COST-EFFECTIVENESS OF PERIODIC MOTOR VEHICLE INSPECTION (PMVI):

A REVIEW OF THE LITERATURE

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16. Abstract

The purpose of this review of 41 studies and reports concerning periodic motor vehicle inspection was to seek evidence as to whether the costs of requiring all motorists to have certain safety components on their vehicles inspected and repaired on a regular basis are less than the benefits gained from such inspections in terms of safer vehicles and fewer vehicle-defect accidents. A number of studies provide evidence that vehicles in some PMVI jurisdictions are in better condition on some components than vehicles in some non-PMVI jurisdictions, but none of these studies involve truly random samples of vehicles-in-use. Similarly, a number of studies have reported some reductions in accidents in association with PMVI (and some have reported the opposite), but no credible evidence was found which demonstrates significant changes in vehicle-defect accidents as a result of PMVI. Thus the few studies which have addressed the cost-benefit question have tended to be rather subjective and speculative because of the shortage of thorough and believable research on PMVI effectiveness.

There is credible evidence that existing PMVI programs are not as reliable in detecting degraded safety components and forcing their repair as was envisioned by PMVI proponents. It is clear that much more could be done to improve the effectiveness of existing PMVI programs. Also auto manufacturers could do more to encourage the maintenance of safe vehicles by providing durable components and built-in indicators of their failure.

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EXECUTIVE SUMMARY

Compulsory motor vehicle inspection has been in effect in some American cities and states for more than 50 years, using either government inspection stations or government-licensed private garages. Yet, despite some favorable studies and the encouragement of the National Highway Traffic Safety Administraton (NHTSA) via its state highway safety program standards, several states have refused to implement a periodic motor vehicle inspection (PMVI) program, and some states which did enact such a program later discontinued it.

Proponents of PMVI argue that some accidents are caused or aggravated by defective vehicle components and that it is important that all vehicles be inspected regularly and be required to meet certain minimum safety standards. On the other hand, critics of PMVI suggest that most owners try to maintain their vehicles in safe operating condition without the threat of mandatory inspections, and they question whether PMVI programs are actually cost-effective. They suggest that the benefits of PMVI in terms of safer vehicles and fewer accidents are not sufficient to outweigh the costs and nuisance of the inspection process.

Through the years a number of studies and reports have presented some data bearing on the benefits and/or costs of PMVI programs. Forty-one of these publications have been reviewed for this report. Unfortunately, not one of them was able to provide definitive evidence on the question of PMVI cost-effectiveness. However, many of them do provide some useful information bearing on this subject. Thus, this review uses them to try to assess the current state of knowledge concerning the benefits and costs of PMVI programs.

Safe Vehicle Condition Studies

In regard to vehicle condition, a study sponsored by the Motor Vehicle Manufacturers Association (McCutcheon and Sherman 1968) and several studies sponsored by NHTSA (Fisher et al. 1971, 1973; Hatch et al. 1976; Innes and Eder 1977; Milne et al. 1978; Eder et al. 1978; Eder 1980) indicate that vehicle safety components tend to be in somewhat better condition on the average in PMVI jurisdictions than in non-PMVI jurisdictions. However, these findings were not consistent for all inspected components, nor even for overall outage rates. Also, none of these studies compared truly random samples of vehicles-in-use (they were mostly volunteers for a free inspection), so that leaves the results open to question. A re-analysis of Fisher's 1971 study indicated that, while the between-state results were statistically significant, they were not large enough to have much practical effect on accident rates (Penn. Office of Budget 1981).

One observation study of random vehicles on the road found no significant differences in taillight outages between five PMVI and three non-PMVI jurisdictions (O'Day and Creswell 1968). In contrast, a random observation study in Massachusetts found headlamp outages increasing gradually from about 1% in the month after the fall inspection to about 2.5% six months after inspection (Bentley and Heldt 1977). Similarly, a random inspection of 20,000 vehicles in New Jersey found a 23% failure rate in the first month after the regular inspection rising to a 39% failure rate 12 months after the regular inspection, and a random/volunteer inspection in Missouri found the rejection rate rising from 40% to 47% for one month versus 12 months after the regular inspection (McMinn 1974; Bentley and Heldt 1977). Also Hatch et al. (1976) found a significant relationship between time since inspection in gross categories (six months, one year, etc.) and the outage rates for one of four brake components included in a regression analysis. Thus these studies do provide some credible evidence for the improvement of some vehicle safety components associated with mandatory inspections.

On the other side, there is also substantial evidence that PMVI programs are not completely reliable in detecting vehicle defects and in forcing them to be repaired. One indicator of this is the above-mentioned 23% failure rate for New Jersey vehicles and 40% rejection rate for Missouri vehicles in the first month after the state-operated inspection. In a Missouri survey of 58 licensed stations Bentley and Heldt (1977) reported an 87.3% compliance rate with state administrative guidelines for facilities, equipment, and record-keeping. In Virginia and New Hampshire Milne et al. (1978) found administrative compliance rates of 94.0% and 78.4% respectively. In covert observations of the procedures followed in 169 Missouri inspections, Bentley and Heldt (1977) found a 77.4% compliance rate with state inspection procedures. Similar covert observations in Virginia and New Hampshire showed 78.6% and 57.4% compliance rates respectively (Milne et al. 1978). In 31 New Hampshire inspections alignment was never checked, wheel bearings were only checked once, the two obviously defective tires were never failed, and the required wheel-pull to check brake condition was not carried out eight times. In Virginia six of 30 stations failed to carry out the required wheel-pull.

Two other studies also demonstrated poor reliability in PMVI programs. In an indepth study of vehicle defects in accidents in Indiana McDonald and Romberg (1977) judged that at least 22% of the discovered inspectable defects had already been present at the time the vehicle was inspected. In Pittsburgh the same vehicle with 13 inspectable defects was inspected at 20 different private stations, and the number of defects found ranged from one to seven with an average of four (Carnegie-Mellon 1975). Perhaps even worse was that an average of 1.75 non-existent defects were found, and these had an average estimated repair cost of $34.93. Of course this was a somewhat atypical situation in Pennsylvania, since only an inspection was purchased without repairs and thus the inspections may have been unusually cursory; but that certainly would not account for the incidence of non-existent defects found.

PMVI Effectiveness and Accident Studies

A number of studies have attempted to evaluate PMVI effectiveness by looking at general accident rates in PMVI and non-PMVI states. Wort (1976) showed that prior to 1968 these overall comparisons favored the PMVI states, while from 1969 to 1973 they favored the non-PMVI states. The Pennsylvania Office of Budget and Administration (1981) found no significant differences in an analysis of 1971–1973 accident data. O'Day and Kaplan (1976) demonstrated the important interaction of population density and PMVI on state accident rates, but Tufte (1974) still found lower 1966–68 accident rates in PMVI states than in non-PMVI states when controlling on population density. Crain (1980) found no significant PMVI effect on 1965 and 1974 accident rates controlling on many factors in addition to population density, while Jackson et al. (1982) did find a substantial PMVI effect on 1979 accident rates also utilizing many control factors.

Loeb and Gilad (1984) reported a time-series analysis of New Jersey accidents from 1929 to 1979 which found an average annual reduction of 304 fatalities associated with the introduction of PMVI in 1938. However, this study suffers from only having nine points in the base period, and the exceedingly large fatality reduction found suggests that not all important factors were taken into account in the model. The lack of a significant PMVI effect on injuries also tends to reduce the credibility of the fatalities results. Tufte (1974) warned against making the jump from statistical association to causal inference without also exercising common sense. While the New Jersey time-series analysis provides one piece of evidence in strong support of PMVI effectiveness, one would want to see these results replicated in a number of PMVI states by different researchers before concluding that PMVI is genuinely effective in reducing fatalities and accidents to the extent reported by Loeb and Gilad.

In support of a relationship between safer vehicles and lower accident rates, Wilson (1973) reported that 1970–1971 general accident rates were somewhat lower in parts of New Brunswick with lower rejection rates at the time of inspection. However, two studies tried unsuccessfully to find a relationship between time since inspection and being in an accident (Garrett and Tharp 1969; Reinfurt and Symons 1974). The only study which looked at accident rates of inspected and uninspected vehicles in the same area (Huntsville, Ala.—Schroer and Peyton 1977) found lower accident rates in the inspected vehicles, but these were vehicles whose owners had volunteered them for a free diagnostic inspection, so the comparability of the two populations is open to question. However, they also reported that these vehicles had at least a 5.3% reduction in accident involvement in the period after the diagnostic inspection compared to the period before the inspection.

Given the rather small proportion of vehicle-related accidents found in accident investigations and the many known and unknown factors which affect a state's general accident rates, it may be unrealistic to attempt to evaluate PMVI effectiveness by looking at general accident rates. In the tri-level study of accident causation in Indiana, Treat and Stansifer (1977) found vehicle defects to be definitely causal in about one out of 19 accidents and definitely or probably causal or severity-increasing in about one out of eight accidents. Only one out of 41 accidents in this not-very-rigorous-PMVI state were definitely or probably caused solely by vehicle defects. Unfortunately, there have been no comparable accident investigation studies in non-PMVI jurisdictions, but what data are available suggest that these findings on vehicle defects in accidents are fairly typical for all states.

The few references to vehicle-defect accidents in the PMVI literature have had to make use of police-reported accident data. Because of the differences in accident reporting forms and procedures, these data are not likely to be comparable across state lines, even for the supposedly-comparable Fatal Accident Reporting System (O'Day et al. 1978). A NHTSA technical note (1975) reported dramatic reductions in police-reported vehicle-defect accidents in Texas (12% in 1951 to 4% in 1971) and Nebraska (6.1% in 1968 to 2.6% in 1972) in association with the introduction of PMVI, but one must be skeptical about such large changes being caused by PMVI. It seems likely that some changes in accident reporting procedures and practices accounted for at least part of these large reductions. More credible perhaps is the report (Eder et al. 1978) that in 1975 1.3% of the accidents in PMVI Cincinnati were attributed to vehicle defects compared to 1.8% in the rest of the state; but still one wonders about any possible differences in accident reporting practices which might relate to this difference.

A small study in Pennsylvania of 67 defect-related accidents found no relationship to the imputed length of time since inspection (Carnegie-Mellon 1975). Bentley and Cooper (1977) reported a larger study of 3000 defect-related accidents in New Jersey (out of

200,000) which similarly found no relationship to time since inspection. They suggested this procedure as potentially the most useful employment of police-reported accident data for evaluating PMVI, but no other studies of this sort were found.

Cost-Effectiveness Studies

Given the uncertainties concerning the effectiveness of PMVI in reducing accidents, it is not surprising that all of the studies of PMVI cost-effectiveness have been quite speculative. Even with credible data on fatalities, injuries, and accidents avoided due to PMVI, it would be difficult to place a precise dollar value on these benefits because of the inherent difficulties of determining the economic value of the average fatal victim's life. It is somewhat easier to determine the costs of a PMVI program, at least the costs of the actual inspection procedures. How much to add as the vehicle owner's time and driving costs is more uncertain, and how much to include as the costs of forced repairs is even more uncertain. Among the ten reviewed studies which provided some cost estimates, only Thompson (1983) included an estimate for expedited repairs, and none included an estimate for unnecessary repairs forced by PMVI (a problem demonstrated by Schroer and Peters (1977) as well as by Carnegie-Mellon (1975)).

The only study which strongly supported the cost-effectiveness of PMVI was that of Loeb and Gilad (1984) in New Jersey, but their conclusion was based on their seemingly unrealistic finding that PMVI saved 304 lives and avoided 37,910 accidents annually in New Jersey. Thompson (1983), Abbene (1978), NHTSA (1975), and Carnegie-Mellon (1975) said that PMVI <u>might</u> be cost-effective, depending on which assumptions one regarded as reasonable regarding the effectiveness of PMVI in reducing accidents, regarding the dollar value of fatality and accident reductions, and regarding the costs of a PMVI program. California Highway Patrol (1974), NHTSA (1976), Wort (1976), and Tarrants and Voas (1981) were more pessimistic in their cost-effectiveness analyses. Based on this review of the research data presently available, it appears that PMVI programs could be considered cost-effective <u>only</u> if one accepted unrealistic assumptions about PMVI effectiveness in reducing accidents, or if one underestimated the full costs of a PMVI program including unnecessary repairs, or both.

Conclusions

It is clear that there is a shortage of satisfactory research for determining the effectiveness of PMVI programs in reducing accidents. Under NHTSA contract, Bentley and Cooper (1977) proposed a large-scale experimental program comparing accident rates for inspected and uninspected vehicles in the same geographic area. Probably their proposal is impractical and too expensive, but some less extensive and still useful research which could be carried out with existing accident data include:

1) Comparing vehicle-defect accident rates in PMVI and non-PMVI states using Fatal Accident Reporting System and National Accident Sampling System data sets.
2) Looking at vehicle-defect accidents in relation to time since inspection using accident files from PMVI jurisdictions.
3) Looking at before-after vehicle-defect accident rates in states which have introduced PMVI but have maintained the same accident reporting procedures, utilizing time-series regression techniques.
4) Replicating the Loeb-Gilad type of time-series analysis with general accident data in other PMVI states besides New Jersey.

While it is difficult to conclude that PMVI is cost-effective in a safety sense, many jurisdictions may still want to continue or initiate PMVI programs. Among the suggestions in the literature for improving PMVI reliability and cost-effectiveness, responsible PMVI officials should consider the following:

1) Concentrating on older more defect-prone vehicles.
2) Concentrating on safety critical components such as brakes, tires, and steering.
3) Perhaps eliminating semi-annual inspections in order to reduce costs.
4) Extensive monitoring and enforcement of inspection station compliance with administrative regulations and inspection procedures, including a well-publicized program of covert inspections or a system of random cost-free reinspections.

Alternatively, it may be that educational efforts coupled with a well-publicized police inspection program (perhaps concentrating on older vehicles or vehicles with easily observed defects such as light outages) could be more cost-effective than mandatory PMVI. In any event, as automobile manufacturers provide more durable vehicle components and more built-in indicators of component deterioration or failure (in order to simplify self-inspection and to encourage routine repair), there may be less need either for a PMVI program or for a police inspection program to force motorists to keep their vehicles in safe operating condition.

LIST OF REVIEWED PMVI LITERATURE

Introduction

Ever since the "horseless carriage" began traveling on American roads, motor vehicle traffic accidents have been bringing death, injury, and property destruction to those persons unfortunate enough to be involved. Such accidents are most often attributed to human error, but some proportion of traffic accidents are reported to be caused or exacerbated by defective vehicle equipment—particularly brakes, tires, and steering systems. While vehicle owners should have a selfish incentive to maintain their vehicles properly, and thus to reduce their chances of being involved in an accident, such maintenance requires both time and money.

To attempt to improve the safety of the driving environment, most states passed laws requiring certain minimum standards for vehicle safety components such as lights and brakes, and these can be enforced by the police when they happen to observe the defective equipment. Since the 1960's these state laws have been augmented by national standards for safety equipment on new vehicles as promulgated by the National Highway Traffic Safety Administration.

In addition, beginning in the 1920's, many states and cities established mandatory periodic motor vehicle inspection (PMVI) programs which require motorists to have certain vehicle components inspected once or twice a year and to display a sticker on the windshield indicating that the vehicle has passed inspection. As a result of the federal Highway Safety Act of 1966 NHTSA was required to encourage every state to establish a comprehensive PMVI program, and, under the authority of the National Traffic and Motor Vehicle Safety Act of 1966, to establish more stringent Vehicle-in-Use standards—which were issued in 1973. However, most states were unwilling to implement the new standards, and many refused to establish a PMVI program at all amid increasing controversy as to whether PMVI programs have sufficient benefits to be worth their considerable costs. In 1975 Congress weakened NHTSA's sanctioning authority in regard to enforcement of state program policies, and subsequently a number of states discontinued their mandatory PMVI programs.

Among the PMVI programs, only New Jersey, Delaware, the District of Columbia, and certain cities have made use of government-operated inspection stations. All the other PMVI programs have made use of private garages which are licensed to perform the required inspections for the state, and, in recent years, even New Jersey has supplemented its state stations with a system of licensed private garages. With the private inspection station system the state makes some attempt to monitor the quality of inspections, but the extent of such monitoring varies greatly. In 1976 the inspection fees ranged from nothing in Delaware up to $8.00 at some Pennsylvania stations, with an average of about $3.50. At that time seven states had semi-annual PMVI programs, and 22 had annual PMVI programs (Crain, 1980). Some other states, such as Maryland, have required that vehicles be inspected at the time of a change in ownership.

In the 1970's a number of states experimented with substitute inspection programs using various plans for random or spot police inspections. In California four different levels of inspection were tried out for one year in different groups of counties: 100% (actually 88%), 30%, 15%, and none. In the post-experiment inspections of vehicles which had not been inspected in the previous year no significant differences were found in outage rates. Thus the different levels of inspection did not seem to have any carry-over effect to encourage improvement of vehicles which were not inspected. NHTSA concluded that none of these substitute inspection programs in these states was an adequate substitute for a full PMVI program (Eder et al., 1978).

Factors Relevant to PMVI Cost-Effectiveness

Undoubtedly most seriously defective vehicle safety components are eventually repaired voluntarily by the owner, or else the vehicle is scrapped. Some persons have fairly long tolerances for a defective headlamp, but few would continue to drive a vehicle if its brakes stopped working entirely. However, even a very conscientious owner may drive for some time with some vehicle components in a degraded or failed condition without knowing about it, particularly ones which are not easily observed such as worn brake linings or pads, improper headlight aim, or a cracked spring. Of course in the interim, no matter whether the delay in obtaining repairs is intentional or unintentional, such vehicles are more accident-prone than they should be. O'Day and Creswell (1968) presented a useful analytic model of the role of PMVI among other factors in affecting traffic accidents. They also provided a helpful discussion of the types of components most amenable to improvement through a PMVI program. As an example, they reported a study of taillamp outages in five PMVI and three non-PMVI cities which found only small differences in outage rates. However, they mentioned that McCutcheon and Sherman (1968) found large differences in steering wheel free play between non-PMVI Ann Arbor and three PMVI cities.

While the purpose of the present review is to consider the benefit-to-cost ratio attributed to periodic motor vehicle inspection systems, much of the literature treats two separate aspects of the process. The first of these has to do with the effectiveness of mandatory PMVI programs in reducing the time lag from degradation or failure of a component to its repair—thus in improving the general safety condition of vehicles.

The second aspect has to do with the relative contribution of motor vehicle inspection to accident reduction, and thus with the potential for saving lives and reducing injuries and property destruction from improvements in the general safety condition of vehicles.

Taking these two issues together, one may consider whether the benefits of a PMVI program (in terms of reduced frequency and severity of accidents—and perhaps increased service life of the inspected vehicles) are worth the costs of the inspection program. Such costs include inspection fees, time and driving costs for the vehicle owner, state administrative costs, and sometimes unnecessary repairs induced by the inspection system. The cost of necessary repairs is not usually considered as a PMVI system cost because most such repairs would eventually have to be made anyway. However, Thompson (1983) did treat some of these repair costs as PMVI costs because presumably PMVI forces the repairs to be made earlier than they would be made without PMVI.

Reviews presented in this report are organized around these three themes—effectiveness of inspection, potential accident reduction from inspection, and cost-benefit or cost-effectiveness of PMVI programs. Following the main body of the report, annotations of the referenced studies and reports are presented in a bibliographic appendix, and a second appendix lists other literature relevant to PMVI which was found in the bibliographic searches but which was not reviewed for this report.

Effectiveness of Inspections in Improving Vehicle Condition

A number of past studies have compared the general condition of vehicles in PMVI jurisdictions and in non-PMVI jurisdictions, and the PMVI vehicles have generally come out ahead. In 1968 McCutcheon and Sherman (1968) compared the condition of vehicles at inspection in Washington, D.C. (annual), Cincinnati (semi-annual), and Memphis (tri-annual) with the results of state police inspection checklanes in non-PMVI Ann Arbor. Even though Ann Arbor is atypically high in average income and education, its vehicles had much higher defect rates. Vehicle failure rates on at least one of the 18 categories were 93.7% in Ann Arbor, 42.6% in Washington, 34.1% in Cincinnati, and 12.4% in Memphis (14 categories only). This report not only provides evidence that PMVI leads to better-maintained vehicles than no inspection, but it also supports the thesis that the frequency of inspections is an important contributor to safer vehicles.

Two NHTSA-sponsored studies by Ultrasystems (Fisher et al., 1971, 1973) also came to similar conclusions. The first compared the results for randomly selected and drop-in vehicles inspected at six diagnostic centers in California, a diagnostic center in Pennsylvania, a diagnostic center in New Jersey, and the two city inspection stations in Washington, D.C. For the common inspected components Pennsylvania, with its semi-annual private-station system, had the lowest outage rate (5.93%), followed by Washington (7.44%) and New Jersey (8.93%), each of which have annual government-operated inspections, and by California (10.7%), which had a random police inspection system. The second study compared similar representative samples from four diagnostic centers in Illinois; from single diagnostic centers in Alabama, Arizona, Missouri, and Washington state; and from NHTSA's mobile inspection van in Hartford, Connecticut. Among these six states only Missouri had a PMVI program (annual at private stations), but it turned out to have the highest outage rates in the state comparisons. On the other hand, all six states had higher outage rates than did Pennsylvania, the District of Columbia, and New Jersey in the earlier study. The Missouri results suggest that there are significant differences in the quality of inspection programs in the various PMVI states. A re-analysis of the 1971 data by the Pennsylvania Office of Budget and Administration (1981) found that the differences between Pennsylvania and the other three jurisdictions were statistically significant, but they concluded that these differences were not large enough to have much practical effect on accident rates.

