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Evaluation of FMVSS 214 Side Impact Protection Dynamic Performance Requirement

Phase 1: Correlation of TTI(d) with Fatality Risk in Actual Side Impact Collisions of Model Year 1981-1993 Passenger Cars

Plan for Phase 2: Effect of FMVSS 214 and Correlation of TTI(d) with Actual Fatality Risk in Model Year 1992-2000 Passenger Cars

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16. Abstract
Federal Motor Vehicle Safety Standard (FMVSS) 214, "Side Impact Protection" was amended in 1990 to assure occupant protection in a dynamic test that simulates a severe right-angle collision. It was phased into new passenger cars during model years 1994-97. The test involves a Moving Deformable Barrier hitting the side of a vehicle. Side Impact Dummies are seated adjacent to the impact point. A Thoracic Trauma Index, TTI(d) is measured on the dummies.

The standard will be evaluated in two phases. Phase 1, completed in this report, is a statistical analysis of relationships between front-seat TTI(d) and fatality risk in actual side impacts on the highway, in baseline, pre-standard vehicles of model years 1981-93, based on Fatality Analysis Reporting System (FARS) data from late 1980 through early 1998. The report also presents a plan for Phase 2, a proposed statistical comparison of side-impact fatality and injury rates in cars produced immediately after vs. immediately before the implementation of FMVSS 214.

The principal finding of Phase 1 is a statistically significant association of TTI(d) with side-impact fatality risk in passenger cars of model years 1981-93. The observed relationship is stronger, however, in 2-door cars than in 4-door cars. Each reduction of TTI(d) by one unit is associated with an estimated 0.927 percent reduction of fatality risk in side impacts of 2-door cars. The association between TTI(d) and fatality risk in the corresponding analysis of baseline 4-door cars was not statistically significant.

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EXECUTIVE SUMMARY

Federal Motor Vehicle Safety Standard (FMVSS) 214, "Side Impact Protection" was amended in 1990 to assure occupant protection in a dynamic test that simulates a severe right-angle collision. It is one of the most important and promising safety regulations issued by the National Highway Traffic Safety Administration (NHTSA). It was phased into new passenger cars during model years 1994-97. In 1993, side impacts accounted for 33 percent of the fatalities to passenger car occupants.

The current FMVSS 214 is the culmination of many years of research to make passenger cars less vulnerable in side impacts, and especially to reduce fatality risk to the nearside occupant when a car is struck in the door area by another vehicle - the configuration responsible for the majority of side-impact fatalities. Interacting with the United States and international safety communities, NHTSA developed:

- A test configuration using a Moving Deformable Barrier (MDB) simulating a severe intersection collision between two passenger vehicles.

- Injury criteria, above all a Thoracic Trauma Index (TTI) that predicts the severity of thoracic injuries when occupant's torsos contact the interior side surface of a car.

- A Side Impact Dummy (SID) on which TTI could be reliably measured in side impact tests. The injury score measured on the dummy is called TTI(d).

- Two technologies that, singly or in combination, significantly reduced TTI(d) from its baseline levels in model year 1980-88 production vehicles:

    1. **Structure** modifications such as stronger pillars, sills, roof rails, seats or cross-members, to reduce door intrusion into the passenger compartment.

    2. **Padding** capable of absorbing significant energy at a force-deflection rate safe for occupants. It is a thick plastic foam - not a soft pad.

- The new FMVSS 214, allowing TTI(d) up to 90 in 2-door cars and 85 in 4-door cars.

The Government Performance and Results Act of 1993 and Executive Order 12866 require agencies to evaluate their existing programs and regulations. The objectives of an evaluation are to determine the actual benefits - lives saved, injuries prevented, damages avoided - and costs of safety equipment installed in production vehicles in connection with a rule.

FMVSS 214 will be evaluated in two phases. Phase 1, contained in this report, is a statistical analysis of relationships between TTI(d) and fatality risk in actual side impacts on the highway, in baseline, pre-FMVSS 214 cars of model years 1981-93. It is based on Fatality Analysis Reporting System (FARS) data from late 1980 through early 1998. It will tell us if the cars with lower

TTI(d) had lower fatality risk. The analysis is possible because many pre-standard cars were tested during the development of FMVSS 214, and those models have been on the road for a long time and have been involved in many crashes. However, Phase 1, based on pre-standard cars, will not estimate the benefits of FMVSS 214 itself.

Phase 2 is a statistical comparison of side-impact fatality and injury rates in cars produced immediately after vs. immediately before the implementation of FMVSS 214. It is designed to measure the actual effects of specific modifications used to achieve compliance with FMVSS 214: structures and padding. Since those changes were only introduced in 1994-97, and since it takes years for crash files to accumulate sufficient data for statistical analyses, Phase 2 is unlikely to be completed before 2001. This report presents an analysis plan for public review and comment.

Side air bags have begun to supplement structure and padding in some cars. As of 1999 it does not appear that sufficient crash cases involving side air bags can accumulate within the Phase 2 time frame for meaningful statistical analyses. NHTSA plans to start an evaluation in 2002, but that date could be expedited in response to higher sales volumes or other considerations. In addition, NHTSA's New Car Assessment Program (NCAP) has provided consumers with information since 1997 about side impact performance in a test 5 mph faster than the FMVSS 214 compliance test. By 2002 there may be enough data to study the correlation of Side-NCAP results with fatality risk in real-world side impacts.

In most of the Phase 1 analyses, the "side-impact fatality risk" of a make-model is the ratio of the occupant fatalities in side-impact crashes to "purely frontal" crashes (a control group). This definition and various other statistical tools help isolate genuine crashworthiness differences between make-models and minimize possible biases due to models having different types of drivers whose crash involvement rates can vary considerably.

The primary finding of Phase 1 is a statistically significant association of TTI(d) with side-impact fatality risk: the lower the TTI(d), the lower the fatality risk. This result is obtained when all baseline-tested make-models of 1981-93 passenger cars are analyzed together.

A closer look at the data, however, immediately reveals different relationships in **2-door cars** and **4-door cars**. The association between TTI(d) and fatality risk in actual side impacts is quite strong in 2-door cars, and the more closely the actual crashes resemble the FMVSS 214 test, the stronger the relationship. But the data show at most a weak relationship between TTI(d) and actual fatality risk in 4-door cars. The difference is unexplained at this time. Data/statistical problems could be masking some of the effect in 4-door cars. And even if the true effect is indeed much stronger in older 2-door cars than 4-door cars, there is no obvious reason why that should be so. A possible factor is that there were stark differences in TTI(d) among pre-standard 2-door cars, including some very poor performers - whereas most 4-door cars, even before FMVSS 214, had fairly similar, fairly adequate performance.

In summary, does lower TTI(d) mean lower fatality risk? These analyses generally say "yes," but leave some unanswered questions even about the baseline, pre-FMVSS 214 passenger cars of Phase 1. Needless to say, they should not be used to predict exactly what effectiveness will be found for FMVSS 214 in more recent passenger cars during Phase 2. Nevertheless, they show that FMVSS 214 has, at the very least, already saved lives by mandating redesign of the 2-door models with the poorest performance.

The main findings and conclusions of Phase 1 are the following:

SIDE IMPACT PERFORMANCE OVER THE YEARS

- Average TTI(d) in the FMVSS 214 test configuration, by model year, was approximately:

	2-Door Cars	**4-Door Cars**
FMVSS 214 requirement	*90*	*85*
Model Year		
1981-90 (baseline)	110	80
1993 (just before FMVSS 214)	97	74
1997 (post-FMVSS 214)	74	65

- In 2-door cars, average performance improved from much worse than the FMVSS 214 requirement to somewhat better.

- In 4-door cars, average performance improved from slightly better than the FMVSS 214 requirement to much better.

- In make-models produced throughout 1993-97, approximately
  - 56 percent got substantial structure, usually with padding, during 1994-97
  - 27 percent got mainly padding
  - 17 percent remained unchanged, and already met FMVSS 214 in 1993

TTI(d) AND SIDE-IMPACT FATALITY RISK: 2-DOOR CARS OF MODEL YEARS 1981-93

- There is a statistically significant association between TTI(d) and side-impact fatality risk in pre-standard 2-door cars. This association was found in regression analyses, correlation analyses, and matched comparisons of make-models with low and high TTI(d).

- In the regression analyses, each reduction of TTI(d) by one unit is associated with an estimated 0.927 percent reduction of fatality risk in side impacts.

- TTI(d) averaged 110 in these cars, and the best score for any model was 82. A reduction of TTI(d) from the "average" 110 to the "best practices" 82 corresponds to a 23 percent* fatality reduction in side impacts.

- The effect of TTI(d) was strongest in the crashes that most closely resembled the FMVSS 214 test configuration (all effects are statistically significant):

	Fatality Reduction (%) for Reducing TTI(d)	
	By One Unit	**From 110 to 82**
In all side impacts	0.927	23*
In occupant compartment impacts	1.080	26
For all nearside occupants	0.999	25
Nearside occupants in compartment impacts	1.280	30
Impacts by another passenger car	1.310	31
Nearside compartment impacts by a passenger car	1.730	39

- Correlation analyses, and matched comparisons of make-models with low and high TTI(d) produced nearly the same results as the regression analyses: significantly lower fatality risk in models with low TTI(d).

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* $1 - (1 - .00927)^{110 - 82} = 23$ percent

TTI(d) AND SIDE-IMPACT FATALITY RISK: 4-DOOR CARS OF MODEL YEARS 1981-93

- Regression, correlation and matched-comparison analyses of pre-standard 4-door cars showed at most a weak association between TTI(d) and side-impact fatality risk.

- In one regression analysis, each reduction of TTI(d) by one unit was associated with a nonsignificant 0.168 percent reduction of fatality risk in side impacts, and in another regression analysis, it was associated with a nonsignificant 0.047 percent increase.

- TTI(d) averaged 80 in baseline 4-door cars, and the best score for any small- to mid-sized model was 62. A reduction of TTI(d) from the "average" 80 to the "best practices" 62 corresponds to a 3 percent[1] fatality reduction in side impacts, by the first regression analysis, and a 1 percent[2] increase, by the second.

- In the regression analyses, the effect of TTI(d) did not show any pattern of getting either stronger or weaker in crashes that more closely resembled the FMVSS 214 test configuration.

- Twelve analyses tested the correlation of TTI(d) with side/frontal fatality risk at the make-model level. They produced one statistically significant positive coefficient [the lower the TTI(d) the lower the risk], four nonsignificant positive coefficients, and seven nonsignificant negative coefficients.

- Twelve analyses compared side/frontal fatality risk in matching make-models with low and high TTI(d). Eight showed fatality reductions up to 16 percent in the models with low TTI(d). Four showed increases. None of the effects was statistically significant.

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[1] $1 - (1 - .00168)^{80 - 62} = 3$ percent

[2] $1 - (1 + .00047)^{80 - 62} = -1$ percent

CHAPTER 1

INTRODUCTION AND BACKGROUND

Federal Motor Vehicle Safety Standard (FMVSS) 214, amended in 1990 to assure occupant protection in a dynamic test that simulates a side impact collision, is one of the most important and promising safety regulations issued by the National Highway Traffic Safety Administration (NHTSA). Crash data are coming on line to evaluate whether this regulation and the vehicle modifications that improve performance in the side impact test are effective in reducing fatality risk in actual side impact crashes of production passenger cars.

1.1 The dynamic side impact standard

The current FMVSS 214[1] was phased into new passenger cars during model years 1994-97. The Final Rule[2], issued in October 1990 required at least 10 percent of passenger cars produced between September 1, 1993 and August 31, 1994 to meet the standard; at least 25 percent of cars produced between September 1, 1994 and August 31, 1995; at least 40 percent of cars between September 1, 1995 and August 31, 1996; and all cars after September 1, 1996[3]. Manufacturers declared ("self-certified") what make-models complied with FMVSS 214 during the three-year phase-in period. NHTSA as well as the manufacturers advised the public on what models were certified[4].

In 1993, the last year before the phase-in, 6,922 passenger car occupants were fatally injured in side impacts, accounting for 33 percent of the fatalities to passenger car occupants[5]. The side of the car is the second most frequent impact location in fatal crashes, exceeded only by frontals. The side impact problem was likely to increase, in relative terms, as air bags and greater use of safety belts reduced fatalities in frontals and rollovers.

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[1]*Code of Federal Regulations*, Title 49, General Printing Office, Washington, 1998, Part 571.214.

[2]*Federal Register* 55 (30 October 1990): 45752.

[3]Manufacturers also had the option of 100 percent of their cars meeting the standard beginning on September 1, 1994 and no requirement before that date. *Code of Federal Regulations*, Title 49, Part 571.214 S3. (2) (d).

[4]*NHTSA Hails Safety Features in Model Year 1994 Passenger Cars and Light Trucks and Vans*, Press Release No. NHTSA 38-93, U. S. Department of Transportation, Office of the Assistant Secretary for Public Affairs, Washington, 1993.

[5]*Traffic Safety Facts 1993*, NHTSA Report No. DOT HS 808 169, Washington, 1994, p. 102.

In truth, the development of FMVSS 214 began long before the Final Rule was issued in 1990. By the 1960's researchers understood that the side doors of passenger cars were vulnerable in side impacts. There was little structure to slow down a striking vehicle and prevent the door from intruding into the passenger compartment and contacting the occupant at a dangerous velocity. To strengthen the doors, engineers at General Motors placed side door beams inside them, front-to-rear, parallel to the sills and roof rails, starting in some 1969 cars[6]. They developed a quasi-static (slow-moving) test to measure the crush resistance of doors by gradually forcing a rigid cylinder into the side of the car. The Society of Automotive Engineers and, subsequently, NHTSA welcomed side door beams. The agency issued the original, "static" FMVSS 214, effective January 1, 1973, requiring passenger cars to meet specified force levels on the crush test[7], and resulting in the introduction of side door beams in all cars.

By the late 1970's, if not earlier, researchers suspected that side door beams alone were insufficient to slow intrusion significantly in a severe impact by another vehicle[8]. NHTSA's 1982 evaluation of the "static" FMVSS 214, indeed, did not show a reduction of fatality risk to occupants of cars struck in the side by other vehicles[9]. Side door beams were not ineffective: they significantly reduced fatality risk in side impacts with fixed objects, saving 480 lives per year, and they reduced by 25 percent the risk of a nonfatal hospitalization to a nearside occupant in a compartment impact by another vehicle. They just weren't strong enough to reduce fatalities in that crash mode.

NHTSA began to develop a new version of FMVSS 214, while retaining the "static" requirement in view of its benefit in fixed-object collisions. The new regulation was aimed at reducing fatality risk to the nearside occupant when a car is struck in the door area by another vehicle - the configuration responsible for the majority of side impact fatalities. In developing the new regulation, NHTSA used a systematic approach, including much interaction with the public and the research community[10]. The process, typical of a new generation of NHTSA rulemaking, was far more complex than 1960's regulation. Nearly every step was complicated, since researchers from the United States and international safety communities offered numerous alternative injury criteria, dummies, test configurations, etc., that were given consideration. The selected approach included:

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[6]Hedeen, C.E. and Campbell, D.D., *Side Impact Structures*, Paper No. 690003, Society of Automotive Engineers, New York, 1969.

[7]*Code of Federal Regulations*, Title 49, General Printing Office, Washington, 1981, Part 571.214.

[8]*Side Impact Conference*, NHTSA Report No. DOT HS 805 614, Washington, 1980.

[9]Kahane, C.J., *An Evaluation of Side Structure Improvements in Response to Federal Motor Vehicle Safety Standard 214*, NHTSA Technical Report No. DOT HS 806 314, Washington, 1982.

[10]*Final Regulatory Impact Analysis - New Requirements for Passenger Cars to Meet a Dynamic Side Impact Test FMVSS 214*, NHTSA Publication No. DOT HS 807 641, Washington, 1990.

- A review of crash data, indicating that the archetypal side impact fatality involved a fast-moving car striking a slow-moving car in the door, at a right angle (typical intersection collision).

- A review of injury data, indicating that a large proportion of the nearside occupants' life-threatening injuries occurred when the sides of their torsos contacted the interior side surface (most frequently the door) of the car. (Head injuries were the most frequent cause of fatalities in side impacts; they have been directly addressed by another regulation, FMVSS 201 - Occupant Protection in Interior Impact[11].)

- Experimental impacts to cadavers. The Thoracic Trauma Index (TTI) was found to be an excellent predictor of thoracic injury severity (after controlling for the age of the test subject). $TTI = ½ (G_R + G_{LS})$, where G_R is the greater of the peak accelerations of either the upper or the lower rib, expressed in g's and G_{LS} is the lower spine (T12 vertebra) peak acceleration. Pelvic g's are an additional injury criterion, but TTI is the key predictor of life-threatening injuries.

- Development of a Side Impact Dummy (SID) on which TTI (as well as pelvic g's) can be reliably measured in a side impact test configuration. The injury score measured on the dummy is called TTI(d).

- Development of a Moving Deformable Barrier (MDB) representing a generic 3000-pound passenger vehicle and a test procedure that simulates an MDB moving 30 mph hitting, at a right angle, the door area of a subject vehicle, traveling 15 mph. (It is accomplished by having the MDB travel at 33.5 mph at an angle of 63 degrees with the longitudinal centerline of a stationary test vehicle. The wheels of the MDB are "crabbed" 27 degrees toward the rear of the test vehicle to obtain a right-angle contact.)

- Testing of a variety of production 1980-88 passenger cars to learn the baseline distribution of TTI(d). Some baseline testing continued after the Final Rule was issued in 1990, up to model year 1993 cars just before the phase-in period.

- Demonstration of two technologies that, singly or in combination can significantly reduce TTI(d) from its baseline levels in production vehicles:

    1. **Structure** modifications such as substantially strengthening pillars, sills, roof rails, seats or cross-members of a car, and stronger overlap between doors and pillars, sills, etc., to slow down and reduce the extent of door intrusion into the passenger compartment.
    2. **Padding** capable of absorbing significant energy at a force-deflection rate safe for occupants. It is a thick plastic foam - not a soft pad.

[11]*Code of Federal Regulations,* Title 49, General Printing Office, Washington, 1998, Part 571.201.

- Regulatory analysis to estimate the lives saved by reducing TTI(d) to various levels, and the extent of vehicle modifications needed to secure those levels - and, finally -

- Promulgation of the new FMVSS 214, allowing TTI(d) up to 90 in 2-door cars and 85 in 4-door cars. The effective date was a phase-in schedule for model years 1994-97.

The new regulation is called the "dynamic" FMVSS 214 because it involves a fast-moving impact by the MDB, rather than slow crushing by a cylinder. NHTSA believed that manufacturers could meet the standard (with just passing scores) by installing only padding in most cars, and without change in many cars. More extensive structural modifications might be needed, however, if manufacturers aimed to drop TTI(d) well below the FMVSS 214 requirement.

1.2 Discussion of evaluation goals

The Government Performance and Results Act of 1993[12] and Executive Order 12866[13] (October 1993) require agencies to evaluate their existing programs and regulations. The objectives of an evaluation are to determine the actual benefits - lives saved, injuries prevented, damages avoided - and costs of safety equipment installed in production vehicles in connection with a rule.

FMVSS 214 will be evaluated in two phases. Phase 1, contained in Chapters 2-7 of this report, is a statistical analysis of relationships between TTI(d) and fatality risk in actual side impacts on the highway, in baseline, pre-FMVSS 214 cars of model years 1981-93. It will tell us if the cars with lower TTI(d) indeed had lower fatality risk. While Phase 1, based on pre-standard cars, will not estimate the benefits of FMVSS 214 itself, it can give a preliminary idea whether reducing TTI(d) is potentially a good strategy for saving lives.

Phase 2 will be a statistical comparison of side impact fatality and injury rates in cars produced immediately after vs. immediately before the implementation of FMVSS 214. It is designed to measure the actual effects of specific modifications used to achieve compliance with FMVSS 214: structures and padding. Since these changes were only introduced in 1994-97, and since it takes years for crash files to accumulate sufficient data for statistical analyses, Phase 2 is unlikely to be completed before 2001. However, Chapter 7 of this report presents an analysis plan for public review and comment.

A brief discussion of other NHTSA standards and evaluations yields insight on why a multi-phase strategy makes sense for FMVSS 214. Previous NHTSA evaluations can be subdivided into two types.

A **before-after** evaluation pertains to a specific, well-defined item of safety equipment that was installed at known dates in all or most make-models. (The installation date may vary among

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[12]*Government Performance and Results Act of 1993*, Public Law 103-62, August 3, 1993.

[13]*Federal Register* 58 (4 October 1993): 51735.

make-models and/or individual vehicles, but they are known for each vehicle or model.) Examples are driver air bags[14], center high mounted stop lamps[15], etc. A car either has a driver air bag or does not have one (there is no such thing as half an air bag), and it is known rather exactly which cars have them. These evaluations are relatively the simplest, because it is enough to compare the fatality, injury or crash risk in vehicles produced immediately before vs. after the safety improvement.

If a safety improvement was not a specific, clearly-defined, one-time modification, but there is a performance test that furnishes numerical scores for various vehicles, a **parametric** evaluation can explore the correlation of test scores and risk in crashes. For example, the New Car Assessment Program (NCAP) has scored frontal crash test performance of passenger cars since 1979 - but it is not a FMVSS and its effect has not been limited to the implementation of any single, specific technology. The evaluation[16] showed that belted drivers of cars with good NCAP scores had lower fatality risk in actual head-on collisions than belted drivers of cars with poor scores. It showed that improving NCAP scores is a good strategy for reducing fatality risk in frontal crashes - without identifying or estimating a benefit for any one, specific technological improvement.

The evaluation of dynamic FMVSS 214 can apply both methods - in different ways at different times. The compliance test for FMVSS 214, like NCAP, produces numerical scores for cars, TTI(d) and pelvic g's, suitable for a parametric evaluation. One important goal of the evaluation is to find out if cars with low TTI(d) have lower fatality risk in side impact crashes than cars with high TTI(d), and to calibrate a relationship between TTI(d) and actual fatality risk.. Parametric analysis is already possible for the relatively extensive set of pre-standard make-models that were baseline-tested during 1981-93, since those models have been on the road for many years and have been involved in many crashes. Phase 1 (Chapters 2-7) of the evaluation is the parametric analysis of those 1981-93 models.

Eventually, though, we need to calibrate the relationship of TTI(d) to fatality risk based on today's cars, not those of the 1980's. Phase 2 will repeat the parametric analysis for cars meeting FMVSS 214 or produced just before the standard (model years 1992-2000). However, that analysis will require accumulation of several more years of crash data plus additional FMVSS 214 testing of certain make-models to fill out the data base of TTI(d) scores. Chapter 8 presents an analysis plan.

At the same time, unlike NCAP, FMVSS 214 is well-suited for a before-after evaluation. It phased in explicit limits on TTI(d) and pelvic g's. Thanks to information supplied by the

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[14]Kahane, C.J., *Fatality Reduction by Air Bags*, NHTSA Technical Report No. DOT HS 808 470, Washington, 1996.

[15]Kahane, C.J., *The Long-Term Effectiveness of Center High Mounted Stop Lamps in Passenger Cars and Light Trucks*, NHTSA Technical Report No. DOT HS 808 696, Washington, 1998.

[16]Kahane, C.J., *Correlation of NCAP Performance with Fatality Risk in Actual Head-On Collisions*, NHTSA Technical Report No. DOT HS 808 061, Washington, 1994.

manufacturers, NHTSA has detailed lists of when make-models were modified to meet FMVSS 214 and what was modified. We can identify the models that got structure plus padding during 1994-97, or got only padding, or remained unchanged. The other important goal of the evaluation is to estimate the fatality-reducing benefits of (1) structure plus padding and (2) padding only - and to estimate the overall effect of FMVSS 214 on fatality risk in side impacts. Chapter 8 contains a plan for the Phase 2 before-after evaluation.

On the other hand, no before-after evaluation is possible in Phase 1, based on the pre-standard, 1981-93 models. NHTSA has test scores on a fairly wide cross-section of make-models, comprising a wide range of TTI(d). But the agency usually does not have specific explanations why some cars had much better scores than others. We can surmise that it's due to differences in structures, simply because the energy-absorbing padding characteristic of today's cars was not in wide use 10-20 years ago. But we have few details about the differences in the structures. Furthermore, the baseline tests were not set up on a "before-after" basis. Most of the make-models were tested just once. The data base includes only one make-model that was tested, and then retested several years later after its side structure was known to have been redesigned: the 1982-83 Nissan Sentra 2-door was selected for baseline testing and had high TTI(d). Nissan subsequently changed the structure to delay the collapse of the door. They ran a cross member across the A-pillars through the dash, reinforced the B-pillar at the sill level and added some floor stiffeners[17]. TTI(d) was substantially lower in the 1987 Sentra, and as we shall see in Section 3.5, so was the side impact fatality rate. That's as close as Phase 1 gets to a "before-after" analysis.

1.3 Analysis overview

In most of the Phase 1 analyses and throughout the Phase 2 plan, the "side impact fatality risk" of a make-model is the ratio of its occupant fatalities in side-impact crashes to its occupant fatalities in "purely frontal" crashes (a control group). The objective is to isolate genuine crashworthiness differences between make-models and to minimize possible biases due to models having different types of drivers whose crash involvement rates can vary considerably. A review of procedures in previous evaluations can shed light on the distinction between vehicle and driver factors.

The evaluation of NCAP, a measure of **frontal** crashworthiness for belted occupants, had almost the ideal crash data base: head-on collisions between two passenger cars[18]. When two cars collide head-on, the behavior of each driver before the collision has become irrelevant. It makes no difference if one drove recklessly and the other properly; once they collide, the question of which driver survives is almost purely a matter of crashworthiness. When cars with good NCAP scores hit cars with poor scores, there were consistently more fatalities in the cars with the poor scores.

Unfortunately, a similar "self-controlling" approach is not possible for side impact. A head-on collision is symmetrical, in the sense that both drivers are exposed to essentially the same crash

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[17]Kanianthra, J. (NHTSA R&D), e-mail to C.J. Kahane, February 16, 1999.

[18]Kahane (1994 NCAP), pp. 7-11.

event (especially if the cars are of equal weight). A right-angle collision is not. One car is struck in the side, at great risk to its occupants, while the striking vehicle has frontal damage. The analogy to the NCAP evaluation would be fatal side-to-side impacts. However, side-to-side impacts are rarely fatal and, in any case, this is not the type of side impact directly addressed by FMVSS 214.

Since we cannot use the method with the most control, let us next consider the least controlled approach: analysis of side impact fatality rates per million car registration years. It is often said that some make-models have much higher fatality rates than others because of the types of people who drive them, and that these differences in the rates thoroughly obscure any genuine variations in crashworthiness. Just how large the differences are is best illustrated by the data in Table 1-1, compiled by the Insurance Institute for Highway Safety[19]. Actual fatality rates, shown in the left columns of Table 1-1 are almost 9 times as large for some make-models as for others. The Institute attempted to adjust these fatality rates to take into account the age and sex of drivers involved and the car size. The middle columns show the Institute's predicted fatality rates, based solely on the car's size and the age/gender distribution of its drivers. The "Fatality Risk Index" is 100 (Actual/Predicted). Even these adjusted "Fatality Risk Indices" can vary by a factor of nearly 5. The sportier cars have disproportionately higher fatality rates and risk indices even though their design may be intrinsically quite crashworthy. Analysis based on side impact fatality rates per million registration years is probably the least likely method to produce convincing results. It is attempted only in Chapter 7, with mediocre success.

The compromise approach is to study the effect of TTI(d) and/or FMVSS 214 on the ratio of side impact fatalities to a **control group** of fatalities quite unlikely to be affected by the design of the side structure. The control group in this evaluation consists of "purely frontal" fatalities, with principal damage entirely on the front of the car, and where the "most harmful" event was not a rollover or other noncollision. The rationale is that all the various driver factors that cause some models to have high side impact fatality rates will also, by and large, inflate their frontal fatality rates by similar proportions. The ratio of side to frontal fatalities should be more constant than the raw fatality rates. Good TTI(d) scores should reduce side impact fatalities but have little effect on pure frontals, thus lowering the ratio. It is the same approach as was used to evaluate the fatality reduction by the "static" FMVSS 214[20]. It is the mirror image of the evaluation of air bags, where pure frontals were the group affected by the safety improvement and nonfrontals were the control group[21].

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[19]"Status Report Special Issue: Occupant Death Rates by Car Series," *Insurance Institute for Highway Safety Status Report*, Vol. 24 (November 25, 1989).

[20]Kahane (1982), Chapter 6.

[21]Kahane (1996), pp. 9-12, 25.

TABLE 1-1: FATALITY RISK INDICES BASED ON FATALITIES
PER MILLION REGISTERED VEHICLE YEARS
(MY 1985-87 cars in CY 1986-88; source - Insurance Institute for Highway Safety)

	Fatality Rate		**Fatality Risk**		**Fatality Rate**		**Fatality Risk**
	Actual	**Predicted**	**Index**		**Actual**	**Predicted**	**Index**
Volvo 740/760 4dr	60	140	43	Ford Escort 4dr	180	270	67
Ford Taurus SW	70	150	47	Ford Tempo 4dr	180	180	100
Lincoln Town Car	80	120	67	Buick LeSabre	180	140	129
VW Jetta 4dr	110	250	44	Olds Calais 2dr	190	190	100
Chev Cavalier SW	110	200	55	Ford Tempo 2dr	200	260	77
Toyota Cressida	110	190	58	VW Golf 4dr	200	250	80
Audi 5000	110	170	65	Nissan Maxima	200	250	80
Olds Ciera SW	110	150	73	Chev Nova 4dr	200	210	95
Cadillac DeVille 2dr	110	140	79	Buick Regal 2dr	200	190	105
Cadillac DeVille 4dr	110	120	92	Subaru 4dr	200	180	111
Ford Escort SW	120	220	55	Pont Grand Am 2dr	210	280	75
Volvo 240	120	190	63	Honda Civic 2dr	230	280	82
Pont Grand Am 4dr	120	190	63	Ford T-Bird	230	250	92
Olds Ciera 2dr	120	180	67	Dodge Omni 4dr	230	210	110
Pont Grand Prix	120	170	71	Chev Cavalier 4dr	230	190	121
Buick Century 4dr	120	160	75	Mercury Cougar	240	220	109
Mercury Gr Marquis	120	150	80	Chev Celebrity 2dr	240	150	160
Mercury Sable	130	200	65	Toyota Corolla 2dr	250	380	66
Pontiac 6000	130	170	76	Nissan 200SX	250	330	87
Chev Celebrity SW	130	170	76	Pont Sunbird 4dr	250	180	139
Olds Ciera 4dr	130	150	87	BMW 300 2dr	260	340	76
Buick Electra	130	140	93	Hyundai Excel 4dr	260	260	100
Ford Taurus	140	200	70	Plym Reliant 4dr	260	160	163
Olds Calais 4dr	140	190	74	Chev Cavalier 2dr	270	260	104
Honda Accord 2dr	140	180	78	Pont Sunbird 2dr	280	240	117
Subaru SW	140	170	82	Plym Horizon 4dr	280	210	133
Chev Caprice SW	140	170	82	Chev Monte Carlo	280	210	133
Ford Crown Vic	140	160	88	Dodge Aries 4dr	290	190	153
Nissan Sentra 2dr	150	430	35	Ford Escort 2dr	300	290	103
Honda Prelude	150	310	48	Dodge Daytona	310	320	97
Buick Somerset 2dr	150	220	68	Chev Spectrum 2dr	320	250	128
Mazda 626	150	200	75	Chev Chevette 2dr	340	250	136
Honda Accord 4dr	150	170	88	Pontiac Fiero	360	380	95
Olds 98	150	150	100	Plym Turismo	360	260	138
Olds Delta 88	150	130	115	Pontiac Firebird	380	310	123
Chrys 5th Avenue	150	120	125	Honda CRX	390	530	74
Toyota Celica	160	280	57	Chev Sprint	410	290	141
Toyota Corolla 4dr	160	230	70	Chev Chevette 4dr	410	190	216
Mercury Topaz 4dr	160	200	80	Nissan 300ZX	420	420	100
Chrys New Yorker	160	160	100	Ford Mustang	440	370	119
Chev Caprice 4dr	160	140	114	Dodge Charger	450	330	136
Honda Civic 4dr	170	260	65	Chev Camaro	490	380	129
Chev Celebrity 4dr	170	160	106	Chev Corvette	520	360	144

The use of a control group will filter out many driver factors, but not all. For example, young males, and drivers of sporty 2-door cars are more prone than others to push their cars to the limit, lose control, and slide sideways into fixed objects - increasing the side-to-frontal fatality ratio. Female drivers have proportionately more side impacts, perhaps because they are slower to enter intersections and more often become the struck vehicle. Older drivers are especially vulnerable to side impacts if they misjudge the speed or distance of approaching traffic when they make a left turn or cross a road. Vehicle factors can also affect the ratio of side to purely frontal fatalities: air bags, because they substantially reduce pure frontals while having little effect in side impacts; antilock brake systems (ABS), because they are associated with a shift from frontal crashes to side impacts[22]. Additional statistical techniques are used throughout Chapters 3-6 to control explicitly or implicitly for these residual driver and vehicle effects on the side-to-frontal fatality ratio. These techniques include: regression analysis, use of matching make-models for the "before" and "after" FMVSS 214 cars, separate analyses for 2-door and 4-door cars, and exclusion of models that got air bags or ABS at the same time as they reduced TTI(d).

The Phase 1 analyses examine if good TTI(d) is associated with low fatality risk in all types of side impacts, combined. They also investigate if the association is especially strong in the types of side impacts that more closely resemble the FMVSS 214 test: compartment impacts, nearside occupants, impacts by another passenger car, etc. A similar approach is planned for Phase 2.

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[22]Kahane, C.J., *Preliminary Evaluation of the Effectiveness of Antilock Brake Systems for Passenger Cars,* NHTSA Technical Report No. DOT HS 808 206, Washington, 1994.

CHAPTER 2

CRASH DATA FILES WITH SIDE IMPACT TEST INFORMATION

Most of the analyses of this report examine the ratio of occupant fatalities in side impacts to frontal impacts as a function of a car's Thoracic Trauma Index [TTI(d)] measured on a Side Impact Dummy in a FMVSS 214 test. For that purpose, it is necessary to create a data file of fatal crash records involving cars with known TTI(d) scores. Using the Fatality Analysis Reporting System (FARS) data for calendar years 1980 through early 1998, a file was created containing 43,510 records of fatally injured occupants in model year 1981-96 passenger cars that were identical or similar to a model that had undergone the FMVSS 214 test procedure as of September 1996. Over 94 percent of these people occupied pre-FMVSS 214 cars similar to models that were baseline-tested during the development of FMVSS 214: an adequate sample to perform the Phase 1 analyses of this evaluation. Fewer than 6 percent were in cars certified to meet FMVSS 214: insufficient data to proceed with Phase 2 of the evaluation.

2.1 A file of side impact test results

The starting point for creating the crash data base is to compile the results of all test impacts in which TTI(d) was measured by applying the FMVSS 214 compliance test procedure, or its equivalent to a production passenger car. From 1981 through the end of the model year 1996 test program, results are available to NHTSA for 121 individual cars, comprising 106 distinct make-model-year-body style combinations (i.e., for certain combinations, two or more vehicles were tested). Of the 121 individual tests, 55 were NHTSA compliance tests of MY 1994-96 cars that the manufacturers had certified as meeting FMVSS 214, comprising 53 distinct make-model-year-body style combinations (there were 2 retests).

The remaining 66 were "baseline," pre-FMVSS 214, MY 1980-93 cars; 43 were tested by government contractors (41 sponsored by NHTSA and 2 by Transport Canada) and 23 by manufacturers in the process of researching and developing FMVSS 214. For no other FMVSS does there exist so complete a historical record of pre-standard performance, including some cars with TTI(d) far above what FMVSS 214 now allows. The 43 government-sponsored tests comprise essentially three series: 20 MY 1980-85 cars in the initial research leading up to the FMVSS[1]; 12 tests of MY 1988-90 cars to support the regulatory analysis at the time the FMVSS was proposed; and 11 tests of MY 1992-93 cars to get a final baseline just before the standard's phase-in period. The second series was supplemented by 14 baseline tests of MY 1988 vehicles, performed by the manufacturers and confidentially submitted to NHTSA. The manufacturers also performed and made public a total of 9 tests on two 1990 make-models to investigate the repeatability of the procedure. NHTSA's compliance and baseline test results are documented in

[1] *Final Regulatory Impact Analysis - New Requirements for Passenger Cars to Meet a Dynamic Side Impact Test FMVSS 214*, NHTSA Publication No. DOT HS 807 641, Washington, 1990, pp. IIIC-7 - IIIC-15.

the agency's crash test data base[2]. The 66 baseline tests comprise 53 distinct make-model-year-body style combinations, including 20 2-door models and 33 4-door models.

The FMVSS 214 test is designed to simulate a typical severe intersection collision between two moving vehicles in which a 3000 pound car strikes the test vehicle at a 90 degree angle in the occupant compartment area. The test simulates a striking vehicle traveling at 30 mph and the test vehicle at 15 mph. In FMVSS 214, however, the simulation is achieved by having the test vehicle stand still. The striking vehicle is a "moving deformable barrier" (MDB) that travels at 33.5 mph at an angle of 63 degrees with the longitudinal centerline of the test vehicle. The wheels of the MDB are "crabbed" 27 degrees toward the rear of the test vehicle to ensure that the front of the MDB is parallel to the side of the test vehicle at the moment of impact, as in a 90 degree highway collision. (When these parameters were calculated to the nearest .01, the speed is 33.54 mph, the heading angle 63.43 degrees, and the crabbing angle 26.57 degrees.) There are correctly restrained, instrumented Side Impact Dummies (SID) in the front and rear seats adjacent to the struck side of the test vehicle. TTI(d) and pelvic g's are measured on both the front and rear seat dummies. However, throughout this report, except for Section 6.8, **"TTI(d)" always refers to the measurement on the front seat dummy**.

$$TTI(d) = \tfrac{1}{2} (G_R + G_{LS})$$

where G_R is the greater of the peak accelerations of either the upper or the lower rib, expressed in g's and G_{LS} is the lower spine (T12 vertebra) peak acceleration[3].

Each of the 121 tests described above was run on production cars with SID dummies and an MDB at or very near the FMVSS 214 speeds. We have excluded the tests on cars experimentally modified with padding or structures because the results would not apply to the crash-involved production vehicles on FARS. We excluded tests that didn't use SID and MDB, or had impact speeds such as 25 mph or 39 mph, as they are obviously not directly comparable to FMVSS 214 results.

One inconsistency among the 121 tests is that the impact speed, although close to 33.54 mph, varied slightly among tests. Specifically, though, the speed was often slightly above 33.54 mph in the baseline tests and always slightly below 33.54 mph in the compliance tests. (It is customary at NHTSA to perform compliance tests at slightly below the speed in the FMVSS.) An adjustment for the speed differences would make all the results more exactly comparable; without it, the compliance tests would understate the TTI(d) at 33.54 mph and many of the baseline tests would overstate it.

Empirical data were used to derive the adjustment factor. Starting in model year 1997, NHTSA's New Car Assessment Program (NCAP) has included side impact tests with the same configuration

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[2]Maintained by the NHTSA Office of Vehicle Safety Research.

[3]*Code of Federal Regulations*, Title 49, General Printing Office, Washington, 1998, Part 571.214.

as the FMVSS 214 compliance test, but at an MDB speed 5 mph higher: 38.5 mph. Fifteen make-model-year-body style combinations of MY 1997 or 1998 passenger cars were tested for both FMVSS 214 compliance and side NCAP. The average TTI(d) was 64.80 in the compliance tests and 88.39 in the side NCAP tests. In other words, a 14.9 percent increase in speed (from 33.5 to 38.5 mph) was associated with a 36.4 percent increase in TTI(d) (from 64.80 to 88.39). Since

$$\log(1.364) / \log(1.149) = 2.23,$$

the empirical elasticity of TTI(d) to MDB speed is close to 2 (at least for MDB speeds in the mid-30's). It is appropriate to adjust TTI(d) by the square of the speed discrepancy:

$$\text{TTI(d) adjusted} = \text{TTI(d) observed} * (33.54/\text{SPEED})^2$$

In the remainder of this report, “TTI(d)” always designates the speed-adjusted, not the observed TTI(d). When two or more cars of the same make-model-year-body style were tested, the adjusted TTI(d)’s were averaged. Through MY 1996, there are 106 make-model-year-body style combinations with known TTI(d), ranging from 40.0 to 131.0. Of the 106, 53 were baseline, pre-FMVSS 214 models, and 53 were MY 1994-96 models, certified to meet FMVSS 214 and compliance-tested by NHTSA.

