

TECHNICAL REPORT

The Impact of Extended Vehicle Emission Warranties on California's Independent Repair Shops

Lloyd Dixon

Prepared for the California Air Resources Board



RAND INFRASTRUCTURE, SAFETY, AND ENVIRONMENT

The research described in this report was sponsored by the California Air Resources Board through Agreements 00-604 and 03-612 and was conducted within RAND Infrastructure, Safety, and Environment (ISE), a unit of the RAND Corporation

Library of Congress Cataloging-in-Publication Data

Dixon, Lloyd S.

The impact of extended vehicle emission warranties on California's independent repair shops / Lloyd Dixon.

p. cm.

"TR-235."

Includes bibliographical references.

ISBN 0-8330-3750-1 (pbk. : alk. paper)

1. Service stations—California. 2. Environmental law—Compliance costs—California. 3. Warranty. 4. Air—Pollution—California—Prevention—Costs. I. Title.

TL153.D548 2005

629.28'6—dc22

2005003657

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Published 2005 by the RAND Corporation
1776 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138
1200 South Hayes Street, Arlington, VA 22202-5050
201 North Craig Street, Suite 202, Pittsburgh, PA 15213-1516
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Preface

Automobile manufacturers will likely be producing large numbers of partial-zero emission vehicles (PZEVs) to satisfy part of California's Zero Emission Vehicle Program, which went into effect with model-year 2005 vehicles. The emission control systems of PZEVs must be covered under warranty for 15 years or 150,000 miles, far longer than current warranty requirements. When the California Air Resources Board (CARB) adopted the extended warranty requirement in 1998, it expressed concern that extended warranties might adversely affect the independent repair industry because warranty repairs must be done at new-car dealer repair shops. CARB consequently asked the RAND Corporation to assess the potential impacts of extended warranties on the independent repair industry and to evaluate alternatives for mitigating any adverse impacts from those warranties.

This report examines and quantifies, where possible, the effects of extended vehicle warranties on the independent repair industry from 2003 to 2020. It also identifies options for reducing or mitigating adverse effects. As such, this report should be of interest to automakers, the vehicle repair industry, vehicle owners, and government agencies concerned with the economic impact of environmental regulations. This research was sponsored by the California Air Resources Board through Agreements 00-604 and 03-612.

This research was conducted within RAND Infrastructure, Safety, and Environment (ISE), a unit of the RAND Corporation. The mission of ISE is to improve the development, operation, use, and protection of society's essential man-made and natural assets and to enhance the related social assets of safety and security of individuals in transit and in their workplaces and communities. The ISE research portfolio encompasses research and analysis on a broad range of policy areas including homeland security, criminal justice, public safety, occupational safety, the environment, energy, natural resources, climate, agriculture, economic development, transportation, information and telecommunications technologies, space exploration, and other aspects of science and technology policy.

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Summary

The California Air Resources Board (CARB) allows automobile manufacturers to satisfy part of the state's Zero Emission Vehicle (ZEV) Program requirements by manufacturing and selling partial-zero emission vehicles (PZEVs). When new, PZEVs must meet very stringent emission standards, and in an effort to keep emissions low as the vehicles age, CARB requires that they be covered by a comprehensive 15-year/150,000-mile emissions-system warranty. The PZEV warranty extends the three-year/50,000-mile emissions warranty currently required in California. To be covered under warranty, repairs must usually be done at dealer repair shops and, thus, CARB has expressed concern that extended warranties may adversely affect independent repair shops.

This report examines and quantifies, where possible, the effects of extended vehicle warranties on the independent repair industry. The findings are based on a survey of the vehicle-repair behavior of drivers in 366 households across California, a survey of repairs at 48 independent repair shops and 28 dealer repair shops in California, existing data on the vehicle repair and maintenance industry, and models of the vehicle fleet that were developed by CARB.

Effects of Extended Warranties on Independent Repair Shop Revenue

A model of consumer expenditures at independent and dealer repair shops was used to estimate the impact of extended emission warranties on revenues at independent repair shops. Estimates were based on scenarios for the number of PZEVs produced between 2003 and 2020.¹ In the scenario in which manufacturers produce the maximum number of PZEVs that can be used to satisfy ZEV program requirements (the "maximum-PZEV" scenario), the

¹The ZEV program took effect in the 2005 model year, although manufacturers produced PZEVs in 2003 and 2004 to generate credits that can be used to satisfy ZEV program requirements.

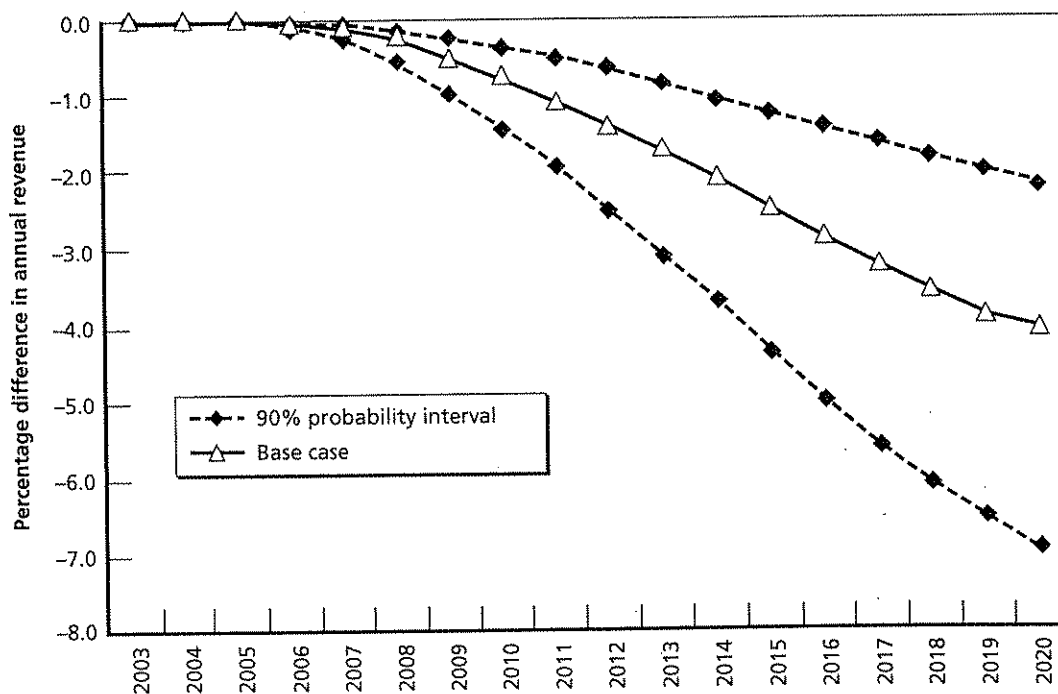
number of PZEVs on the road increases gradually starting in 2003 and reaches 38 percent of the light-duty vehicles (LDVs) in California by 2020.

Independent Repair Shop Revenue in California Will Continue to Grow with Extended Warranties but at a Slower Rate

Figures S.1 through S.4 present the predictions for the maximum-PZEV scenario in constant year-2004 dollars. Extended warranties have no effect on independent repair shop revenue in California between 2003 and 2005 because warranties for the first three years or 50,000 miles of a PZEV's life remain the same as those on vehicles with standard emission warranties. Using a base-case set of parameter values, revenue at independent repair shops is predicted to be 0.8 percent lower (\$120 million of \$15.4 billion) in the maximum-PZEV scenario than it otherwise would be in 2010 and 4.1 percent lower (\$730 million of \$17.9 billion) in 2020.²

There is considerable uncertainty in many of the parameters that underlie the predictions. This analysis, thus, examines how the results change when the parameters are allowed to vary over their likely ranges. The result is that the predicted decline in independent repair shop revenue in 2020 ranges from 2.2 to 6.9 percent (\$375 million to \$1.3 billion) in the maximum-PZEV scenario (as shown by the 90-percent probability intervals in Figures S.1 and S.2).³

Figure S.1
Percentage Difference in Annual Revenue at Independent Repair Shops Due to Extended Warranties, 2003–2020, Maximum-PZEV Scenario

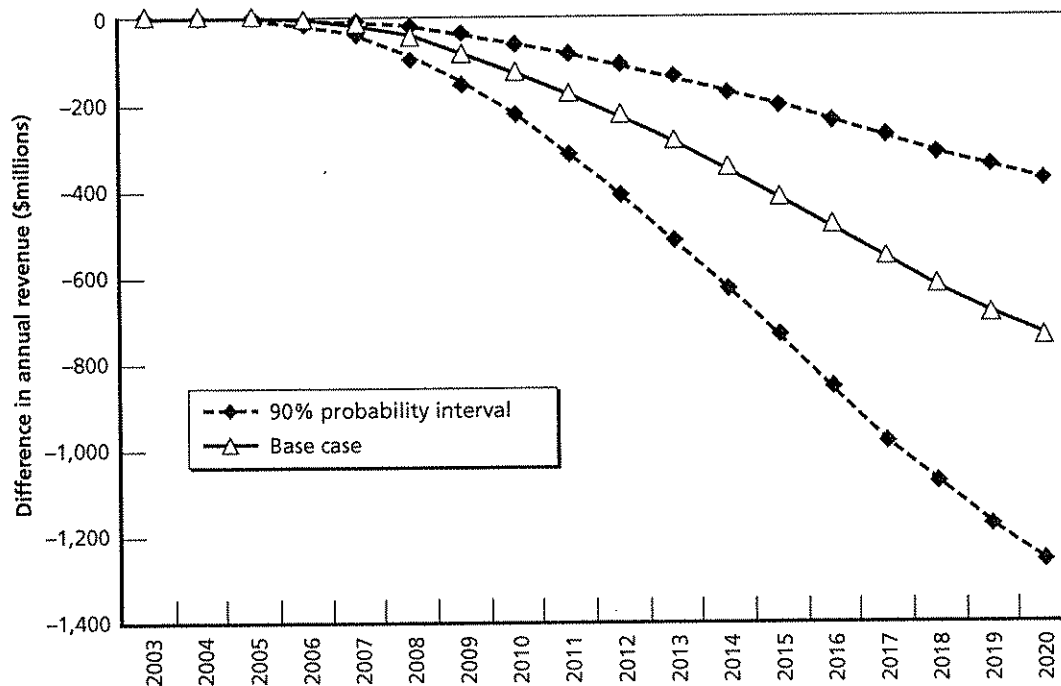


RAND 7R235-S.1

² Estimates of independent repair shop revenue do not include revenue from collision repairs and vehicle customization. Including these types of service would increase the baseline for independent repair shop revenue and thus reduce the percentage decline in revenue somewhat from that predicted here.

³ The 90-percent probability interval is determined by the uncertainty in the parameters that underlie the prediction. There is a 90-percent chance that the effect of extended emissions warranties will fall in the interval, given the assumptions on the distributions of the underlying parameters.

Figure S.2
Dollar Difference in Revenue at Independent Repair Shops Due to Extended Warranties, 2003–2020,
Maximum-PZEV Scenario



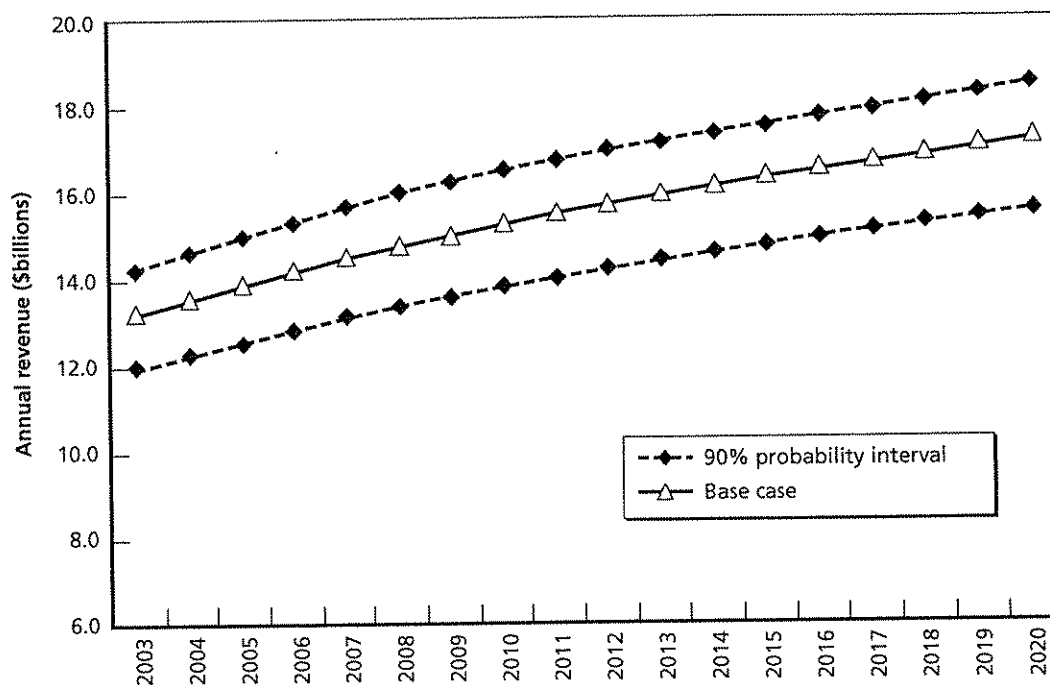
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Even though revenue at independent repair shops will be lower with extended warranties than it would be if warranties were not extended, revenue at independent repair shops in California will grow between 2003 and 2020 even with extended warranties (see Figure S.3). Projected revenue climbs 30 percent between 2003 and 2020 in the maximum-PZEV scenario with extended warranties and 36 percent without them. This increase is driven by a projected 32-percent rise in the number of vehicles on the road between 2003 and 2020 and a gradual increase in average vehicle age over this period. Figure S.4 shows the change over time in independent repair shop revenue with extended warranties from the level of revenues in 2003.

While it seems plausible that manufacturers will produce enough PZEVs to just satisfy as much of the ZEV program as program rules allow, the number they will actually produce is uncertain. Manufacturers could conceivably produce fewer PZEVs than in the maximum-PZEV scenario, or competitive pressures could induce them to produce more than in the maximum-PZEV scenario. The effects of extended warranties were thus simulated under various scenarios for the number of PZEVs produced. The effects were found to be roughly proportional to the number of PZEVs produced. Even when it was assumed that all vehicles sold after 2008 carried extended warranties, revenue at independent repair shops grew 25 percent between 2003 and 2020. The growth in independent repair shop revenue would not be as large if the vehicle fleet grows more slowly than expected.

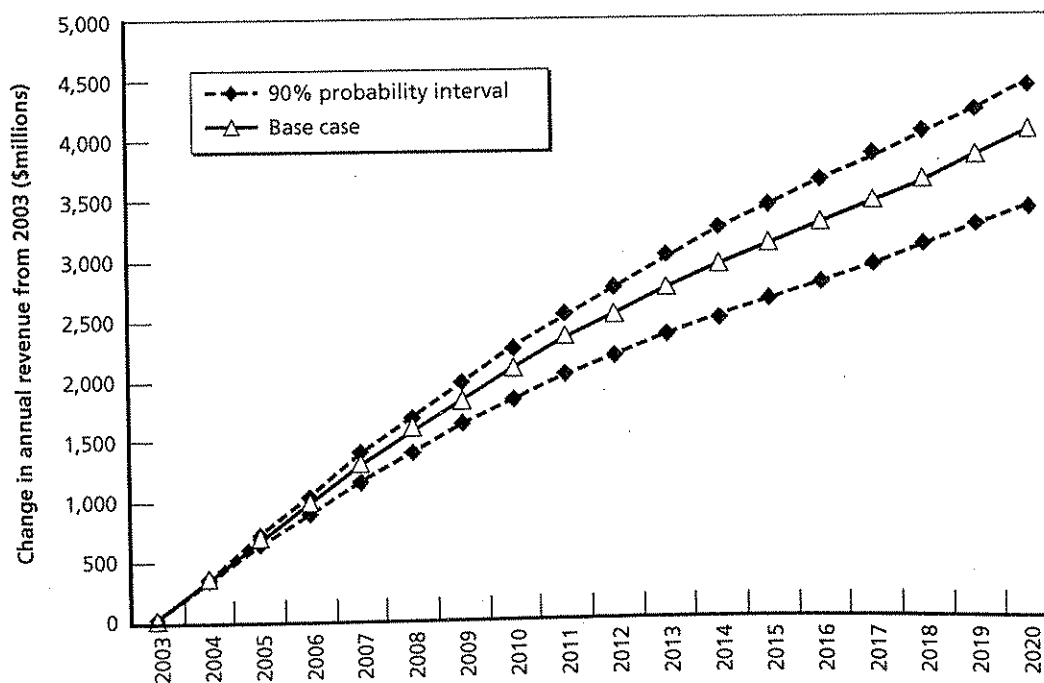
While there is some evidence that the durability of emission-control systems has improved in recent years, sufficient data were not available to project future improvements. Thus, the effects of extended emission warranties are predicted assuming no change in durability. Durability may improve, however, and the simulations in this report show that

Figure S.3
Annual Revenue at Independent Repair Shops with Extended Emission Warranties, 2003–2020, Maximum-PZEV Scenario



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Figure S.4
Change in Annual Revenue at Independent Repair Shops from 2003 with Extended Warranties, 2003–2020, Maximum-PZEV Scenario



RAND TR235-S.4

estimates assuming no change in durability will likely overstate changes in independent repair shop revenue when durability improvements are factored in.

More specifically, there are two types of durability improvements of interest. First, durability may improve even if warranties are not extended due to the phase-in of more stringent vehicle certification requirements and more extensive emissions testing of vehicles in use. Such an improvement would reduce the impact of extended warranties on independent repair shops because there would be fewer repairs that could migrate from independents to dealers. This type of durability improvement would thus cause the estimates in this report to overstate the actual effect of extended emission warranties on independent repair shops. Second, extended emission warranties might also improve durability. Such an improvement could, on the one hand, magnify the adverse effects of extended warranties on independent repair shops because, in addition to reducing the share of work that goes to independents, extended warranties would reduce the overall amount of work to be split. On the other hand, durability improvements caused by extended emission-system warranties could cause fewer non-emission-system repairs to migrate from independents to dealers (so called pull-along work) when warranties are extended.

Based on estimates of the amount of non-emission work that is done along with emission work, the simulations show that improvements in durability due to extended emission warranties will likely reduce the negative impact of extended emission warranties on independent repair shops. Thus, the predictions here (which assume no change in durability) will again tend to overstate the effects of extended emission warranties.

Effects on Shop Workers, Owners, and Consumers

By reducing revenue at independent repair shops from what it would be otherwise, extended warranties may adversely affect workers at independent repair shops, independent repair shop owners, and consumers.

Extended Warranties Should Not Cause Layoffs in the Repair Industry as a Whole, Although There May Be Layoffs at Some Independent Repair Shops

Aggregate revenue at independent repair shops is predicted to grow even with extended warranties. Thus, there should be no need to lay off current workers at independent repair shops as a whole. However, the findings of this study suggest that some independent repair shops will likely be more affected by extended emission warranties than others. Extended warranties may, thus, cause layoffs at some independent repair shops even though employment at all independent shops combined grows. These layoffs may cause hardship for some workers. Whether or how many independent repair shops might have to lay off employees could not be quantified; however, because the impacts of extended warranties are felt only gradually over time, workforce reductions could possibly be handled through normal attrition. In addition, workers may be able to quickly find employment at other independent repair shops or at dealer repair shops.

Extended Warranties Will Likely Reduce Profits of Independent Repair Shop Owners Somewhat

In the standard competitive economic model, increases in demand raise prices, which in turn increase profits of the firms currently in business above the normal return on capital. In the

case of the repair industry, these extra-normal profits would encourage new independent repair shops to enter the market, reducing prices and profits per firm. Extended emission warranties will cause demand for services at independent repair shops to increase more slowly than it would without extended warranties. This implies that existing independent repair shops will enjoy fewer periods of extra-normal profits than they would otherwise. The loss to current owners is the discounted present value of these foregone profits.

Several factors will moderate the significance of these losses. First, compared with many other industries, it seems easy for new firms to enter the vehicle-repair industry. Easy entry will limit the amount of extra-normal profits. Second, many of the losses will be felt ten or more years in the future. The relatively high discount rate appropriate for small-business profits and the long lead times for the effects of extended warranties will substantially reduce the present value of the losses. Finally, as reported above, independent repair shop revenue is expected to grow 30 percent over 18 years with extended warranties and 36 percent without them. It seems unlikely that the present value of the lost profits will be large relative to the size of discounted profits over this period.

There Will Likely Continue to Be a Large Number of Independent Repair Shops in Most Parts of the State

Slower revenue growth at independent shops may mean fewer independent repair shops than there would be otherwise. Fewer repair shops may mean that repair shops are less conveniently located for some consumers. It may also mean less competition and possibly higher prices at both dealer and independent repair shops.

Investigation of how slower growth in revenue may translate into slower growth in the number of repair shops (or may translate into more rapid decline in the number of independent repair shops if other factors are causing consolidation in the industry) was beyond the scope of this analysis. Revenue growth between 2003 and 2020 is predicted to be 6.0 percentage points slower with extended warranties, so the effect on the number of repair shops is not likely to be great, and a large number of independent repair shops will still likely be in the state.

The reduction in the number of repair shops per vehicle could have more significant consequences for consumers in some parts of the state than in others. For example, the effects could be greater in sparsely populated rural areas where there are few dealer or independent repair shops to start with. This analysis did not allow a determination of whether or how effects on the number of repair shops will vary by region or how the effects on consumers of any declines in the number of shops that did occur will differ between urban and rural areas.

It should be noted, though, that added business at dealer repair shops may induce dealers to open up more locations, which would offset some of the decline in the number of independent repair shops. A full analysis of the effect of extended emissions warranties on drivers and Californians more generally would also need to consider benefits in dimensions not examined here including cleaner air and more durable vehicle emission control systems.

Policy Implications

The study results suggest that the effect of extended emission warranties on independent repair shops will not be large and will be felt only gradually over time. The California Air Resources Board may still want to consider programs to reduce the impacts that do exist. Options are examined in Chapter Eight for preventing or reducing the effects that occur in the first place, reducing the negative ramifications of effects that do occur, and compensating repair shop owners for their losses.

Policies that facilitate the transition of workers at independent repair shops to new jobs could be an attractive way to reduce negative ramifications that do occur. Requiring automakers to cover emission repairs using service contracts that allow repairs to be done at an approved network of independent repair shops is a potentially promising option for reducing the declines in business at independent repairs shops. Consumer education on emission warranties also is a potentially promising option for reducing the effects on independent repair shops. Better information on warranties may reduce the frequency with which drivers go to a dealer for repairs that are not covered under warranty because such information will clarify what the warranty does and does not cover, and better information may also dispel any notions that maintenance work must be done at the dealer to maintain the warranty. While the effects of emission-system warranties predicted by this analysis suggest that the benefits of such interventions will not be great, it is up to policymakers to determine whether further exploration of these options is warranted.

Acknowledgments

Many people contributed to this study. First, thanks go to the 360-plus individuals who took the time to complete the household vehicle-repair survey and the 48 independent repair shops and 28 dealer repair shops that participated in the repair-shop survey. They took time out of their busy schedules to help create the data needed for this analysis.

Steve Albu, Paul Hughes, and Sarah Carter of the Mobile Source Control Division of the California Air Resources Board provided valuable feedback throughout this project and provided several databases used in the analysis.

This study benefited from the input of many people in the aftermarket repair industry. Aaron Lowe of the Automotive Aftermarket Industry Association provided useful comments on the study design and survey questionnaires and spearheaded the effort to write a letter of endorsement from the aftermarket industry for inclusion with the repair-shop survey. Michael Conlon of Conlon, Frantz, Phelan & Pires, LLP; Deanne M. Ottaviano of Arnt Fox Kintner Plotkin & Kahn, PLLC; John Goodman of the Automotive Aftermarket Legislative Council; and Frank Hampshire of the Motor & Equipment Manufacturers Association also contributed to the study. Special thanks go to Brad Walker, executive director of the Automotive Service Councils of California, for soliciting his members via e-mail to participate in the repair shop survey.

Peter Welsh of the California Motor Car Dealers Association and Steve Mazor of the Automobile Club of Southern California also provided useful information.

Most of the household interviews were done under contract with the Robert Thomas Brown Company. The interviewers were ably recruited and supervised by Karen Meyer. Juan E. Rudeke of JER Communications conducted interviews in Spanish and conscientiously followed up with the repair shops to complete the surveys.

At RAND, Kathy Rosenblatt was heavily involved in the design of the survey instruments. She also coordinated both the household and repair shop surveys. Beverly Weidmer of the Survey Research Group provided feedback on the survey instrument. Brian

Williams provided much appreciated statistical advice. Pat Williams generated the mailings for the repair shop survey and provided administrative assistance.