As part of the first study Fisher et al. carried out a small experiment comparing the condition of 63 vehicles whose owners responded to direct mail solicitation from registration lists, of 32 vehicles whose owners responded to direct mail plus telephone calls with special inducements, and of 63 vehicles whose owners came to the diagnostic centers independently. In comparing these three samples they found no more significant differences in component outages than would be expected by chance, and they concluded that volunteer drop-in samples would be satisfactory and that selection of random samples from registration lists was not necessary. However, the numbers in the three groups seem rather small to support such an important conclusion, and all of the NHTSA-sponsored studies suffer from lack of knowledge about how representative their largely-volunteer samples really are.

Another NHTSA-sponsored comparative study was carried out by Automated Sciences Group, Inc. (Hatch et al. 1976), this time using the NHTSA mobile inspection van set up in parking lots in five cities in each of six states: Pennsylvania, Missouri, California, Illinois, and two new states, Texas and Maryland. Texas has long had an annual private-station PMVI system, while Maryland requires a fairly extensive inspection at the time a vehicle changes ownership. In the Maryland sample 37.5% of the inspected vehicles had previously been inspected. In this study, participation in the inspections was entirely on a voluntary drop-in basis, so the representativeness of the state samples is open to serious question. In the analysis, regression techniques were used to control for 20 possible explanatory variables, such as vehicle age and owner income. In comparing outage rates on 34 components which were supposed to be inspected in some states, 16 components had significantly lower outage rates in states in which they were part of the inspection program. On the other hand, there were six components in which the outage rates were significantly lower in the non-inspection states. A multiple regression analysis with four brake components as dependent variables found the outage rates for one of them (front lining thickness) to be significantly related to time since inspection in gross categories (six months, one year, etc.).

In the comparison of Pennsylvania results with each of the other states, Pennsylvania had 12 components with significantly lower outage rates than Missouri, while Missouri had six components with significantly lower outage rates than Pennsylvania. The comparable ratios of Pennsylvania with the other states were Illinois 14 to 5, California 15 to 4, Maryland 15 to 3, and Texas 22 to 3. Again, the semi-annual PMVI program in Pennsylvania seems to have contributed to Pennsylvania vehicles being generally in better condition than in non-PMVI states, but, in this six-state comparison, PMVI Texas came out at the bottom and no-inspection Illinois was in the middle. It is also disturbing that Illinois vehicles rated ahead of Pennsylvania vehicles on five components, including both wheel cylinders and tire tread. Based on these studies comparing semi-annual PMVI Pennsylvania with other states, Abbene (1978) concluded that semi-annual PMVI is 20–25% more effective in improving vehicle condition than annual PMVI.

Another multi-state study was carried out rather incidentally in connection with NHTSA's diagnostic inspection demonstration program in Alabama, Arizona, Puerto Rico, Tennessee, and Washington, D.C. (Innes and Eder, 1977). Again participants were volunteers, so the representativeness of the samples is open to question. Nevertheless, the dramatic differences found between the vehicles in non-PMVI Alabama and Arizona (93.2% and 91.9% failure rates) and the vehicles in the PMVI jurisdictions Chattanooga and Washington (47.4% and 48.0% failure rates) again support the potential value of PMVI in improving vehicle condition. However, PMVI Puerto Rico had a failure rate of 90.4%, again demonstrating that there are substantial differences in the effectiveness of different PMVI programs.

In 1977 Bentley and Heldt provided NHTSA with a report and a manual on procedures for states to use in evaluating the effectiveness of their PMVI programs in improving vehicle condition. A key concept in this report was a Measure of Effectiveness (MOE) score derived from a special inspection of a random sample of vehicles. It was determined by comparing the outage rates of vehicles at different lengths of time from their regular inspections and extrapolating an inferred outage rate in the absence of PMVI. In validating these methods with a sample of 666 vehicles in Missouri (half drop-in and half recruited with police assistance), Bentley and Heldt found Missouri vehicles in slightly worse condition the longer the time from the regular inspection to the special inspection. About 40% of the vehicles checked within one month of their regular inspection were rejected on at least one component compared to about 47% after 12 months. A MOE of 25.3% was calculated. Similarly, McMinn (1974) reported some degradation with time since inspection in a randomly inspected sample of 20,000 vehicles in New Jersey. As reported by Bentley and Heldt (1977), the rejection rate rose from 23% one month from the regular inspection to 39% 12 months after the regular inspection, and they calculated an MOE for New Jersey inspections of 38.0%. They also calculated an inspection MOE of 76.3% for headlamp outages in a special study in semi-annual PMVI Massachusetts.

A final NHTSA multi-state study (Milne et al. 1978) was carried out by the Chilton Company in four states in order to test the Bentley and Heldt evaluation procedures more widely. These were Virginia and New Hampshire with semi-annual private-station inspections, Maine with annual private-station inspections, and Maryland with private-station inspections on change of vehicle ownership. This time, mass merchandiser facilities (K-Mart, etc.) were used for most of the inspections, but the participating vehicles were again voluntarily recruited. There were no significant differences among these four states in overall defect rates, with at least 60% of each state's vehicles failing on at least one component. In no state were significant differences found in the incidence of defects in relation to the time since the previous inspection. McDonald and Romberg (1977) also found no relationship between number of defects and mileage since inspection in their study of accident-involved vehicles in Indiana.

Virginia, New Hampshire, and Maryland required wheel pull as part of their inspections, while Maine did not. However, the inspections found a total brake assembly failure rate of 13.0% in Maryland, 15.6% in New Hampshire, 18.1% in Maine, and 19.5% in Virginia. This suggests that the less frequent but perhaps more thorough change-of-ownership inspections in Maryland may have been more effective than the semi-annual New Hampshire and Virginia inspections in maintaining proper brake condition.

Among the eleven state trial substitute inspection programs summarized by Eder et al. (1978), two provided a direct comparison of vehicle condition in PMVI and non-PMVI jurisdictions. In Ohio only 11.35% of the vehicles in the Cincinnati PMVI station were defective, while 35.19% of the vehicles inspected randomly by the police in the rest of Ohio were defective. In Tennessee results from the regular inspection station in PMVI Memphis and from the free diagnostic inspection station in PMVI Chattanooga showed that the vehicles in those PMVI cities were in better condition than vehicles tested at a special inspection station in non-PMVI Knoxville. Also the California Highway Patrol (1974) reported that its experiment with different levels of inspection effort found that the vehicles in counties with higher levels of random inspection tended to be in better condition than vehicles in the counties with low or no inspection levels.

NHTSA (Eder 1980) also sponsored a before-after study of vehicle condition in Idaho after it discontinued its state inspection program in 1976. The NHTSA mobile inspection van was used at the same parking lot locations in the fall of 1976 and again in the fall of 1978, and the participating vehicles were voluntarily recruited on a drop-in basis. The results were that brakes, steering, suspension, and power train components were somewhat worse in 1978 than in 1976, while body components (lights, etc.) were about the same. This was true even though the 1978 sample was somewhat older than the 1976 sample (average of 5.4 years compared to an average of 4.7 years). This study in one state provides evidence that PMVI can induce some improvements in the safety condition of a state's vehicles, or at least that discontinuing PMVI has a somewhat negative effect on the condition of a state's vehicles.

Reliability Problems with Inspection Programs

On the other side of the coin, there is considerable evidence that PMVI programs are far from being as effective in improving vehicle safety conditions as would be desirable, even in Pennsylvania. A Carnegie-Mellon University study (1975) involved having the same vehicle with 13 implanted defects inspected at 20 private stations in Pittsburgh. All of the defects were on the list of inspection items for Pennsylvania. The number of defects found ranged from one to seven with an average of 3.96. In addition, the number of non-existent defects reported ranged from none to seven with an average of 1.75 and with an average estimated repair cost of $34.93. These Pittsburgh inspection stations might not be typical of the rest of the state, but the Carnegie-Mellon study also looked at 6,000 inspection forms from various inspection stations all over the state, and they found a great variation in rejection rates among different inspection stations. Such findings concerning inspection effectiveness may help to explain why Hatch et al. found vehicles in no-inspection Illinois in better condition than Pennsylvania vehicles on some components.

Similar inspection station problems were found in the AVCO study (Bentley and Heldt 1977) in Missouri and in the Chilton study (Milne et al., 1978) in New Hampshire and Virginia. In evaluating compliance with state requirements for inspection facilities, equipment, and procedures at 90 stations in New Hampshire and 85 stations in Virginia, overall compliance rates were determined as 94.0% in Virginia and only 78.4% in New Hampshire. In regard to mechanic knowledge of state standards (e.g., minimum brakeshoe lining thickness), only 45.9% in Virginia and 24.4% in New Hampshire were able to answer three out of five questions correctly. Covert inspections were also made of the inspection process at 30 stations in each state, using 14 inspection items in Virginia and 15 items in New Hampshire. The overall compliance rates were 78.6% in Virginia and 57.4% in New Hampshire. Eight of the 30 stations in New Hampshire and six of the 30 stations in Virginia did not carry out the required wheel pull to check the brakes. Not one station in New Hampshire failed the two obviously defective tires. In Missouri Bentley and Heldt estimated the statewide administrative compliance rate as 87.3%, while the covert inspections provided a compliance rate of 77.4%. So Missouri seemed to be somewhere between Virginia and New Hampshire in the operational conduct of its PMVI program.

Another relevant study was carried out as an adjunct to the Indiana tri-level accident causation study (Treat and Stansifer 1977). McDonald and Romberg (1977) looked at 131 defective components (on 52 vehicles) which were at least possible causes of 7.7% of the accidents investigated in-depth. Of these 131 components 74 (56.5%) should have been inspected according to Indiana's PMVI regulations. The investigators judged that 16 of these (21.6%) had been defective at the time of the vehicle's inspection, while 11 had failed since the inspection, and no judgment could be made on the other 47 components. Similarly, the investigators found 1600 defects which should have been inspected (most not accident-causing) on the total of 562 vehicles analyzed in-depth. Over a quarter of the defects were judged to have been defective at the time of inspection. As mentioned above, no relationship was found between the number of defective components on a vehicle and its mileage since its state inspection.

The diagnostic inspection demonstration program (Innes and Eder, 1977) also provided some useful information on problems in the vehicle repair industry which relate to the quality of repairs available for components found to be defective at an inspection. In this program the inspections were free and presumably of high quality. However, motorists found to have defective components had to go elsewhere to obtain repairs. If they obtained repairs they could return for a free reinspection. Overall 27.2% of the returnees after their first inspection failed their reinspection. However, the reinspection failure rates varied greatly—from only 2% in Washington, to 10% in Tennessee, to 14% in Puerto Rico, to 33% in Arizona, to 50% (!) in Alabama. The average repair cost after the diagnostic inspection was $57.25. However, a special study in Alabama (Schroer and Peters, 1977) showed that 23% of the repairs involving 32% of the repair costs were considered unnecessary by the diagnostic team. These were repairs to components which had not failed the first inspection and which were not recommended or optional repairs in conjunction with the repair of a failed component.

Unfortunately, none of the studies of vehicle condition provide completely acceptable evidence of the effect of PMVI on average vehicle condition. The McCutcheon and Sherman (1968) and the Ohio (Eder et al., 1978) comparisons may be misleading, because vehicle owners may tend to try to have their vehicles in unusually good condition before they go in for a city-run inspection. Also one wonders how truly random were the selections of vehicles inspected by the police. And all seven of the NHTSA-sponsored studies have the problem that they inspected largely volunteered vehicles, which may or may not provide truly representative samples of each state's vehicles.

Thus, while the evidence of past studies suggests that vehicle safety condition is at least somewhat better on the average in some PMVI states and cities than in non-PMVI states, it also suggests that this is not true for all PMVI areas or for all safety-critical components. Many areas which have PMVI do not require inspection of all important safety components, and many licensed inspection stations do not conduct proper inspections of all the components they are required by law to inspect. In addition, there is evidence that frequently repairs of inspected components which are found to be defective are not properly made. It has been suggested that a major reason for the frequent poor quality of inspections is the reluctance of state legislatures to set realistic maximum inspection fees. For example, the New York Department of Motor Vehicles (1982) estimates that a proper inspection should take about 30 minutes. Yet in New York the inspection fee was just raised to $6.00 in 1980 (from $3.00). These low inspection fees clearly discourage the hiring of highly qualified inspection mechanics and encourage the finding of items which need to be repaired so that the station can try to recover its full inspection costs. The Pennsylvania Office of Budget and Administration (1981) estimated that a complete inspection according to Pennsylvania guidelines would take over an hour, and it recommended a reduction in the items to be inspected.

Changes in Vehicle-Defect Accidents with PMVI

The tri-level study of accident causation carried out by Indiana University's Institute for Research in Public Safety (Treat and Stansifer, 1977) is frequently referred to in the inspection literature as a source of information on the role of vehicle defects in causing accidents. Preliminary data from this seminal in-depth study of accidents in Monroe County, Indiana, had indicated that 6.0% of accidents were definitely caused and a further 9.9% were probably caused by vehicle defects (NHTSA 1975). However, the final report reduced these figures somewhat (Treat and Stansifer 1977). It concluded that vehicle defects were definitely causal or severity-increasing in 4.5%, probably causal or severity-increasing (at least 80% probability) in a further 8.1%, and possibly causal or severity-increasing (at least 25% probability) in a further 12.6% of the 420 accidents studied in-depth. The results of the Indiana study (usually the preliminary ones) were cited by many of publications included in this review, but only one mentioned the fact that these vehicle defects were seldom the sole cause of the accidents. In both the in-depth and the 2,558 less thorough on-site accident investigations only 2.4% of the accidents were judged to have been definitely or probably caused only by vehicle defects.

The most frequent certain, probable, or possible causal defects (8.8% in the indepth study) involved worn and/or underinflated tires, defects which are difficult to improve very much in a once-a-year inspection. The second most frequent causal defects (7.6% in the indepth study) were brake problems such as gross failure, side-to-side imbalance, and delay. Looking just at "certain" causal factors, brake problems were cited in 2.9% of the indepth cases, while tire and wheel problems were cited in 0.5% of these cases. Yet only a few states include a wheel pull to check brake linings as part of their PMVI procedures. Treat and Stansifer (1977) report that these findings agree with a similar on-site study in Great Britain and with other smaller studies in the United States.

In addition to these special accident investigation studies, many police agencies record observed vehicle defects on their accident reporting forms. However, surprisingly few references to these data were found in the literature review. NHTSA (1975) did cite data from Texas which showed a decline from 12% in 1951 to 4% in 1971 in defective vehicle involvement in accidents. Also cited were data from Nebraska which showed a decline from 6.1% in 1968 to 2.6% in 1972 in defective vehicle involvement in rural accidents following the implementation of a PMVI program. In addition, Eder et al. (1978) mentioned that 1975 Ohio accident data showed vehicle defects in 1.3% of the accident-involved vehicles in PMVI Cincinnati, compared to 1.8% in random inspections in the rest of the state. Surprisingly, these figures are much smaller than the 17% defect-related accidents found in Ohio Turnpike accident data for 1966–1970 (O'Day and Carlson 1973). The comparable figures reported for the Indiana Turnpike and for the Pennsylvania Turnpike were 12% and 7% respectively. They reported a 3% defective vehicle rate for 1970 Texas accidents.

The Pennsylvania Office of Budget and Administration (1981) reported that for 1974 to 1976 the proportions of accidents in which vehicle-related factors were considered by the police to be the primary cause varied from 0.8% to 1.8% for fatal accidents, from 2.5% to 3.0% for injury accidents, and from 1.9% to 2.5% for property damage only accidents. The Carnegie-Mellon study (1975) mentioned that about 2.5% of police-reported accidents in Pennsylvania involve vehicle defects, and an attempt was made to see if such vehicle-related accidents were more likely the further from the time of vehicle inspection. However, only 67 such accidents were studied, and no relationship with time since the inspection was found. In a larger study Bentley and Cooper (1977) reported that preliminary results from a study of 3,000 vehicle-related accidents in New Jersey (out of 200,000) showed no consistent relationship with time since inspection.

One would not expect such police reports of vehicle defects to be very accurate, because the police seldom have an opportunity to do more than a superficial inspection of the involved vehicles. As part of the Indiana tri-level study Shinar and Treat (1977) compared the police report of vehicle defects with their own findings in 124 in-depth accident cases. As would be expected, the investigating team found far more defects than the police did, but most of them were not considered contributing factors in the accidents. In the six cases in which the police had cited defective brakes as a contributing factor, the team agreed on four cases but judged that defective brakes were not a causal factor in the other two cases. Also the team cited defective brakes as causal factors in three other cases in which the police had not mentioned them. The police accident form did not provide for checking tire problems, so this problem was ignored by the police reports, while it was considered at least possibly causal in seven accidents investigated by the special team.

This study was rather limited in scope, but it supports the expectation that police accident reports are likely to both under-report and incorrectly report vehicle defects as contributing factors in accidents. A study of vehicle-related accidents in 1976 Fatal Accident Reporting System (FARS) data (O'Day <u>et al.</u> 1978) suggests that there may even be over-reporting of vehicle defects in some police-reported accidents. In eight states the defect rates reported as contributing to the fatal accidents varied from 1.3% in Michigan to 9.9% in Ohio to 12.9% in Connecticut. A review of some of the hard-copy records in Ohio and Michigan showed that the Ohio accident report form had a special place to indicate vehicle defects separately from accident causation information; yet this vehicle defect information was always coded as a contributing factor in the accident in the Ohio FARS data. Thus defective tires were shown as contributing to the accident 177 times in Ohio and only 12 times in Michigan where defects were only indicated in a single contributing circumstances section of the form (with two mentions possible). Clearly the types of police reporting forms and specified procedures have a great deal to do with the types of data on vehicle defects available in state accident files. Thus, without further information it is difficult to tell whether the dramatic changes in vehicle-related accidents reported in Texas and Nebraska reflect some genuine reductions in vehicle defects or whether they may be largely accounted for by changes in police report forms or procedures.

Reductions in All Accidents from PMVI

In addition to these studies of vehicle-related accidents, there have been a number of studies which have looked at general accident trends in relation to PMVI. The most notable of these was the recent time-series analysis of accidents carried out by the New Jersey Institute of Technology (NJIT). Jackson et al. (1982) looked at New Jersey accident data back to 1929, and they found a rapidly rising accident rate in the 1930's and then a large drop in 1938, the year New Jersey instituted a semi-annual inspection program. Trying various models with different numbers of 13 independent variables, such as year, population, income, registered vehicles, drunk driving arrests, PMVI or not, and war years or not, they concluded that PMVI was associated with an average annual saving of 314 lives and an annual average reduction of 37,949 accidents since 1938! [These numbers were later revised to 304 lives saved and 37,910 accidents avoided in Loeb and Gilad (1984).] Surprisingly, none of the tested models found a significant reduction in injuries. The estimate of 304–314 lives saved per year due to PMVI seems unrealistic, considering that in the late 1970's New Jersey had only about 1,100 fatalities per year. Also the lack of a concomitant reduction in injuries suggests that the models used in the time-series analyses were not adequate to cover all the important changes affecting accident rates over the 51 years analyzed (e.g., improvements in emergency medical services). While the regression analysis seems quite sophisticated, the use of year as a surrogate for all other relevant changes over time is clearly inadequate, and the fact that there are only nine points in the baseline period may partially account for the unbelievably large fatality reductions found. Clearly there must be some other important variables which co-vary with inspection to show such a large impact, and it doesn't make sense to propose that vehicle inspection in New Jersey is currently saving 314 (or 304) lives per year. Before presenting such dubious results the same types of models should be replicated in other inspection and non-inspection states.

This was the only study found which looked at general accident trends in relation to PMVI within a single state. However, a number of studies have made such comparisons among states. Jackson et al. provided a useful summary of some of these studies (1982:20–25). In 1963 Mayer and Hoult reported that states with a state-operated system had lower death rates in relation to miles traveled than did states with other inspection systems which in turn had lower death rates than states with no inspection systems during the period 1948–1959. In 1966 Buxbaum and Colton also reported results favorable to PMVI in an analysis of 1960 death rates of men aged 45–54. In this analysis they controlled separately on four independent factors: region, population, registered vehicles, and average gasoline consumption. In 1967 Fuchs and Leveson analyzed the relationship between death rates and inspection by multiple regression techniques to control on ten independent factors. While inspection appeared highly significant by itself, it was no longer significant controlling on the other factors.

Surprisingly, only one of the studies discussed in this review cited Little's study (1968,1971) comparing death rates in six states which had introduced PMVI between 1951 and 1961 with six matching states which already had PMVI and with six matching states which never had PMVI. For each PMVI state he used accident data for the six years before and the six years after beginning PMVI. In this single-factor analysis he found a 10.2% increase in the fatality rates in the six test states, a 4.8% increase in the six PMVI control states, a 4.6% increase in the six non-PMVI control states, and a 1.9% increase for the whole United States. He concluded that general death rates are not a good measure for evaluating the effectiveness of PMVI programs.

Tufte (1974) compared 1966–1968 fatality rates in PMVI and non-PMVI states, and he found the rates about 9% lower in PMVI states in a regression analysis controlling for the log population density. However, he warns that statistical association does not necessarily mean causal effect, and he suggests that there are many factors besides population density and PMVI which can affect general accident rates. He seems to agree with Little (1968) and O'Day and Creswell (1968) that these general accident data are a poor source for trying to prove the value of PMVI.

In 1976 Wort, in testimony before the Illinois Motor Vehicle Laws Commission, presented a comparison of traffic death rates in states with and without PMVI from 1949 to 1973. He found that the trends had changed in 1968 to favor the non-PMVI states for the last five years of his series.

In discussing the design of an appropriate experiment on the relation of PMVI to accident rates, Bentley and Cooper (1977) presented data on 1971 state fatality and injury accident rates. They obtained very mixed results, and they also concluded that general accident data comparisons between states or even over time in one state are not very useful for evaluating the effectiveness of PMVI.