2.2 Twins: cars similar to the side impact test vehicles

Although FMVSS 214 scores most accurately characterize the performance of the specific make-model-year-body style that was tested, they may also apply, with some accuracy, to cars of the same make-model and body style, but of a different model year. In many cases, vehicle modifications from one model year to the next are negligible and have nothing to do with side impact performance. A typical strategy for manufacturers is to make few changes, if any, for three to five years after a redesign.

Moreover, while the TTI(d) for a 2-door car is never acceptable for the 4-door car of the same make-model, or vice-versa, the results for the 4-door sedan could perhaps apply to the 4-door station wagon or hatchback if these cars essentially have the same side structure in the occupant compartment area as the 4-door sedan. Likewise, results for a 2-door coupe could sometimes apply to the 2-door hatchback or convertible of the same make-model, or vice-versa.

These two extensions greatly expand the set of vehicles with “known” TTI(d).

This evaluation, however, will not employ one other conceivable extension of the test data. When two or more make-models produced by the same manufacturer share a body platform, as evidenced by identical wheelbase and drive system - e.g., Buick Regal, Chevrolet Lumina, Oldsmobile Cutlass Supreme and Pontiac Grand Prix - a test for one of these models might apply to the others. This approach has been cautiously followed on frontal crash tests such as NCAP[4]. It is not prudent for a study of side impacts. Side structures such as doors can vary a lot from one model to another, even when the models share the same chassis and frame. Although it is true that some corporate "cousins" are essentially identical vehicles except for the nameplate (e.g., Dodge Colt and Plymouth Colt), too many are not - e.g., the Regal, Lumina, Cutlass Supreme and Grand Prix.

NHTSA staff reviewed each of the 106 tested models individually to select the acceptable twins. The procedure was to start with the TTI(d) test vehicle and look at nearby model years of the same make-model, working forwards one year at a time until the next major or minor redesign, and then working backwards one year at a time to the previous redesign. The identification of "redesigns" was sometimes a judgment call, but it was based on tangible evidence including:

- Manufacturers informing NHTSA that a car was modified to meet FMVSS 214. If so, the modified cars could not be twins for the unmodified cars, or vice-versa.

- A change in the actual wheelbase (not counting mere reporting changes such as rounding to the nearest inch).

- *Ward's Automotive Yearbooks* stating that a car was redesigned or got new sheet metal.

- Comparison of photographs from one MY to the next to see if cars were identical, very similar, or clearly different.

- "Model change codes" in some VINs (Nissan, Toyota) to indicate redesigns.

- Exterior length (bumper to bumper). Typically, but not always, a cumulative change of 4 inches or more indicates cars have become too different to be any kind of twins, whereas differences up to one inch might indicate no more than a trivial cosmetic change.

- Curb weight. Typically, but not always, a cumulative change of 200 pounds or more indicates cars have become too different to be any kind of twins, whereas differences up to 50 pounds .

Alphabetic codes are assigned to indicate the quality of the match:

<u>Body style</u>

X   Same body style as the 214 test vehicle (eligible body styles are 2-door convertible, 2-door coupe/sedan, 3-door hatchback, 4-door sedan, 5-door hatchback, station wagon)

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[4]Kahane, C.J., *Correlation of NCAP Performance with Fatality Risk in Actual Head-On Collisions*, NHTSA Technical Report No. DOT HS 808 061, Washington, 1994, p. 29. *New Car Assessment Program Results, Model Years 1987-1991*, NHTSA Office of Market Incentives, September 1991.

Y Same number of side doors as the 214 test vehicle, but a different body style - allowed only if pictures and other evidence suggest the two vehicles are essentially the same from the back of the occupant compartment forwards

Model year

A The model year of the twin is equal to or greater than the MY of the 214 test vehicle, but prior to any subsequent redesign

B The model year of the twin precedes the MY of the 214 test vehicle, with no intervening redesign

If a specific make-model-year-body style was a twin to two or more test vehicles, NHTSA staff selected just one "best" matching test vehicle on a case-by-case basis.

When all the twins were added to the study, the number of make-model-year-body style combinations in model years 1981-96 with known TTI(d) grew from 106 to 469. A vehicle-oriented file of 469 records is created, specifying the make-model-year-body style of the twin, the make-model-year-body style of the corresponding test vehicle, the test results, and the two parameters describing the quality of the match between the twin and the test vehicle. The 53 baseline-tested make-models generated 339 twins, but the 53 compliance-tested models only 130, since many of them had only existed for a year or two as of MY 1996.

2.3 A file of FARS cases with side impact test information

The next tasks are to identify all fatal crashes involving one of the 469 make-model-year-body style combinations with known TTI(d), and to append the FMVSS 214 test results to the other data on the crash. As of November 1998, NHTSA's Fatality Analysis Reporting System (FARS) contained a record of every fatal crash in the United States from 1975 through early 1998[5]. The 469 “twins,” however, are limited to MY 1981-96. Thus, the FARS data used in this report are limited to MY 1981-96 passenger cars in calendar years 1980 through early 1998.

Before FARS data can be linked to the FMVSS 214 test results, it is obviously necessary for both files to have accurate and identically defined make-model and body-type information. The Vehicle Identification Number (VIN) is the one vehicle identifier that has exactly the same meaning on FARS and the test data base. The series of VIN analysis programs used in previous NHTSA evaluations including the study of vehicle size and safety[6] were expanded to cover model years 1981-97. These programs, based entirely on the VIN, identify a vehicle's make-model,

[5] *FARS 1998 Coding and Validation Manual,* NHTSA National Center for Statistics and Analysis, Washington, 1998.

[6] Kahane, C.J., *Relationships between Vehicle Size and Fatality Risk in Model Year 1985-93 Passenger Cars and Light Trucks*, NHTSA Technical Report No. DOT HS 808 570, Washington, 1997, pp. 15-18.

model year and body type, and the type of restraint system for the driver and the right-front passenger.

Each vehicle is assigned two four-digit codes: its fundamental car group (CG) and specific make-model (MM2). These codes replace any make-model information already on FARS or the test data base. The MM2 codes generally, but not exactly, follow the pre-1991 FARS and NASS definitions. FARS cases with missing or ambiguous VINs are deleted. Body style (BOD2), based on the VIN, can be a 2-door convertible, 2-door coupe/sedan, 3-door hatchback, 4-door sedan, 5-door hatchback, or a station wagon.

From calendar year 1980 through early 1998, FARS contains 305,973 vehicle records with valid, decodable VINs of MY 1981-96 passenger cars involved in fatal crashes. No fewer than 58,942 of these vehicles (19 percent) belonged to one of the 469 CG-MM2-BOD2-MY combinations that has been FMVSS 214-tested or that is a "twin" of a 214-tested vehicle. The FARS vehicle data and the "twin" data base defined in the preceding section are merged to create a vehicle-oriented file of 58,942 records, including FARS variables describing the crash and the vehicle, and the FMVSS 214 test results for the matching test vehicle. Because earlier model years have been on the road longer and had more time to accumulate FARS data, 54,976 of these records are pre-FMVSS 214 cars, while only 3,966 are cars certified to meet FMVSS 214.

Three parameters that could not be reliably obtained from FARS are added to the file: the availability of air bags, the probability that the car has antilock brakes (ABS), and the curb weight in pounds. Information on whether a car has driver-only or dual air bags is decoded from the VIN and/or from tables of what types of occupant protection were offered by make-model and year[7]. The proportion of cars equipped with ABS is tabulated by make-model and year in *Ward's Automotive Almanacs*. The plain-English make-model names in the almanacs are translated to the numeric CG and MM2 codes to provide a look-up table of the probability that a car is equipped with ABS, as a function of its CG, MM2 and MY. Curb weights of passenger cars are accurately encoded in R. L. Polk's *National Vehicle Population Profile*. Polk has its own codes for vehicle make, model-subseries, body style, etc., and tabulates weights by those codes. NHTSA staff translated the Polk codes to CG, MM2, BOD2 and MY and created a look-up table of registration-weighted average curb weights by CG, MM2, BOD2 and MY[8].

Next, the vehicle-oriented file is merged with FARS person-level data to create an occupant-oriented file. There were 43,510 occupant fatalities in the 58,942 vehicles; of these, 38,446 were drivers or right-front passengers, 3,498 were rear-seat outboard occupants, and 1,566 were in center, other or unknown seat positions.

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[7]Kahane, C.J., *Fatality Reduction by Air Bags*, NHTSA Technical Report No. DOT HS 808 470, Washington, 1996, Appendix A.

[8]Kahane (1997), pp. 63-64.

Among the 38,446 front-outboard occupant fatalities, only 2,267 were in cars certified to meet FMVSS 214, insufficient data to attempt Phase 2 of the evaluation at this time. But 36,179 were in baseline, pre-standard cars, an adequate sample for Phase 1 of the evaluation.

Among the 36,179 fatalities in baseline cars, 3,400 were at seat positions equipped with air bags, or in cars with standard ABS, or in cars with more than 10 percent optional ABS. The presence of air bags or ABS is a major confounding factor for most of the analyses of this report, as will be discussed in subsequent chapters. Since only a small proportion of the baseline cars had air bags or ABS, many complications can be avoided, with minimal loss of sample size, by excluding them from the analyses.

There remain 32,779 fatality cases in baseline cars with known TTI(d), without air bags or ABS (or less than 10 percent optional ABS). Of these, 10,938 were in some type of side impact (IMPACT2 = 2, 3, 4, 8, 9, or 10) while 12,019 were in purely frontal impacts (IMPACT2 = 12 and M_HARM ≠ 1-7: i.e., the most harmful event was not a rollover, fire or other noncollision). The remainder were in partially frontal impacts, rollovers, rear impacts, or in other or unknown crash types. The 10,938 side-impact and 12,019 purely frontal fatality cases, however, supply the data for most of the analyses for Phase 1 of this evaluation.

Additionally, a vehicle-oriented file of 6,741 cars that fatally injured a pedestrian, pedalcyclist or other nonoccupant (HARM_EV = 8, 9,or 15) is created to support one analysis in Chapter 7.

The following variables are defined for each vehicle and occupant on the occupant-oriented file:

- VIN
- Model year
- Car group (4 digit code derived from VIN)
- Make-model (4 digit code derived from VIN)
- Body style (CV, 2 dr coupe/sedan, 3 dr HB, 4 dr sedan, 5 dr HB, SW)
- Curb weight from the Polk file (pounds)
- Air bag equipped at that seat position (0=no, 1=yes)
- ABS: proportion of cars of that make-model-year so equipped (ranges from 0 to 1)

- Calendar year of the crash
- Number of vehicles in the crash
- Principal impact point for this vehicle
- First harmful event in the crash
- Most harmful event for this vehicle
- In a 2-vehicle crash, description of the “other” vehicle (car, light truck, heavy truck)

- Occupant’s fatality outcome
- Seat position
- Age
- Gender
- Belt use

- Ejection

- Model year and body style of the matching FMVSS 214 test car
- TTI(d) for the front-seat dummy in the matching FMVSS 214 test car, test-speed adjusted
- Pelvic g's for the front-seat dummy
- TTI(d) for the rear-seat dummy
- Pelvic g's for the rear-seat dummy

- Quality of the model-year match (A or B)
- Quality of the body-style match (X or Y)

The TTI(d) and pelvic g's written on this file are those recorded on the SID dummies in the FMVSS 214 test vehicle during a 33.54 mph impact by a moving deformable barrier and <u>not</u> those actually experienced by occupants of the crash-involved vehicle on FARS, which are, of course, unknown. An occupant is "belted" if either a manual or an automatic belt (or, for passengers up to age 5, a child safety seat) was used, according to FARS (MAN_REST = 1, 2, 3 or 8 or AUT_REST = 1 in 1980-90; REST_USE = 1, 2, 3 or 8 in 1991-98; also for passengers up to 5 years old, MAN_REST or REST_USE = 4). The description of the "other" vehicle (car, light truck or heavy truck) is obtained only in two-vehicle crashes, by analysis of its first three VIN characters, if possible, or from the FARS variable BODY_TYP, otherwise.

CHAPTER 3

CORRELATION OF TTI(d) WITH SIDE/FRONTAL FATALITY RATIOS IN INDIVIDUAL FMVSS 214 BASELINE TEST MODELS

The relative risk of fatalities in real-world side impact crashes can be estimated by taking the ratio of fatalities in side impacts relative to a control group of purely frontal fatalities. For Phase 1 of this evaluation, ratios were calculated for front-outboard occupants age 30-65 in 43 pre-standard, MY 1980-92 car models that were baseline-tested by the FMVSS 214 procedure. The correlation of the real-world fatality ratio and the Thoracic Trauma Index [TTI(d)] of the front-seat dummy on the FMVSS 214 test is statistically significant: the make-models with lower TTI(d) have lower fatality risk. Results are different, however, for 2-door and 4-door cars. Two-door cars, with a wide range of TTI(d) performance including some very poor scores prior to FMVSS 214, had a relatively strong correlation between TTI(d) and fatality risk in side impacts. But in the 4-door cars, whose TTI(d) before FMVSS 214 was typically in a moderate range, there was only a doubtful association between TTI(d) and side impact fatality risk.

3.1 The 1981-1996 trend in TTI(d)

TTI(d) ranged from 40 to 131 among the 121 passenger cars tested during 1981-96. Since FMVSS 214 requires 2-door cars to have TTI(d) of 90 or less, and 4-door cars, 85 or less, it is evident that side impact performance varies considerably in production cars, ranging from very good to very poor in some pre-standard cars.

Specifically, though, the average TTI(d) performance has improved steadily over time, from an average of 95 in the cars that were tested from MY 1981 to 68 in MY 1996:

1981	95	1985	91	1989	88	1993	79
1982	93	1986	86	1990	86	1994	75
1983	92	1987	85	1991	84	1995	71
1984	90	1988	88	1992	75	1996	68

These are sales-weighted averages of the make-models that were actually tested, plus their twins, as defined in Section 2.3. “Sales” data were obtained by linking the 214 test data base and R.L. Polk’s *National Vehicle Population Profile*, as described in Section 7.1. A preliminary estimate for MY 1997 is that average TTI(d) was 65, i.e., slightly lower than in MY 1996. Figure 3-1 graphs these averages and illustrates the steady downward trend in TTI(d) - both before and during the 1994-97 phase-in period for FMVSS 214.

However, the pattern in Figure 3-1 can be misleading, because it is really the confluence of three separate tendencies. One factor is the long-term market shift from 2-door to 4-door cars. Figure 3-2 indicates that 50 percent of MY 1981 cars were 2-door models, but only 24 percent of MY 1996 cars. (These statistics are based on all passenger cars, not just those with known TTI(d).)

FIGURE 3-1

AVERAGE TTI(d) BY MODEL YEAR, 1981-1996
(passenger cars with known TTI(d); weighted by sales)

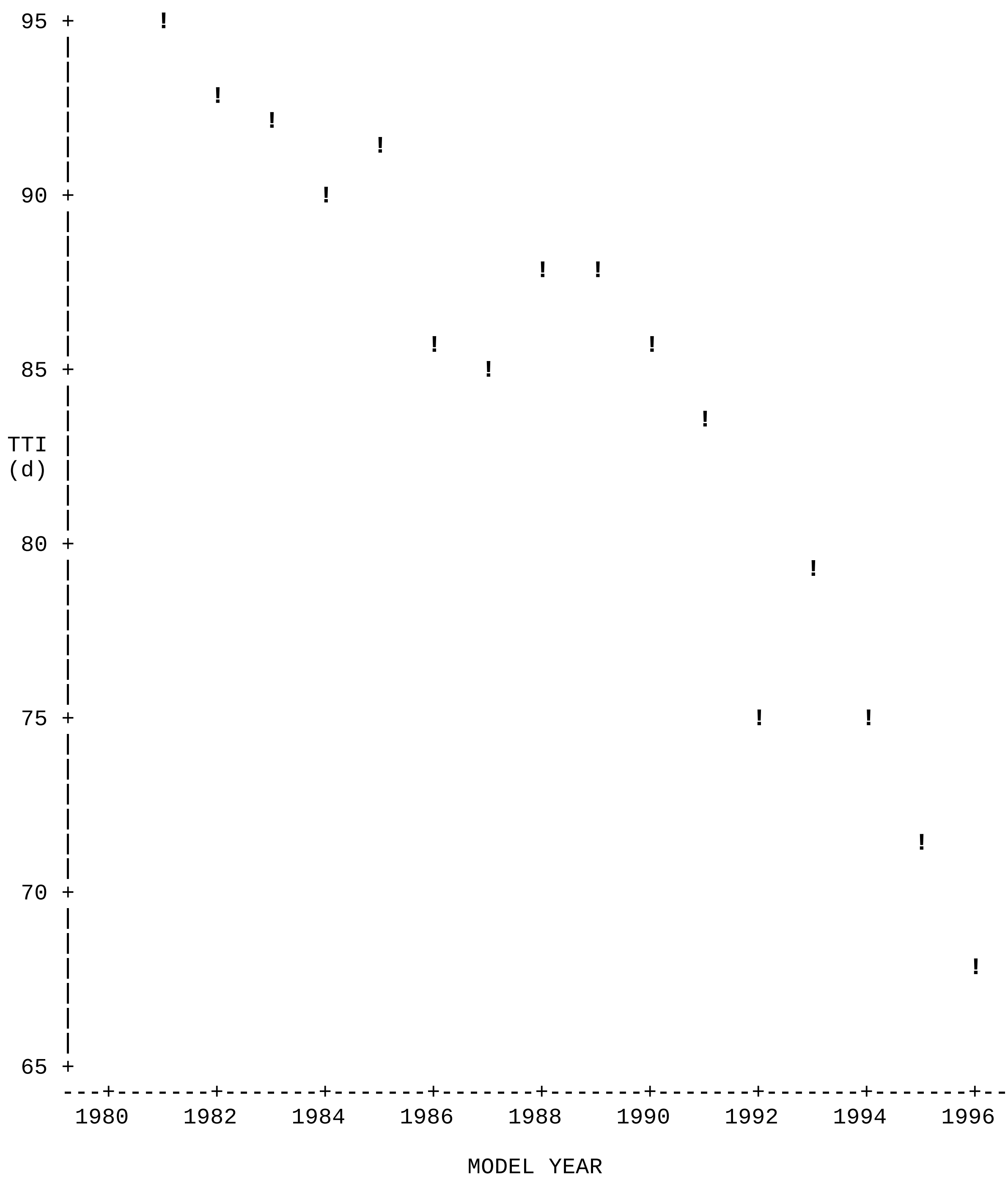
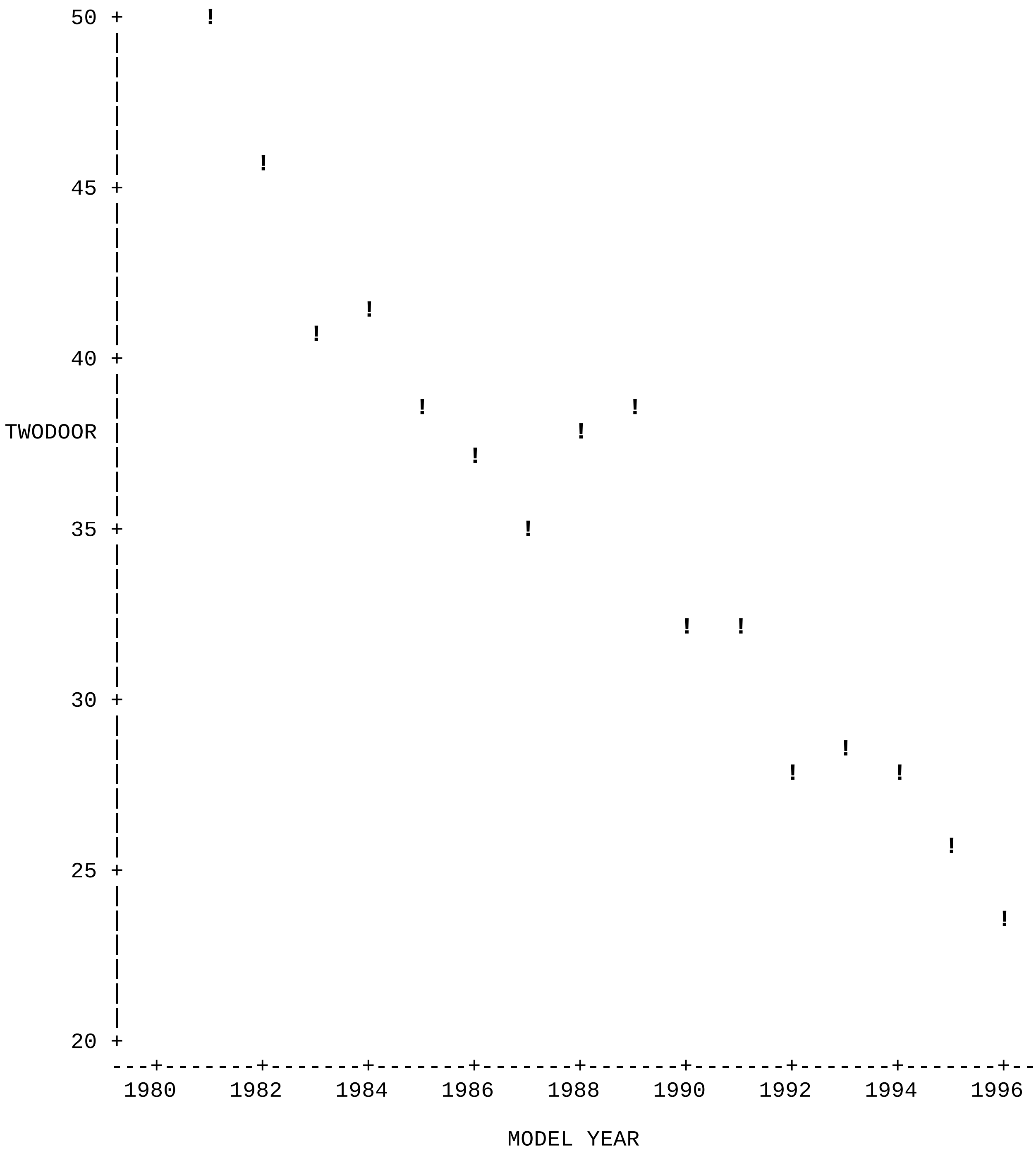


FIGURE 3-2

PERCENTAGE OF NEW CARS WITH TWO DOORS



In fact, the shift from 2-door to 4-door cars began in MY 1976 and it appears to be a result of demographics (as the baby-boomers age, they prefer 4-door cars) as well as changing tastes. Since 4-door cars have a number of safety advantages, such as a substantially lower risk of occupant ejection, this trend, not required by any regulation, saves lives[1]. A second factor is that TTI(d) was historically much higher, on the average, for 2-door cars than 4-door cars[2]. Thus, the shift from 2-door to 4-door cars lowers the overall average TTI(d). The third factor is that 2-door and 4-door cars each experienced, in their own way, a reduction of TTI(d) during 1981-96. Figure 3-3 graphs the following TTI(d) scores by model year:

2-DOOR CARS

1981	108	1985	114	1989	109	1993	97
1982	114	1986	112	1990	109	1994	88
1983	118	1987	107	1991	112	1995	80
1984	117	1988	109	1992	109	1996	75

4-DOOR CARS

1981	88	1985	84	1989	77	1993	74
1982	86	1986	78	1990	78	1994	72
1983	85	1987	79	1991	78	1995	68
1984	84	1988	78	1992	69	1996	66

Figure 3-3 shows that the average TTI(d) was substantially higher for 2-door cars than 4-door cars at all times, but especially prior to MY 1992. During MY 1981-91, average TTI(d) was fairly steady around 110 for 2-door cars and 80 for 4-door cars. The former is well above the FMVSS 214 requirement for 2-door cars (90) while the latter is slightly below the requirement for 4-door cars (85). What is interesting, though, is that when they are graphed separately, neither the 2-door nor the 4-door TTI(d) shows much of an improvement before 1992. The steady downward march of the combined average in Figure 3-1 was an artifact of the shift from 2-door to 4-door cars. Starting about 1992, two years before the actual phase-in of FMVSS 214 but two years after the Final Rule on FMVSS 214 was announced, average TTI(d) drops steadily - dramatically in 2-door cars and to a lesser extent in 4-door cars. By MY 1996, the average for 2-door cars (75) is just below the pre-standard average for 4-door cars (about 80), while the average for 4-door cars (66) is well below the requirements of the FMVSS.

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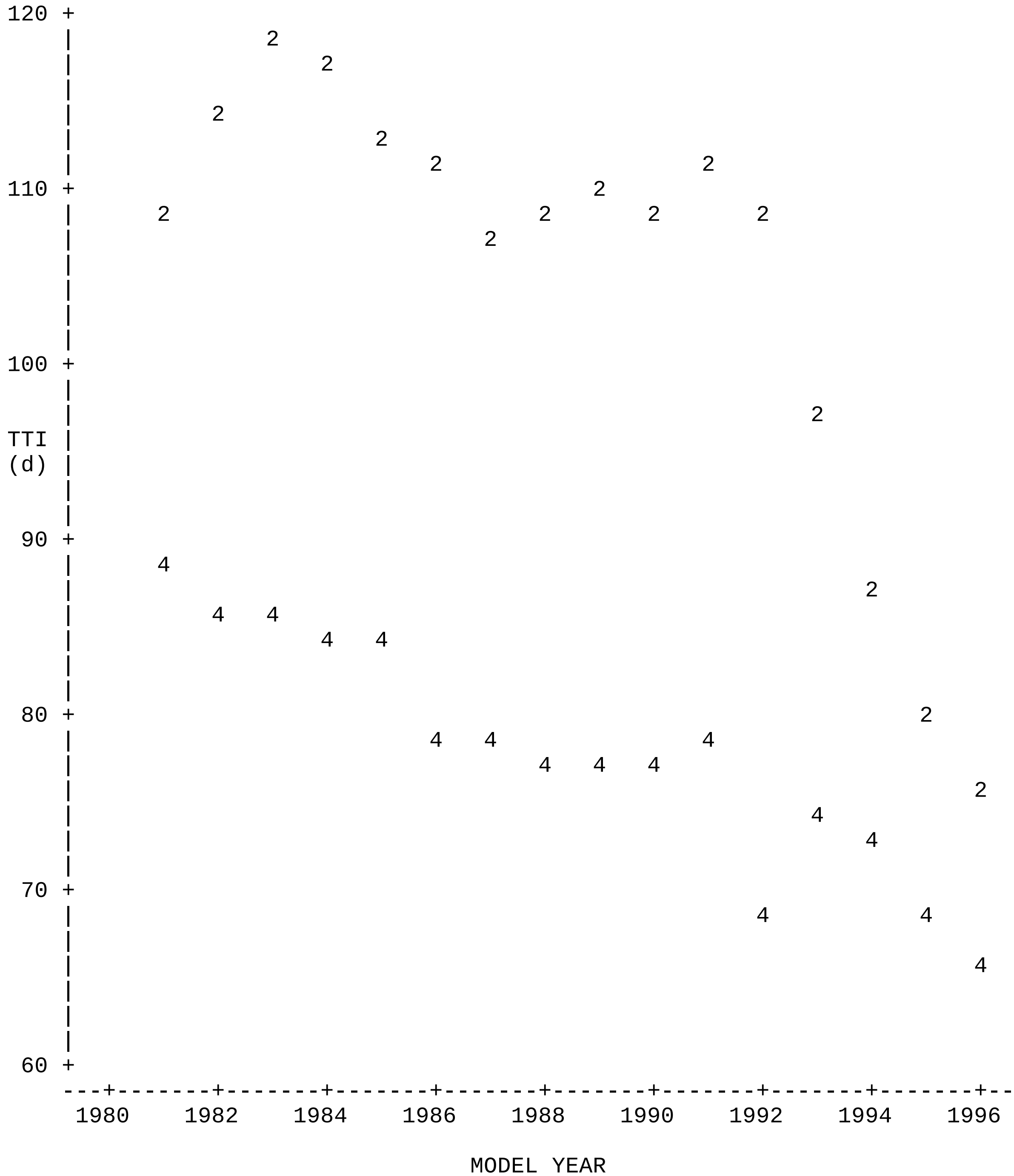
[1]Kahane, C.J., *An Evaluation of Door Locks and Roof Crush Resistance of Passenger Cars*, NHTSA Technical Report No. DOT HS 807 489, Washington, 1989, pp. 218-219.

[2]*Final Regulatory Impact Analysis, New Requirements for Passenger Cars to Meet a Dynamic Side Impact Test FMVSS 214*, NHTSA Publication No. DOT HS 807 641, Washington, 1990, pp. IIIC-19 - IIIC-25.

FIGURE 3-3: AVERAGE TTI(d) BY MODEL YEAR, 2-DOOR VS. 4-DOOR
(passenger cars with known TTI(d); weighted by sales)



3.2 Side-impact fatality risk by make-model

The simplest way to measure side-impact fatality risk in the real world for any make-model is to compute its rate of side-impact occupant fatalities per million registration years. As explained in Section 1.3, this approach would be unsatisfactory. Fatality rates vary among make-models by factors up to 9:1 because of differences in their drivers, overshadowing any crashworthiness differences. Section 1.3 recommends computing side-impact fatalities relative to a control group of purely frontal fatalities, unaffected by side-structure improvements. The driver factors that increase side-impact fatalities will also tend to increase frontal fatalities. The ratio of side/frontal fatalities will not vary as much from model to model as the side fatality rate per million years.

Thus, the basic analyses in Phase 1 of this evaluation compare the real-world ratio of side impacts to purely frontal fatalities to TTI(d) in the various individual baseline-tested make-models. Phase 1 is limited to the pre-FMVSS 214 cars that were baseline-tested. These cars belong to model years 1980-93. This technique - aggregating the crash data by make-model, computing a ratio of "relevant" to "control group" crashes, and investigating its correlation with a parameter obtained through vehicle testing - has been used in other NHTSA research, especially in studies of rollover propensity[3].

The method has three important advantages: (1) It is conservative. It analyzes fatality rates for a small number of genuinely independent data points - the individual make-models that were tested. (2) It creates an opportunity to scan the list of make-models and check if there is some obvious factor biasing the fatality ratios - e.g., if all the cars with low [or high] TTI(d) were sporty cars. (3) It is visual. Fatality ratios can be graphed as a function of TTI(d) for these make-models, revealing the pattern and the outliers, if any, in the relationship. The correlation coefficient for the scatterplot appraises the statistical significance of the visible pattern.

The analyses use the FARS data base defined in Section 2.3. In the FARS data, "side" impacts can initially be defined by IMPACT2 (the principal impact location) being 2, 3, 4, 8, 9, or 10. That includes nearside and farside impacts, compartment-centered and off-center damage, fixed-object and multivehicle crashes, side-damage rollovers and nonrollovers - i.e., an all-encompassing group of crashes where good TTI(d) scores might help a lot or just a little.

"Purely frontal" fatalities are defined by IMPACT2 = 12 and M_HARM ≠ 1-7 (principal damage in the front of the car, and the "most harmful" event was not a rollover or other noncollision). These fatalities involve side impact performance very little or not at all. They ought to be unaffected by TTI(d) scores. They are surrogates for a car experiencing a unit of exposure without a side-impact fatality. "Partially frontal" impacts such as those with IMPACT2 = 1 or 11,

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[3]Harwin, E.A. and Brewer, H.K., "Analysis of the Relationship between Vehicle Rollover Stability and Rollover Risk Using the NHTSA CARDfile Accident Database," *Journal of Traffic Medicine*, Vol. 18, No. 3, 1990; *Technical Assessment Paper: Relationship between Rollover and Vehicle Factors*, NHTSA Docket No. 91-068-N01-0003, Washington, 1992; the ratio of rollovers to fixed-object crashes was correlated with a static stability factor, tilt table ratio or critical sliding velocity by make-model.

or with a most-harmful-event rollover are excluded from the control group because they might involve side-structure integrity to a modest extent.

Ratios of side to purely frontal fatalities among front-seat outboard occupants - drivers and right front passengers - can be computed in the 1980-98 FARS data for each tested make-model (each tested make-model-year-body style combination, plus its twins, as defined in Section 2.2). It is unwise, however, to include every pre-FMVSS 214 make-model that was baseline-tested or to use all of the available FARS data. There are still important driver-related differences that cause the fatality risk to vary among make-models despite the use of frontals as a control group, and there are even ways that the use of the control group can add biases to the analysis.

Above all, the ratio of side to frontal fatalities is strongly related to the occupant's age. Figure 3-4 graphs the logarithm of the ratio of side/pure frontal occupant fatalities by the occupant's age. The relationship is highly nonlinear and U-shaped. Since ¾ of fatally injured front-seat occupants are drivers, we are primarily modeling a driver-age effect. Younger drivers have high proportions of side impacts because a combination of inexperience and aggressiveness motivates them to take risks and pull out in traffic and get hit in the side, or lose control and hit fixed objects sideways. Older drivers have increasing difficulty judging the speed and distance of oncoming traffic and are often hit in the side while turning, etc. People aged 30 to 65 have lower risk of side impacts relative to frontals than younger or older people. In turn, make-models with a concentration of young or old drivers will have inflated side/frontal fatality rates.

Whereas techniques such as regression can control for age differences, simple tabulations of fatality ratios by make-model do not. One way to make the results more comparable from model to model is to use only the FARS data for occupants **age 30 to 65**. By dropping the youngest and the oldest people, who have much higher side/frontal fatality ratios, and concentrating on the wide range in the middle, we can eliminate the biases against make-models that have high proportions of young or old drivers.

Air bags and antilock brake systems (ABS) can also be sources of bias. Since air bags reduce fatality risk in pure frontal impacts by about 30 percent and have little or no effect in side impacts, the presence of air bags ought to increase the ratio of side to frontal fatalities substantially[4]. ABS is associated with a reduction in frontal impacts [with other vehicles] and an increase in side impacts [with fixed objects][5]. They also substantially increase the ratio of side to frontal fatalities. Side/frontal fatality ratios will be strongly biased against make-models with air bags and ABS, regardless of their TTI(d). The only remedy is to make all the data equal with regard to the presence of air bags and ABS. Fortunately, most of the baseline test vehicles were not equipped with air bags or ABS, or at least had some "twins" without air bags or ABS. The analysis can be limited to cars without air bags or ABS with just a minimal loss of data. FARS cases are

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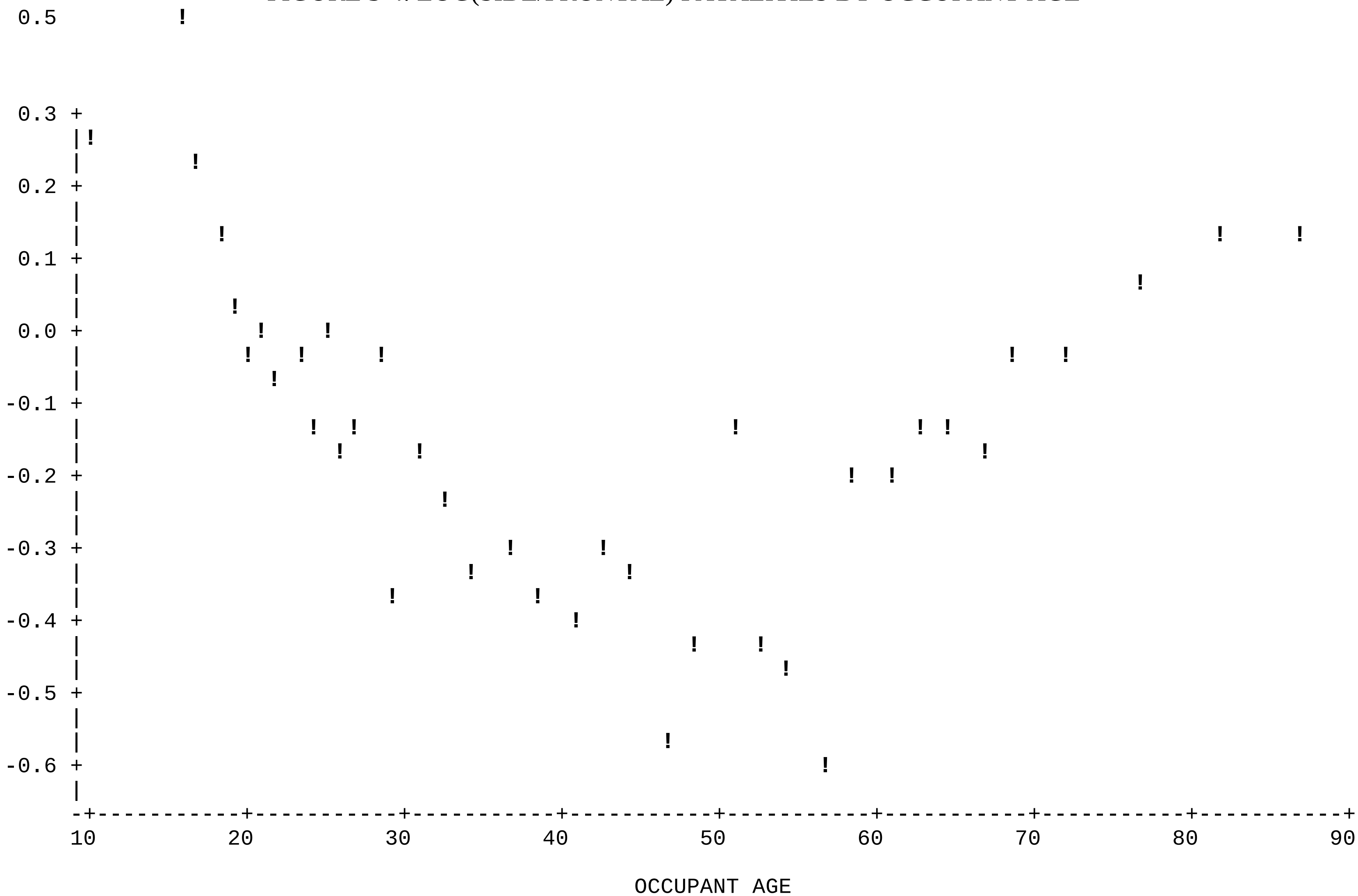
[4]Kahane, C.J., *Fatality Reduction by Air Bags*, NHTSA Technical Report No. DOT HS 808 470, Washington, 1996, pp. 23-33.

[5]Kahane, C.J., *Preliminary Evaluation of the Effectiveness of Antilock Brake Systems for Passenger Cars*, NHTSA Technical Report No. DOT HS 808 206, Washington, 1994.

FIGURE 3-4: LOG(SIDE/FRONTAL) FATALITIES BY OCCUPANT AGE



excluded if the occupant's position was equipped with air bags, or if the cars of that make-model-year had standard ABS or more than 10 percent of them had optional ABS.

A correlation of frontal and side-impact crashworthiness could potentially bias the analyses. If the cars with the best side impact protection are also the safest in frontals, their side/frontal fatality ratio might not be any lower than for cars that perform poorly in both crash modes. One way to test for such correlations is to compare the front-seat TTI(d) of baseline-test vehicles with the drivers' Head Injury Criteria (HIC) and chest g's in the New Car Assessment Program (NCAP), a 35 mph frontal barrier impact with belted dummies. The correlation coefficients of TTI(d) with frontal HIC and chest g's are not statistically significant in either 2-door or 4-door cars. In fact, the correlations of TTI(d) with HIC are not even positive. The results show little evidence that frontal and side-impact crashworthiness are confounded in the 1980-93 cars:

	2-Door Cars	4-Door Cars
N of cars with baseline TTI(d) and NCAP tests	17	21
Correlation coefficient of TTI(d) with HIC	- .247	- .180
Prob > | r | under H_0: r = 0	.340	.434
Correlation coefficient of TTI(d) with chest g's	.195	.030
Prob > | r | under H_0: r = 0	.453	.896

The side/frontal fatality ratios for the individual make-models are each based on finite quantities of FARS data and have sampling error: the fewer the data, the greater the probable error. Test vehicles with fewer than 10 associated FARS cases are excluded from the analysis, since a fatality ratio based on so few cases would not be statistically meaningful.

3.3 Initial correlation analysis: all baseline test vehicles

Table 3-1 lists 43 baseline test vehicles, ordered by their TTI(d) for the front-seat dummy from the lowest (40.00) to the highest (131.03). The TTI(d) scores received the minor test-speed adjustments defined in Section 2.1. The four right columns display the combined FARS front-outboard occupant data for each of the 43 make-models, for a range of model years before and/or after the test model year during which the design did not change, the occupant did not have an air bag, and the car did not have ABS (or had at most 10 percent optional ABS).

For example, a 1988 Lincoln Town Car 4-door sedan was tested and had TTI(d) = 40. Table 3-1 shows FARS statistics for 1981-89 Town Cars: fatalities in side impacts and purely frontal impacts of front-outboard occupants **age 30-65**. The right column is the dependent variable, the logarithm of the ratio of side impact to purely frontal fatalities. Log ratios are often used in analyses of this type because they tend to have better linear correlations with crash parameters than the ratios themselves. A negative number indicates a low risk of fatality in a side impact, relative to the control group of purely frontal fatalities; a positive number indicates high risk.

