*AWC*EFF*BF*(r/R)$$

where:

F_X is brake force;

p_1, p_o are brake line pressure and brake shoe retainer spring pushout pressure;

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*This is one of a series of rather complicated equations and applies to hydraulic brake systems. For a complete expression see reference 31.

EFF is the mechanical efficiency of the brake mechanism;

BF is the braking factor which is related to drum drag and the actuating force of the brake shoe;

(r/R) is the ratio of effective drum radius to effective tire radius;

AWC is the wheel cylinder area.

Stopping distance is then determined by the sum of brake forces over axles, the frictional properties of the tire/road interface, and the momentum of the vehicle. Given such a relationship, it is then possible to predict the effect of some failure, like a leaky wheel cylinder which reduces effective line pressure, on stopping distance under various conditions of vehicle velocity, load, and tire condition. Unfortunately, very few if any analyses of this nature have been performed.

Continuing the argument, it is possible to consider the effect of increased stopping distance, or degraded performance of other component systems, on accident causation. As illustrated in the model in Figure 1, the crash process itself is a function of driver behavior, of vehicle performance, and of road environment (which for simplicity can be assumed to include the behavior and performance of other vehicles in the traffic stream). This area is the most poorly understood of the whole process, even though it is most closely related to the ultimate goal of reducing crash losses. Modeling and analysis have been performed only for the most simplified situations. For example, rear-end collisions are a function of the initial velocities of the vehicles involved, the deceleration rate of the lead vehicle, the initial spacing between vehicles, the reaction time of the following driver, and the deceleration rate of the following vehicle. Yet even in a recent paper the variability of the situation has caused one author to adopt various simplifying assumptions, such as identical initial velocities and/or decleration rates for both vehicles (Tolle, 1973). Given these limitations, the study did show substantial increases in the probability of a crash, given a particular overtaking, as velocities increased and as initial spacings decreased. While the author did not explicitly examine the effect of changes in brake force, his model indicates that a given percentage reduction in brake force produces twice as great a percentage increase in the probability of an accident occurring. However, the model does not identify the probability that such potentially crash-producing events will occur. In a detailed analysis of truck accident involvement on the Ohio Turnpike, Scott (1971) examined the relative frequencies of trucks overtaking cars and vice-versa and determined that trucks were substantially over-involved relative to the number of truck-overtaking car events, as the striking vehicle in rear-end accidents. Scott was unable to determine if the overinvolvement was due to generally poorer stopping distances of trucks, or to trucks' general lack of agility in crash-avoidance situations, or to a higher incidence of brake defects in trucks, or to the tendency of truck drivers to highball on downgrades in order to build up momentum for climbing the next hill. While no one has been able to predict precisely the effect of reduced braking performance on the number of accidents, these two studies indicate that such an analysis can potentially be performed and empirically verified. Furthermore, with sufficient data and understanding of the crash process, similar analyses can be performed for the performance of other components in other types of crashes.

Over the past several pages, the relationship between preventive maintenance procedures and specific crash causes has been examined in some detail. Stated again, the relationship is: preventive maintenance determines how rapidly a component will fail and how long the component will remain in the failed state before it is replaced; given that a component has failed it will adversely affect the operating performance of the vehicle; degraded operating performance will increase the probability of a crash occurring in a particular traffic situation; finally, the increase (or decrease) in probability of an accident in a given situation integrated over the duration of the failure yields the net change in accident probability attributable to a change in preventive maintenance practice. As has been seen, the relationships are quite complex, and the analysis is often confounded by other variables like the relation between tire tread condition and braking performance or like the interaction between the following distance chosen by the driver and stopping distance in producing rear-end crashes.

The present state-of-the-art does not allow one to predict directly the effect of the systematic preventive maintenance on crash causation, but many of the pieces are present. Further, by breaking the process into a number of steps, one can more specifically determine the relationship that is ultimately being sought, and even if complete measurement is not possible, specific areas can be verified by hard evidence.

The step-by-step appraoch used here also suggests two other important points for the evaluation. First, statistical analyses of accident data to determine effects must be performed with great care, considering the number of confounding variables, but when such analyses do indicate significant effects, they represent very strong evidence of program effectiveness. Second, "soft" defects, i.e., those not producing immediate catestrophic failures, may significantly contribute to crash causation but escape even in-depth investigations, and so certain suspicious classes of crashes, particularly those involving loss-of-control, need to be critically reviewed for both direct and indirect evidence of mechanical problems, even though they may be classified as examples of driver error or poor road conditions.

The major problem with the step-by-step approach is that is does not yield immediate answers. An alternative approach, which is discussed in the next few pages, attempts a more direct approach to resolving problems. Components are ranked in terms of safety criticality by a panel of experts. Then the frequency of failure of each component is determined. The product of safety criticality and failure frequency is used to indicate the likely importance of a particular component to safety and hence to establish maintenance priorities. The approach was first evolved by Operations Research Incorporated and was later refined and elaborated by Booz-Allen, using much more detailed component specifications. A summary of the Booz-Allen study follows.