The Pennsylvania Office of Budget and Administration (1981) carried out a regression analysis of 1971–1973 state fatality and injury accident data using up to 17 demographic, socioeconomic, environmental, and highway factors as independent variables. They were able to explain up to 82% of the variance in fatality rates and up to 42% of the variance in combined fatality and injury accident rates. However, they did not find significant differences between PMVI and non-PMVI states when controlling on the other important factors.

The Carnegie-Mellon study (1975) looked at 1974 accident rates among the states, and it found that random-inspection states had the lowest fatality rates in relation to miles traveled, followed by states with semi-annual PMVI, states with annual PMVI, and states with no inspection programs. The authors also attempted a regression analysis with up to 19 independent variables, but no model was able to explain more than 55% of the variations in state accident rates. They suggested that a satisfactory model should explain at least 90% of the variance, since vehicle defects cause such a small proportion of accidents.

In 1980 the American Enterprise Institute published a rather critical review of state inspection programs by Mark Crain. He presented a new analysis of state fatality, injury, and accident rates in 1974 and in 1965, using multiple regression analysis with eight independent factors which together explained about 75% of the variance in fatality rates and about 56% of the variance in injury and accident rates. He looked at five dichotomous dependent variables in relation to inspection systems: PMVI or not, spot-check inspection or not, state-operated PMVI or not, etc. Thus the "not" categories were rather curious mixtures. The only finding of significance (at a 90% level) showed that states with spot-check systems had lower death rates than all other states together, which corresponds to the Carnegie-Mellon findings.

Most recently the NJIT study (Jackson et al. 1982) included a regression analysis of 1979 fatality and injury rates for 46 states and the District of Columbia, using up to 17 independent variables. It found a significant (95% level) negative association of fatalities with inspection, showing an average reduction of 140–150 fatalities in the inspection states. It also found a negative association of inspections with injuries, but the injury reduction numbers were not clearly presented.

O'Day and Kaplan (1976) also carried out a general regression analysis of factors affecting 1972–73 fatality rates in the 48 contiguous states. They found the log of population density to be by far the most significant factor, explaining by itself 67.6% of the variation in state fatality rates in relation to state population. They also pointed out that, whereas the early PMVI states tended to be densely populated eastern states, the 12 states adopting PMVI between 1966 and 1975 tended to be well below average in population density. Thus, the changes in the average population density of the PMVI states could have a lot to do with the Carnegie-Mellon, Crain, and Wort findings that death rates were no longer lower in PMVI states than in non-PMVI states. O'Day and Kaplan found that the logarithmic transformation of population density was much more effective as an explanatory variable than was absolute population density. Crain did use logarithmic transformations for all of his continuous variables, but Jackson et al. apparently just used absolute population density in their regression analyses—although they reported trying out various data transformations also.

There is also one study in the literature which compares general accident rates in a single area in relation to whether vehicles had been inspected or not (Schroer and Peyton, 1977). This was in Huntsville, Alabama, in connection with the diagnostic inspection demonstration project there. The authors found a 9.1% to 21.1% lower accident rate among the inspected vehicles, compared to the uninspected vehicles in the same city. This study is the one research effort which comes close to the kind of large-scale experiment proposed by Bentley and Cooper (1977) to study PMVI effectiveness. They recommend random assignment of vehicle owners to inspection and non-inspection groups and then following their accident experience over one or two years. Unfortunately, due to the voluntary nature of participation in the Huntsville inspection program, it is difficult to know how significant these findings are. Schroer and Peyton (1977) also reported at least a 5.3% reduction in accidents for the inspected vehicles in the period after the diagnostic inspection compared to the period before the inspection. In New Brunswick Wilson (1973) reported that 1970–71 general accident rates were significantly lower in areas where the rejection rates at the annual inspection were lower, presumably indicating that the vehicles in those areas were generally in safer condition and thus less accident-involved.

There were also two studies which attempted to relate general accident involvement (not just vehicle-defect accidents) to time since inspection. In Virginia Garrett and Tharp (1969) were not able to find any relationship between time since inspection and general accident involvement. Similarly, Reinfurt and Symons (1974) found no significant relationship between the introduction of PMVI and accidents or between time since inspection and accidents in North Carolina and Florida. However, in Virginia the number of accidents studied was rather small, and in Florida the inspection follow-up period was quite short for seeking a significant relationship in general accident data, while in North Carolina the data on date of inspection turned out to be unsatisfactory. Symons and Reinfurt (1975) presented some important statistical considerations for such time studies, including the large numbers of inspected vehicles and accidents which must be analyzed in order to find a statistically significant relationship.

Given the evidence from the Indiana tri-level study that vehicle defects were definitely or probably the sole cause in only 2.4% of the accidents studied, given the many other factors which seem related to accident rates, and given the evidence of rather substantial differences in the effectiveness of various PMVI programs, it seems unreasonable to expect to find definite relationships between general accident experience and the presence or absence of PMVI programs in the American states (as Little stated in 1968). Clearly more desirable would be comparative in-depth studies of accident causation in states with different types of inspection programs or no inspection program. The one study of this type in the literature took place in a PMVI state, but no information is available comparing the general condition of Indiana vehicles with the general condition of vehicles in other PMVI and non-PMVI states. It may be that vehicle defects cause larger proportions of accidents in non-inspection states than they did in Indiana. However, in the absence of such comparative in-depth studies it is very difficult to draw any firm conclusions on the effectiveness of various types of PMVI programs in reducing accidents. Alternatively, the kind of large-scale experiment proposed by Bentley and Cooper (1977) could also be very informative if it could be carried out, but the practicality of randomly assigning vehicle owners living in the same area to mandatory inspection and non-inspection groups is open to serious question.

It should be noted that in connection with the Department of Transportation's Highway Safety Needs Report (1976), a panel of 103 experts (including 40 governor's representatives for highway safety) was surveyed regarding their perceptions of the effectiveness of various countermeasures in reducing the frequency and severity of traffic accidents. Among 43 countermeasures which were rated, current PMVI procedures were ranked 40th, while new PMVI procedures focusing on safety critical components were ranked 34th. Clearly the consensus of experts in the field was that PMVI was not a highly effective safety program.

Cost-Effectiveness of PMVI

The first discussion of the cost-effectiveness of PMVI programs was found in a NHTSA report by the Office of State Vehicle Programs (1975). Using a 1972 study on the societal costs of motor vehicle accidents, preliminary Indiana tri-level data on vehicle-related accidents, and estimates of inspection costs of $2.42 for a minimum inspection (10 minutes) and $6.12 for a maximum inspection (24 minutes—with wheel pull), this study estimated that a minimum-inspection PMVI would only have to be 6% to 15% effective in reducing vehicle-related accidents to be cost-effective, and a maximum-inspection PMVI would only have to be 14% to 39% effective in reducing vehicle-related accidents to be cost-effective. However, the inspection cost figures appear low and do not include motorist's travel and time costs nor the costs of expedited or unnecessary repairs, and of course the Indiana estimates of accidents caused by vehicle defects were revised downward at the completion of the full study. Also, despite the dramatic changes reported in Nebraska, Texas, and New Jersey, it is questionable that average PMVI programs are even 6% effective in reducing vehicle-related accidents.

The Department of Transportation's Highway Safety Needs Report (1976) also considered the cost-effectiveness of PMVI and of an alternative not-clearly-described program entitled "Tire and Braking System Safety Critical Inspection—Selective." The current PMVI programs were estimated to have a 10% effectiveness in reducing vehicle-related accidents, while the selective tire and braking program was estimated to have a 25% potential effectiveness. The bases for the various cost estimates were not clearly explained, but the study estimated that the selective program would cost $250,533 per life saved, while extending PMVI to all states would cost $2,120,535 per life saved. A computational error was evidently made regarding the latter figure, and the correct figure appears to be $221,841. Among 37 evaluated countermeasures the selective program ranked 22nd in cost-effectiveness, while extending the current PMVI program ranked 31st but should have ranked 20th.

In an update of the 1976 report Tarrants and Voas (1981) placed these two countermeasures last and next-to-last in cost-effectiveness among 17 ranked countermeasures. Based on advice from a panel of experts (ten from NHTSA, one from FHWA, and two from private research organizations), they estimated only a 4.3% effectiveness for the Selective Tire and Braking Inspection and only a 1.9% effectiveness for Current PMVI Practices. They estimated that the first program could save 73 lives per year at an average cost per fatality forestalled of $2,285,127, while extending current PMVI to all states could save 44 lives per year at an average cost per fatality forestalled of $7,665,127. However, the nine-fold computational error from 1976 may still be perpetuated in the latter figure.

In 1977 the Government Accounting Office reviewed the studies of PMVI, and the Comptroller General made a report to Congress. It concluded that, while there was evidence that vehicle defects cause some accidents, there was no conclusive evidence that PMVI programs were cost-effective in reducing such accidents. It recommended that Congress direct NHTSA to undertake priority research on the cost-effectiveness of PMVI programs in reducing accidents.

The Carnegie-Mellon study (1975) attempted to assess the cost-effectiveness of PMVI in Pennsylvania, using both actual inspection costs and an estimate of motorist's time and driving costs. While police accident data showed mechanical failures as contributing factors in only about 2.5% of Pennsylvania accidents, it used the preliminary Indiana tri-level data as a more realistic estimate of vehicle-related accidents. It estimated that, if in the absence of PMVI 15.9% of Pennsylvania accidents would have been caused by vehicle defects, and if PMVI in Pennsylvania was 46% effective in reducing such vehicle-related accidents, then Pennsylvania's semi-annual PMVI system was cost-effective. The authors recognized that neither assumption was probable, but they suggested that the Pennsylvania system could be made more cost-effective by increasing state monitoring activities, by changing to annual inspection, and by not inspecting vehicles less than two years old.

The NJIT report (Jackson et al., 1982) also looked at the cost-effectiveness of PMVI in New Jersey. Using three different sets of estimates of the costs of motor vehicle accidents, actual data on the costs of inspections in New Jersey, estimates of motorist driving and time costs and of expedited repair costs, and the results of the regression analyses for reductions in fatalities, injuries, and accidents, a benefit-cost ratio of at least 1.86 was found. In their later article Loeb and Gilad (1984) dropped a reduction in injuries as part of the benefit estimates, but they still projected 1.24:1 as a reasonable benefit-to-cost ratio for PMVI in New Jersey. Unnecessary repairs were not taken into account, and of course the validity of the great reductions in fatalities, injuries, and accidents shown in the regression analyses is essential to these conclusions supporting the cost-effectiveness of PMVI in New Jersey.

A cost-effectiveness analysis by Wort (1976) used 6% as the proportion of vehicle-related accidents, 10% as the estimated effectiveness of PMVI in reducing such accidents, and $20 as the average total inspection cost. He concluded that PMVI in Illinois would cost 20 times its benefits in reduced accidents.

Similarly, a California Highway Patrol discussion of cost-effectiveness (1974) compared mandatory inspection at inspection stations, random roadside inspection, and selective roadside inspection. Using preliminary data from the Indiana study of accident causation and making various assumptions about inspection effectiveness and costs, the authors found any random inspection system more effective than a mandatory system, and they found that the lower the inspection rate the more cost-effective the inspection program. Pointing out that the oldest 50% of the vehicle population has 75% of the vehicle defects, the report concluded that a selective roadside inspection program concentrating on vehicles over four years old seemed to be the most cost-effective approach.

Abbene (1978) reviewed the literature in an attempt to determine if semi-annual PMVI in Virginia was cost-effective. Based on NHTSA multi-state studies which included semi-annual PMVI Pennsylvania, he estimated that semi-annual PMVI is 20–25% more effective than annual PMVI in improving vehicle condition. Using three possible estimates of defect-related accidents and two sets of accident cost estimates, he came up with various needed rates of effectiveness in reducing defect-related accidents in order for Virginia's program to be cost-effective. He concluded that the Virginia program might possibly be cost-effective, but he admitted that annual programs would be more likely to be cost-effective. However, his benefit figures seem quite inflated because he multiplied all injury accidents in Virginia by the estimated cost of a disabling injury accident, and also his owner cost figures seem quite low ($5 per inspection including motorist time).

Crain (1980) provided some thoughtful discussion of the issues in determining the cost-effectiveness of PMVI, but, since his analysis did not indicate that PMVI had any effect on accident rates, he did not need to try to determine actual cost-benefit ratios. He did suggest that PMVI programs are primarily a legally mandated benefit to the auto repair industry.

Thompson (1982) provided an interesting and perhaps more balanced discussion of the entire PMVI issue, and he attempted some speculative estimates of the cost-effectiveness of a nationwide, comprehensive, semi-annual PMVI system with a reliability of 90%. He assumed that such a program could reduce total accidents compared to a no-inspection program by 10%, thus saving $60 to $100 per vehicle per year, and he estimated that the average cost for two inspections per vehicle would be $78, including driving and time costs and the costs of making repairs earlier than in a no-inspection system. These estimates provided cost-benefit ratios on both sides of the cost-effectiveness question. He suggested that eliminating inspection of vehicles less than three years old and varying the inspection periods on other vehicles in relation to their condition at the time of inspection could lead to an optimal PMVI system which was clearly cost-effective. However, his assumption of a 10% reduction in all accidents from a reliable PMVI program seems quite unrealistic, and how he determined that traffic accidents cost $600 to $1000 per year per vehicle (which would be $96,000,000,000 to $160,000,000,000 annually for about 160,000,000 registered vehicles) is not mentioned at all.

Summary and Conclusions

The effectiveness of various parts of the motor vehicle inspection process have been addressed by many authors. These parts include:

1. The effect of vehicle inspection on vehicle condition.
2. The reliability (or effectiveness) of inspection and repairs.
3. Observation of vehicle defects in accident-involved vehicles.
4. The relationship between inspection and accidents.
5. Overall cost/benefit of the inspection process.

To summarize the findings of this literature review, five graphs are presented—one for each item on the list above. On each graph the vertical axis represents the believability of the report—a matter of judgment but based on consideration of the quality of the data or the analytical methods employed. The horizontal axis represents the degree to which the overall findings of the study were favorable or unfavorable to PMVI.

The first graph (Figure 1) indicates that most studies of inspected and uninspected vehicles have found a positive correlation between vehicle condition and the presence of an inspection program. The major exception is Fisher's 1973 study which compared the condition of vehicles in six states and found that condition was poorest in Missouri—the only state of the six with a PMVI program. Hatch, in a later study, observed that Texas vehicles with PMVI were in poorer condition than Missouri's. Also Milne found no significant differences among vehicles in Maine, Maryland, New Hampshire, and Virginia. Bentley and Heldt reported three studies in Massachusetts, Missouri, and New Jersey which found vehicles in better condition the sooner they were checked after their regular inspection, and Hatch found time since inspection to be significantly related to outage rates for one out of four brake components checked. However, O'Day and Creswell found no significant differences in taillight outages between five PMVI cities and three non-PMVI cities. Still, in the majority of these studies, PMVI jurisdictions were observed to have vehicles in somewhat better condition than non-PMVI jurisdictions.

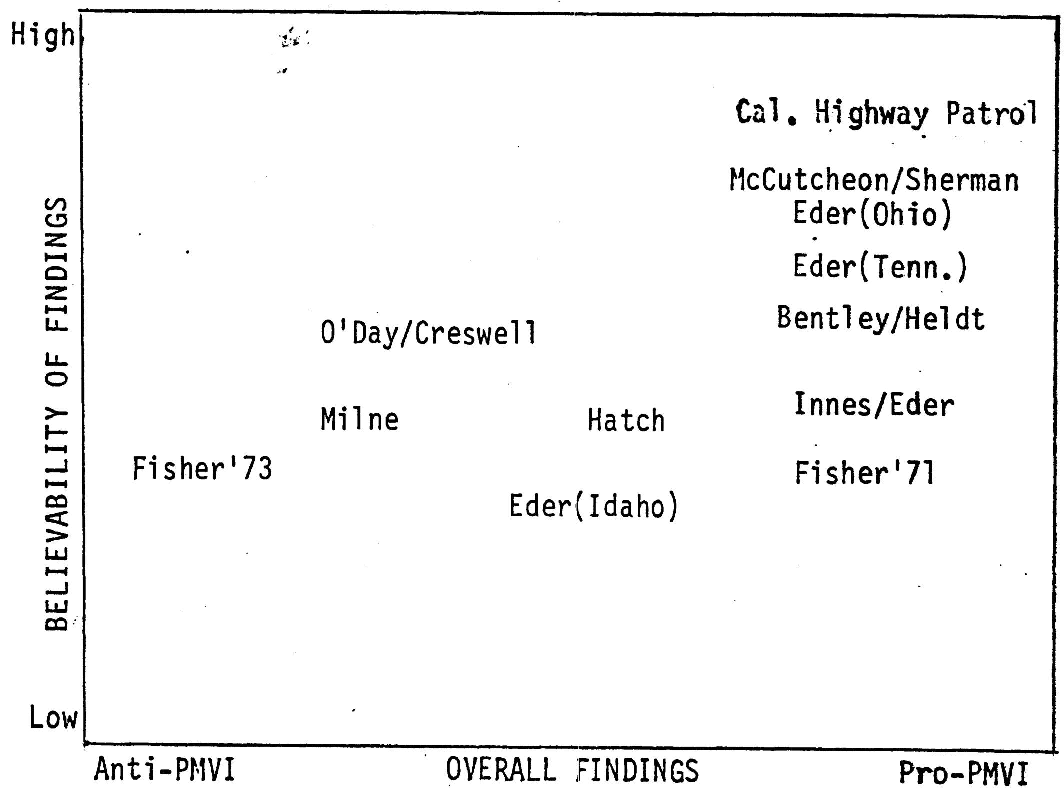

Figure 1
Quality and Findings of Studies of PMVI and Vehicle Condition

There is some question about the methodology of most of these studies. Vehicles participating in the measurement programs were generally volunteered by their owners, and it is not possible to assess the effect of this. In the McCutcheon-Sherman study most of the PMVI vehicle owners came to city-operated inspection stations, and many might have repaired their vehicles prior to inspection. In spite of such problems, it seems reasonable to draw two conclusions:

1. That vehicle condition is frequently but not always better in jurisdictions with a periodic inspection program.
2. That there is considerable variability in the quality of inspection in various PMVI jurisdictions.

Figure 2 concerns the reliability or effectiveness of the inspection process in finding defects and forcing repairs. For this category, most of the reports seem rather believable, but reliability or effectiveness is generally found to be poor. There are three components which may be considered: (1) The chance of detecting a defect if it is present, (2) the chance of forcing that defect to be repaired properly and at reasonable cost, and (3) the chance of forcing unnecessary repairs.

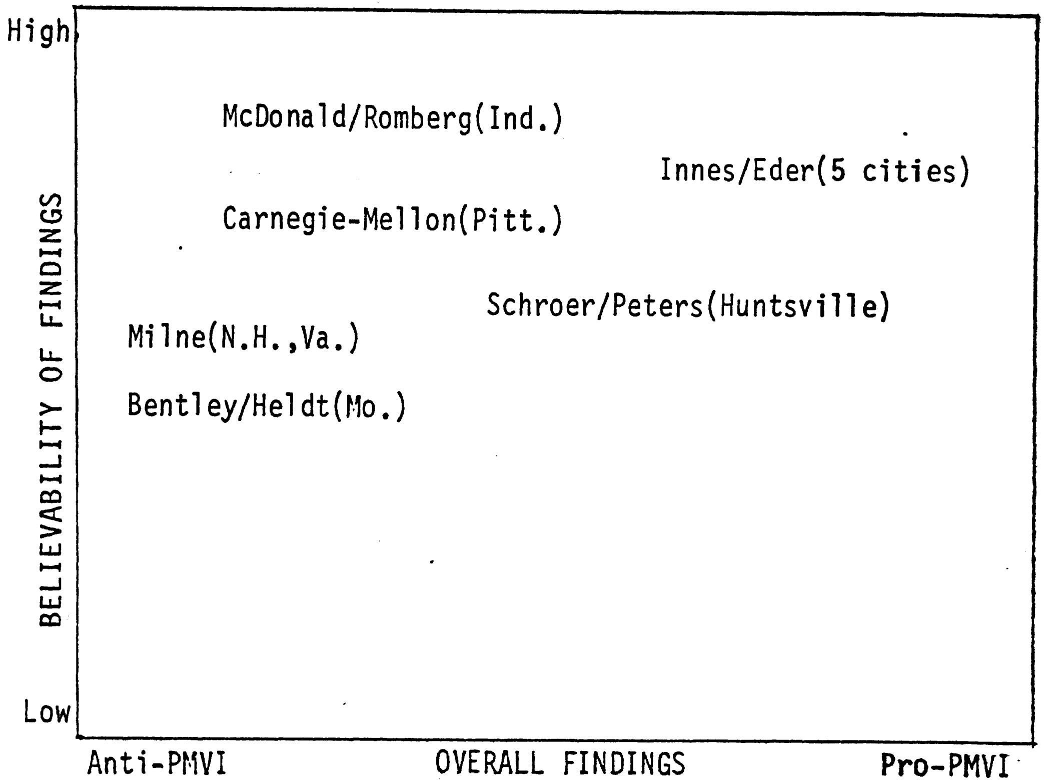

Figure 2
Quality and Findings of Studies of Inspection Reliability

The Carnegie-Mellon study reported an average of $35.00 in unnecessary repairs in an experiment with 20 inspection stations in Pittsburgh. They further reported that, on the average, these same stations found only 4 of 13 planted defects. Innes and Eder reported that 50% of the vehicles found defective in an Alabama inspection were still defective at a reinspection, although this figure was only 2% for Washington, D.C. McDonald and Romberg reported that one-quarter of the defects observed in an in-depth examination of crashed cars in PMVI Indiana had been present in those cars at the time of inspection. Milne reported that about 20% of the inspection stations covertly observed in New Hampshire and Virginia failed to pull a wheel, although this was required by the state codes. Bentley and Heldt reported compliance rates with inspection procedures in Missouri between those in Virginia and New Hampshire.