TABLE 3-1: ALL SIDE IMPACTS, TTI(d) vs. SIDE IMPACT FATALITY RISK
(front outboard occupants age 30-65 in 43 pre-FMVSS 214 make-models with no air bags and < 10% ABS)

TTI (d)	FMVSS 214 Test MY-Make-Model	N of Doors	FARS MY Range	N of Fatalities Age 30-65 Total	Side	Purely Frontal	**Side Impact Fatality Risk** Log(Side/Front)
40.00	1988 Lincoln Town Car	4	1981-89	299	115	184	**- 0.470**
50.73	1988 Chevrolet Caprice	4	1981-90	638	233	405	**- 0.553**
61.79	1989 Plymouth Colt Vista	4	1984-91	26	14	12	**+ 0.154**
65.60	1992 Chevrolet Lumina	4	1990-91	117	41	76	**- 0.617**
71.81	1980 AMC Concord	4	1981-83	57	29	28	**+ 0.035**
73.50	1988 Oldsmobile Calais	4	1986-91	127	56	71	**- 0.237**
74.80	1990 Pontiac 6000	4	1989-91	52	28	24	**+ 0.154**
76.43	1988 Pontiac Bonneville	4	1987-91	37	13	24	**- 0.613**
76.82	1990 Ford Taurus	4	1990-91	14	4	10	**- 0.916**
77.76	1981 Honda Civic	4	1981	37	13	24	**- 0.613**
77.79	1984 Chevrolet Celebrity	4	1982-88	927	387	540	**- 0.333**
78.22	1988 Ford Taurus	4	1986-89	481	200	281	**- 0.340**
78.70	1988 Oldsmobile Delta 88	4	1986-91	264	106	158	**- 0.399**
81.21	1986 Chevrolet Cavalier	4	1982-86	586	231	355	**- 0.430**
82.22	1985 Chevrolet Spectrum	2	1985-89	66	26	40	**- 0.431**
82.23	1987 Chevrolet Cavalier	4	1987-88	178	74	104	**- 0.340**
85.62	1988 Hyundai Excel	4	1986-89	290	106	184	**- 0.551**
85.72	1992 Honda Accord	4	1990-91	182	67	115	**- 0.540**
88.10	1988 Chevrolet Sprint	4	1986-88	50	24	26	**- 0.080**
88.65	1981 Chevrolet Citation	4	1981-85	357	157	200	**- 0.242**
91.56	1992 Nissan Sentra	4	1991-94	115	50	65	**- 0.262**
92.12	1982 Chevrolet Citation	2	1981-85	98	35	63	**- 0.588**
93.54	1983 Ford Escort	4	1982-85	424	185	239	**- 0.256**
98.00	1988 Ford Escort	4	1988-90	157	73	84	**- 0.140**
98.06	1987 Nissan Sentra	2	1987-90	217	89	128	**- 0.363**
101.53	1981 Ford Granada	2	1981-82	24	9	15	**- 0.511**
102.88	1982 Honda Civic	4	1982-83	76	37	39	**- 0.053**
105.10	1988 Volkswagen Golf	2	1985-92	48	20	28	**- 0.336**
105.12	1983 Mazda 626	4	1983-87	126	71	55	**+ 0.255**
108.00	1988 Ford Escort	2	1988-90	179	72	107	**- 0.396**
108.17	1988 Chevrolet Sprint	2	1985-88	103	47	56	**- 0.175**
109.20	1988 Chevrolet Corvette	2	1984-85	88	49	39	**+ 0.228**
110.00	1988 Ford Mustang	2	1981-93	715	380	335	**+ 0.126**
110.00	1988 Ford Festiva	2	1988-93	205	59	146	**- 0.906**
110.44	1981 Plymouth Horizon	4	1981-90	373	138	235	**- 0.532**
111.00	1988 Oldsmobile Calais	2	1985-91	216	96	120	**- 0.223**
114.41	1981 Volkswagen Rabbit	2	1981-84	109	50	59	**- 0.166**
117.30	1988 Buick Regal	2	1988-91	113	47	66	**- 0.340**
117.38	1982 Dodge 400	2	1982-83	32	16	16	**0.000**
118.37	1981 Ford Granada	4	1981-82	95	40	55	**- 0.318**
118.86	1981 Dodge Omni	2	1981-87	178	87	91	**- 0.045**
129.35	1982 Nissan Sentra	2	1982	34	17	17	**0.000**
131.03	1983 Nissan Sentra	2	1983-86	192	102	90	**+ 0.125**

In a few cases, the FARS MY range excludes the MY of the test vehicle. For example, a 1988 Chevrolet Corvette was tested, but only the 1984-85 Corvettes are analyzed, because all subsequent models, including the test vehicle, had ABS. Similarly, the FARS N is low for 1990-91 Ford Taurus because only right-front passengers can be included: all drivers had air bags.

Figure 3-5 graphs the log fatality ratios by TTI(d) for these 43 make-models. Two-door cars are indicated by stars, 4-door by circles. The statistically more meaningful data points based on 100 or more FARS cases are **blacked in**, the others are not. Although not a perfect correlation, there is no question that the data points in Figure 3-5 tend to cluster along the diagonal, especially the statistically more important blacked-in points. Relative fatality risk in side impacts is higher as TTI(d) increases. There is only one obvious outlier among the blacked-in points (Ford Festiva, a small economy car with an exceptionally low relative risk factor). Generally, most of the cars with TTI(d) < 100 have a risk factor lower than -0.2, while many of the cars with TTI(d) > 100 have risk factors higher than -0.2.

The strength of the relationship between TTI(d) and side impact fatality risk at the make-model level can be gauged by computing the weighted correlation coefficient[6] for the scatterplot in Figure 3-5. Each of the 43 data points is weighted by the total N of fatal crash cases as shown in Table 3-1. The correlation coefficient is +.477. Since the probability of observing a more positive coefficient by chance alone, given 43 data points, is .0006, this coefficient is statistically significant at the .01 level. **This positive coefficient is an effect in the "right" direction**: the lower the TTI(d), the lower the side-impact fatality risk.

There are three reasons that the correlation coefficient is less than 1. The most important is that many factors besides TTI(d) cause the measure of fatality risk to vary from model to model, such as variations in the types of people who drive them, the roadways they are driven on, etc. Second, the fatality risk statistic for each make-model is calculated from a finite number of fatality cases and it is not necessarily a precise estimate (sampling error in the dependent variable). Even if the definition of "side impact" were limited to a subset of crashes where, theoretically, a stronger relationship of TTI(d) to fatality risk would be expected, the correlation coefficient would not necessarily rise since the samples are getting smaller. Third, the TTI(d) measurements are usually based on a single test vehicle and might have been slightly different if another test vehicle of the same make-model-year-body type had been used (measurement error in the independent variable).

3.4 Why 2- and 4-door cars should be studied separately

Table 3-1 and Figure 3-5 show a good overall correlation between TTI(d) and side/frontal fatality risk, but they also demonstrate clearly that 2-door and 4-door cars had quite different TTI(d) performance during Phase 1. The 14 best TTI(d) scores, and 20 of the 21 best were 4-door cars; 12 of the 14 worst were 2-door cars. These are two populations that barely overlap. Does the

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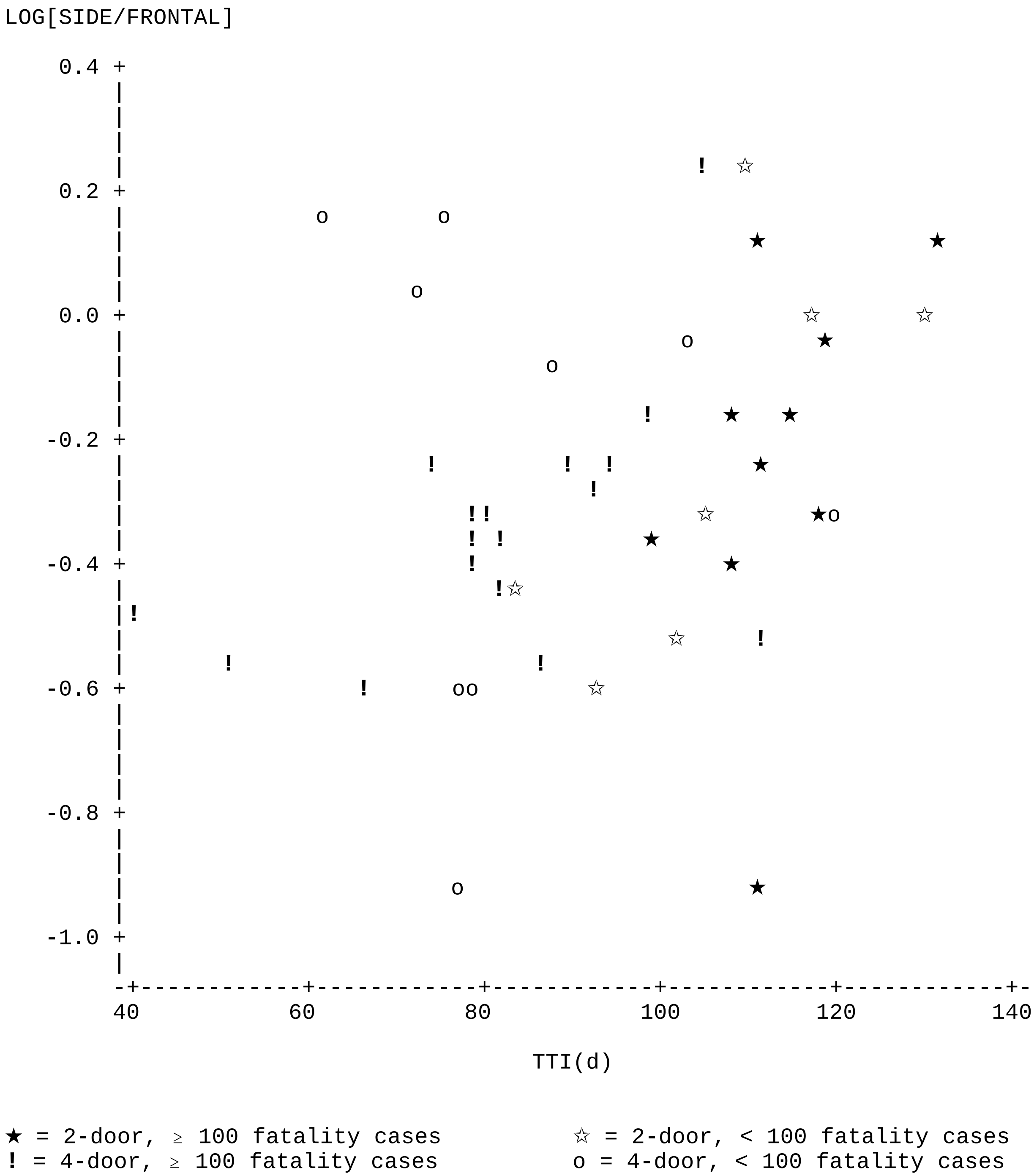
[6] *SAS® Procedures Guide, Version 6, Third Edition,* SAS Institute, Inc., Cary, NC, 1990, p. 218.

FIGURE 3-5: ALL SIDE IMPACTS
LOG RATIO OF SIDE TO PURE FRONTAL FATALITIES AGE 30-65, BY TTI(d)
(front outboard occupants in 43 pre-FMVSS 214 make-models with no air bags and < 10% ABS)



overall correlation between TTI(d) and side/frontal fatality risk merely reflect that 2-door cars have higher fatality risk and higher TTI(d) than 4-door cars? Figure 3-5 does not provide an easy answer. If all the blacked-in circles (4-door cars) were along a low horizontal line, and the stars (2-door cars) along a high horizontal line, it would be clear that the primary factor is N of doors, not TTI(d), and that the positive correlation coefficient merely reflects the confounding of N of doors with TTI(d). But the blacked-in circles and stars in Figure 3-5 seem to fall, more or less, along a single diagonal line. That's encouraging. It is consistent with the hypothesis that TTI(d) has a relationship with fatality risk, independent of the N of doors. Nevertheless, we can hardly be sure of what Figure 3-5 is saying, given the scatter in the data.

Additionally, there are several parameters strongly correlated with fatality risk and also having different values in 2-door and 4-door cars. Above all, 2-door cars have a high proportion of young drivers, who have high rates of side impacts relative to frontals, as was shown in Figure 3-4. On the other hand, 4-door cars have higher proportions of older and female drivers, who also have high rates of side impacts relative to frontals. Hopefully, limiting the data to people age 30-65 controlled for most of the age differences. But it is still difficult, when the two populations are so heterogeneous, to separate the effect of TTI(d) from the influence of other parameters confounded with N of doors, especially in a relatively simple analysis such as this one, where multivariate methods are not available.

More convincing assessments of the true effects of TTI(d) can be obtained by analyzing 2-door and 4-door cars separately. Furthermore, within each of these separate analyses, it will be advisable to look over the make-models involved and perhaps exclude those cars whose structures or drivers are so different from the others that their presence distorts the results and obscures the main trends in the data.

3.5 Correlation in 2-door cars

Table 3-2 lists the 17 2-door make-models that were baseline tested, ordered by TTI(d) from the lowest (82.22) to the highest (131.03). It includes all the 2-door cars in Table 3-1. The four right columns display the FARS fatality counts of front outboard occupants age 30-65 and the log(side/frontal) measure of risk. Curb weights are also shown.

Figure 3-6 graphs the log fatality ratio by TTI(d) for these 17 make-models. It is essentially a "close-up" of the right upper section of Figure 3-5, since most of the Phase 1 test results with high TTI(d) were 2-door cars. Except for three outliers, Table 3-2 and Figure 3-6 show a clear trend to higher relative fatality risk in side impacts as TTI(d) increases. The six make-models with the lowest TTI(d) all have low side impact fatality risk, with the log ratios running from -.588 to -.336. The four models with the highest TTI(d) have high risk factors, ranging from -.045 to +.125. Figure 3-6 shows, other than the three outliers, a rather steady march up the diagonal. Two of the outliers, not too far from the diagonal, are the Chevrolet Corvette and Ford Mustang, sporty cars with high fatality risk in side impacts (+.228, +.126) and median TTI(d). (They were barely noticeable as outliers in the less close-up Figure 3-5.) The third, further from the diagonal, is the Ford Festiva, a small economy car with an exceptionally low risk factor (-.906) and median TTI(d).

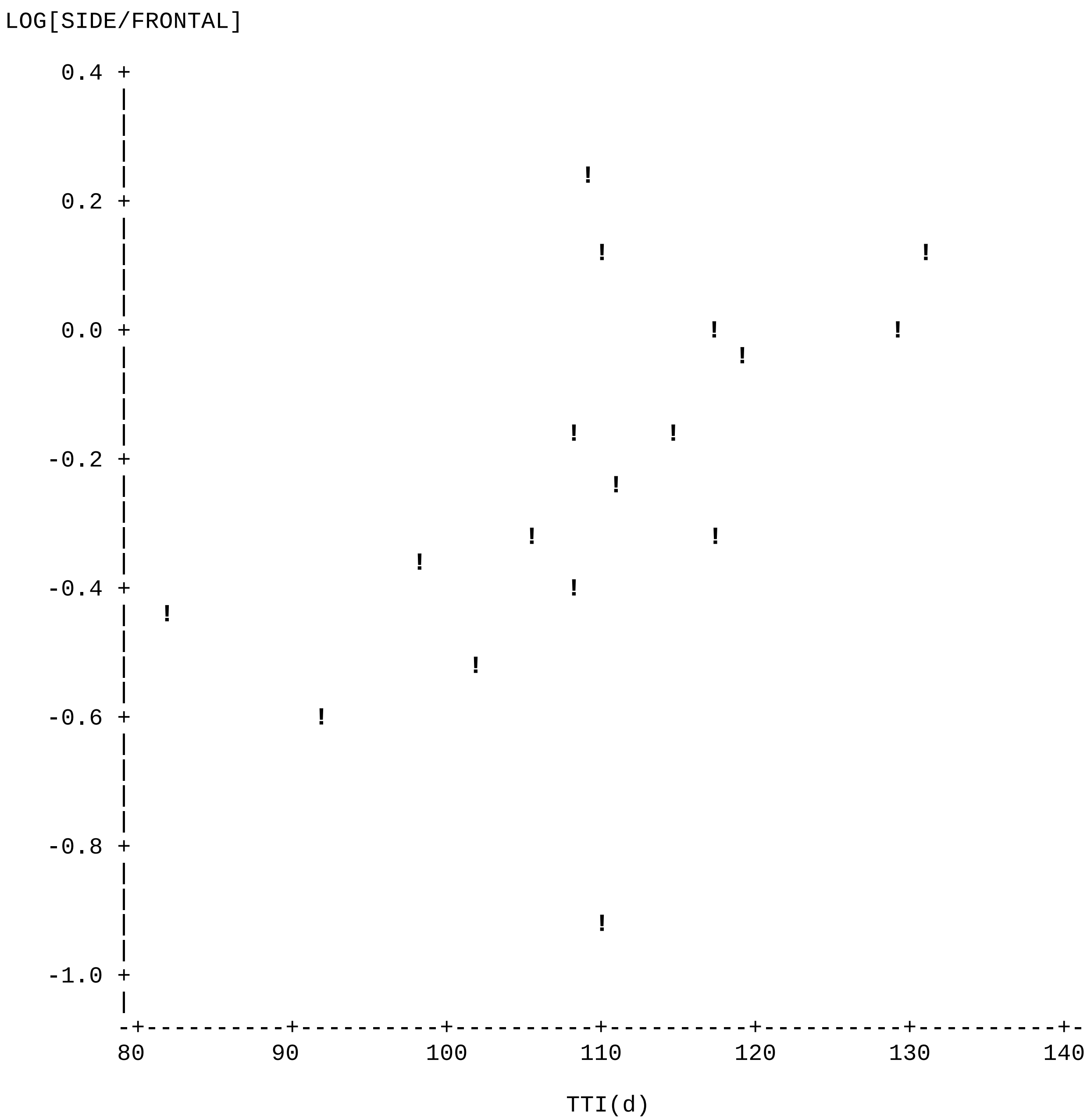
TABLE 3-2

2-DOOR MAKE-MODELS, ALL SIDE IMPACTS: TTI(d) vs. SIDE IMPACT FATALITY RISK
(front outboard occupants age 30-65 in 17 pre-FMVSS 214 make-models with no air bags and < 10% ABS)

TTI (d)	FMVSS 214 Test MY-Make-Model	FARS MY Range	Curb Weight	N of Fatalities Age 30-65 Total	Side	Purely Frontal	**Side Impact Fatality Risk** Log(Side/Front)
82.22	1985 Chevrolet Spectrum	1985-89	1888	66	26	40	**- 0.431**
92.12	1982 Chevrolet Citation	1981-85	2505	98	35	63	**- 0.588**
98.06	1987 Nissan Sentra	1987-90	2178	217	89	128	**- 0.363**
101.53	1981 Ford Granada	1981-82	2863	24	9	15	**- 0.511**
105.10	1988 Volkswagen Golf	1985-92	2184	48	20	28	**- 0.336**
108.00	1988 Ford Escort	1988-90	2285	179	72	107	**- 0.396**
108.17	1988 Chevrolet Sprint	1985-88	1536	103	47	56	**- 0.175**
109.20	1988 Chevrolet Corvette	1984-85	3191	88	49	39	**+ 0.228**
110.00	1988 Ford Mustang	1981-93	2903	715	380	335	**+ 0.126**
110.00	1988 Ford Festiva	1988-93	1743	205	59	146	**- 0.906**
111.00	1988 Oldsmobile Calais	1985-91	2525	216	96	120	**- 0.223**
114.41	1981 Volkswagen Rabbit	1981-84	1959	109	50	59	**- 0.166**
117.30	1988 Buick Regal	1988-91	3061	113	47	66	**- 0.340**
117.38	1982 Dodge 400	1982-83	2525	32	16	16	**0.000**
118.86	1981 Dodge Omni	1981-87	2286	178	87	91	**- 0.045**
129.35	1982 Nissan Sentra	1982	1890	34	17	17	**0.000**
131.03	1983 Nissan Sentra	1983-86	1875	192	102	90	**+ 0.125**

FIGURE 3-6

2-DOOR MAKE-MODELS, ALL SIDE IMPACTS
LOG RATIO OF SIDE TO PURE FRONTAL FATALITIES AGE 30-65, BY TTI(d)
(front outboard occupants in 17 pre-FMVSS 214 make-models with no air bags and < 10% ABS)



This method allows an inspection of all the individual make-models that constitute the data. Except for the Corvette and the Mustang, all are either small economy cars or the 2-door versions of average-sized, non-luxury cars. Except for Corvette and Mustang, these 2-door cars might be expected to attract a somewhat young but otherwise fairly average group of drivers. Importantly, a review of Table 3-2 does not show any obvious differences between the cars with low TTI(d) and high TTI(d). It shows a mix of small economy cars and average-sized cars throughout the range of TTI(d). This review provides encouragement that the trend seen in Figure 3-6 may be due to genuine differences in side impact crashworthiness, rather than, say, a clustering of sportier or more luxurious cars at one end of the TTI(d) range.

Two of the outliers, Corvette and Mustang, are not surprising. Higher performance cars typically attract drivers who test the limits of performance and sometimes lose control, resulting in high rates of side impacts, especially with fixed objects. It is difficult to understand, though, why the side/frontal fatality ratio in the Ford Festiva is so much lower than the other small economy cars in Table 3-2. We shall see in Tables 7-1 and 7-2 that this is a consequence of a high fatality rate in frontal impacts, rather than an especially low rate in side impacts. However, NHTSA has no explanation why this model's frontal fatality rate is high; for example, Festiva's chest g's on the New Car Assessment Program, a 35 mph frontal impact test, were a quite satisfactory 46 for the driver dummy and 42 for the passenger dummy[7].

The strength of the relationship between TTI(d) and side impact fatality risk at the make-model level can be gauged by computing the correlation coefficient for the scatterplot in Figure 3-6, with each data point weighted by the total N of fatal crash cases as shown in Table 3-2. The correlation coefficient is .418. Since the probability of observing a more positive coefficient by chance alone, given 17 data points, is .0476, this coefficient is statistically significant at the .05 level. Notwithstanding the three outliers, the data suggest that 2-door cars with better TTI(d) scores have significantly lower fatality risk in side impacts.

It is noteworthy in Table 3-2 that the 1983-86 Nissan Sentra has the high TTI(d) while the 1987-90 Nissan Sentra has fairly low TTI(d) among pre-FMVSS 214 2-door cars. The older Sentra has 102 side-impact fatalities relative to 90 pure frontals. In the later Sentra, the ratio is 89 to 128. That is a remarkable 39 percent reduction in side-impact fatalities relative to frontals in one pre-FMVSS 214 vehicle that may have been consciously redesigned with a goal of improving test performance (see Section 1.2).

Despite a reduced sample size, Table 3-3 and Figure 3-7 show an enhanced correlation between TTI(d) and fatality risk when the definition of a "side" impact is a nearside compartment strike (IMPACT2 = 9 for drivers and 3 for passengers) and a "purely frontal" crash is the same as above. The seven make-models with the lowest TTI(d) all have a fatality risk factor more negative than -1, while the six with high TTI(d) all have a risk factor more positive than -1. Although Corvette and Mustang still have higher than expected risk and Festiva, lower, they are not nearly as far out of line as in Table 3-2. Corvette and Mustang have lower risk than three of

[7] *New Car Assessment Program Results, Model Years 1987-1991*, NHTSA Office of Market Incentives, Washington, 1991.

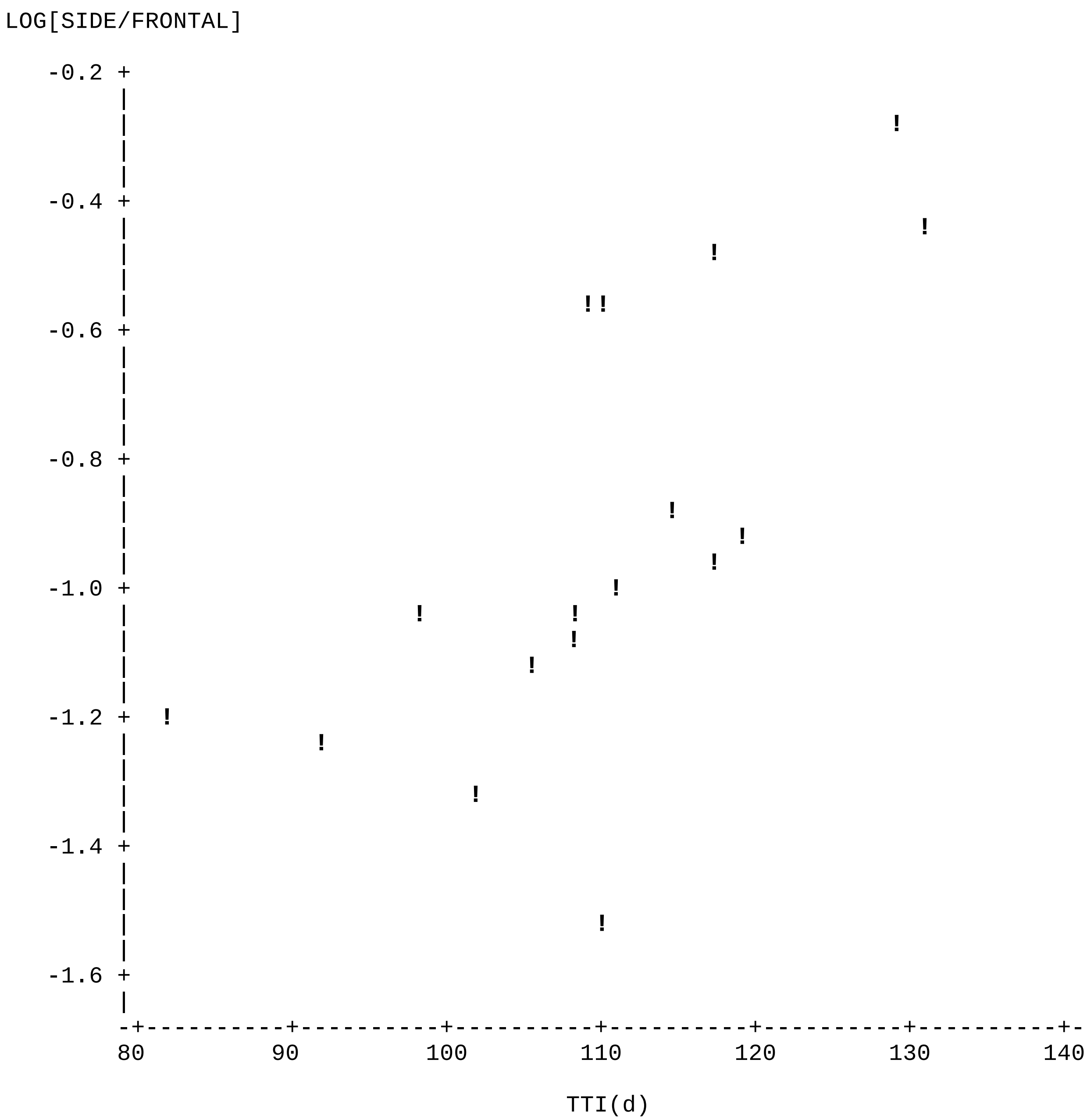
TABLE 3-3

2-DOOR MAKE-MODELS, NEARSIDE COMPARTMENT IMPACTS: TTI(d) vs. SIDE IMPACT FATALITY RISK
(front outboard occupants age 30-65 in 17 pre-FMVSS 214 make-models with no air bags and < 10% ABS)

TTI (d)	FMVSS 214 Test MY-Make-Model	FARS MY Range	Curb Weight	N of Fatalities Age 30-65 Total	Nearside Compartment	Purely Frontal	**Side Impact Fatality Risk** Log(Side/Front)
82.22	1985 Chevrolet Spectrum	1985-89	1888	52	12	40	**- 1.204**
92.12	1982 Chevrolet Citation	1981-85	2505	81	18	63	**- 1.253**
98.06	1987 Nissan Sentra	1987-90	2178	173	45	128	**- 1.045**
101.53	1981 Ford Granada	1981-82	2863	19	4	15	**- 1.322**
105.10	1988 Volkswagen Golf	1985-92	2184	37	9	28	**- 1.135**
108.00	1988 Ford Escort	1988-90	2285	143	36	107	**- 1.089**
108.17	1988 Chevrolet Sprint	1985-88	1536	76	20	56	**- 1.030**
109.20	1988 Chevrolet Corvette	1984-85	3191	61	22	39	**- 0.573**
110.00	1988 Ford Mustang	1981-93	2903	526	191	335	**- 0.562**
110.00	1988 Ford Festiva	1988-93	1743	178	32	146	**- 1.518**
111.00	1988 Oldsmobile Calais	1985-91	2525	164	44	120	**- 1.003**
114.41	1981 Volkswagen Rabbit	1981-84	1959	83	24	59	**- 0.899**
117.30	1988 Buick Regal	1988-91	3061	91	25	66	**- 0.971**
117.38	1982 Dodge 400	1982-83	2525	26	10	16	**- 0.470**
118.86	1981 Dodge Omni	1981-87	2286	127	36	91	**- 0.927**
129.35	1982 Nissan Sentra	1982	1890	30	13	17	**- 0.268**
131.03	1983 Nissan Sentra	1983-86	1875	147	57	90	**- 0.457**

FIGURE 3-7

2-DOOR MAKE-MODELS, NEARSIDE COMPARTMENT IMPACTS
LOG RATIO OF SIDE TO PURE FRONTAL FATALITIES AGE 30-65, BY TTI(d)
(front outboard occupants in 17 pre-FMVSS 214 make-models with no air bags and < 10% ABS)



the four models with the highest TTI(d), and Festiva is only slightly lower than the next lowest model. Thus, Figure 3-7 shows a more consistent distribution of the data points along the diagonal than Figure 3-6. The weighted correlation coefficient is .496. Since the probability of observing a more positive coefficient by chance alone is .0214, this coefficient is statistically significant at the .05 level.

Table 3-4 and Figure 3-8 show correlation between TTI(d) and fatality risk when the side impacts are nearside compartment strikes by another vehicle and the control group fatalities are purely frontal impacts by another vehicle. The cars with lower TTI(d) generally have a fatality risk factor below -1, while those with high TTI(d) all have a risk factor above -1. Corvette and Mustang are no longer outliers. Their drivers have high rates of side impacts with fixed objects, but since Table 3-4 is limited to impacts by other vehicles, the experience of Corvette and Mustang is not too different from other make-models. Festiva continues to have a risk factor lower than expected. The conspicuous outlier here is the Dodge 400. Its high observed risk factor, however, is based on just 16 FARS cases and is not too meaningful, statistically. Except for that outlier, Figure 3-8 shows a moderately diagonal alignment of the data points. The weighted correlation coefficient is .452. Since the probability of observing a more positive coefficient by chance alone is .0343, the coefficient is statistically significant at the .05 level. Thus, Figures 3-7 and 3-8 produce quite similar correlation coefficients, even though, at first glance, Figure 3-7 presents a stronger relationship. However, the Dodge 400 outlier in Figure 3-8 is given little weight because of its limited sample size, while the numerically important Mustang, an outlier in Figure 3-7, is nearly in line with the other data points in Figure 3-8.

Three other analyses were performed for 2-door cars. The correlation coefficients were in the "right" direction (positive) like the preceding ones, but they fell short of statistical significance. The ratio of all side impacts by another vehicle to all purely frontal impacts by another vehicle had correlation .408 with TTI(d); the probability of observing a more positive coefficient by chance alone is .052. The ratio of all side impacts by a passenger car to purely frontal impacts by a passenger car had correlation .387 with TTI(d), $p = .077$. The ratio of nearside compartment impacts by a passenger car to purely frontal impacts by a passenger car had $r = .360$, $p = .114$. In the last two analyses, the sample sizes for some of the individual make-models are quite small.

3.6 Correlation in 4-door cars

Table 3-5 lists 26 pre-standard 4-door make-models that were baseline-tested, showing FARS statistics for seats without air bags and cars without ABS (or less than 10 percent optional ABS). They are ranked by TTI(d) from the lowest (40.00) to the highest (118.37). The FARS statistics are front-outboard fatalities age 30-65, in all types of side impacts and in purely frontal impacts, for a range of model years before and/after the test model year during which the design did not change.

The first two cars are listed in *italics* because they are quite different from most of the others. The Lincoln Town Car and Chevrolet Caprice are much larger than the other cars, have different types of drivers, and much lower TTI(d). In fact, the pre-standard, 1988 Lincoln Town Car's 40.00 is the lowest TTI(d) ever recorded as of 1997, lower than any post-standard car. The

TABLE 3-4: 2-DOOR MAKE-MODELS, NEARSIDE COMPARTMENT IMPACTS BY ANOTHER VEHICLE
TTI(d) vs. SIDE IMPACT FATALITY RISK
(front outboard occupants age 30-65 in 17 pre-FMVSS 214 make-models with no air bags and < 10% ABS)

TTI (d)	FMVSS 214 Test MY-Make-Model	FARS MY Range	Curb Weight	N of 2-Veh. Fatals Age 30-65: Total	Nearside Compartment	Purely Frontal	**Side Impact Fatality Risk** Log(Side/Front)
82.22	1985 Chevrolet Spectrum	1985-89	1888	30	8	22	**- 1.012**
92.12	1982 Chevrolet Citation	1981-85	2505	54	14	40	**- 1.050**
98.06	1987 Nissan Sentra	1987-90	2178	103	31	72	**- 0.843**
101.53	1981 Ford Granada	1981-82	2863	12	3	9	**- 1.099**
105.10	1988 Volkswagen Golf	1985-92	2184	17	6	11	**- 0.606**
108.00	1988 Ford Escort	1988-90	2285	93	20	73	**- 1.295**
108.17	1988 Chevrolet Sprint	1985-88	1536	52	17	35	**- 0.722**
109.20	1988 Chevrolet Corvette	1984-85	3191	15	5	10	**- 0.693**
110.00	1988 Ford Mustang	1981-93	2903	284	104	180	**- 0.549**
110.00	1988 Ford Festiva	1988-93	1743	122	24	98	**- 1.407**
111.00	1988 Oldsmobile Calais	1985-91	2525	106	34	72	**- 0.750**
114.41	1981 Volkswagen Rabbit	1981-84	1959	59	16	43	**- 0.989**
117.30	1988 Buick Regal	1988-91	3061	46	16	30	**- 0.629**
117.38	1982 Dodge 400	1982-83	2525	16	10	6	**+ 0.511**
118.86	1981 Dodge Omni	1981-87	2286	62	17	45	**- 0.973**
129.35	1982 Nissan Sentra	1982	1890	18	8	10	**- 0.223**
131.03	1983 Nissan Sentra	1983-86	1875	99	43	56	**- 0.264**

FIGURE 3-8

2-DOOR MAKE-MODELS
NEARSIDE COMPARTMENT IMPACTS BY ANOTHER VEHICLE
LOG RATIO OF SIDE TO PURE FRONTAL FATALITIES AGE 30-65, BY TTI(d)
(front outboard occupants in 17 pre-FMVSS 214 make-models with no air bags and < 10% ABS)

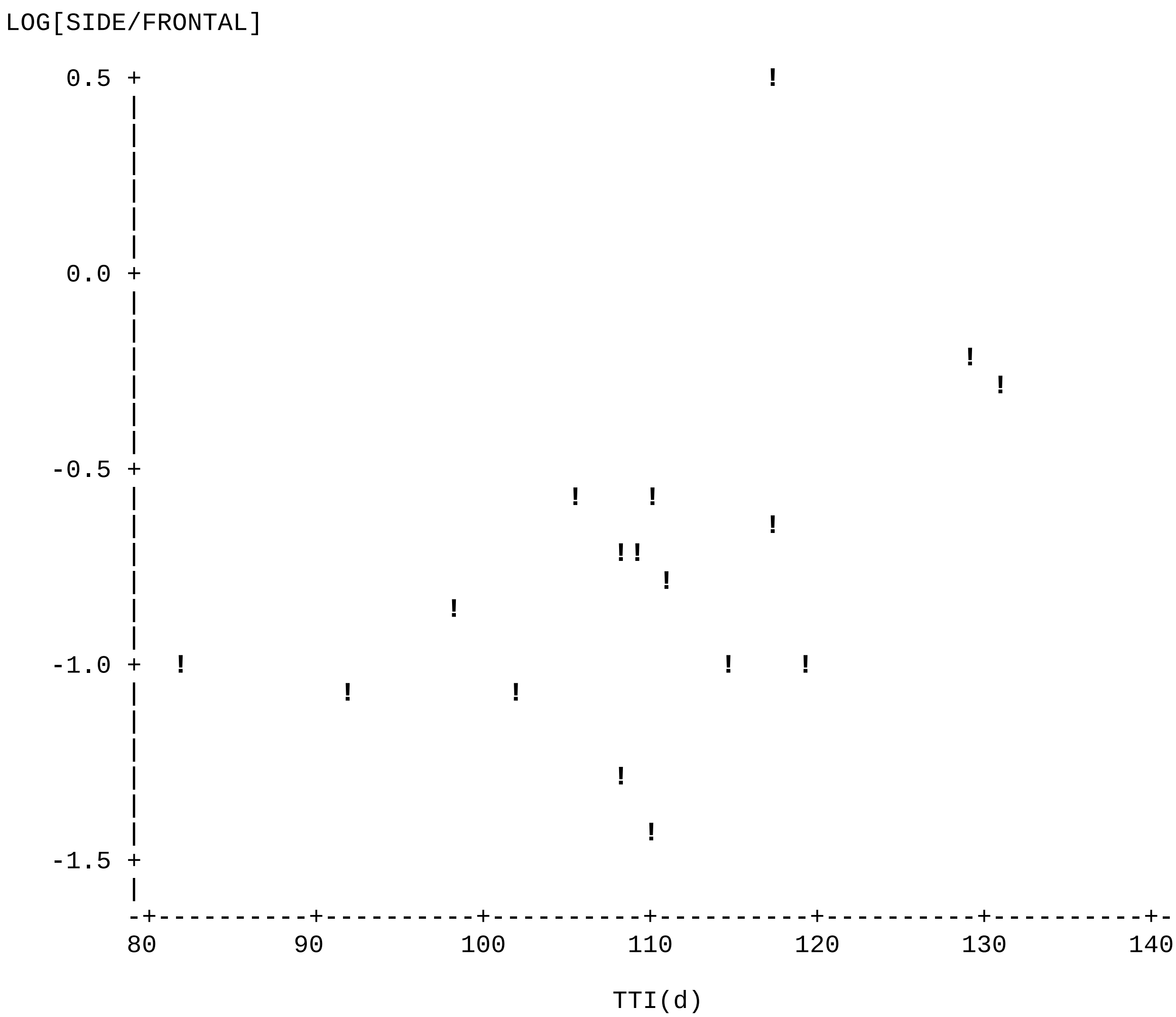


TABLE 3-5: 4-DOOR MAKE-MODELS, ALL SIDE IMPACTS, TTI(d) vs. SIDE IMPACT FATALITY RISK
(front outboard occupants age 30-65 in 24 pre-FMVSS 214 make-models with no air bags and < 10% ABS)

TTI (d)	FMVSS 214 Test MY-Make-Model	FARS MY Range	Curb Weight	N of Fatalities Age 30-65: Total	Side	Purely Frontal	**Side Impact Fatality Risk** Log(Side/Front)
40.00	*1988 Lincoln Town Car*	*1981-89*	*4055*	*299*	*115*	*184*	*- 0.470*
50.73	*1988 Chevrolet Caprice*	*1981-90*	*3640*	*638*	*233*	*405*	*- 0.553*
61.79	1989 Plymouth Colt Vista	1984-91	2638	26	14	12	**+ 0.154**
65.60	1992 Chevrolet Lumina	1990-91	3263	117	41	76	**- 0.617**
71.81	1980 AMC Concord	1981-83	3013	57	29	28	**+ 0.035**
73.50	1988 Oldsmobile Calais	1986-91	2592	127	56	71	**- 0.237**
74.80	1990 Pontiac 6000	1989-91	2838	52	28	24	**+ 0.154**
76.43	*1988 Pontiac Bonneville*	*1987-91*	*3302*	*37*	*13*	*24*	*- 0.613*
76.82	1990 Ford Taurus	1990-91	3147	14	4	10	**- 0.916**
77.76	1981 Honda Civic	1981	1973	37	13	24	**- 0.613**
77.79	1984 Chevrolet Celebrity	1982-88	2793	927	387	540	**- 0.333**
78.22	1988 Ford Taurus	1986-89	3062	481	200	281	**- 0.340**
78.70	1988 Oldsmobile Delta 88	1986-91	3220	264	106	158	**- 0.399**
81.21	1986 Chevrolet Cavalier	1982-86	2404	586	231	355	**- 0.430**
82.23	1987 Chevrolet Cavalier	1987-88	2378	178	74	104	**- 0.340**
85.62	1988 Hyundai Excel	1986-89	2158	290	106	184	**- 0.551**
85.72	1992 Honda Accord	1990-91	2870	182	67	115	**- 0.540**
88.10	*1988 Chevrolet Sprint*	*1986-88*	*1600*	*50*	*24*	*26*	*- 0.080*
88.65	1981 Chevrolet Citation	1981-85	2534	357	157	200	**- 0.242**
91.56	1992 Nissan Sentra	1991-94	2339	115	50	65	**- 0.262**
93.54	1983 Ford Escort	1982-85	2142	424	185	239	**- 0.256**
98.00	1988 Ford Escort	1988-90	2321	157	73	84	**- 0.140**
102.88	1982 Honda Civic	1982-83	1984	76	37	39	**- 0.053**
105.12	1983 Mazda 626	1983-87	2429	126	71	55	**+ 0.255**
110.44	1981 Plymouth Horizon	1981-90	2211	373	138	235	**- 0.532**
118.37	1981 Ford Granada	1981-82	2954	95	40	55	**- 0.318**

50.73 for the Chevrolet Caprice is also lower than most cars certified to meet FMVSS 214. Both of these models have fairly low ratios of side to frontal fatalities. It is not clear if their statistics are directly comparable to the other 4-door make-models.