Defect probabilities were estimated from leasing fleet maintenance and repair data covering 327,000 maintenance and repair actions over three years on a fleet of about 6,000 cars. This source was used because it came from a controlled sample with a complete maintenance history and was the only source that contained comprehensive data on actual failures.

The effect of a fault is a relative measure. That is, it is a measure of the severity of a generic fault in comparison with other faults where a generic fault is the likelihood of an accident occurring if a defect occurs. The "Delphi" technique was used to estimate these effects.

This procedure as applied to this problem calls for a number of knowledgeable people to take a rank-ordered list of effects and estimate the relative importance of each with respect to the one above it on the list, together with a rationale for their estimate. The results are summarized and recirculated for additional balloting rounds until convergence occurs, when the standard deviation of the values supplied by the experts is less than 10 percent. The effects scale developed covers approximately four codes of magnitude.

The three primary faults leading to a safety failure are loss of dynamic control, loss of driver visual inputs, and driver impairment. Loss of the dynamic control functions occurs through loss of the braking, steering, or power management functions, where power management is defined as those functions associated with acceleration and deceleration of the vehicle, excluding the braking system. Loss of visual inputs is considered as originating from extravehicular or intravehicular sources.

The Delphi techniques of estimating effects yielded a semi-logarithmic plot of effect versus fault category, where the effect was on the log scale and covered five orders of magnitude 10^{-4} to 10^{0}. The location of a specific defect (e.g., steering system jammed) on this scale was determined by asking the experts who participated in the Delphi technique to decide which two faults the specific defect lies between. This was then plotted on the graph and the resulting effect determined.

Once component criticalities were computed, the benefits of current standards in criticality reduction were assessed. Only a few of the motor vehicle standards in effect during the course of the study directly affected vehicle component criticality.

The major task of the study was to formulate new standards which would reduce the criticality of those components and subsystems found to rank highest on the ordered criticality test. Standards can take two forms: (1) those which affect failure probability by increasing the reliability of components--e.g., specify replacement part quality and standardize motor vehicle inspection; (2) those which affect probability by incorporating redundancy in a subsystem so that a failure of one component does not result in a fault.

A comparison of the step-by-step approach with the criticality method, therefore, reveals that the former attempts to identify the sequence of events leading to an accident due to defective equipment and to assess the efficacy of intervention at the start of the sequence on the events which follow. The sequence includes the frequence and persistence of a defect, the effect on vehicle performance, the interaction of vehicles before the onset of difficulties and the action of the driver prior to the crash. While the step-by-step approach provides several points of intervention and a strong theoretical basis for inspection procedures, it is extremely difficult to define and conduct the empirical procedure necessary to determine the various relationships.

The criticality method avoids these empirical difficulties by obtaining the opinions of "experts." However, the question of how these experts derived their opinions remains. The criticality method actually avoids the difficulties by assuming that if consensus can be obtained among these experts, then their answers will probably be correct. However, there is no scientific justification for this expert opinion; therefore, the results are open to skepticism. The advantage of this method is that it provides answers quickly and that utilization of the knowledge of people who are active in the field in an inspection program is probably better than not having a program of having one based on guesswork.

III. AN OVERVIEW OF THE JURISDICTION OF THE BUREAU OF MOTOR CARRIER SAFETY

Introduction

Of the several federal agencies which are responsible for the regulation of motor carriers, two are of interest here. They are the Interstate Commerce Commission which is responsible for the economic regulation of interstate common and contract carriers and the Bureau of Motor Carrier Safety which is responsible for the safety aspects of all interstate motor carriers--common, contract, exempt and private. To accurately assess the role of the Bureau of Motor Carrier Safety (BMCS), a knowledge of the sources and history of the regulatory authority of the Bureau is essential as well as an understanding of the circumstances in which they apply.*

Interstate Commerce Commission

With the passage of Part II of the Interstate Commerce Act in 1935, motor carriers were subjected to federal [safety] regulations if they engaged in interstate commerce. The pertinent sections of the Interstate Commerce Act charge that the Interstate Commerce Commission (ICC) has the responsibility to establish:

> . . . reasonable requirements with respect to adequate service, transportation of baggage and express, uniform systems of accounts, records and reports, preservation of records, qualifications of drivers and maximum hours of service of employees and safety of operation of equipment.**

It is these latter areas--qualifications of drivers, hours of service and safety of operation of equipment which are of primary interest here. The act defined two types of commerce which were (and still are) subject to regulation:

(1) Interstate Commerce: . . . Commerce between any place in a state and any place in another state or between places in the state through another state, whether such commerce moves wholly by motor vehicle or partly by motor vehicle, or partly by rail, express or water.**

(2) Foreign Commerce: . . . Commerce whether such commerce moves wholly by motor vehicle or partly by motor vehicle and partly by rail, express or water, (a) between any place in the United States and any place in a foreign country, or between places in the United States through a foreign country; (b) between any place in the United States and place in a territorial possession of the United States insofar as

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*It should be noted, however, that this is only a simplistic approach to a complex legal and operational system. There are many legal and administrative decisions affecting the jurisdictions and operation of the two agencies.