The consensus of the literature seems to be that inspection programs are far from 100% effective. This suggests that some measure of effectiveness (by state) would be appropriate in statistical comparisons among states. In addition, it may be appropriate to develop methods to make existing programs more reliable.

Figure 3 concerns the relationship between police-reported vehicle defects and accidents. Police indications of vehicle defects as accident causes can not be considered

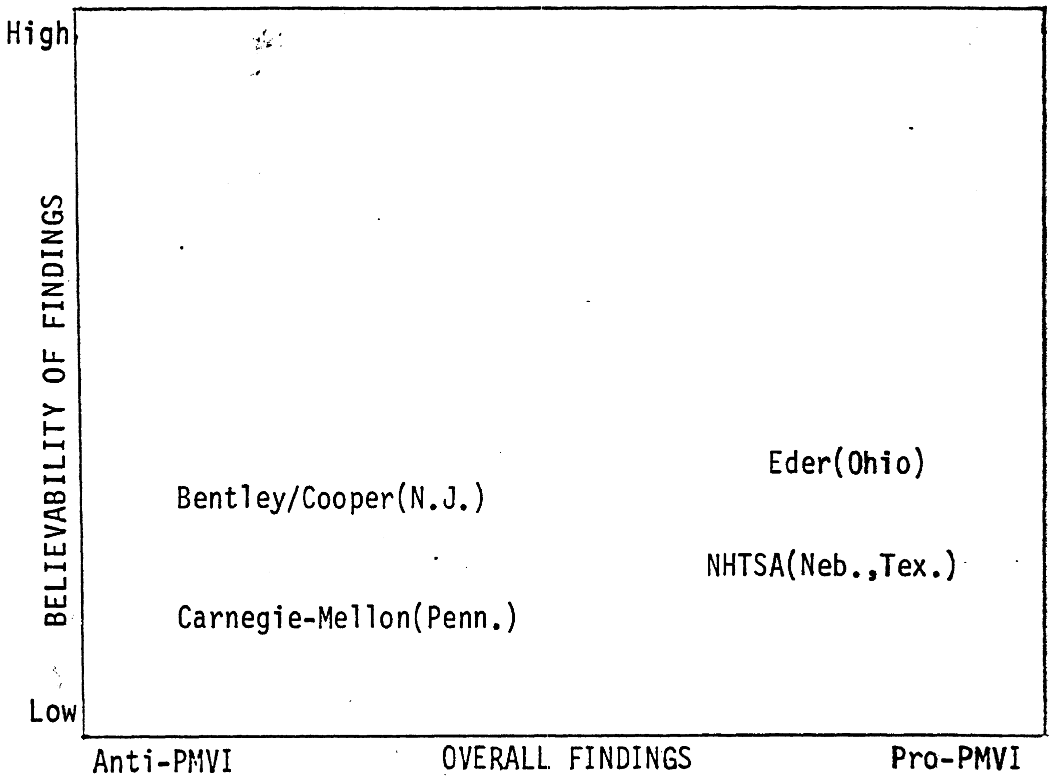

Figure 3
Quality and Findings of Studies of Vehicle Defects in Accidents

completely reliable, but there were four reports found which provided some data relevant to PMVI effectiveness in reducing vehicle-related accidents. The Carnegie-Mellon study found no relationship between time since inspection and the recording of vehicle defects on the accident report; however, this finding was based on a small sample and is not given much weight. Bentley and Cooper reported a much larger study in New Jersey (3,000 defect-related accidents) which also found no relationship to time since inspection. Eder reported that vehicle defects in accidents in Cincinnati were less frequent than in the remainder of the state (which was undergoing a trial substitute random inspection program at that time).

Both Texas and Nebraska reported sharp declines in the proportion of accidents with vehicle defects following introduction of inspection—Texas from 12% to 4%, and Nebraska from 6.1% to 2.6%. These findings would strongly support the effectiveness of PMVI, but the differences reported seem unbelievably large when compared to other data.

Figure 4 considers reports of the relationship between accidents or accident rate and PMVI. Perhaps the most prominent recent report (Jackson; Loeb) concerns the New Jersey program, and it provides the widely quoted finding that vehicle inspection reduces fatal accidents by over 22%. The time series analysis of New Jersey data certainly indicates that there was a substantial change in fatality count in the years after PMVI

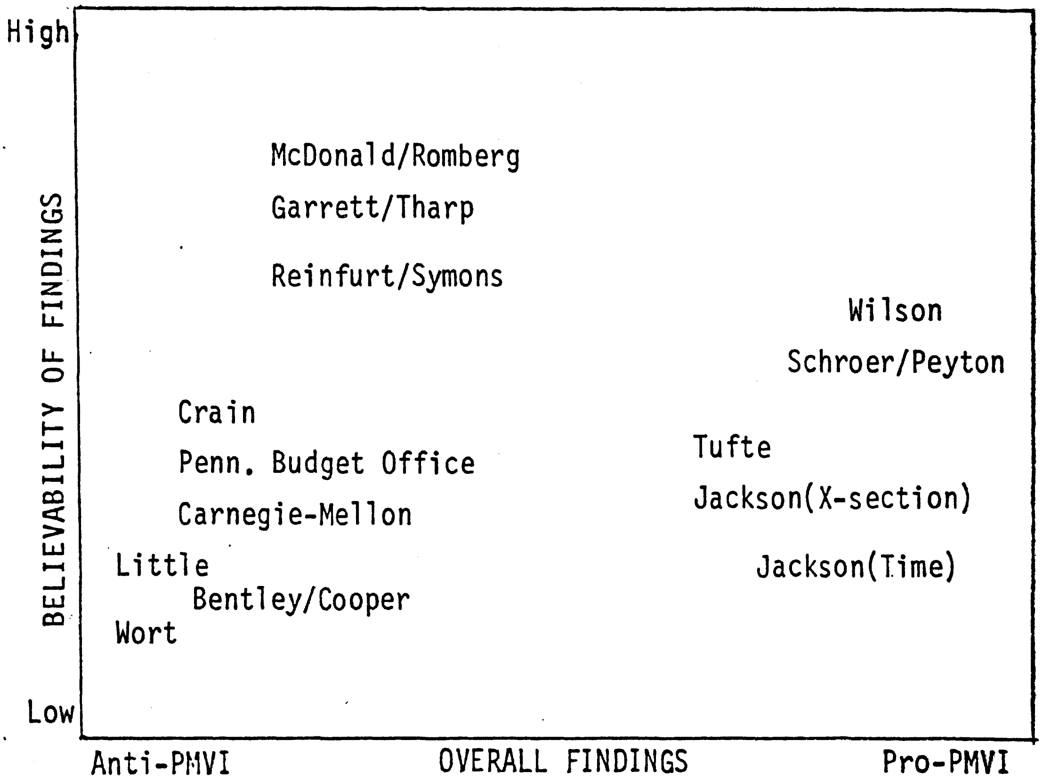

Figure 4
Quality and Findings of Studies of General Accident Data

introduction, but it does not present a very persuasive argument that only motor vehicle inspection was responsible throughout this period. Little compared fatality rates before and after the introduction of inspection in six states, and found that fatality rate increased more in the inspection states than in control states. While he did not use the more sophisticated time series methods, his findings are persuasive that fatality rate is a poor measure of the effectiveness of PMVI. Several other studies (Crain, Penn. Office of Budget, Carnegie-Mellon) also found no significant differences among PMVI and non-PMVI states when controlling on other relevant factors.

Tufte used PMVI as an example of the method of regression analysis, and he reported an inverse association between vehicle inspection and fatality rate even after accounting for a population density effect. He points out, however, that such correlations are not conclusive evidence of "causation," and that there are certainly many other factors which he did not consider. His residual analysis method suggests a fatality reduction of the order of 9% associated with vehicle inspection, but it was based on data from only 1966 to 1968.

Three studies (Garrett, McDonald, Reinfurt) found no relationship between time since inspection and being in an accident. Schroer and Peyton reported a lower accident rate among vehicles which had been inspected, but the effect of volunteerism in the sample is suspect. However, Wilson's data showing fewer accidents in areas with lower rejection rates at inspection seem probably reliable.

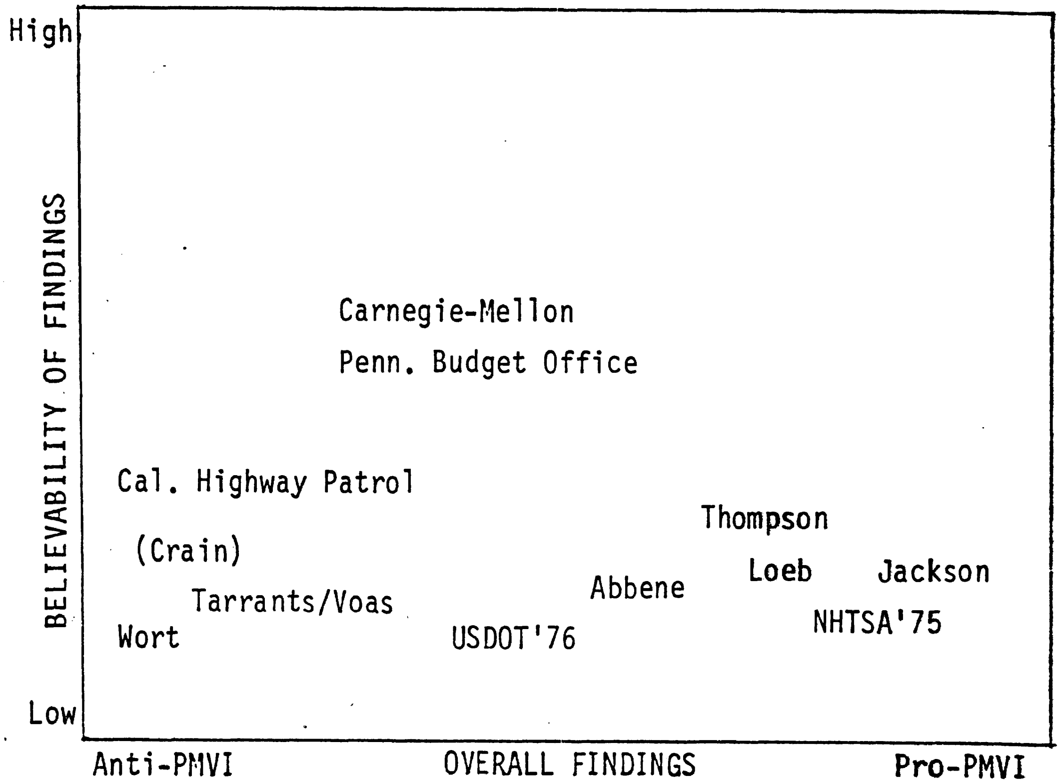

Figure 5
Quality and Findings of Studies of PMVI Cost-Effectiveness

The final graph (Fig. 5) concerns reports which consider cost/effectiveness or cost/benefit. Again, one of the most quoted reports is Jackson's on the New Jersey experience, which suggests an almost 2:1 benefit-to-cost ratio associated with the 22% reduction. However, the Loeb article reduced this to 1.24:1. A second method used in the New Jersey report (a cross-sectional analysis of states) suggests that the benefit is less than half of the 22%, and this would bring the benefit/cost ratio to about 1:1.

A 1975 NHTSA study reports a 1:1 benefit/cost ratio assuming a 14%−39% reduction in vehicle-defect-related accidents (assumed to be 16% of all accidents) if the annual inspection costs are about $6.00. The combination of the costs of unneeded repairs and of time and travel associated with inspection make the $6.00 unrealistic. The Carnegie-Mellon study reported that vehicle inspection would be cost effective if vehicle defects caused 16% of all accidents and inspection were 46% effective; but they did not believe that either condition was true.

Thompson found that vehicle inspection might be cost effective if it induced a 10% reduction in all accidents and cost $78 per inspection (including an allowance for "expedited" repairs), but his estimates of accident costs seem faulty. On the negative side, Crain argued that there was no effect of inspection on accidents at all, and thus a cost benefit analysis was immaterial.

Although the literature is somewhat mixed, there seems to be relatively little support for PMVI on a safety cost-effectiveness basis. Other possible reasons for PMVI programs—reduction of pollution due to vehicle emissions, or extending the useful lifetime of vehicles by appropriate preventive maintenance—have not been explored in this report. With the change in policy regarding NHTSA sanctions, inspection has become a matter for local political choice, and many jurisdictions evidently are comfortable with the inspection systems which are in place.

Evidence in many of the reports reviewed here suggests that many existing PMVI programs are considerably less than 100% effective in identifying defects and forcing repairs. A NHTSA-sponsored study (Bentley and Heldt 1977) proposed methods for local jurisdictions to do some self-evaluation of their PMVI operations, and it was intended to improve operating practices in the field. Given that PMVI has reverted to a state or local option, it would seem appropriate that NHTSA continue to encourage local evaluation activities and efforts to make inspections more reliable and effective.

The key to minimizing undesirable component outages is to provide durable components, to detect their failure quickly when they do deteriorate (O'Day and Carlson 1973; McMinn 1974), and to promote rapid repair. The auto industry has already responded to this challenge in such ways as the General Motors Corporation disk brake noise indicator of a need for new pads, and with warning systems for light outage, low windshield washer fluid, etc. Whether modern electronic methods will lead to a reduced need for governmental inspection remains to be seen, but it can be hoped that modern electronics, clever design, and the market place will lead to an enhanced capability for early detection and repair.

In conclusion, there is little question that periodic inspection can lead to somewhat improved vehicle condition, and that "better vehicles" have some potential for lower involvement in accidents. However, essentially all of the literature which supports PMVI as having safety benefits greater than the cost is based on correlation or regression studies from which causal inferences must be drawn with great caution, plus frequently inflated benefit estimates and incomplete cost estimates. None of the reviewed studies were able to provide credible evidence that current PMVI programs are cost-effective on a cost—"safety benefit" basis. This is mainly because there is a shortage of convincing research on the effectiveness of PMVI in reducing vehicle-defect accidents. More credible research efforts are needed before making any final conclusion regarding PMVI cost-effectiveness.

APPENDIX A

ANNOTATED REVIEWS OF SELECTED REPORTS CONCERNING PMVI

Abbene, John. J. Semi-annual vs. Annual Motor Vehicle Inspection: An Evaluation of the Literature and a Benefit-Cost Analysis. Charlottesville: Virginia Highway and Transportation Research Council, February 1978, 38 pp.

This is a fairly cautious review of the issues and available data relevant to determining the benefits and costs of Virginia's semi-annual PMVI versus an annual PMVI program. Abbene uses preliminary data from the Indiana tri-level study of accident causation which indicates that 6% of accidents are definitely and another 10% are probably caused by vehicle defects; but he does point out that vehicle defects were the sole definite or probable cause in only 3% of the accidents. He uses the McCutcheon-Sherman (1968) comparison of inspection results on semi-annual and annual PMVI work; the first Fisher et al. (1971) study comparing semi-annual and annual PMVI (Pennsylvania vs. New Jersey, Washington, and California); and the Hatch et al. study of Pennsylvania compared to five other states to estimate that semi-annual PMVI improves vehicle condition 20–25% compared to annual PMVI. Also he cites the rather surprising results of McMinn's random inspection study in New Jersey (1974) which indicated that most vehicle deterioration took place within four months of inspection, and did not get much worse in the following nine months. This suggests the potential value of more frequent inspection in improving vehicle condition.

Turning to the effect of PMVI on accident rates, he concludes that the various cross-sectional studies are inconclusive because of the many variables which have not been controlled. He also points out that Garrett and Tharp (1969) in Virginia and the Carnegie-Mellon study (1975) in Pennsylvania found no relationship between the length of time since inspection and involvement in a defect-related accident. He also mentions studies that show more defects in older and higher mileage vehicles, and he suggests consideration of varying inspection frequency with the age of the vehicles. In addition, he discusses a telephone survey which showed that 85.3% of Virginians approved of PMVI, and that 71.6% preferred semi-annual to annual inspections.

Abbene begins his discussion of cost-effectiveness by mentioning the many uncertainties involved, particularly regarding accident costs. He makes use of two sets of accident cost figures and three estimates of the percent of accidents caused by vehicle defects (6%, 11%, and 16%) to calculate six possible figures for societal costs of defect-related accidents in Virginia—ranging from $28 million to $120 million. However, each of these figures is inflated by an error he made in multiplying the cost of every injury accident in Virginia by $5000 or $7500 (53,170 of them) even though those figures were supposed to represent the average cost of the much smaller set of disabling injuries. On the consumer cost side he estimates inspection costs as $5.00 per inspection (the $4.00 fee plus $1.00 for the motorist's time) plus $510,000 in state costs. This comes to $33,000,000 for a semi-annual inspection and $16,760,000 for an annual inspection. He concludes that if 16% of the accidents would be defect-caused without PMVI, and if the higher set of (inflated) cost figures were valid, and if PMVI were at least 28% effective in reducing defect-caused accidents, then semi-annual PMVI would be barely cost-effective. Under similar assumptions, an annual PMVI program would only have to be 14% effective in reducing defect-related accidents to be cost-effective. He mentions the Carnegie-Mellon (1975) estimate that 75% is probably the maximum effectiveness that a good PMVI program could attain, and he suggests that 50% might be a more realistic level of effectiveness, in which case semi-annual inspection might be cost effective. He says that the analysis shows that a semi-annual program is less cost-beneficial than an annual program would be, but he concludes that, given the uncertainties of available data, there is no clear reason for abandoning the present semi-annual PMVI program.

Bentley, Geoffrey and Paul W. Cooper. Safety Status Data Collection Methodology: Vol. III, Task Report on PMVI Experiment Design. Wilmington, Mass.: AVCO Corp, September. 1977, 97 pp. (Report DOT/HS 802 573).

This report for one part of a larger contract presents a detailed experimental design for evaluating the effect of a PMVI program in terms of reduced accident rates. First it discusses the inadequacies of using existing state fatal and injury data for the evaluation of PMVI effectiveness. It presents 1971 fatal and injury rate comparisons for all PMVI states vs. all non-PMVI states, for 10 PMVI states vs. 10 geographically matched non-PMVI states, and for 8 PMVI wheel-pull states vs. 8 less closely matched non-PMVI states. The comparison rates are calculated both treating each state equally and weighting each state's data in relation to its population. Four of the six injury rate comparisons which they present favor the PMVI states, but eight of the nine fatality rate comparisons strongly favor the non-PMVI states. The authors conclude that, without controlling on other variables, the results are meaningless and that a new experiment is needed.

They then discuss the large vehicle sample sizes that would be needed to statistically compare two groups on general accident rates, and the even much larger numbers which would be needed for comparisons of general fatality rates. These numbers would be considerably smaller, but still quite large, if accident investigation teams were in place to determine which of the accidents of the involved vehicles were defect-related. They discuss a number of experimental designs and conclude that any involving more than one state would be unsatisfactory because of the difficulty of matching on all other relevant exogenous factors. They also say that analyzing a change in one state from or to PMVI would not be satisfactory because of the inability to control for temporal effects. The one approach which they suggest might be useful with available state data involves looking at changes in vehicle-defect accident rates in relation to time since last inspection. This could provide some evidence as to whether the PMVI program in a particular state was effective or not, but it could not demonstrate the degree of effectiveness compared to no PMVI. They report that a preliminary analysis of 3,000 defect-related accidents in New Jersey (out of 200,000) found no consistent relationship with time since the vehicle inspection (personal communication from Robert McMinn).

The proposed experimental design involves choosing a relatively isolated region of a "typical" state and randomly assigning half of all registered vehicles in the area to mandatory PMVI for one or two years. Then a comparison would be made between either general accident rates or team-investigated defect-related accident rates. The sample sizes required would vary depending on estimates of defect-related accidents and of the potential effectiveness of inspection. Using 10% and 50% respectively, 90,000 vehicles in each group would be needed for a one-year comparison of general accident rates, and 7,040 vehicles for a one-year comparison of defect-related accident rates. For a two-year Latin square design these sample sizes could be halved. Estimated costs for any of these designs would be about two million dollars.

Bentley, Geoffrey K. and Richard W. Heldt. Safety Status Data Collection Methodology: Vol. I, Summary; Vol. II, Report on Development and Validation of Evaluation Procedures; Vol. V, Motor Vehicle Inspection Program Evaluation Procedures Manual;

Vol. VI, Computer Documentation. Wilmington, Mass: AVCO Corp., September 1977, 32 pp., 218 pp., 64 pp., 118 pp. (NHTSA Reports DOT-HS-802 571, 572, 575, 576). [Also summarized in "Procedures to Evaluate the Effectiveness of PMVI", Warrendale: Penn.: Society of Automotive Engineers, September 1977, 17 pp. (SAE Paper 770814)].

These documents describe three types of procedures to be used by a state in evaluating the effectiveness of its PMVI programs in improving vehicle condition. The basic procedure is a field inspection of representative samples of vehicles drawn from different parts of the state, and with different lengths of time since inspection. Then a measure of effectiveness (MOE) for the inspection of a given component could be calculated by relating the varying outage rates to the time since the vehicle was inspected. Twenty-one items were listed for inclusion in the random inspections. The second procedure involves visits to inspection stations to check on compliance with state rules and regulations regarding facilities, equipment, and records. The third procedure involves various methods of covertly observing the inspection process at a stratified sample of stations to check on the correct implementation of the test procedures.