Figure 3-9 is a scatterplot of the log fatality ratios by TTI(d) for the full set of 26 make-models. As in Figure 3-5, the data points based on 100 or more FARS cases are **blacked in**. Although the blacked-in points do not really fit a diagonal line, there is still some promise of positive overall correlation, because there are three points with low TTI(d) and low risk (Town Car, Caprice, Lumina), a pack of points in the middle, and one point with high TTI(d) and high side/frontal risk: 1983 Mazda 626, with TTI(d) = 105.1 [by MY 1996, TTI(d) had been cut to 59 in the Mazda 626]. Plymouth Horizon, however, is an outlier, with high TTI(d) and low side/frontal risk. Indeed, the weighted correlation coefficient is +.364. Since the probability of observing a more positive coefficient by chance alone, given 26 data points, is .0339, this coefficient is statistically significant at the .05 level.

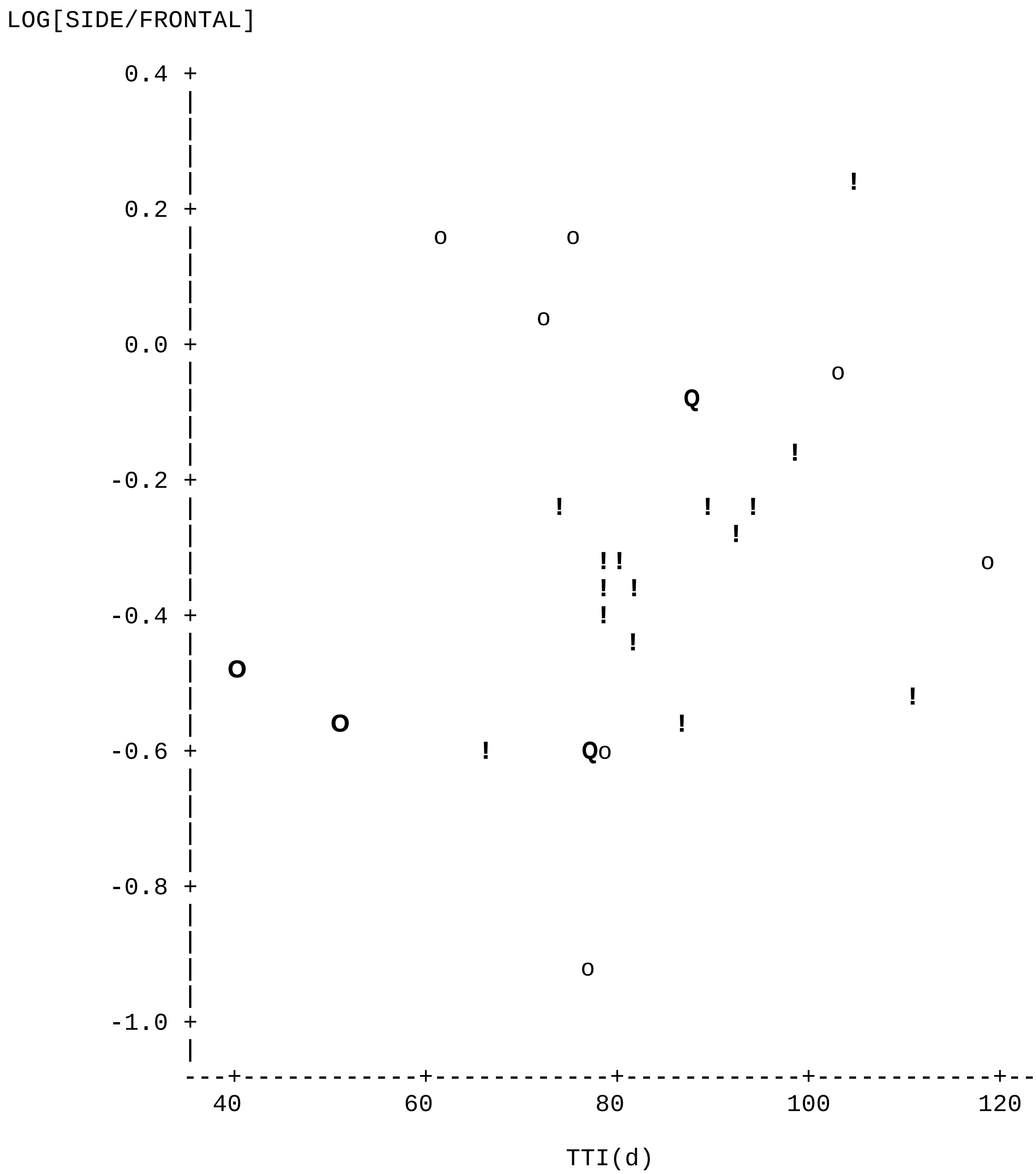
A closer look at Figure 3-9, however, suggests that the data points for Town Car and Caprice, shown as large squares, may be "driving" the result because they are far off to the left and are also based on large N. The situation is analogous to our earlier problems of mixing 2-door and 4-door cars. Does the overall correlation between TTI(d) and side/frontal fatality risk merely reflect that big, rugged cars such as Town Car and Caprice have lower side/frontal fatality risk and lower TTI(d) than average-size 4-door cars? We could never be sure if it is specifically TTI(d) or if it is other size- and weight-related factors that cause Town Car and Caprice to have lower-than-average risk.

A better assessment of the effect of TTI(d) can perhaps be obtained by limiting the analysis to 4-door cars in a middle range of weights, 1900-3299 pounds. That excludes the Town Car and Caprice, and also two other models shown in italics in Table 3-5: Pontiac Bonneville, weighing slightly over 3300 pounds, and Chevrolet Sprint, weighing much less than 1900.

The 22 make-models in Table 3-5 weighing 1900-3299 pounds are a fairly representative mix of economy sedans and family sedans. None of them are obviously "luxury," "sporty," or designed for a special market. There do not appear to be any unusual factors that are confounded with TTI(d). At most, there is a tendency for the newer and heavier cars to have, on the average, lower TTI(d), but there are several exceptions to that rule - e.g., the 1981 Honda Civic has relatively low TTI(d).

Nevertheless, limiting the data to cars weighing 1900-3299 pounds might impose a statistical handicap: it limits the *effective* range of TTI(d) scores. A first glance at Tables 3-2 and 3-5 indicates the range of TTI(d) in 4-door cars (61.79 to 118.37, after excluding Town Car and Caprice) is even wider than in 2-door cars (82.22 to 131.03). But many of the 4-door cars with large FARS samples are concentrated in a narrow range from 77.79 to 93.54, while the 2-door cars are more uniformly distributed across their full range. Concentration in the middle especially diminishes the power of correlation analyses. We may be between a "rock" of results driven by the Town Car and Caprice and a "hard place" of data that are not ideally suited for correlation analyses.

FIGURE 3-9: ALL BASELINE 4-DOOR MAKE-MODELS, ALL SIDE IMPACTS
LOG RATIO OF SIDE TO PURE FRONTAL FATALITIES AGE 30-65, BY TTI(d)
(front outboard occupants in 26 pre-FMVSS 214 make-models with no air bags and < 10% ABS)



! = weight 1900-3299, ≥ 100 fatality cases
O = weight ≥ 3300 or < 1900, ≥ 100 fatality cases
o = weight 1900-3299, < 100 fatality cases
Q = weight ≥ 3300 or < 1900, < 100 fatality cases

Figure 3-10 graphs the log fatality ratio by TTI(d) for the 22 make-models weighing 1900-3299 pounds. Excluding the Town Car and Caprice makes a visible difference. The "anchor" on the lower left is gone. Although some of the points are still close to a diagonal line, the outliers look more influential than in Figure 3-9 and the correlation coefficient will be lower. Indeed, the correlation coefficient dropped to +.101 (versus +.364 in Figure 3-9). It is still in the right direction but no longer statistically significant (the probability of observing a more positive coefficient by chance alone, given 22 data points, is .328). There do not appear to be any obvious explanations why some models' fatality ratios are above the diagonal (AMC Concord, Pontiac 6000, Mazda 626) while others are lower (Lumina, Horizon, Granada). The most satisfactory explanation is simply that TTI(d) does not have much correlation with the side/frontal fatality risk.

Five other analyses were performed on the 4-door make-models - including and excluding Town Car and Caprice. Table 3-6 summarizes the principal results of this chapter: the correlation coefficients in the six analyses of 4-door cars, and the corresponding results for 2-door make-models, and for all make-models combined. (The analyses in the last row were based on quite small FARS samples.)

The six analyses of 2-door make-models consistently produced positive correlations of TTI(d) with side/frontal fatality risk, with coefficients varying only between .360 and .496. Three of the coefficients are statistically significant at the .05 level. The fact that the coefficient stays about the same in the later analyses, even though the FARS sample size is considerably smaller, indicates that the relationship may be strongest in the types of side impacts that most closely resemble the FMVSS 214 test (subsequent chapters will provide more information on this).

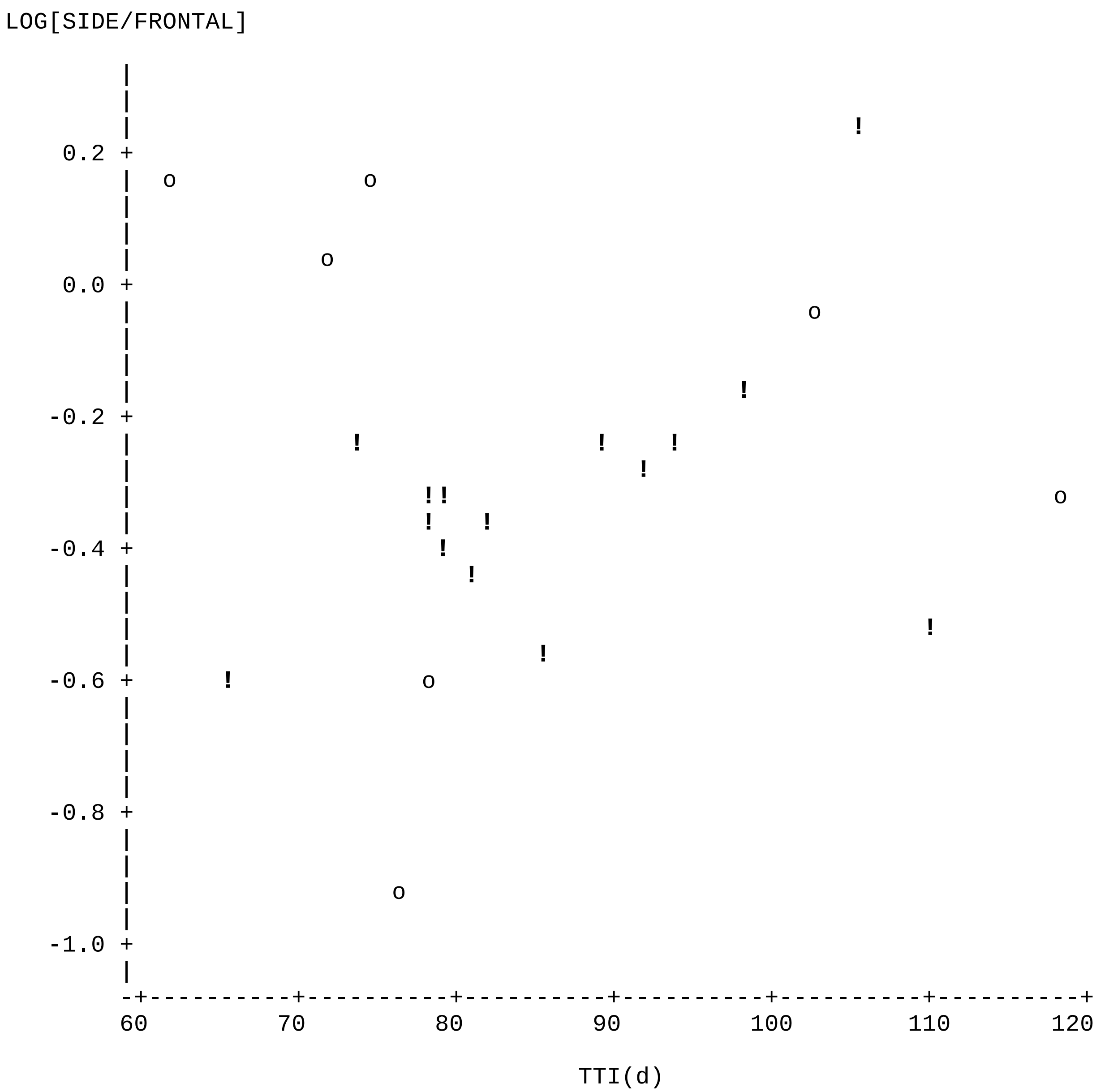
By contrast, the analyses of 4-door cars at best show a doubtful relationship between TTI(d) and fatality risk. When Town Car and Caprice are included, only the first analysis (all types of side impacts) produced a statistically significant positive coefficient, +.364. It is the only statistically significant result for 4-door cars in this report. The other five analyses produced nonsignificant coefficients ranging from -.024 to +.234. Excluding Town Car and Caprice made each coefficient somewhat less positive. Only the first remained above zero. None were statistically significant.

For the combined analyses of 2-door and 4-door cars, the coefficients are usually (but not necessarily, as was explained in Section 3.4) in between the 2-door and 4-door results. All six are positive, although they range as low as +.093. Three of them are statistically significant.

The obvious question is, "Why are the results different for 2-door and 4-door cars?" A discussion is best deferred until after the presentation of the remaining analyses. The "Discussion of Findings" follows Chapter 8 in the text.

FIGURE 3-10

4-DOOR MAKE-MODELS WEIGHING 1900-3299 POUNDS, ALL SIDE IMPACTS
LOG RATIO OF SIDE TO PURE FRONTAL FATALITIES AGE 30-65, BY TTI(d)
(front outboard occupants in 22 pre-FMVSS 214 make-models
weighing 1900-3299 pounds, with no air bags and < 10% ABS)



! = weight 1900-3299, ≥ 100 fatality cases

o = weight 1900-3299, < 100 fatality cases

TABLE 3-6: CORRELATION COEFFICIENT OF TTI(d)
WITH SIDE/FRONTAL FATALITY RATIOS IN INDIVIDUAL MAKE-MODELS

	All 2-Door	All 4-Door	1900-3299 lb. 4-Door	All 2- and 4-Door
All side impacts / All pure frontals	+ .418*	+ .364*	+ .101	+ .477**
Nearside compartment impacts / All pure frontals	+ .496*	+ .234	- .025	+ .376**
All side impacts by other vehicles / Pure frontals by other vehicles	+ .408	+ .172	- .018	+ .220
Nearside compartment impacts by other vehicles / Pure frontals by other vehicles	+ .452*	- .012	- .052	+ .093
All side impacts by other cars / Pure frontals by other cars	+ .387	+ .224	- .097	+ .329*
Nearside compartment impacts by other cars / Pure frontals by other cars	+ .360	- .024	- .300	+ .122

*Statistically significant at the .05 level
**Statistically significant at the .01 level

CHAPTER 4

COMPARISON OF SIDE/FRONTAL FATALITY RATIOS IN THREE QUANTILE GROUPS OF TTI(d)

The independent variable in this evaluation is the Thoracic Trauma Index [TTI(d)] of the front-seat dummy in the baseline tests of pre-FMVSS 214, Phase 1 cars. The dependent variable - fatality risk in real-world side impact crashes - is estimated by taking the ratio of fatalities in side impacts to a control group of purely frontal fatalities. An intrinsic problem in the data is that TTI(d) and/or the side/frontal fatality ratio can vary with vehicle weight, driver age and gender, vehicle age, availability of air bags or ABS, etc. If only it were possible to isolate two [or three] groups of cars that are similar in all those other variables, but one group has low TTI(d), the second, high TTI(d) [and the third, median TTI(d)]. Then we could compare the fatality ratios in the two [three] groups and make the case that fatality differences are due to TTI(d), not the confounding effects of those other variables. The analysis would preserve the spirit, although not the computational method, of the statistically most powerful procedure in NHTSA's evaluation of the New Car Assessment Program: a direct comparison of cars with good and poor scores[1]. The findings are that side impact fatality risk is lower in the group with the better scores, always among the 2-door cars and sometimes (but not significantly) even in the 4-door cars.

4.1 Fatality risk in 3 quantile groups of TTI(d): 2-door cars

The job of obtaining well-matched high and low TTI(d) groups is not so difficult with 2-door cars. The first step is to make all the data uniform on air bags and ABS by eliminating the relatively small number of cars with air bags, standard ABS, or more than 10 percent optional ABS. That leaves the 17 make-model-year combinations described in Table 3-2. Those 17 vehicles, except for Chevrolet Corvette and Ford Mustang, although varying widely in TTI(d), were a quite homogeneous and representative group of 2-door cars, neither high-performance nor luxury cars. Corvette and Mustang were in the middle of the TTI(d) range. Moreover, the 2's in Figure 4-1 show that **average** TTI(d) for 2-door cars is nearly constant as a function of curb weight. Thus, if the FARS cases were ranked by TTI(d) and split into three groups - low, middle and high - the middle group might be skewed by the presence of Corvette and Mustang, but at least the low and high groups ought to be quite similar to one another in every respect except TTI(d).

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[1]Kahane, C.J., *Correlation of NCAP Performance with Fatality Risk in Actual Head-On Collisions*, NHTSA Technical Report No. DOT HS 808 061, Washington, 1994, Chapter 5: analysis of head-on collisions between cars with NCAP scores lower than x and cars with scores higher than y, where x < y, showed significantly lower fatality risk in the cars with the good scores. This was the only analysis that showed significant effects for each of the three body region scores in NCAP.

FIGURE 4-1: AVERAGE TTI(d) BY CURB WEIGHT - 2-DOOR VS. 4-DOOR
(Cars with no air bags and < 10% ABS)

```
   120 +
       |
       |       2
       |                      2
       |            2
   110 +                                2    2    2
       |  2
       |                 2         2
       |
       |
   100 +
       |
       |                 4
       |            4
       |
    90 +
       |                      4
       |
TTI(d) |                           4
       |                                     4
    80 +                                4
       |
       |                                          4
       |
       |
    70 +
       |
       |
       |
       |
    60 +
       |
       |
       |
       |
    50 +                                                    4
       |
       |
       |
       |
    40 +                                                              4
       ---+----+----+----+----+----+----+----+----+----+----+----+----+--
        1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600 3800 4000

                                  CURB WEIGHT
```

As in Chapter 3, the FARS data for this analysis initially include the front outboard fatality cases (side and purely frontal impacts) for each of the 17 tested make-models, for a range of model years before and/or after the test model year during which the design did not change. "Side" impacts are initially defined by IMPACT2 = 2, 3, 4, 8, 9, or 10, and "purely frontal" impacts by IMPACT2 = 12 and M_HARM ≠ 1-7. Model years/occupants with air bags or ABS are excluded as in Table 3-2. Initially, occupants of all ages are included; the data are not limited to people age 30-65. The next step is to subdivide the cases into 200 pound class intervals of curb weight and observe the range of TTI(d) in each class interval:

Curb Weight	N of Cases	Lowest TTI(d)	Highest TTI(d)	Range
1300-1499	101	108.2	108.2	none
1500-1699	156	108.2	108.2	none
1700-1899	1009	82.2	131.0	49
1900-2099	535	82.2	131.0	49
2100-2299	1615	85.5	118.9	33
2300-2499	617	92.1	118.9	27
2500-2699	1124	92.1	117.4	25
2700-2899	989	101.5	110.0	9
2900-3099	1117	110.0	117.3	7
3100-3299	904	109.2	117.3	8

Whereas Figure 4-1 shows that the average value of TTI(d) is nearly constant as a function of curb weight in 2-door cars, the variance of TTI(d) is certainly not. In the two lightest weight groups, all cars have TTI(d) = 108.2 for the simple reason that they are all Chevrolet Sprints, and only one Sprint was tested. Since there are no "low TTI(d)" or "high TTI(d)" cars in those weight groups, they are of no further use in analyses whose objective is to compare low and high TTI(d) cars of the same weight, etc. All the analyses in this section will be based on 2-door cars weighing 1700 to 3299 pounds.

The remaining weight groups have nonzero ranges of TTI(d), but the range steadily gets smaller with increasing weight. In other words, the cars with exceptionally low or high TTI(d) will be lighter than average, and by default, the cars in the middle will be heavier than average.

The next step is to generate the cumulative distribution function of TTI(d) for the 7910 cases of cars weighing 1700-3299 pounds:

TTI(d)	N	%	Cumul. %	TTI(d)	N	%	Cumul. %
82.2	189	2.4	2.4	110.0	3402	43.0	69.8
85.5	9	0.1	2.5	111.0	541	6.8	76.7
92.1	266	3.4	5.9	114.4	272	3.4	80.1
98.1	661	8.4	14.2	117.3	238	3.0	83.1
101.5	57	0.7	14.9	117.4	67	0.8	84.0
105.1	162	2.0	17.0	118.9	669	8.5	92.4
108.0	598	7.6	24.6	129.3	72	0.9	93.4
109.2	181	2.3	26.8	131.0	526	6.6	100.0

Ideally, the data could be subdivided into the lowest 15 percent, the middle 70 percent and the highest 15 percent. Use of 15 percent tails is a good compromise between the conflicting objectives of obtaining adequate sample sizes in the "low" and "high" groups while assuring a palpable difference in TTI(d) in the two groups. Since TTI(d) has a discrete distribution, it is impossible to place the boundaries between groups at exactly the 15th and 85th percentiles. A boundary of 102 between the low and middle groups comes close to the goal, since 14.9 percent of the cases have TTI(d) below 102. It seems appropriate to place the boundary between the middle and the high group at 115, even though it will place 19.9 percent rather than 15 percent of the data in the high group, because the TTI(d) scores 117.3 and 117.4 are closer to 118.9 than to 114.4 and thus ought to be joined to the high group.

When the FARS data are aggregated into the three TTI(d) groups, the fatality counts of front outboard occupants of all ages in side impacts (IMPACT2 = 2, 3, 4, 8, 9, 10) and purely frontal impacts (IMPACT2 = 12 and M_HARM $\neq$ 1-7) are as follows:

TTI(d) Group	Average TTI(d)	Side Impacts	Purely Frontal	Total N	Side / Frontal
< 102	94.26	528	654	1182	.807
102-115	109.92	2662	2494	5156	1.067
> 115	123.11	812	760	1572	1.068

In the low group, where the average TTI(d) is 94.26, side impact fatalities are easily outnumbered by pure frontals. The ratio of side to purely frontal fatalities is .807. In the high group, with average TTI(d) = 123.11, side impact deaths outnumber frontals, and the ratio is 1.068. The difference between the low and high groups is substantial and in the right direction. The middle group, on the other hand, has a side/frontal ratio of 1.067, almost the same as the high group. Based on its average TTI(d) of 109.92, we might have expected something closer to the midpoint between .807 and 1.068.

Let us now examine the average values of other key parameters for the three groups:

TTI(d) Group	Curb Weight	Occupant Age	Female %	Belted %	ABS %
< 102	2242	35.36	42.6	28.2	0.0
102-115	2630	30.29	35.9	29.2	0.0
> 115	2261	33.62	41.3	24.9	0.1

TTI(d) Group	Passenger %	Convertible %	Vehicle Age	Model Year	Calendar Year
< 102	23.8	0.0	4.46	1986.30	1990.75
102-115	28.7	6.0	4.71	1986.37	1991.07
> 115	25.3	0.8	5.05	1984.64	1989.69

The low and high groups are quite similar on every parameter except TTI(d), whereas the middle group differs on several important parameters, often due to the influence of Corvette and Mustang. The average curb weight is 2,242 in the low group and 2,261 in the high group. It is a much higher 2,630 in the middle group. That is a consequence of the narrowing range of TTI(d) values as weight increases: the heavier cars are primarily in the middle group. The low and high groups are similar in average occupant age (35.36, 33.62) and percent female (42.6, 41.3) while the middle group occupants are substantially younger (30.29) and less often female (35.9). That reflects the type of people who drove Corvette and Mustang during the years when the data were collected. For the same reason, most of the convertibles are in the middle cohort. The three groups are similar on belt use and seat position. By definition, there are few ABS (and no air bags) in any group. The high group, as might be expected, are on the average slightly older cars from earlier model years in earlier calendar years, but the differences are small because TTI(d) did not really start to drop until MY 1993 (see Figure 3-3).

This approach did not produce a middle group comparable to the others. But the high and low groups are so well matched that we may, with some confidence, directly compare their fatality statistics by a simple contingency table analysis:

TTI(d) Group	Average TTI(d)	Side Impacts	Purely Frontal
< 102	94.26	528	654
> 115	123.11	812	760

The relative reduction of side impact fatalities with low TTI(d) is

$$1 - [(528/654) / (812/760)] = \textbf{24.4 percent}$$

and it is statistically significant at the .01 level because Chi-Square (χ^2) for the 2x2 table is 13.17. (If TTI(d) had no effect at all, we would hypothesize the same distribution of fatalities, by impact location, in the low and high TTI(d) groups; the χ^2 test for the 2 x 2 table of fatalities by TTI(d) group and impact location tests the null hypothesis. For statistical significance at the .05 level, χ^2 must exceed 3.84, and for the .01 level, 6.64.)

Since the average TTI(d) is 94.26 in the low group and 123.11 in the high group, that 24.4 percent fatality reduction corresponds to a drop of

$$1 - (1 - .244)^{1 / (123.11 - 94.26)} = 0.964 \text{ percent per unit reduction of TTI(d)}$$

This is very close to the .927% coefficient that will be obtained for TTI(d) in Section 5,2, where a regression analysis is performed on essentially the same data (2-door car occupants of all ages).

The three quantile groups can be made more similar in their occupant age distributions by limiting all the data to occupants age 30-65, as was done throughout Chapter 3 (although this restriction will not necessarily do anything to relieve the divergence in the vehicle weight distributions). For occupants age 30-65 the distributions of fatalities and mean values of other key parameters are as follows:

TTI(d) Group	Average TTI(d)	Side Impacts	Purely Frontal	Total N	Side / Frontal
< 102	94.25	159	246	405	.646
102-115	110.02	726	834	1560	.871
> 115	123.36	269	280	549	.961

The side/frontal fatality ratio now follows a sequence of .646 in the low group, .871 in the middle group and .961 in the high group.

TTI(d) Group	Curb Weight	Occupant Age	Female %	Belted %	ABS %
< 102	2251	43.49	41.5	29.6	0.0
102-115	2555	41.63	40.5	31.5	0.0
> 115	2291	43.08	44.6	25.7	0.2

TTI(d) Group	Passenger %	Convertible %	Vehicle Age	Model Year	Calendar Year
< 102	16.5	0.0	4.92	1986.12	1991.04
102-115	20.1	5.5	4.92	1986.43	1991.34
> 115	18.9	1.5	5.25	1984.82	1990.07

All three groups are quite similar on every parameter except TTI(d) and curb weight. Limiting the data to people age 30-65 brought the middle group in line with the others not only on average occupant age but even percent female occupants. The average curb weight continues to be substantially higher in the middle group. The contingency table analysis comparing the high and low groups is:

TTI(d) Group	Average TTI(d)	Side Impacts	Purely Frontal
< 102	94.25	159	246
> 115	123.36	269	280

For people age 30-65, the relative reduction of side impact fatalities with low TTI(d) is

1 - [(159/246) / (269/280)] = **32.7 percent**

and it is statistically significant at the .01 level ($\chi^2 = 8.94$).

Five other analyses of 2-door cars, using alternative definitions of a "side" impact and a "control group" crash, plus the preceding ones, are documented in Appendix A (Analysis No. 1), including average car weights, occupant ages, etc. They are summarized in Tables 4-1 (occupants of all ages) and 4-2 (occupants age 30-65). The principal results were:

OCCUPANTS OF ALL AGES		Fat. Red. for Low TTI(d)	
"Side" Impact	Control Group	%	χ^2
Any	Any pure frontal	24.4	13.17
Nearside compartment	Any pure frontal	30.9	14.88
Any/other vehicle	Pure frontal/other veh.	18.4	4.09
Nearside compartment/other veh.	Pure frontal/other veh.	29.8	8.38
Any/passenger car	Pure frontal/car	30.9	6.20
Nearside compartment/car	Pure frontal/car	38.2	7.11

TABLE 4-1

2-DOOR CARS, OCCUPANTS OF ALL AGES
SIDE IMPACT FATALITY RISK FOR THREE QUANTILE GROUPS OF TTI(d)
(front outboard occupants of 2-door cars with no air bags and < 10% ABS)

TTI(d) Group	Average TTI(d)	Side + Pure Frontal Fatalities		Side Fatality Reduction for Low vs. High TTI(d)	
		N	Side/Frontal	%	χ^2
ALL SIDE IMPACTS					
< 102	94.26	1182	.807	24.4	13.17**
102-115	109.92	5156	1.067		
> 115	123.11	1572	1.068		
NEARSIDE COMPARTMENT IMPACTS					
< 102	94.18	903	.381	30.9	14.88**
102-115	109.92	3824	.533		
> 115	123.17	1179	.551		
ALL SIDE IMPACTS BY ANOTHER VEHICLE					
< 102	94.21	707	.948	18.4	4.09*
102-115	110.00	2562	1.013		
> 115	123.59	895	1.162		
NEARSIDE COMPARTMENT IMPACTS BY ANOTHER VEHICLE					
< 102	94.23	528	.455	29.8	8.38**
102-115	109.99	1956	.537		
> 115	123.55	682	.647		
ALL SIDE IMPACTS BY A PASSENGER CAR					
< 102	94.34	328	.918	30.9	6.20*
102-115	110.04	1116	.996		
> 115	123.54	410	1.330		
NEARSIDE COMPARTMENT IMPACTS BY A PASSENGER CAR					
< 102	94.14	246	.439	38.2	7.11**
102-115	110.05	837	.497		
> 115	123.68	301	.710		

*Statistically significant at the .05 level
**Statistically significant at the .01 level

TABLE 4-2

2-DOOR CARS, OCCUPANTS AGE 30-65
SIDE IMPACT FATALITY RISK FOR THREE QUANTILE GROUPS OF TTI(d)
(front outboard occupants of 2-door cars with no air bags and < 10% ABS)

TTI(d) Group	Average TTI(d)	Side + Pure Frontal Fatalities Age 30-65		Side Fatality Reduction for Low vs. High TTI(d)	
		N	Side/Frontal	%	χ^2
ALL SIDE IMPACTS					
< 102	94.25	405	.646	32.7	8.94**
102-115	110.02	1560	.871		
> 115	123.36	549	.961		
NEARSIDE COMPARTMENT IMPACTS					
< 102	94.25	325	.321	36.2	7.44**
102-115	110.01	1192	.429		
> 115	123.43	421	.504		
ALL SIDE IMPACTS BY ANOTHER VEHICLE					
< 102	94.12	250	.748	35.3	6.56*
102-115	110.13	885	.817		
> 115	124.26	317	1.156		
NEARSIDE COMPARTMENT IMPACTS BY ANOTHER VEHICLE					
< 102	94.27	199	.392	38.8	5.72*
102-115	110.12	696	.429		
> 115	124.25	241	.639		
ALL SIDE IMPACTS BY A PASSENGER CAR					
< 102	94.08	121	.704	47.2	6.65**
102-115	110.19	407	.817		
> 115	124.12	147	1.133		
NEARSIDE COMPARTMENT IMPACTS BY A PASSENGER CAR					
< 102	93.89	97	.366	45.1	3.93*
102-115	110.19	320	.429		
> 115	124.11	105	.667		

*Statistically significant at the .05 level
**Statistically significant at the .01 level

OCCUPANTS AGE 30-65		Fat. Red. for Low TTI(d)	
"Side" Impact	Control Group	%	χ^2
Any	Any pure frontal	32.7	8.94
Nearside compartment	Any pure frontal	36.2	7.44
Any/other vehicle	Pure frontal/other veh.	35.3	6.56
Nearside compartment/other veh.	Pure frontal/other veh.	38.8	5.72
Any/passenger car	Pure frontal/car	47.2	6.65
Nearside compartment/car	Pure frontal/car	45.1	3.93

Every analysis in Tables 4-1 and 4-2 shows an appreciable, statistically significant reduction in side/frontal fatality ratio for the low TTI(d) group relative to the high TTI(d) group. Every analysis shows an intermediate ratio for the middle TTI(d) group. Reductions are typically stronger in nearside compartment impacts, in strikes by a passenger car and when the data are limited to people age 30-65. The χ^2 values, however, do not necessarily increase in tandem with stronger reductions, because the sample sizes get smaller, as shown in Tables 4-1 and 4-2. Appendix A shows that the high and low TTI(d) groups are always well-matched on average curb weight and occupant age. The cars in the middle group are, on the average, always heavier, and their occupants are younger when the data are not limited to people age 30-65.

In some ways, this relatively simple analysis method produced the strongest relationships between TTI(d) and fatality risk as evidenced by the largest fatality reductions for "good" relative to "poor" TTI(d) scores. All findings were statistically significant. However, one caveat applies here even more than on the preceding correlation and subsequent regression analyses: the fatality statistics for the low and high TTI(d) group are based on just five make-models apiece that were impact-tested, and even though the make-models appear to be fairly "representative" and well-matched on curb weight, driver age, etc., we cannot be sure if the observed fatality reduction is more an artifact of these particular models than a consequence of the differences in TTI(d). At least, the regression and correlation analyses used data from all 17 tested make-models, not just ten, and are thus slightly less subject to the idiosyncracies of the particular make-models.

4.2 Fatality risk in 3 quantile groups of weight-normalized TTI(d): 2-door cars

In the preceding analyses, the "middle" TTI(d) group of cars always weighed more, on the average, than the "low" and "high" groups. We have already seen that it is a consequence of the heteroscedasticity of TTI(d): the heavier the cars, the narrower the range of test results; thus, most of the heavier cars score in the middle 70 percent of the overall range of TTI(d). A relatively simple fix, it would seem, is **first** to split up the data into 200-pound class intervals of curb weight and **then** to take the lowest 15 percent, middle 70 percent and highest 15 percent of TTI(d) scores within each weight interval.

The procedure is not quite so simple, because some of the weight intervals include only two or three tested make-models or their twins, and thus only two or three discrete values of TTI(d). For example:

CARS WEIGHING 2700-2899

TTI(d)	N	%	Cumul. %
101.5	57	5.8	5.8
110.0	932	94.2	100.0

CARS WEIGHING 2900-3099

TTI(d)	N	%	Cumul. %
110.0	1004	89.9	89.9
117.3	113	10.1	100.0

The only way to split either of the above into three subgroups containing 15, 70 and 15 percent of the cases is sometimes to assign cars with the same TTI(d) (usually the same make-model) to different subgroups. For instance, among cars weighing 2700-2899 pounds, there is little choice except to assign some of the cars with TTI(d) = 110.0 to the "low" group along with all the 101.5's, a large portion of the 110's to the "middle" group, and the rest of the 110's to the "high" group. The assignment should be done by a quasi-random but repeatable algorithm - i.e., the assignment should not depend on any characteristics of the crash, the vehicle, the drivers, etc., but it should be the same every time.

The last two digits of the FARS case number ST_CASE are useful for assigning cases. We may safely assume that the last two digits of ST_CASE are uncorrelated with any important variables about the crash, such as whether it was a side or frontal impact, occupant age, etc. Define

NEWTTI(d) = 10000 ROUND(TTI(d),.01) + MOD(ST_CASE,100)

In other words, round TTI(d) to two decimal places, multiply by 10,000, and then replace the last two zeros with the last two digits of ST_CASE. That transforms TTI(d), a variable that might have only two or three discrete values in any class interval of curb weight, to NEWTTI(d), a variable that can have hundreds of different integer values and is, for all practical purposes, a continuous distribution. The "low" group will consist of the lowest 15 percent of the NEWTTI(d) distribution within each weight interval, the "middle" group will contain the middle 70 percent, and the "high" group, the highest 15 percent. This method is arbitrary in taking cars of the same original TTI(d) and assigning them to different groups, but it is repeatable because ST_CASE is always the same and dictates the choice of group.

When the FARS data are aggregated into the three groups, the fatality counts of front outboard occupants of all ages in side impacts and purely frontal impacts are as follows:

TTI(d) Group	Average TTI(d)	Side Impacts	Purely Frontal	Total N	Side / Frontal
Low 15% for its weight	100.22	572	637	1209	.898
Middle 70% for its weight	110.62	2827	2706	5533	1.044
High 15% for its weight	118.56	604	564	1168	1.071

Since there may now be considerable overlap in the TTI(d) scores of the three quantile groups, the difference in the average TTI(d) of the low group (100.22) and the high group (118.56) is only 18.34, whereas it was 28.85 in the basic analysis of the preceding section. This disadvantage is compensated by gaining essentially the same average curb weights in all three groups:

TTI(d) Group	Curb Weight	Occupant Age	Female %	Belted %	ABS %
Low 15% for its weight	2489	33.22	39.0	28.0	0.0
Middle 70% for its weight	2502	30.79	37.4	28.7	0.0
High 15% for its weight	2496	34.47	39.8	26.2	0.2

TTI(d) Group	Passenger %	Convertible %	Vehicle Age	Model Year	Calendar Year
Low 15% for its weight	26.2	0.7	4.55	1986.07	1990.61
Middle 70% for its weight	28.1	5.3	4.74	1986.14	1990.88
High 15% for its weight	24.6	2.0	4.92	1985.34	1990.26

All three groups are quite similar on every parameter except TTI(d) and occupant age. Even occupant age does not differ that much among the groups (33.22, 30.79, 34.47). The high and low groups are especially well matched and may again be compared directly:

TTI(d) Group	Average TTI(d)	Side Impacts	Purely Frontal
Low 15% for its weight	100.22	572	637
High 15% for its weight	118.56	604	564

The relative reduction of side impact fatalities with low TTI(d) is

$$1 - [(572/637) / (604/564)] = \textbf{16.2 percent}$$

and it is statistically significant at the .05 level (χ^2 = 4.60). Since the average TTI(d) is 100.22 in the low group and 118.56 in the high group, that 16.2 percent fatality reduction corresponds to a drop of

$$1 - (1 - .162)^{1 / (118.56 - 100.22)} = 0.956 \text{ percent per unit reduction of TTI(d)}$$

This is almost exactly the same fatality reduction per TTI(d) unit as in the corresponding analysis of Section 4.1 (.964).

When the data are limited to occupants age 30-65, all three quantile groups are closely matched on every parameter except TTI(d):

TTI(d) Group	Average TTI(d)	Side Impacts	Purely Frontal	Total N	Side / Frontal
Low 15% for its weight	99.76	173	240	413	.721
Middle 70% for its weight	110.98	792	905	1697	.877
High 15% for its weight	118.78	188	216	404	.870

TTI(d) Group	Curb Weight	Occupant Age	Female %	Belted %	ABS %
Low 15% for its weight	2500	42.01	39.0	28.1	0.0
Middle 70% for its weight	2417	42.05	42.1	30.6	0.0
High 15% for its weight	2532	43.32	42.1	29.2	0.2

TTI(d) Group	Passenger %	Convertible %	Vehicle Age	Model Year	Calendar Year
Low 15% for its weight	17.4	0.2	5.12	1985.69	1990.80
Middle 70% for its weight	20.3	4.8	4.96	1986.19	1991.14
High 15% for its weight	17.1	2.7	5.01	1985.71	1990.71

Nevertheless, the trends in the results are not as strong as in Section 4.1. The side/frontal fatality ratio for the middle group is not halfway in between the low and high group, but is about the same as the high group. The fatality reduction for the low group relative to the high group is

$$1 - [(173/240) / (188/216)] = 17.2 \text{ percent}$$

but it is not statistically significant ($\chi^2 = 1.79$), as it is based on much smaller N's than the "all ages" result.