Laura Baldwin and Eric Peltz of RAND provided technical reviews of the draft report. Their detailed and insightful comments improved the report considerably. Debra Knopman, vice president and director of RAND Infrastructure, Safety, and Environment, managed the review process and provided valuable feedback on the policy conclusions presented here. Susan Turner and D.J. Peterson facilitated the final steps of the review, and Nancy DeFavero did a superb job of editing the final report.

As always, any errors are the responsibility of the author.

Abbreviations

CAP2000	Compliance Assurance Plan 2000
CARB	California Air Resources Board
C.I.	confidence interval
CO	carbon monoxide
EGR	exhaust gas recirculation
EWIRP	Emission Warranty Information Reporting Program
gm	gram
HC	hydrocarbons
ISE	RAND Infrastructure, Safety, and Environment
LDV	light-duty vehicle
LEV	low emission vehicle
MY	model year
MEMA	Motor & Equipment Manufacturers Association
NO _x	oxides of nitrogen
OBD	on-board diagnostic (system)
PZEV	partial-zero emission vehicle
ZEV	zero emission vehicle

Introduction

California's Zero Emission Vehicle Program allows automobile manufacturers to meet part of the program's requirements by producing and selling partial-zero emission vehicles (PZEVs).¹ PZEVs must meet very stringent exhaust and evaporative emission standards.² In addition, emission-related components must be covered under warranty for 15 years or 150,000 miles, far longer than current warranty requirements.³

These longer warranties will likely reduce lifetime vehicle emissions, but may adversely affect *independent repair shops* (repair shops not associated with new car dealers). To be covered under warranty, repairs must usually be done at *dealer repair shops* (repair shops associated with new car dealers).⁴ Thus, extended warranties may shift business from independent repair shops to dealer repair shops and result in economic losses for owners of and workers at independent repair shops. The repair industry in California is large, and the potential impacts of extended warranties on the industry warrant consideration.⁵

The purpose of this report is to better understand and quantify where possible the effects of extended vehicle warranties on independent repair shops. It also aims to identify ways to help mitigate any such adverse affects.

¹ The Zero Emission Vehicle Program requires manufacturers to produce for sale vehicles that emit no exhaust emissions under all operating conditions (zero emission vehicles, or ZEVs). The number of vehicles that must be produced is tied to vehicle sales in California and ramps up gradually over time. The program has been significantly modified multiple times since it was first adopted in 1990 and took effect in the 2005 model year.

² PZEVs meet the tailpipe emission standards of super-ultra-low-emission vehicles, or SULEVs (which are 90-percent cleaner than the average new 2003 model-year car) and have zero evaporative emissions. Evaporative emissions are caused by the evaporation of fuel from the vehicle, and vehicles with "zero evaporative emissions" have fewer such emissions when their engines are running or not running. For more information about PZEVs, see <http://www.driveclean.ca.gov/en/gv/faq/index.asp>.

³ PZEVs on the road today are gasoline-powered vehicles. PZEVs could conceivably also run on other fuels, such as natural gas.

⁴ Manufacturers reimburse dealer repair shops for warranty repairs.

⁵ As is documented in this report, annual revenues for the vehicle repair industry in California are on the order of \$18 billion, with independent repair shops accounting for roughly 70 percent of the total.

Evolution of Warranty Requirements

Between model years 1973 and 1989, California required manufacturers to provide a five-year or 50,000-mile (whichever occurs first) warranty for parts listed on an "emission warranty parts list" (California Code of Regulations, Title 13, Section 2036). The emission warranty parts list was developed by the California Air Resources Board (CARB) and included a large number of parts related to the various emission-control systems on vehicles (CARB, 1990).

Warranty requirements changed for model year 1990 and later vehicles. Now, manufacturers are required to provide a three-year/50,000-mile warranty on any defect that causes the malfunction-indicator, or check-engine light, to illuminate.⁶ Manufacturers are also required to fix any malfunction that causes the vehicle to fail California's Inspection and Maintenance Program (the Smog Check Program) during this period.⁷ In addition, manufacturers are required to warrant certain "high-priced" parts for seven years or 70,000 miles (California Code of Regulations, Title 13, Section 2037). CARB adjusts the threshold for high-priced parts yearly—it was \$420 for 2001 model-year vehicles (CARB, 2000a). Manufacturers are responsible for identifying the high-priced parts in their vehicles. The list of parts can vary from manufacturer to manufacturer and from vehicle model to vehicle model. Appendix A lists examples of emission-related parts.

Federal emission warranty requirements also apply.⁸ Federal law requires manufacturers to warrant that their vehicles will pass the EPA-approved inspection and maintenance program established by the state or local jurisdiction in which the vehicle operates for two years or 24,000 miles, whichever occurs first. This requirement is weaker than the California requirement, but federal law also requires the warranty to cover the catalytic converter, the electronic emission control unit, and the on-board diagnostic (OBD) system for eight years or 80,000 miles, which is stronger than the California requirement for these parts.

The PZEV requirements essentially extend the California's three-year/50,000-mile warranty to 15 years/150,000 miles. Manufacturers are required to fix any malfunction that causes the check-engine light to illuminate or the vehicle to fail a smog check during this period. Vehicle owners are required to properly maintain their vehicles during the warranty period, but exactly what owners must do to prove compliance is not clear-cut.⁹

⁶ The *check-engine light* is a light on the vehicle instrument panel that illuminates when the emission-control system malfunctions.

⁷ These provisions are part of the vehicle's performance warranty. Manufacturers are also required to replace defective emission-related parts for three years or 50,000 miles regardless of whether the vehicle fails a smog check or the check-engine light illuminates. This latter requirement is the defects warranty.

⁸ The California warranty on these parts is seven years or 70,000 miles, but manufacturers must honor the federal warranty for these components even if the vehicle is sold in California.

⁹ Emission warranties are not required on zero emission vehicles because they emit no pollutants (at least directly).

Organization and Overview of This Report

Chapter Two discusses the various factors that influence the impact of extended emission warranties on the independent repair industry. One important factor is the durability of the emission-control system. Durability is important because it influences the total repair expenditures to be split between independent and dealer repair shops. Chapter Two also examines data on recent trends in durability of emission-control systems.

Models used in this study to predict the effects of extended emission warranties are based in large part on two surveys conducted as part of this study. Chapter Three describes those surveys and the survey methods, sample sizes, and response rates. Households across California were surveyed to determine where they take their vehicles for repair, how much they spend, their knowledge about vehicle warranties, and how their behavior would change if emission warranties were extended. Independent and dealer repair shops across the state were surveyed to determine how emission-related repairs are linked with other repairs.

Chapters Four and Five present data from the surveys. Chapter Four breaks out consumer expenditures on vehicle repair and maintenance by type of repair (e.g., emission-related versus non-emission-related) and type of repair facility (dealer repair shop versus independent repair shop). Chapter Four also reports findings on how emission-related repairs are bundled with non-emission-related repairs at independent and dealer repair shops. These findings are used to estimate the amount of non-emission-related work that may shift over to dealers if emission warranties are extended.¹⁰

The effect of extended emission warranties on independent repair shops will depend in part on what consumers know about the warranties and on their preferences for having their vehicles repaired at independent versus dealer repair shops. Chapter Five reports survey results on consumer knowledge about emission warranties. It also summarizes drivers' answers to questions on where they would take their vehicles for repair if emission warranties were extended.

Chapter Six predicts the effects of extended emission warranties on the independent repair industry. The number of PZEVs that will be produced over time is uncertain. Thus, predictions are made using five different scenarios for the number of PZEVs produced. Because the number of PZEVs grows over time and the effects of extended emission warranties are felt only as vehicles age, the predictions run through 2020.

The independent repair and dealer repair shops that participated in the survey were asked what might be done to reduce the impact of extended emission warranties. Their answers and other options for mitigating adverse effects are discussed in Chapter Seven.

Chapter Eight summarizes the findings and discusses their policy implications.

¹⁰ Non-warranty work that shifts over to dealers along with the warranty work is sometimes referred to as *drag-along work* in the repair industry.

Factors Influencing the Impact of Extended Emission Warranties and Recent Trends in Durability

This study seeks to estimate the effect of requiring PZEVs to carry a 15-year/150,000-mile emission warranty on independent repair shops while holding other aspects of CARB's emission reduction strategy for mobile sources of emissions (i.e., vehicles) constant. Ideally, this analysis would compare business at independent repair shops if warranties were not extended (the baseline) with business at independent repair shops if warranties were extended, other things being equal. The baseline would thus account for changes that would occur even if warranties were not extended, such as changes in vehicle emission standards, vehicle in-use compliance programs, and vehicle certification requirements.

This chapter first identifies factors that may affect the baseline as well as the change in business at independents due to extended warranties. It also examines how owners of independent repair shops and current and future workers at independent repair shops might be affected. Finally, in an effort to better understand how durability may change over time in the baseline, data are presented on recent trends in emission-system durability.

Factors that Influence the Impact of Extended Emission Warranties

The impact of extended emission warranties on those who own or work at independent repair shops will depend on three main factors:

- How manufacturers change the durability of emission-control systems
- How consumers change where they take their vehicles for repair
- Opportunities available to those who own and work at independent repair shops.

Each of these factors is addressed in turn.

Changes in Durability

Changes in Durability Unrelated to Extended Emission Warranties. *Durability* refers to the length of time that the emission-control system continues to meet performance standards before requiring repair. Greater durability means fewer repairs and thus less business for the vehicle repair industry. It could be that durability will improve over time for reasons that have nothing to do with extended warranties and that extended warranties would make little difference in durability. Durability is determined by a number of factors in addition to warranty requirements:

- On-board diagnostic system requirements
- CARB's in-use testing and recall programs
- The mileage level at which the vehicle is certified to meet emission-control requirements
- Concern among manufacturers about how durability affects consumer satisfaction and company reputation.

The OBD system monitors the emission control system and must meet detailed requirements specified by CARB. When an emission-system malfunction occurs, the OBD system illuminates the check-engine light on the dashboard. Manufacturers may increase the durability of emission-control equipment to avoid such malfunctions. The first generation of OBD requirements (OBDI) was phased in between 1988 and 1991. OBDII was phased in between 1994 and 1996. CARB is considering options for OBDIII, but the features of this system and the implementation dates remain undetermined as of this writing.

Every year, CARB's In-Use Compliance Program tests a number of different engine families to determine whether they comply with emission standards. As discussed later, CARB tests only a small fraction of all engine families each year. The In-Use Compliance Program changed in 2004 with the implementation of the Compliance Assurance Plan, 2000 (CAP2000). Under CAP2000, manufacturers play a much greater role in documenting compliance of their vehicles and will test all their engine families at specified mileage intervals. It seems likely that, over time, this increased scrutiny will increase the durability of emission control systems.

Manufacturers must demonstrate that their PZEVs meet emission standards at a higher mileage than the mileage for current vehicles before they can be certified for sale in California. Such demonstrations are done using protocols that simulate aging of components in laboratories or that are based on extrapolating deterioration rates from road tests on a few demonstration vehicles. For PZEVs, compliance with emissions standards is required to be demonstrated at 150,000 miles, as opposed to 120,000 miles required for standard vehicles.¹ This higher certification standard will presumably increase the durability of PZEVs regardless of the warranty requirements.

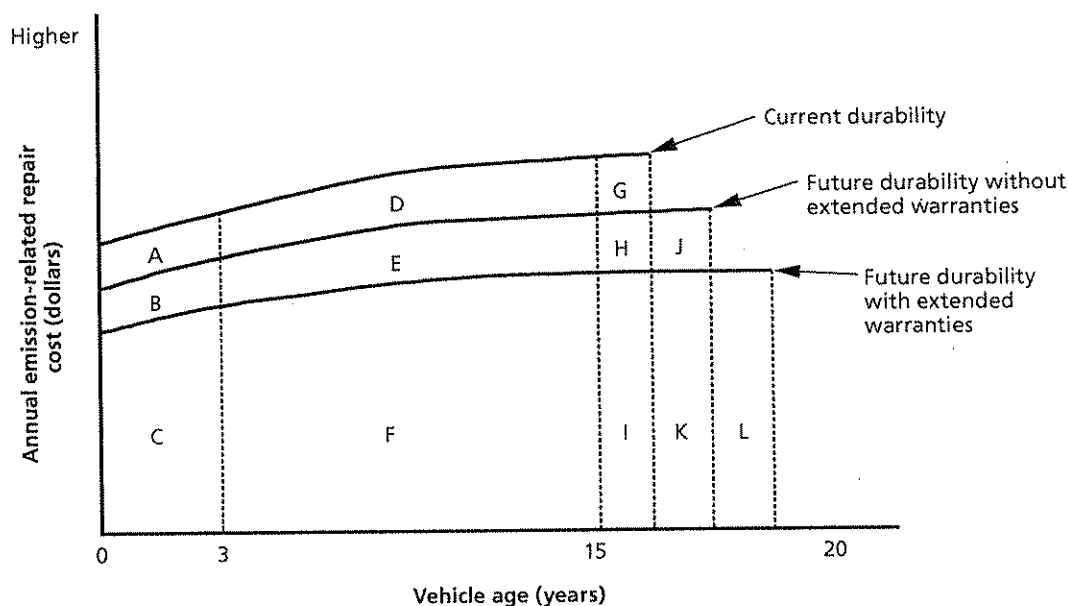
It is difficult to predict how competitive pressure will affect durability. Technological innovation might be used to reduce vehicle prices but leave durability unchanged. Technological innovation might also be used to improve durability while leaving price unchanged.

¹ Prior to 2004, manufacturers were required to certify emission control systems of vehicles at 100,000 miles. CARB's LEVII program requires the emission control system to be certified at 120,000 miles starting in 2004.

Overall, it thus seems likely that durability of emission control systems will improve over time even absent extended emission warranties. Figure 2.1 shows how increased durability might affect overall emission-system repairs. The top curve in the figure illustrates annual emission-system repair costs (at independent and dealer repair shops combined) as a function of vehicle age for non-PZEVs produced today. The area under the curve represents total costs of emission-system repairs over the life of the vehicle. The middle curve illustrates repair costs if durability improves in the absence of extended warranties. Its position reflects the fact that increased durability will reduce emission-related repairs over the expected life of current vehicles. Increased durability could also conceivably increase vehicle life, thus offsetting some of the decline in repairs that would occur if vehicle life did not change (areas J and K in Figure 2.1 represent the increased expenditures). There appears to be little empirical evidence, however, on how increased emission-system durability affects vehicle life. For example, there appear to be no studies that examine the role of emission-system performance on the decision to scrap a vehicle. If increased emission-system durability did not increase vehicle life, the middle curve in Figure 2.1 would not extend to the right of the top curve.

Changes in Durability Due to Extended Emission Warranties. When faced with longer warranties, manufacturers at one extreme may leave the design of the emission-control system unchanged. In such a case, they would simply increase the price of new vehicles to cover the expected increase in warranty costs. At the other extreme, manufacturers might redesign the system so that there is no increase in expected warranty expenditures. They may design the system with a greater margin for error, improve manufacturing quality so that fewer sub-par parts are used, or use parts that have longer lifetimes. They would again presumably increase the price of new vehicles to cover the cost of the additional durability.

Figure 2.1
Effect of Changes in Durability on Annual Emission System Repairs, by Vehicle Age



Increased durability due to extended emission warranties is illustrated by the bottom curve in Figure 2.1. As stated above, increased durability could conceivably extend vehicle life. If it does, the bottom curve will extend to the right of the middle curve. How manufacturers will respond to extended warranties depends on the relative costs of extra durability and warranty repairs (and their impact on profits) and on the impact of the various approaches on customer satisfaction and company reputation. There appear to be no empirical studies that examine the effects of extended vehicle warranties on durability. Thus, it is not known whether and how much the bottom curve in Figure 2.1 will shift down from the middle curve and extend farther to the right when warranties are extended.

Appendix B examines how the impacts of extended emission warranties compare when there are changes in durability with the impacts when there are no changes in durability. The results in Appendix B show that improvements in durability that occur whether or not warranties are extended reduce the negative impact of extended warranties on independent repair shop revenue. The negative effect is reduced because there are fewer repairs that can potentially shift from independents to dealers. In contrast, improvements in durability caused by extended warranties can add to the impact of shifting work from independents to dealers by reducing the overall repair work (at independents and dealers combined) to be done.

Taking into consideration non-emission work that is pulled along with the emission work that shifts from independents to dealers can reverse the impact of durability improvements caused by extended emission warranties. Such durability improvements reduce emission repairs, but they also reduce the non-emission work that migrates from independents to dealers. The result is that more non-emission repairs remain at independents than would otherwise be the case because there is less emission-repair work to pull along with non-emission work.² The analysis in Chapter Six investigates whether it is likely that this effect will offset the tendency for durability improvements caused by extended warranties to magnify the impact of extended warranties on independent repair shops.

Changes in Where Consumers Take Their Vehicles for Repair

The effect of extended emission warranties will depend on the extent to which drivers change where they take their vehicles for repair. In the context of Figure 2.1, this change would be represented by a change in the proportion of the area under the curves that accrues to independents. An important factor in any such change will be the driver's understanding of the warranty. If drivers are unaware of the warranty, their behavior will not change. Uncertainty about warranty provisions can lead to various outcomes. For example, drivers who are very uncertain about what the warranty covers may go to the dealer to have all sorts of problems fixed because they think some of those problems might be covered. Once those drivers get to the dealer, they may have work done even if it is not covered under warranty. On the other hand, drivers may stay with independent repair shops because they believe the warranty is very limited.

Convenience and the relative cost and quality of service at dealers versus independents will also determine how consumers respond to extended emission warranties. Consumers may have some non-warranty work done at the dealer when they take their vehicle in

² It is assumed that changes in emission system durability do not affect non-emission system repairs.

for a warranty repair if the convenience of having all repairs and maintenance done at once outweighs any savings from having the non-warranty work done at an independent. Consumers may stick with the independent if the repair costs are sufficiently low and if it is inconvenient or unpleasant to take the car to the dealer for warranty repairs.

Opportunities Available to Those Who Own and Work at Independent Repair Shops

A shift in auto-repair business from independent repair shops to dealer repair shops may result in losses to those who own or work at independent repair shops. The effects on owners and workers will depend on the speed and size of the shift and whether extended warranties mean slower, but still positive, growth in independent repair shop revenue or a faster decline in repair-shop revenue.

Slower growth in industry-wide revenues will likely mean that current repair shop owners will not enjoy the excess profits that encourage new firms to enter the industry or encourage current owners to expand their businesses. Slower growth also means less opportunity for new firms to enter the business, although the capital needed to start these firms could presumably be invested in other areas (dealer repair shops, for example). If it turned out that extended warranties caused revenue to decline more rapidly than it would have otherwise, current owners would more frequently suffer the abnormally low profits that cause firms to exit a shrinking industry. There may be some opportunities to sell facilities and equipment to dealer repair shops, but the match between what the dealers want and what the independents have to offer will likely be imprecise.

Current workers at independent repair shops will not likely be harmed if the extended warranties mean slower, but still positive, growth at independent repair shops. Slower growth may mean fewer opportunities for future workers, but there will likely be opportunities for these future workers at dealer repair shops or in other lines of work. Current workers may be adversely affected if it turns out that extended emission warranties result in a more rapid decline in revenue at independent repair shops, but the size of the loss for workers depends on the rate of decline in independent repair shop revenue and on how quickly workers are able to shift jobs. Impacts on current workers will be less if the effects of extended emission warranties are felt only gradually over time. Reduction in the work force might then occur through normal attrition. Losses will be low if workers are able to quickly find new jobs—for example, at dealer repair shops that may be hiring to accommodate increased demand.

A decline in independent repair shop revenue could reduce the number of independent repair shops, lessen competition in the repair industry, and hurt consumers as a whole. Prices for repairs might increase. Fewer independent repair shops than otherwise would be the case may mean that the remaining repair shop locations are less convenient for some consumers. There are factors that could counter such trends, however. Increased business at dealer repair shops could result in dealer repair shops opening branch shops or new dealers entering the market. Automobile manufacturers may open stand-alone repair facilities.³

³ *Stand-alone repair shops* refers to shops that are authorized to do warranty repairs but that are not directly associated with a new-car sales facility.

Recent Trends in Durability

Data available from CARB provide some insight into trends in emission-system durability in recent years.

Data Examined

To investigate trends in emission-system durability, data were assembled from CARB's

- In-Use Compliance Program
- Emission Warranty Information Reporting Program (EWIRP)
- Databases on voluntary, influenced, and ordered recalls and service campaigns
- Light-Duty Vehicle Surveillance Program.

In-Use Compliance Program. As discussed above, the In-Use Compliance Program tests vehicles that are in use to determine whether they comply with emission standards. CARB tests only a small fraction of overall engine families each year, but targets those engine families that it has reason to believe are most likely to fail. Between six and 15 vehicles in each engine family are tested. Most of the vehicles tested are approaching three years old, and are at the end of the three-year/50,000-mile warranty period (CARB, 2001a).⁴ Engine families that emit more than the standard on average are subject to recall.⁵ The percentage of engine families that fails reflects both initial emission-control system design and system durability.

Emission Warranty Information Reporting Program. Under the EWIRP, manufacturers must notify CARB when 1 percent of any emission-control part in a particular engine family and model year has been replaced under warranty. Manufacturers must then provide quarterly reports on the subsequent number of parts replaced. When more than 4 percent of an emission system-component has been replaced under warranty, CARB may require the manufacturer to replace the part on all vehicles in the engine family (California Code of Regulations, Title 13, Article 2.4, Section 2143).⁶

Voluntary, Influenced, and Ordered Recalls and Service Campaigns. Manufacturers must report all recalls for emission-related components to CARB whether or not they result from the EWIRP or In-Use Compliance Program. Manufacturers provide information on (1) recalls that are done voluntarily without any involvement by CARB, (2) influenced recalls where CARB notifies the automaker based on EWIRP data that it sees a potential problem and the automaker then initiates a recall, and (3) service campaigns. An automaker may set up a service campaign when a problem with an emission-control system causes no increase

⁴ Through 1998, CARB could test only vehicles with less than 50,000 miles. The cutoff was increased to 75,000 miles in 1999.

⁵ Engine families that emit more than the allowable amount of emissions but exceed the standard by less than 10 percent are considered "marginal" failures. Currently, CARB does not take corrective action for marginal failures, although it has the authority to do so.

⁶ For the 1994 model year and later, CARB has the authority to order recalls if the failure rate exceeds 2 percent (California Code of Regulations, Title 13, Article 2.4, Section 2143). However, current policy is not to consider recalls when the failure rate is less than 4 percent (Urkov, 2002).

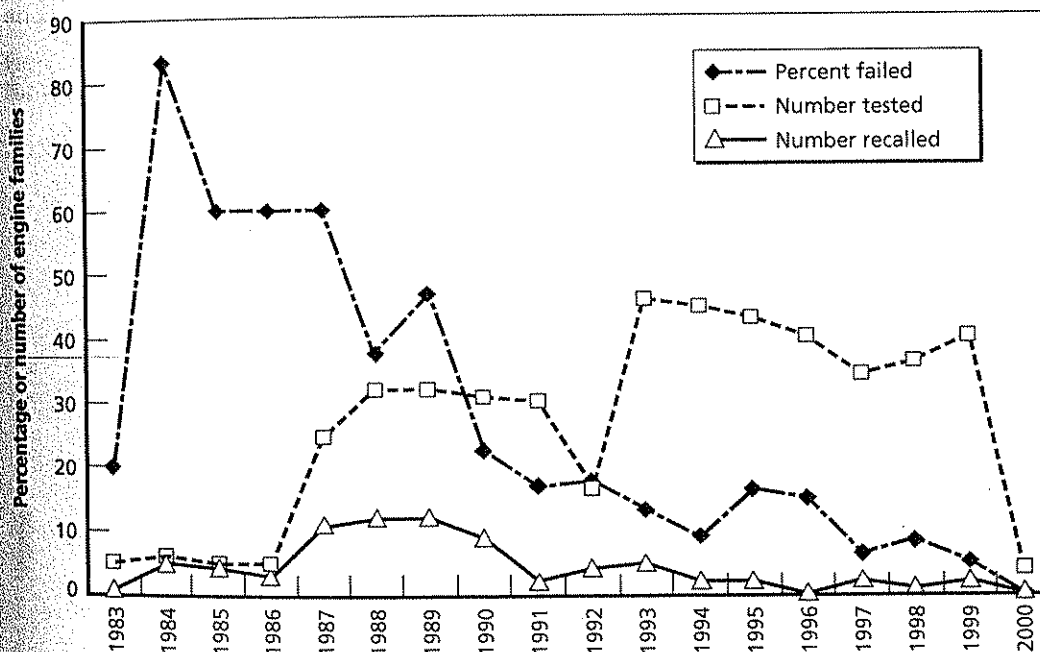
in emissions.⁷ The manufacturer notifies vehicle owners that the problem will be fixed under warranty the next time the vehicle is brought in for repair.