The field evaluation procedures were validated by inspecting 666 vehicles for 60 components at a St. Louis inspection station. About half the vehicles were voluntary drive-ins, and half were selected with police assistance. The overall reject rate on Missouri-inspected items gradually increased (but not in a smooth curve) from 40% in the first month after a vehicle's regular inspection to about 47% 12 months after the regular inspection. The calculated MOE was 25.3%, indicating that the Missouri inspection program was somewhat effective in improving vehicle condition. Similar calculation of an MOE for 20,000 vehicles randomly inspected in New Jersey resulted in a figure of 38.0%. In New Jersey 23% of the vehicles inspected within one month of their regular inspection were rejected, and this rejection rate rose to 39% for a vehicle checked 12 months after inspection. An observational study of headlamp outage in semi-annual PMVI Massachusetts found about 1% outage in the first month after inspection, rising gradually to about 2.5% in the sixth month after inspection. The MOE was calculated to be 76.3%. Somehow the authors estimated that without inspection the outage rate would be 8.9%. They also present data from 7,149 free inspections in Maryland which showed that vehicles previously inspected due to title changes were in no better condition than never-inspected vehicles, but these results were biased by the fact that the never-inspected group tended to consist of newer cars. Results controlling on vehicle age were not mentioned.

In validating compliance with administrative requirements at 58 stations in St. Louis and Springfield, an overall compliance rate of 87.3% was obtained. There were only small differences by type of facility. Most of the noncompliance had to do with outside area requirements and records, stickers, and forms. The covert test processes were validated in three counties observing 169 inspections by means of various ruses. On ten items which were simple to observe, the statewide compliance rate was estimated at 77.4%. This included 96% on pulling one wheel, but only 30% on checking alignment.

The evaluation procedures manual briefly describes how to carry out the procedures discussed above with illustrations of how these were or could be applied in Missouri. The computer documentation volume explains how to use the AVCO computer programs to determine compliance rates, measures of effectiveness, etc.

California Highway Patrol. Final Report on Motor Vehicle Inspection Experiment. Sacramento: December 1974, 44 pp. plus 9 appendices.

In addition to the results which have been summarized by Eder (1978), this report presents partial results from the baseline and experimental period inspections in the 15 participating counties. Overall, about 14–17% of the inspected vehicles were found to have at least one safety critical defect. The rates tended to be slightly higher in the baseline period when mainly unstickered (not previously inspected) vehicles were inspected than in the experimental period when more random selection procedures were used. The results were not consistent among counties in the same level of inspection group, but in general in the post-experiment inspections those counties with higher inspection rates had fewer defective vehicles than those counties with lower inspection rates (including no inspection).

This report also attempted to analyze the cost-effectiveness of three types of inspection programs: mandatory inspection at inspection stations, random roadside inspection, and selective roadside inspection. Using preliminary data from the Indiana study of vehicle defects as accident causes and making various assumptions about inspection effectiveness and costs, the authors found any random inspection system more cost-effective than a mandatory system, and they found that the lower the inspection rate the more cost-effective the inspection program. Pointing out that the oldest 50% of the vehicle population has 75% of the vehicle defects, the report concluded that a selective roadside inspection program concentrating on vehicles over four years old seemed to be the most cost-effective approach.

Carnegie-Mellon University, Program in Engineering and Public Affairs. An Assessment of Pennsylvania's Periodic Motor Vehicle Inspection System. Pittsburgh: December 1975, 171 pp.

This was an interesting attempt to research many aspects of the effectiveness of Pennsylvania's motor vehicle inspection system which had required semi-annual inspections at licensed private inspection stations (17,000 in 1975) since 1929. Of greatest interest was a field experiment in which the same car with 13 implanted defects was inspected at 20 different stations in Pittsburgh. All defects were ones listed for inspection in the Pennsylvania inspection guidelines. The number of defects found ranged from one to seven with an average of 3.96. Only two stations issued official rejection forms, and none carried out the required half-mile road test. In addition, the number of non-existent defects found ranged from none to seven with an average of 1.75 and an average estimated repair cost of $34.93. There was almost no relationship between the safety sensitivity of a defect and its likelihood of being diagnosed.

It is possible that these inspections were more cursory than usual because they were not coupled with a request for the station to go ahead and make necessary repairs. Nevertheless this study seems to be a serious indictment of Pennsylvania's inspection system and of the adequacy of inspection station monitoring by the 67 state police inspectors. An independent estimate of the average time needed for an adequate inspection following Pennsylvania standards came out to almost 30 minutes; yet the average inspection fee in 1975 was about $6.50. The authors suggested that developing a more rational inspection program which concentrated on components with high failure rates and accident potential would be a cost-effective improvement of the system. However, they suggested that the maximum feasible effectiveness of an inspection program in preventing defect-related accidents would be about 75%.

A study of 6000 inspection forms turned into the state showed that 70% of the vehicles passed without further repairs. Some stations passed almost all vehicles and some rejected almost all. About 20% of low-mileage cars were rejected compared to about 40% of high-mileage cars. An analysis of accident data tried to see if there were more defect-related accidents the longer the time of accident from the time of inspection, but only 62 defect-related accidents were analyzed and no relationship to time since inspection was found.

An analysis of 1974 fatality and injury rates per 100,000,000 miles traveled showed the lowest fatality rates in states with random inspection systems, followed by states with semi-annual systems, states with annual systems, and states with no inspection programs. The injury rates provided contradictory results, but the variations in injury rates were so large that there must have been substantial differences in the completeness of reporting of injury accidents in the various states. It was recognized that this single-factor analysis was not very conclusive, and it was pointed out that the random-inspection states had tended to adopt more of the other federal highway safety standards than the other states. A regression analysis was also carried out with up to 19 independent variables, but none of the 200 regressions were able to explain more than 55% of the variance in fatality rates, and some of the best equations found a negative PMVI effect. The authors suggested that a satisfactory regression equation should explain at least 90% of the variance in accident rates, considering the small proportion of accidents which are caused by vehicle defects. Also discussed was the NHTSA study using mobile inspection teams which found higher outage rates on some important safety components in Pennsylvania than in California with its random inspection system (Hatch et al. 1976).

The authors reported that mechanical failures were listed as contributing factors in only 2.5% of Pennsylvania accidents. In seeking to determine the cost-effectiveness of Pennsylvania's inspection system, they made use of the early results of the Indiana tri-level accident investigation study which found 6% of accidents to be definitely caused by vehicle defects and a further 9.9% to be probably caused by such defects. Using federal estimates of $200,000 per fatality and $7,200 per injury, they estimated $1,612,000,000 as the societal cost of 1974 motor vehicle accidents in Pennsylvania. The cost of inspections was estimated at $118,925,000 including motorist time and travel cost (but not necessary or unnecessary repair costs). If in the absence of inspections 15.9% of all types of accidents in Pennsylvania would have been caused by vehicle defects (would not have taken place except for these defects), and if the inspection program was at least 46% effective in detecting potential defects and having them corrected and thus in preventing their accident-causing failure in the period before the next inspection, then the inspection program could be considered cost-effective.

The authors admitted that neither assumption was probable in Pennsylvania in 1975. However, they suggested that by not inspecting cars during their first two years and by changing to an annual inspection program the inspection program costs could be substantially reduced without greatly reducing program effectiveness, thus considerably increasing the cost-benefit ratio of the inspection program. They also suggested that rather small increments in costs for monitoring inspection stations more thoroughly could substantially increase program effectiveness in detecting outages of important safety components. In addition, they suggested that the substitution of a program to randomly inspect 12% of vehicles annually (5 minutes at a cost of $5.50) would be much cheaper than the current program and might be just as effective.

The cost-benefit speculation is interesting, but it is not well thought out and coherently presented. The main value of this report is the strong evidence for the poor effectiveness of the then-current Pennsylvania inspection program which was clearly far from cost-beneficial even if one disregards the additional costs of necessary and unnecessary repairs. And it seems likely that this finding is typical of the great majority of inspection states which use licensed private garages to conduct their inspections.

Comptroller General of the United States. Effectiveness of Vehicle Safety Inspections Neither Proven Nor Unproven: Report to the Congress. Washington: General Accounting Office, December 1977, 27pp.

This report briefly summarizes the history of federal involvement with periodic motor vehicle inspection since it was included as the first standard in the highway safety program standards issued in 1967. At that time 22 states and the District of Columbia had PMVI programs, and ten states added PMVI by 1969. Eleven other states had approved experimental programs, but by 1977 only 29 states still had PMVI and two had on-going experimental programs. In 1973 NHTSA under court order mandated the Vehicle-in-Use standards as required by Congress, which included pulling two wheels to check brakes, but still most PMVI states did not include even the pulling of one wheel in their inspection procedures. After Congress temporarily lifted NHTSA's sanctioning authority in 1976, motor vehicle safety inspection activities in the states generally declined.

The GAO found that the fundamental difficulty in trying to get the states to meet NHTSA's PMVI standards was the lack of evidence for the cost-effectiveness of PMVI programs. While NHTSA had established that some accidents are indeed caused or aggravated by vehicle defects, particularly poor brakes and tires, it had not followed through on planned research to determine the effectiveness of PMVI in reducing such accidents in relation to the cost and inconvenience of a PMVI program.

The GAO recommended that Congress reject DOT's recommendation that state compliance be made optional; require modified standards that permit more state program flexibility; and direct DOT to undertake priority research on the effectiveness of PMVI programs in reducing accidents.

Crain, W. Mark. Vehicle Safety Inspection Systems: How Effective?. Washington: American Enterprise Institute for Public Policy Research, 1980, 70 pp.

In this stimulating monograph Crain critically reviews the history of motor vehicle inspection activities in the American states and at NHTSA from an economic perspective. He points out that only about 6% of accidents may be definitely attributed to mechanical failure, and he questions how effective PMVI can be in reducing such accidents.

To study this issue he provides a regression analysis of 1965 and 1974 state accident data—deaths per registered vehicle, non-fatal injuries per 1000 miles traveled, and non-fatal accidents per 1000 miles traveled (why the fatality rate uses registered vehicles isn't clear). He looks at the effects on these rates of 5 inspection dichotomies: states with and without PMVI statewide, states with PMVI in at least one locality vs. all others, states with biannual PMVI vs. all others (with or without PMVI), the two states with state-operated stations vs. the 48 others, and states with random inspections vs. all others (with and without PMVI). He controls on eight other independent variables: population density, per capita fuel consumption, median family income, federal aid proportion of road mileage, 18-24 population percentage, license renewal eye and written test or not, and per capita alcohol consumption, and three levels of accident reporting requirement dollar thresholds. Together these variables explain about 75% of the variance in death rates, and 50-60% of the variance in non-fatal rates. He indicates that the regression results are significant at the 99.5% level. In general he found no statistically significant relationships between types of inspection operations and accident rates, although PMVI is almost significantly related positively (!) to death rates compared to non-PMVI states, and spot inspections are almost related significantly to death rates compared to PMVI states and no-inspection states combined.

Although some of Crain's inspection dichotomies are rather strange and he makes use of only a limited number of possibly relevant independent variables, the basic finding of no significant differences in accident rates in relation to type of inspection system seems reasonable. Since vehicle-related accidents are just a small proportion of a state's accidents it would be surprising to find significant changes in overall accident rates caused by PMVI. To really test the effect of PMVI on accidents one would need to look at differences in vehicle-related accidents among states, although accurate data of this sort would require much more thorough accident causation investigations in the states to be compared than the police are normally able to carry out.

Having shown that PMVI is not effective in reducing accidents, Crain discusses PMVI as primarily a benefit to the auto service industry. He provides data on vehicle inspection fees, station certification fees and requirements, and applications approved and denied, and he discusses the poor quality of state monitoring and the incentives private stations have to not conduct a thorough and honest inspection. He concludes that PMVI programs are essentially another example of government regulations supporting a special interest group more than the public. His discussion is interesting, but without data on differences in vehicle-related accidents in different states his conclusion that PMVI had no effect on accidents is not well-supported.

Eder, Leslie. Impact of Discontinuing Idaho's Periodic Motor Vehicle Inspection Program (A Before and After Outage Rate Study). Washington, NHTSA, Feb. 1980, 36 pp. (NHTSA Technical Report DOT HS-805 243).

Idaho had a mandatory PMVI program in effect from Jan 1, 1966, until June 30, 1976. To study changes in vehicle condition in relation to discontinuing the PMVI program, NHTSA sponsored inspection of vehicles in shopping centers and blocked-off city streets throughout the state, both in the fall of 1976 and again in the fall of 1978. NHTSA's mobile van was used for the free inspections, and vehicles were recruited by mass media publicity and on a drop-in basis.

Very high outage rates were found in both samples. For the 1976 sample these rates were: body (including components and headlight aim) 93.9%, brakes 15.4%, steering (including tires) 81.7%, suspension 1.6%, and power train 5.5%. For 1978 these rates were somewhat higher except for body components: body 91.6%, brakes 19.7%, steering 88.7%, suspension 7.7%, and power train 16.1%. The 1978 sample was slightly older (average 5.4 years) than the 1976 sample (average 4.7 years), but still the 1976 sample had slightly fewer outages in components by age of vehicle. This study provides some indication that PMVI contributes to improved vehicle condition (or at least that discontinuation of PMVI contributes to poorer vehicle condition). However, the number of vehicle outages seemed to be very high even in 1976, and the small changes found in 1978 do not suggest a large increase in accident potential with the discontinuation of the PMVI program.

Eder, Leslie E., Noel Bleich, and Mario Damiata. The NHTSA Trial Substitute Motor Vehicle Inspection Programs. Washington: NHTSA, July 1978, 66 pp. (NHTSA Technical Report DOT HS-803 535).

This document briefly summarizes the results of NHTSA-approved trial motor vehicle inspection programs in 11 states: California, Connecticut, Iowa, Maryland, Michigan, Nevada, North Dakota, Ohio, Tennessee, Washington, and Wisconsin. The authors conclude that none of these alternate state programs were an adequate substitute for a statewide PMVI program.

The most elaborate experiment was carried out for one year in California. There four levels of effort for random roadside inspections were carried out in 4 groups of counties. However, the planned comparison of baseline defect rates with experimental defect rates was not feasible because of various problems such as changes in the vehicle selection process. Nevertheless, a post-experimental inspection of vehicles which had not previously been inspected showed no significant difference in safety critical defect rates among the four groups of counties. This suggested that different levels of random enforcement did not have much carry-over effect in encouraging uninspected vehicle owners to improve their vehicle maintenance practices. Overall, the number of uninspected vehicles with at least one "safety critical" violation was about 20%. Michigan also used different inspection levels (25%, 10%, 5%) in different counties, but found no carryover effect of the different levels in making previously uninspected vehicles safer.

Another California experiment involved short-form and long-form inspections in different counties. The short-form inspection did not include lamps. In the post-experimental inspections, vehicles which had been long-form inspected in the previous year had fewer lamp outages (31.5%) than vehicles which had been short-form inspected (38.5%), and both groups of vehicles had fewer outages than vehicles which had not been inspected in the previous year (47.9%). Thus there was some evidence that an inspection contributes to improvement even in components which are not inspected.

Two states, Ohio and Tennessee, were able to compare local PMVI programs with random inspection programs elsewhere in the state. In Ohio in 1975 35.19% of the randomly inspected vehicles were defective compared to only 11.35% in PMVI Cincinnati. Also, in the accident data, 1.8% of the accident-involved vehicles outside Cincinnati had defects which caused the accident compared to only 1.3% of the Cincinnati vehicles. In Tennessee the comparison showed that PMVI Memphis and Chattanooga had fewer defective vehicles than non-PMVI Knoxville, but no accident data were presented.

Most of the trial state programs found that vehicles which were inspected were "safer" at a later inspection than vehicles which had not been inspected, but none were able to demonstrate that a program of randomly inspecting only some vehicles was as effective in improving the general condition of vehicles as a comprehensive PMVI program.

Fisher, Franklin G., Jr., Randolph Eidemiller, and Peter Biche. Vehicle-in-Use Safety Standards Study: Summary and Final Report (also 12 other volumes). Newport Beach, Cal.: Ultrasystems, August 1971, 28 pp. and 411 pp. (NHTSA Reports DOT HS-800 559, 560). [Also summarized in Franklin G. Fisher, Jr., and George Parker. "An In-Depth Look at the Safety Status of Vehicles on the United States Highway", Warrendale, Penn.: Society of Automotive Engineers, January 1973, 21 pp. (SAE Paper 730229)].

This was the first NHTSA-sponsored study to compare the safety condition of random samples of vehicles in different states. Outage data was obtained for 117 components from 500 vehicles at one diagnostic center in semi-annual PMVI Pennsylvania, from 507 vehicles at one diagnostic center in annual state-operated PMVI in New Jersey, from 442 vehicles at two city-operated inspection stations in annual PMVI

Washington, D.C., and from 1027 vehicles from six diagnostic centers in random-inspection California. Although there were some problems of data comparability across inspection centers, the results generally favored semi-annual PMVI. For the components tested in all four areas the overall outage rates were: Pennsylvania 5.93%, Washington 7.44%, New Jersey 8.93%, and California 10.70%. The same ordering was found when the comparison was limited to the 56 common components included in the standard inspection programs in each area, and also when the comparison was limited to 32 safety sensitive components.

In Washington vehicles coming for their annual inspections were considered an adequate representative sample. In California, Pennsylvania, and New Jersey it was desired to obtain vehicle samples which were representative of each state's vehicle profile for the 14 major make/model groups over the 1964–1970 model years. This was done by selecting samples from vehicle registration lists for the zip codes in the vicinity of the eight centers. Selected owners were contacted by mail with a return postcard and asked to participate in the free inspection. Nonrespondents were also contacted by telephone if their numbers were listed in the local telephone directories. Actual response rates were not given, but initial letters were mailed to 4,365 owners in California, to 3,333 owners in Pennsylvania, and to 5,468 owners in New Jersey. It was planned to supplement these selected samples with profile-fitting vehicles which came independently to buy the diagnostic center's services, but due to cooperation problems with center managers not many vehicles were obtained in this way. So the samples were further supplemented by use of newspaper advertising to recruit volunteers with the needed types of vehicles. Over one quarter of the California vehicles and 10–12% of the Pennsylvania and New Jersey vehicles were recruited in this way.

Prior to the main study a mini-experiment was conducted in California to compare three different methods of recruitment. For this experiment only owners of Impalas, Galaxies, and Beetles were involved. For Group I enough letters were sent with return cards to obtain 63 inspected vehicles. How many letters this required is not indicated, but the initial mailing was 113. For Group II exactly 63 letters were sent and repeated contacts were made with offers of increasing inducements to try to obtain participation. The final response rate was 32 of the 63, or 50.8%. Group III consisted of 63 vehicles of the appropriate types which came to the diagnostic centers independently. In the comparisons of the three groups on outage rates for the 117 inspected components no more significant differences were found than would be expected by chance. The authors concluded that drop-in samples selected to fit a general vehicle profile should be adequately representative vehicle samples without having to go through a stratified selection process from state registration lists. However, the relatively low response rates in Groups I and II (with which Group III was compared) and the small numbers of vehicles in each group leave this conclusion open to considerable doubt.

Fisher, Franklin G., Jr., Peter Biche, and Randolph Eidemiller. Status of Vehicles-in-Use Study: Summary Final Report and Final Contract Report. Newport Beach, Cal.: Ultrasystems, July 1973, 33 pp. and 239 pp. (NHTSA Reports DOT HS-800 894, 898).

This second NHTSA-sponsored study by Ultrasystems checked the safety components of vehicle samples in one area each of Alabama, Arizona, Connecticut, Missouri, and Washington, and in four areas of Illinois. Existing diagnostic inspection facilities were used except in Connecticut where NHTSA's mobile inspection van was used. The tested 1964–1972 vehicles came from drop-ins and volunteers recruited through the mass media plus some recruited by direct mail using Polk registration data to attempt to ensure representative samples of 20 make/model groups. Except in Connecticut 128 discrete assessments were made of 111 components. Compared to the first study (Fisher et al. 1971), more objective criteria were developed to improve consistency across diagnostic centers. About 1000 vehicles were tested in Illinois, and about 500 were tested in each of the other locations.

The basic purpose of this study was to compare the condition of vehicles in different topographic, climatic, and rural/urban areas. However, the initial plan of using Missoula, Montana, to represent mountainous terrain and Mobile, Alabama, to represent a hot coastal area did not work out because neither city had a satisfactory diagnostic inspection facility. Thus Spokane and Birmingham were substituted. The four centers in Illinois were selected to represent different degrees of urbanicity.

This study also provided another opportunity to compare vehicle condition in PMVI and non-PMVI states. This time the one PMVI state, Missouri, had higher overall outage rates than any of the five non-PMVI states. The rates on 97 common tested components were: Connecticut 9.30%, Alabama 10.38%, Illinois 10.52%, Arizona 12.86%, Washington 14.62%, and Missouri 15.21%. Because of the somewhat subjective judgments involved for many inspection items and the potential for varying interpretations among the different centers, a further comparison was made using just 16 objective inspection items (nine of them involving lights). For these items the overall outage rates were lower, but the state ordering was fairly similar: Connecticut 6.00%, Arizona 6.38%, Illinois 6.83%, Washington 7.05%, Missouri 7.71%, and Alabama 7.97%. For 41 common safety sensitive components the overall outage rates were Connecticut 6.73%, Alabama 7.54%, Illinois 7.83%, Arizona 10.91%, Missouri 12.12%, and Washington 13.35%. Also of interest were general tables showing that the older the vehicle and also the more stop-and-go driving reported by the owner the higher the outage rates.