Other analyses are documented in Appendix A (Analysis No. 2) and summarized in Tables 4-3 (occupants of all ages) and 4-4 (occupants age 30-65). The principal results were:

OCCUPANTS OF ALL AGES		Fat. Red. for Low TTI(d)	
"Side" Impact	Control Group	%	χ^2
Any	Any pure frontal	16.2	4.60
Nearside compartment	Any pure frontal	24.0	7.20
Any/other vehicle	Pure frontal/other veh.	14.4	1.88
Nearside compartment/other veh.	Pure frontal/other veh.	33.1	8.48
Any/passenger car	Pure frontal/car	26.5	3.29
Nearside compartment/car	Pure frontal/car	41.2	6.61

OCCUPANTS AGE 30-65			
Any	Any pure frontal	17.2	1.79
Nearside compartment	Any pure frontal	18.9	1.37
Any/other vehicle	Pure frontal/other veh.	28.2	3.17
Nearside compartment/other veh.	Pure frontal/other veh.	37.1	3.92
Any/passenger car	Pure frontal/car	36.5	2.57
Nearside compartment/car	Pure frontal/car	39.8	2.18

In general, and not surprisingly, these analyses produced less contrast between the low and the high group, and fewer statistically significant differences (two exceptions: nearside compartment by another vehicle and nearside compartment by a car had higher contrasts here). One objective of this analysis was to make the middle group more directly comparable to the low and high groups, but that goal was not fully achieved. In the "all ages" analyses, the middle group still consisted of younger occupants than the low and high groups. In the "age 30-65" analyses, parity was achieved on both curb weight and occupant age, but reduced sample sizes and the inclusion of many cars with near-average TTI(d) in the low and high groups made it intrinsically difficult to show a strong trend of increasing side/frontal fatality ratios from the low to the middle to the high

TABLE 4-3

2-DOOR CARS, OCCUPANTS OF ALL AGES: SIDE IMPACT FATALITY RISK
FOR THREE QUANTILE GROUPS OF WEIGHT-NORMALIZED TTI(d)
(front outboard occupants of 2-door cars with no air bags and < 10% ABS)

TTI(d) Group	Average TTI(d)	Side + Pure Frontal Fatalities N	Side + Pure Frontal Fatalities Side/Frontal	Side Fatality Reduction for Low vs. High TTI(d) %	Side Fatality Reduction for Low vs. High TTI(d) χ^2
ALL SIDE IMPACTS					
Low 15% for its wt.	100.22	1209	.898	16.2	4.60*
Mid 70% for its wt.	110.62	5533	1.044		
High 15% for its wt.	118.56	1168	1.071		
NEARSIDE COMPARTMENT IMPACTS					
Low 15% for its wt.	99.89	898	.410	24.0	7.20**
Mid 70% for its wt.	110.63	4140	.529		
High 15% for its wt.	118.54	868	.539		
ALL SIDE IMPACTS BY ANOTHER VEHICLE					
Low 15% for its wt.	98.57	619	1.043	14.4	1.88
Mid 70% for its wt.	110.83	2915	.992		
High 15% for its wt.	118.99	630	1.218		
NEARSIDE COMPARTMENT IMPACTS BY ANOTHER VEHICLE					
Low 15% for its wt.	98.46	443	.462	33.1	8.48**
Mid 70% for its wt.	110.77	2243	.533		
High 15% for its wt.	118.89	480	.690		
ALL SIDE IMPACTS BY A PASSENGER CAR					
Low 15% for its wt.	99.05	287	.993	26.5	3.29
Mid 70% for its wt.	110.74	1292	1.003		
High 15% for its wt.	119.61	275	1.350		
NEARSIDE COMPARTMENT IMPACTS BY A PASSENGER CAR					
Low 15% for its wt.	98.56	207	.438	41.2	6.61*
Mid 70% for its wt.	110.66	973	.509		
High 15% for its wt.	119.72	204	.744		

*Statistically significant at the .05 level
**Statistically significant at the .01 level

TABLE 4-4

2-DOOR CARS, OCCUPANTS AGE 30-65: SIDE IMPACT FATALITY RISK FOR THREE QUANTILE GROUPS OF WEIGHT-NORMALIZED TTI(d)
(front outboard occupants of 2-door cars with no air bags and < 10% ABS)

TTI(d) Group	Average TTI(d)	Side + Pure Frontal Fatalities Age 30-65		Side Fatality Reduction for Low vs. High TTI(d)	
		N	Side/Frontal	%	χ^2
ALL SIDE IMPACTS					
Low 15% for its wt.	99.76	413	.721	17.2	1.79
Mid 70% for its wt.	110.98	1697	.877		
High 15% for its wt.	118.78	404	.870		
NEARSIDE COMPARTMENT IMPACTS					
Low 15% for its wt.	99.44	322	.342	18.9	1.37
Mid 70% for its wt.	111.02	1309	.448		
High 15% for its wt.	118.52	307	.421		
ALL SIDE IMPACTS BY ANOTHER VEHICLE					
Low 15% for its wt.	98.12	215	.792	28.2	3.17
Mid 70% for its wt.	111.14	1015	.839		
High 15% for its wt.	119.29	222	1.114		
NEARSIDE COMPARTMENT IMPACTS BY ANOTHER VEHICLE					
Low 15% for its wt.	98.05	166	.383	37.1	3.92*
Mid 70% for its wt.	111.14	801	.451		
High 15% for its wt.	118.63	169	.610		
ALL SIDE IMPACTS BY A PASSENGER CAR					
Low 15% for its wt.	98.31	105	.750	36.5	2.57
Mid 70% for its wt.	111.00	474	.866		
High 15% for its wt.	120.25	96	1.182		
NEARSIDE COMPARTMENT IMPACTS BY A PASSENGER CAR					
Low 15% for its wt.	97.85	83	.383	39.8	2.18
Mid 70% for its wt.	110.83	367	.445		
High 15% for its wt.	119.52	72	.636		

*Statistically significant at the .05 level groups. In Table 4-4, only the last three analyses show a strong contrast between the low and the high group **and** a fatality ratio for the middle group that is close to the midpoint of the low and high ratios. Although these results for 2-door cars are all in the "right" direction and many of them are statistically significant, they are somewhat of a letdown and caveat on the very strong results of Section 4.1.

4.3 Fatality risk in 3 quantile groups of weight-normalized TTI(d): 4-door cars

The data on pre-standard 4-door cars without air bags and with no ABS or less than 10 percent optional ABS can likewise be subdivided into three quantile groups based on the overall distribution of TTI(d) (as in Section 4.1) or the distribution of TTI(d) within each 200 pound class interval of curb weight (as in Section 4.2).

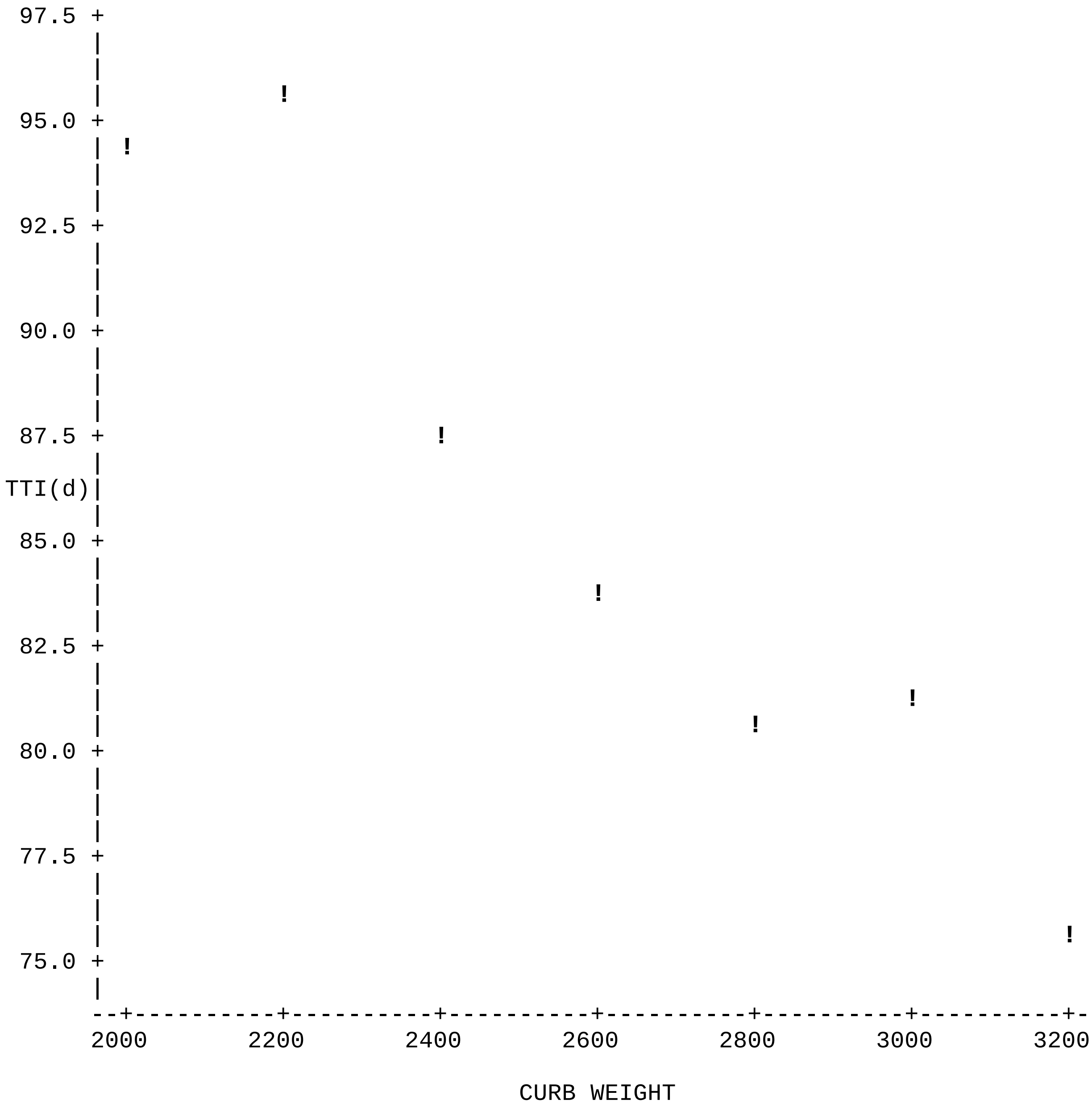
The first method does not work. The 4's in Figure 4-1 show that average TTI(d) in baseline 4-door cars is **not** constant as a function of curb weight, but decreases steadily as weight increases. Even when the Lincoln Town Car and Chevrolet Caprice, two heavy baseline-test cars with low TTI(d) are excluded, Figure 4-2 shows that average TTI(d) still decreases sharply as weight increases within the 1900-3299 pound range. As we shall see, when the FARS cases are ranked by overall TTI(d) and split into three groups, the low group is the heaviest, on the average, and the high group is the lightest.

Twenty-six make-models of 4-door cars were baseline-tested. Consistent with the approach in Sections 4.1 and 4.2, the FARS cases corresponding to the 26 make-models are first subdivided into 200 pound class intervals of curb weight in order to compute the range of TTI(d) in each class interval:

Curb Weight	N of Cases	Lowest TTI(d)	Highest TTI(d)	Range
1500-1699	126	88.1	88.1	none
1700-1899	none			
1900-2099	509	77.1	102.9	26
2100-2299	2444	85.6	110.4	25
2300-2499	2621	61.8	105.1	43
2500-2699	1295	61.8	105.1	43
2700-2899	2547	61.8	118.4	57
2900-3099	1536	71.8	118.4	47
3100-3299	1335	65.6	78.7	13
3300-3499	109	76.4	76.4	none
3500-3699	1492	50.7	50.7	none
3700-3899	159	50.7	50.7	none
3900-4099	567	40.0	40.0	none
4100-4299	21	40.0	40.0	none

FIGURE 4-2

4-DOOR CARS WEIGHING 1900-3299 POUNDS
AVERAGE TTI(d) BY CURB WEIGHT
(Cars with no air bags and < 10% ABS)



Only the weight intervals ranging from 1900-3299 pounds have a nonzero variance of observed TTI(d). The other intervals have no variance because at most one vehicle in each interval was tested. As in Sections 4.1 and 4.2, the statistical analyses will be limited to the weight intervals with nonzero variance (1900-3299 pounds). However, a separate side/frontal fatality ratio will be calculated and shown for the Caprice + Town Car for comparison with the remaining data.

An exploratory analysis using the method of Section 4.1 will demonstrate that the low and high TTI(d) groups do not match on average curb weights. The cumulative distribution function of TTI(d) for the 12,287 cases of cars weighing 1900-3299 pounds is:

TTI(d)	N	%	Cumul. %	TTI(d)	N	%	Cumul. %
61.8	49	0.4	0.4	82.2	415	3.4	56.8
65.6	275	2.2	2.6	85.6	730	5.9	62.7
66.1	6	0.0	2.7	85.7	405	3.3	66.0
71.8	126	1.0	3.7	88.7	907	7.4	73.4
73.5	293	2.4	6.1	91.1	27	0.2	73.6
74.8	128	1.0	7.1	91.6	246	2.0	75.6
76.8	43	0.3	7.5	93.5	937	7.6	83.2
77.1	15	0.1	7.6	98.0	423	3.4	86.7
77.8	2322	18.9	26.5	102.9	193	1.6	88.3
78.2	1118	9.1	35.6	105.1	287	2.3	90.6
78.7	803	6.5	42.1	110.4	896	7.3	97.9
81.2	1383	11.3	53.4	118.4	260	2.1	100.0

Ideally, the data should be subdivided into the lowest 15 percent, the middle 70 percent and the highest 15 percent. Boundaries of 78 between the low and middle groups, and 95 between the middle and the high groups place 26.5 percent of the cases in the low group and 16.8 percent of the cases in the high group. However, when the data are subdivided, the average car weight is 2,803 pounds in the low group, 2,581 pounds in the middle group, and 2,337 pounds in the high group. (Similar weight disparities occur if the boundaries are raised or lowered.) The disparities are simply too large for us to consider a direct comparison of the fatality ratios in any two quantile groups. Details are shown in Appendix A, Analysis No. 3. No further analyses will be conducted using these quantile groups.

Satisfactory quantile groups are obtained by using the same procedure as in Section 4.2 - i.e., defining the variable

NEWTTI(d) = 10000 ROUND(TTI(d),.01) + MOD(ST_CASE,100)

The "low" group consists of the lowest 15 percent of the NEWTTI(d) distribution within each 200-pound weight interval, the "middle" group contains the middle 70 percent, and the "high" group, the highest 15 percent. When the FARS data for cars weighing 1900-3299 pounds are aggregated into the three groups, the fatality counts of front outboard occupants of all ages in side impacts and purely frontal impacts are as follows:

TTI(d) Group	Average TTI(d)	Side Impacts	Purely Frontal	Total N	Side / Frontal
Caprice & Town Car	*47.91*	*905*	*1334*	*2239*	*.678*
Low 15% for its weight	77.30	836	1026	1862	.815
Middle 70% for its weight	84.98	4089	4519	8608	.904
High 15% for its weight	98.99	859	958	1817	.897

The three quantile groups are have nearly identical average curb weights and are also quite well matched on occupant age, gender, and other key variables (whereas the Caprice/Town Car group is much heavier and has substantially older and more often male occupants):

TTI(d) Group	Curb Weight	Occupant Age	Female %	Belted %	ABS %
Caprice & Town Car	*3750*	*56.66*	*38.9*	*33.1*	*0.0*
Low 15% for its weight	2600	45.11	47.6	35.0	0.0
Middle 70% for its weight	2593	47.97	48.8	37.1	0.2
High 15% for its weight	2624	46.59	46.2	39.6	0.6

TTI(d) Group	Passenger %	Station Wagon %	Vehicle Age	Model Year	Calendar Year
Caprice & Town Car	*23.7*	*0.0*	*6.04*	*1985.08*	*1991.12*
Low 15% for its weight	25.3	17.6	5.11	1986.41	1991.51
Middle 70% for its weight	26.8	17.1	5.21	1985.92	1991.12
High 15% for its weight	25.9	5.4	5.26	1985.63	1990.88

The Caprice and Town Car have a lower side/frontal fatality ratio than any of the other groups, but they diverge from the other vehicles on so many characteristics that it is hard to say what portion of the fatality reduction, if any, should be attributed to TTI(d). The low, middle and high groups, on the other hand, are well matched and may be compared directly. The side/frontal fatality ratios are .815, .904 and .897, respectively. In other words, the low group has a somewhat lower ratio than the high group, but the middle group does not have an intermediate ratio. Specifically, a direct comparison of the low and high groups shows:

TTI(d) Group	Average TTI(d)	Side Impacts	Purely Frontal
Low 15% for its weight	77.30	836	1026
High 15% for its weight	98.99	859	958

The relative reduction of side impact fatalities with low TTI(d) is

$$1 - [(836/1026) / (859/958)] = \mathbf{9.1\ percent}$$

This is in the "right" direction, but it is not statistically significant (χ^2 = 2.09).

When the data are limited to occupants age 30-65, the three quantile groups match even more closely on occupant age and gender:

TTI(d) Group	Average TTI(d)	Side Impacts	Purely Frontal	Total N	Side / Frontal
Caprice & Town Car	*47.32*	*905*	*1334*	*942*	*.589*
Low 15% for its weight	77.18	309	499	808	.619
Middle 70% for its weight	85.06	4089	4519	3528	.731
High 15% for its weight	99.09	312	423	735	.738

TTI(d) Group	Curb Weight	Occupant Age	Female %
Caprice & Town Car	*3772*	*49.09*	*38.3*
Low 15% for its weight	2607	45.47	51.2
Middle 70% for its weight	2584	45.94	49.9
High 15% for its weight	2607	45.53	50.1

The low group now shows a larger reduction of fatality risk relative to the high group, and the middle group has a fatality ratio between the low and high groups, although it is not at the midpoint. The Caprice and Town Car only have a slight advantage over the other groups here. The direct comparison of the low and high groups is based on:

TTI(d) Group	Average TTI(d)	Side Impacts	Purely Frontal
Low 15% for its weight	77.18	309	499
High 15% for its weight	99.09	312	423

The relative reduction of side impact fatalities with low TTI(d) is

1 - [(309/499) / (312/423)] = **16.0 percent**

This is in the "right" direction, and it is higher than the corresponding result for the "all ages" analysis. In fact, it is this report's most favorable result for 4-door cars weighing 1900-3299 pounds. Nevertheless, since it is based on fewer data than the "all ages" estimate, it still falls short of statistical significance (χ^2 = 2.83).

Other analyses are documented in Appendix A (Analysis No. 4) and summarized in Tables 4-5 (occupants of all ages) and 4-6 (occupants age 30-65). The principal results were:

OCCUPANTS OF ALL AGES		Fat. Red. for Low TTI(d)	
"Side" Impact	Control Group	%	χ^2
Any	Any pure frontal	9.1	2.09
Nearside compartment	Any pure frontal	8.7	1.27
Any/other vehicle	Pure frontal/other veh.	5.9	.54
Nearside compartment/other veh.	Pure frontal/other veh.	6.3	.44
Any/passenger car	Pure frontal/car	- 2.9	.05
Nearside compartment/car	Pure frontal/car	- 10.2	.39

OCCUPANTS AGE 30-65			
Any	Any pure frontal	16.0	2.83
Nearside compartment	Any pure frontal	14.2	1.40
Any/other vehicle	Pure frontal/other veh.	10.1	.67
Nearside compartment/other veh.	Pure frontal/other veh.	11.1	.55
Any/passenger car	Pure frontal/car	- 6.0	.08
Nearside compartment/car	Pure frontal/car	- 5.6	.05

TABLE 4-5: 4-DOOR CARS, OCCUPANTS OF ALL AGES - SIDE IMPACT FATALITY RISK FOR THREE QUANTILE GROUPS OF WEIGHT-NORMALIZED TTI(d)
(front outboard occupants of 4-door cars, 1900-3299 pounds, with no air bags and < 10% ABS)

TTI(d) Group	Average TTI(d)	Side + Pure Frontal Fatalities N	Side + Pure Frontal Fatalities Side/Frontal	Side Fatality Reduction for Low vs. High TTI(d) %	Side Fatality Reduction for Low vs. High TTI(d) χ^2
ALL SIDE IMPACTS					
Caprice & Town Car	*47.91*	*2239*	*.678*		
Low 15% for its wt.	77.30	1862	.815	9.1	2.09
Mid 70% for its wt.	84.98	8608	.904		
High 15% for its wt.	98.99	1817	.897		
NEARSIDE COMPARTMENT IMPACTS					
Caprice & Town Car	*47.92*	*1837*	*.377*		
Low 15% for its wt.	77.43	1465	.428	8.7	1.27
Mid 70% for its wt.	84.95	6672	.475		
High 15% for its wt.	99.02	1407	.469		
ALL SIDE IMPACTS BY ANOTHER VEHICLE					
Caprice & Town Car	*47.95*	*1358*	*.889*		
Low 15% for its wt.	77.05	1191	1.026	5.9	.54
Mid 70% for its wt.	85.15	5625	1.120		
High 15% for its wt.	99.38	1137	1.090		
NEARSIDE COMPARTMENT IMPACTS BY ANOTHER VEHICLE					
Caprice & Town Car	*47.95*	*1100*	*.530*		
Low 15% for its wt.	77.18	915	.556	6.3	.44
Mid 70% for its wt.	85.13	4286	.616		
High 15% for its wt.	99.45	867	.594		
ALL SIDE IMPACTS BY A PASSENGER CAR					
Caprice & Town Car	*48.01*	*506*	*.698*		
Low 15% for its wt.	77.31	477	.971	- 2.9	.05
Mid 70% for its wt.	85.73	2439	.985		
High 15% for its wt.	99.49	482	.944		
NEARSIDE COMPARTMENT IMPACTS BY A PASSENGER CAR					
Caprice & Town Car	*47.98*	*418*	*.403*		
Low 15% for its wt.	77.11	370	.529	- 10.2	.39
Mid 70% for its wt.	85.65	1920	.562		
High 15% for its wt.	99.48	367	.480		

TABLE 4-6: 4-DOOR CARS, OCCUPANTS AGE 30-65 - SIDE IMPACT FATALITY RISK FOR THREE QUANTILE GROUPS OF WEIGHT-NORMALIZED TTI(d)
(front outboard occupants of 4-door cars, 1900-3299 pounds, with no air bags and < 10% ABS)

TTI(d) Group	Average TTI(d)	Side + Pure Frontal Fatalities Age 30-65		Side Fatality Reduction for Low vs. High TTI(d)	
		N	Side/Frontal	%	χ^2
ALL SIDE IMPACTS					
Caprice & Town Car	*47.32*	*942*	*.589*		
Low 15% for its wt.	77.18	808	.619	16.0	2.83
Mid 70% for its wt.	85.06	3528	.731		
High 15% for its wt.	99.09	735	.738		
NEARSIDE COMPARTMENT IMPACTS					
Caprice & Town Car	*47.38*	*785*	*.324*		
Low 15% for its wt.	77.35	662	.327	14.2	1.40
Mid 70% for its wt.	85.00	2803	.375		
High 15% for its wt.	98.90	584	.381		
ALL SIDE IMPACTS BY ANOTHER VEHICLE					
Caprice & Town Car	*47.37*	*552*	*.741*		
Low 15% for its wt.	77.14	505	.753	10.1	.67
Mid 70% for its wt.	85.23	2306	.878		
High 15% for its wt.	99.51	454	.838		
NEARSIDE COMPARTMENT IMPACTS BY ANOTHER VEHICLE					
Caprice & Town Car	*47.40*	*458*	*.445*		
Low 15% for its wt.	77.32	403	.399	11.1	.55
Mid 70% for its wt.	85.16	1802	.467		
High 15% for its wt.	99.54	358	.449		
ALL SIDE IMPACTS BY A PASSENGER CAR					
Caprice & Town Car	*47.60*	*223*	*.593*		
Low 15% for its wt.	77.29	200	.695	- 6.0	.08
Mid 70% for its wt.	86.02	1025	.817		
High 15% for its wt.	99.05	197	.655		
NEARSIDE COMPARTMENT IMPACTS BY A PASSENGER CAR					
Caprice & Town Car	*47.51*	*190*	*.357*		
Low 15% for its wt.	77.40	162	.373	- 5.6	.05
Mid 70% for its wt.	85.82	824	.461		
High 15% for its wt.	98.74	161	.353		

None of the analyses showed a statistically significant difference between the low and the high groups. The comparison of the low and high groups yielded a result in the "right" direction (a positive fatality reduction) in 8 of 12 analyses. The fatality ratio for the middle group was between the ratios of the low and high groups in only 2 of the 12 analyses. The ratio for Caprice and Town Car was lower than for any of the three quantile groups in 10 of the 12 analyses; however, the differences were not large when the data were limited to occupants age 30-65.

In general, the results are more positive for 4-door cars than the preceding correlation and subsequent regression analyses. The fact that many of the TTI(d)'s of baseline 4-door cars "bunched up" in the middle of the range, a handicap in correlation and regression analyses (see Section 3.6), is not a problem here because we specifically compared the best to the worst performers. Nevertheless, even these analyses do not indicate a significant relationship between TTI(d) and real-world fatality risk in baseline 4-door cars.

CHAPTER 5

REGRESSION OF THE SIDE/FRONTAL FATALITY RATIO BY TTI(d)

The relative risk of fatalities in side impact crashes in Phase 1, pre-FMVSS 214 cars is emulated by the ratio of fatalities in side impacts relative to purely frontal fatalities, a control group. This relationship between this ratio and the Thoracic Trauma Index [TTI(d)] of the front-seat dummy on baseline side-impact tests can be analyzed by logistic regression, controlling for other factors such as driver age and vehicle weight. The analyses produced divergent results for 2-door and 4-door passenger cars. In 2-door cars, the association between TTI(d) and fatality risk in side impacts was a statistically significant: the lower the TTI(d), the lower the risk. But in the 4-door cars, there was little or no association between TTI(d) and fatality risk.

5.1 Initial logistic regressions: 2-door and 4-door cars combined

The FARS data base defined in Section 2.3 drives logistic regression analyses of side impact fatality risk, relative to a control group of "purely frontal" crashes, by TTI(d) and a list of control variables including driver age and sex.

Logistic regression on disaggregate data, using maximum likelihood principles, is performed by the LOGIST procedure on the Statistical Analysis System (SAS)[1]. The data points in the regressions are cases of fatally injured drivers and right-front (RF) passengers involved in side impacts or purely frontal crashes of passenger cars with known front-seat TTI(d) scores. The dependent variable, SIDE, has value 1 or 2. In this chapter, SIDE = 1 for **any** side impact fatality, as defined by IMPACT2 being 2, 3, 4, 8, 9, or 10. That includes nearside and farside impacts, compartment-centered and off-center damage, fixed-object and multivehicle crashes, side-damage rollovers and nonrollovers - i.e., an all-encompassing group of crashes where good TTI(d) scores might help a lot or just a little. SIDE = 2 for any purely frontal fatality, as defined by IMPACT2 = 12 and M_HARM ≠ 1-7 (principal damage in the front of the car, and the "most harmful" event was not a rollover or other noncollision). These fatalities involve side impact performance very little or not at all. They ought to be unaffected by TTI(d) scores. They are surrogates for a car experiencing a unit of exposure without a side-impact fatality. "Partially frontal" impacts such as those with IMPACT2 = 1 or 11, or with a most-harmful-event rollover are excluded from the control group because they might involve side-structure integrity to a modest extent.

The data here do not correspond exactly to the classic "dose-response" model of logistic regression, in which test subjects (e.g., machines) are assigned to groups that receive different doses of a harmful agent (e.g., a corrosive liquid). Subjects are "failures" if they respond unfavorably to the agent, "successes" if they do not. Logistic regression calibrates the proportion

[1] *SAS/STAT® User's Guide, Version 6, Fourth Edition*, Volume 2, SAS Institute, Cary, NC, 1989, pp. 1071-1126.

of failures as a function of the size of the dose. Whereas side-impact fatalities may readily be considered "failures" in response to a "dose" of TTI(d), purely frontal fatalities are hardly "successes" except in an abstract sense that they represent a unit of exposure successfully endured without a side-impact fatality. Nevertheless, NHTSA has successfully applied logistic regression to other data where the dependent variable equaled 1 for a "relevant" crash and 2 for a control-group crash[2]. As an additional check, the data will also be analyzed by a weighted least-squares linear regression model in Section 6.9. It produces nearly the same results as the logistic regressions.

Logistic regression uses a large number of **individual** observations of side-impact and purely frontal fatalities, comprising a wide variety of actual combinations of the independent variables, to predict the **probability of a side-impact fatality** under any hypothetical combination of the independent variables. Specifically, the model generates an equation which expresses the log-odds of a side impact fatality as a linear function of the independent variables:

$$\log(\text{side fatals}/\text{purely frontal fatals}) = A_0 + A_1 * \text{TTI(d)} + A_2 * V_2 + \ldots$$

The principal independent variable is the TTI(d) score for the front-seat dummy on the FMVSS 214 test. It is entered directly, without any transformations (except the minor test-speed adjustment defined in Section 2.1). Thus, the regression coefficient will indicate the change in the log-odds of a fatality, given a one-unit increase in TTI(d) - e.g., from 85 to 86. For example, a coefficient of .01 indicates that a one-unit increase in TTI(d) is associated with a 1 percent side-impact fatality increase relative to the control group:

$$\log(S_{TTI}/PF_{TTI}) = A_0 + .01 * \text{TTI(d)} + A_2 * V_2 + \ldots$$
$$\log(S_{TTI+1}/PF_{TTI+1}) = A_0 + .01 * (\text{TTI(d)}+1) + A_2 * V_2 + \ldots$$
$$\log(S_{TTI+1}/PF_{TTI+1}) - \log(S_{TTI}/PF_{TTI}) = .01$$
$$(S_{TTI+1}/PF_{TTI+1}) / (S_{TTI}/PF_{TTI}) = \exp(.01) = 1.01$$

A positive coefficient for TTI(d) is an effect in the "right" direction: the lower the TTI(d), the lower the side-impact fatality risk. A coefficient of .01 implies that any TTI(d) improvement of 25, e.g., from 100 to 75, is associated with a $1 - (.99)^{25} = 22$ percent reduction of fatality risk in side impacts.

The other potential independent variables are "control" variables that happen to be confounded with TTI(d) and also with the dependent variable. As a result, the raw data might attribute an "effect" to TTI(d) that in fact has a lot more to do with one of these other variables. For example, a hypothetical analysis of the full MY 1981-96 data set would have to take into account that, in most make-models, air bags were implemented not long before FMVSS 214. Thus, for

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[2]Hertz, E.; Hilton, J.; and Johnson, D.M., *An Analysis of the Crash Experience of Light Trucks and Vans Equipped with Antilock Braking Systems*, NHTSA Technical Report No. DOT HS 808 278, Washington, 1995. Hertz, E.; Hilton, J.; and Johnson, D.M., *An Analysis of the Crash Experience of Passenger Cars Equipped with Antilock Braking Systems*, NHTSA Technical Report No. DOT HS 808 279, Washington, 1995.

the overall MY 1981-96 fleet, cars with air bags have lower average TTI(d) than cars without air bags. Of course, the air bag did not **cause** the TTI(d) reduction, it merely accompanied the reduction. At the same time, since air bags are effective in purely frontal crashes but not side impacts, the dependent variable increases. The raw data would say that the side/frontal fatality ratio increased in cars with lower TTI(d), but that "effect" would in fact be due to air bags and have nothing to do with TTI(d).

By adding control variables to the regression analysis, we can adjust out these types of biases and separate the true effect of TTI(d) from the spurious effects of variables confounded with TTI(d). The most important potential control variables are the ones that interact strongly with both TTI(d) and the dependent variable; they produce biases like the one for air bags[3]. However, it is also desirable to include control variables that have an exceptionally strong correlation with just one; even if the correlation with the other is weak, failure to include that control could still bias the results.

We must also look for unexpected sources of confounding. For example, at first glance, we might not expect correlation between driver age and TTI(d). But if younger people drive older cars - i.e., early pre-FMVSS 214 cars - they may be driving cars with higher TTI(d).

Occupant age has exceptionally strong association with fatal crash involvement risk. To properly model its effect, it is useful to graph log(side/frontal) fatality risk by occupant age. Figure 3-4 showed a highly nonlinear and more or less parabolic relationship. As explained in Section 3.1, young drivers have many side impacts because they take risks, pull out into traffic, or lose control and hit fixed objects sideways. Old drivers misjudge the speed of oncoming traffic and are often hit in the side while turning. The side/frontal fatality ratio is lowest at about age 50. The nonlinear effect can be modeled by a quadratic term AGE^2 in addition to the linear term AGE. Whereas a more complex series of piecewise linear functions was thought to be needed in NHTSA's evaluation of vehicle size and safety[4], the relatively strong symmetry in Figure 3-4 suggests that a quadratic regression should be satisfactory and have the advantage of simplicity.

Nearly all types of fatality rates per million car years decrease as curb weight increases[5]. However, since side and frontal fatality rates both decrease as curb weight increases, it is not clear whether the **ratio** of the two would increase or decrease. It depends on whether side impacts decrease more quickly than frontal impacts as weight increases, or vice-versa, or both about the same. In 2-door cars, Figure 5-1 shows that side impact fatalities increase relative to frontals as mass goes up. There's a nice, linear relationship between log (side/frontal) fatalities and curb

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[3]Reinfurt, D.W., Silva, C.Z., and Hochberg, Y., *A Statistical Analysis of Seat Belt Effectiveness in 1973-75 Model Cars Involved in Towaway Crashes [Interim Report]*, NHTSA Publication No. DOT HS 801 833, Washington, 1976, pp. 29-31.

[4]Kahane, C.J., *Relationships between Vehicle Size and Fatality Risk in Model Year 1985-93 Passenger Cars and Light Trucks*, NHTSA Technical Report No. DOT HS 808 570, Washington, 1997, pp. 5-6 and 38.

[5]*Ibid*., pp. 93-102.

weight, suggesting that curb weight can be entered as a simple, linear variable in the logistic regressions. In general, the heavier 2-door cars are sportier cars with more aggressive drivers who tend to have high rates of side impacts with fixed objects. Figure 5-2 does not show a similar trend for 4-door cars. If there is any overall trend it is downwards, but in the middle weights (1900-3300 pounds), where most of the cars are, it is essentially flat. As long as regressions are performed separately for 2- and 4-door cars, it will be satisfactory to enter curb weight as a linear variable. However, in a combined regression it will be necessary to recognize that the weight effect is different for 2- and 4-door cars and to include an interaction term

WTX2DR =	Curb Wt - 2469	for 2-door cars
	0	for 4-door cars

where 2,469 pounds is the average weight of the 2-door cars in our FARS sample. It is subtracted from the curb weight in order to get a meaningful coefficient for TWODOOR (see below). The subtraction of a constant from one of the control variable will not affect the coefficient for TTI(d) or its statistical significance.

Vehicle age and the calendar year of the crash are both somewhat confounded with TTI(d): the earlier calendar years of data will have only pre-FMVSS 214 cars, and in the later calendar years, the pre-FMVSS 214 cars will be the older cars. Vehicle age tends to have linear relationships with fatality rates (positive or negative, depending on the type of crash), except that cars less than a year old may deviate from the trend line[6]. The trend appears to be a result of cars getting different (typically younger) drivers and exposure patterns as they age. Figure 5-3, however, does not show a strong vehicle age trend for log(side/frontal) fatalities in 4-door cars. In 2-door cars, vehicle age trends are a little stronger than in 4-door cars, but still quite weak compared to the occupant age effect. Figure 5-4 shows little or no association of log(side/frontal) fatalities with calendar year.

Figures 5-3 and 5-4 suggest that vehicle age and calendar year variables might be not be needed, but in logistic regression, additional variables can often be explored without harming the model. At first glance it makes sense to define two linear control variables: VEHAGE, the actual vehicle age (CY - MY), but set to zero if this is negative, and CY, the actual calendar year; plus BRANDNEW, set to 1 if CY $\leq$ MY, 0 otherwise. That approach did not work. In this data set, where all the cars are MY 1981 or later, there are no old cars in the early calendar years but quite a few in the later years. Thus, VEHAGE and CY are too correlated with one another, and too little correlated with the dependent variable, to coexist in the regression: one will get a coefficient with the wrong sign, and the other will get a distorted coefficient. If we cannot have both, we can choose one or the other. Since Figure 5-4 shows little or no calendar year effect, CY is dropped from the analyses.

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[6]*Evaluation of the Effectiveness of Occupant Protection: Federal Motor Vehicle Safety Standard 208*, NHTSA Technical Report No. DOT HS 807 843, Washington, 1992, pp. 39-41.