Light-Duty Vehicle Surveillance Program.⁸ CARB periodically recruits vehicles that are five years old for a smog-check and then repair, if necessary. The vehicles are randomly selected from vehicles registered within 25 miles of CARB's El Monte, California, office. CARB records the number and percentage of vehicles that fail the smog check and the hydrocarbon (HC), carbon monoxide (CO), and oxides of nitrogen (NO_x) emissions standards before and after repair.

Findings

In-Use Compliance Program. Figure 2.2 reports the number of engine families tested, the percentage failing the test, and the number of engines recalled from 1983 through 2000 by the In-Use Compliance Program (CARB, 2001a). The proportion of engine families failing has been falling since the program began, and there were no failures in 2000 (although only four engine families were tested in 2000).

Figure 2.2
Number of Engine Families Tested, Percentage Failing, and Number Recalled in CARB's In-Use Compliance Program



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⁷ An example might be a manufacturing defect that causes no change in current emissions but reduces the durability of the part.

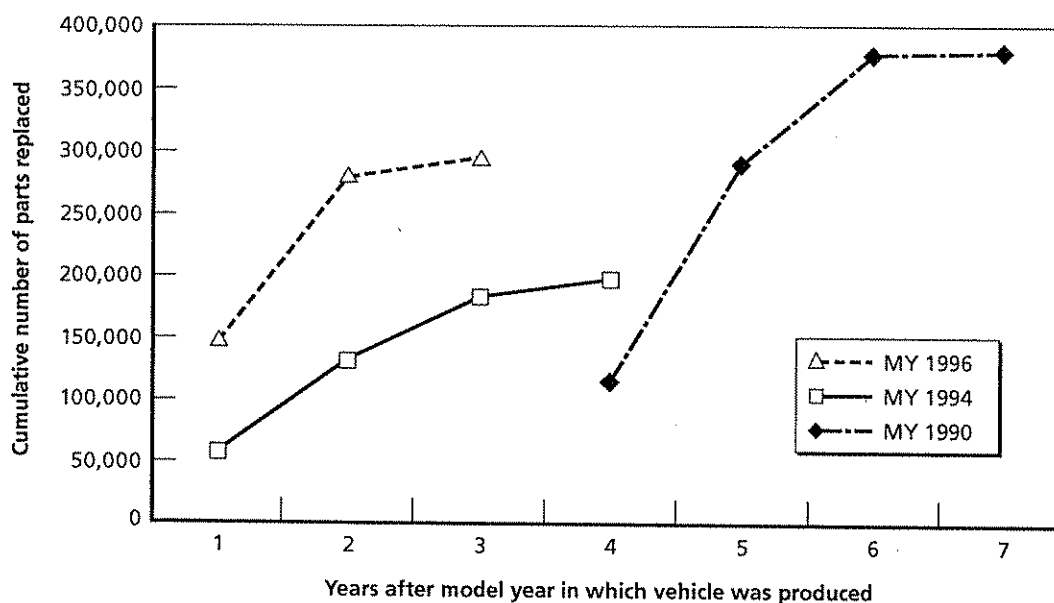
⁸ Light-duty vehicles are all passenger cars and trucks with a gross vehicle-weight rating of less than 8,500 pounds.

A number of factors may be responsible for the drop in the failure rate. The initial decline in the late 1980s may be due in part to an increase in the number of vehicles tested. CARB targets for testing the engine families most likely to fail, so the percentage of engine families failing will likely fall as the number tested rises. The sizable number of recalls between 1987 and 1990 may have induced some of the decline in the failure rate. The decline in the failure rate may also have been due to the phase-in of OBDI between 1988 and 1992, the phase-in of OBDII between 1994 and 1996, and the spread of electronic fuel injection controlled by faster computers during the 1990s.⁹ Other factors, such as changes in durability simulation protocols used in vehicle emission certification may have also played a role.

The trends in Figure 2.2 suggest that there has been a real improvement in emission-control system performance at least during the first three years of a vehicle's life. This likely implies a decline in warranty repairs during the early part of a vehicle's life, but the implications for later years are uncertain.

Emission Warranty Information Reporting Program. Figure 2.3 shows the number of replaced parts reported to the EWIRP for three different model years: 1990, 1994, and 1996. For each model year (MY), the cumulative number of parts replaced through the year specified on the horizontal axis is shown. For example, roughly 200,000 parts were replaced on MY1994 vehicles through 1998 (four years after the model year) (Carter, 2002).

Figure 2.3
Cumulative Number of Emission-Related Parts Replaced, by Number of Years Between Model Year and Reporting Year



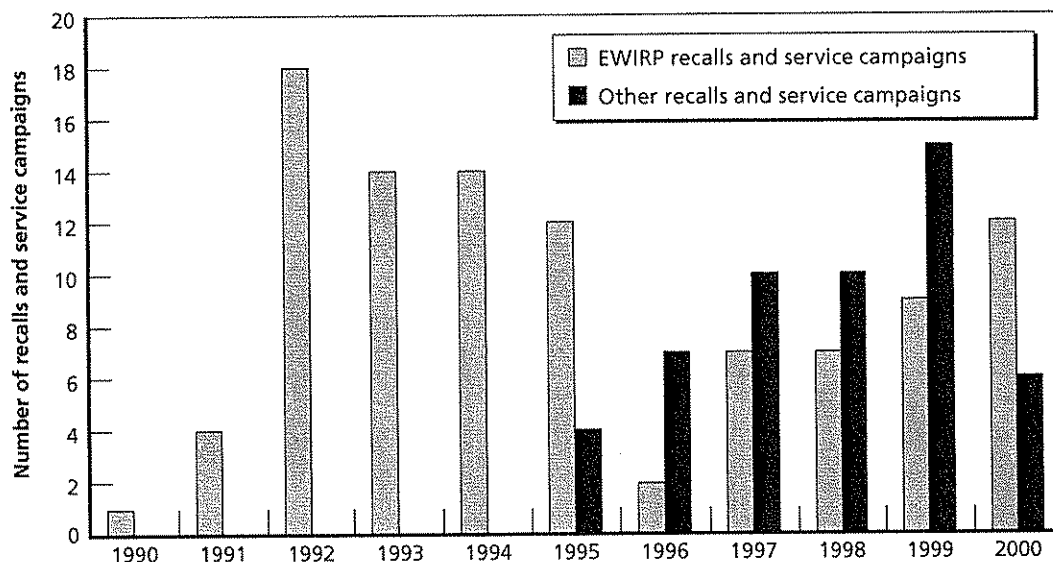
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⁹ The spread of fuel injection was not explicitly required by CARB regulations but was induced by tighter emission standards and perhaps by more stringent compliance testing.

Warranty replacements occur primarily during the first three years of a vehicle's life under a three-year/50,000-mile warranty. The slow start to the program in 1990 presumably explains the greater lag for model year 1990 than for 1994 and 1996. The number of parts replaced fell between the 1990 and 1994 model years but jumped in 1996.¹⁰ The rise between 1994 and 1996 may not reflect a decrease in durability, however. OBDII was phased in between 1994 and 1996, and the increase in warranty replacements may be due to problems detected by OBD II that were not detected before. Additional data are necessary to determine whether the MY1996 jump in replacement rates was a one-time uptick in an otherwise declining trend in replacement rates, or whether there is no underlying trend in durability.

Voluntary, Influenced, and Ordered Recalls and Service Campaigns. Figure 2.4 reports the number of recalls and service campaigns ordered by the Emission Warranty Information Reporting Program between 1990 and 2000 (CARB, 2001b) and the number of other recalls and service campaigns (CARB, 2001c). Other recalls and service campaigns include voluntary, induced, and ordered recalls and service campaigns other than those resulting from the EWIRP.¹¹ The data suggest no trend in the number of recalls. The number of EWIRP recalls and service campaigns declined between 1993 and 1996 but then rose between 1997 and 2000. The number of other recalls rose during the second half of the 1990s. As before, the rise in both measures in the second half of the 1990s may reflect the phase-in of OBDII, and not a decline in durability. What is more, the number of EWIRP recalls and, to a lesser

Figure 2.4
Number of EWIRP and Other Recalls and Service Campaigns, by Calendar Year



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¹⁰ Increases in motor vehicle sales only explain a small part of the rise between 1994 and 1996: Sales of U.S. motor vehicles rose 0.3 percent between 1994 and 1996, but U.S. motor vehicle sales rose nearly 9 percent between 1990 and 1994, even though the number of parts replaced dropped between those model years (Ward's Communications, 1999, p. 15).

¹¹ Other recalls and service campaigns include those for the In-Use Compliance Program. Figure 2.4 excludes recalls and service campaigns for software reprogramming because such recalls are not due to a component failure.

extent, the number of other recalls depends on a number of factors other than the portion of parts that fail. CARB considers factors such as the emissions impacts and the number (as opposed to percentage) of vehicles affected in deciding which recalls to pursue. Additional data are necessary to disentangle changes in recalls due to durability from changes due to other factors.

Light-Duty Vehicle Surveillance Program. Table 2.1 presents the results of the Light-Duty Surveillance Program in 1990, 1995, and 2000. The percentage of five-year old vehicles that failed a smog check dropped dramatically between 1990 and 1995 and dropped somewhat between 1995 and 2000, although the latter difference is not statistically significant. The bottom three sets of rows in Table 2.1 show the average emissions in grams per mile (gm/mi) for all vehicles tested before repair and the percentage reduction in average emissions after all repairs are done that are needed to pass the smog check. For both HC and CO, the percentage reduction in emissions falls across the three waves. The percentage reduction for NOx did not change much over the period.

The results of the Light-Duty Surveillance Program suggest that the durability of emission control systems is improving, at least during the first five years of a vehicle's life. The percentage of vehicles failing a smog check fell, and the decline in emissions reductions suggests that less substantial repairs were required. As before, however, there are other factors that could explain these trends. It could be that the smog-check program became more vigorously enforced over this period. Emissions control systems could have malfunctioned as often as before, but were more frequently required to be fixed by the smog check program before the vehicles were recruited for the Light-Duty Vehicle Surveillance Program.

Synthesis. Taken together, the data in Figures 2.2 through 2.4 and in Table 2.1 provide some suggestion that emission-system durability has improved in recent years, at least during the first three to five years of a vehicle's life. The in-use compliance data suggest improvement during the first three years of vehicle life, and the light-duty surveillance data

Table 2.1
Results of Light-Duty Vehicle Surveillance Program

Outcome	MY1985 Vehicles Tested in 1990	MY1990 Vehicles Tested in 1995	MY1995 Vehicles Tested in 2000
Number of vehicles tested	31	46	16
Average odometer reading (miles)	94,900	61,000	103,900
Percentage failing smog check	94	26	19
95% confidence interval ^a	[86, 100]	[13, 39]	[0, 38]
Initial HC emissions (gm/mi)	2.64	0.63	0.34
% reduction after repair	54	15	9
Initial CO emissions (gm/mi)	25.50	8.25	3.75
% reduction after repair	40	22	0
Initial NOx emissions (gm/mi)	1.32	0.90	0.59
% reduction after repair	21	17	21

^aConfidence intervals are calculated using $\pm 1.96 \sqrt{p(1-p)/N}$, where p is the estimated percentage and N is the sample size.

suggest improvement during the first five years. However, the data do not warrant strong conclusions. There are other possible explanations for the improvements observed, and the data on emission-parts replacements and emission-related recalls do not suggest that there has been improvement in durability (although these data may not be good indicators of underlying durability trends).

The data do not allow predictions of how durability will change over time if warranties are not extended or what the incremental effect of extended emission warranties on durability would be. First, even if it is possible to confirm improvements in durability in the recent past, it is difficult to project how durability will change in the future. Second, while the data suggest improvements in early vehicle life, how these improvements translate into changes in emissions repairs later in vehicle life is uncertain. It could be, for example, that fewer repairs earlier on mean more repairs later. Finally, this discussion has not been specific to PZEVs. While the emission-control systems in PZEVs are similar to the emission-control systems in vehicles today, PZEVs could have their own unique durability issues.

Because data are insufficient to project how durability will change in the future, the effects of extended emission warranties are predicted assuming no change in durability. In particular, it is assumed that (1) durability in the future without extended warranties will remain the same as the durability for vehicles on the road today and (2) extended emission warranties will not change emission-system durability. As demonstrated above, predicting the effects of extended emission warranties while assuming no change in durability can in principle understate or overstate projections that consider changes in durability. As shown in Chapter Six, however, it turns out that estimates developed assuming no change in durability will likely overestimate the effect of extended emissions warranties if durability does indeed improve.

Survey Methods

This chapter describes the two surveys that were conducted to collect data for this study. The chapter first describes the household survey of vehicle repair behavior and then the repair-shop survey.

Household Survey

Between April and September 2001, 366 randomly selected households were interviewed in California by phone. Households were eligible for the survey if they owned or leased a passenger car, sports utility vehicle, minivan, or pickup built between 1985 and 1999. The survey went back to 1985 because repair behavior for vehicles up to 15 years old is required to estimate the effects of a 15-year/150,000-mile warranty. The 2000 and 2001 model years were excluded because extended vehicle warranties will likely have little effect on vehicles less than two years old. Partway through the survey period, the 1997 through 1999 model years were also excluded because data for a substantial number of vehicles in these model years had already been collected. If households had more than one vehicle in the eligible range, one was randomly selected.

Survey Content

The main purpose of the household survey was to collect information on where drivers take their vehicles for repair and maintenance (independent versus dealer repair shops), how much they spend, and how these two variables vary by vehicle age and repair type. To this end, information was collected on four different types of repair and maintenance episodes:

- the last time repair or maintenance was done on a vehicle (excluding oil changes, simple maintenance such as replacing windshield wipers and light bulbs or putting air in the tires, repair of damage from a collision, and customization of the vehicle)

- the last time repair or maintenance was done on the drive train of the vehicle (unless drive train repairs were done during the episode described in the first item in this list)¹
- the last time the vehicle was repaired, at least in part, because it failed a smog check
- the last time the vehicle was repaired, at least in part, because the check-engine light came on.

A vehicle-repair *episode* includes all the repairs and maintenance done during a visit to a repair shop (or work done by the vehicle owner or by his or her friends or family members). For example, an episode can include brake work as well as repairs on the emission system.

The survey focused on repairs related to a smog check or the check-engine light because those repairs are targeted by the extended emission warranty. The check-engine light is designed to come on only when there is a problem with the emission-control system.² According to CARB staff, nearly all repairs that are required following illumination of the check-engine light will be covered by the extended emission warranty (Hughes, 2001). This analysis went back to the last repair due to a failed smog check or illumination of the check-engine light (if there were any such repairs during the period the survey respondent owned or leased the vehicle) to increase the number of these relatively rare repairs in the dataset.

For each type of repair, the survey participant was asked whether the repairs were done by

- an independent repair shop,
- a dealer repair shop, or
- a mechanic who works out of his or her home.

Participants were asked whether they did the repairs themselves or whether the repairs were done by friends or family members without pay. Participants were also asked how much they paid for the repairs, and, if they bought the parts themselves, where the parts were purchased, and how much they cost.

Survey participants were asked a series of questions about emission warranties to gauge their understanding of those warranties. They were also presented with a number of hypothetical scenarios designed to reveal how they would respond to extended emission warranties. Finally, participants were asked whether they had purchased a service contract for the vehicle selected for the survey and whether the service contract had been used to cover any of the reported repair and maintenance.³

The survey concluded by asking participants about their household income and ethnic group. This information was used to evaluate the representativeness of the sample.

¹ *Drive-train repairs* are defined as repairs to the engine, transmission, fuel system, exhaust system, or emission-control system. The following are examples of non-drive-train repairs: repair of the heater, air conditioner, or radiator; tire replacement, rotation, or rebalancing; brake work; repair or maintenance of the steering system; and repair of shocks, struts, or vehicle suspension.

² The *check-engine light* should not be confused with the *service-indicator light* on some vehicles. The service-indicator light comes on when regularly scheduled maintenance is required. And, whereas the service-indicator light can often be turned off by the driver, turning off the check-engine light can typically only be done by the dealer or repair shop.

³ *Service contracts* cover repairs and sometimes cover maintenance beyond the warranty that comes with a new vehicle. Consumers must purchase service contracts (see Chapter Four for a more detailed discussion). Service contracts are also referred to as "extended warranties," but that term is not used here to avoid confusion with the extended emission warranties required for PZEVs.

Survey Protocol and Response Rates

The survey instrument was pre-tested on the survey interviewers and colleagues of project staff and then revised. Eight interviewers who were trained over several sessions conducted the surveys. Interviewers met with project staff during the course of the survey to discuss their experiences and to resolve different interpretations of the questions being asked in the survey. The survey instrument was modified slightly during the course of the survey. Most interviews required 10 and 20 minutes to complete, and participants were assured that all the information they provided would remain confidential. Interviews were conducted in either English or Spanish.

Phone numbers were selected from a list of random phone numbers for California provided by Survey Sampling Incorporated. Calls were made during the day and in the evenings and on both weekdays and weekends. A number was called eight times at different times of the day and on different days of the week before being removed from the calling list.

Survey Sampling Incorporated does its best to remove business and government numbers and numbers that have been disconnected, but some such numbers remained in the list. Table 3.1 reports the disposition of the random phone numbers used in the survey. For many of the numbers, no household was reached. Panel A shows that many of the numbers were for businesses or government agencies or were disconnected. Panel A does not include numbers that had been called before the survey ended but were not called at least eight times.

Panel B reports the disposition of the phone numbers for which a household was reached. Of the 755 households eligible for the survey ($378 + 11 + 366$), 366 completed the survey, which translates to a 48-percent response rate. Five of the surveys were later dropped because

Table 3.1
Completion Rates for Household Survey

	Number of Phone Numbers
A. Households not reached	
Disconnected number	461
Business or government number	238
Other ^a	323
Total	1,050
B. Households reached	
Not eligible ^b	236
Over quota ^c	57
Did not speak English or Spanish	28
Refused	378
Started survey but terminated	11
Completed	366
Total	1,076
Response rate	48 percent

^aIncludes fax lines and cases in which there was no answer after eight tries.

^bThis category includes households that did not have an MY1985 through MY1999 vehicle.

^cHouseholds in this category had an MY1997–1999 vehicle, but quotas for these model years had already been met.

they were internally inconsistent or inadequately filled out. Thus, the analysis is based on 361 surveys.

Characteristics of Survey Participants and Selected Vehicles

Table 3.2 reports the household income and ethnicity for the survey respondents. (A high percentage of, but not all, participants provided this information.) Households with incomes less than \$25,000 are somewhat underrepresented in the sample, but this is to be expected because it is presumably less likely that these households will own or lease vehicles built since 1985 than will other households. Hispanics, Asians, and Pacific Islanders are also underrepresented. Further analysis is needed to determine whether vehicle repair behavior varies by ethnic group and whether the underrepresentation of Hispanics and Asians in the sample biases the results.

The age distribution of the 361 vehicles from the household survey used in the analysis is shown in Table 3.3. The reader should note that the age distribution in Table 3.3 does not match the age distribution of vehicles on the road. In the predictions of the effects of extended warranties in Chapter Six, the age distribution is reweighted to reflect the real-world vehicle-age distribution.

Table 3.2
Demographics of Household Survey Participants (percentage of respondents)

	Survey Respondents	California Census
A. Household Income	N = 337 ^a	N = 10.4 million ^c
Less than \$25,000	21	26
\$25,000 to \$50,000	33	28
\$50,000 to \$75,000	22	22
\$75,000 to \$100,000	11	10
Greater than \$100,000	12	14
B. Racial and ethnic group	N = 359 ^b	N = 33.9 million ^d
White, not Hispanic or Latino	63	47
Hispanic or Latino	17	32
Black, not Hispanic or Latino	8	6
Asian and Pacific Islander	5	11
Multi-racial	2	3
Others	2	1
Do not know	0.3	—

^aIncome was not provided by 24 participants.

^bEthnicity was not provided by two participants.

^cHousehold income is from 1990 census because 2000 data were not yet available (California Employment Development Department, "Labor Market Information: Income by Families and Households in California, 1990 Census" [www.calmis.ca.gov/file/democ90/apic11.htm]). The 1990 income cutoffs were inflated to year 2000 dollars using the consumer price index.

^dRacial and ethnic groups are based on 2000 U.S. Census (California Department of Finance, 2001).

Table 3.3
Model Year of Vehicles in Household Survey

Model Year	Age	Survey Respondents
2001	0	0
2000	1	0
1999	2	21
1998	3	29
1997	4	22
1996	5	43
1995	6	32
1994	7	23
1993	8	29
1992	9	25
1991	10	21
1990	11	22
1989	12	22
1988	13	20
1987	14	19
1986	15	15
1985	16	17
Unknown	Unknown	1
Total	—	361

Repair Shop Survey

Sample Frame

The sample frame for the repair shop survey was the California Department of Consumer Affairs' Automotive Repair Data File. All repair facilities in the state are required to register with the Department of Consumer Affairs. Registration fees are nominal, and other than filling out a form, there are apparently no registration requirements. Shops in the Automotive Repair Database are categorized by type (see Table 3.4). Shops that are likely to do the types of repairs affected by extended emission warranties are grouped in Panel A of the table. As can be seen, dealer repair shops account for less than 10 percent of all the shops that may do drive-train repairs. Shops that are unlikely to do drive-train repairs are grouped in Panel B. Because extended emission warranties are likely to affect shops that do drive-train repairs as opposed to shops that do only other repairs, the sample was restricted to shops in Panel A.

A total of 167 shops were randomly selected from the 1,605 new-car dealer repair shops in the Automotive Repair Data File. The RAND study team examined the shops' names in all repair-shop categories other than new-car dealers, and from that examination determined that dealer repair shops were for the most part accurately categorized in the new-dealer category. However, based on the names of the shops, independent repair shops were not accurately categorized in the Automotive Repair Data File. Thus, independent repair shops were randomly selected from all categories, excluding new-car dealer repair shops, and then

Table 3.4
Repair Shops Registered in California That Are Likely or Unlikely to Do Drive-Train Repairs, as of March 2001

Shop Type	Number of Shops
A. Shops Likely to do Repairs on Drive Train	
New car dealer	1,605
Independent garage	11,564
Service station	2,024
Smog-check station ^a	1,251
Foreign auto repair	1,486
Mobile automotive repair	875
Transmission repair shop	1,242
Muffler/exhaust repair shop	761
Other ^b	2,074
Total	22,882
B. Shops Unlikely to do Repairs on Drive Train	
Auto body and paint shop	4,013
Tire shop	1,437
Brakes/front-end-alignment shop	759
Glass shop	753
Motorcycle repair shop	427
Radiator repair shop	456
Other ^c	1,152
Total	8,997
C. Other^d	2,467
Total	34,346

SOURCE: California Department of Consumer Affairs, 2001.

^aSmog checks are done at many different types of repair shops, not only those included in this category.

^bIncludes chain stores (such as Pep Boys); tune-up, oil, and lube shops; used-car-only dealers; and engine-overhaul shops.

^cIncludes auto wreckers, oil-and-lube-only shops, and air-conditioning repair shops.

^dIncludes shops classified as "Other" in the Automotive Repair Database or those with a missing or invalid business type code.

shops that seemed to be unlikely to do drive-train repairs (for example, shops whose names indicated that they were a glass or brake shop) were manually removed. Ultimately, 365 independent repair shops were selected for the survey.

Survey Content

Independent repair shops were asked to provide information on five consecutive vehicles that they repaired that met the following criteria:

- Had a California license plate
- Were built in model year 1986 or later
- Had 150,000 miles or less on the odometer.

Participants were asked to list the cost of work, including parts, labor, tax, and any amounts billed to a service contract, in roughly 30 different repair categories for each vehicle. They were asked to indicate whether all, some, or none of the work in each category was required to repair a problem related to the illumination of the check-engine light and whether all, some, or none of the work in each category was required to pass a smog check. Participants were also asked how they thought their business would be affected by extended emission warranties and whether they had any suggestions for how to mitigate or reduce any negative impacts from such warranties.

Dealer repair shops were asked to provide similar information as that provided by independent shops on five consecutive vehicles that met the following criteria:

- Had a California license plate
- Were built in model year 1986 to 1998
- Had 150,000 miles or less on the odometer
- Were brought in for service because the check-engine light was on or turned on intermittently, or because the vehicle had failed a smog check.