Since very similar procedures had been used in Ultrasystem's previous study in California, New Jersey, Pennsylvania, and Washington, D.C., an Equivalent Component Index of 91 items was used to compare all ten jurisdictions. For this comparison the second set of data was restricted to the same 14 make/model groups and the same 1964-1970 model years as the first set of data. The overall outage rates were Washington, D.C. 5.80%, Pennsylvania 6.26%, New Jersey 9.34%, Connecticut 9.72%, California 11.25%, Alabama 11.35%, Illinois 12.00%, Arizona 14.67%, Missouri 17.18%, and Washington state 17.25% (but 11 of the common components were missing in the D.C. data, and seven were missing in Connecticut). Thus the three fairly rigorous PMVI jurisdictions looked very good, but Missouri with a rather non-rigorous PMVI program was very near the bottom. However, since the comparison vehicles in the second data set were two years older when inspected than the vehicles in the first data set when they were inspected, it is hard to know whether these comparisons between the two data sets are truly meaningful. Presumably these comparisons would have been more meaningful if they had been controlled on age of vehicle at the time of inspection.

Garrett, John W. and Kenneth J. Tharp. Development of Improved Methods for Reduction of Traffic Accidents. Washington: Highway Research Board, 1969, 163 pp. (NCHRP Report 79).

This report is primarily concerned with the use of existing and improved accident records for understanding accident causation and thus for the development of accident reduction countermeasures. However, it also discusses some useful non-accident data such as inspection records. As an example of the use of these data it describes a study in semi-annual PMVI Virginia of accident frequency in relation to time since inspection. It found no increase in the likelihood of a vehicle being in an accident as time passed since its inspection, although the number of vehicles sampled seemed rather small for expecting such a relationship to show up in the total accident data.

Hatch, William, James De Armon, and Cheryl Louie. State Inspection Program Evaluation and Data Analysis: Vol. I, Summary Report; Vol. II, Technical Report. Silver Spring, Md.: Automated Sciences Group, Inc., December 1976, 17 pp., 75 pp. (NHTSA Reports DOT HS 802 149, 150).

This report describes the results of a vehicle condition survey carried out in six states in 1972–73, using a mobile van set up in parking lots in 5 cities in each state. From 1,569 to 1,804 vehicles were inspected in each state. It was hoped to obtain a representative sample of vehicles in each state, but participation was voluntary, and there turned out to be substantial differences among the states in such factors as vehicle age and owner income.

A total of 67 vehicle components were inspected. Of these, 65 were regularly inspected in Pennsylvania's semi-annual PMVI system, 51 were regularly inspected in Missouri's annual PMVI system, 33 were regularly inspected in Texas' annual PMVI system, 63 were regularly inspected in Maryland's change-of-ownership inspection system, and 34 were regularly inspected in California's state police random roadside inspection system. The sixth state, Illinois, had no inspection program. In Maryland, 37.5% of the vehicles had been previous inspected, but the comparable figure for California was not given.

For the six states combined, by far the highest outage component was headlight aim (79%). Other components with an outage greater than 11% were windshield washers (27%), brake fluid level (18%), side marker lamps or lenses (16%), backup lamp or lens (16%), and power steering fluid level (15%). Rear brake lining thickness, front brake lining thickness, rear tire tread depth, and front tire tread depth each had 7% outage rates.

The major analysis compared outage rates for each of 34 components in states in which that component was supposed to be inspected and in states in which that component was not supposed to be inspected . Apparently all the inspected vehicles in California and Maryland were included in the first category if the component was on the states' inspection lists, whether or not the vehicle had actually been inspected. This analysis found that 16 of the 34 components had significantly lower outage rates in states in which they were supposed to be inspected. When the data were further analyzed by regression techniques to control for 20 possible explanatory variables (vehicle age, vehicle use, income, etc.) a slightly different set of 16 components had significantly lower outage rates in the inspection states, while 6 components had significantly higher outage rates in the inspection states. Most of the components which were significantly better in the inspection states had to do with lighting and suspensions, but three brake components were also significantly better in these states. On the other hand, 3 of the 4 tire components were significantly worse in the inspection states. A multiple regression analysis with four brake components as dependent variables found the outage rates for one of them (front) lining thickness) to be significantly related to time since inspection in gross categories (six months, one year, two years, etc.).

Since Pennsylvania was the state with nominally the most extensive inspection program (including pulling both a front and a rear wheel for brake inspection), data were also presented comparing Pennsylvania outage rates with each of the other states on 28 components. In the comparison with Missouri, Pennsylvania had 12 components with significantly lower outage rates, while Missouri had 6 components with significantly lower outage rates. For Illinois, this ratio was 14 to 5; for California it was 15 to 4; for Maryland it was 13 to 3; and for Texas it was 22 to 3. Pennsylvania had significantly lower outage rates for rear brake lining thickness than each of the other states. Still, it is interesting that no-inspection Illinois had lower outage rates on five components than did Pennsylvania, including both wheel cylinders and tire tread depth.

This study provides fairly strong evidence that vehicle components in states where they are inspected tend to be in better condition than in states where they are not inspected, but this finding is not true of all inspected components—suggesting that the quality of inspection programs for some components is not very high.

Innes, Joseph J. and Leslie E. Eder. Motor Vehicle Diagnostic Inspection Demonstration Program—Summary Report. Washington: Department of Transportation, October 1977, 95 pp. (NHTSA Report DOT HS-802 760).

This report summarizes the results of a large-scale comprehensive safety and emissions inspection program carried out in 1975 and 1976 in Alabama, Arizona, Puerto Rico, Tennessee, and Washington, D.C. Over 66,000 vehicles were inspected and reinspected 125,000 times. Owners of 1968–73 passenger cars were recruited to participate voluntarily in the program. They were provided a free diagnostic inspection and a free reinspection if they had repairs made, and then a new inspection cycle was available six months later. Three of the locations were PMVI jurisdictions, but the relationship of this program to the mandatory inspection programs is not indicated.

Almost 75% of the vehicles failed the initial inspection with an average of 2.9 defects in the rejected vehicles. Interestingly, the failure rates were much lower in the PMVI jurisdictions Tennessee (47.4%) and Washington (48.0%) than in non-PMVI Alabama (93.2%) and Arizona (91.9%). However, Puerto Rico, despite its PMVI program, had a 90.4% failure rate. Only about one third of the vehicles returned for a second cycle inspection, but the second cycle failure rate was again a quite high 60.7% overall. The report didn't say how many of these returnees had had repairs made after the first inspection. Again Tennessee and Washington had much lower failure rates than the other three jurisdictions. Brake problems were the most prevalent type of defect found (34.9%) in the initial inspections, followed by emissions problems, alignment problems, and tires and wheels problems. The average contractor cost for an inspection ranged from $9.29 in Puerto Rico to $27.97 in Washington, and the average time ranged from 20 minutes in Puerto Rico to 29 minutes in Tennessee.

As an experiment, each location had a control sample which was given rather minimal pass-fail information about the inspected components and a treatment sample which was given more complete information. Of course for many components such as lights this made no difference, but for complex systems such as brakes or emissions the more complete diagnostic information resulted in better quality repairs, lower costs, or both—at least for the half of the failed vehicles which returned for reinspection with their repair bills.

The average indicated repair cost was $57.25. About one-half of the repairs were made at independent garages, one-sixth at chains, three-tenths at car dealers, and 4% were made by the owners themselves. Overall 27.2% of the inspected and repaired vehicles failed again at the reinspection with insignificant differences between the treatment and control samples. However, the reinspection failure rates in the first cycle varied widely, from about 2% in Washington, to about 10% in Tennessee, to about 14% in

Puerto Rico, to about 33% in Arizona, to about 50% in Alabama! Major types of reinspection failure were emissions (22.3%), lighting (18.1%), alignment (14.0%), and brakes (11.0%).

The results of this demonstration program suggest that PMVI does have an effect in improving the general condition of vehicles and perhaps also in improving the quality of repairs carried out by the automotive repair industry. Whether this beneficial effect is sufficient to be cost-effective in terms of accident reduction is not discussed.

Jackson, Barry, Peter D. Loeb, and Karen A. Franck. Comprehensive Analysis of the New Jersey Motor Vehicle Inspection System. Newark: New Jersey Institute of Technology, August 1982, 96 pp. [See also Loeb and Gilad 1984.]

First the present New Jersey inspection system is briefly described. In 1981 the inspection fee of $2.50 almost covered the operational costs of $14,514,474. A total of 124 safety items are inspected, and engine emissions are tested. The most common safety failures involve headlamps and tires. A literature review on PMVI effectiveness mentions McCutcheon and Sherman (1968), Hatch et al. (1976), the preliminary Indiana accident causation study results, five cross-state studies of general accident rates, the Huntsville study of inspections and accidents (Schroer and Peyton 1977), and the reported changes in defect-related accidents in Texas and Nebraska after the introduction of PMVI.

The major new data reported in this study involved a time-series regression analysis of New Jersey fatalities, injuries, total accidents, and death rates per 100,000,000 miles traveled from 1929 through 1979. As independent variables the tested models included annual data on maximum speed limit, gas consumption, licenses revoked for drunk driving, population, per capita income, vehicle registrations, licensed drivers, vehicle miles traveled, number of inspections per year, a GNP price deflator, and dummy variables for the years of the Great Depression and for the years of World War II. Of course the key variable was inspection (1938–1979) or not (1929–1937). Also year was used as a proxy for technological change over time.

New Jersey fatality data show 1,305 traffic deaths for 1937, the fourth largest number in New Jersey history despite the tremendous increases in miles traveled since then. (The three highest years were 1971, 1972, and 1973.) In 1938, the first year of inspection, this number dropped 31% to 905 (a decrease of 399 fatalities). Using various combinations of independent variables the resulting models were able to explain 91.6-93.6% of the variance in fatalities over these years. Controlling on the other variables, the dummy variable for PMVI or not was associated with a reduction of 314–404 fatalities, so the authors conservatively estimate that inspection has saved at least 314 lives annually in New Jersey.

Strangely, however, when the same models were applied to the injury data, the results were not significant. These results are not presented in the report, but the authors mention that some of the models even found a positive association of injuries with inspection. On the other hand, the results using all accidents as the dependent variable were again highly significant—with various models explaining 93.7-94.6% of the variance and with estimates of 24,343–47,199 fewer accidents each year as a result of inspections (their conservative choice is 37,949).

Also presented is another multi-state regression analysis using 1979 fatality and injury data from 46 states and the District of Columbia. Seventeen independent variables were used in the analysis, including population density, per capita income, highway mileage, precipitation, etc., and of course PMVI or not. Only two models are presented, but they indicate a reduction of 140–150 fatalities in the states having PMVI programs. These two models explained 98.5% and 98.4% of the variance in fatality rates. However, the authors mentioned that a few of the models resulted in (nonsignificant) positive associations of fatalities with PMVI. They also present two models run with state injury data which show significant reductions of 2.70 injuries "per capita" [per 1,000 population??] and 34.71 injuries per 100,000,000 miles traveled.

Finally they discuss the relationship of these findings to the cost-effectiveness of PMVI in New Jersey. They use a study by Hartunian, Smart, and Thompson in 1980 to estimate fatality and injury costs and a 1976 NHTSA study to estimate property damage accident costs (all inflated to 1981 dollars). Thus each fatality forestalled is valued at $271,454; each injury forestalled is valued at $2,883; and each property damage only accident forestalled is valued at $877. They estimate the 1981 benefits from forestalling 314 fatalities as $85,236,556 and from avoiding 23,908 property damage only accidents (63% of the 37,949 reduction in accidents shown by the time-series analysis) as $20,967,202. Since the time-series analysis did not show a significant reduction in injuries, they substitute an estimate 17,056 forestalled injuries based on the cross-state regression analysis. This adds $49,172,488 in benefits and makes a total estimated benefit of PMVI in 1981 of $155,376,206. They point out that this number is conservative because it doesn't include some difficult-to-value aspects of accident costs. They also present two other total benefit figures based on National Safety Council and NHTSA studies in 1975. In 1981 dollars these benefit totals were even higher, $202,436,343 and $265,139,254 respectively.

In contrast to these large numbers, they present $15,114,474 as the cost of inspections; $50,822,203 as the opportunity value of motorist driving and wait time; and $17,609,911 as the vehicle driving costs (average of 20 miles at 18 cents per mile for nearly 5,000,000 inspections). Thus the total costs are estimated at $83,546,588. They do not include any repair costs because they say there is no consensus as to whether inspection increases or decreases repair costs over time (since timely repairs should increase service life). In sum, they find a benefit-to-cost ratio of at least 1.85 to 1 for PMVI in New Jersey.

The major problem with this interesting study is that it shows too large an effect of PMVI to be believable. When accident investigation studies show such a small percentage of accidents as being caused by vehicle defects, it is just not credible that New Jersey's quick and non-comprehensive safety inspections are saving 314 lives per year. The time-series analysis suffers from only having nine baseline data points before PMVI began, and year as an independent variable does not sufficiently control for all important changes over time. The regression methods seem statistically sound (although somewhat out-of-date), and the authors did try out many different models and data transformations, but realistically one must conclude that there must be some other significant variables which were not included in the analysis which co-vary with PMVI, or else some errors were made in the way the data were input and analyzed. Also it seems quite inconsistent to find no significant reductions in injuries from the time-series analysis and then to substitute an inferred injury reduction from the multi-state analysis in the determination of benefits.

If a more credible figure were used for the current annual reduction in fatalities as a result of PMVI (even 50 seems optimistic), and if no injury reductions were assumed, then PMVI in New Jersey would not be cost-effective even based on the high NHTSA accident cost figures. Until this type of time-series analysis is replicated in other states and similar large reductions are found, and until comparative accident investigation studies in PMVI and non-PMVI states demonstrate that vehicle defects really cause such large proportions of accidents, the results of this study must be considered highly doubtful. It should be remembered that McMinn reported in 1974 (Bentley and Cooper 1977) that there was no consistent relationship between vehicle-defect accidents and time since inspection in 200,000 New Jersey accidents.

Little, Joseph W. The Fallacy of Evaluating Periodic Motor Vehicle Inspection by Death Rates. Ann Arbor: Highway Safety Research Institute, 1968, 19 pp. [Also as "Uncertainties in Evaluating Periodic Motor Inspection by Death Rates", Accident Analysis and Prevention 2: 301–313 (March 1971)].

The author argues that, if the regimen of traditional periodic vehicle inspection programs lowers death rates in inspecting states, the following arguments should be supportable by empirical data:

1. Some of the mechanical deficiencies which could cause fatal accidents are detected by periodic inspections, and as a result the number of such defects in the population is reduced.

2. The number of fatal crashes is consequently reduced.

3. In the years immediately following institution of a periodic inspection program, the traffic death rate among residents of the state would be lower than indicated by an extrapolation of the trend of death rates during previous years.

4. By contrast, a state which did not begin periodic inspections would not show the same improvement.

Using six states which introduced periodic inspection programs after World War II and had at least six years of operation at the time this paper was written (1968), two other groups of states were defined and compared with these: six states which had long had vehicle inspection programs and six which had never had such programs. Comparison states were selected for the test states judgmentally, and the fatality rate change was computed for each comparison. Test states (those which had recently introduced motor vehicle inspection) showed an increase of 10.2% in fatality rates in the six-year period following introduction, inspecting control states 4.8%, noninspecting control states, 4.6%, and the U.S. as a whole 1.9%.

Little notes that no sensible person is likely to argue that inspecting cars makes them more susceptible to fatal accidents. On the other hand, if initiating inspections can't contribute to lowering the death rate within states, then inspections surely can't account for the differences among states. Little believes that something more fundamental than inspections is at work in producing and changing death rates, and he suggests that this may mask the relatively small effect of inspection on fatalities.

Little did not use a time series analysis technique to show changes in the individual states, or in the comparisons. As a result, it is possible that his premise number 3 (that the state which has begun inspections has a lower death rate than it would have had by extrapolation) is not proven or disproven. For example, a state could have had a continuing increase in fatality rate for six years, introduced inspection, and had a level fatality rate for the six years thereafter. The mean of the prior six years would be below the mean of the post six years, but the introduction of inspection would be associated with the leveling.

Loeb, Peter D. and Benjamin Gilad. "The Efficacy and Cost-Effectiveness of Vehicle Inspection: A State Specific Analysis Using Time Series Data", Journal of Transport Economics and Policy 18 (2): 145-164 (May 1984). [See also Jackson et al. 1982.]

This article presents the results of the New Jersey time series analysis which is reported more fully in the report by Jackson, Loeb and Franck (1982). Surprisingly, the numbers in the regression tables in this article are slightly changed, and they now estimate an annual fatality reduction of 304 and an annual accident reduction of 37,910 as a result of PMVI in New Jersey. They do not discuss in this article the cross-state analysis which was in the report, and in the cost-benefit analysis they leave out any benefits for injury reduction since the time series analysis showed none that could be attributed to PMVI. Thus the three possible benefit estimates which they present are $79,507,442; $103,467,670; and $168,469,558. Comparing these to the total PMVI cost estimate of $83,546,528, the cost-benefit ratio of PMVI in New Jersey comes out as 0.95:1, 1.24:1, or 2.02:1. They believe 1.24:1 is the most credible ratio.

Comments concerning the credibility of these findings are included in the longer review of the full NJIT report.

McCutcheon, Robert W. and Harold W. Sherman. The Influence of Periodic Motor Vehicle Inspection on Mechanical Condition. Ann Arbor: Highway Safety Research Institute, July 1968, 68 pp. [Also in Journal of Safety Research 1(4): 184-193 (December 1969)].

This was one of the first studies to look at the effect of PMVI on the mechanical condition of cars. Inspection results from the tri-annual PMVI Memphis, semi-annual PMVI Cincinnati, and annual PMVI Washington, D.C., were compared with the findings from a police checklane of 591 representative vehicles in non-PMVI Ann Arbor. There were over 1200 vehicles in the comparison from each of the PMVI locations. Eighteen components were checked in Ann Arbor, Cincinnati, and Washington, and 14 in Memphis.

The results indicated a direct relationship between the frequency of inspection and the safety of vehicles in a city. The rates of vehicles with at least one defect were 93.9% in Ann Arbor, 42.6% in Washington, 34.1% in Cincinnati, and 12.4% in Memphis. Similarly the number of defects per rejected vehicle followed the same pattern. These results in favor of PMVI are particularly impressive because Ann Arbor residents tended to be higher in socioeconomic status than the residents of the other cities, and thus might have been expected to be above average in attempting to keep their vehicles in safe condition.

All of the PMVI sites in this experiment were government-operated. While the cars inspected in these jurisdictions were not volunteered, the owners did know that they were going to be inspected, and they may have prepared their vehicles accordingly. No attempt was made to correct for this possibly biasing factor.

McDonald, Stephen T. and Robert A. Romberg. Tri-Level Study, Modification Task 2, Final Report on Driver/Vehicle Characteristics Related to Vehicle Condition and Causation and an Assessment of Indiana PMVI Effectiveness to Reduce the Frequency and Severity of Accidents Caused by Vehicular-Related Malfunctions/Degradations. Bloomington: Indiana University Institute for Research on Public Safety, June 1977, 74 pp. (NHTSA Report DOT HS 805 095).

An analysis of the condition of 54 components on 671 vehicles involved in 420 accidents studied in-depth showed that 52 vehicles (7.7%) had at least one defective component which definitely or probably caused the accident. Older vehicles (18.4% for those over nine years old), convertibles (17.6%), vans (22.0%), pickups (14.0%), and vehicles with drivers under 20 (14.7%) were more likely to have accident-causing defects.

In these vehicles 131 defective components were found which definitely, probably, or possibly caused the accident or increased its severity. These included 57 components which were not mandatorily inspected in Indiana's own motor vehicle inspection program (16 related to brakes, 20 to tires, 12 related to lighting and vision, and 9 others). Of the 74 components which should have been inspected, 16 (21.6%) were judged to have been defective at the time of inspection, 11 (14.9%) were judged to have been adequate at the time of inspection, and for 47 (63.5%) a judgment for the time of inspection could not be made. The presumed defective items which passed inspection included 3 brake components, 4 tires and wheels components, 8 steering system components, and 1 suspension component.

An analysis of over 1,600 PMVI-inspected defective components (33 component types) on 562 vehicles (not only accident-causing defects) found no relationship between the number of defective components on a vehicle and its mileage since inspection. Of 568 gradually deteriorating components (windshield wipers, tie rod ends, control arms, tires—17 components in all) 28.9% were judged to have been defective at the time of inspection.

Of course this analysis provides no information on how many additional accidents there might have been in Monroe County without the Indiana inspection program. But it does demonstrate that such an annual inspection program cannot be expected to completely eliminate accident-causing vehicle defects, because a large share of accident-causing defects are not included in the inspection guidelines, and because many of the accident causing defects are of a sudden failure type which even a very efficient inspection program could not prevent. It also demonstrates that many accident-causing defects which should have been found and corrected in the Indiana inspection program were able to pass inspection, a situation which is probably true of many state inspection programs.

McMinn, Robert W. "Periodic Motor Vehicle Inspection," SAE-Australasia 34(5): 192–199 (Sept.-Oct. 1974).

From his experience as Deputy Director of the New Jersey Department of Motor Vehicles, McMinn discusses some of the problems in operating a cost-effective PMVI program. The state inspection lanes in New Jersey were operating on the basis of 90 seconds per vehicle, with 6 inspectors per lane. However, he felt that the inspection process paid insufficient attention to the critical safety items, and included too many other items. On the other hand, he suggested that, given the small proportion of accidents which are caused by vehicle defects, New Jersey might be spending too much of its safety budget on PMVI.

He also made reference to a random inspection study of 20,000 vehicles in New Jersey, using a mobile inspection van. This study found that 35% of the vehicles sampled 4 months after their regular inspection had one or more defects, and this percent increased very little for vehicles sampled from five to twelve months after their regular inspection. Of vehicles sampled within one month of their regular inspection, 23% had at least one defect.

McMinn also discussed the potential value of built-in defect indicators in encouraging timely repairs without inspection. He referenced the brake warning light, the "noise-maker" incorporated into the front disk brake system of the Oldsmobile, and an Electro-Sensor Panel on some Toyotas (with lights which monitor 11 functions—4 lighting, 4 fluid level, and 3 brake variables).