FIGURE 5-1

2-DOOR CARS: LOG(SIDE/FRONTAL) FATALITIES BY CURB WEIGHT

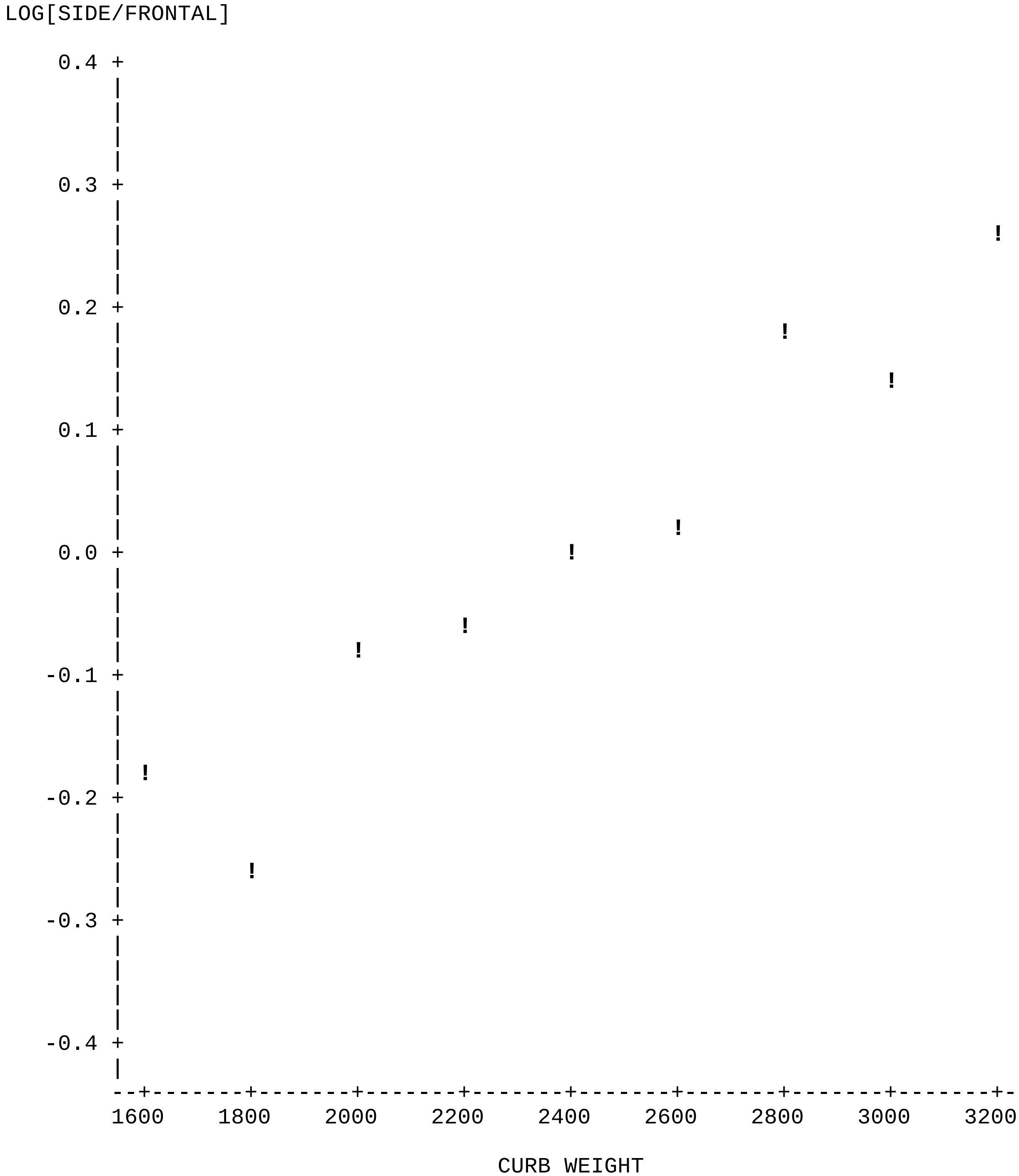


FIGURE 5-2

4-DOOR CARS: LOG(SIDE/FRONTAL) FATALITIES BY CURB WEIGHT

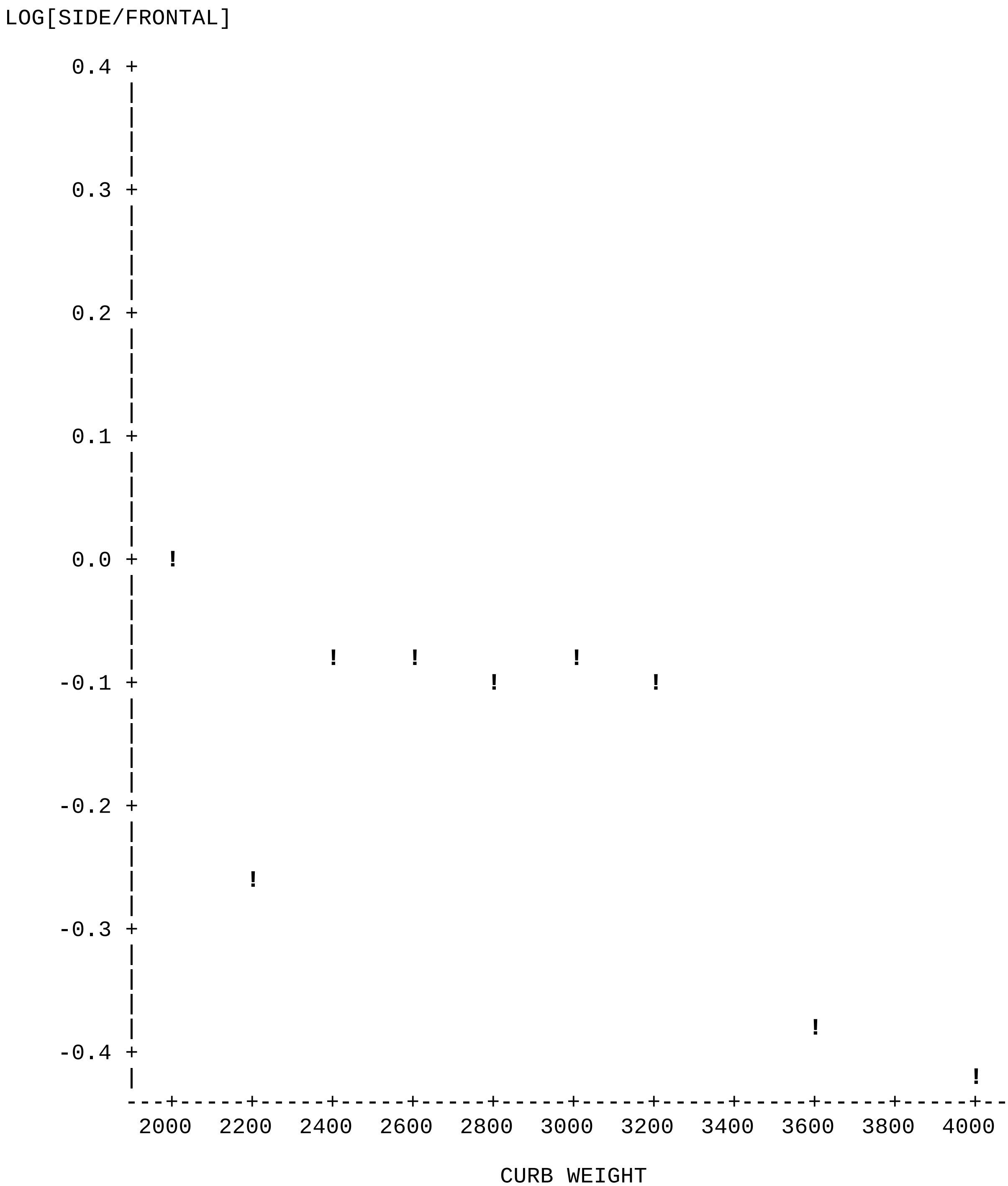


FIGURE 5-3

4-DOOR CARS: LOG(SIDE/FRONTAL) FATALITIES BY VEHICLE AGE

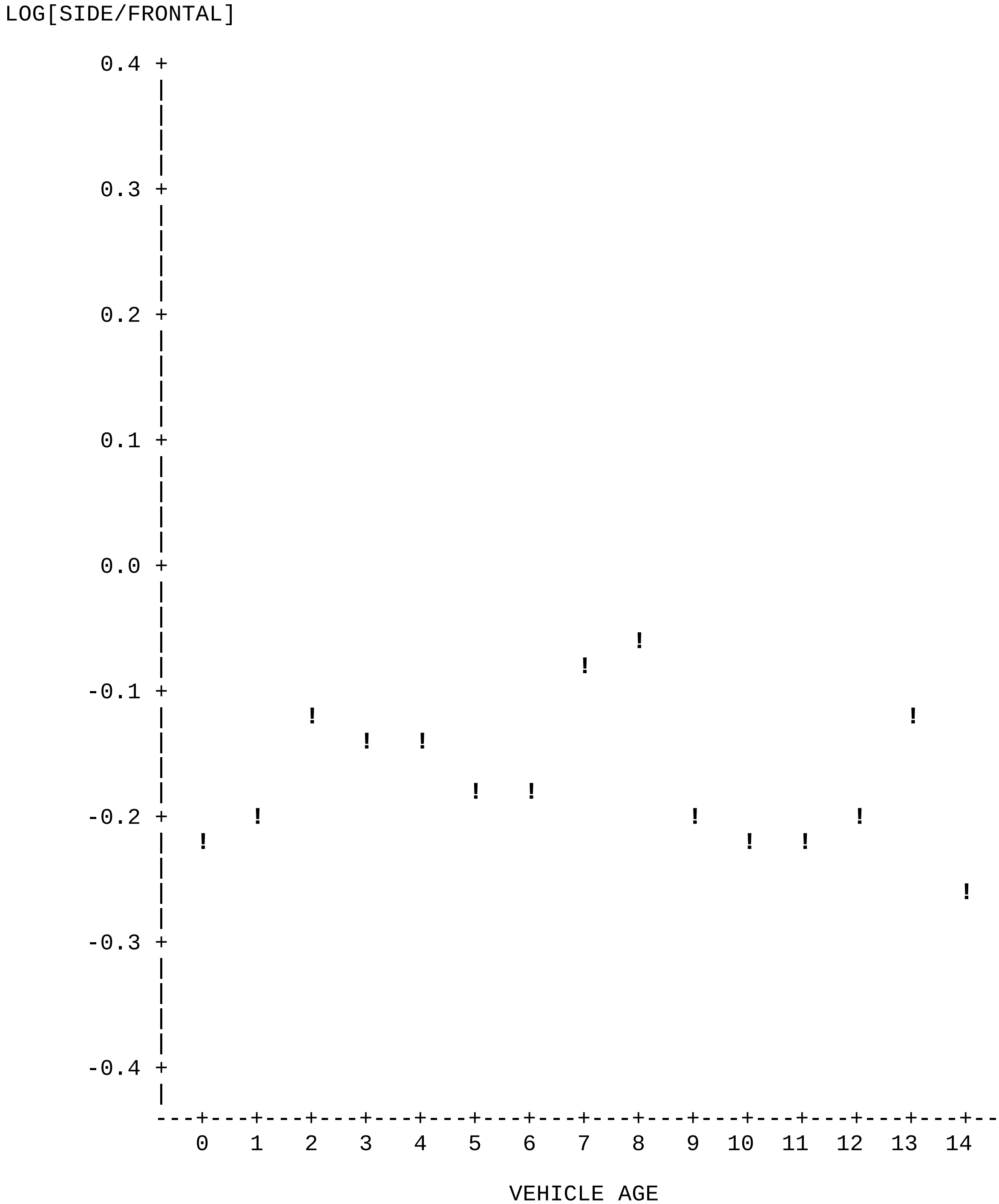
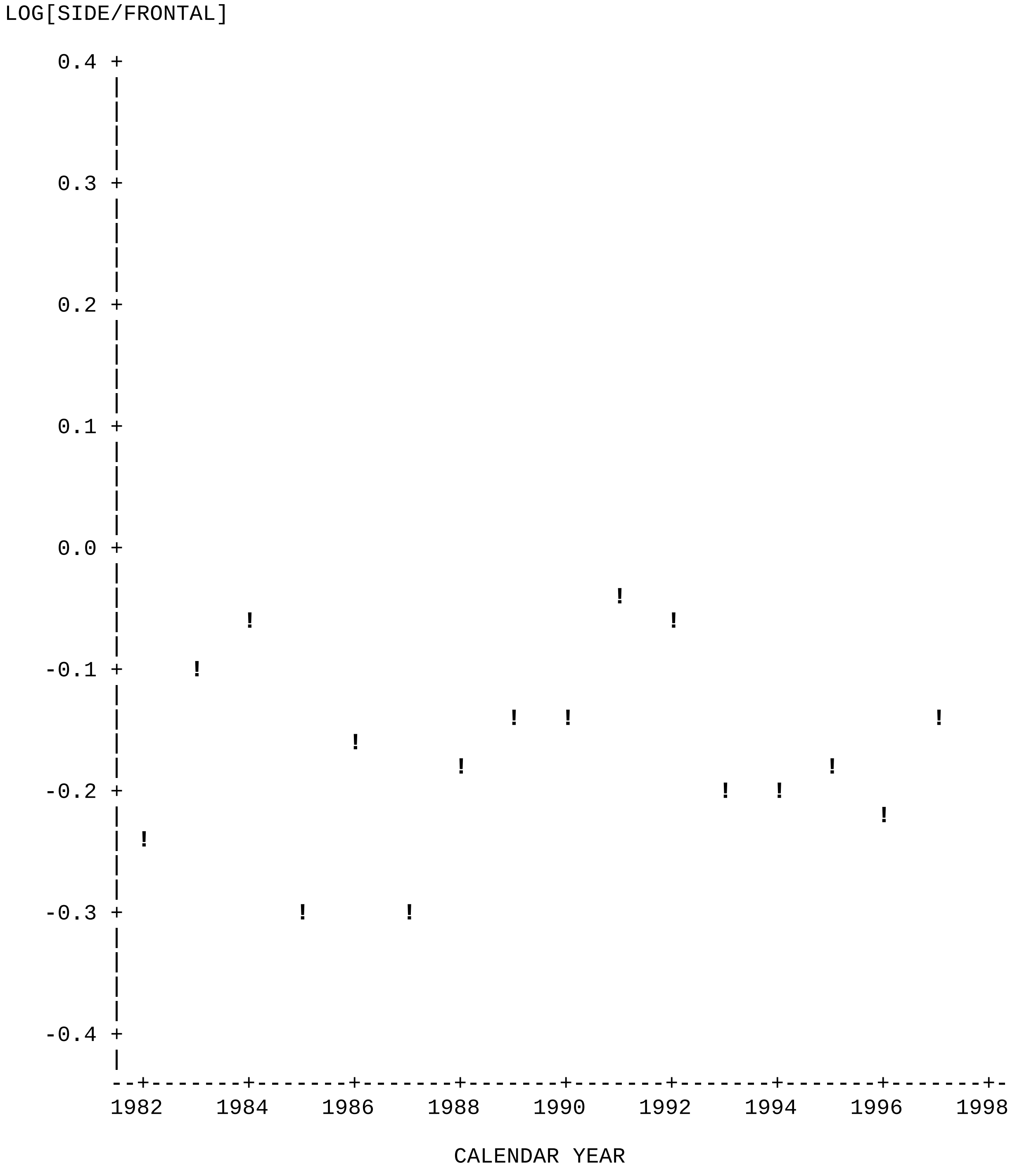


FIGURE 5-4

4-DOOR CARS: LOG(SIDE/FRONTAL) FATALITIES BY CALENDAR YEAR



Four other control variables are simpler to define. Female drivers have proportionately more side impact fatalities, relative to frontals, than males, presumably reflecting different exposure patterns and different behavior at intersection, turning and lane-changing situations. FEMALE is defined to be 1 for female occupants, 0 for males. Safety belt use increased throughout 1981-98, and that makes it confounded with TTI(d) to some extent. Belts are more effective in frontal than in side impacts; furthermore, belt users may have exposure or behavior patterns that make them less prone to frontal impacts than nonusers. Thus, belt use is associated with a higher ratio of side to frontal fatalities. BELT = 1 if used, 0 if not used or unknown, as defined from the FARS variables in Section 2.3. RF passengers are relatively more likely to die in side impacts than drivers, perhaps because the left-turn-across-traffic is a common configuration of fatal side impacts that especially puts the passenger at risk. RFPASS = 1 for passengers, 0 for drivers. In regressions that combine 2-door and 4-door cars, TWODOOR = 1 for 2-door cars, 0 for 4-door car. TWODOOR is strongly associated with TTI(d) because baseline 2-door cars had higher TTI(d) than 4-door, and it is likely to have an interaction with the dependent variable even after controlling for occupant age, gender, etc.

Air bags and antilock brakes (ABS) present special problems for the analysis. The presence of air bags and ABS are quite confounded with both TTI(d) and the dependent variable. Either, and often both, were installed in many models in the early 1990's, more or less the same time when TTI(d) performance began to improve (see Figure 3-3). Since air bags reduce fatality risk in pure frontal impacts by about 30 percent and have little or no effect in side impacts, the presence of air bags ought to increase the ratio of side to frontal fatalities substantially[7]. ABS is associated with a reduction in frontal impacts with other vehicles and an increase in side impacts with fixed objects[8]. They, too, ought to increase the ratio of side to frontal fatalities. Fortunately, in the Phase 1 FARS data, only 9 percent of the cars have air bags or standard ABS or more than 10 percent optional ABS. The overwhelming majority, 91 percent, like most cars of the 1980's have neither air bags nor ABS. Consistent with the approach in Chapters 3 and 4, we can make the analysis simpler and more convincing, with relatively little data loss, by limiting the regressions to occupant cases in seat positions unequipped with air bags, and in make-models without ABS, or with at most 10 percent optional ABS.

The initial combined regression for 2-door and 4-door cars comprises 22,928 data points: fatality cases involving baseline-tested make-models, more or less equally split between side impacts (10,922) and purely frontal impacts (12,006). The regression as a whole has a chi-square score of 495.910 with 11 degrees of freedom ($p < .0001$, indicating a strong overall relationship between the probability of a side impact and the independent variables). The regression coefficients for the individual independent variables are:

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[7]Kahane, C.J., *Fatality Reduction by Air Bags*, NHTSA Technical Report No. DOT HS 808 470, Washington, 1996, pp. 23-33.

[8]Kahane, C.J., *Preliminary Evaluation of the Effectiveness of Antilock Brake Systems for Passenger Cars*, NHTSA Technical Report No. DOT HS 808 206, Washington, 1994.

Variable	DF	Parameter Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square	Standardized Estimate	Odds Ratio
Intercept	1	-0.0942	0.2355	0.1600	0.6892	.	.
TTI(d)	**1**	**0.00437**	**0.00138**	**10.0240**	**0.0015**	**0.049907**	**1.004**
TWODOOR	1	0.0806	0.0436	3.4096	0.0648	0.021278	1.084
CURBWT	1	-0.00001	0.000048	0.0451	0.8319	-0.003020	1.000
WTX2DR	1	0.000383	0.000067	33.0236	0.0001	0.059766	1.000
AGE	1	-0.0341	0.00313	118.1954	0.0001	-0.426466	0.966
AGE*AGE	1	0.00036	0.000032	127.1699	0.0001	0.439402	1.000
FEMALE	1	0.1823	0.0279	42.7644	0.0001	0.049864	1.200
BELT	1	0.2792	0.0288	93.9998	0.0001	0.072678	1.322
RFPASS	1	0.1655	0.0315	27.5499	0.0001	0.040265	1.180
VEHAGE	1	0.000897	0.00421	0.0454	0.8312	0.001753	1.001
BRANDNEW	1	-0.0871	0.0540	2.6046	0.1066	-0.013230	0.917

TTI(d) has a coefficient of + .00437. It is in the "right" direction, and it is statistically significant at the .01 level, as evidenced by the Chi-Square (χ^2) statistic of 10.0240. A χ^2 that size or more would have had .0015 probability of occurrence by chance alone. For statistical significance at the .05 level, χ^2 has to exceed 3.84, and for the .01 level, 6.64. This initial regression suggests that side-impact fatality risk increases by .437 percent with every unit increase in TTI(d).

TWODOOR has a nonsignificant coefficient of .0806, suggesting that 2-door cars have more or less the same side impact fatality risk as 4-door cars when all other factors, including TTI(d), age, weight, etc. are equal. The coefficients for CURBWT and WTX2DR confirm the trends seen in Figures 5-1 and 5-2: there is little or no association of curb weight with the side/frontal fatality ratio in 4-door cars, but a positive association, statistically significant at the .01 level, in 2-door cars. The coefficients of the control variables AGE, AGE*AGE, FEMALE, BELT and RFPASS are all statistically significant at the .01 level, as evidenced by χ^2 well over 6.64, and are in the appropriate direction. The strong negative coefficient for AGE and positive coefficient for AGE*AGE indicate a successful quadratic regression that generates a parabola similar to the raw data in Figure 3-4. The coefficients for VEHAGE and BRANDNEW are not statistically significant.

Chapters 3 and 4 indicated that the relationship between TTI(d) and the side/frontal fatality ratio is quite different in 2-door and 4-door cars. We can statistically test for such a difference by repeating the regression with one additional variable, an interaction term TTIX2DR defined as:

TTIX2DR =	TTI(d) - 110	for 2-door cars
	0	for 4-door cars

where 110 is the average TTI(d) of baseline 2-door cars. With this interaction term, the regression coefficients change to:

Variable	DF	Parameter Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square	Standardized Estimate	Odds Ratio
Intercept	1	0.2940	0.2752	1.1411	0.2854	.	.
TTI(d)	**1**	**0.00182**	**0.00166**	**1.1983**	**0.2737**	**0.020832**	**1.002**
TTIX2DR	**1**	**0.00815**	**0.00299**	**7.4484**	**0.0063**	**0.024408**	**1.008**
TWODOOR	1	0.1365	0.0483	7.9985	0.0047	0.036039	1.146
CURBWT	1	-0.00008	0.000054	2.0317	0.1540	-0.022749	1.000
WTX2DR	1	0.000457	0.000072	40.3366	0.0001	0.071321	1.000
AGE	1	-0.0342	0.00314	118.7236	0.0001	-0.427513	0.966
AGE*AGE	1	0.000361	0.000032	128.0640	0.0001	0.441069	1.000
FEMALE	1	0.1826	0.0279	42.8496	0.0001	0.049923	1.200
BELT	1	0.2818	0.0288	95.6300	0.0001	0.073361	1.326
RFPASS	1	0.1652	0.0315	27.4206	0.0001	0.040178	1.180
VEHAGE	1	0.000535	0.00421	0.0161	0.8989	0.001045	1.001
BRANDNEW	1	-0.0868	0.0540	2.5826	0.1080	-0.013176	0.917

TTIX2DR has coefficient .00815. It is statistically significant at the .01 level, as evidenced by $\chi^2 = 7.45$. In other words, the TTI(d) effect is significantly stronger in 2-door cars than in 4-door cars. The coefficient for TTI(d) dropped to .00182, still in the right direction, but no longer statistically significant ($\chi^2 = 1.20$). This regression says that the effect of TTI(d) in 4-door cars is a fairly negligible .182 percent increase in side-impact fatality risk per unit increase in TTI(d). In 2-door cars, the effect is the sum of the coefficients for the main and interaction terms: a .997 percent increase in fatality risk per unit increase in TTI(d).

The coefficients for the influential control variables AGE, AGE*AGE, FEMALE, BELT and RFPASS are again in the expected direction and, in fact, are almost the same as in the preceding regression. The coefficients for TWODOOR and WTX2DR still have the expected sign and became somewhat stronger.

This regression indicates we should continue the strategy of Chapters 3 and 4 and perform separate analyses for 2-door and 4-door cars of the pre-FMVSS 214 era (Phase 1). Combined analyses would have to include the interaction term TTIX2DR, an undesirable complication, or they would produce a TTI(d) coefficient that is a somewhat meaningless average of the distinct 2-door and 4-door effects.

Additionally, in phase 1, most of the high TTI(d) scores are 2-door cars and almost all of the good scores are 4-door cars. The differences between 2-door and 4-door cars, including the differences in the types of drivers, will unavoidably drive the analyses. Even though the preceding regressions seemed to do a nice job separating the effects of TTI(d) from covariates such as occupant age and gender, we could never be intuitively sure that the combined regressions truly calibrate the safety effects of TTI(d) rather than merely compare the relative safety and crash distributions of 2-door and 4-door cars.

5.2 Analysis of 2-door cars

The principal regression for baseline 2-door cars without air bags and with no ABS or less than 10 percent optional ABS comprises 8,167 data points: fatality cases almost equally split between side impacts (4,120) and purely frontal impacts (4,047). The regression includes the same control variables as the preceding ones, except TWODOOR, WTX2DR and TTIX2DR can be omitted since all cars are 2-door. It generates the following coefficients:

Main Regression for 2-Door Cars

Variable	DF	Parameter Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square	Standardized Estimate	Odds Ratio
Intercept	1	-1.4984	0.3271	20.9868	0.0001	.	.
TTI(d)	**1**	**0.00927**	**0.00248**	**13.9318**	**0.0002**	**0.046486**	**1.009**
CURBWT	1	0.000351	0.000048	52.7771	0.0001	0.091636	1.000
AGE	1	-0.0287	0.00577	24.7200	0.0001	-0.274655	0.972
AGE*AGE	1	0.000254	0.000064	15.6673	0.0001	0.217433	1.000
FEMALE	1	0.1238	0.0473	6.8624	0.0088	0.033166	1.132
BELT	1	0.2472	0.0506	23.8661	0.0001	0.061344	1.280
RFPASS	1	0.2357	0.0524	20.2086	0.0001	0.057883	1.266
VEHAGE	1	0.00845	0.00726	1.3544	0.2445	0.016221	1.008
BRANDNEW	1	-0.1047	0.0832	1.5831	0.2083	-0.017506	0.901

The coefficient for TTI(d) is +.00927. It is in the right direction and it is statistically significant at the .01 level, as evidenced by $\chi^2 = 13.93$. This coefficient generates our best estimate of the effect of reducing TTI(d) in Phase 1, baseline 2-door cars. The average TTI(d) in MY 1981-91 2-door cars was 110 (see Section 3.1). The lowest TTI(d) for any 2-door car prior to MY 1994, representing the "best practices" during the pre-standard era, was 82 (see Table 3-2). If TTI(d) performance in pre-standard 2-door cars had improved from the average level (110) to the best practices level (82), the coefficient suggests a fatality reduction of

$$1 - (1 - .00927)^{110 - 82} = 23 \text{ percent}$$

in side impacts. That is a substantial reduction considering that the data comprise all types of side impacts - farside as well as nearside, off-center as well as compartment-centered, etc.

The coefficients for the control variables are not too different from the preceding regressions (specifically, CURBWT has a coefficient similar to WTX2DR in the preceding regressions). All coefficients have the appropriate sign. VEHAGE and BRANDNEW are not statistically significant.

5.3 Analysis of 4-door cars

Two regressions will be presented for 4-door cars. The first includes the FARS data for **all** the 4-door make-models that were baseline-tested, including the heaviest and lightest cars. Seat positions equipped with air bags and cars with standard ABS or more than 10 percent optional ABS are excluded. There are 14,761 fatality cases, with side impacts (6,802) somewhat outnumbered by purely frontal impacts (7,959). The coefficients are:

All 4-Door Cars

Variable	DF	Parameter Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square	Standardized Estimate	Odds Ratio
Intercept	1	0.2907	0.2794	1.0827	0.2981	.	.
TTI(d)	**1**	**0.00168**	**0.00167**	**1.0214**	**0.3122**	**0.016086**	**1.002**
CURBWT	1	-0.00009	0.000054	2.7884	0.0950	-0.027016	1.000
AGE	1	-0.0333	0.00386	74.1743	0.0001	-0.423119	0.967
AGE*AGE	1	0.000365	0.000038	90.7310	0.0001	0.467274	1.000
FEMALE	1	0.2220	0.0346	41.0375	0.0001	0.061064	1.249
BELT	1	0.2979	0.0351	72.0351	0.0001	0.079064	1.347
RFPASS	1	0.1197	0.0396	9.1242	0.0025	0.028976	1.127
VEHAGE	1	-0.00271	0.00519	0.2730	0.6013	-0.005327	0.997
BRANDNEW	1	-0.0639	0.0713	0.8039	0.3699	-0.009091	0.938

The TTI(d) coefficient, + .00168 is in the "right" direction, but it is not statistically significant (χ^2 = 1.02), and it is fairly negligible in comparison to the +.00927 coefficient in the 2-door cars. It is almost the same as the TTI(d) coefficient in the second combined regression (.00182), the one with the interaction term TTIX2DR. In that regression, the TTI(d) coefficient represented the effect in 4-door cars. The effects of the control variables are also about the same as in that regression.

The preceding analysis included the Lincoln Town Car and Chevrolet Caprice, two models that are much bigger and heavier than the other baseline test cars, have much lower TTI(d) (40 and 51, respectively, as compared to an average of 86 for the other baseline 4-door cars), and also have low side/frontal fatality ratios, as discussed in Section 3.6. To what extent are they "driving" the analysis? Does the positive TTI(d) coefficient merely reflect that big, rugged cars have low side/frontal fatality risk? Although regression allows us to control for some factors such as driver age, we cannot be sure if it is specifically TTI(d) or if it is other size-related factors that cause Town Car and Caprice to have lower-than-average risk.

Consistent with the approach in Chapters 3 and 4, we can also limit the analyses of 4-door cars to a middle range of weights, 1900-3299 pounds. The baseline test cars in that weight range were an exceptionally homogeneous mix of economy sedans and family sedans (see Table 3-5). Here, there is less danger that other factors could "drive" the TTI(d) coefficient. A potential disadvantage, however, is that the TTI(d) of many baseline 4-door cars are concentrated in a narrow range from 77 to 94 (whereas the 2-door cars are more uniformly distributed across their full range - see Section 3.6). Concentration in the middle could diminish the power of regression analyses. This regression comprises 12,287 fatality cases, including 5,781 side impacts and 6,506 purely frontal impacts. The coefficients are:

4-Door Cars Weighing 1900-3299 Pounds

Variable	DF	Parameter Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square	Standardized Estimate	Odds Ratio
Intercept	1	0.3237	0.2937	1.2145	0.2704	.	.
TTI(d)	**1**	**-0.00047**	**0.00188**	**0.0635**	**0.8011**	**-0.003014**	**1.000**
CURBWT	1	-0.00001	0.000062	0.0534	0.8173	-0.002821	1.000
AGE	1	-0.0358	0.00418	73.6068	0.0001	-0.456361	0.965
AGE*AGE	1	0.000397	0.000042	90.4960	0.0001	0.506553	1.000
FEMALE	1	0.2190	0.0376	33.8553	0.0001	0.060349	1.245
BELT	1	0.2684	0.0383	49.0177	0.0001	0.071520	1.308
RFPASS	1	0.0688	0.0430	2.5537	0.1100	0.016725	1.071
VEHAGE	1	0.000948	0.00576	0.0270	0.8694	0.001829	1.001
BRANDNEW	1	-0.0174	0.0774	0.0507	0.8218	-0.002496	0.983

Exclusion of the Town Car and Caprice had only a modestly unfavorable effect on the TTI(d) coefficient, taking it from slightly positive to barely negative (in the "wrong" direction). Its value, -.00047, is not statistically significant ($\chi^2 = 0.06$). The coefficients of the control variables did not change in any important way from the preceding regression.

The TTI(d) coefficients from both regressions are very small in practical terms. The average TTI(d) in MY 1981-91 4-door cars was 80 (see Section 3.1). The lowest TTI(d) for any 4-door car weighing 1900-3299 pounds, prior to MY 1994, representing the "best practices" during the pre-standard era, was 62 (see Table 3-5). If TTI(d) performance had improved from the average level (80) to the best practices level (62), the coefficient from the second regression suggests a fatality reduction of $1 - (1 + .00047)^{80 - 62} = -0.8$ percent, essentially no change. If we substitute the TTI(d) coefficient from the first regression (including Town Car and Caprice) into this equation, the fatality reduction improves to $1 - (1 - .00168)^{80 - 62} = 2.9$ percent, but that's still a rather negligible effect.

In other words, the regressions for 4-door cars produce essentially the same results whether or not Town Car and Caprice are included: little effect attributed to TTI(d). That contrasts with the correlation analyses in Section 3.6, where inclusion of Town Car and Caprice yielded statistically significant positive association between make-models' TTI(d) and side/frontal fatality rates. The ability of regression analyses to control carefully for factors such as driver age and gender may explain why it made less of a difference here. Even though regression results are about the same either way, it nevertheless seems preferable to analyze the data excluding Town Car and Caprice, since it eliminates doubts that those models might be "driving" the results. In the remainder of this report, the regressions on 4-door cars will all be limited to models weighing 1900-3299 pounds.

5.4 Sensitivity tests

The crash data base developed in Section 2.3 is not limited to exact matches for cars that were FMVSS 214-tested but includes their "twins": cars of similar, but not necessarily identical model years or body styles. The FMVSS 214 test is not a perfectly accurate measure of TTI(d) for the test make-model, to the extent that most models were tested just once and the result could be slightly higher or lower than the average for repeated tests[9]. But it could be even less accurate for the twins. In general, the more distant the twin, the less accurate the TTI(d) estimate.

When regressions are run on a data base where one of the independent variables is inaccurately measured, the regression coefficient for that variable will usually be weaker than if it had been perfectly measured. Conversely, dropping the more distant "twins" could result in larger TTI(d) coefficients - although their statistical significance won't necessarily increase because the data sample is smaller.

Section 2.2 included two criteria for the quality of the match between the test vehicle and the FARS case vehicle, based on the body style and the model year:

<u>Body style</u>

X Same body style as the 214 test vehicle
Y Same number of side doors as the 214 test vehicle, but a different body style

<u>Model year</u>

A The model year of the twin is equal to or greater than the MY of the 214 test vehicle
B The model year of the twin precedes the MY of the 214 test vehicle

The regressions so far included cars with any level of match quality (X or Y with A or B). Now, the regressions of Sections 5.2 and 5.3 will be rerun with the data limited to the better matches - i.e., by excluding categories Y or B, or both of them.

The upper section of Table 5-1 shows that additional restrictions of the data set have little payoff in the analyses for 2-door cars. The basic analysis using all available twins produced a TTI(d)

[9] *Final Regulatory Impact Analysis - New Requirements for Passenger Cars to Meet a Dynamic Side Impact Test FMVSS 214*, NHTSA Publication No. DOT HS 807 641, Washington, 1990, pp. IIIA-65 - IIIA-84 discusses test-to-test variability, suggesting the relative error is 10 percent or substantially less - considered quite acceptable for NHTSA compliance tests.

TABLE 5-1

INFLUENCE OF THE TEST DATA-FARS DATA MATCH QUALITY
ON THE COEFFICIENT OF TTI(d) IN THE LOGISTIC REGRESSIONS
(front outboard occupants of cars with no air bags and < 10% ABS)

Matches Accepted		**TTI(d) Regression Coefficient**	**N of FARS Cases**	**Chi-Square**
	2-DOOR CARS			
X Y A B	All matches accepted	**.00927**	8,167	13.93*
X A B	Exact body style match	**.00879**	5,490	12.15*
X Y A	FARS MY ≥ test MY	**.00974**	5,120	13.85*
X A	Exact body style + FARS MY ≥ test MY	**.00909**	4,305	11.65*
	4-DOOR CARS WEIGHING 1900-3299 POUNDS			
X Y A B	All matches accepted	**- .00047**	12,287	.06
X A B	Exact body style match	**- .00222**	10,135	1.19
X Y A	FARS MY ≥ test MY	**- .00118**	8,503	.32
X A	Exact body style + FARS MY ≥ test MY	**- .00244**	7,135	1.15

*TTI(d) coefficient is in the “right” direction and statistically significant at the .01 level.

coefficient of .00927. With a sample of 8,167 crash cases, the χ^2 is 13.93, the highest level recorded in Table 5-1. Requiring an exact body-style match (e.g., excluding coupes if the test vehicle was a hatchback or convertible) did not help: the coefficient actually dropped to .00879, while the sample was reduced to 5,490 cases. Requiring the FARS model year to be equal to or greater than the test MY (up to the next minor or major redesign) improved the TTI(d) coefficient to .00974, but with the sample reduced to 5,120 cases, χ^2 dropped slightly to 13.85. Imposing both of these restrictions simultaneously lowered the coefficient to .00909 and χ^2 to 11.65.

Nevertheless, all of the sensitivity tests for 2-door cars produced positive TTI(d) coefficients that are statistically significant at the .01 level.

The lower section of Table 5-1 shows that restricting the data set of 4-door cars does not strengthen the relationships between observed TTI(d) and side impact fatality risk. The three sensitivity tests each produced slightly negative TTI(d) coefficients, none of them statistically significant.

The sensitivity tests suggest that further restrictions of the data set are unnecessary, and the full data set is the best choice for the regression analyses.

CHAPTER 6

REGRESSION ANALYSES FOR SELECTED SUBGROUPS OF THE DATA

The test for FMVSS 214 most closely simulates the dynamics of a nearside occupant when a car is hit in the compartment area by another light vehicle, especially a passenger car. If TTI(d) is generally correlated with fatality risk in side impacts, it ought to be especially correlated with risk in those impacts that are nearside, in the compartment area and/or by a passenger car - although there could also be correlations in other types of side impacts. When the logistic regressions of side impact fatalities relative to a control group of purely frontal crashes are limited to particular subgroups of side impacts, the results for Phase 1, pre-standard 2-door cars show the desired alignment: positive results in all subgroups, but the closer the crash to a FMVSS 214 configuration, the higher the correlation of TTI(d) with fatality risk. The results for pre-standard 4-door cars do not show any discernible patterns or statistically significant association between TTI(d) and fatality risk.

6.1 Effect of TTI(d) by impact location

In a side impact, a vehicle or object contacts the outside of the car's side structure, possibly forcing that structure into the car; almost immediately or perhaps subsequently, the inside of the side structure and the occupant come into contact, possibly resulting in occupant injury. A crashworthy side structure resists or slows down intrusion of contacting vehicles or objects and also contains energy-absorbing materials to cushion the impact with the occupant. Intrusion resistance may reduce the speed at which the side structure eventually contacts the occupant; energy absorption may help reduce the injury risk at any given speed. Both capabilities are essential to obtain a good TTI(d) score on the FMVSS 214 test, since it involves an intruding side structure coming into contact with a nearside occupant. In other words, a car with an excellent TTI(d) score probably has good intrusion resistance **and** energy absorption, whereas a dismal score is probably evidence of inferior performance on both counts.

When the impact is centered on the occupant compartment area, as defined by IMPACT2 = 3 or 9 in FARS, it is likely that intrusion will occur. That type of impact brings all the capabilities of the side structure into play. If the damage is primarily away from the compartment, as evidenced by IMPACT2 = 2, 4, 8, or 10, there might be little or no intrusion. However, there might still be some intrusion, and in any case there can be contact between the occupant and the side structure, making energy absorption important. These considerations, plus the fact that the FMVSS 214 test is itself a compartment impact, lead us to expect TTI(d) to have higher correlation with fatality risk in compartment crashes than in off-center crashes, but that there still might be some correlation even in the off-center crashes.

Table 6-1 compares the relationships of TTI(d) and fatality risk in compartment impacts and off-center side impacts of 2-door cars. As in Section 5.2, the tool is logistic regression of fatality cases involving 2-door, pre-FMVSS 214 (Phase 1) make-models without air bags and with no

TABLE 6-1

2-DOOR CARS: INFLUENCE OF THE IMPACT LOCATION ON THE COEFFICIENT OF TTI(d) IN THE LOGISTIC REGRESSION OF SIDE/PURE-FRONTAL FATALITIES
(front outboard occupants of 2-door cars with no air bags and < 10% ABS)

	IMPACT2	**TTI(d) Regression Coefficient**	**N of Side Impact Fatals**	**Chi-Square**
Baseline (all side impact fatalities)	2,3,4,8,9,10	**.00927**	4,120	13.93**
Occupant compartment impacts	3,9	**.01080**	3,107	16.08**
Off-center impacts	2,4,8,10	**.00510**	1,013	1.57
Nearside impacts	8,9,10 for drivers; 2,3,4 for RF	**.00999**	2,666	12.22**
Farside impacts	2,3,4 for drivers; 8,9,10 for RF	**.00842**	1,454	5.78*
Nearside compartment impacts	9 for drivers; 3 for RF	**.01280**	2,052	16.62**

*TTI(d) coefficient is in the “right” direction and statistically significant at the .05 level.

**TTI(d) coefficient is in the “right” direction and statistically significant at the .01 level.

ABS or less than 10 percent optional ABS. The data base consists of FARS cases of cars identical to a vehicle that had been FMVSS 214-tested, plus the “twins” of such vehicles as defined in Section 2.2 (same make-model, same or similar model year and body style). The dependent variable SIDE = 1 for any driver or right front (RF) passenger fatality in a side impact and SIDE = 2 for any driver or RF fatality in a purely frontal impact (IMPACT2 = 12 and M_HARM $\neq$ 1-7). The independent variables are identical to those in Section 5.2 - i.e., the TTI(d) score for the front-seat dummy on the FMVSS 214 test, plus curb weight, occupant age, sex, belt use and seat position, and vehicle age. The “baseline” regression of Section 5.2 counted any FARS case with IMPACT2 = 2, 3, 4, 8, 9, 10 as a side impact. It was based on 4,120 side impact fatalities and 4,047 purely frontal fatalities. The result, shown in the first line of Table 6-1, was a regression coefficient of .00927 for TTI(d). This is in the “right” direction (the higher the TTI(d), the worse the side impact fatality risk). It is statistically significant at the .01 level as evidenced by Chi-Square (χ^2) statistic of 13.93. (For statistical significance at the .05 level, χ^2 has to exceed 3.84, and for the .01 level, 6.64.)

Next, the 4,120 side impact fatalities are subdivided into 3,107 compartment impacts (IMPACT2 = 3 or 9) and 1,013 off-center impacts (IMPACT2 = 2,4,8,10). Two separate regressions are run: the first counts only the 3,107 compartment impacts as “SIDE = 1” and keeps the original 4,047 purely frontal impacts as “SIDE = 2” (and does not use the off-center impacts as data points at all). The second counts only the 1,013 off-center impacts as “SIDE = 1" and retains the original 4,047 purely frontal impacts as “SIDE = 2.”

In the regression on the compartment impacts, the coefficient for TTI(d) is .01080, higher than the baseline coefficient of .00927. Despite the attenuation of the sample size, the coefficient continues to be statistically significant at the .01 level, and its χ^2 has increased to 16.08.

In the off-center impacts, the TTI(d) coefficient is .00510. Although in the “right” direction, it is not statistically significant (χ^2 = 1.57). The TTI(d) coefficient in compartment impacts is more than twice as large as the coefficient in off-center impacts.

The coefficients for the various control variables in these two regressions are nearly identical to one another, and to the baseline regression, with one exception: the coefficient for BELT is even stronger than baseline in the compartment-impact regression, but close to zero in the off-center impacts. That makes sense: it says that belts are substantially less effective in a compartment impact than in a frontal impact, but about equally effective in off-center side impacts and frontal impacts.

TTI(d) can be expected to have higher correlation with the fatality risk of the nearside occupant (as defined in FARS by IMPACT2 = 8-10 for drivers or 2-4 for RF passengers) than the farside occupant (IMPACT2 = 2-4 for drivers or 8-10 for RF passengers). The FMVSS 214 test only measures the TTI(d) of nearside dummies. A nearside impact brings all the capabilities of the side structure into play, especially intrusion resistance, since the structure may contact the occupant while it is still being forced into the compartment by the striking vehicle. In a farside impact, intrusion resistance is less important because the intrusion phase of the impact is usually finished before the occupant contacts the structure. Potential benefits of an energy-absorbing side structure are also diminished because a large proportion of farside injuries involve contact with vehicle surfaces other than the side structure. Nevertheless, there are still many farside injuries involving torso contact with the side structure, and the regulatory analysis predicted that a reduction in TTI(d) would be effective for farside occupants, although not as much as for nearside occupants[1].

Table 6-1 indicates that the 4,120 side impact fatalities comprise 2,666 nearside and 1,454 farside occupants. Separate regressions are run for each of these subgroups relative to the control group of 4,047 purely frontal fatalities. The TTI(d) coefficient for the nearside impacts is .00999 and it is statistically significant at the .01 level (χ^2 = 12.22). The TTI(d) coefficient for the farside impacts is a slightly weaker .00842, but still strong enough for statistically significance at the .05 level (χ^2 = 5.78). Table 6-1 suggests that a good TTI(d) score is associated with reduced fatality risk in both nearside and farside impacts of 2-door cars. The observed effectiveness is slightly higher in the nearside impacts, as expected, but not to the extent that one effectiveness is clearly higher than the other.