Attention was restricted to vehicles brought into the dealer because of an illuminated check-engine light or failed smog check, because the dealer repair survey is primarily used to quantify how non-emission repairs are bundled with emission repairs. Model years 1999, 2000, and 2001 were excluded from the dealer survey, because repairs to these vehicles likely fall under the current three-year/50,000-mile emission warranty and would not be affected by extending the warranty to 15 years/150,000 miles. Dealers were asked to provide both the amount billed to the customer and the amount billed to the manufacturer in each of the roughly 30 different repair categories.

Survey Protocol and Response Rates

Repair shops were first called to explain the nature of the survey and asked if they would be willing to participate. The survey instruments were then mailed to the shops with a brief description of the study, a letter from CARB urging shops to participate, and a postage-paid return envelope. The mailing to independent repair shops also included a letter of endorsement from a coalition of aftermarket-repair industry associations.⁴ Shops regularly received return phone calls to encourage them to participate and to answer any questions they had. As an incentive to participate, each shop completing the survey was paid \$20.

Response to the survey was disappointing. While most shops said they would participate when they were initially contacted, few actually did. During follow-up phone calls, a large fraction of the shops said they had never received the survey. If a shop had not received the survey, the survey team confirmed the shop's address and resent the survey using priority mail to ensure that the survey would arrive quickly and in a distinctive package. In an effort to increase the number of participating independent repair shops, an e-mail request

⁴ The letter was signed by the Automotive Repair Coalition, the Automotive Service Councils of California, the Automotive Trade Organizations of California, and the California Automotive Wholesalers' Association.

was sent to roughly 200 shops on the e-mail distribution list of the Automotive Service Councils of California.⁵ This effort netted five responses. The number of independent repair shops sampled was increased from 365 to 370 to account for these additional five shops.

Panel A of Table 3.5 shows the disposition of the independent repair shop sample. Of the 370 shops the survey team attempted to contact, 57 could not be reached because the phone number was not in service, the number was for a fax line, it was a wrong number, or there was no answer. Another ten shops were not eligible to participate in the survey because they did not do drive-train repairs. Of the 303 independent shops that were contacted for the survey and were eligible, 48 (16 percent), completed the survey. The response rate was almost identical for the dealer repair shops (see Panel B).

These low response rates (and the small number of shops) increase the likelihood that the repair shops participating in the survey are not representative of the overall population of repair shops. For example, independent repair shops that do an unusually large amount of emission-system work, and thus have more to lose if warranties are extended, may be overrepresented in the sample. These data, therefore, are not used to estimate the overall frequency of emission-related repairs at independent repair shops. Rather, they are used to determine how non-emission-related repairs are linked with emission-related repairs. Future efforts to collect this type of information should consider either a much greater incentive to

Table 3.5
Repair Shop Survey Response Rates

	Number of Repair Shops
A. Independent Repair Shops	
Attempted to contact	370
Phone number not in service	17
No answer	15
Fax number or wrong number	25
Not eligible	10
Contacted and eligible	303
Completed survey	48
Response rate	16 percent
B. Dealer Repair Shops	
Attempted to contact	167
Phone number not in service	1
No answer	0
Fax number or wrong number	2
Not qualified	0
Contacted and eligible	164
Completed survey	28
Response rate	17 percent

⁵ The request was e-mailed by Brad Walker, executive director of the Automotive Service Councils of California.

participate in the study or a different survey mode (such as collection of data over the phone or in person).

Overall, the 48 independents and 28 dealers participating in the survey provided information on 232 and 118 vehicles, respectively (see Table 3.6). Even though dealers were asked to exclude vehicles in model years 1999 through 2001, some were included anyway. Independents also included two vehicles built before the 1986 model-year cutoff.

Table 3.6
Number of Vehicles in Repair-Shop Survey, by Vehicle Model Year

Model Year	Independent Repair Shop Survey	Dealer Repair Shop Survey
2001	0	0
2000	2	4
1999	15	2
1998	12	26
1997	19	34
1996	17	15
1995	22	12
1994	16	4
1993	17	3
1992	18	4
1991	15	5
1990	21	3
1989	21	2
1988	15	3
1987	10	1
1986	9	0
1984	1	0
1982	1	0
Unknown	1	0
Total	232	118

Expenditures at Independent and Dealer Repair Shops

This chapter presents findings on where drivers take their vehicles for repair and how repair and maintenance expenditures are split across repair categories. It begins by describing the expenditure classification scheme used in the analysis. Data from the household vehicle repair survey (see Chapter Three) are used to quantify the split of expenditures between dealer and independent repair facilities and among repair categories. Data from the dealer and independent repair shops are used to break down repair categories in more detail and to better understand how warranty repairs are bundled with non-warranty repairs.

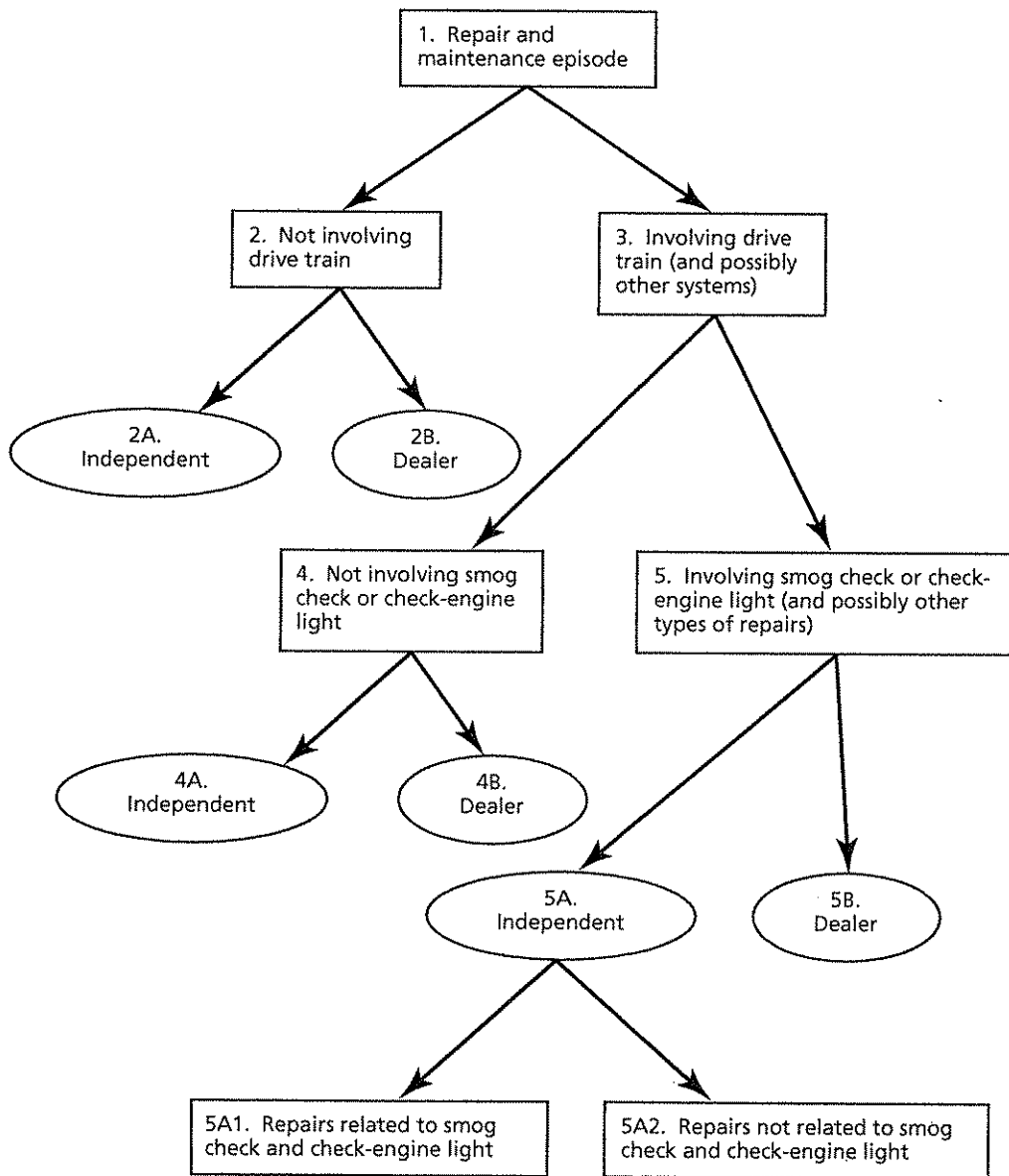
Classification of Expenditures

Figure 4.1 illustrates how vehicle-repair episodes are classified.¹ Boxes 1 through 5 categorize *entire* episodes by the type of repair that was done during an episode, and ovals 2A through 5B categorize episodes according to where the repair was done. Boxes 5A1 and 5A2 break down the different types of repairs done during a particular vehicle-repair episode.

Box 1 represents a repair and maintenance episode. As discussed in Chapter Three, repairs due to collisions or customization of the interior or exterior of the vehicle are not included. Repair and maintenance episodes are first separated into those that do not involve the drive train (Box 2) and those that do (Box 3). Episodes that involve work on the drive train can also include repair and maintenance of non-drive-train systems (the brakes, for example). Repair episodes involving the drive train are then separated into those that do not involve a failed smog check or illumination of the check-engine light (Box 4) and those that

¹ Vehicle-repair *episodes* are the events household survey respondents described when questioned about the last time they had repair or maintenance done on their vehicles or the last time they had specific types of repairs done (see Chapter Three for a description of the household survey).

Figure 4.1
Classification Scheme for Repair Episodes and Expenditures



do (Box 5). Episodes in Boxes 2, 4, and 5 are separated according to whether the work is done at an independent repair shop or at a dealer repair shop.

So far, entire repair episodes have been categorized. Boxes 5A1 and 5A2, respectively, at the bottom of Figure 4.1 separate expenditures at an independent repair shop during a repair episode involving a smog check or the check-engine light into repairs that are related to the smog check and the check-engine light and those that are not.

Box 5A1 in Figure 4.1 and the associated expenditures in Box 5A2 are expenditures that might be eliminated (due to increased durability) or transferred to dealers (which are represented by oval 5B) because of extended emission warranties. Emission warranties may also cause some shift of other repairs done at independents (Ovals 2A and 4A) to dealers (Ovals 2B and 4B).

Breakdown of Expenditures Reported in the Household Survey

Table 4.1 reports the percentage breakdown of expenditures reported for the repair episodes analyzed in the household survey. The results are reported by type of repair episode and then separately for three vehicle-age categories. The first age category covers repair episodes for vehicles that were less than three years old at the time of the repair (these vehicles may have been older at the time of the survey). Even though there is a relatively small number of repair episodes in this category, the vehicle-age cutoff was set at three years because the current comprehensive emission warranty expires when the vehicle reaches three years of age or 50,000 miles, whichever occurs first. The second category covers vehicles from three to 11 years old. The third category includes vehicles 12 years old and older. This breakpoint between the second and third age categories was selected because, on the whole, it produced the lowest amount of statistical uncertainty in the estimates. Where warranted by the number of observations, the three-to-11-years-old category was further divided into vehicles three to six years old and seven to 11 years old in some subsequent analyses. This subdivision was chosen because the current California warranty on high-priced emission parts runs until the vehicle is seven years old or has reached 70,000 miles.

The expenditures for a repair episode include only those made by a survey respondent or someone in his or her household. They do not include repairs covered under warranty or under service contracts. These repairs were excluded from the survey because survey respondents usually do not know the cost of repairs covered under warranty and often do not know the cost of repairs covered under service contracts. Assumptions on the costs of repairs paid for by service contracts used in the prediction models are described in the next section.

The division of expenditures between episodes involving a drive-train repair and episodes that do not involve a drive-train repair (see first set of rows in Panel A of Table 4.1) is based on the last repair and maintenance episode reported by a household. Thus, it should reflect the division of expenditures between drive-train and non-drive-train episodes across the population of vehicles in California in each age category. Of the 361 respondents, 298 reported that repair or maintenance had been done since they had owned or leased the vehicle, with 63 percent of the expenditures occurring during episodes involving the drive train and the remaining 37 percent occurring in episodes that did not. For vehicles zero to

Table 4.1
Breakdown of Expenditures by Repair Type and Destination, by Vehicle Age

	Vehicle Age at Time of Repair (Years)			
	All Ages ^a	0 to 2	3 to 11	12 to 16
A. Breakdown by Repair Type				
Total repair and maintenance expenditures (1)	N = 298	N = 29	N = 175	N = 90
Percentage involving drive train and possibly other systems (3)	63	40	65	65
90-percent confidence interval	[55, 70]	[6, 63]	[54, 73]	[52, 76]
Repair and maintenance involving drive train (3)	N = 195	N = 12	N = 108	N = 62
Percentage involving smog check and check-engine light and possibly other types of repairs (5)	25	14	31	15
90-percent confidence interval	[16, 37]	[0, 67]	[17, 45]	[6, 26]
B. Breakdown by Destination				
Repairs not involving drive train (2)	N = 180	N = 22	N = 110	N = 46
Percentage at independents (2A)	77	65	69	96
90-percent confidence interval for percentage at independents	[70, 83]	[39, 86]	[59, 78]	[91, 99]
Drive-train repairs not involving smog check or check-engine light (4)	N = 58	N = 3	N = 36	N = 18
Percentage at independents (4A)	54	36	58	82
90-percent confidence interval for percentage at independents	[55, 77]	[0, 100]	[43, 73]	[61, 98]
Drive-train repairs involving smog check or check-engine light (5)	N = 94	N = 14	N = 56	N = 18
Percentage at independents (5A)	67	11	63	90
90-percent confidence interval	[48, 83]	[0, 100]	[38, 83]	[76, 99]

Notes: The numbers in parentheses in the far-left column refer to the numbered items in Figure 4.1.

N = Number of repairs episodes.

^aThe number of episodes in each age category does not necessarily sum to the number of episodes under "All Ages" because the repair date or the vehicle age at the time of the survey (and thus the vehicle age at the time of repair) was missing for some vehicles.

two years old, the proportion of expenditures in episodes involving drive-train repair was 40 percent; the proportion was 65 percent for vehicles three to 11 years old.

The 90-percent confidence interval for each parameter estimate is shown in brackets in the table. There is a 90-percent probability that this interval contains the true parameter. The confidence intervals were constructed using bootstrap techniques.² Due to the small sample sizes, the confidence intervals for many of the estimates are wide. For example, the

² Samples of 361 observations were randomly drawn from the 361 original observations of the household survey, with replacement of each observation after it is drawn and the parameter reestimated. The process was repeated 10,000 times, and the 5th and 95th percentiles of the distribution for each parameter were used to construct the 90-percent confidence intervals. With 10,000 draws, the bounds of the confidence intervals were stable to two significant digits.

proportion of expenditures for repair and maintenance that occur in episodes involving drive-train repairs runs from 6 to 63 percent for vehicles less than three years old.

To help better interpret the results, Figure 4.2 overlays findings for each of the vehicle-age categories onto the expenditure classification scheme. The percentage figures shown with the vehicle-age groups refer to the percentages of total repair expenditures. For example, 13 percent of repair and maintenance expenditures on vehicles between 3 and 11 years old are made during repair episodes that involve a smog check or the check-engine light and that are done at independent repair shops (see the numbers to the left of Oval 5A). The numbers are calculated by successively multiplying the percentages for each branch in the tree diagram. (Refer back to Table 4.1 for the percentage breakdown for each individual branch.)

The breakdown of repairs and maintenance episodes involving the drive train (see Box 3 in Figure 4.2) into episodes that do and do not involve a smog check or the check-engine light (see Boxes 4 and 5) is based on the last drive-train repair. This may not necessarily be the last repair, which increases the sample size from what it would have been if only the last repair was considered. As can be seen in the second set of rows in Panel A of Table 4.1, the proportion of expenditures in episodes involving a smog check or the check-engine light rises from only 14 percent for vehicles less than three years old to 31 percent for vehicles three to 11 years old. It drops back down to 15 percent for vehicles 12 to 16 years old. This decline may be partly because emission-related problems in older vehicles are less frequently repaired than those in younger vehicles or because non-emission mechanical repairs (e.g., valve jobs, oil and water pump replacement, timing belt replacement) are much more common for older vehicles. But, the decline may also be because most vehicles in this age category do not have a check-engine light. Vehicles 12 years old in 2001 were built in the 1989 or 1990 model year, and OBDI was phased in between 1988 and 1991. What is more, many of the repairs reported in the household survey were done prior to 2001, meaning that many of the vehicles in the 12-to-16-year age category were built before model year 1989.

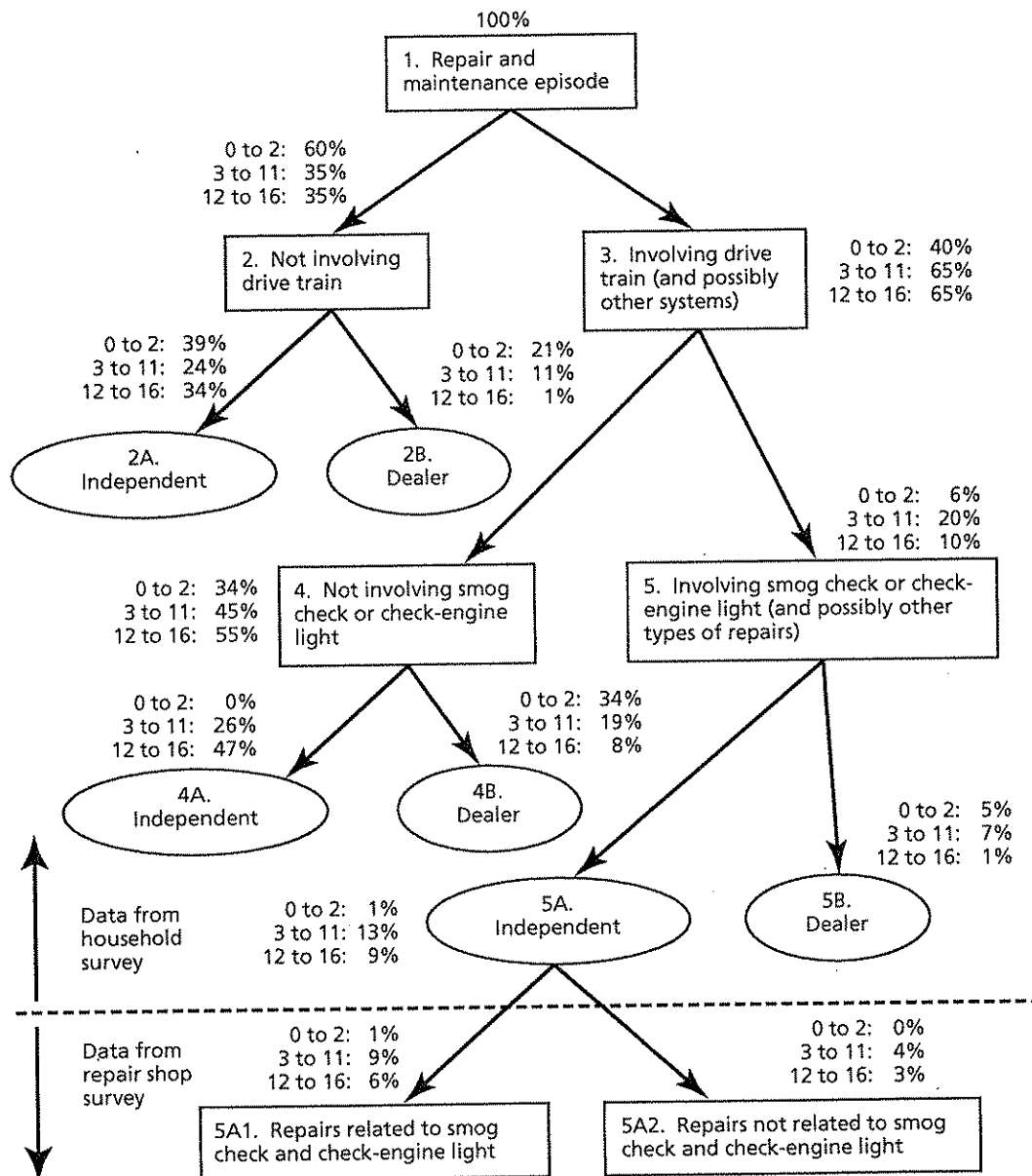
Panel B of Table 4.1 reports the percentage of expenditures that goes to independent repair shops by type of repair episode. As expected, the fraction of expenditures at independent repair shops rises as vehicles age and reaches a very high percentage by the time a vehicle is 12 to 16 years old.

Prevalence of Work at Independent Repair Shops Covered by Service Contracts

As mentioned previously, *service contracts* cover repairs and sometimes maintenance beyond the terms of the warranty that comes with a new vehicle.³ In contrast to manufacturer warranties, which are included in the price of a new vehicle, consumers must pay for service contracts. They can be purchased from a dealer of new or used cars or from other companies that offer insurance-like products. Service contracts vary in where they require repairs to be done. Service

³ As stated earlier, coverage for repairs and maintenance beyond the warranty that comes with a new vehicle is sometimes referred to as an extended warranty and sometimes as a service contract. In this report, both are referred to as service contracts to avoid confusion with extended emission warranties.

Figure 4.2
Breakdown of Repair and Maintenance Expenditures for Vehicles by Vehicle Age



contracts written by new-car dealers typically require repairs to be done at dealer repair shops. Others allow repairs to be done within a large network of authorized independent repair shops.

Not much data appear to be available on the proportion of repair and maintenance covered by service contracts at independent repair shops. Such information is relevant to the analysis here because the data on household expenditures do not include repairs or maintenance covered by service contracts. Extended emission warranties may shift some work that had been covered by service contracts from independents to dealers.

The data collected from households allow for a very rough estimate of the amount of work covered by service contracts at independents. Table 4.2 shows the percentage of vehicles in the household survey with service contracts that were active at the time of the survey. Roughly 30 percent of vehicles less than seven years old had such warranties, dropping to only 2 percent for older vehicles.

Table 4.3 shows the percentage of repair episodes at independent repair shops that were covered at least in part by a service contract, as reported in the household survey. Across all vehicle ages, coverage by service contracts was rare for non-drive-train repairs. Only 5 percent (2 percent with all repairs covered plus 3 percent with some repairs covered) of 119 repair episodes at independents for non-drive-train repairs fell into this category. Coverage for drive-train-repair episodes at independents that did not involve a smog check or the check-engine light was also infrequent: Only 6 percent of episodes were covered fully or in part by service contracts. By comparison, 14 percent of episodes involving a smog check or the check-engine light were covered fully or partially by service contracts. Coverage was less common for older vehicles.

The percentage of episodes covered by service contracts will translate into the percentage of repair-shop revenue from service contracts if (1) revenue per episode is the same whether or not service contracts were used and (2) the service contract covers all repairs. Because the service contract frequently does not include all the repairs in an episode, the percentage of revenue from covered repairs will be less than the sum of the proportion of episodes that are partially or fully covered.

The analysis in Chapter Six of extended emission warranties assumes that the proportion of revenue covered by service contracts that shifts from dealers to independents is the same as the proportion of direct household expenditures that shifts. This assumption cannot

Table 4.2
Vehicles with a Service Contract in Effect at Time of Survey

Vehicle Age at Time of Interview (years)	Number of Vehicles	Percentage of Vehicles	90% Confidence Interval
2	21	33	[16, 50]
3-6	126	29	[22, 36]
7-11	120	2	[0, 4]
12-16	93	2	[0, 4]

Note: N = 360.

Table 4.3
Percentage of Repair Episodes at Independent Repair Shops That Were Covered at Least in Part by a Service Contract, by Vehicle Age

	Vehicle Age At Time of Repair (Years)				
	All Ages ^a	2	3 to 6	7 to 11	12 to 16
A. Non-Drive-Train Repairs^b	N = 119	N = 10	N = 41	N = 32	N = 35
All repairs were covered	2	0	0	3	3
Some repairs were covered	3	20	2	0	0
No repairs were covered	96	80	98	97	97
Do not know if repairs covered	0	0	0	0	0
B. Drive-Train Repairs Not Involving Smog Check or Check-Engine Light^c	N = 82	N = 1	N = 22	N = 22	N = 37
All repairs were covered	1	0	0	5	0
Some repairs were covered	5	100	5	0	3
No repairs were covered	91	0	86	95	97
Don't know if repairs covered	2	0	9	0	0
C. Drive-Train Repairs Involving Smog Check or Check-Engine Light^d	N = 44	N = 3	N = 11	N = 16	N = 13
All repairs were covered	0	0	0	0	0
Some repairs were covered	14	100	9	6	0
No repairs were covered	86	0	91	94	100
Do not know if repairs covered	0	0	0	0	0

^aThe number of episodes in each age category does not necessarily sum to the number of episodes under "All Ages" because the repair date or the vehicle age at the time of the survey (and thus the vehicle age at the time of repair) was missing for some vehicles.