Milne, James A., Charles R. Cantwell, and William Meroney. State PMVI Program Evaluation. Radnor, Penn.: The Chilton Company, August 1978, 211 pp. (NHTSA Report DOT/HS 804 127).

This is a report concerning the trial implementation and improvement of inspection program evaluation procedures recommended by a previous NHTSA contractor (Bentley and Heldt 1977). Administrative evaluations were carried out at 90 private stations in four areas of New Hampshire and at 85 private stations in three areas of Virginia. Both states had semi-annual PMVI programs. Compliance rates were determined for ten items relating to the facilities, ten items relating to required equipment, and two items relating to inspection stickers and books. In Virginia the overall compliance rate was 94.0%, while in New Hampshire it was only 78.4%. For the inspection stickers and books, compliance was 97.9% in Virginia, while it was only 54.5% in New Hampshire. Only small differences were found in either state in relation to type of station (garage, dealer, etc.).

One of the facilities items related to the qualifications of an inspection mechanic at each station. He was asked about state standards for brakeshoe lining thickness and four similar questions. The station was considered in compliance on this item if the mechanic answered three of the five questions correctly. However, only 45.9% of the inspection mechanics in Virginia and 24.4% in New Hampshire were able to do this. In New Hampshire only one mechanic answered all five questions correctly, while 15 missed all five.

The authors concluded that in general the administrative evaluation procedures were adequate, but that improvements were needed in the rating forms, in the procedures for selecting the station samples, and in the methods for calculating sampling errors.

A second tested evaluation procedure involved covert investigations at about 30 stations in each state. Fourteen inspection tests were checked in Virginia, and 15 were checked in New Hampshire. The overall compliance rates were 78.6% in Virginia and 57.4% in New Hampshire. In New Hampshire alignment was not inspected at any station, and wheel bearings were inspected at only one station. While tires were inspected at 29 New Hampshire stations, not one failed the two obviously defective tires on the inspection vehicle. Both New Hampshire and Virginia required a wheel pull, but eight stations in New Hampshire and six stations in Virginia did not pull the wheel to check the brake condition.

The authors found the covert evaluation procedures generally practicable, but they recommended expanding the data form beyond simply yes-no checking and improving the sample selection and sampling error calculation procedures.

A third evaluation effort involved a thorough inspection of vehicle condition in samples of about 900 pre-1976 passenger cars in each of four states. In addition to the wheel-pull states of New Hampshire and Virginia, these included the semi-annual PMVI state of Maine and non-PMVI Maryland (which does require a wheel-pull inspection with change of ownership). Some 64 components were inspected for compliance with both the particular state's and the federal Vehicle-in-Use standards. Police assistance was not available in selecting vehicles, so the sampled vehicles had to be recruited voluntarily. Although the NHTSA mobile inspection van was available, most inspections were conducted in mass merchandisers' facilities (K-Mart, etc.) at shopping centers. The authors suggested that random police selection would improve the samples, that the data forms be improved, and that a driver questionnaire be included. They also questioned the usefulness of the Bentley and Heldt recommended Measure of Effectiveness (MOE) score which relates the failure rate for a component to the time since it was previously inspected.

Comparison of the data on brake condition showed a total brake assembly failure rate of 15.6% in New Hampshire, 18.1% in Maine, 19.5% in Virginia, and 13.0% in Maryland. These data suggest that wheel-pull PMVI as practiced in New Hampshire and Virginia does not significantly improve brake condition, although given the voluntary and not necessarily representative samples of vehicles no definite conclusions are possible. In all four states at least one defect was found in at least 60% of the inspected vehicles, with more defects in older and higher mileage vehicles. The highest failure rates were for lights and signals. Defective tires were found on at least 10% of the vehicles in each state. Overall no significant differences in defect rates were found in any of the states in relation to time since the previous inspection, although there was a slight time relationship for tire defects.

As a final task the report discussed various types of experiments which might be used to measure the effectiveness of PMVI programs. It concluded that the only practicable approach is the kind of before-after experiment which was then underway in Idaho which had terminated its PMVI program in 1976. Suggestions were offered for improving the Idaho before-after study.

Overall the results found in these four states provide little evidence that PMVI, as actually practiced, is effective in improving safety critical components of vehicles in use, even when wheel-pull is included among the required inspection procedures.

National Highway Traffic Safety Administration, Office of State Vehicle Programs. Costs and Benefits of Motor Vehicle Inspection. WAshington: January 1975, NHTSA Technical Note DOT HS-801-614, 34 pp.

This is a rather speculative attempt to estimate the costs and benefits of a nationwide annual motor vehicle inspection program. It starts with a 1972 federal study on the societal costs of motor vehicle accidents, and it estimated a 1973 societal loss of $25.54 billion from non-pedestrian and non-motorcycle accidents. Then it used early data from the Indiana tri-level accident causation study which found vehicle defects definitely causative in 6.0% and probably causative in a further 9.9% of the accidents studied. Thus 1973 societal losses from accidents caused by vehicle defects were estimated to be between $1.6 and $4.3 billion.

On the inspection costs side an AVCO report is used to estimate average costs of a minimum safety inspection (10 minutes) at $2.42; a medium safety inspection (12 minutes) at $3.56; and a maximum safety inspection (24 minutes—including two wheel pulls) at $6.12. Thus for 101 million passenger vehicles national costs would range from $244 million to $618 million depending on the extent of the inspection.

Although both the accident cost data and the inspection cost data are open to question, the differences are so large that it seems probable that accidents caused by vehicle defects do cost society more than a national inspection system would, even if motorists' time and driving costs were added to the inspection program cost. In fact, since the estimates of vehicle-related accidents came from a state which had a minimal mandatory inspection program in place, it seems likely that without inspections the national cost of vehicle-related accidents might be even higher.

However, the crucial issue in the cost-benefit analysis is how effective an inspection program might be in reducing accidents caused by vehicle defects. In support of a substantial effectiveness rate two analyses of state police accident data are reported. From 1968 to 1972 Nebraska reported a drop from 6.1% to 2.6% in defective vehicle involvement in all rural accidents. Similarly, from 1951 to 1971 Texas reported a drop from 12% to 4% in defective vehicle involvement in accidents. If these 57% and 67% effectiveness rates as a result of the introduction of PMVI were accurate, then a periodic motor vehicle inspection program would seem clearly cost-effective. However, one wonders if there might not be some other factors, such as changes in accident reporting procedures, which might account for these dramatic reductions in vehicle defects in accidents.

Using the cost estimates presented above, a minimum inspection program would only have to be 6% to 15% effective in eliminating vehicle-related accidents to be cost-effective, and a maximum inspection program would only have to be 14% to 39% effective to be cost-effective. However, despite the Nebraska and Texas reports, there are real questions as to whether the typical state inspection program is even 6% effective in reducing vehicle-related accidents. And there are other costs of an inspection program which should be taken into account—the costs of motorists' time and driving and the costs of unnecessary repairs caused by improper inspections. Presumably the costs of necessary repairs should not be charged to the program because the motorist would have to make them sometime anyhow. In fact, this report pointed out that another difficult-to-cost benefit of an inspection program is the saving in longer vehicle life from forced preventive maintenance. It quotes a Swedish report that the average service life of Swedish vehicles went from 10.4 to 14.2 years after the implementation of a national inspection program. Of course these sorts of savings imply a more thorough diagnostic inspection than is typical of inspection programs currently in use in the American states, only a few of which even pull one wheel for a brake inspection.

New York State Department of Motor Vehicles. PMVI in New York State? Yes. Albany: April 1982, 6 pp.

This pamphlet briefly states the case for continuing and improving the PMVI program in New York. It references the Indiana tri-level accident causation study as evidence that vehicle defects do cause accidents; the Idaho before and after inspection study as evidence than an annual inspection program leads to safer vehicles; and the New Jersey evaluation study as evidence that an inspection program can reduce accidents. No new data on the subject are included.

The pamphlet states that a properly conducted inspection in New York should take about 30 minutes. However, the maximum inspection fee is only $6.00 (raised from $3.00 in 1980). The inconsistency in these statements is not discussed, but it points up a common problem with most PMVI programs which make use of private inspection stations but do not permit them to charge a fee high enough to cover the costs of conducting the inspection correctly. The pamphlet does mention that 21.2% of the inspected vehicles failed at least one aspect of the inspection in 1980–81.

O'Day, James and William L. Carlson. "Detection of Defects in Accidents", Warrendale, Penn.: Society of Automotive Engineers, 1973, 5 pp. (SAE Paper 730584).

This paper discusses a number of sources of information on vehicle defects in accidents—the early tri-level data from Indiana, the Sachs study from the Highway Safety Foundation (9.5% with some vehicle defect), the 20 MVMA-sponsored multi-disciplinary accident investigation (MDAI) programs, the Ohio Turnpike, the Pennsylvania Turnpike, the Indiana Turnpike, and the 1970 Texas state accident files. They give 18% as the proportion of definite, probable, or possible defect-related accidents in Indiana, but their analysis of the MDAI files found only 4.6% of the accident-involved passenger cars to have a defect, and only half of these were considered causal in the accident. However, the MDAI studies concentrated on vehicles less than four years old, so their samples were not very representative. Data from the three turnpike authorities for 1966–70 showed vehicle defects as 7% in Pennsylvania accidents, 17% in Ohio accidents, and 12% in Indiana accidents, but it's not clear if these were all considered causal. For Texas only about 3% of the accident-involved vehicles had defects noted on the accident forms. Probably these differences have more to do with different accident reporting forms and procedures than with real differences among these states.

The authors point out that because of its infrequency (once or twice a year) PMVI can not expect to make great changes in the rates of degraded or defective components. They go on to point out the value of some of the built-in indicators of vehicle problems which were then in use—the fuel gage, the oil pressure and generator lights, tire wear bars, etc. They suggested that a major challenge to automotive engineering is to design relatively cheap defect indicators which would encourage drivers to make needed repairs without waiting for a state-mandated inspection.

O'Day, James and Jay L. Creswell, Jr. "Periodic Motor Vehicle Inspection and Predictive Analytical Modeling", HSRI Research 3: 1–8 (October 1968).

The authors briefly discuss the issues involved in evaluating the effectiveness of a PMVI system. They mention that six studies of general accident data (mostly fatal accidents) seemed to support the effectiveness of PMVI in reducing accidents, but they point out that there are so many factors affecting the variation in each state's fatality rate that the correlations presented in these studies "do not constitute an adequate explanation of the nature or existence of a causal relationship between PMVI and accident rates."

Then they present a useful analytical model of the various factors, including the level of inspection, which influences the mechanical condition of cars and thus their safety. Inspections can improve mechanical condition by shortening the length of time between the failure of a component and its discovery and correction. But the potential effect of inspection varies greatly among different types of components. For a fairly long-lived component such as a taillamp, whose failure is easily observed and which is usually fixed voluntarily within a fairly short period, a mandatory inspection program is not likely to have much effect. On the other hand, headlight aim may tend to get out of tolerance fairly quickly and go undetected and uncorrected for a long time, so a mandatory inspection program would have a much greater potential effect on components of this sort. Indeed, they conducted an experimental observation study of taillamp outages in 5 PMVI cities and 3 non-PMVI cities, and found no significant differences between the two groups of cities. On the other hand, a comparison of steering wheel play in non-PMVI Ann Arbor and three PMVI cities (McCutcheon and Sherman 1968) showed a much higher defect rate in Ann Arbor.

They point out that, while in general the more frequent the inspection the more effect it can have on components which fail quickly and are repaired slowly, cost considerations suggest that a well-managed annual inspection may be more cost-effective than a poorly managed semi-annual inspection. They also point out that better design of some components could make them longer lasting, and that efforts to make defects more easily detected (such as colored wear bars on tires or audible scraping sounds indicating worn brake pads) could lead to improved mechanical condition without inspection. Thus PMVI programs could concentrate more cost-effectively on the remaining short-lived long-time-to-repair components.

O'Day, James and Richard J. Kaplan. Analysis of Fatality Data by State. Ann Arbor: Highway Safety Research Institute, July 1976, 45 pp. (Report No. UM-HSRI-76-21).

This report analyzes the relationship of 1972–73 traffic accident fatalities in the various states to differences in a number of possibly relevant demographic, geographic, and roadway characteristics. First a correlation analysis showed six variables having fairly high correlations with a fatality rate based on state population. A major factor was population density, and trial of a number of transforms showed that a second degree polynomial and a logarithmic transformation were about equally successful in relating population density to fatality rate. Regression analysis showed that just three variables—log density, annual number of rainy days, and percent of unsurfaced roads—could explain 76.3% of the variance in the state fatality rates. Log density alone was able to account for 67.6% of the variance in these rates.

Since in its early years PMVI was instituted primarily in the more densely populated eastern states, it is not surprising that the early accident analyses found lower fatality rates in PMVI states than in non-PMVI states. However, the 12 states implementing PMVI from 1966 to 1975 averaged much lower population densities than the early PMVI states and the other non-PMVI states. Thus the differences in fatality rates between the PMVI states and non-PMVI states became much smaller when the accident data from the 1970s were utilized.

O'Day, James, Richard Kaplan, Marion Compton, and Paul Ruschmann. Data Sources to Support the NHTSA Defect Investigation System. Ann Arbor: Highway Safety Research Institute, March 1978, 131 pp. (NHTSA Report DOT HS-803 531).

Among the sources studied for this project was the Fatal Accident Reporting System (FARS) data on vehicle defects in fatal accidents throughout the United States. The FARS data file contains provision for coding one or two "defect" entries per vehicle as contributing factors in the accident. Table 2 presents the 1976 vehicle defect data for eight states. The percentage of fatal-accident-involved vehicles with at least one vehicle defect supposedly contributing to the accident varied from 1.3% in Michigan to 9.9% in Ohio to 12.9% in Connecticut. More than half of the defects involved tires or wheels.

To try to understand why the FARS data contained such large differences among states the hard copy files were consulted for 64 vehicle defect accidents in Michigan and for 248 defect accidents in Ohio. It was found that the Ohio reporting form has a separate box for classifying vehicle defects in addition to a place for indicating accident causation, while the Michigan form does not provide such encouragement to note vehicle defects separately from their causal role. Apparently the FARS analysts in Ohio then coded any mention of defects on the accident report form into the contributing factors area of the FARS form. Presumably these differences in forms help to account for tires being cited

177 times in Ohio and only 12 times in Michigan. Clearly the types of accident report forms and specified procedures have a lot to do with the completeness of vehicle defect information in state accident files, and one must be very cautious in using these data for cross-state comparisons or even for within-state comparisons over time.

Pennsylvania Office of Budget and Administration. Motor Vehicle Inspection. Harrisburg: Commonwealth of Pennsylvania, January 1981, 54 pp.

This 1981 publication reviewed most of the PMVI literature through 1975, including some items which were not mentioned in any other PMVI discussions. Among these was a NHTSA study in 1972 which used a four-factor multiple regression analysis to find that PMVI accounted for only 2% of the state variations in 1968 fatality rates per 100,000,000 miles traveled; a NHTSA study in 1972 which looked at fatality rates per 1,000 registered vehicles from 1954 to 1968 and found that differences between PMVI and non-PMVI states were insignificant after 1966; and the Little study (1968) which found that fatality rates per 100,000 population increased more in six states which initiated PMVI in the 1950s and 1960s than in six matching non-PMVI states and in the nation as a whole.

The main original data presented in this study involved a multiple regression analysis and an analysis of covariance of 1971–1973 state fatality accident rates and combined fatality and injury accident rates based on miles traveled, population, and vehicles registered. Using up to 17 demographic, socioeconomic, environmental, and highway factors as independent variables (but not including population density), the analysis was able to explain from 49% to 82% of the variance in the annual fatality accident rates and from 22% to 42% of the variance in the combined fatality and injury accident rates. However, controlling on the significant independent variables, only one of 18 comparisons of mean accident rates for eight semi-annual PMVI states, for 24 annual PMVI states (including Washington, D.C.), and for 19 non-PMVI states was found to be statistically significant, and this result favored the non-PMVI states.

Also new was a phi coefficient analysis of some of the component outage differences found between jurisdictions in the 1968 McCutcheon-Sherman and the 1971 Fisher et al. studies. This analysis obtained phi coefficients from .01 to .11 between various outage rates in Pennsylvania data compared to data from Washington, D.C., New Jersey, and California. The report concluded that, while the differences between Pennsylvania and the other jurisdictions were statistically significant, they were too small to be of much practical significance in terms of causing differences in accident rates.

A third new set of data involved an analysis of vehicle defects in police-reported accidents in Pennsylvania for 1969 to 1978. During these years the proportions of all police-noted causal factors which were vehicle related ranged from 1.3% to 2.6% for fatal accidents, from 2.1% to 2.9% for injury accidents, and from 1.8% to 3.8% for property damage only accidents. For 1974, 1975, and 1976 the proportions of accidents in which vehicle-related factors were considered the primary cause ranged from 0.8% to 1.8% for fatal accidents, from 2.5% to 3.0% for injury accidents, and from 1.9% to 2.5% for property damage only accidents. While these data are clearly less reliable than data from the Indiana tri-level accident causation study, they tend to agree with that study in finding that vehicle-related factors make up a quite small proportion of accident causal factors, particularly for fatal accidents. They also agree with the Indiana data in finding brake, tire, and steering defects to be the most prevalent vehicle-related accident causes.

In conclusion, the report points out that the vehicle components most often rejected in the inspection process are not generally those most crucial to safe vehicle operation, and it suggests that Pennsylvania could save vehicle owners a considerable amount of money and trouble with little effect on accident rates by changing from a semi-annual to an annual PMVI system. It also points out that a thorough inspection following all the Pennsylvania regulations to the letter would probably take one to one and a half hours and would cost considerably more than the average of $7.50 then charged by official inspection stations. The report suggests that these extensive requirements lead to cutting corners in the inspection process, and it suggests that the required procedures in an annual inspection be reduced to concentrate on the safety critical components.

Implicit in this report, but never stated, is the possibility that even such an annual inspection might not be cost-effective in terms of safety benefits and that vehicle owners in Pennsylvania (but not the automobile service industry) might be better off if PMVI were discontinued entirely. A cover letter with this report stated that the Thornburgh administration planned to move ahead with the proposed change to annual inspections, and this change did take place in August, 1982, along with a reduction in the number of components to be inspected.

Randall, Donald A. <u>A Study Regarding the Addition of Motor Vehicle Safety Inspection to Motor Vehicle Emissions Inspection.</u> Washington: Auto Service Councils, Inc., January 1984, 28 pp.

This is a short compendium of information favorable to the implementation of PMVI and emissions inspection in the states. It discusses the preliminary Indiana tri-level data on vehicle defects in accidents, the Huntsville study of accident rates in relation to inspection, the New Jersey study supposedly demonstrating the cost-effectiveness of PMVI, the Idaho and McCutcheon-Sherman studies showing that PMVI improves vehicle condition, and a number of surveys showing public support for safety and emissions inspections. It also mentions a number of potential benefits besides safety emanating from inspection programs, such as noise abatement, lengthened vehicle service life, improved fuel economy and performance, identification of vehicles subject to recall, and identification of stolen vehicles.

Reinfurt, Donald W. and Michael J. Symons. <u>Statistical Techniques for Evaluating the Effect of State Motor Vehicle Inspection Programs in Reducing Highway Accidents.</u> Chapel Hill: University of North Carolina Highway Safety Research Center, March 1974, 46 pp.

The authors discuss two studies which attempted to relate the introduction of PMVI to reductions in accidents. In North Carolina PMVI was introduced in 1966, and motorists were supposed to be inspected in a certain month corresponding to the last digit of their license number. Thus it should have been possible to determine for accident-involved vehicles the number of months from their inspection to their accident. However, the data showed no significant relationship between length of time from the supposed inspection and the number of accidents. A 1% sample of inspection records was obtained, and it turned out that only a little over half of the sampled vehicles had obtained their inspections in the expected month. So the study results were necessarily inconclusive.

Florida introduced PMVI in 1968, and it used a similar method for phasing in inspections. However, in Florida the inspection records were computerized, so the actual inspection date for accident-involved vehicles could be obtained. But these data also failed to show any consistent relationship between inspections and accidents or any significant increase in accidents in relation to time from inspection—although the period studied was a rather short one (five months). Thus the data are considered to favor the null hypothesis of no PMVI effect on accidents.

The authors conclude that, given the small proportion of accidents caused by mechanical defects and the incompleteness of inspections in North Carolina and Florida in regard to all safety critical components, only a study focusing on accidents which involve mechanical defects could hope to find a significant PMVI effect on accidents.

Schroer, Bernard J. and J. F. Peters. An Evaluation of Vehicle Repair Costs for Auto Check Participants. Huntsville: University of Alabama, February 1977, 76 pp.

As part of the federal diagnostic inspection demonstration program over 15,000 vehicle inspections were conducted in Huntsville. A large proportion of these vehicles had one or more defects which required repair, and about one third of these returned for another free inspection following repairs. For 2,062 reinspected vehicles for which detailed repair cost information was available an analysis was carried out concerning the extent of unnecessary repairs—defined as repairs to components which had not failed the first inspection and which were not recommended or optional in relation to the required repair of a related component.

Overall, 23% of the repairs involving 32% of the repair costs were considered unnecessary by the diagnostic team. These included 36% of the suspension, 30% of the ignition/emissions, 24% of the brake, 18% of the steering, and 9% of the wheel alignment repairs. There were only small differences by repair facility. Females were somewhat more likely to be victims of unnecessary repairs than were males.

The data do show a significant decline in unnecessary repairs over the 16 months of the project. Presumably this demonstrates the value of the availability of a free independent diagnostic center in promoting higher quality standards in the repair industry, a quality control check which is not normally available in state PMVI programs.