The coefficients for the control variables in these two regressions are nearly identical to one another, and to the baseline regression, with two exceptions: (1) The coefficient for BELT is strong in nearside and weak in farside impacts - i.e., belts are substantially less effective in a nearside impact than in a frontal impact, but only slightly less effective in a farside impact than in a frontal impact. (2) The coefficient for RFPASS is stronger than baseline in nearside impacts and negative in farside impacts. In other words, relative to pure frontal fatalities, RF passengers have higher likelihood of a nearside fatality than drivers and lower likelihood of a farside fatality. This is because there are more high-severity crashes with right side damage (nearside for RF, farside for the driver) than left side damage (farside for RF, nearside for the driver): the raw FARS statistics show more left-side than right-side impact fatalities, but that is because the RF seat is unoccupied in so many cars; if the RF seat were always occupied, there would be more right-side than left-side impact fatalities.

An especially large effect for TTI(d) might be expected in nearside compartment impacts, as defined in FARS by IMPACT2 = 9 for drivers or 3 for RF passengers, since that is the impact location closest to the FMVSS 214 test. Indeed, Table 6-1 shows a very strong .01280 regression coefficient for TTI(d), statistically significant at the .01 level (χ^2 = 16.62) and stronger than the effect in any other group on that table. Approximately half of all side impact fatalities are nearside compartment impacts.

None of these patterns, or any other pattern show up in the corresponding analyses of 4-door cars. Section 5.3 presented a regression for 4-door cars weighing 1900-3299 pounds without air bags and with no ABS or less than 10 percent optional ABS. The regression, shown as the "baseline" in Table 6-2, produced a near-zero coefficient of -.00047 for TTI(d): it is in the "wrong" direction, but it is not statistically significant (χ^2 = .06). Table 6-2 shows that the TTI(d)

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[1]*Final Regulatory Impact Analysis, New Requirements for Passenger Cars to Meet a Dynamic Side Impact Test FMVSS 214,* NHTSA Publication No. DOT HS 807 641, Washington, 1990, pp. IV-1 - IV-20.

TABLE 6-2

4-DOOR CARS: INFLUENCE OF THE IMPACT LOCATION ON THE
COEFFICIENT OF TTI(d) IN THE LOGISTIC REGRESSION OF SIDE/PURE-FRONTAL FATALITIES
(front outboard occupants of 4-door cars weighing 1900-3299 pounds with no air bags and < 10% ABS)

	IMPACT2	**TTI(d) Regression Coefficient**	**N of Side Impact Fatals**	**Chi-Square**
Baseline (all side impact fatalities)	2,3,4,8,9,10	**- .00047**	5,781	.06
Occupant compartment impacts	3,9	**- .00057**	4,409	.08
Off-center impacts	2,4,8,10	**- .00019**	1,372	.004
Nearside impacts	8,9,10 for drivers; 2,3,4 for RF	**- .00113**	3,914	.28
Farside impacts	2,3,4 for drivers; 8,9,10 for RF	**+ .00076**	1,867	.08
Nearside compartment impacts	9 for drivers; 3 for RF	**- .00083**	3,038	.13

No coefficient is statistically significant at the .05 level.

coefficients in the regressions for each of the subgroups are likewise close to zero: -.00057 in compartment impacts and -.00019 in off-center damage; -.00113 in nearside and +.00076 in farside; and -.00083 in nearside compartment impacts. None of these coefficients is statistically significant; in fact, χ^2 never exceeds 0.28.

Thus, in the 4-door cars, there are no statistically significant positive correlations between TTI(d) and fatality risk, nor is there a pattern of stronger effects in the subgroups of side impacts that more closely resemble the FMVSS 214 test.

6.2 Effect of TTI(d) by type of vehicle or object contacted

The FMVSS 214 test most closely resembles a nearside compartment impact by a passenger car. That is because the Moving Deformable Barrier (MDB), the striking "vehicle" on the test, was developed in the 1980's to simulate the average 3000-pound car of that era. The front of the MDB had the same height, geometry and force-deflection characteristics as the front of such a car. By contrast, the front of a typical light truck is higher off the ground and stiffer than an MDB, and its mass is higher, too. Heavy trucks and fixed objects resemble an MDB even less. Considering just the similarity of actual crashes to the FMVSS 214 test, we would expect higher correlation of TTI(d) with fatality risk in side impacts by another passenger car than in side impacts by a light truck, a heavy truck or a fixed object.

A second reason to anticipate higher effectiveness in side impacts by another vehicle than in side impacts with fixed objects is that intrusion reduction capabilities play a more important role. When a car is struck in the side by another car, the initial intrusion rate of the door structure can be close to the impact speed of the bullet vehicle and substantially higher than the eventual Delta V of the target vehicle. In an uncrashworthy car, the contact between the side structure and the nearside occupant may be close to the higher, impact speed, whereas an excellent side structure can delay that contact and reduce its speed closer to the lower, Delta V. But in a collision with an immovable, rigid fixed object, or a massive, nearly rigid vehicle such as a heavy truck, the eventual Delta V and the initial impact speed are much closer, and intrusion resistance will have less influence on the contact velocity between the occupant and the side structure.

On the other hand, good side structure may have a benefit that is greater in side impacts with fixed objects than in multivehicle crashes: it may help the vehicle "slide by" the object and reduce the overall severity of the crash. In fact, the fatality reduction by the 1973 requirements of FMVSS 214 based on a static test of door strength was entirely in fixed-object crashes, for that reason[2]. The additional dynamic test for FMVSS 214 specifically simulates multivehicle crashes in part because the original static test primarily reduced fatalities in single-vehicle crashes[3]. Yet it is quite possible that the new standard could also have benefits in the fixed-object crashes by

[2] Kahane, C.J., *An Evaluation of Side Structure Improvements in Response to Federal Motor Vehicle Safety Standard 214*, NHTSA Technical Report No. DOT HS 806 314, Washington, 1982, Section 4.3 and Chapters 6 and 9.

[3] *Final Regulatory Impact Analysis*, pp. II-1 - II-3.

intensifying the effects of the earlier requirement, and the effectiveness in fixed-object crashes would not necessarily be lower than in multivehicle crashes. Specifically, the agency conducted pole tests as well as MDB impacts with baseline and modified cars; the relative reduction of TTI(d) in the modified vehicles was slightly smaller in the pole tests than in the MDB impacts, but not by much[4].

Table 6-3 compares the relationships of TTI(d) and fatality risk in side impacts of 2-door cars (without air bags and with no ABS or less than 10 percent optional ABS) depending on the vehicle or object contacted. The first row of Table 6-3 is once again the "baseline" regression in which "SIDE = 1" is a driver or RF passenger fatality in any side impact and "SIDE = 2" for any driver or RF fatality in any purely frontal impact. The coefficient for TTI(d) is .00927 for TTI(d).

The next row is a similar regression, except "SIDE = 1" for a driver or RF passenger fatality in a side impact **in a single-vehicle crash** (as defined by VE_FORMS = 1, generally an impact with a fixed object) while "SIDE = 2," as in the baseline, for **any** purely frontal fatality, single-vehicle or multivehicle. There are 1,611 single-vehicle side impacts. The coefficient for TTI(d) is .01150, somewhat higher than baseline, and statistically significant at the .01 level ($\chi^2 = 8.99$).

In the next row, "SIDE = 1" for side impact fatalities in **multivehicle crashes** (VE_FORMS $\geq$ 2), and "SIDE = 2" once again for any purely frontal fatality, single or multivehicle. The regression coefficient for TTI(d) is .00841, slightly lower than baseline and in single-vehicle crashes, but still significant at the .01 level ($\chi^2 = 9.24$). Table 6-3 suggests that a good TTI(d) score is associated with reduced fatality risk in both fixed-object and multivehicle side impacts of 2-door cars. The effectiveness in the two types of crashes is more or less the same.

The coefficients for the control variables in these two regressions differ from one another in plausible ways: (1) The coefficient for curb weight is strongly positive in the fixed-object crashes (because the heaviest 2-door cars are the sportiest and they have high rates of side impacts with fixed objects) but negligible in the multivehicle crashes. (2) The effect of occupant age is consistently negative in side impacts with fixed objects (the older, the fewer), but has the usual parabolic shape in the multivehicle crashes. (3) Females have low rates of side impacts with fixed objects and high rates of side impacts by other vehicles.

The two preceding regressions were run with the same control group: all purely frontal fatalities, both single and multivehicle. Another possibility is to use a control group of single-vehicle frontals for the single-vehicle side impacts, and multivehicle frontals for multivehicle side impacts. That approach was also tried out and yielded nearly identical results.

The next three lines of Table 6-3 display regression coefficients for TTI(d) in side impacts where the striking vehicle is a passenger car, a light truck or a heavy truck. The regression setup is somewhat different from the earlier analyses of this report. The FARS data file used in the preceding analyses (driver and RF passenger fatalities in vehicles with known TTI(d) and side or

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[4] *Ibid*., pp. IIIC-33 - IIIC-34.

TABLE 6-3

2-DOOR CARS:
INFLUENCE OF THE VEHICLE/OBJECT CONTACTED ON THE COEFFICIENT OF TTI(d) IN THE LOGISTIC REGRESSION OF SIDE/PURE-FRONTAL FATALITIES
(front outboard occupants of 2-door cars with no air bags and < 10% ABS)

Side impact with/by	**TTI(d) Regression Coefficient**	**N of Side Impact Fatals**	**Chi-Square**
Baseline (all side impact fatalities)	**.00927**	4,120	13.93**
Fixed object	**.01150**	1,611	8.99**
Any other vehicle	**.00841**	2,509	9.24**
Another passenger car	**.01310**	987	7.51**
Light truck	**.00329**	809	.37
Heavy truck	**.00742**	389	.93
Nearside compartment impact by a passenger car	**.01730**	494	8.26**

**TTI(d) coefficient is in the "right" direction and statistically significant at the .01 level.

purely frontal damage) is now limited to the crashes involving exactly **two** vehicles (VE_FORMS = 2). FARS is then investigated to obtain a classification of the "other" vehicle in the crash. If the other vehicle is MY 1981-97 and has a valid VIN, the vehicle type (car, light truck or heavy truck) is obtained by decoding the VIN. If it is pre-1981 or has a missing or nonvalid VIN, vehicle type is defined from the FARS variable BODY_TYP. "Heavy trucks" here comprise all highway vehicles with Gross Vehicle Weight over 10,000 pounds, including tractor-trailers, straight trucks, buses, heavy-duty pickup trucks, construction equipment, etc. "Light trucks" encompass pickup trucks, pickup cars (such as Chevrolet El Camino), vans and sport utility vehicles under 10,000 pounds Gross Vehicle Weight. Cases were deleted if the "other" vehicle was a motorcycle, small special vehicle, or of unknown body type. The "other" vehicle could have damage anywhere, not necessarily frontal.

The side impacts and the control group of purely frontal impacts were both limited to two-vehicle crashes with the same type of "other" vehicle. For example, in the regression where the other vehicle is a light truck "SIDE = 1" for a driver or RF passenger fatality in a case car that had side impact damage upon colliding with a light truck and "SIDE = 2" for a driver or RF passenger fatality in a case car that had purely frontal damage upon colliding with a light truck[5].

Table 6-3 shows there were 987 driver and RF passenger fatalities in cars with known TTI(d) that got hit in the side by another passenger car, 809 that got hit by a light truck, and 389 by a heavy truck. The TTI(d) coefficient for side impacts by another passenger car is a strong .01310. It is statistically significant at the .01 level (χ^2 = 7.51) and it is higher than the baseline (.00927) or the coefficient in fixed-object crashes (.01150). It is also higher than the coefficient for side impacts by light trucks (.00329) or heavy trucks (.00742), neither of which are statistically significant.

We might expect the largest effect for TTI(d) in nearside compartment impacts by a passenger car, since that is the impact location and striking vehicle simulated by the FMVSS 214 test. Table 6-3 confirms that expectation for 2-door pre-standard cars. The regression coefficient for TTI(d) is .01730, statistically significant at the .01 level (χ^2 = 8.26), and it is the highest coefficient for any analysis in this report.

A coefficient of .01730 corresponds to a substantial fatality reduction. The average TTI(d) in MY 1981-91 2-door cars was 110 (see Section 3.1), whereas the best score for a 2-door car prior to MY 1994 was 82 (see Table 3-2). If TTI(d) performance in pre-standard 2-door cars had improved from the average level (110) to the "best practices" level (82), the coefficient suggests a fatality reduction of $1 - (1 - .01730)^{110 - 82}$ = 39 percent. Effectiveness is estimated to be this high,

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[5]An alternative approach would have been to limit just the side impacts to a particular type of "other" vehicle but to allow the control group to include all purely frontal impacts by another vehicle of any type. The advantage of this approach is a larger control group, enhancing statistical significance. The disadvantage is a possibility of bias: if a particular make-model's drivers, say, are especially prone to colliding with heavy trucks, both laterally and frontally, the ratio of side impacts with heavy trucks to frontal impacts with anything would be high, inappropriately suggesting this make-model is a poor performer in side impacts - while the ratio of side impacts with heavy trucks to frontal impacts with heavy trucks would not be elevated. All of the analyses in Tables 6-3 and 6-4 were repeated with the alternative approach, and produced results that were essentially identical to those shown in the tables, using the selected approach.

however, only in nearside compartment impacts by another passenger car. According to Table 6-3, they constitute just 12 percent (494 out of 4,120) of the fatalities in side impacts of 2-door cars.

These patterns do not show up in the corresponding analyses of 4-door cars. Table 6-4 summarizes the regressions for 4-door cars weighing 1900-3299 pounds without air bags and with no ABS or less than 10 percent optional ABS. The "baseline" regression produced a near-zero coefficient of -.00047 for TTI(d). Regressions for the various subgroups produced a range of nonsignificant coefficients, ranging from -.00411 to +.00154. Chi-square never exceeds 0.85. The results in Table 6-4 do not favor impacts by another passenger car: the most positive findings are in impacts with fixed objects and light trucks, the most negative in impacts by heavy trucks and compartment impacts by a car; all coefficients, however, are not statistically significant.

6.3 Effect of TTI(d) by occupant age group

The strength of the relationship between TTI(d) and fatality risk in side impacts could vary depending on the age of the occupant. The issue can be addressed by statistical analysis of FARS data. The regressions of the ratio of side-impact to purely frontal fatalities by TTI(d) and various control variables can be run separately for younger occupants and older occupants. If the analyses consistently show a higher, more positive TTI(d) coefficient among the younger occupants, that result would suggest that younger people might benefit more from TTI(d) improvements than older people.

Table 6-5 compares the TTI(d) coefficients for occupants up to 45 years old, and for people age 46 or more. The upper half of Table 6-5 examines 2-door cars without air bags and with no ABS or less than 10 percent optional ABS. The first row of Table 6-5 is the usual baseline analysis encompassing occupants of all ages, yielding a TTI(d) coefficient of .00927. The next row limits the regression to people up to 45 years of age. In other words, "SIDE = 1" for a driver or RF passenger fatality up to 45 years old in a side impact and "SIDE = 2" for a driver or RF passenger fatality up to 45 years old in a purely frontal impact. In the 2-door cars, 3,464 of the 4,120 side impact fatalities were 45 years old or less. The coefficient for TTI(d) rises to .01080 and it is statistically significant at the .01 level (χ^2 = 14.78). But when the regression is limited to people 46 years old or more, the coefficient drops to .00494 and it is not statistically significant (χ^2 = .87). The effect for the younger occupants is more than double the observed effect for the older occupants.

In these regressions, the coefficients for the control variables AGE and AGE^2 are close to zero and not statistically significant, as might be expected: within each age group, there is a lot less difference than between the groups. The effects of the other control variables remain about the same as in the baseline regression.

The lower half of Table 6-5 presents corresponding regressions of 4-door cars weighing 1900-3299 pounds. Here, for the first time, the trend is in the same direction as in the 2-door cars. The

TABLE 6-4

4-DOOR CARS:
INFLUENCE OF THE VEHICLE/OBJECT CONTACTED ON THE COEFFICIENT OF TTI(d) IN THE LOGISTIC REGRESSION OF SIDE/PURE-FRONTAL FATALITIES
(front outboard occupants of 4-door cars weighing 1900-3299 pounds with no air bags and < 10% ABS)

Side impact with/by	**TTI(d) Regression Coefficient**	**N of Side Impact Fatals**	**Chi-Square**
Baseline (all side impact fatalities)	**- .00047**	5,781	.06
Fixed object	**+ .00154**	1,088	.21
Any other vehicle	**- .00133**	4,693	.44
Another passenger car	**- .00113**	1,679	.10
Light truck	**+ .00036**	1,653	.01
Heavy truck	**- .00340**	815	.48
Nearside compartment impact by a passenger car	**- .00411**	938	.85

No coefficient is statistically significant at the .05 level.

TABLE 6-5

INFLUENCE OF OCCUPANT AGE ON THE COEFFICIENT OF
TTI(d) IN THE LOGISTIC REGRESSION OF SIDE/PURE-FRONTAL FATALITIES
(front outboard occupants of cars with no air bags and < 10% ABS)

Occupant Age Group	**TTI(d) Regression Coefficient**	**N of Side Impact Fatals**	**Chi-Square**
2-DOOR CARS			
Baseline (all ages)	**+ .00927**	4,120	13.93**
Up to 45 years old	**+ .01080**	3,464	14.78**
46 or more years old	**+ .00494**	656	.87
4-DOOR CARS WEIGHING 1900-3299 POUNDS			
Baseline (all ages)	**- .00047**	5,781	.06
Up to 45 years old	**+ .00111**	2,834	.18
46 or more years old	**- .00289**	2,947	1.12

**TTI(d) coefficient is in the “right” direction and statistically significant at the .01 level.

"baseline" regression produced a near-zero coefficient of -.00047 for TTI(d). When the side impact and control group fatalities are limited to people 45 years old or less, the coefficient rises to a modest effect in the right direction, +.00111; it is not statistically significant. For people 46 years old or more, the coefficient worsens to -.00289; that, too, is not statistically significant.

In both the 2-door and the 4-door cars, the TTI(d) coefficient is more positive for the younger occupant.

Another key statistic in Table 6-5 is that in 4-door cars the majority of side impact fatalities are 46 years or older: 2,947 of 5,781. By contrast, in the 2-door cars, only 656 of 4,120 fatalities were 46 years or older. Thus, one factor that makes the overall results for 4-door cars less favorable than for 2-door cars is the prevalence of older occupants in the 4-door cars. If both groups had the same age distribution, the results would have been closer.

Nevertheless, it is important not to overstate the impact of occupant age. In the 2-door cars, even the analyses of older occupants generated positive TTI(d) coefficients, whereas in the 4-door cars, even the regressions for younger occupants only generated coefficients that were barely positive. Clearly, occupant age is not the only factor inducing divergent results for 2-door and 4-door cars. Moreover, when the occupant age distribution was further split up into class intervals (e.g., up to 35, 36-60, 61 or more), we did not get monotone trends of more negative TTI(d) coefficients with higher age, and we still did not get a statistically significant positive coefficient for the youngest age group in 4-door cars.

6.4 Belted vs. unrestrained occupants

Another issue in developing the FMVSS 214 test was whether to use belted or unrestrained Side Impact Dummies. NHTSA frankly thought it didn't make that much difference because they believed that an occupant or dummy's peak g's in a nearside compartment impact usually occur before the belt system tightens to fully restrain the occupant. The agency originally proposed an unrestrained test since it represented a worst-case scenario and it might help in evaluating the capability of the farside door to remain closed during the crash. The agency changed to belted dummies in its 1990 Final Rule, supported by most of the industry. The dramatic increase in belt use in the late 1980's had made belted occupants the norm and unrestrained the exception. This would make FMVSS 214, up to a point, a test of the belt system as well as the side structure in a side impact. Also, a belted dummy is less likely to become damaged during a test and, in that sense, would be more repeatable on subsequent tests[6].

There are actually two separate but interrelated issues here. The first is whether **belts** are effective in side impacts. Although that issue is outside the scope of this evaluation, it may be noted that the answer is definitely yes[7]. They are probably more effective in farside than in

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[6] *Ibid.*, pp. IIIA-64 - IIIA-65.

[7] Evans, L., *Traffic Safety and the Driver*, Van Nostrand Reinhold, New York, 1991, p. 233.

nearside impacts, and are least effective in a nearside compartment impact. The issue addressed here, however, is whether a reduction in **TTI(d)** would have different effects among belt users and nonusers. NHTSA's hypothesis is that the effects ought to be similar, but especially in nearside impacts, because the occupant's most severe contacts usually occur before the belt system tightens. In a farside impact, though, the unrestrained occupant is likely to obtain larger **absolute** benefits from a good side structure, since the belted occupant is already well protected and less likely to contact or be ejected through the side structure; it is not so clear, however, that the unrestrained occupant would also derive larger **relative** benefits (which is what the TTI(d) coefficient measures).

Table 6-6 presents the results of separate regressions for belted and for unrestrained occupants in all types of side impacts. If NHTSA's hypothesis is correct, there shouldn't be much difference in the TTI(d) coefficients.

The first row of Table 6-6 is the baseline analysis for 2-door cars, comprising FARS cases reported as unrestrained, belted, or with unknown belt use, yielding a TTI(d) coefficient of .00927. A "belted" occupant is defined here as MAN_REST = 1, 2, 3 or 8 or AUT_REST = 1 in 1980-90; REST_USE = 1, 2, 3 or 8 in 1991-98; also for passengers up to 5 years old, MAN_REST or REST_USE = 4. An "unrestrained" occupant is one with MAN_REST = 0 and AUT_REST $\neq$ 1 in 1980-90 or REST_USE = 0 in 1991-98. Other occupants have "unknown" belt use and are included only in the baseline regression. The next row of Table 6-6 limits the regression to unrestrained occupants. In other words, "SIDE = 1" for an unrestrained fatality in a side impact and "SIDE = 2" for an unrestrained fatality in a purely frontal impact. The control variables for this regression are the same as in the baseline, except that BELT is omitted because all cases have the value zero (unrestrained). The coefficient for TTI(d) is .00703 for the unrestrained occupants and it is statistically significant at the .05 level (χ^2 = 4.94). The coefficient for belted occupants is higher, .01200, and it too is statistically significant at the .05 level (χ^2 = 6.16).

The lower half of Table 6-6 displays corresponding results for 4-door cars. The TTI(d) coefficient among the unrestrained occupants is -.00076, while for belted occupants it is -.00249. Neither of these coefficients are statistically significant.

Thus, the results of two comparisons of the TTI(d) effect between unrestrained and belted occupants show: one more positive for the belted, the other slightly more negative for the belted. As hypothesized by NHTSA, there is little trend in either direction.

If the side impact cases are subdivided four ways - nearside vs. farside and belted vs. unrestrained - the number of cases in each regression is generally too small to produce statistically significant TTI(d) coefficients. However, in nearside impacts, the TTI(d) coefficients observed for belted occupants are almost the same as those observed for unrestrained occupants, both in 2-door and

TABLE 6-6

INFLUENCE OF BELT USE ON THE COEFFICIENT OF
TTI(d) IN THE LOGISTIC REGRESSION OF SIDE/PURE-FRONTAL FATALITIES
(front outboard occupants of cars with no air bags and < 10% ABS)

Occupant Belt Use	**TTI(d) Regression Coefficient**	**N of Side Impact Fatals**	**Chi-Square**
	2-DOOR CARS		
Baseline (unrestrained+belted+unk.)	**+ .00927**	4,120	13.93**
Unrestrained	**+ .00703**	2,370	4.94*
Belted	**+ .01200**	1,251	6.16*
	4-DOOR CARS WEIGHING 1900-3299 POUNDS		
Baseline (unrestrained+belted+unk.)	**- .00047**	5,781	.06
Unrestrained	**- .00076**	2,710	.09
Belted	**- .00249**	2,384	.54

*TTI(d) coefficient is in the “right” direction and statistically significant at the .05 level.

**TTI(d) coefficient is in the “right” direction and statistically significant at the .01 level.

in 4-door cars. In farside impacts of 2-door cars, on the other hand, the observed TTI(d) coefficient is higher for belted than unrestrained occupants. That is not the expected result; however, it is based on a sample of just 386 belted farside fatalities.

6.5 Ejected vs. nonejected occupants

FMVSS 214 includes a requirement that the doors remain closed during the crash test. NHTSA projected that it would reduce occupant ejections in side impact crashes[8]. However, this requirement is separate from and additional to the measurement of TTI(d) in the test, and NHTSA did not claim that a good TTI(d) score *per se* ought to be associated with a low rate of occupant ejection. On the other hand, experience with the side door beams installed in response to the original 1973 version of FMVSS 214 showed that cars equipped with the beams had substantially reduced rates of occupant ejection and fewer door openings and door latch or hinge damage in side impacts[9]. In view of that finding, it is not impossible that good TTI(d) scores - to the extent they are evidence of crashworthy side structures - could be associated with reduced rates of fatalities involving occupant ejection. Nevertheless, we would expect most of the TTI(d) effect in the nonejection fatalities, since they are far more likely to involve occupant contacts with the interior side structure as modeled in the FMVSS 214 test.

Table 6-7 compares the TTI(d) coefficients for ejected side-impact fatalities, and nonejected fatalities. The upper half addresses 2-door cars without air bags and with no ABS or less than 10 percent optional ABS. The baseline analysis encompasses all side-impact fatalities and uses all purely frontal fatalities as the control group, yielding a TTI(d) coefficient of .00927. In the analysis of ejected fatalities, "SIDE = 1" for a driver or RF passenger fatality who was totally or partially ejected in a side impact. However, the control group fatalities are not limited to ejectees in frontal crashes because so few people are ejected in frontals. Instead the control group consists of nonejected as well as ejected purely frontal fatalities, but since the side impact ejectees are almost all unrestrained, the control group will be limited to unrestrained purely frontal fatalities. The coefficient for TTI(d) drops to .00482 and it is not statistically significant.

The third row of Table 6-7 presents a regression of nonejection side impact fatalities, with all purely frontal fatalities as the control group. The coefficient for TTI(d) rises to .01110 and it is statistically significant at the .01 level ($\chi^2 = 16.88$). That's the highest value of χ^2 for any TTI(d) coefficient in this report. The results suggest that most of the TTI(d) effect in 2-door cars is on the nonejection fatalities, as it should be, but that there might also be a modest effect in the right direction for ejectees. Analyses of 4-door cars are summarized in the lower section of Table 6-7. The TTI(d) coefficient for ejectees is positive, +.00332, but it is not statistically significant. The observed effect for nonejectees is a nonsignificant -.00157. Thus, the results for ejectees are quite similar in 2-door and 4-door cars, whereas the findings for nonejectees show the same contrast between 2-door and 4-door cars as most of the other results in this report.

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[8]*Final Regulatory Impact Analysis*, p. IV-40.

[9]Kahane (1982), pp. 319-327.

TABLE 6-7

INFLUENCE OF OCCUPANT EJECTION ON THE COEFFICIENT OF
TTI(d) IN THE LOGISTIC REGRESSION OF SIDE/PURE-FRONTAL FATALITIES
(front outboard occupants of cars with no air bags and < 10% ABS)

Side Impact Fatals	**Control Group: Purely Frontal Fatals**	**TTI(d) Regression Coefficient**	**N of Side Impact Fatals**	**Chi-Square**
2-DOOR CARS				
Baseline (all side impact fatals)	All fatals	**+ .00927**	4,120	13.93**
Ejected fatals	All unrestrained fatals	**+ .00482**	791	1.02
Nonejected fatals	All fatals	**+ .01110**	3,119	16.88**
4-DOOR CARS WEIGHING 1900-3299 POUNDS				
Baseline (all side impact fatals)	All fatals	**- .00047**	5,781	.06
Ejected fatals	All unrestrained fatals	**+ .00332**	460	.50
Nonejected fatals	All fatals	**- .00157**	5,166	.64

**TTI(d) coefficient is in the “right” direction and statistically significant at the .01 level.

6.6 Drivers vs. right-front passengers

The FMVSS 214 requirements are identical for the left and the right side of a car[10]. Compliance tests are sometimes performed on the left side, at other times on the right. Side structures on the left and right of a car are generally identical or very similar. The steering assembly - present on the left and absent on the right compartment areas - has not been considered a factor in test performance. This report has assumed so far that TTI(d) results are applicable to both the driver and the right front (RF) passenger, no matter what side of the car was actually tested. That assumption can be empirically tested by calibrating the relationship between TTI(d) and fatality risk separately for drivers and RF passengers. If the TTI(d) coefficients are substantially different, it could be a sign that drivers' test results do not necessarily apply to RF passengers, or at least that the distribution of occupants (age, gender) or impact types is so different on the left and right that it impinges on the TTI(d)-fatality risk relationship.

Table 6-8 calibrates TTI(d) coefficients separately for drivers and RF passengers. In 2-door cars, the baseline analysis combining drivers and RF passengers yields a TTI(d) coefficient of .00927. When the analysis is limited to the 2,859 side impact fatalities who were drivers, and the 3,081 purely frontal fatalities who were drivers, the coefficient for TTI(d) rises very slightly to .00955. It is statistically significant at the .01 level ($\chi^2 = 11.21$). The RF sample size is smaller because the RF seat is often unoccupied. For the 1,261 RF side impact fatalities and 966 purely frontal RF fatalities, the regression produces essentially the same TTI(d) coefficient, .00845, although it is not statistically significant ($\chi^2 = 2.82$), in view of the smaller sample size.

In 4-door cars, the combined analysis generated a coefficient of -.00047 for TTI(d). Separate analyses produced quite similar TTI(d) coefficients of -.00038 for drivers and -.00106 for RF passengers. None of these are statistically significant.

The similarity of the TTI(d) coefficients for drivers and RF passengers in both 2-door and 4-door cars empirically supports our hypothesis that driver and RF tests are essentially interchangeable.

Although drivers and RF passengers had similar TTI(d) coefficients, the control variables AGE, AGE*AGE and FEMALE had stronger coefficients for drivers than RF passengers: while driver age and gender have strong relationships with crash involvement risk as well as survivability, RF age and gender have no direct relationship with crash involvement risk, only with survivability.

6.7 Analysis of SID pelvic g's in place of or in addition to TTI(d)

TTI(d) is not the only parameter measured on the FMVSS 214 test. The peak lateral acceleration is measured on the Side Impact Dummy (SID) and it is not allowed to exceed 130 g's[11].

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[10] *Code of Federal Regulations*, Title 49, General Printing Office, Washington, 1997, Part 571.214.S3.

[11] *Ibid.*, Part 571.214.S5.2.

TABLE 6-8

INFLUENCE OF OCCUPANT SEAT POSITION ON THE COEFFICIENT OF
TTI(d) IN THE LOGISTIC REGRESSION OF SIDE/PURE-FRONTAL FATALITIES
(front outboard occupants of cars with no air bags and < 10% ABS)

Side Impact Fatals	**Control Group: Purely Frontal Fatals**	**TTI(d) Regression Coefficient**	**N of Side Impact Fatals**	**Chi-Square**
		2-DOOR CARS		
Baseline (all side impact fatals)	All fatals	**+ .00927**	4,120	13.93**
Drivers	Drivers	**+ .00955**	2,859	11.22**
RF passengers	RF passengers	**+ .00845**	1,261	2.82
		4-DOOR CARS WEIGHING 1900-3299 POUNDS		
Baseline (all side impact fatals)	All fatals	**- .00047**	5,781	.06
Drivers	Drivers	**- .00038**	4,132	.03
RF passengers	RF passengers	**- .00106**	1,649	.08

**TTI(d) coefficient is in the “right” direction and statistically significant at the .01 level.

However, NHTSA's *Final Regulatory Impact Analysis* for FMVSS 214 does not project any life savings as a consequence of improved SID pelvic g scores: it only claims a reduction in nonfatal fractures of the pelvis[12]. If so, and if the analyses of Chapters 5 and 6 were to be rerun with SID pelvic g's as the injury criterion instead of TTI(d), we would ideally expect no association between SID pelvic g's and fatality risk in actual side impacts. If the analyses were rerun with SID pelvic g's in addition to TTI(d), we would ideally expect the TTI(d) coefficient to stay unchanged and the SID pelvic g's coefficient to be close to zero.

In regression analyses, however, the results do not always affirm ideal expectations. When two independent variables are quite correlated with each other, the regression may confuse which is which. If only the "wrong" variable (SID pelvic g's) is entered, the regression may see it as a surrogate for the "right" one (TTI(d)) and attribute the right variable's effect to the wrong one. If both variables are entered, the regression sometimes will assign a large positive coefficient to the one and a large negative coefficient to the other, neither of which should be interpreted at face value as the true impact of each factor.

SID pelvic g's and TTI(d) are, in fact, rather correlated with one another. Figure 6-1 graphs the average SID pelvic g's for 2-door and 4-door cars by model year from 1981 through 1996. These are sales-weighted averages, based on the FMVSS 214 test vehicles and all of their "twins," computed by the same procedure that was used for TTI(d) in Figure 3-3. The SID pelvic g averages decreased from about 160 to 80 in 2-door cars and 110 to 80 in 4-door cars, with most of the improvement coming just before or during the FMVSS 214 phase-in period:

2-DOOR CARS

1981	165	1985	150	1989	128	1993	128
1982	172	1986	147	1990	132	1994	107
1983	170	1987	147	1991	130	1995	91
1984	161	1988	131	1992	123	1996	82

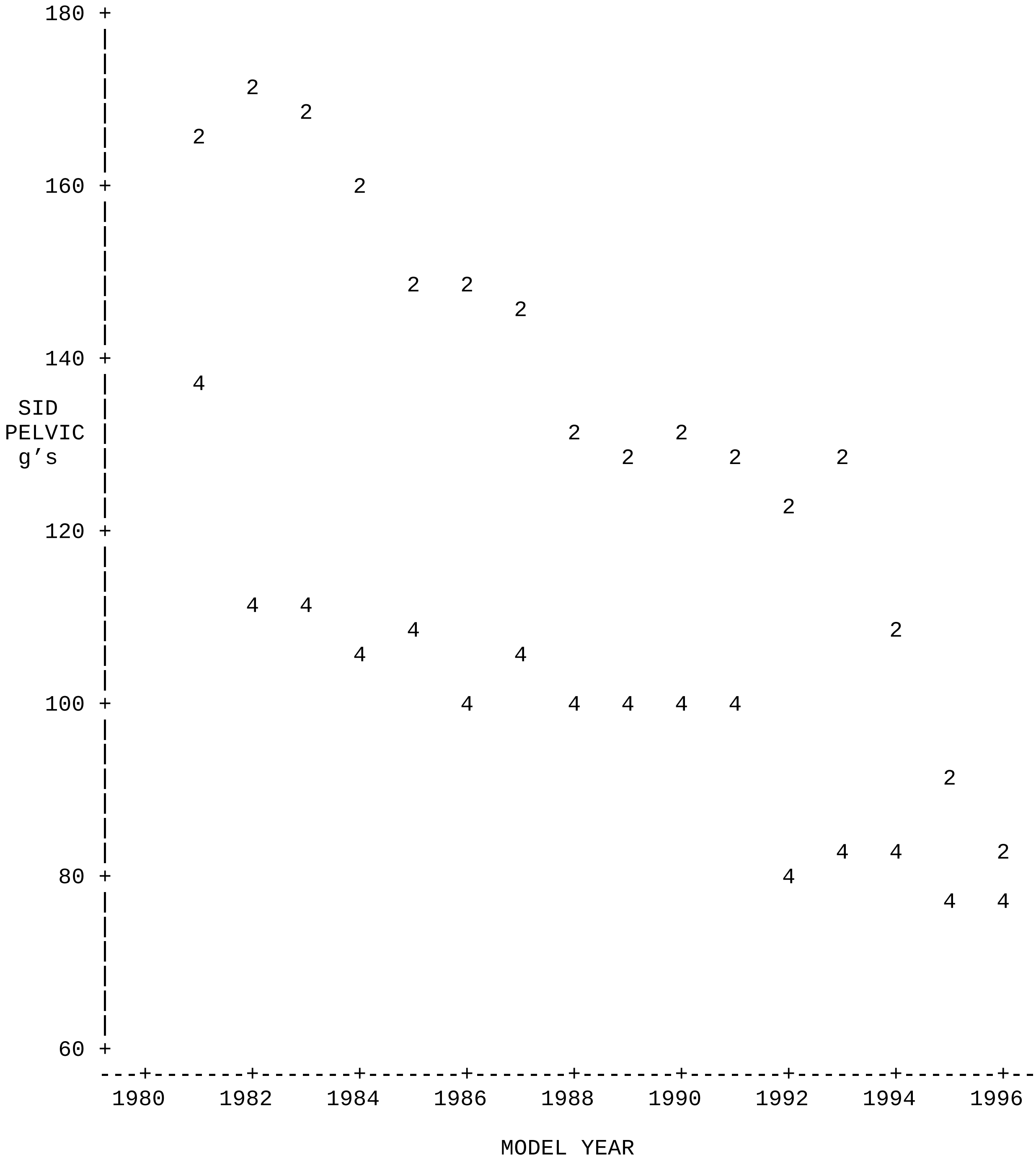
4-DOOR CARS

1981	137	1985	110	1989	101	1993	84
1982	112	1986	100	1990	101	1994	82
1983	112	1987	104	1991	100	1995	78
1984	106	1988	99	1992	81	1996	77

Figure 6-1 shows quite similar trends for SID pelvic g's as Figure 3-3 showed for TTI(d): (1) a dramatic reduction in SID pelvic g's after FMVSS 214 was phased in; (2) substantially worse scores for pre-standard 2-door cars than pre-standard 4-door cars; (3) the gap between 2-door

[12]*Final Regulatory Impact Analysis*, pp. IV-36 - IV-39.

FIGURE 6-1: AVERAGE SID PELVIC g's BY MODEL YEAR, 2-DOOR VS. 4-DOOR
(passenger cars with known SID pelvic g's; weighted by sales)



and 4-door cars was narrowed or even eliminated with FMVSS 214. Those similarities create an initial impression that SID pelvic g's and TTI(d) are, empirically, almost interchangeable parameters.

Figures 3-3 and 6-1, however, are based on model year **averages**. The extent of intercorrelation between the parameters is better understood by studying **individual** scores. Figure 6-2 is a scatterplot of SID pelvic g's by TTI(d) for 40 individual 2-door cars that were FMVSS 214-tested. In general, the cars with low TTI(d) have low SID pelvic g's (many of these are post-standard cars) and the few cars with very high TTI(d) have high SID pelvic g's, but in the middle range of TTI(d) the SID pelvic g's can be almost anything: positive but far from perfect correlation. Indeed, when the data points in Figure 6-2 are sales-weighted (after including all of their "twins"), the correlation between TTI(d) and SID pelvic g's is .549, statistically significant at the .01 level, yet low enough we can run regressions with these independent variables and be fairly confident that their effects will not be confused.

Figure 6-3 is the corresponding scatterplot for 72 4-door cars. It shows a somewhat higher correlation than Figure 6-2 - i.e., the points are generally closer to the diagonal. In fact, the sales-weighted correlation coefficient is .809. That is already high enough to raise concern that regressions could sometimes confuse the effects of the two variables, especially if neither of them is strongly correlated with the dependent variable.

Table 6-9 displays the regression coefficients obtained when the main regression - for 2-door cars with no air bags and with no ABS or less than 10 percent optional ABS - is run with just TTI(d) as an injury criterion parameter, with just SID pelvic g's, or with both. The control variables are the same in all cases. The usual baseline regression, with just TTI(d), yields a coefficient of .00927 for TTI(d), in the "right" direction and statistically significant at the .01 level (χ^2 = 13.93). When SID pelvic g's are substituted for TTI(d) as the only injury criterion, the regression coefficient drops to a weak .00066 and loses all statistical significance (χ^2 = .33). When both parameters are entered in the same analysis, the regression makes a clear choice between them: it gives TTI(d) a coefficient of .00926, nearly identical to baseline, statistically significant at the .01 level (χ^2 = 13.61), while attributing little or nothing to SID pelvic g's, giving them a coefficient of just .00004.

These findings are strongly consistent with NHTSA's position that TTI(d), not SID pelvic g's, is the key determinant of fatality risk in side impacts. It is especially reassuring that the regression utterly dismisses SID pelvic g's when they are offered as *Ersatz* for TTI(d), even though the two parameters have superficially similar trends. It does much to refute the argument that "the cars with low TTI(d) are just generally safer cars, and that's why they have relatively low side impact fatality rates, and you would have gotten the same result if you had put in any other parameter that generally correlates with being a good, safe car."