**Definitions of terms from Interstate Commerce Act, 49USCA, Transportation.

> such transportation takes place within the United States . . . . Truck movements from interior points to docks where the traffic is transferred to vessels for further shipment to points outside the United States, uninterrupted except for the necessary interchange, are in foreign commerce.

The act also permits the use of a third party (broker) in arranging for transportation services [as defined by the Interstate Commerce Act], viz . . .

> The term 'broker' means any person not included in the term 'motor carrier' and not a bona fide employee or agent of any such carrier, who or which, as principal or agent, sells or offers for sale any transportation subject to this chapter, or negotiates for, or holds himself or itself out by solicitation, advertisement, or otherwise as one who sells, provides, furnishes, contracts, or arranges for such transportation.

For all types of carriers, the Act specifies that the Interstate Commerce Commission is the regulatory body which has the authority to establish the rates, routes, rules, regulations and conditions (including safety) governing the movement of goods in interstate and foreign commerce. (The intent of the shipper at the time the goods are first placed into commerce determines whether it is inter-state or intra-state commerce. Thus the effect of the act is far reaching--even to the local level.) Most goods are subject to economic regulations (rates). However, agricultural products (as a general class) are generally exempt from economic regulations and hence the movers of these goods are called Exempt Carriers.

The exempt carrier and private carrier, while exempt from economic regulations, are nonetheless subject to the safety regulations.

Another exemption to carriers of interstate commerce has to do with the movement of goods within commercial zones. While highly specified, the zones can generally be thought of as areas immediately surrounding the municipalities in the United States. Movement of interstate goods within these commercial zones is generally exempt from certain safety and economic regulations whereas movement of interstate goods out of or into the zone is subject to regulations.

Carriers are also classified by Type of Route Service such that:

A. *REGULAR-ROUTE SCHEDULED SERVICE* -- one who undertakes to transport property for compensation between fixed termini and over a regular route or routes upon established or fixed time schedules.

B. *REGULAR-ROUTE NONSCHEDULED SERVICE* -- same as A, except not on a fixed schedule.

C. *IRREGULAR-ROUTE RADIAL SERVICE* -- operates over irregular routes from a fixed base point or points to places located with a radial area fixed or authorized by the ICC or from such places back to the fixed point.

D. *IRREGULAR-ROUTE NONRADIAL SERVICE* -- same as C, except the area within which the service may operate is defined geographically.

E. *LOCAL CARTAGE SERVICE* -- one who transports property wholly within a municipality or between contiguous municipalities or within a zone adjacent to and commercially a part of any such municipality or municipalities. That is, a local cartage service operates within a commercial zone.

Thus the Interstate Commerce Act not only defined interstate commerce but also exerted controls over the movement of goods and the movers of those goods.

Bureau of Motor Carrier Safety

In 1966 the Department of Transportation Act* transferred the safety functions of the Interstate Commerce Commission to the Department of Transportation, Bureau of Motor Carrier Safety,** within the Federal Highway Administration. The Bureau has the responsibility for Parts 390 through 397 under Title 49 of the Code of Federal Regulations.

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*P.L. 89-670, 80 Stat 931 (1966), 49 U.S.C. Sections 1651-1659 (Supp. IV, 1968) (effective 4-1-67).

**See 49 CFR Section 1.48 (a), (f), (g), (h), (k), (1971).

In the words of the Bureau, their mission is:

> . . . to reduce commercial vehicle accidents; to decrease fatalities, injuries, and property losses caused by commercial vehicle accidents; and to help reduce casualties and economic loss due to all types of motor vehicle accidents (driver--vehicle--highway--cargo). The Bureau also initiates research and development projects within the Highway Administration to devise safer means of operating commercial vehicles. The authority for the Bureau's various programs is contained in the Department of Transportation Act, the Interstate Commerce Act, and the Explosives and Combustibles Act.
>
> The Bureau, under a delegation from the Federal Highway Administrator, promulgates and administers the Motor Carrier Safety Regulations and the Hazardous Materials Regulations governing trucks and buses operating in interstate or foreign commerce.*

These safety functions, codified as the Federal Motor Carrier Safety Regulations (FMCSR) include: Qualifications of Drivers; Driving of Motor Vehicles; Parts and Accessories Necessary for Safe Operation; Notification, Reporting and Recording of Accidents; Hours of Service of Drivers; [Vehicle] Inspection and Maintenance; Transportation of Hazardous Materials, Driving and Parking Rules; and Transportation of Migrant Workers. The FMCSR apply to <u>all</u> classes of carriers including for hire (common and contract) carriers of property, for-hire carriers of passengers, and carriers of agricultural commodities, livestock, and horticultural commodities engaged in interstate and foreign commerce. The other functions (economic) detailed by the Interstate Commerce Act and previously described are still administered by the ICC.

Conclusion

As the above description indicates, the circumstances in which BMCS regulations apply, although well defined are rather complicated. An ideal study of the effects of these

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*Publication: <u>The Bureau of Motor Carrier Safety</u>, Federal Highway Administration, U.S. Department of Transportation.

regulations on safety would require exact knowledge of their applicability to each accident surveyed. Since such data are unavailable, a substitute must be developed which will correlate with BMCS jurisdiction.

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