Schroer, Bernard J. and William F. Peyton. The Effects of Automobile Inspections on Accident Rates. Huntsville: University of Alabama, August 1977, 81 pp. [Also in Accident Analysis and Prevention 11(1): 61–68 (March 1979)].

As part of the federal diagnostic inspection demonstration program accident rates of inspected and uninspected 1968–73 vehicles were compared for Huntsville residents during the 21 months from April 1975 through December 1976. Attempts were made to adjust for differences in age and sex of drivers and socio-economic status of ZIP code areas.

Over the 21 months the 8,493 inspected vehicles (out of 38,583 in Huntsville) had 753 police-reported accidents in Madison County after being inspected, an annual rate of 11.953%. Adjusting to try to include the accidents of inspected vehicles which took place prior to their inspection, the authors estimated a 13.111% annual accident rate for uninspected vehicles. Since 90% of the inspected vehicles had at least one substandard component and only one-third of these returned for inspection after repairs in this voluntary program, it is likely that large proportions of the inspected vehicles were not repaired. The adjusted accident rate for the inspected vehicles was 12.050%, and the adjusted accident rate for the uninspected vehicles was 13.263%, a 9.1% difference. The unadjusted accident rate for inspected vehicles which returned for one or more inspections was only 10.343%, a 21.1% reduction from the uninspected vehicles unadjusted accident rate. For the first 12 months of the program the authors reported a 5.3% reduction in accidents for the inspected vehicles in the period after the diagnostic inspection compared to the period before the inspection. They inferred that this reduction was really 11.8% on the basis of differences in the distribution of the types of drivers involved in the accidents.

The authors concluded that the potential for accident reductions with diagnostic inspections is somewhere between 9% and 21%. However, due to the voluntary nature of participation in the inspection program it is difficult to judge how much the accident rate differences were the result of the improved mechanical condition of the inspected vehicles and how much they were due to more cautious types of drivers volunteering to take part in the inspection program.

Shinar, David and John R. Treat. Tri-Level Study: Modification Task 3: Validity Assessment of Police-Reported Accident Data. Bloomington: Indiana University Institute for Research in Public Safety, June 1977, 102 pp. (NHTSA Report DOT HS-805 087).

This report compares the characteristics of 124 in-depth accident cases studied by the Indiana University accident investigation team with the data marked on the police accident forms for the same accidents. The police reports came out very poorly in this comparison, even for such easily observable characteristics as road surface composition (concrete or blacktop), horizontal and vertical alignment of the road, and posted speed limit. Also the police classified 38 accidents (38.6%) as property damage only in which the accident investigation team found that at least one injury had occurred. Even age of the driver was wrong 11.6% of the time, and model year was wrong or missing 15% of the time.

As would be expected, the police reports greatly underreported the presence of vehicle defects. For example, out of 207 vehicles the police cited defective brakes four times, while the team cited defective brakes 94 times (although usually not as a possible cause of the accident). The police reported no defects in lights or steering, while the team found 40 and 76 defects respectively. There was also considerable underreporting of view obstructions, road defects, and human condition factors (drinking, fatigue, defective eyesight, etc.), although there was also some incorrect reporting in these areas, particularly in reporting foreign substances on the roadway.

Assuming that any such items checked by the police officer indicated some causal involvement, agreements were somewhat higher for contributing factors in the accidents. Agreements were highest for direct human causes (speeding, failure to yield, etc.), followed by vehicular causes, environmental causes, and human condition causes. For example, the team found inadequate brakes to be possibly causal in seven of the 124 accidents. The police agreed with this in four of the cases, failed to cite brakes in the other three cases, and incorrectly cited brakes in two other cases. However, the police accident form did not provide for checking tire problems, so this factor was ignored in the police reports, while it was considered possibly causal in seven accidents by the team. Analysis of the data by night and day found few differences of significance. Analysis by police agency suggested that the state police reports were somewhat more accurate than those of the county or municipal police. An additional comparison of police-reported drinking data in 1,317 accidents investigated on-site by the IRPS team (level B data) apparently found higher agreements than on vehicle defect causal data, but, strangely, the overall agreement/ disagreement data are not given in the report.

It is unfortunate that this vehicle factors comparison was limited to 124 accident cases, only a few of which involved vehicle defects. However, these data are sufficient to suggest substantial underreporting and incorrect reporting of vehicle defects as causal factors in police accident reports in Indiana, and by inference, in other states as well.

Symons, Michael J. and Donald W. Reinfurt. "A Model for Evaluating the Effectiveness of Motor Vehicle Inspection Programs", Accident Analysis and Prevention 7 (4): 281–288 (1975).

Symons and Reinfurt present a statistical model for evaluating the effectiveness of motor vehicle inspection programs in reducing traffic accidents in relation to the duration of time from inspection to accident involvement. The model is based on the assumption that the waiting time between crashes follows an exponential function. They look at the sample sizes needed to detect a significant effect on general accident data, depending on various assumptions as to the average frequency of accidents, the estimated effectiveness of inspections, and the length of time for studying accident involvements. They conclude that these numbers are quite large, perhaps 600,000 if one makes a conservative assumption about accident effectiveness and studies accident involvements for a 24 month period.

Tarrants, William E. and Robert B. Voas. Highway Safety Needs Study: 1981 Update of 1976 Report to Congress. Washington: NHTSA, October 1981, 112 pp. (NHTSA Report DOT-HS-806 283).

This update considered 20 countermeasures, 17 of which had been included in the 1976 needs report. These included the two inspection-related countermeasures: Tire/Brake System Safety Critical Inspection—Selective and Periodic Motor Vehicle Inspection—Current Practices. Cost estimates for implementing these countermeasures were updated by taking into account inflation and the reduction in the number of states currently implementing PMVI. New ratings of effectiveness were determined by a panel of 13 experts (ten from NHTSA, one from FHWA, and two from private research organizations) using a Delphi technique.

For the Selective Tire and Braking Inspection countermeasure it was estimated that 1,700 lives could be saved per year, but that the countermeasure would only be 4.3% effective, thus saving 73 lives per year at an average cost of $2,285,127 per fatality forestalled. This countermeasure ranked 16th in cost-effectiveness among the 17 ranked countermeasures.

For extending current PMVI practices to all states it was estimated that 2,300 fatalities could be saved, but that the countermeasure would be only 1.9% effective, thus saving 44 lives per year at an average cost of $7,665,152 per fatality forestalled. The two-year incremental cost was estimated at $9.1 billion including a motorist inspection fee of $8.50 (p. 29). This countermeasure ranked last in cost-effectiveness.

Thus this report was much more pessimistic about the cost-effectiveness of inspection programs than was the 1976 report. However, one wonders if the same nine-fold computational error regarding PMVI program costs was perpetuated in the present report.

Thompson, Fred. "Assessing the Merits of Alternative Motor Vehicle Safety Inspection Programs.", paper presented at the APPAM Research Conference, October 20-22, 1983, in Philadelphia. New York: Columbia University Graduate Program in Public Policy Administration, 37 pp. [Also as "Regulating Motor Vehicle Safety Maintenance: Can We Make It Cost-Effective?", Journal of Health Politics, Policy and Law 9(4): 695-715 (Winter 1985)].

This paper contains a thoughtful if somewhat disjointed discussion of the issues involved in determining the cost-effectiveness of PMVI programs. As part of this discussion it probably contains the most complete review of the literature found in any PMVI publication.

After a brief review of the history of PMVI, Thompson presents the four basic assumptions underlying PMVI programs: (1) drivers underinvest in safety maintenance due to costs and/or ignorance of problems; (2) a significant proportion of accidents are caused by mechanical defects or failures; (3) periodic vehicle inspection can identify and correct some of these defects, thus reducing accidents; and (4) vehicle inspection is relatively cheap and therefore a cost-effective means of increasing traffic safety. He then discusses most of the studies that are included in this review on the characteristics of accidents with PMVI. He is impressed with the New Jersey time series analysis (Jackson et al. 1982) showing a 22–40% reduction in fatalities in 1938 as a result of the introduction of vehicle inspection, but he wonders how much of a contribution to accident reduction vehicle inspection is currently making in New Jersey. He also presents a summary of the results from six comparative state studies (including Crain 1980) and concludes that vehicle inspection has reduced fatalities from 0% to 10%. He expresses doubts about the adequacy of a simple, additive, linear model to provide useful evaluation of the PMVI effect, especially given the problems of multicollinearity and measurement error. However, he points out that five of these studies used only a single year's accident data, and he suggests that a panel study over a 20-year period might provide more useful results.

Next Thompson presents an interesting discussion of individual risk assessment and some of the factors which lead motorists not to voluntarily invest in high levels of vehicle maintenance, including low income and education. Then he discusses the interim results of the tri-level accident causation study in Indiana and suggests that PMVI may have reduced accidents overall from 2% to 5% there. He also cites with caution police data on changes in vehicle defects in fatal accidents in New Jersey (25% in 1938 compared to 8% in 1945), Nebraska, and Texas. He makes a best estimate that, in the absence of inspection, 10–12% of all accidents would be caused by mechanical failure. Finally as evidence of PMVI effectiveness he discusses five studies, including two of NHTSA's multi-state studies, which indicate that PMVI does tend to improve vehicle condition, although he notes that the 1972–73 multi-state study (Hatch et al. 1976) contained some anomalous findings regarding PMVI Pennsylvania, non-PMVI Illinois, and PMVI Texas. He also discusses approvingly the O'Day and Creswell (1968) analytical model of PMVI effectiveness, and he reports two studies (Carnegie-Mellon in Pennsylvania and one in which he participated in California) indicating the reliability problems faced by private station PMVI systems.

He concludes with a speculative discussion of the potential cost-effectiveness of a comprehensive, semi-annual, 90% reliable PMVI system. On the cost side he estimates $53 for two inspections per year, including driving and wait time costs, plus about $25 for making repairs earlier than would be done without PMVI (it's not clear if these include unnecessary repairs resulting from faulty inspection). On the benefit side, he estimates that such a program could bring about a 90% reduction in safety-related defects and thus reduce accidents and accident costs overall by 10%, which would provide a $60–$100 savings per vehicle. Whether such a program would be cost-effective depends on which of the latter figures one uses (60:78 or 100:78 benefit-to-cost ratios). However, he makes no mention of the source of his accident cost figures. They imply a national societal cost of ten times $60 or $100 times 160,000,000 vehicles, or $96 billion to $160 billion. (The National Safety Council estimate for 1980 was 164.9 million vehicles; the Federal Highway Administration's estimate was 161.6 million vehicles.) Both these accident cost figures and his estimate of a 10% reduction in all accidents from an effective PMVI program seem quite unrealistic. He concludes that, even if such a PMVI system were not cost-effective, an optimal system which applied only to vehicles over 3 years old and which varied the frequency of reinspection in relation to the results of the previous inspection would certainly be cost effective.

The 1985 article is a reorganized and more tightly written version of the original paper, but no new evidence is provided to support the unrealistic estimate of a potential cost benefit of $60 to $100 per vehicle.

Treat, John R. and Rickey L. Stansifer. "Vehicular Problems as Accident Causes—An Overview of Available Information", Warrendale, Penn.: Society of Automotive Engineers, March 1977, 16 pp. (SAE Paper 770117).

This paper summarizes the results of the Indiana tri-level accident causation study. From 1972 to 1975 2,558 accidents in Monroe County, Indiana, were investigated on-site (Level B) and a subset of 420 of these were investigated in-depth (Level C). About one-fourth of the accidents involved injuries and three quarters were property damage only. This study provides the most definitive data available on vehicle defects as causes of traffic accidents. At the time Indiana had an annual motor vehicle inspection program utilizing licensed private inspection stations.

Vehicle defects were found to be definitely causal (necessary for the accident to occur) in 4.5% of the in-depth cases and in 4.1% of the on-site cases, definitely or probably causal or severity-increasing in 12.6% of the in-depth cases and 9.1% of the on-site cases, and definitely or probably or possibly causal or severity increasing in 25.2% of the in-depth cases and 14.7% of the on-site cases. These vehicle defect causes were much less frequent than human and environmental causes, and, of course. many accidents had more than one cause. Only 2.4% of both the in-depth and on-site cases were considered to be definitely or probably caused only by vehicle defects.

Also presented are the results of a number of other similar but mostly less thorough attempts to assess the role of vehicle defects in accident causation. Mentioned are a Belgian study in which 24% of the accidents were "caused or aggravated" by mechanical defects; a Highway Safety Foundation study in which vehicle factors were considered causal in 9.5% of the accidents; a Calspan study which found "vehicle breakdowns" as a causal factor in 4% of 704 rural accidents based on police reported data; a Calspan study which found vehicle factors as causes in 3.3% of 630 investigated accidents; and a Califoria Highway Patrol study which found vehicle problems causal in 6% and contributory in 12% of 409 serious single vehicle accidents. Most relevant was a British on-site study of 2,130 accidents in which vehicle defects were a main contributing factor in 8.1% of the accidents of all types. However, only 2.5% of the accidents involved only a vehicle defect.

All of these detailed studies found that brake system problems and tire defects were the most common accident-causing defects. Gross failure, side-to-side imbalance, and delay were the predominant brake problems. Inadequate tread depth and under-inflation were the predominant tire problems in the Indiana data. Tire blow-out was a significant problem in the British data (1.3%), but was a possible cause in only 3 of the 2558 Indiana accidents. In the in-depth study tire and wheel defects were cited as definite, probable, or possible causes or severity-increasing factors in 8.8% of the accidents, and brake system defects were cited in 7.6% of the accidents. Other vehicle problems cited included steering problems 3.6%, inoperable lights 3.1% (mostly stop lights—inoperative headlamps were a possible cause in only one accident); vision obstructions 1.0% (snow, condensation, etc. on the window); deficient vision hardware 1.0% (mirrors, wipers, defrosters); body and doors 0.7% (door or hood coming open); power train and exhaust problems 1.0% (mostly power loss—only 1 of 2,558 accidents resulted from running out of gas); driver controls 0.7% (e.g., stuck accelerator); and other problems 0.5%.

Most of these studies took place in jurisdictions which required regular motor vehicle inspection of some type, so it seems likely that vehicle defects would play an even larger role in accidents in non-inspection jurisdictions. However, they demonstrate clearly that human and environmental factors are more important accident causes than vehicle defects in a PMVI jurisdiction, and it seems likely that this is true in non-PMVI jurisdictions as well. Clearly even a very thorough and efficient inspection could be expected to prevent a rather small proportion of the total accidents in a jurisdiction.

Tufte, Edward R. Data Analysis for Politics and Policy. Englewood Cliffs, N.J.: Prentice-Hall, 1974, 179 pp.

This is a general book on applied statistics techniques for policy analysis, but the introductory chapter uses fatality data in PMVI and non-PMVI states for illustrating some of the problems of applied statistical analysis. First he presents a state comparison of 1966–68 fatality rates (per 100,000 population) which showed PMVI states tending to have lower fatality rates (average 26.1) than non-PMVI states (average 31.9). Similarly in relation to 100 million miles travelled he found a rate of 5.48 fatalities in the PMVI states and 5.95 fatalities in the non-PMVI states. He warns his readers about the potential problems of different data quality in different states, and then he goes on to look for other possible explanatory factors in the observed association of PMVI and lower fatality rates. The first one he looks at is population density, and he found a strong relationship between the log of population density and the population fatality rate. Then he discusses two methods of "controlling" for the effect of population density. He grouped the states into three population density groups and found that the PMVI states had lower fatality rates than the non-PMVI states within each density group, but he warns that such a matching method is not very satisfactory because of the small number of groups and the large variability within each group. Secondly, he controlled for density by fitting a regression line on a scatterplot of log density and fatality rate and calculating the residual in each state of the difference between the actual and the predicted fatality rate. This residual can be considered as that part of the death rate unexplained by density. This analysis showed that the PMVI states had a fatality rate averaging 1.63 below the expected rate controlling for density, while the non-PMVI states had a fatality rate averaging 0.90 higher than expected. Thus fatality rates appeared to be about 9% lower in PMVI states than in non-PMVI states even after controlling for the variation in population density. However, the author points out that such an inference is far from conclusive. Adjustments for other possibly relevant factors should be attempted, and it should be recognized that not all relevant factors can be defined or measured.

In his introduction Tufte includes this warning to users of applied statistics: "Statistical techniques do not solve any of the common-sense difficulties about making causal inferences. Such techniques may help organize or arrange the data so that the numbers speak more clearly to the question of causality—but that is all statistical techniques can do. All the logical, theoretical, and empirical difficulties attendant to establishing a causal relationship persist no matter what type of statistical analysis is applied. 'There is,' as Thurber moralized, 'no safety in numbers, or in anything else.'"

U.S. Department of Transportation. The National Highway Safety Needs Report. Washington: April 1976, 154 pp. (NHTSA Report DOT/HS 801 892). Also The National Highway Safety Needs Study (App. A: Literature Summary; App. B: Countermeasures Evaluated; App. C: Advisory Panel Findings; App. D: State Surveys); prepared by Research Triangle Institute, March 1976, 560 pp.

This was a rather confusing attempt to evaluate the potential cost-effectiveness of over 50 countermeasures in reducing the severity or frequency of accidents. Among these are two countermeasures relating to vehicle inspection—titled "Periodic Motor Vehicle Inspection-Current Practice" and "Tire and Braking System Safety Critical Inspection-Selective".

The latter is defined as an annual inspection focusing on safety critical vehicle components for a representative sample of vehicles in each state, but no indication of sample size is provided, so it is difficult to understand how the estimated costs were determined. Start-up costs for this program were estimated at $94.7 million and annual recurring costs were estimated at $183.2 million for the 90% of the vehicle population not already covered by such a program. Apparently money saved by eliminating the current PMVI programs was not taken into account. The target population for this countermeasure was estimated at 4% of all registered motor vehicles, and the effectiveness of the program in forestalling fatalities and injuries and in reducing accidents was estimated at 25%. Thus over a ten-year period it was estimated that this program could forestall 4,591 fatalities at an average discounted cost of $250,533 per life saved.

Similar calculations were used to estimate the cost-effectiveness of extending the current PMVI programs to the 30% of the population not then covered by PMVI. Start-up costs were again estimated at $94.7 million, and annual recurring costs were estimated at $59.6 million. The target population was again estimated at 4% of all registered vehicles, and the effectiveness of the program was estimated at 10%. Over ten years it was estimated that extending PMVI to all states would forestall 1,836 fatalities. A computational error in the Needs Study led to reporting this as $2,120,535 per fatality, but the corrected average cost per life saved is $221,841.

The bases for the estimated costs, the estimated target populations, and the estimated rates of program effectiveness are not at all clear. The text of the report mentioned using $5.00 as the estimated cost per inspection including travel and waiting time, but this is not consistent with the total cost figures presented. Chapter 12 of Appendix A does contain a useful review of the literature on PMVI programs and their effectiveness, including a map of inspection states.

In the report, cost-effectiveness ratings were presented for 37 different countermeasures in relation to average cost per fatality forestalled. Far and away most cost-effective was the implementation of mandatory seatbelt laws. The selective tire and braking inspection program ranked 22nd, and extending the current PMVI program to all states ranked 31st, but it would have ranked 20th if the computational error had not been made.

A panel of 103 experts including 40 governor's highway safety representatives was also asked to rate the effectiveness of some 52 somewhat differently defined "direct impact action items" in reducing the severity or frequency of accidents for the target population, using a six-point scale. Of 43 countermeasures for which the average ratings were reported, current PMVI procedures ranked 40th, while new PMVI procedures focusing on safety critical components ranked 34th. The researchers were not able to find any statistical correlations between these ratings of countermeasure effectiveness and their own ratings of effectiveness based on the literature search.

Wilson, F.R. "Evaluation of a Compulsory Motor Vehicle Inspection Program in New Brunswick, Canada", in Documentation, Seventh World Meeting of the International Road Federation, Munich, October 1973, pp. C3: 40–43.

Annual compulsory motor vehicle inspection was introduced in New Brunswick in 1969. In order to evaluate this program the quality of vehicle condition in various catchment areas was measured by giving out questionnaires at a sample of private inspection stations. The questionnaires included rejection information for the various inspected components and the costs of the needed repairs in order to pass inspection. During 1970 ands 1971 2,022 completed questionnaires were received, a 71.6% return rate. Analysis of the questionnaires showed that the higher the quality of vehicles coming for an inspection in a given area the lower the overall 1970–71 accident rates (based on estimates of miles driven in each area). These findings were generally significant at a 10% level, and some were significant at a 5% level. The repair cost data could not be used to determine the cost-effectiveness of the program because of the lack of comparable information of the costs of accidents.

Wort, Larry F. "Periodic Motor Vehicle Inspection: Its Accident Prevention Potential, Costs, and Benefits". Springfield: Illinois Dept. of Transportation, April 1976, 18 pp.

In testimony before the Illinois Vehicle Laws Commission, Wort presented a 1949-1973 trend chart showing that after 1968 states without PMVI had lower traffic death rates than states with PMVI. He mentioned a California study which showed that 6% of single vehicle accidents were caused by vehicle defects (no citation) and also the preliminary 6% vehicle-related accident finding of the Indiana tri-level study. Referencing O'Day and Creswell's 1968 analysis of lamp outages, he said that only 10% of these accidents could be prevented by PMVI, or 0.6% of all accidents. He estimated total inspection costs as at least $20 per vehicle (with an average of 50 minutes station time) including driver travel and time costs. Using National Safety Council estimates of accident costs, he concluded that the cost-benefit ratio of PMVI in Illinois would be 20:1—definitely not worth the cost.

APPENDIX B

CITATIONS FOR SOME OTHER PMVI LITERATURE WHICH WAS NOT REVIEWED

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