^bSee Oval 2A in Figure 4.1.

^cSee Oval 4A in Figure 4.1.

^dSee Oval 5A in Figure 4.1.

be validated, but the proportion of repair episodes covered by service contracts is small (particularly for vehicles three through 14 years old—the vehicles that are affected by the extended emission warranty), and this assumption will likely have little effect on the results.

Bundling of Emission-Related and Other Repairs

A longer emission warranty may not only cause work covered by the warranty to migrate from independent shops to dealer repair shops, it may also pull over non-warranty work that is done in conjunction with the warranty work. This subsection presents findings from the repair shop survey on how work related to a smog check or illuminated check-engine light is bundled with other work. These data are used to estimate the split of expenditures, represented by oval 5A and boxes 5A1 and 5A2 in Figure 4.1.

Table 4.4 presents the share of revenues at surveyed independent repair shops that are from repairs due to a failed smog check or an illuminated check-engine light (see the columns labeled "All Vehicles"). These numbers correspond to the ratio of revenues represented by box

Table 4.4
Share of Independent Repair Shop Revenues Related to a Smog Check or the Check-Engine Light, by Vehicle Age

Vehicle Age (years)	All Vehicles			Vehicles Repaired at Least in Part Due to a Failed Smog Check or an Illuminated Check-Engine Light		
	Number of Vehicles ^a	% of Revenues	90% Confidence Interval	Number of Vehicles ^a	% of Revenues	90% Confidence Interval
0 to 2	17	28	[12, 56]	5	85	[79, 94]
3 to 6	68	35	[16, 32]	32	70	[60, 81]
7 to 11	65	30	[21, 42]	32	65	[51, 80]
12 or more	77	30	[21, 39]	34	67	[52, 83]
All ages	230 ^b	28	[23, 33]	104 ^c	67	[59, 75]

^aThe number of vehicles in each age category does not exactly parallel the number of vehicles by model-year in Table 3.6 because the age of the vehicle when the repair was done is sometimes different than the age of the vehicle at the time of the survey.

^bVehicle age was missing for three vehicles.

^cVehicle age was missing for one vehicle.

5A1 in Figure 4.1 to the sum of revenues represented by ovals 2A, 4A, and 5A. The findings are based on 230 vehicles repaired at 48 independent repair shops.^{4,5} The 90-percent confidence intervals are also reported. These ranges are not good estimates of the share of revenues that independents will lose because of extended emission warranties. First, as will be discussed in Chapter Six, not all vehicles in California will necessarily have extended emission warranties. Second, extended emission warranties do not apply to vehicles more than 14 years old, and independents will likely continue to do emission repairs on vehicles in this age category. Third, the low response rates to the survey mean that the experiences of these shops may not be representative of all independent repair shops that do drive-train repairs. Finally, these percentages are relevant to shops that do drive-train repairs. The proportion of revenues that will be lost will be lower after independents that do not do drive-train repairs are added in.

For the above four reasons, the percentage of revenues at the surveyed independent repair shops that derives from smog-check and check-engine repairs is not used in the quantitative predictions of the effects of extended emission warranties. However, data are used on the bundling of emission-related and non-emission-related repairs during repair episodes that involve repairs related to a smog check or the check-engine light (represented by the split between Boxes 5A1 and 5A2 in Figure 4.1). As shown in the bottom row of Table 4.4, 67 percent of the revenue in such episodes was due to repairs related to a smog check or the check-engine light, with the 90-percent confidence interval ranging from 59

⁴ The 48 independent repair shops returned data on 232 vehicles, but the cost data on two vehicles were too incomplete to use in the analysis.

⁵ As described above, respondents were asked if all, some, or none of the repairs in each repair category were related to a smog check or the check-engine light. The percentage of total repairs related to a smog check or the check-engine light was calculated assuming alternatively that all and none of the repairs in the "some" category were related to a smog check or the check-engine light. The average of the two results is reported in Table 4.4.

to 75 percent. The remaining revenue was from repairs or maintenance on other systems. The percentages of revenue from repairs related to a smog check or the check-engine light in all but the first age category (0–2) are quite similar; the percentage (85 percent) is higher for vehicles less than three years old. The 90-percent confidence interval for all vehicle ages translates to between \$80 and \$160 per repair episode for repairs that are not related to a failed smog check or the check-engine light. This is repair work that may be pulled along when emission-related work migrates to dealers.

Data on dealer repairs provide another perspective on the amount of non-emission-repair work that may be pulled along with emission repair work. Specifically, the data were used to estimate the amount of non-warranty work that is done at dealers during episodes involving warranty work. The ratio suggests the amount of non-warranty work that dealers might expect to pick up with the increase in emission-related warranty work.

Table 4.5 reports findings for the 118 vehicles repaired at 28 dealer repair shops. As stated earlier, these vehicles were brought in for repair at least in part because the check-engine light was on or coming on intermittently, or because the vehicle had recently failed a smog check. For vehicles of all ages, 32 percent of the repair costs (the combined costs billed to the customer and to the auto manufacturer under the warranty) were covered under warranty. The fifth column in the table indicates that 73 percent of repairs is covered under warranty for the 48 vehicles on which warranty repairs were done. The remaining 27 percent is non-warranty work that is done at the dealership along with the warranty work. As expected, warranty work on emission-related repairs is done on only vehicles less than seven years old. Across all 48 vehicles, the amount of non-warranty work averages \$120 per repair episode. This estimate falls within the \$80 to \$160 per repair episode range estimated above for independent repair shops.

Table 4.5

Share of Dealer Repair Costs Covered by Warranty for Repair Episodes Involving a Failed Smog Check or Check-Engine Light, by Vehicle Age

Vehicle Age (years)	All Vehicles			Vehicles With Warranty Repair		
	Number of Vehicles ^a	% of Revenue	90% Confidence Interval	Number of Vehicles	% of Revenue	90% Confidence Interval
0 to 2	7	95	[90, 100]	7	95	[90, 100]
3 to 6	86	41	[32, 52]	41	72	[60, 84]
7 to 11	16	0	[0, 0]	0	–	–
12 to 14	9	0	[0, 0]	0	–	–
All ages	118	32	[24, 42]	48	73	[61, 85]

^a The number of vehicles in each age category does not exactly parallel the number of vehicles by model-year in Table 3.6 because the age of the vehicle when the repair was done is sometimes different than the age of the vehicle at the time of the survey.

Consumer Knowledge About Emission Warranties and Expected Response to Extended Emission Warranties

How extended emission warranties will affect the independent repair industry will depend in part on what drivers know about those warranties. Owners who do not know that a warranty is in place will be less likely to take their vehicles to the dealer for repair than those who do. This chapter first examines what drivers know about the emission warranties that are currently required. It then examines where drivers say they would take their vehicles for repair if emission warranties were extended. Their responses provide insight into how extended emission warranties would affect vehicle repair decisions and will be used in the prediction model presented in Chapter Six.

Consumer Knowledge About Emission Warranties

The 361 drivers who completed the household survey were asked if any type of warranty or service contract was in effect on the vehicle selected for the study. They were also asked whether any part of the manufacturer's warranty was in effect. Table 5.1 tabulates their answers to these questions, by vehicle age and mileage. The first vehicle category contains vehicles that are less than three years old and have less than 50,000 miles. As discussed in Chapter One, for this category of vehicles, manufacturers are required to repair a malfunction that causes the check-engine light to illuminate or failure to pass a smog check. The second category includes vehicles that do not meet the cutoffs for the first category but are less than eight years old and have been driven less than 80,000 miles. Manufacturers are required to warranty repairs of high-priced emission parts on these vehicles.¹ There are no

¹As discussed in Chapter One, the California warranty on high-priced emission parts runs for seven years/70,000 miles, and the federal warranty on the catalytic converter, the electronic emission control unit, and the OBD system runs for eight years/80,000 miles.

Table 5.1
Survey Respondent Knowledge of the Warranty or Service Contract in Effect on Their Vehicles, by Vehicle Age and Mileage (percentage of respondents)

	Vehicle Age/Mileage ^a		
	< 3 years /50,000 (N = 21)	> 3 years/50,000 but < 8 years /80,000 (N = 102)	> 8 years/80,000 (N = 232)
Is any kind of warranty or service contract in effect?			
Yes	86	36	5
No	14	62	94
Do not know	0	2	1
Is any part of the manufacturer-provided warranty in effect?			
Yes	81	13	0.4
No	19	83	98
Do not know	0	4	1

Notes: N = number of respondents. Percentage of respondents who answered correctly is shaded.

^aVehicle age or mileage is missing for six vehicles.

emission-warranty requirements on vehicles eight years old or older or that have been driven more than 80,000 miles.

A high percentage of drivers thought that some kind of warranty or service contract was in effect on the 21 vehicles in the three-year/50,000-mile category. Still, 19 percent of the 21 drivers thought that there was no manufacturer-provided warranty in effect.^{2,3} While drivers of vehicles in the under-three-year/50,000-mile category for the most part correctly thought that a warranty was in effect, most drivers of vehicles in the three-year/50,000-mile and eight-year/80,000-mile categories incorrectly believed that no warranty was in effect. As shown in the middle "Vehicle Age/Mileage" column of Table 5.1, 62 percent of respondents thought that no warranty or service contract was in effect, and 83 percent believed that no manufacturer-provided warranty was in effect. Consumer knowledge of emission warranties thus appears to be very limited.

Table 5.2 explores what drivers who correctly thought some type of warranty was in effect believed the warranty covered. The first question in Table 5.2 asks whether required repairs would be covered if the vehicle failed a smog check or the check-engine light came on tomorrow. There seems to be particular confusion about smog-check failures: 17 percent of the drivers with vehicles less than three years old and with less than 50,000 miles mistakenly thought that failures would not be covered, and another 28 percent did not know. The situation was similar for drivers of vehicles in the eight-year/80,000 mile category. Responses regarding the check-engine light are more accurate (see the second set of rows in Table 5.2).

² These data include data on survey respondents that own or lease their vehicles. Knowledge about warranties may differ between those who own versus those who lease. However, only 5 percent of the vehicles belonging to those who participated in the household survey were leased.

³ Knowledge about a vehicle's warranty may change when ownership of the vehicle changes. This issue was not investigated during the course of this study, but it will become increasingly important as warranties grow longer.

Table 5.2
Knowledge of What an Emission Warranty Covers for Respondents Who Thought Some Part of a Warranty or Service Contract Was in Effect, by Vehicle Age and Mileage (percentage of respondents)

	Vehicle Age/Mileage	
	< 3 years/50,000	> 3 years/50,000 but < 8/80,000
If your vehicle failed a smog check tomorrow, would any required repairs be covered by any warranty or service contract?		
	N = 18	N = 38
All would be covered	28	18
Some might, but others might not	28	47
None would be covered	17	16
Do not know	28	18
If the check-engine light came on tomorrow, would any required repairs be covered by any warranty or service contract?		
	N = 16	N = 34
All would be covered	56	29
Some might, but others might not	31	44
None would be covered	0	6
Do not know	12	21
Would replacement of brake pads be covered tomorrow?		
	N = 17	N = 38
Yes	24	3
No	59	92
Do not know	18	5
Would an oil change be covered tomorrow?		
	N = 17	N = 38
Yes	6	8
No	88	89
Do not know	6	3
Would replacement of the catalytic converter be covered tomorrow?		
	N = 17	N = 38
Yes	65	39
No	12	29
Do not know	24	32
Would an engine tune-up be covered tomorrow?		
	N = 17	N = 38
Yes	12	5
No	71	87
Do not know	18	8

Notes: N = number of respondents. Percentage of respondents who answered correctly is shaded. Percentages may not add to 100 due to rounding.

The catalytic converter is usually a high-priced part that is covered under warranty through eight years/80,000 miles.⁴ Yet, a substantial proportion of respondents who thought that some warranty was in place did not think replacement would be covered. As shown in the second-to-last set of rows in Table 5.2, 29 percent did not think the catalytic converter would be covered on vehicles between three years/50,000 miles and eight years/80,000 miles, and 32 percent did not know. While there are some circumstances in which the catalytic converter might not be covered (it may not be a high-priced part, or coverage would be

⁴ A *catalytic converter* uses catalysts such as platinum and palladium to reduce the pollutants in engine exhaust.

voided because of inadequate maintenance, for example), these answers again suggest that respondents' knowledge about emission warranties is very limited.

Overall, the findings suggest that drivers' understanding of the emission warranties required under state and federal law is poor. There is confusion about when emission warranties are in place and what they cover. The extended emission warranty on PZEVs covers the same repairs as the warranty currently required for three years/50,000 miles. Thus, drivers' understanding of this warranty is probably more relevant for projecting their knowledge about PZEV warranties than drivers' knowledge about the far less comprehensive warranty between three years/50,000 miles and eight years/80,000 miles. But even so, misperceptions about the current three-year/50,000-mile warranty suggest that extended emission warranties may have less effect on the division of business between independent and dealer repair stations than might be expected.⁵

Expected Response to Extended Emission Warranties

To better understand how extended emission warranties would affect consumer behavior, participants in the household survey were presented with a number of hypothetical scenarios. They were asked to assume that a 15-year/150,000-mile warranty that covers any repairs that are needed to pass a failed smog check and that covers most repairs that cause the check-engine light to come on was in effect. They were also asked to assume that the bumper-to-bumper warranty had already expired, which is typically three-years/36,000 miles, because extended warranties will not likely change repair behavior during this period. Survey participants were then asked where they would go first to have the problem diagnosed if

- the vehicle failed a smog check
- the check-engine light came on
- there was some other problem that was not related to a smog check or the check-engine light.

The responses are presented in Table 5.3. Confidence intervals are also included.

Sixty percent of the respondents replied that they would first go to the dealer if either the vehicle failed a smog check or the check-engine light came on. This percentage is much higher than the percentage of expenditures during drive-train-repair episodes involving a smog check or the check-engine light that go to dealer repair shops for vehicles three years old or older. As can be inferred from Table 4.1, 37 percent of expenditures in such repair episodes goes to dealers for vehicles between three and 11 years old and 10 percent goes to dealers for vehicles between 12 and 16 years old.⁶ Once drivers are at the dealer and find out the repairs are covered under warranty, they likely will have the repairs done at the

⁵ Drivers' misperceptions about extended emission warranties will be less of an issue if independent repair shops are able to provide accurate information about what is covered under warranty when drivers bring vehicles to those shops for repair.

⁶ According to Table 4.1 in Chapter Four, 63 percent of vehicles between three and 11 years old go to independents; thus, 37 percent go to dealers. A similar calculation is done for vehicles 12 to 16 years old.

Table 5.3
Where Respondents Would Take Vehicles for Initial Diagnoses Under Hypothetical Scenarios
(percentage of respondents, N = 361)

Where Driver Would Go First to Have the Problem Diagnosed	Failed Smog Check	Check-Engine Light Came On	Problem Other Than One Related to Smog Check or Check-Engine Light
Dealer			
% of respondents	60	60	36
90% confidence interval ^a	[56, 64]	[56, 64]	[32, 40]
Independent repair shop			
% of respondents	36	35	53
90% confidence interval	[32, 40]	[31, 39]	[49, 57]
Mechanic who works out of home or who went to respondent's residence			
% of respondents	2	2	3
90% confidence interval	[1, 3]	[1, 3]	[2, 4]
Other			
% of respondents	2	3	8
90% confidence interval	[1, 3]	[2, 4]	[6, 10]
Do not know			
% of respondents	1	0	0.3
90% confidence interval	[0, 2]	[0, 0]	[26, 34]

Notes: Respondents were told to assume that the bumper-to-bumper warranty had expired but that a 15-year/150,000-mile warranty was in place that covers most repairs needed to pass a smog check or extinguish the check-engine light. They were told to assume that warranty repairs must be done at the dealer. Percentages may not add up to 100 due to rounding.

^aConfidence intervals are calculated using $\pm 1.645 \cdot \sqrt{p(1-p)/N}$ where p is the estimated percent and N is the sample size ($N = 361$).

dealer. Thus, the survey responses suggest that extended emission warranties will affect the division of repair work between independents and dealers (at least if drivers are aware of the warranty).

Drivers who take their vehicles to the dealer for warranty work might also have some non-warranty work done at the same time. To better understand how common this behavior might be, household survey participants were asked whether they would have non-warranty repairs done while their cars were at a dealer for repairs covered under warranty. Panel A of Table 5.4 indicates that roughly three-quarters would have the non-warranty repairs done at the dealer if the non-warranty repairs cost less than \$100. The percentage is lower if the non-warranty repairs cost more than \$100, but 33 percent would still have them done at the dealer, and another 11 percent would go to another dealer for an estimate. These results suggest that some non-emission work will likely shift from independents to dealers along with emission-related work if emission warranties are extended and if the terms of the warranty are understood by drivers.

Panel B of Table 5.4 presents the responses to a similar question posed to survey respondents who said that they would first go to an independent if their vehicle failed a smog check and an extended emission warranty was in effect. The results indicate that not all warranty repairs would be done at the dealer. If the independent repair shop said that it

Table 5.4
Sensitivity of Choice of Repair Shop Type to Cost of Warranty and Non-Warranty Repairs

A. What the driver would do about non-warranty repairs if the vehicle failed smog check and the driver took it to a dealer^a

	Cost of Non-Warranty Repairs			
	< \$100 (N = 215)		> \$100 (N = 213)	
	% of Respondents	90% C.I. ^b	% of Respondents	90% C.I.
Have non-warranty repairs done at the dealer repair shop	74	[69, 79]	33	[28, 38]
Get an estimate at another dealer repair shop	3	[1, 5]	11	[7, 15]
Get an estimate at an independent repair shop	20	[16, 24]	47	[41, 53]
Other	4	[2, 6]	10	[7, 13]
Do not know	0	—	0	—

B. What the driver would do about warranty repairs if the vehicle failed smog check and driver took it to an independent^c

	Cost of Warranty Repairs			
	< \$100 (N = 132)		> \$100 (N = 131)	
	% of Respondents	90% C.I.	% of Respondents	90% CI
Have warranty repairs done at the independent repair shop	55	[48, 62]	24	[18, 30]
Get an estimate at another independent repair shop	14	[9, 19]	26	[20, 32]
Get an estimate at a dealer repair shop	28	[31, 45]	41	[34, 48]
Other	3	[1, 5]	8	[4, 12]
Do not know	0	—	0	—

Notes: N = number of respondents; C.I. = confidence interval. Percentages may not add to 100 due to rounding.

^aQuestion was asked only of survey participants who would first go to the dealer to have the problem diagnosed.

^bConfidence intervals are calculated using $\pm 1.645 \cdot \sqrt{p \cdot (1-p)/N}$.

^cQuestion was asked only of survey participants who would first go to an independent repair shop to have the problem diagnosed.

could do the warranty repair for less than \$100, 55 percent of respondents said that they would have the warranty repair done at the independent repair shop. The percentage drops when repair costs are more than \$100; nevertheless, 24 percent of respondents would still have the work done at the independent shop and another 26 percent would get an estimate at another independent. There appears to be real reluctance on the part of some drivers to take their vehicles to dealer repair shops. These findings suggest that not all warranty repairs would be done at the dealer if emission warranties were extended.

Predicted Effects of Extended Emission Warranties

In this chapter, quantitative predictions of the effects of extended emission warranties on independent repair shop revenue are developed. The chapter starts by describing the methods and data used to predict those effects, and then the predictions themselves are presented. (Much of this discussion is based on data presented in the tables in Chapters Four and Five; as such, those tables are referenced frequently in this chapter.)

Methods and Data

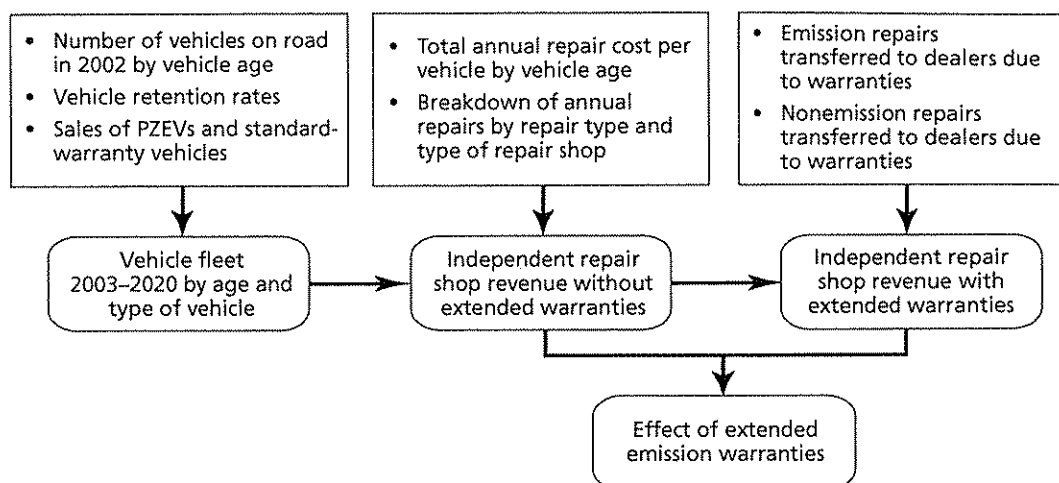
Overview

Figure 6.1 illustrates the overall approach for calculating the effects of extended emission warranties. First, estimates are developed of the number of vehicles in the fleet of light-duty vehicles in California with extended and standard emission warranties by year and vehicle age between 2003 and 2020.¹ These estimates are based on the number of vehicles on the road in 2002 by vehicle age, the fraction of vehicles that survive from one year to the next (the retention rate), and the numbers of new vehicles sold with standard and extended warranties.

A baseline assuming that the warranties on PZEVs are no different than the warranties on other vehicles is then developed. To do this, existing estimates of total repair and maintenance expenditures per vehicle per year are used. These per-vehicle estimates are multiplied by the total number of vehicles in the fleet (grouped by age) to determine annual overall repair and maintenance expenditures between 2003 and 2020. Overall expenditures are then disaggregated by repair type and destination according to the classification scheme

¹ The ZEV program took effect with the 2005 model year, although manufacturers produced PZEVs in 2003 and 2004 to generate credits that can be used to satisfy ZEV program requirements. As will be seen below, manufacturers produced more than 100,000 PZEVs in 2003 and in 2004. Thus, the effects of emission warranties are estimated starting in 2003.

Figure 6.1
Overview of Method for Calculating the Effects of Extended Emission Warranties



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in Figure 4.1. The data from the household and repair-shop surveys are used to implement this disaggregation.

The change in revenue at independent repair shops when emission warranties are extended is predicted using two sets of estimates: (1) estimates of the fraction of emission-related repairs that are transferred to dealers and (2) estimates of the amount of non-emission work that is pulled over to dealers with the emission-related work. Revenue when warranties are extended is compared with revenue in the baseline to determine the overall effect of extended emission warranties. Predictions of revenue over time are not escalated for inflation, so differences in revenue can be compared across different years.

This analysis is based on the repair and maintenance experience for vehicles on the road today. Thus, the predictions of the effects of emission warranties do not consider either the changes in emission-system durability that may occur even if emission warranties are not extended or changes in durability due to longer emission warranties. As discussed in Chapter Two, excluding both sources of change in durability may cause the predictions to overstate or understate the actual effects of extended emission warranties. Later in this chapter, the sensitivity of the results to changes in assumptions about durability will be analyzed.

The effects of extended emission warranties are first predicted using a base-case set of assumptions and parameter values. The base-case assumptions and parameter values are the best estimates given available information. As is apparent from the discussion in Chapter Four, a great deal of uncertainty remains about many of the parameters needed to predict the effect of emission warranties. How this uncertainty may cause the actual effects of extended emission warranties to differ from the base-case prediction is also examined.

The following discussion provides details on the various data and assumptions used in the analysis:

- scenarios for the number of PZEVs in the fleet
- repair and maintenance expenditures per vehicle per year

- data used to split expenditures by repair type and type of repair shop
- assumptions on which expenditures are transferred from independents to dealers.

PZEV Scenarios

Zero emission vehicles (ZEVs) remain very expensive to produce, and the incremental cost of PZEVs over standard-warranty vehicles appears to be moderate (CARB, 2000b; CARB, 2001d; Dixon, Porche, and Kulick, 2002). Thus, it seems plausible that manufacturers will satisfy as much of the California Zero Emission Vehicle Program as possible with PZEVs. CARB staff provided the research team with predictions of the number of new light-duty vehicles (LDVs) that would be sold per year between 2003 and 2020 and estimates of the number of new vehicles that would be PZEVs and ZEVs if manufacturers satisfy as much of the program as possible with PZEVs (the "maximum-PZEV" scenario presented in this chapter).^{2,3} The estimates are presented in Figure 6.2. Total sales of LDVs in California rise from roughly 1.5 million a year in 2003 to 1.8 million in 2020. Sales of PZEVs rise from 110,000 in 2003 to approximately 750,000 in 2010 and 1.0 million in 2020. The number of ZEVs produced remains low, staying below 1,000 through 2011 and rising to approximately 30,000 in 2020. Vehicles with standard warranties decline to roughly 45 percent of new vehicles by 2020.

While it seems plausible that manufacturers will produce enough PZEVs to just satisfy as much of the ZEV program as program rules allow, the number they will actually produce is uncertain. To gauge the sensitivity of the results to PZEV production levels, predictions are made assuming both lower and higher levels of PZEV production. Manufacturers could conceivably produce fewer PZEVs than ZEV program requirements allow. Accordingly, predictions are made assuming that manufacturers produce 75, 50, and 25 percent of the PZEVs in the maximum-PZEV scenario. Manufacturers could also conceivably produce more PZEVs than in the maximum-PZEV scenario. Such a scenario might occur if competitive pressures induced manufacturers to offer extended emission warranties on some or all of their non-PZEVs. The final scenario for PZEV production makes the extreme assumption that the number of PZEVs produced rises sharply between 2005 and 2008 and that all new vehicles produced from 2009 to 2020 have extended emission warranties.⁴ Table 6.1 summarizes these scenarios. In all scenarios, the total number of new LDVs sold remains unchanged.^{5,6}

² Paul Hughes, CARB Mobile Source Control Division, January 2005. CARB's new vehicle sales projections are taken from their EMFAC2002 model, version 2.2.

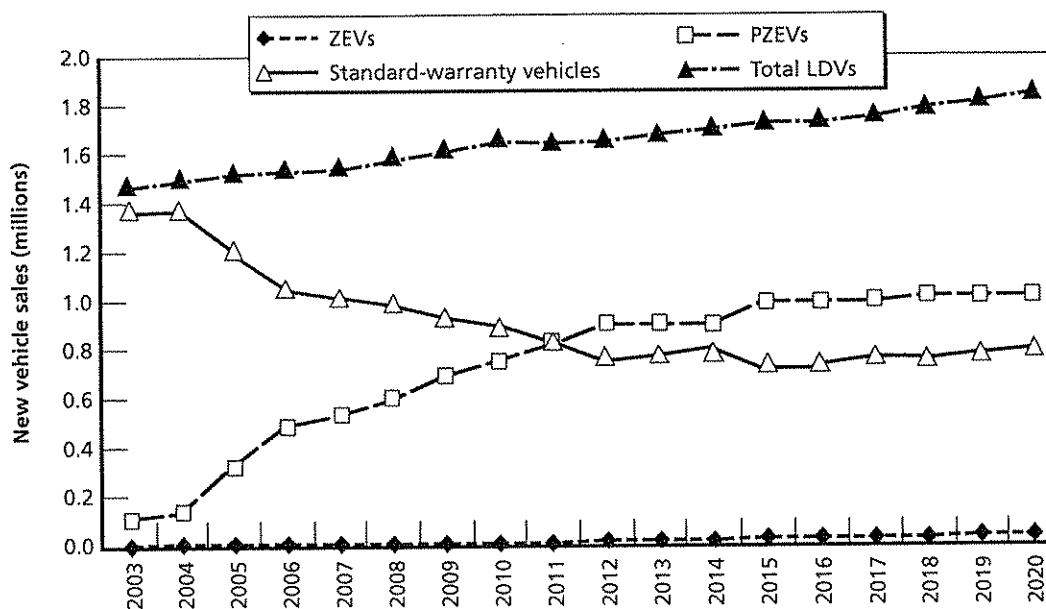
³ Light-duty vehicles are all passenger cars with a gross vehicle-weight rating of less than 8,500 pounds.

⁴ PZEVs account for 20 percent of light-duty vehicle sales in 2005, 40 percent in 2006, 60 percent in 2007, and 80 percent in 2008.

⁵ ZEVs are considered standard warranty vehicles in these scenarios.

⁶ High ZEV costs may cause prices of other new vehicles to increase and thus reduce new-vehicle sales (see Dixon and Garber, 1996). These effects may not be particularly large, however, and they are not considered in this analysis. This analysis projects that 2.1 million new LDVs will be sold in 2020 in the absence of any feedback from higher vehicle prices on vehicle sales. Harrison et al. (2001, p. 16) predict that price feedback will cause new-vehicle sales in California to be 23,761 lower in 2020 than they would be otherwise. The effect estimated by Harrison et al. is approximately 1 percent of vehicle sales. What is more, lower new-vehicle sales will likely mean that vehicles remain on the road longer, and the overall impact of the price feedback on the stock of vehicles on the road will be even less. It should also be noted that an increase in the average age of the fleet favors independent repair shops.

Figure 6.2
Sales of New Light-Duty Vehicles in California in the Maximum-PZEV Scenario



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Table 6.1
Sales of New Light-Duty Vehicles Used in the Five PZEV Scenarios (millions of vehicles)

Scenario	PZEVs	Standard- Warranty Vehicles	Total LDVs
1. Maximum number of PZEVs that can be used to satisfy ZEV program requirements			
2003-2010	3.60	8.74	12.34
2011-2020	9.46	7.74	17.21
2. 75 percent of maximum number of PZEVs			
2003-2010	2.76	9.58	12.34
2011-2020	7.10	10.11	17.21
3. 50 percent of maximum number of PZEVs			
2003-2010	1.92	10.42	12.34
2011-2020	4.73	12.47	17.21
4. 25 percent of maximum number of PZEVs			
2003-2010	1.08	11.26	12.34
2011-2020	2.37	14.84	17.21
5. All new vehicles sold after 2008 are PZEVs			
2003-2010	6.58	5.76	12.34
2011-2020	17.21	0	17.21

The above scenarios for new-vehicle sales are combined with the estimated number of light-duty vehicles on the road by vehicle age in 2002 and with vehicle retention rates to determine the number of standard-warranty and extended-warranty vehicles in the fleet through 2020.

Estimates of the number of LDVs that were on the road in 2002 by vehicle age are taken from CARB's EMFAC2002 emission model (CARB, 2003). As shown in Figure 6.3, the number of vehicles in each age category decreases gradually over time, and there is a substantial number of vehicles 15 years old and older on the road. There were slightly less than 22 million light-duty vehicles on the road in California in 2002.

Estimates of the fraction of vehicles that survive from one year to the next (i.e., the survival rate) are deduced from the EMFAC2002 model and are also shown in Figure 6.3.⁷ After some minor variation early in a vehicle's life, the survival rates decline gradually over time. Because extended warranties cover vehicles up to 15 years old, vehicles that are 15 years old and older are combined and the average survival rate for these vehicles is used.

Expenditures on Repair and Maintenance per Vehicle

The household survey done for this study allowed a breakdown of expenditures by type of repair and where the repair is done, but it does not allow a determination of the total amount spent on repair and maintenance.⁸ For the total amount spent per year per vehicle, this analysis relies on data from industry sources.

The Motor & Equipment Manufacturers Association (MEMA) publishes information on consumer expenditures nationwide in four repair categories by vehicle age:

- regular maintenance (excluding oil changes)
- engine work
- undercar work
- cooling system and air-conditioning (MEMA, 2000).

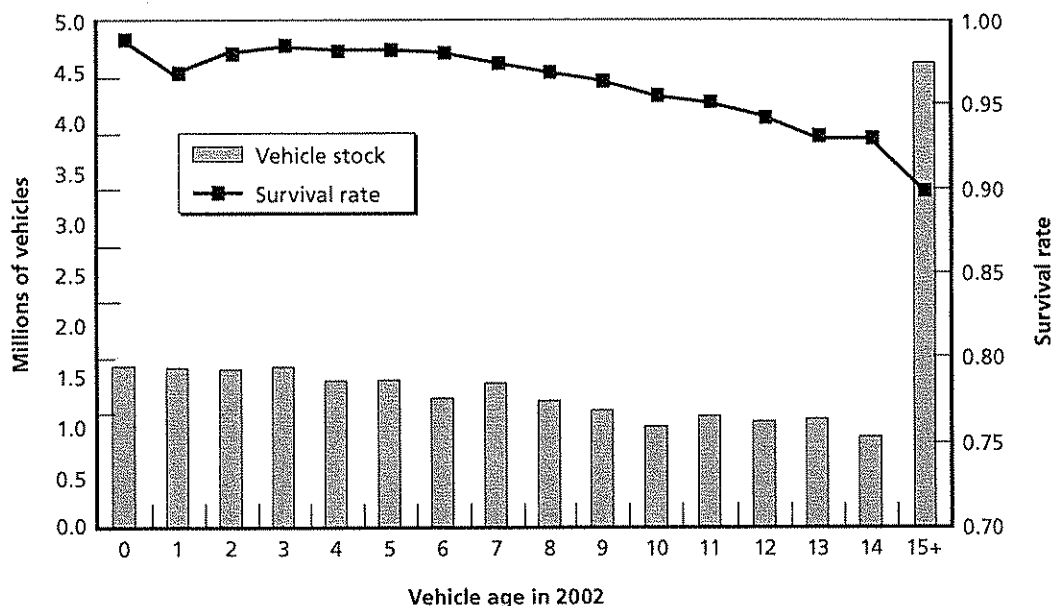
MEMA also provides information on the number of registered vehicles by vehicle age so that expenditures per vehicle can be calculated. The expenditure figures do not include expenditures for repairs due to collisions, work done under warranties or service contracts, customization of a vehicle's interior or exterior, or oil changes (Hampshire, 2002). The expenditures in the four categories listed above also do not include all the various other types of repairs or maintenance. For example, tire repair or replacement and certain types of engine repairs are not included.

The models constructed for this study require repair and maintenance expenditures by vehicle age. The MEMA data provide expenditures by vehicle age, but do not cover all expenditures. Thus, repair-cost data from the Automobile Club of Southern California (which are not reported by vehicle age) are used to scale up the MEMA numbers. The Automobile

⁷ To determine the survival rate, the EMFAC2002 model was used to predict the number of MY2000 vehicles in the fleet each year from 2000 to 2020.

⁸ The survey asked respondents for information on the last repair and the last repair of a certain type, not all repairs during a time interval.

Figure 6.3
Number of Light-Duty Vehicles in California in 2002 by Vehicle Age and Vehicle Survival Rate



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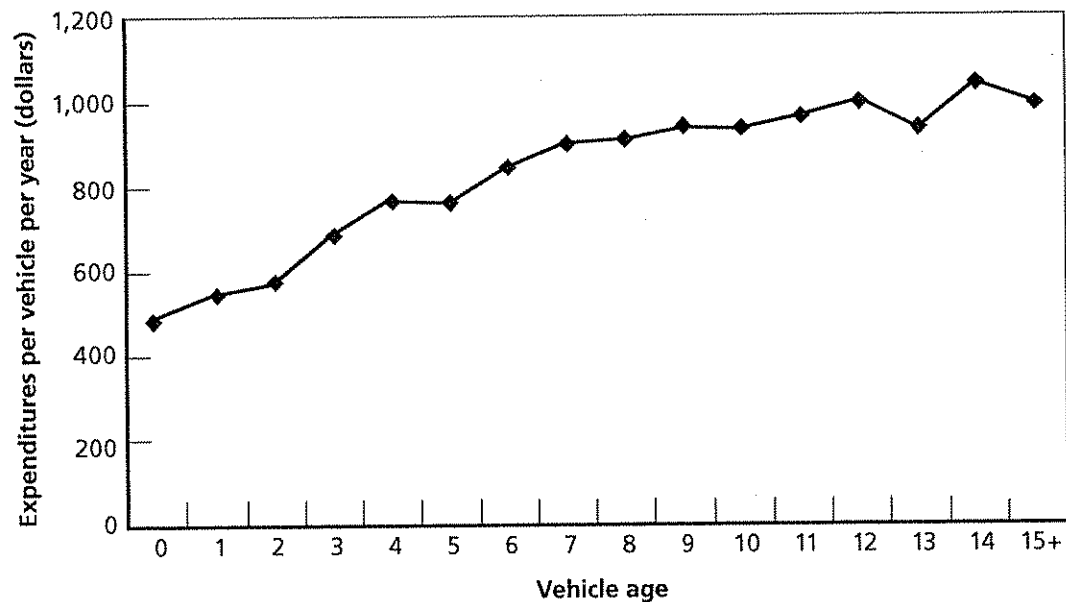
Club estimates that repair and maintenance costs amount to 6.2 cents per mile for a five-year old car (Automobile Club of Southern California, 2000). According to CARB, five-year old cars are driven approximately 12,000 miles a year on average, which implies that repair and maintenance costs are \$744 for the year. The MEMA figures are inflated by 76 percent, which brings the MEMA number for a five-year old car up to the Automobile Club estimate. The figures are also increased by 9.7 percent to account for inflation in general price levels between 2000 and 2004. The results are shown in Figure 6.4. The Automobile Club's estimates are made without regard to whether a driver bought an extended warranty or service contract. Thus, the expenditures shown in Figure 6.4 are interpreted as including repairs covered under extended warranties and service contracts. They do not include expenditures due to manufacturers' warranties, collisions, or customization of the interior or exterior of a vehicle.⁹

The Split of Expenditures by Repair Type and Type of Repair Shop

Results from the household survey conducted for this study are used to divide annual repair and maintenance expenditures per vehicle according to the classification scheme in Figure 4.1 in Chapter Four. Panel A of Table 6.2 shows the parameter values used to determine repair shop revenues for the baseline. The "Base Case" column lists the parameter values used to predict repair shop revenues without extended warranties; they are the percentages calculated from the survey data as reported in Table 4.1. The two columns at the far right of Table 6.2 list the parameter ranges used to evaluate the uncertainty of the base-case prediction (i.e., the lower and upper bounds of the 90-percent confidence interval for the estimated percentage).

⁹ The \$488 annual repair cost for new cars in Figure 6.4 seems high. It could be that the factor used to increase the MEMA figures should vary by vehicle age. Absent better information, a constant factor is used for all vehicle ages, but this issue merits further investigation.

Figure 6.4
Annual Repair and Maintenance Expenditures per Vehicle, by Vehicle Age (in constant year-2004 dollars)



RAND TR235-6.4

The last group of rows in Panel A in Table 6.2 lists the estimates used for the percentage of expenditures for repairs on an emission system during repair episodes at independents involving the emission system (i.e., some non-emission-system work may also be done during the same episode).

The household survey did not capture the costs of repairs at independent shops that were paid through service contracts; nevertheless, results from the survey are applied to overall expenditure estimates that include service contracts. Thus, in effect, service contracts (but not standard manufacturer warranties) are assumed to account for the same proportion of revenues at independents and dealers. The analysis under the section titled "Prevalence of Work at Independent Repair Shops Covered by Service Contracts" in Chapter Four suggests that extended warranties and service contracts account for a modest proportion of overall independent repair shop revenue, and the same is likely true for dealers.¹⁰ Therefore, this assumption will likely have little impact on the results; however, further research on this issue is needed.

Assumptions Used to Determine the Amount of Revenue Transferred from Independents to Dealers

The projections of the impact of extended warranties on independent repair shop revenues assume that extended warranties do not affect where people take vehicles less than three years old and 15 years old and older for repair. The amount of revenue lost by independents on vehicles between three and 14 years old depends on (1) the amount of emission-system-

¹⁰ Due to time and budget constraints, use of extended warranties and service contracts at dealers that was reported in the household survey was not analyzed.

Table 6.2
Parameters Used To Predict Effects of Extended Emission Warranties

Parameter	Vehicle Age (years)	Base Case (%)	Range Used in Uncertainty Analysis	
			Low (%)	High (%)
A. Parameters Used to Determine Breakdown of Expenditures by Type and Destination				
Percentage of total repair expenditures that occur in episodes involving drive-train repairs	0-2	40	6	63
	3-11	65	54	73
	12-16	65	52	76
Percentage of repair expenditures in drive-train repair episodes that involve the emission system	0-2	14	0	67
	3-11	31	17	46
	12-16	15	6	26
Percentage of expenditures in episodes not involving the drive train at independent shops	0-2	65	40	86
	3-11	69	59	78
	12-16	96	91	99
Percentage of expenditures in drive-train episodes not involving emission-system repairs at independents	0-2	0	0	100
	3-11	58	43	73
	12-16	86	60	98
Percentage of expenditures in drive-train episodes involving emission-system repairs at independents	0-2	11	0	100
	3-11	63	38	82
	12-16	90	76	99
Percentage of expenditures in episodes involving emission-system repairs at independents that are for repairs on the emission system	0-2	85	79	94
	3-6	70	60	81
	7-11	65	51	80
	12-16	67	52	83
B. Parameters Used to Determine Revenue Transferred to Dealers by Extended Warranties				
Percentage of expenditures on emission-system repairs in episodes involving emission-system repairs that remain at independents	3-6	10	5	15
	7-14	10	5	15
Amount of non-emission work that is transferred to dealers (the percentage of emission work that is transferred)	3-6	50	20	100
	7-14	50	20	100
Percentage of work in episodes not involving drive-train repairs that is done at dealers	12-14	15	10	25
Percentage of work in drive-train episodes not involving emission-system repairs that is done at dealers	12-14	15	10	25

related repairs transferred from independents to dealers, (2) the amount of non-emission-related repair work pulled along with the emissions-related repairs, and (3) the amount of work done during repair episodes not involving a smog check or the check-engine light that is transferred from independents to dealers.

Emission-System-Related Repairs Transferred from Independents to Dealers. The results of the household survey suggest that it is unlikely that all repairs covered by the extended emission warranty will be done at the dealer repair shops. The survey results are used to estimate the fraction of repairs related to a smog check or the check-engine light that will remain at independents even if the repairs are covered by warranty. The remaining repairs are assumed to switch from independents to dealers for vehicles between three and 14 years old when warranties are extended.

As seen in Table 5.3 in Chapter Five, roughly 35 percent of drivers indicated that they would first go to an independent repair shop if the check-engine light came on or if their vehicle failed a smog check when their vehicle was covered by an extended emission warranty. Twenty-four percent said they would have warranty repairs done once they are at the independent shop, even if those repairs cost more than \$100 (refer to Table 5.4).¹¹ These survey results imply that 9 percent (0.35×0.24) of expenditures on emission-system-related repairs would stay at independents. The fraction of drivers who would first go to independents if their vehicles needed an emission-system-related repair *and* who would then have the emission warranty work done once they are at an independent shop ranges from 6 to 12 percent (based on a 90-percent confidence interval).¹²

The breakout of repairs by type of shop on vehicles less than three years old that were reported by households is consistent with these results. Emission-system repairs are currently covered under the standard emission warranty for three years/50,000 miles, yet the survey suggests that 9 percent of expenditures on emission-related repairs on vehicles less than three years old is done at independents.¹³ The sample size is small, and the sampling error is great for vehicles less than three years old, but the parameter estimates are at least consistent with what households said they would do if warranties were extended.

In the base-case predictions, 10 percent of emission-related repairs is assumed to remain at independents for vehicles between three and 14 years old (see first set of rows in Panel B of Table 6.2). The data suggest that the actual value might fall anywhere between 5 and 15 percent, and this range is used to examine how uncertainty in the underlying parameters affects the predicted effects of extended warranties.

Non-Emission Repairs Pulled Along with Emission Repairs. Data from the repair shop survey are used to estimate the amount of non-emission-related work that will be pulled along with emission-related work from independents to dealers. Dealers reported that 72 percent of the repair costs on vehicles between three and six years old that were brought in

¹¹ Repairs that cost more than \$100 are used in the analysis here because the household survey data indicated that the vast majority of total repair expenditures are from episodes with repair costs over \$100.

¹² Using data from Tables 5.3 and 5.4, this range is calculated as follows: $0.32 \times 0.18 = 0.06$, and $0.40 \times 0.30 = 0.12$.

¹³ Referring to Table 4.1 in Chapter Four, 11 percent of expenditures in repair episodes involving a smog-check or the check-engine light for vehicles less than three years old are made at independents, and 85 percent of these expenditures are emission related (see Table 4.4 in Chapter Four). The product of 11 percent and 85 percent is 9 percent.

for repairs at least in part due to a failed smog check or an illuminated check-engine light were covered by the standard emission warranty (see Table 4.5). This percentage implies that non-emission repairs done during the repair episode amount to 39 percent of the emission repairs during the episode, or, to put it another way, 39 cents of non-emissions work is pulled along for every dollar of emissions work.¹⁴ The confidence interval on the fraction of total repair costs covered by warranty implies that the non-emissions work is between 19 to 67 percent of emissions work.

Non-emission-related repairs as a percentage of total repairs on vehicles brought into independent shops at least in part for emissions-related reasons provide the basis for another estimate of the amount of non-emission work that will shift to dealers along with the emission-related work. Using this percentage will likely result in an overestimate, however, because it is unlikely that all non-emission work will be transferred. The second column from the right in Table 4.4 indicates that, for vehicles between three and six years old, 70 percent of repair costs during repair episodes at independents that involve emission-related repairs are emission-related. This percentage implies that non-emission repairs at independents during these types of episodes are 43 percent of emission repairs.¹⁵ (The 90-percent confidence interval runs from 23 to 76 percent.) This estimate and the confidence-interval range are quite close to the estimate and confidence interval at dealer repair shops for vehicles of the same age. Non-emission repairs as a percentage of emission related repairs at independents is somewhat higher for vehicles 7 to 11 years old. Non-emission-related repairs are 53 percent of emission-related repairs for vehicles 7 to 11 years old, and the 90-percent confidence interval runs from 25 to 96 percent (based on data in Table 4.4).

Based on the above results, the amount of non-emission work that migrates from independents to dealers is set to 50 percent of the emission-related work that transfers from independents to dealers in the base case. While there is uncertainty on what the actual percentage will be, existing data suggest that it will likely fall between 20 and 100 percent. This range is used to evaluate the uncertainty of the predictions (see third-to-last row of Table 6.2).

Repairs Not Involving a Smog Check or the Check-Engine Light. Extended emission warranties may induce drivers to go to the dealer more frequently for repairs, including for repairs that have nothing to do with a smog check or the check-engine light. In the household survey done for this study, drivers were asked where they would take their vehicles for a problem not related to a smog check or the check-engine light if the standard warranty had expired but the extended emission warranty were still in effect. As shown in Table 5.3, 36 percent said they would first go to the dealer to have the problem diagnosed. Once at the dealer, 33 percent said they would have non-warranty repairs that cost more than \$100 done at the dealer, and 11 percent said they would get an estimate at another dealer repair shop (see Table 5.4). Thus, one might expect roughly 15 percent of repairs in repair episodes

¹⁴ Non-warranty work = $((1-p)/p) \times \text{warranty work}$, where p is the fraction of total expenditures covered by warranty.

¹⁵ Non-emission repairs = $((1-p)/p) \times \text{emission repairs}$ where p is the fraction of total expenditures that are emission-related.

not involving a smog check or the check-engine light to be done at dealers during the non-warranty period.¹⁶

While substantially more than 15 percent of repairs not involving the drive train are done at dealers for vehicles less than three years old and vehicles between three and 11 years old, the percentage of work done at dealers is less than 15 percent for vehicles 12 to 16 years old (see Panel B of Table 4.1). When warranties are extended, it is assumed that the amount of such repairs done at dealers rises to 15 percent for vehicles 12 to 14 years old (see the second to last row of Table 6.2). The percentage is allowed to vary between 10 and 25 percent in evaluating the uncertainty of the predictions.¹⁷ Similar assumptions are made for the percentage of drive-train repairs not involving a smog check or the check-engine light that are done at dealer repair shops.

Calculation of Probability Intervals

To gauge the amount of uncertainty in the predictions, a 90-percent probability interval is constructed for the base-case prediction of the effects of extended emission warranties on independent repair shop revenue. There is a 90-percent chance that the effect of extended emissions warranties will fall in the interval, given the assumptions on the distributions of the underlying parameters. The probability interval is conditional on PZEV sales, total LDV sales, vehicle stocks in 2002, vehicle survival rates, and repair and maintenance expenditures per vehicle per year. In addition, the durability of the emission-control system is assumed not to change.

Each of the parameters in Table 6.2 is assumed to be statistically independent and uniformly distributed over its specified range.¹⁸ A value is randomly selected from each parameter range and the resulting set of values is used to predict the effects of extended emission warranties. This process is repeated 10,000 times, and the 5th and 95th percentiles of the distribution for each outcome of interest are reported.¹⁹

Simulation Results

In this section, results of a simulation in which PZEV emission warranties are the same as standard emission warranties are first presented. This case provides a prediction of what independent repair shop revenue would be if there were no change in warranties, and it serves as the baseline for the predictions with extended warranties. Next, the effect of the

¹⁶ The product of 0.36 and $(0.33 + 0.11)$ is approximately 0.15.

¹⁷ The lower bound was arrived at by multiplying the lower bound for the percentage that would first go to the dealer for problems not related to a smog check or the check-engine light (32 percent; see Table 5.3) by a rough estimate of the lower bound that would then have repairs done at the dealer (28 percent plus 7 percent; see Table 5.4). The upper bound is calculated similarly and rounded up to 25 percent.

¹⁸ Dixon and Garber (1996, p. 247) found that the results in another application of this approach were nearly the same when the parameters were assumed to be normally distributed, with a 90-percent probability that the parameter is inside the endpoints of the uniform distribution.

¹⁹ The probability intervals are stable to at least two significant digits with 10,000 draws.

extended warranties using the base-case parameter values when manufacturers satisfy as much of the ZEV program with PZEVs as possible (the maximum-PZEV scenario) is predicted. Finally, results for scenarios with fewer PZEVs and more PZEVs are presented.

Repair Shop Revenue Without Extended Warranties (the Baseline)

Table 6.3 presents predictions of the number of vehicles and expenditures at independent and dealer repair shops when manufacturers satisfy as much of the ZEV program as possible with PZEVs but when PZEVs carry a standard emission warranty. This prediction assumes that annual repair and maintenance expenditures per vehicle (controlling for vehicle age) do not change and that people do not change where they take their vehicles for repair.

The number of PZEVs in the fleet rises gradually from 110,000 in 2003 to 11.2 million in 2020. By 2020, PZEVs account for 38 percent of the fleet. The number of vehicles in the fleet with a standard warranty declines gradually over time. Overall, the number of vehicles in the fleet increases 32 percent between 2003 and 2020.^{20, 21}

The second set of rows in Table 6.3 indicates that repair and maintenance revenue at independents and dealers combined in California totals \$18.5 billion in 2003, rising to \$24.7 billion in 2020. The projections are in constant year-2004 dollars and do not consider inflation in general prices that may occur over the period.

Table 6.3
Results Without Extended Emission Warranties for the Maximum-PZEV Scenario

	2003	2005	2010	2015	2020
Light-Duty Vehicles in Fleet (millions)					
PZEVs	0.1	0.6	3.4	7.4	11.2
Vehicles with standard warranty	22.1	22.6	21.9	19.9	18.0
Total	22.2	23.1	25.3	27.3	29.2
Repair and Maintenance Revenue in California (\$billions) in constant year-2004 dollars					
Independents	13.2	13.8	15.4	16.7	17.9
Dealers ^a	5.3	5.6	6.0	6.4	6.8
Total	18.5	19.4	21.4	23.1	24.7
Percentage of Repair Industry Revenue at Independents by Vehicle Age					
0 to 2	52	52	52	52	52
3 to 11	63	63	63	63	63
12 and above	88	88	88	88	88
All vehicles	71	71	70	69	69

^aExcludes dealer revenue from repairs covered by standard manufacturer warranties.

²⁰ The increase in the size of the fleet is driven by a 26 percent increase in new vehicle sales between 2003 and 2020 and higher retention rates than have been used in previous versions of the EMFAC model.

²¹ The projected increase in the size of the light-duty vehicle fleet is similar to that predicted by the EMFAC2002 model. The EMFAC2002 model predicts that there will be 30.0 million light-duty vehicles in 2020.

The estimate for 2003 translates to \$154 billion when scaled up to the nation as a whole using the proportion of vehicles registered nationwide that are in California.^{22, 23} Estimates from industry associations put the size of the aftermarket repair industry in 1999 at roughly \$150 billion or \$170 billion in year-2004 dollars (MEMA, 2000, p. 3; Automotive Aftermarket Industry Association, 2000, p.). The \$154 billion estimate does not include some expenditure categories that are included in the industry-association estimates. Examples include appearance products and related services, car audio and entertainment centers, and paint, body, and equipment (MEMA, 2000, p. 30). However, it does include repairs covered by extended warranties and service contracts that are excluded from the MEMA estimate. Overall, the predicted size of the repair and maintenance market in California is roughly comparable with industry estimates.²⁴

Approximately 70 percent of predicted annual repair expenditures for all light-duty vehicles in California go to independent repair shops and 30 percent to dealers (see the bottom row of Table 6.3). The independent share is somewhat lower than estimates from other sources, but comparisons are difficult. MEMA (2000, p. 53) reports that roughly 80 percent of expenditures go to independents.

Projected revenue at independent repair shops grows 36 percent between 2003 and 2020 if emission warranties are not extended. This rise is driven by the 32 percent increase in the size of the vehicle fleet over this period and is compounded somewhat by a slight increase in average vehicle age.²⁵

Effects of Extended Emission Warranties

For the maximum-PZEV scenario, the predicted effect of extended emission warranties on the revenue of independent repair shops is presented in Figures 6.5 through 6.8. Each figure shows the effect assuming the base-case set of parameter values (the middle line in each figure) and the 90-percent probability interval for the effect. Figure 6.5 reports the percentage difference between annual revenue at independent repair shops with extended warranties and annual revenue at independent repair shops without extended warranties for each year from 2003 to 2020. For example, independent repair shop revenue is approximately 0.8 percent less in 2010 with extended warranties than without extended warranties using the base-case set of parameter values. Figure 6.6 depicts the dollar difference in annual revenue at independent repair shops with extended warranties versus annual revenue at independent repair shops without extended warranties. For example, revenue is approximately \$120 million less in 2010 with extended warranties than without extended warranties. Annual independent repair shop revenue with extended emission warranties is reported in Figure 6.7. Finally, Figure 6.8 shows the change in independent repair shop

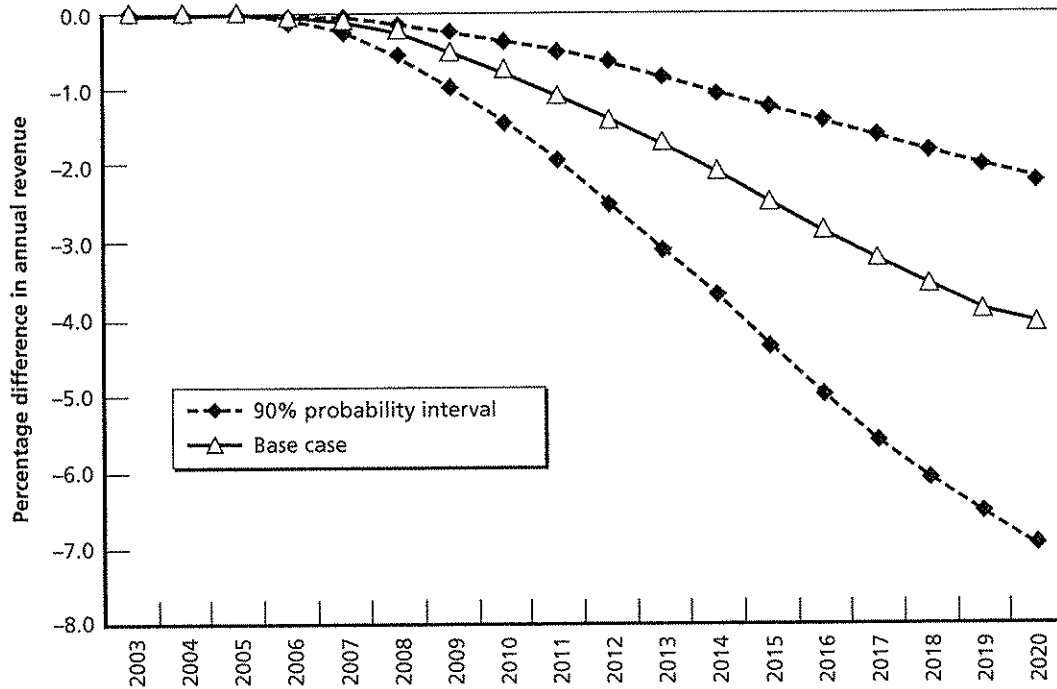
²² Approximately 12 percent of the 208 million vehicles registered nationwide in 1997 were in California (Ward's Communications, 1999, p. 37).

²³ To put these numbers in perspective, California's gross state product was \$1.2 trillion in 1999 (California Department of Finance, 2001). The U.S. gross domestic product was \$10.2 trillion in 2001 (U.S. Bureau of Economic Analysis, 2002).

²⁴ All estimates exclude collision repairs and repairs covered by the manufacturer's warranty.

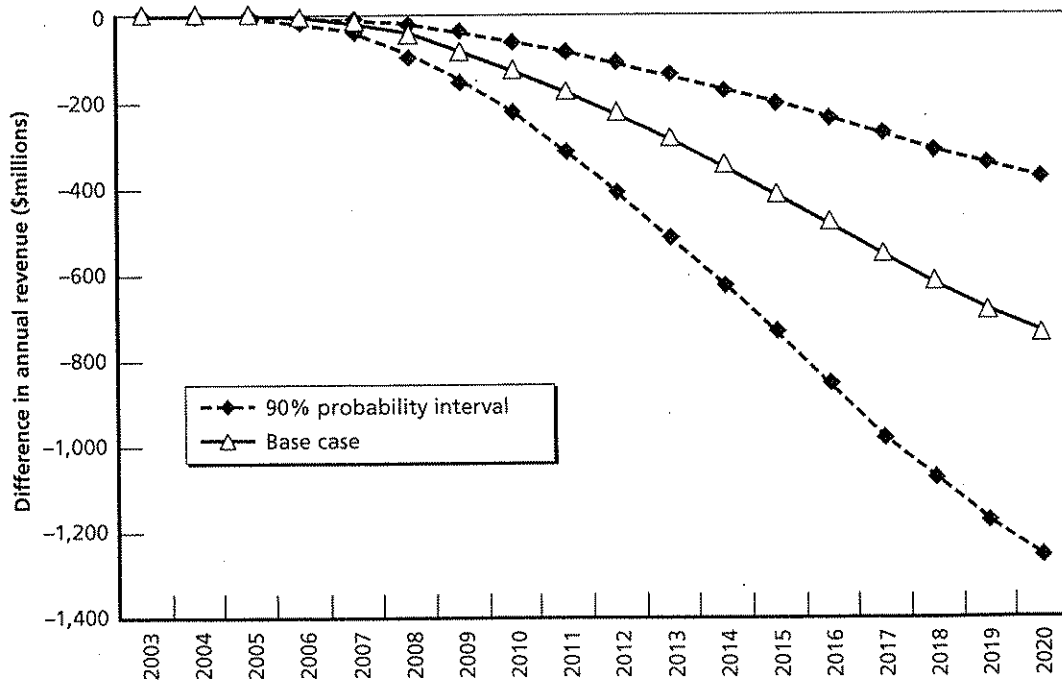
²⁵ The slight increase in average vehicle age is due in part to the use of higher retention rates than were used in previous versions of CARB's EMFAC model. A rise in vehicle age increases the fraction of overall repairs at independent repair shops.

Figure 6.5
Percentage Difference in Annual Revenue at Independent Repair Shops Due to Extended Warranties, 2003–2020, Maximum-PZEV Scenario



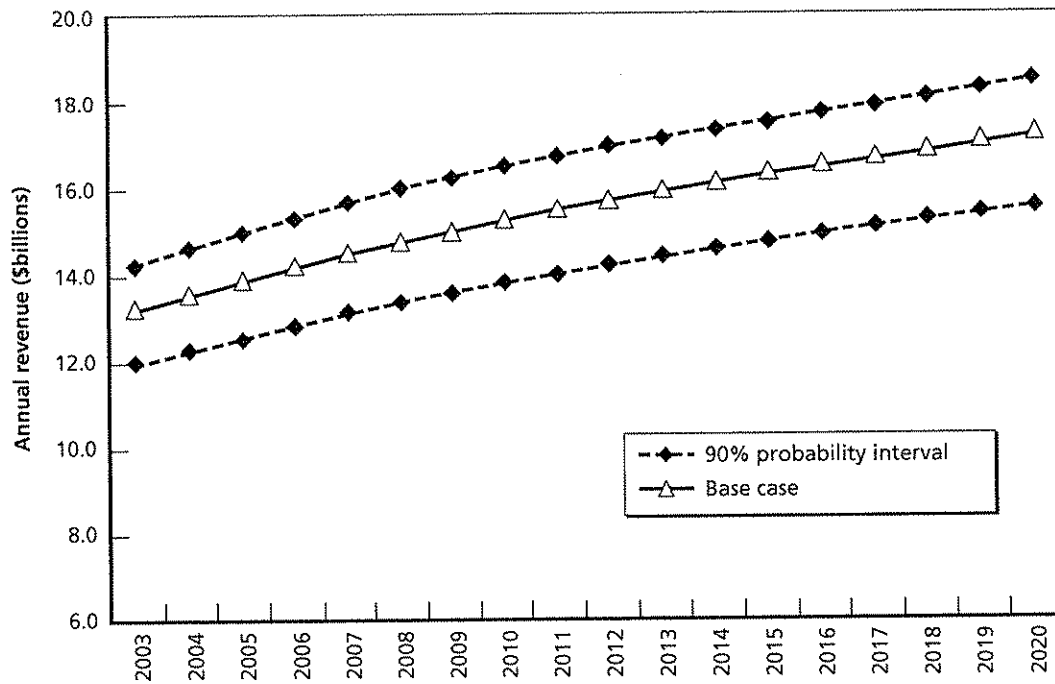
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Figure 6.6
Dollar Difference in Annual Revenue at Independent Repair Shops Due to Extended Warranties, 2003–2020, Maximum-PZEV Scenario



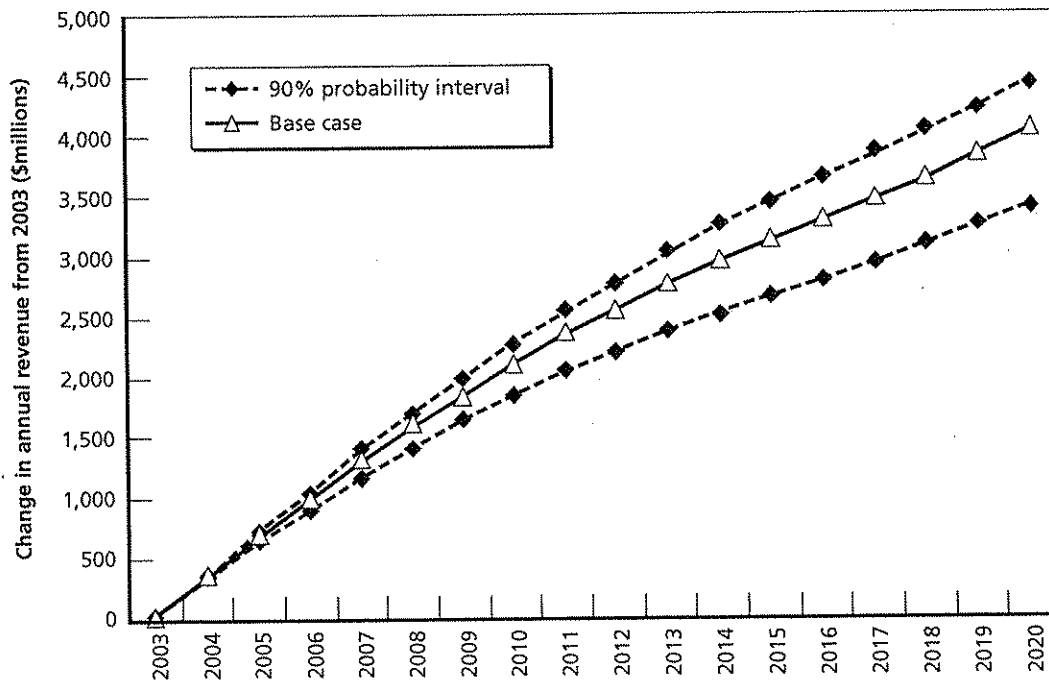
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Figure 6.7
Annual Revenue at Independent Repair Shops with Extended Emission Warranties, 2003–2020, Maximum-PZEV Scenario



RAND TR235-6.7

Figure 6.8
Change in Annual Revenue at Independent Repair Shops from 2003 with Extended Warranties, 2003–2020, Maximum-PZEV Scenario



RAND TR235-6.8

revenue with extended emission warranties from the level in 2003. For example, independent repair shop revenue is projected to be approximately \$2.1 billion higher in 2010 than in 2003 in the base case, controlling for inflation.

Extended emission warranties have no effect between 2003 and 2005 because the extension does not affect the current three-year/50,000-mile warranty. After that, the impact on independent repair shops rises gradually as the number of PZEVs three years old or older increases. By 2020, annual revenue at independent repair shops is 4.1 percent lower (approximately \$730 million lower) in the base case than it would be without extended warranties.

Substantial uncertainty in many of the underlying parameters results in a 90-percent probability interval for the percentage decline in revenue in 2020 that ranges from 2.2 percent to 6.9 percent (\$375 million to \$1.3 billion).

Even though extended warranties will reduce revenue at independent shops from what it would be otherwise, independent repair shop revenue is still expected to rise between 2003 and 2020. As shown in Figure 6.7, projected revenue in California rises from \$13.2 billion in 2003 to \$17.2 billion in 2020. This increase is driven by an increase in the size of the vehicle fleet.

Sensitivity of Results to Changes in the Number of PZEVs

As can be seen from Table 6.4, the effect of extended warranties on independent repair shop revenue is proportional to the number of PZEVs produced. The first four rows demonstrate that the impact of extended warranties declines as the number of PZEVs produced falls. The last row shows that under the extreme assumption that all vehicles produced after 2008 have extended warranties, independent repair shop revenue in 2020 is 7.7 percent lower than if there were no extended emission warranties. In spite of this effect, revenue at independent repair shops still grows by \$3.4 billion, or 25 percent, between 2003 and 2020. The growth in independent repair shop revenue in all these scenarios is conditional on the projected increase in fleet size over this period.

Sensitivity to Changes in the Durability Assumptions

So far, this analysis has assumed no change in emission-system durability. Improvements in durability that occur in the absence of extended warranties reduce the negative impacts of extended warranties on independent repair shops. Improvements in durability caused by extended warranties may either increase or decrease the impacts of extended warranties. To examine whether improvements in durability might magnify the negative impacts predicted here, changes in independent repair shop revenue are predicted assuming that emission warranties increase emission-system durability. The predictions are made using the extreme assumption that there would be no change in durability without emission warranties, and that the increase in durability induced by emission warranties would completely eliminate all emission-related repairs during the life of a PZEV.²⁶

²⁶ The possibility that increased durability might increase vehicle life is not considered. Assuming no increase in vehicle life does not weaken the argument, however, because increasing vehicle life would tend to dampen the effect of extended warranties on independent repair shops.

Table 6.4
Effects of Extended Warranties on Independent Repair Shop Revenue for Various PZEV Sales Levels

Scenario	Growth in Revenue Between 2003 and 2020 With Extended Warranties		Effect of Extended Warranties on Revenue in 2020	
	(\$millions)	Percent Change	(\$millions)	Percent Change
1. Maximum PZEVs	4,000	30	-730	-4.1
2. 75 percent of maximum PZEVs	4,100	32	-550	-3.1
3. 50 percent of maximum PZEVs	4,400	33	-370	-2.0
4. 25 percent of maximum PZEVs	4,500	34	-180	-1.0
5. All new vehicles are PZEVs after 2008	3,400	25	-1,400	-7.7

Note: This table presents predictions for 2020 using base-case parameter values.

Eliminating all emission-related repairs can increase the impact of extended warranties because independent repair shops now also lose emission-related repairs that would stay at the independents during the warranty period as well as repairs that independents would do outside the warranty period. On the other hand, eliminating all emission-related repairs also eliminates the transfer of the non-emission work that would be pulled along when emission-related work migrates from independents to dealers. Non-warranty work that would have moved to dealer repair shops if durability did not improve thus stays at the independents when durability does improve.²⁷

Given the amount of non-emission work that is assumed to be pulled along from independents to dealers in the base case (50 percent of emission work), it turns out that extended emission warranties have less impact on independent repair shops if durability improves than if durability is unchanged. As reported above, independent repair shop revenue declines 4.1 percent in the maximum-PZEV scenario in 2020 with no change in durability. Independent repair shop revenue declines only 3.3 percent with the maximum possible improvement in durability.²⁸

It seems likely that durability will improve whether or not emission warranties are extended, and it is possible that extended warranties will induce manufacturers to improve the durability of emission-control systems. Therefore, the numerical predictions here that assume no change in durability will tend to overstate the impact of emission warranties on independent repair shops.

²⁷ To see how this works algebraically, let E equal emission repairs over a vehicle's life at independent repair shops, αE equal the emission repairs that are transferred to dealers, and $\lambda \alpha E$ equal the amount of non-emission repairs that migrate from independents to dealers (α is between zero and one, and λ is nonnegative). Then, the change in repairs when there is no change in durability is $-E\alpha(1+\lambda)$. Let β be the fraction of emission repairs that is eliminated by durability improvements caused by extended emission warranties (β is between zero and one). Then, the drop in emission repairs at independent repair shops is $-\beta E - (1-\beta)E\alpha(1+\lambda)$. The change in independent repair shop revenue when there is no change in durability will be larger (more negative) when $-E\alpha(1+\lambda) - (-\beta E - (1-\beta)E\alpha(1+\lambda)) < 0$, or when $\lambda > (1-\alpha)/\alpha$. Under the extreme assumption that durability improvements eliminate all repairs at independents, $\beta = 1$, but the relationship between λ and α holds regardless of the value of β .

²⁸ If the amount of non-emission work pulled along from independents to dealers were low enough, the results would reverse. In the model developed for this study, durability improvements will magnify the effects of extended emission warranties if the non-emission-related work that shifts to dealers is 20 percent or less of the emission-related work.

Options for Mitigating the Effects of Extended Emission Warranties

Participants in the repair-shop survey were asked how extended emission warranties would affect their business and what suggestions they had for reducing any negative impacts from those warranties. This chapter first presents the responses of the dealer repair shops and then turns to the responses from the independent repair shops. It closes by discussing other programs and policies that might reduce negative impacts of extended emission warranties.

The Dealer Repair Shop Perspective

Surprisingly, not all dealer repair shops thought they would benefit from extended emission warranties. Table 7.1 indicates that 29 percent of survey respondents on the dealer side felt that their businesses would suffer somewhat or suffer a great deal if one-half of new vehicles came with the longer warranty.¹ The apparent reason for this response was the low reimbursement rate for warranty repairs. Five of the 28 respondents said that reimbursement rates for the labor on warranty repairs was so low that more warranty repairs would hurt their business.

¹ Survey participants were asked the following question: "The California Air Resources Board has extended the warranty on emissions-related repairs for some types of vehicles to 15 years and 150,000 miles. (Emission-related repairs are repairs to parts that affect the emissions of hydrocarbons (HCs), oxides of nitrogen (NOx), carbon monoxide (CO), and other regulated emissions.) If, say, one-half of all new vehicles sold by your manufacturer(s) came with this longer warranty, how would your business be affected over time?" Survey participants were then asked to select one of the following statements: (1) my business would suffer a great deal, (2) my business would suffer somewhat, (3) there would not be much impact on my business, (4) my business would benefit somewhat, or (5) my business would benefit a great deal.

Table 7.1
How Repair Shop Businesses Would Be Affected If One-Half of New Vehicles Came with a 15-Year/150,000-Mile Warranty (percentage of respondents)

How Business Would Be Affected	Dealers (N = 28)	Independents (N = 47)
Suffer a great deal	4	36
Suffer somewhat	25	36
Not much impact	18	23
Benefit somewhat	46	4
Benefit a great deal	7	0

Note: Percentages may not add to 100 due to rounding.

A number of the dealer repair shops (six of 28, or 21 percent) raised concerns that extended emission warranties would cause drivers to do less maintenance on their vehicles.² In their view, poor maintenance was the main reason that emission-related repairs were required.³

Dealers had few suggestions on how to reduce the impacts of extended emission warranties. One dealer suggested that the warranty should cover only parts and that the vehicle owner should cover labor costs. Presumably, this suggestion would be attractive to dealers because it is a way around low reimbursement rates for warranty labor. A second dealer suggested that the state and the automakers should share the costs of longer emission warranties. The respondent was not explicit on how this would reduce the effects of extended emission warranties, but perhaps the respondent thought that cost-sharing would limit the increase in new vehicle prices and the consequent reduction in new-vehicle sales.⁴

The Independent Repair Shop Perspective

As expected, a high percentage of the independent repair shops responded that extended emission warranties would hurt their businesses (see Table 7.1). The results also suggest that extended warranties will likely affect some shops more than others. The primary suggestion from independents for reducing the negative impacts of extended warranties was to allow independents to do warranty repairs. There were several twists on this suggestion:

- Some respondents thought that independents should be allowed to do warranty repairs covered only by the extended part of the emission warranty. That is, respondents

² In principle, consumers have less incentive to maintain their vehicles if repairs will be covered under warranty regardless of whether they properly maintain their vehicles or not. There do not appear to be any studies on the empirical relationship between maintenance behavior and the features of warranties, however.

³ Past experiences may or may not apply to future vehicles. Manufacturers' recommended service on new vehicles increasingly includes only oil, fluid, and filter changes during a vehicle's first 100,000 miles. Whether failure to follow the manufacturers' recommendations will increase emission failures in these vehicles is yet to be seen.

⁴ It is not clear that increased new-vehicle prices caused by longer warranties will decrease new vehicle sales. Extended warranties presumably mean lower consumer repair expenditures, and thus consumers may be willing to pay more for their vehicles.

thought that independents should not do repairs covered by the standard emission warranty or by warranties on non-emission-related repairs.

- Some respondents thought that only licensed and qualified independent repair shops should be allowed to do warranty repairs.
- Another suggestion was that the extended-warranty work should be covered under an insurance-type service contract. Such contracts are marketed today and allow warranty repairs to be done at authorized independent repair shops.
- Echoing the suggestion of a dealer repair shop, one independent suggested that the extended warranty should cover only parts. The labor could presumably then be done at an independent shop.

Another suggestion from the independents was that the state set up a program like the Smog Check's Consumer Assistance Program. This program reimburses eligible drivers for repairs to their vehicles that are needed to pass a smog check. In the case of emission-related repairs, the consumer would pay for the repair and would then be reimbursed by the state. The respondents who advocated this approach did not provide suggestions for how it might be funded.

Other Options for Mitigating the Negative Effects of Extended Emission Warranties

The suggestions from the independents on how to mitigate the negative effects of extended warranties focused on reducing the decline in business at independent repair shops. Approaches identified by various other stakeholders and RAND include government policies that reduce the negative repercussions of a decline in business and government policies that compensate those who are negatively affected by the warranties. In the remainder of this chapter, additional options for reducing the decline in business at independent repair shops are first presented and then other options discussed. The objective in this chapter is simply to enumerate options. The appropriateness of these options in light of the above predictions of the impacts of extended warranties is examined in Chapter Eight.

Policies for Reducing Declines in Independent Repair Shop Revenue

The state might work with dealer and independent-repair-shop associations to create partnerships between dealer shops and independents. Independent repair shops might then become satellite locations for dealer repair shops with (at least some) factory-trained mechanics that are authorized to perform warranty repairs. If warranty repairs really are a money loser for some dealers, such an arrangement might garner support from those dealers.

The state and the repair industry might also set up a program to inform consumers about what is and what is not covered by the extended emission warranty. Better information may reduce the increase in non-warranty work that is done at dealer repair shops when emission warranties are extended. It may also reduce the likelihood that consumers go first to dealers for repairs that are not covered by the warranty. Better information about the

warranty may also reduce the effects of extended warranties by dispelling any notions on the part of consumers that maintenance work must be done at the dealer to maintain the warranty. The ultimate effect of better knowledge about vehicle warranties is hard to predict, however. As shown in Chapter Five, consumers are often unaware that emission-related repairs are covered for eight years or 80,000 miles. Increasing awareness of the extended warranty, while certainly benefiting consumers, may conceivably cause a shift in repairs from independents to dealer repair shops.

Policies that Reduce Negative Repercussions for Independent-Repair-Shop Workers and Owners

Programs that ease the transition to a new job may be beneficial for those who currently work at independent repair shops. Even if employment at independent repair shops as a whole does not decline with extended warranties, there may be layoffs at shops that are particularly hard hit. These layoffs may cause hardships for some workers, which might be eased by job-listing services that advertise opportunities at other independent repair shops or at dealer repair shops. Job training programs could improve mechanics' automotive repair skills or train them for new professions. Finally, supplemental unemployment benefits could provide support while workers are looking for new jobs.

Options for lessening the impact of extended emission warranties on current owners of independent repair shops are less obvious. An electronic bulletin board might make it easier to sell equipment or facilities that are no longer needed.

Policies that Compensate Negatively Affected Owners and Workers

Independent repair shop owners that lose business due to extended emission warranties could in principle be compensated for their losses. Payments should be tied to lost profits. Determining the appropriate payment would be very difficult because of the many factors that determine losses for a particular repair shop, and such losses would have to be forecast over time. Workers at independent repair shops might also be compensated for the losses they incur, net of any payments received, such as unemployment payments. In principle, such payments should be tied to the decline in lifetime earnings caused by extended emission warranties. Such losses would be difficult to quantify, however.

Summary and Policy Implications

The California Air Resources Board allows automobile manufacturers to satisfy part of the California Zero Emission Vehicle Program with partial-zero emission vehicles. PZEVs must meet very stringent emission standards when they are new, and in an effort to keep the emission levels low as vehicles age, CARB requires that PZEVs come with a comprehensive 15-year/150,000 emission-system warranty. To be covered under warranty, repairs must usually be done at dealer repair shops, and thus extended emission warranties will likely shift business from independent repair shops to dealer repair shops. This report attempts to quantify how large these impacts might be and to identify options for reducing or mitigating adverse effects of extended emission warranties. This concluding chapter reviews the findings and discusses their policy implications.

Predicted Effects of Extended Emission Warranties on Independent Repair Shop Revenue

To predict the impact of extended warranties on repair and maintenance expenditures at independent repair shops, a model of drivers' vehicle-repair behavior was constructed and the impacts of extended warranties under different scenarios for PZEV sales were predicted. Manufacturers were initially assumed to satisfy as much as the ZEV program allowed with PZEVs (the "maximum-PZEV" scenario discussed in Chapter Six). In the maximum-PZEV scenario, the number of PZEVs on the road increases gradually beginning in 2003 and reaches 38 percent of the vehicle fleet by 2020. The effects of extended warranties were also predicted when PZEVs sales were 75 percent, 50 percent, and 25 percent of those in the maximum-PZEV scenario and when all new vehicles sold after 2008 were PZEVs.

In the maximum-PZEV scenario, extended emission warranties cause independent repair shop revenue to gradually fall below what it would be if warranties on PZEVs were not extended. Extended warranties have no effect between 2003 and 2005 because warranties for the first three years or 50,000 miles remain the same as those on vehicles with standard emissions warranties. Using a base-case set of parameters, independent repair shop revenue is 0.8 percent (\$120 million) lower in the maximum-PZEV scenario than it would be otherwise in 2010 and 4.1 percent (\$730 million) lower in 2020. There is considerable uncertainty in many of the parameters that underlie the predictions. Thus, the impacts of extended warranties were predicted allowing parameters to vary over their likely ranges. The result was that the predicted decline in independent repair shop revenue in 2020 ranged from 2.2 to 6.9 percent (\$375 million to \$1.3 billion) in the maximum-PZEV scenario.

Even though revenue at independent repair shops will be lower with extended warranties than it would be if warranties were not extended, the simulations showed that independent repair shop revenue would grow between 2003 and 2020 with extended warranties. Independent repair shop revenue is projected to climb 30 percent between 2003 and 2020 in the maximum-PZEV scenario, not including any increase due to inflation, even if warranties *are* extended. This increase is driven by a projected 32-percent rise in the number of vehicles on the road between 2003 and 2020.

The predicted effect of extended warranties on independent repair shops was found to be proportional to the number of PZEVs on the road. Thus, the effects in scenarios in which the number of PZEVs were lower than in the maximum-PZEV scenario were less than those in the maximum-PZEV scenario. Extended emission warranties were projected to cause independent repair shop revenue to fall by 7.7 percent in 2020 when all new vehicles sold after 2008 carried extended warranties, but, even then, revenue at independent repair shops was projected to increase 25 percent between 2003 and 2020. The growth in independent repair shop revenue would not be as large if the vehicle fleet grows more slowly than expected.

The predicted effects of extended warranties assume that the durability of emission-control systems will not change from levels currently observed in the vehicle fleet. Durability may improve even if warranties are not extended due to changes that will be made in vehicle-certification requirements and in the in-use vehicle compliance program. Such an improvement in durability would reduce the impact of extended warranties on independent repair shops because there would be fewer repairs that could migrate from independents to dealers. Extended emission warranties might also improve durability. Such improvement may magnify the adverse effects of extended warranties on independent repair shops because, in addition to reducing the share of work that goes to independents, extended warranties will reduce the overall amount of work to be split. However, improvements in durability may reduce the amount of non-emission work that is pulled along with the emission work that migrates from independents to dealers when warranties are extended. Based on the estimates developed here of the amount of non-emission work that would shift to dealers, the simulations showed that improvements in durability due to extended emission warranties will reduce the negative impact on independent repair shops. Thus, predictions that assume no change in durability will tend to overstate the effects of extended emission warranties. The estimates of independent

repair shop revenue do not include revenues from collision repairs or customization of the interior or exterior of a vehicle. Including such revenues will reduce the percentage declines in revenue reported here.

The impacts of extended warranties on independent repair shops as a whole have been examined in this analysis. Effects may vary from shop to shop, depending on the importance of emission-related repairs to their business.

Effects on Shop Workers, Owners, and Consumers

By reducing revenue at independent repair shops from what it would be otherwise, extended warranties may adversely affect workers at independent repair shops, independent repair shop owners, and consumers. The implications of the predicted effects for each are now examined.

Effects on Independent Repair Shop Workers

Aggregate revenue at independent repair shops are projected to grow even with extended warranties. Thus, there should be no need to lay off current workers at independent repair shops as a whole. However, as suggested by the findings in Chapter Seven, some independent repair shops may be more affected by extended emission warranties than others. Extended warranties may cause workforce reductions at some independent repair shops even though employment at all independent shops combined grows. These workforce reductions may cause hardships for some workers, although whether and to what extent workforce reductions at some shops will be necessary are not known. Even if some repair shops do have to reduce the number of employees, however, the negative impacts on workers may be minimal. First, the impacts of extended warranties are felt only gradually over time, and workforce reductions could possibly be handled through normal attrition. Second, workers may be able to quickly find employment at other independent repair shops or at dealer repair shops.

Extended emission warranties will mean fewer opportunities for future workers in the independent-repair industry, but there may be more opportunities at dealer repair shops. Also, future workers will be able to train for jobs in other industries. Thus, there will likely be no adverse effects on future workers.

Effects on Owners of Independent Repair Shops

In the standard competitive economic model of an industry, increases in demand raise prices, which then in turn increase profits of the firms currently in business above the normal return on capital. These extra-normal profits encourage new firms to enter the market, reducing prices and profits per firm. Extended emission warranties will cause demand for services at independent repair shops to increase more slowly than it would without extended warranties. This implies that existing independent repair shops will enjoy fewer periods of extra-normal profits than they would otherwise. The loss to current owners is the discounted present value of these foregone profits.

Several factors will moderate the significance of these losses. First, compared with many industries, it seems easy for new independent repair shops to enter the industry. This will

limit the amount of extra-normal profits. Second, many of the losses will be felt ten or more years in the future. The relatively high discount rate appropriate for small-business profits and the long lead times for the effects of extended warranties will substantially reduce the present value of the losses. Finally, independent repair shop revenue is expected to grow 30 percent over 18 years with extended emission warranties and 36 percent without them. It seems unlikely that the present value of the lost profits will be large relative to the size of discounted profits over this period for the independent repair industry as a whole. Some shops may be hurt more than others, although this study is not able to determine whether and to what extent this will be the case.

Extended emission warranties will mean fewer opportunities for new businesses to enter the independent repair industry. But analogous to workers, there may be increased opportunities in the dealer repair industry, and there are opportunities to invest capital in other sectors of the economy.

Effects on Consumers

Slower revenue growth at independent shops may mean fewer independent repair shops than there would be otherwise. Fewer repair shops may mean that repair shops are less conveniently located for some consumers. It may also mean less competition and possibly higher prices at both dealer and independent repair shops. This study did not analyze how slower growth in revenue may translate into slower growth in the number of repair shops (or more rapid decline in the number of independent repair shops if other factors are causing consolidation in the industry). Revenue growth between 2003 and 2020 is predicted to be 6.0 percentage points lower with extended warranties, so the effect is not likely to be great, and there is still likely to be a large number of independent repair shops in the state.¹

The reduction in the number of repair shops per vehicle could have more significant consequences for consumers in some parts of the state than in others. For example, the effects could be greater in sparsely populated rural areas where there are few dealer or independent repair shops to start with. An analysis of whether or how effects on the number of repair shops would vary by region or how the effects on consumers of any declines in the number of shops that did occur would differ between urban and rural areas, however, was beyond the scope of this study. It should be noted, though, that added business at dealer repair shops may induce dealers to open up more locations, which would offset some of the decline in the number of independent repair shops. A full analysis of the effect of extended emission warranties on drivers and Californians more generally would also need to consider benefits in dimensions not examined here—including cleaner air and more durable vehicle emission-control systems.

Thinking About Policy Options

When the California Air Resources Board adopted the extended warranty requirement for PZEVs in November 1998, members of the board expressed concern that extended

¹ As was shown in Table 3.4, there are currently almost 23,000 independent repair shops in California that likely do drive-train repairs.

warranties may adversely affect the independent repair industry. The board members then directed staff within CARB to assess the size of the potential impacts and report back to them with "findings and proposals, and if appropriate, to help mitigate any adverse impacts" (CARB, 1998).

The findings in this report suggest that extended warranties will have little impact on workers in the independent repair industry as a whole, although extended warranties may cause some shifting of employment among repair shops. Programs that facilitate the transition to new jobs could be beneficial. Examples of such programs include job-listing services that alert workers to job openings at independent and dealer repair shops. It could be worthwhile to consider enhancing such programs, but the costs and payoffs of doing so should be carefully weighed. Because the effects of extended warranties will be felt only gradually over time, employment levels may adjust smoothly without government intervention, and there may not be much payoff from programs in this area.

Extended warranties will likely have adverse effects on current owners of independent repair shops. Overall, the study findings suggest that these effects will not be large and will be felt only gradually over time. CARB may nevertheless consider programs to reduce the impacts that do exist. Absent changing the terms of extended warranties, there are three general approaches CARB may consider for reducing impacts on independent repair shop owners. CARB may attempt to (1) prevent or reduce effects that occur in the first place, (2) reduce the negative ramifications of effects that do occur, and (3) compensate owners for their injuries. In conclusion, the attractiveness of each of these approaches, starting with the last one, is assessed.

Compensating independent repair shop owners for losses due to extended warranties seems impractical. This analysis has focused on independent repair shop revenue, but the proper measure of loss is foregone profits. It would be difficult, and costly, to estimate foregone profits for the tens of thousands of independent repair shops in California, and sizable uncertainty in the estimates would likely always remain. A source of funding for such a scheme would also need to be secured.

Options for reducing the negative ramifications of the impacts on owners that do occur do not seem to be much more promising. CARB might help to set up listing services that make it easier for independents to sell equipment or facilities that are no longer needed. The private sector seems well suited to providing such services, however.

Requiring automakers to cover emission repairs using service contracts is a promising option for preventing the negative effects in the first place. Many different types of service contracts are on the market today, and many allow repairs to be done within an approved network of independent repair stations. Service contracts need not cover all warranty repairs or all emission repairs; rather, they could cover only the additional repairs covered by the extended emission warranty. No government funding is required for this option, although CARB's ability to require automakers to offer such service contracts needs to be further investigated. Automakers may not favor such an option because it requires them to monitor the quality and necessity of the work they pay for at a larger number of shops. However, there are existing service-contract administrators that specialize in this type of oversight. Before proceeding with service-contract programs, the cost of setting up and running such programs relative to the cost of performing warranty work through existing dealer networks

should be examined. Any additional costs will be passed on at least in part to Californians in the form of higher new-vehicle prices.

A consumer education program on emission warranties is another potentially promising option for reducing impacts in the first place. Better information about warranties may dispel any notions that maintenance work must be done at the dealer to maintain the warranty, reducing the extent to which extended warranties influence where consumers take their vehicles for maintenance. Better information may also reduce the frequency with which consumers go to a dealer for repairs that are not covered by an extended emission warranty because they are uncertain whether a repair is covered by the warranty or not. Education programs would benefit consumers, but how effective they would be in reducing the impacts of extended warranties is uncertain. In principle, those programs could even increase the impact on independent repair shops by alerting very poorly informed consumers that a warranty exists. The relationship between the costs of education programs and their impact on consumer knowledge about warranties also needs to be further examined.

This analysis suggests that the effect of extended emission warranties on the independent repair industry will not be large and that the benefits from the policy interventions discussed above would not be great. It is up to policymakers, however, to assess whether benefits from such interventions outweigh their costs.

Examples of Emission-Related Parts

Table A.1 provides examples of emission-related automotive parts. These examples are extracted from CARB's list of emission-related parts (CARB, 1990).

Table A.1
Examples of Emission-Related Parts

Air Induction System	Positive Crankcase Ventilation
Temperature sensor elements	PCV valve
Vacuum motor for air control	Oil filler cap
Turbocharger or supercharger	Exhaust Gas Recirculation (EGR) System
Electronic Fuel Injection	EGR valve body
Pressure regulator	Solenoid vacuum valve
Fuel distribution manifold	Backpressure transducer
Fuel injectors	Air injection system
Air-Fuel Ratio Control	Pump
Oxygen sensor	Pressure relief valve
Electronic control unit	Catalyst and Exhaust System
Ignition System	Catalyst beads
Points/rotor/condenser	Converter body and internal supports
Speed sensor	Exhaust manifold
Spark plugs	Exhaust port liners
Ignition wires and coil	Thermal Reactor
Mechanical Components	Reactor casing and lining
Intake valves/exhaust valves	Exhaust manifold
Camshaft and valve guides	Computer Controls
Evaporative Control System	Electronic control unit (ECU)
Vapor storage canister	All sensors associated with ECU
Vapor liquid separator	Computer-coded engine parameters
Filler cap	

Role of Durability in Determining the Impact of Extended Emission Warranties on Independent Repair Shops

This appendix investigates how changes in emission-system durability affect the impact of extended emission warranties on the revenue of independent repair shops. The first section of this appendix presents an analytic model for the impact of extended emission warranties when durability does change, the second section presents a model of the impact when durability does not change, and the third section examines the difference between impacts with and without changes in durability. Figure B.1 (a slightly modified version of Figure 2.1 in Chapter Two) illustrates the impact of changes in durability. The figure provides the framework for this analysis.

The Impact of Extended Emission Warranties When Durability Changes

Assume that α_i is the proportion of emission-system repair work done at independent repair shops *without* extended warranties during period i . Specifically,

α_0 = the proportion of emission-system repair work done at independent repair shops when a vehicle is less than three years old

α_1 = the proportion of emission-system repair work done at independent repair shops when the vehicle is between three and 15 years old

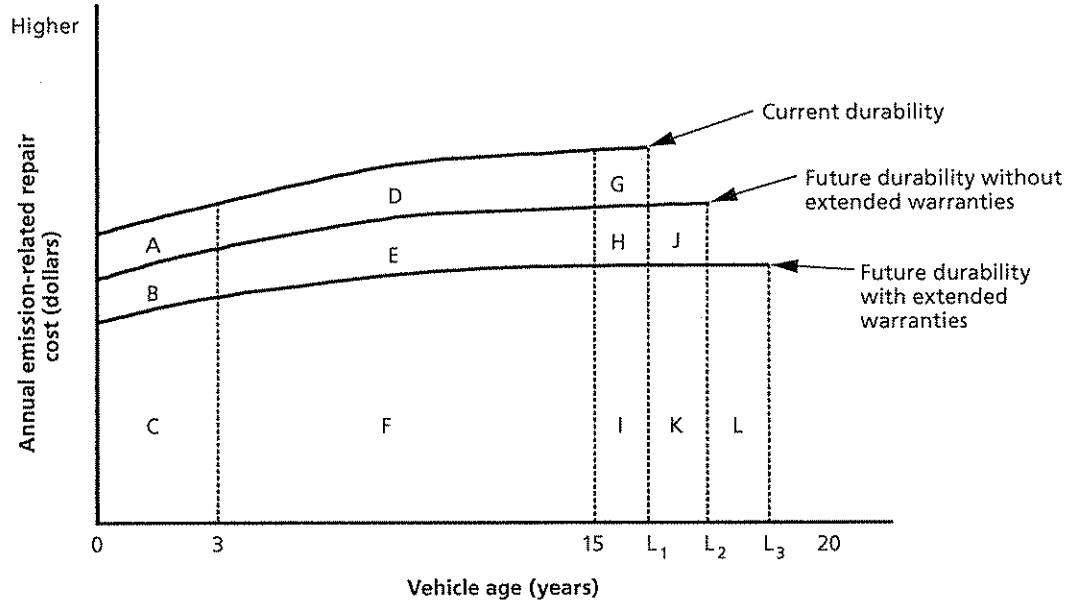
α_2 = the proportion of emission-system repair work done at independent repair shops when the vehicle is between 15 years old and the expected life of vehicles on the road today (L_1)

α_3 = the proportion of emission-system repair work done at independent repair shops when the vehicle is between the expected life of current vehicles (L_1) and the expected life of vehicles in the future without extended warranties (L_2)

Assume that β_i is the proportion of emission-system repair work done at independent repair shops *with* extended warranties during period i . Specifically,

Figure B.1

Framework for Evaluating Impact of Changes in Durability on Annual Emission System Repairs



RAND TR235-B.1

β_0 = the proportion of emission-system repair work done at independent repair shops when the vehicle is less than three years old

β_1 = the proportion of emission-system repair work done at independent repair shops when the vehicle is between three and 15 years old

β_2 = the proportion of emission-system repair work done at independent repair shops when the vehicle is between 15 years old and the expected life of vehicles on the road today (L_1)

β_3 = the proportion of emission-system repair work done at independent repair shops when the vehicle is between the expected life of current vehicles (L_1) and the expected life of vehicles in the future without extended warranties (L_2)

β_4 = the proportion of emission-system repair work done at independent repair shops when the vehicle is between the expected life of the vehicle in the future without extended warranties (L_2) and the expected life of vehicles in the future with extended warranties (L_3).

For the purposes of this discussion, we assume there is no change in the fraction of non-emission work done at independents. In other words, no non-emission work is pulled along when emission work moves from independents to dealers.

Given the above assumptions, the independent repair-shop revenue from emission repairs in the future without extended warranties is:

$$R_{wo} = \alpha_0(B+C) + \alpha_1(E+F) + \alpha_2(H+I) + \alpha_3(J+K) \quad (B.1)$$

Revenue in the future with extended warranties is:

$$R_w = \beta_0 C + \beta_1 F + \beta_2 I + \beta_3 K + \beta_4 L \quad (B.2)$$

If one assumes that the proportion of revenues that goes to independents remains unchanged except during the extended warranty period (that is, $\alpha_0 = \beta_0$, $\alpha_2 = \beta_2$, $\alpha_3 = \beta_3$), then the impact of extended emission warranties on independent repair shops ($R_w - R_{wo}$) is:

$$\Delta_c = (\beta_1 - \alpha_1)F - (\alpha_0 B + \alpha_1 E + \alpha_2 H + \alpha_3 J - \beta_4 L) \quad (B.3)$$

The first term in Equation B.3 captures the shift of business from independents to dealers (β_1 will likely be less than α_1). The second term captures the decline in business caused by improved durability due to the extended warranty (offset by the an increase in business due to longer vehicle life).

Impact of Extended Emission Warranties when Durability Does Not Change

If durability does not change, then the change in revenue at independent repair shops is:

$$\Delta_{nc} = (\beta_0 - \alpha_0)(A+B+C) + (\beta_1 - \alpha_1)(D+E+F) + (\beta_2 - \alpha_2)(G+H+I) \quad (B.4)$$

If we again assume that $\alpha_0 = \beta_0$, $\alpha_2 = \beta_2$, then the difference reduces to:

$$\Delta_{nc} = (\beta_1 - \alpha_1)(D+E+F) \quad (B.5)$$

The subscript "nc" stands for no change in durability. The change in independent revenue due to extended emission warranties is again negative because β_1 will be less than α_1 .

Difference in Change in Revenue With and Without Changes in Durability

The difference between the change in revenue when durability changes and when it does not change is indeterminate:

$$\Delta_c - \Delta_{nc} = (\alpha_1 - \beta_1)D - (\alpha_0 B + \beta_1 E + \alpha_2 H + \alpha_3 J - \beta_4 L) \quad (B.6)$$

The first term in Equation B.6 shows that changes in durability that occur in the absence of extended emission warranties reduce the effect of emission warranties on independent repair shop revenue (the difference is less negative). The second term shows that changes in durability caused by extended emission warranties may increase declines in revenue at independent repair shops due to extended emission warranties. The greater declines occur to the extent that extended emission warranties cause the overall amount of repair work done during the life of the vehicle (whether at independents or dealers) to decline.

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