As usual, the corresponding analyses of 4-door cars yield unclear findings. The lower section of Table 6-9 shows that the baseline coefficient in the regression with just TTI(d) was a near-zero -.00047. When SID pelvic g's are substituted for TTI(d), the coefficient improves to a still near-zero, but now positive +.00069. (Many of the FARS cases in the baseline regression cannot be

FIGURE 6-2: 2-DOOR CARS - SID PELVIC g's BY TTI(d)
(individual FMVSS 214 test vehicles)

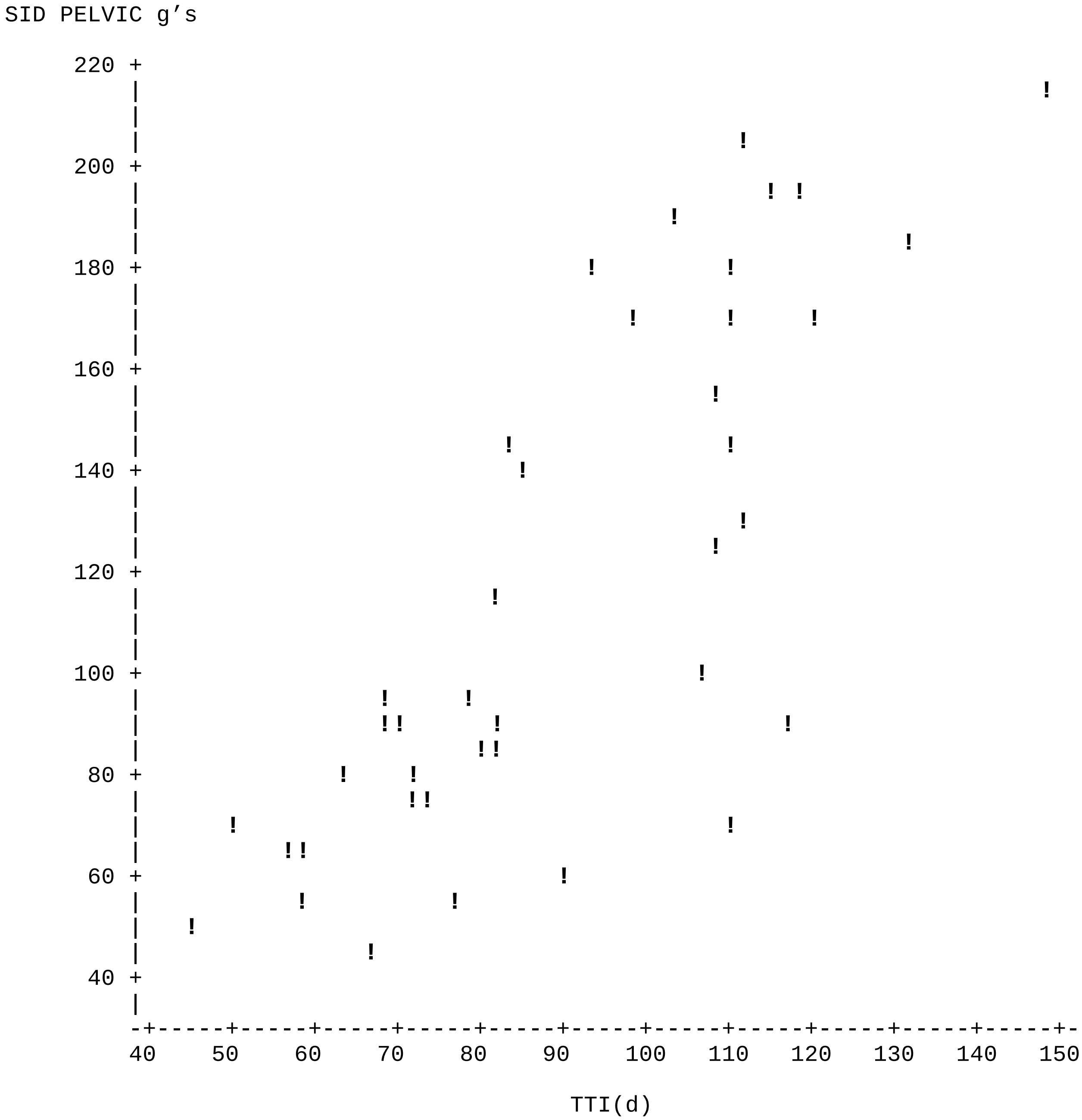


FIGURE 6-3: 4-DOOR CARS - SID PELVIC g’s BY TTI(d)
(individual FMVSS 214 test vehicles)

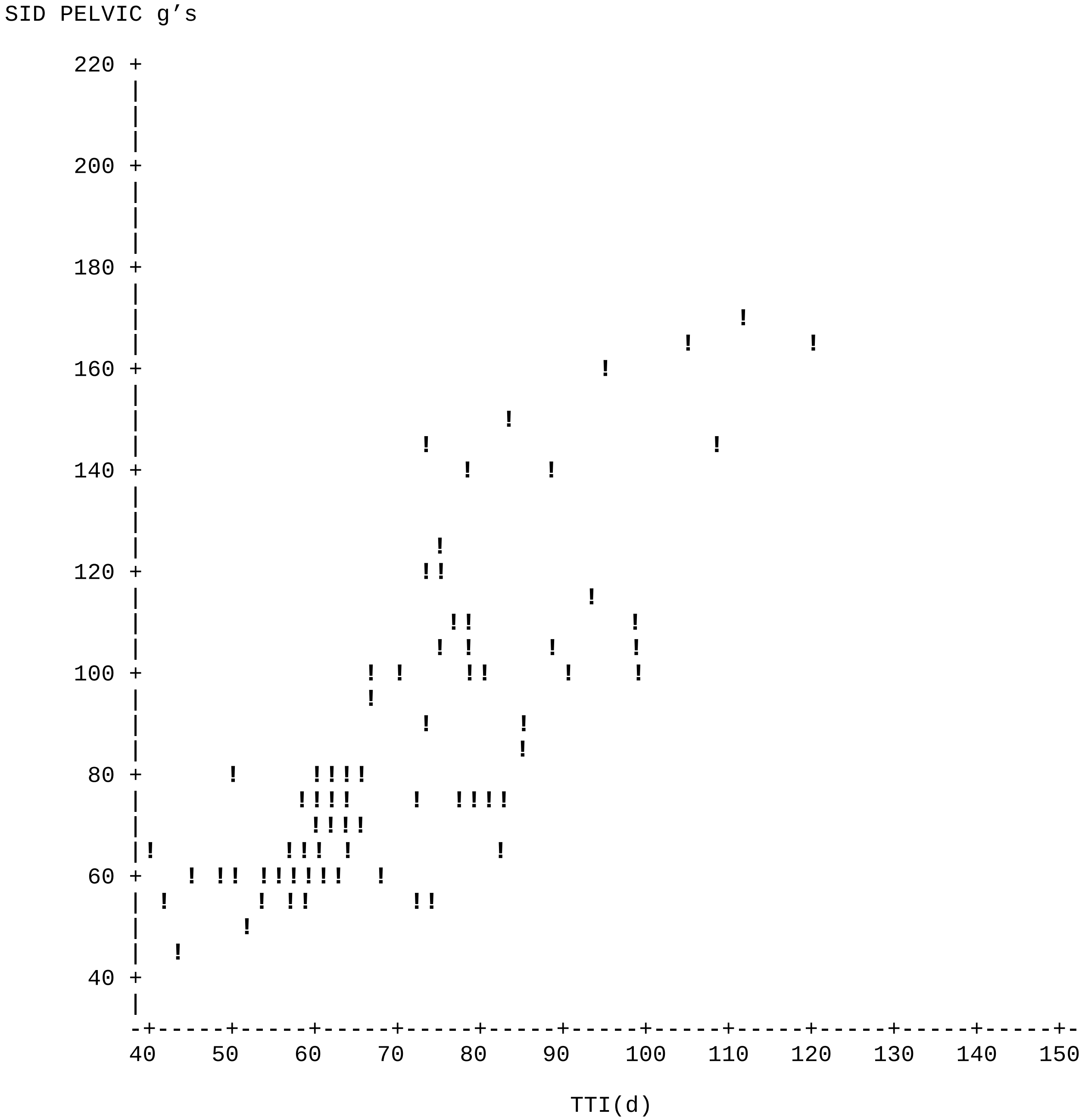


TABLE 6-9

COMPARISON OF THE EFFECTS OF TTI(d) AND SID PELVIC g's
IN LOGISTIC REGRESSIONS OF SIDE/PURE-FRONTAL FATALITIES
(front outboard occupants of cars with no air bags and < 10% ABS)

SID Injury Parameter	**Regression Coefficient**	**N of Side Impact Fatals**	**Chi-Square**
	2-DOOR CARS		
TTI(d) only (baseline regression)	**+ .00927**	4,120	13.93**
Pelvic g's only	**+ .00066**	4,120	.33
TTI(d)	**+ .00926**	4,120	13.61**
Pelvic g's	**+ .00004**		.001
	4-DOOR CARS WEIGHING 1900-3299 POUNDS		
TTI(d) only (baseline regression)	**- .00047**	5,781	.06
Pelvic g's only	**+ .00069**	4,264	1.18
TTI(d)	**- .00376**	4,264	1.82
Pelvic g's	**+ .00157**		2.97

**TTI(d) coefficient is in the "right" direction and statistically significant at the .01 level.

No pelvic g's coefficient is statistically significant at the .05 level.

used here, since certain key FMVSS 214 tests of cars with high sales volumes had missing data on pelvic g's.) When both parameters are entered, the TTI(d) coefficient deteriorates to -.00376 while the SID pelvic g's coefficient improves to +.00157. That may indicate the regression is confusing two intercorrelated parameters, intensifying the coefficients and giving them opposite signs; it is hard to say for sure because neither is statistically significant.

6.8 Analysis of back-seat occupant TTI(d)

In the FMVSS 214 test, TTI(d) is computed for the SID in the back seat by the same procedure as for the front-seat dummy. The results are not absolutely comparable because the test impact is concentrated on the front compartment, resulting in the front-seat dummy being exposed to a more severe hit. In relative terms, however, NHTSA expected a TTI(d) reduction for the front or back-seat occupant to result in the same percentage reduction of thoracic injuries due to occupant contact with side structures[13]. Figure 6-4 shows patterns in the sales-weighted average of back-seat TTI(d), by model year, that are essentially the same as for front-seat TTI(d) (Figure 3-3) and, for that matter, front-seat SID pelvic g's (Figure 6-1). Back-seat TTI declined from about 105 in1981-88 to 65 in 1996 in 2-door cars, and from 80 in 1981-88 to 66 in 1996 in 4-door cars, with most of the improvements coming during the 1994-96 phase-in of FMVSS 214. Regressions of back-seat occupants' fatality risk in side impacts by back-seat TTI(d), set up the same way as the preceding analyses of front-seat occupants, might be expected to show similar coefficients for TTI(d).

It is, however, not possible to perform statistically meaningful analyses of back-seat occupants cases at this time because the occupancy and fatality rates in the back seat are so much lower than for drivers and RF passengers. Whereas 4,120 driver and RF passenger fatality cases in side impacts were available for the analyses of 2-door cars, and 5,781 in 4-door cars, there are only 392 side-impact fatality cases of rear-outboard occupants of 2-door cars and 627 in 4-door cars: about one-tenth the sample size. The regression coefficient for rear-seat TTI(d) is not statistically significant in either 2-door or 4-door cars.

6.9 Weighted least-squares regressions of aggregate data

All the regression analyses to this point use disaggregate logistic regression. Section 5.1 presented a caveat that the data do not correspond exactly to the classic "dose-response" model of logistic regression, in which test subjects are "successes" or "failures." Section 5.1 also promised that the data would also be analyzed by a weighted, aggregate least-squares linear regression model to check if it supported the same conclusions as the logistic regressions.

The strategy is to subdivide the fatality cases into cells, based on their values of TTI(d), age, gender, etc. Each cell contains a number of fatality cases, some of them side impacts, some pure frontals. It is possible to compute log(side fatalities/purely frontal fatalities) in each cell: e.g., if a

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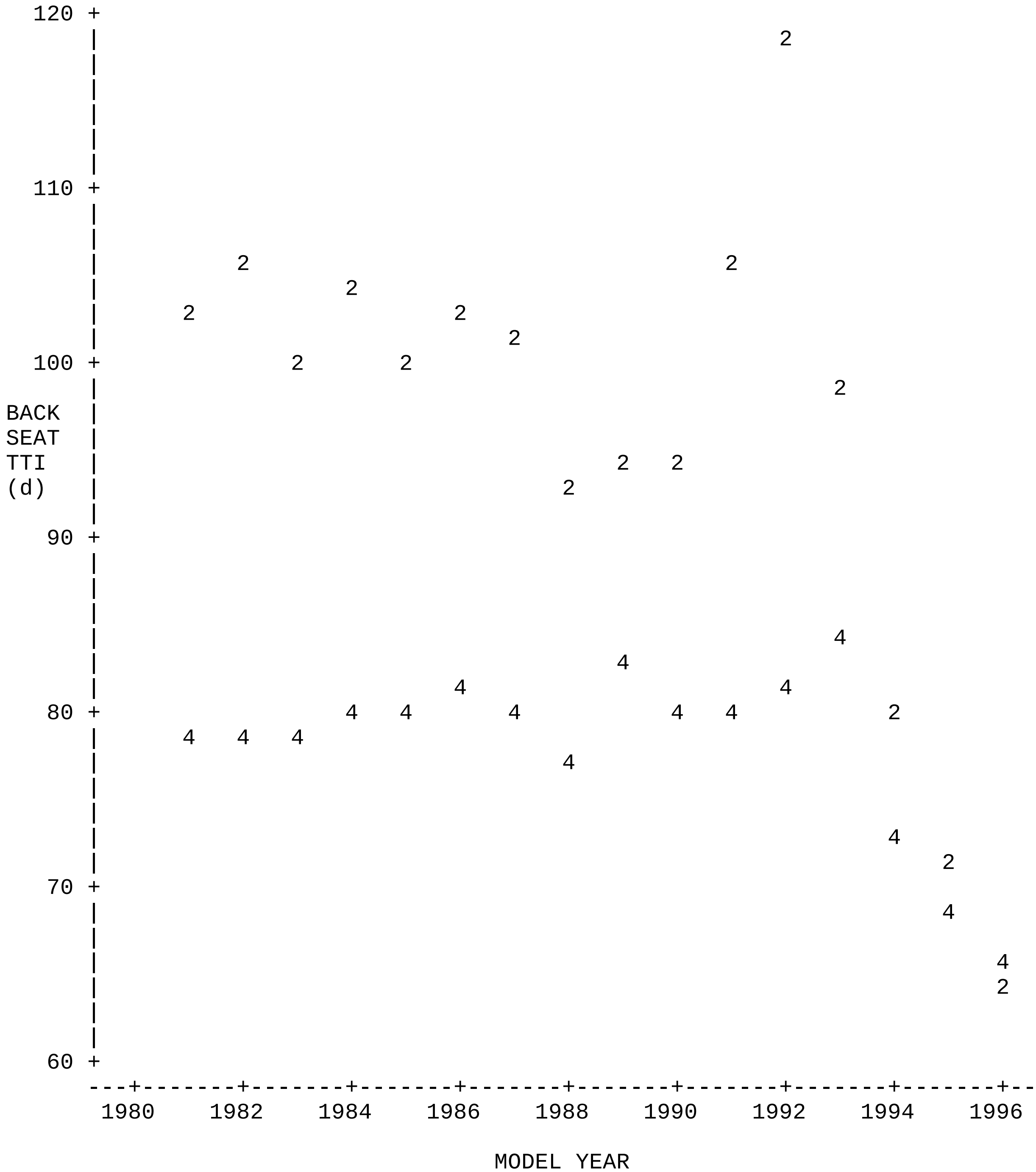
[13] *Ibid*., pp. IV-26 - IV-35.

FIGURE 6-4: AVERAGE BACK-SEAT TTI(d) BY MODEL YEAR, 2-DOOR VS. 4-DOOR
(passenger cars with known rear seat TTI(d); weighted by sales)



cell contains 20 cases, 12 side impacts and 8 pure frontals, log(12/8) = .405. In the regression, each cell is a data point, the value of log(side/frontal) for that cell is the dependent variable, the N of fatality cases in that cell is the weight factor, and the independent variables are the averages of TTI(d), age, etc. for that cell. The General Linear Model (GLM) procedure of the Statistical Analysis System (SAS) performs a weighted least-squares regression on those data points[14].

The strategy for defining cells is to group each of the independent variables into a limited number of separate values or ranges of values. Dichotomous variables such as FEMALE or BELTED already have just two possible values. Continuous variables such as TTI(d), occupant age, or vehicle weight, however, need to be subdivided into class intervals (ranges). It is desirable to include every independent variable that had a statistically significant coefficient in the preceding regressions, but since each different combination of the independent variables potentially defines a separate cell, we have to be careful not to define more cells than the data will allow.

The independent variables with statistically significant coefficients in the regressions of Sections 5.2 (2-door cars) and 5.3 (4-door cars weighing 1900-3299 pounds) were TTI(d), CURBWT, occupant age (AGE and AGE*AGE), gender (FEMALE), belt use (BELT) and seat position (RFPASS). Vehicle age (VEHAGE and BRANDNEW) was never significant and can be omitted here.

An immediate problem is that RF passenger fatalities are outnumbered by driver fatalities by nearly 3 to 1. If the relatively small number of RF passenger cases were subdivided into cells by all the other independent variables, it would lead to an impractical number of sparse cells. It is better to limit the aggregate regressions to **drivers only**, where substantial numbers of crash cases are available to fill the cells. The strategy will be to mimic the two driver-only logistic analyses documented in Section 6.6 and Table 6-8, one on 2-door cars and the other on 4-door cars weighing 1900-3299 pounds.

It is up to the analyst to choose the number of class intervals, and their boundaries, for each independent variable; the tradeoffs are to have enough intervals to make the variable "feel" continuous, but not to create too many sparse cells. The more intuitively important the variable, the more class intervals it ought to have. The specific class intervals or discrete values of the independent variables will be:

TTI(d): 61-72.49, 72.5-77.49, 77.5-82.49, 82.5-87.49, 87.5-92.49, 92.5-97.49, 97.5-102.49, 102.5-107.49, 107.5-112.49, 112.5-117.49, 117.5-127.49, 127.5-133 (12 class intervals)

Driver age: 16-20, 21-30, 31-40, 41-50, 51-60, 61-70, 71-80, 81-97 (8 class intervals)

Curb weight: 1500-2399, 2400-2799, 2800-3299 (3 class intervals)

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[14] *SAS/STAT® User's Guide, Version 6, Fourth Edition*, Volume 2, SAS Institute, Cary, NC, 1989, pp. 891-996.

Gender: 1 = female, 0 = not female (2 values)

Belt use: 1 = belted, 0 = not belted or unknown if belted (2 values)

At first glance, there could be 1152 = 12x8x3x2x2 cells. However, some of the cells cannot exist (e.g., there are no pre-FMVSS 2-door cars with TTI(d) 61-72.49 or 72.5-77.49 and no 4-door cars with TTI(d) 127.5-133). Others are empty because there do not happen to be any fatality cases on FARS with that combination of the TTI(d), age, curb weight, gender and belt use, although such cases could theoretically have happened. With these FARS data, there are actually 363 cells with data in them for 2-door cars. Since the FARS data include 5,835 driver fatality cases for 2-door cars (side + purely frontal impacts), that is an average of 16 cases per cell. With 4-door cars, there are 536 cells containing 8,996 cases, an average of nearly 17 per cell. Both exceed the density of 10 expected cases per cell that is considered desirable for running multidimensional contingency table analyses[15].

Nevertheless, 92 of the 363 cells among the 2-door cars have only side impact fatalities and zero frontals, or only frontals and zero side impacts. Here, log(side/frontal) cannot be directly computed. It is necessary to change each zero to some small positive number in order to compute a logarithm: specifically to 0.4, the largest number to one decimal place that rounds down to zero. Similarly, 87 of the 536 cells of 4-door cars have zero frontals or zero side impacts, and those zeros are changed to 0.4.

The 363 cells for the 2-door cars each contribute a data point to a weighted least-squares regression, with log(side/frontal) for that cell as the dependent variable, the cell-average values of TTI(d), AGE, AGE*AGE and CURBWT as well as the values of FEMALE and BELT as independent variables, the N of fatality cases (side + frontal, but not counting any added 0.4) as the case weight. This regression had an R-squared of .178 and an overall F-value of 12.84 (6 model df, 356 error df, p < .0001) indicating a rather good fit with the data. **Every** regression coefficient was statistically significant, as indicated by t-values over 2:

Parameter	Estimate	t for H0: Parameter=0	Pr > |t|	Std Error of Estimate
INTERCEPT	-1.234797128	-2.81	0.0052	0.43951979
TTI(d)	**0.011207780**	**3.53**	**0.0005**	**0.00317789**
CURBWT	0.000268578	3.91	0.0001	0.00006871
AGE	-0.043972093	-4.90	0.0001	0.00896961
AGE*AGE	0.000423811	4.31	0.0001	0.00009831
FEMALE	0.170780051	2.70	0.0072	0.06315480
BELT	0.279104800	4.18	0.0001	0.06676169

[15]Dixon, W.J., ed., *BMDP Statistical Software, 1983 Printing with Additions*, University of California Press, Berkeley, 1983, p. 160 would recommend at least 5 side-impact and 5 frontal cases, or a total of at least 10 per cell.

In particular, the regression calibrates a coefficient of +.01121 for TTI(d), in the "right" direction and statistically significant at the 0.1 level ($t = 3.53$, $p < .0005$). This is quite close to the +.00955 coefficient obtained in the logistic regression for drivers of 2-door cars (see Section 6.6 and Table 6-8). Furthermore, the t-value is 3.53 and its square is 12.46, and that is quite close to the $\chi^2 = 11.22$ for the logistic regression (since the error df are as high as 356, t squared is essentially equivalent to χ^2). Indeed, the regression coefficients for **all** of the variables, and their values of t squared are remarkably similar to the corresponding coefficients in the logistic regression, and their χ^2 values:

Drivers of 2-door cars

	Least-Squares Regression		Logistic Regression	
	Coeff.	t squared	Coeff.	χ^2
TTI(d)	.01121	12.46	.00955	11.22
CURBWT	.000269	15.29	.000282	24.41
AGE	- .0440	24.01	- .0384	25.80
AGE*AGE	.000424	18.58	.000382	18.94
FEMALE	.1708	7.29	.1509	7.30
BELT	.2791	17.47	.2502	17.82

This is reassuring evidence that the logistic and the least-squares model calibrate the data essentially the same way, and give essentially the same statistical power to their calibrations.

The regression for 4-door cars weighing 1900-3299 pounds was based on 536 cells. It had an R-squared of .312 and an overall F-value of 40.05 (6 model df, 529 error df, $p < .0001$) indicating a excellent fit with the data. The regression coefficients were:

Parameter	Estimate	t for H0: Parameter=0	Pr > |t|	Std Error of Estimate
INTERCEPT	0.4590977940	1.18	0.2395	0.38987650
TTI(d)	**-.0007729316**	**-0.32**	**0.7478**	**0.00240212**
CURBWT	0.0000403952	0.49	0.6277	0.00008326
AGE	-.0548272992	-8.64	0.0001	0.00634905
AGE*AGE	0.0006147943	9.86	0.0001	0.00006237
FEMALE	0.3343672449	6.97	0.0001	0.04796702
BELT	0.2959926714	5.95	0.0001	0.04973632

The coefficient for TTI(d), -.00077, is near-zero and it is not statistically significant ($t = -.32$). It is essentially equivalent to the near-zero coefficient obtained in the logistic regression for drivers of 4-door cars, -.00038. Again, the regression coefficients for all of the variables, and their values of t squared are remarkably similar to the corresponding coefficients in the logistic regression, and their χ^2 values:

4-door cars weighing 1900-3299 pounds

	Least-Squares Regression		Logistic Regression	
	Coeff.	t squared	Coeff.	χ^2
TTI(d)	- .00077	.10	- .00038	.03
CURBWT	.000040	.24	.000015	.04
AGE	- .0548	74.65	- .0520	87.56
AGE*AGE	.000615	97.22	.000583	113.24
FEMALE	.3344	48.58	.3164	52.33
BELT	.2960	35.40	.2855	39.92

In these two analyses, least-squares and logistic regression were basically interchangeable models that produced similar findings and gave them about the same level of statistical significance. But the least-squares method already encounters a problem with sparse cells, even under these most favorable circumstances: regressions on drivers only, in all types of side impacts. The method cannot be applied to a combination of drivers and RF passengers, or for any subgroup of side impacts such as nearside, compartment-centered, etc., without an unacceptable number of sparse cells - or by omitting independent variables that ought not be omitted. Thus, logistic regression is the method of choice for the detailed analyses of this report.

CHAPTER 7

SIDE IMPACT FATALITIES PER 1,000,000 REGISTRATION YEARS BY TTI(d)

The simplest way to analyze the data is to compute fatalities in side impact crashes per 1,000,000 car registration years and to study relationships of the fatality rates with TTI(d). It is not a good strategy, because there are so many factors besides TTI(d) that cause fatality rates per year to vary from one make-model to another - e.g., annual mileage, driver age and gender, vehicle mass - yet many of these factors cannot be easily controlled because registration data do not specify the age and gender of the driver, etc. Still, why not try it? Two analyses of registration-based fatality rates in Phase 1, pre-FMVSS 214 cars are attempted here: a study of the rates in the specific make-models that were baseline-tested, and a regression of fatality rates per million years. The results parallel the findings of Chapters 3 and 5, although they are statistically weaker in addition to being intuitively less convincing.

7.1 Side impact fatality rates in individual FMVSS 214 test make-models

Vehicle registration years are a well-understood measure of exposure. R. L. Polk's *National Vehicle Population Profile*[1] enables highly accurate estimation of vehicle years, by make-model, model year, body style and calendar year. Section 2.3 described the creation of a file of FARS cases of make-model-year-body style combinations that had been FMVSS 214-tested, plus their "twins" (cars of identical or nearly identical design that presumably would have experienced the same test results). In order to compute fatality rates per 1,000,000 vehicle years, it is necessary to translate Polk codes into the make-model and body-style codes on the crash data file. There has to be exact correspondence between the files: any vehicle excluded from the crash data has to be excluded from the registration data. Any vehicle included in the crash data has to have an equivalent on the Polk file.

National Vehicle Population Profile data were accessed in the calendar years (1981-97) and model years (1981-96) that are on the crash file. Polk identifies passenger cars by their make (MAKE_ABR), model year, model-subseries (SERS_ABR) and body style (STYL_ABR). Software written for NHTSA's evaluation of vehicle size and safety[2], and extended to model years 1981-97 for this study maps each combination of these Polk codes to a unique combination of the VIN-based codes on the crash file: car group (CG), make-model (MM2) and body type (BOD2).

With one exception, it is possible to set up a rather exact correspondence between cars on the crash file and their exposure in registration years. That exception is cars that were less than a year

[1] Annual publication of the R. L. Polk Co., Detroit.

[2] Kahane, C.J., *Relationships between Vehicle Size and Fatality Risk in Model Year 1985-93 Passenger Cars and Light Trucks*, NHTSA Technical Report No. DOT HS 808 570, Washington, 1997, pp. 63-64. At that time the program covered model years 1985-93.

old in any particular calendar year - i.e., whose model year is greater than or equal to the calendar year. The Polk file for each calendar year specifies how many cars were registered as of July 1 of that year. New cars registered after July 1 are not included in the Polk file. FARS, on the other hand, contains records of all fatal crashes involving new cars, at any time in the calendar year, no matter how late they were registered. Numerical fixes to make the FARS and Polk data on new cars correspond better[3] are available if new cars are critical to the analysis, but are not advisable here, since the overwhelming majority (89 percent) of the cases are cars at least one year old. Instead, data with MY $\geq$ CY, for any CY from 1980 onwards, are excluded from both the crash and registration files (11 percent of the crash cases used in Chapters 3-6 are excluded here).

The extract generated from the Polk file includes the following variables: CY (1982-97), CG (car group), MM2 (make-model), BOD2 (body style), MY (1981-96, MY < CY), the curb weight and REGS, the number of registered vehicles, as of July 1 in that calendar year, of the specified CG, MM2, BOD2 and MY. It also includes the car group, make-model, MY and body style of the matching FMVSS 214 test car, its TTI(d), and the variables describing the closeness of the match, as defined in Section 2.2.

Unfortunately, Polk data have no information on the age and gender of drivers. The proportion of cars with ABS is defined at the CG-MM2-MY level from tables in *Ward's Automotive Almanacs* and appended to the exposure file, exactly as was done with the crash file in Section 2.3. Polk data do not specify what individual vehicles had air bags. However, the proportions of vehicles with driver air bags, and with passenger air bags, are likewise tabulated at the CG-MM2-MY level and appended to the exposure file. Since the air bag information on the crash file was originally specified at the individual occupant level, that information is now superseded by these tables, to assure identical data definitions on the crash and exposure files.

As in most of the preceding chapters, analyses will be limited to Phase 1, pre-FMVSS 214 make-models that were baseline tested. Model years are excluded if 10 percent or more of the cars had driver air bags or ABS.

TTI(d) was measured on 17 different pre-standard 2-door cars. In Section 3.5, the ratio of side impact to purely frontal fatalities was computed for each of these 17 make-models, using all the FARS data, and the correlation of these 17 fatality ratios with the TTI(d) scores was computed. Here, FARS and Polk data are used to compute side impact fatalities - drivers and right front (RF) passengers - per million vehicle years in each make-model and see if these rates correlate with TTI(d).

Table 7-1 lists the 17 test vehicles, ordered by TTI(d) from the lowest (82.22) to the highest (131.03). The four right columns display the FARS and Polk data for each of the 17 make-models, for a range of model years before and/or after the test model year during which the design did not change. New cars (MY $\geq$ CY) are excluded from both FARS and Polk. If a test vehicle had fewer than 20 associated FARS cases, it is excluded from the analysis, since a fatality rate based on so few cases would not be statistically meaningful.

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[3] *Ibid.*, pp 71-73.

TABLE 7-1

2-DOOR MAKE-MODELS: TTI(d) vs. SIDE IMPACT FATALITY RISK PER 1,000,000 CAR YEARS
(front outboard occupant fatalities in 17 pre-FMVSS 214 make-models with < 10% air bags and < 10% ABS)

TTI(d)	FMVSS 214 Test MY-Make-Model	FARS MY Range	Curb Weight	Side Impact Fatals	Car Years (000)	Fatals / 10^6 Years	Log(Fatals/Years)
82.22	1985 Chevrolet Spectrum	1985-89	1893	75	1050	71	- 9.547
92.12	1982 Chevrolet Citation	1981-85	2502	106	1760	60	- 9.718
98.06	1987 Nissan Sentra	1987-90	2184	255	4969	51	- 9.877
101.53	1981 Ford Granada	1981-82	2859	24	485	49	- 9.915
105.10	1988 Volkswagen Golf	1985-92	2192	65	1357	47	- 9.946
108.00	1988 Ford Escort	1988-90	2285	262	3828	68	- 9.590
108.17	1988 Chevrolet Sprint	1985-88	1530	105	1103	95	- 9.260
109.20	1988 Chevrolet Corvette	1984-85	3188	91	891	102	- 9.189
110.00	1988 Ford Mustang	1981-89	2890	1394	12568	111	- 9.107
110.00	1988 Ford Festiva	1988-93	1740	142	2035	70	- 9.570
111.00	1988 Oldsmobile Calais	1985-91	2525	223	3585	62	- 9.685
114.41	1981 Volkswagen Rabbit	1981-84	1956	124	2126	58	- 9.750
117.30	1988 Buick Regal	1988-91	3082	102	2120	48	- 9.942
117.38	1982 Dodge 400	1982-83	2526	29	448	65	- 9.645
118.86	1981 Dodge Omni	1981-87	2286	327	2734	120	- 9.031
129.35	1982 Nissan Sentra	1982	1889	34	552	62	- 9.694
131.03	1983 Nissan Sentra	1983-86	1876	257	3865	66	- 9.619

For example, a 1985 Chevrolet Spectrum was tested. Table 7-1 shows FARS statistics for 1985-89 Chevrolet Spectrum: 75 driver and RF passenger fatalities in side impacts, 1,050,000 registration years, a fatality rate of 71 per million years, and a log fatality rate of -9.547. The log rate is calculated because it is usually more suitable for correlation analyses than the simple fatality rate.

Figure 7-1 graphs the log fatality rates by TTI(d) for the 17 make-models. It shows poor overall correlation. Indeed, the registration-weighted correlation coefficient is only .170. Although in the "right" direction, it is not statistically significant, because the probability of observing a more positive coefficient by chance alone, given 17 data points, is .257.

Table 7-1 and Figure 7-1 show considerable variation in the fatality rate from model to model. For example, Chevrolet Corvette, Ford Mustang and Dodge Omni (Charger) have over 100 side impact fatalities per million years. However, it has been known for a long time that these three models have high fatality rates in all types of crashes, largely because they attract young, high-risk drivers[4]. Conversely, cars like Volkswagen Golf and Rabbit have exceptionally low fatality rates - in side impacts and elsewhere. Any real crashworthiness differences are likely to be obscured by other factors when simple fatality rates per million years are computed without any explicit or implicit (through a control group) adjustment for driver age **or** curb weight, or any other factors[5].

To illustrate that point, Table 7-2 and Figure 7-2 present corresponding fatality rates in purely frontal crashes (IMPACT2 = 12 and M_HARM $\neq$ 1-7). Figure 7-2 shows almost the identical pattern as Figure 7-1: numerous outliers and poor overall correlation with TTI(d). The correlation coefficient of purely frontal fatality risk with TTI(d) is -.137. It is in the "wrong" direction, and it is not statistically significant. Although it may be considered a good omen that the correlation of TTI(d) with side impact fatality risk is a positive number, and with frontal fatality risk, negative, all results are too weak in a statistical sense to support any inferences.

Table 7-3 presents the fatality rates of 23 4-door make-models in side impacts. The first two models, Lincoln Town Car and Chevrolet Caprice, are listed in *italics* because they are quite different from the others and are excluded from the correlation analysis. They have higher mass, older drivers and much lower TTI(d). Table 7-3 shows that the fatality rate of the Town Car is exceedingly low, and Caprice, relatively low.

As in other chapters, the analysis of 4-door cars is limited to make-models weighing 1900-3299 pounds, thus excluding Town Car and Caprice. The remaining 21 models in Table 7-3 are a fairly representative mix of economy and family sedans. Fatality rates vary. Nevertheless, most of the

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[4]"Status Report Special Issue: Occupant Death Rates by Car Series," *Insurance Institute for Highway Safety Status Report*, Vol. 24, November 25, 1989.

[5]In Chapter 3, at least, we gained some control over driver age by limiting the analysis to fatalities age 30-65; here, we cannot limit the age distribution of the fatalities because the Polk data have no corresponding information on the driver age distribution of the vehicle registration years.

FIGURE 7-1

2-DOOR MAKE-MODELS: LOG RATIO OF SIDE IMPACT FATALITIES
TO CAR REGISTRATION YEARS, BY TTI(d)
(front outboard occupant fatalities in 17 pre-FMVSS 214
make-models with < 10% air bags and < 10% ABS)

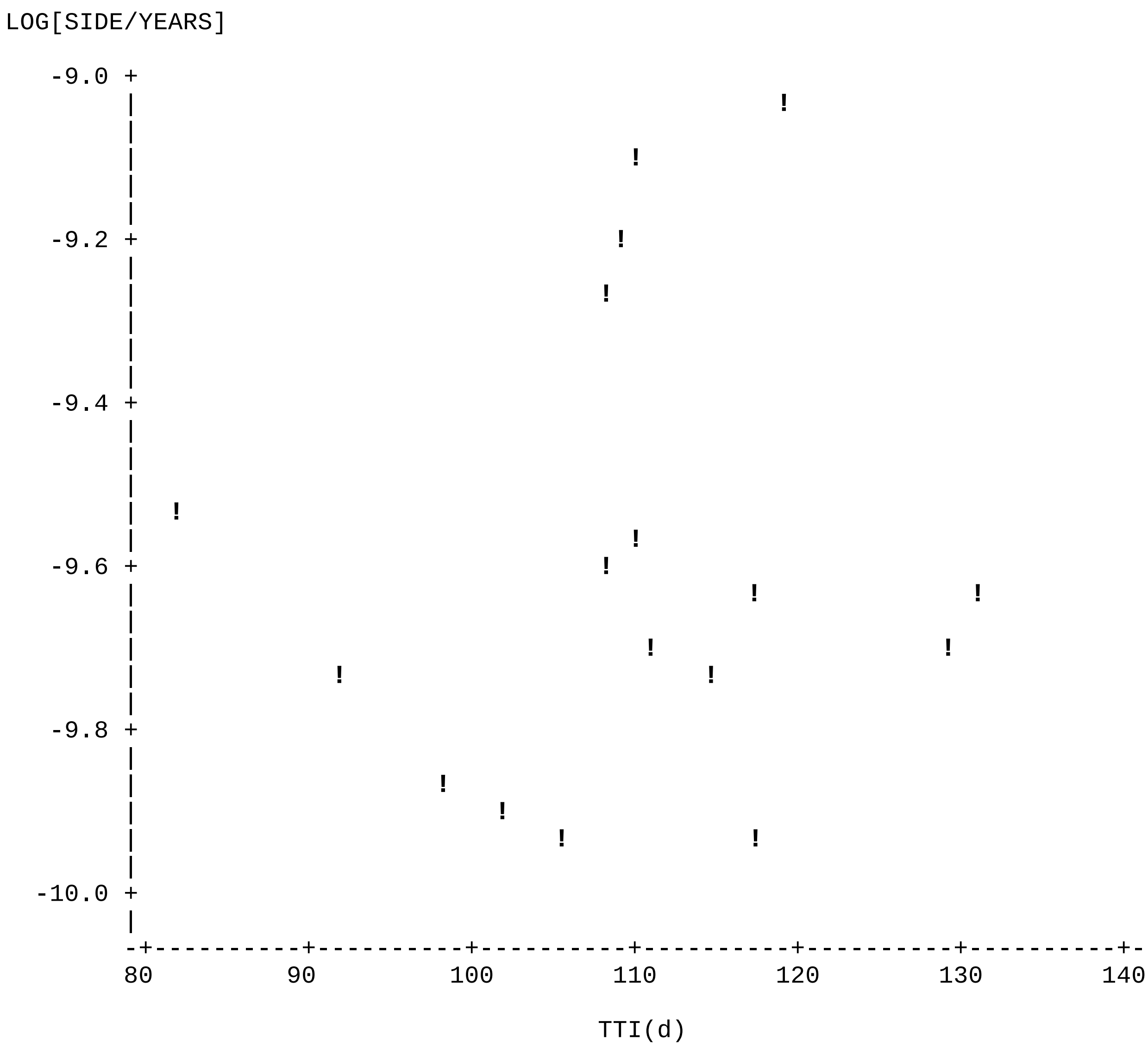


TABLE 7-2

2-DOOR MAKE-MODELS: TTI(d) vs. PURELY FRONTAL FATALITY RISK PER 1,000,000 CAR YEARS
(front outboard occupant fatalities in 17 pre-FMVSS 214 make-models with < 10% air bags and < 10% ABS)

TTI(d)	FMVSS 214 Test MY-Make-Model	FARS MY Range	Curb Weight	Purely Frontal Fatals	Car Years (000)	Fatals / 10^6 Years	Log(Fatals/Years)
82.22	1985 Chevrolet Spectrum	1985-89	1893	88	1050	84	- 9.387
92.12	1982 Chevrolet Citation	1981-85	2502	132	1760	75	- 9.498
98.06	1987 Nissan Sentra	1987-90	2184	305	4969	61	- 9.698
101.53	1981 Ford Granada	1981-82	2859	32	485	66	- 9.627
105.10	1988 Volkswagen Golf	1985-92	2192	76	1357	56	- 9.790
108.00	1988 Ford Escort	1988-90	2285	263	3828	69	- 9.586
108.17	1988 Chevrolet Sprint	1985-88	1530	127	1103	115	- 9.069
109.20	1988 Chevrolet Corvette	1984-85	3188	105	891	76	- 9.481
110.00	1988 Ford Mustang	1981-89	2890	1083	12568	86	- 9.359
110.00	1988 Ford Festiva	1988-93	1740	280	2035	138	- 8.891
111.00	1988 Oldsmobile Calais	1985-91	2525	259	3585	72	- 9.535
114.41	1981 Volkswagen Rabbit	1981-84	1956	127	2126	60	- 9.726
117.30	1988 Buick Regal	1988-91	3082	105	2120	50	- 9.913
117.38	1982 Dodge 400	1982-83	2526	32	448	71	- 9.546
118.86	1981 Dodge Omni	1981-87	2286	280	2734	102	- 9.187
129.35	1982 Nissan Sentra	1982	1889	33	552	60	- 9.724
131.03	1983 Nissan Sentra	1983-86	1876	221	3865	57	- 9.769

FIGURE 7-2: 2-DOOR MAKE-MODELS - LOG RATIO OF PURELY FRONTAL FATALITIES TO CAR REGISTRATION YEARS, BY TTI(d)
(front outboard occupant fatalities in 17 pre-FMVSS 214 make-models with < 10% air bags and < 10% ABS)

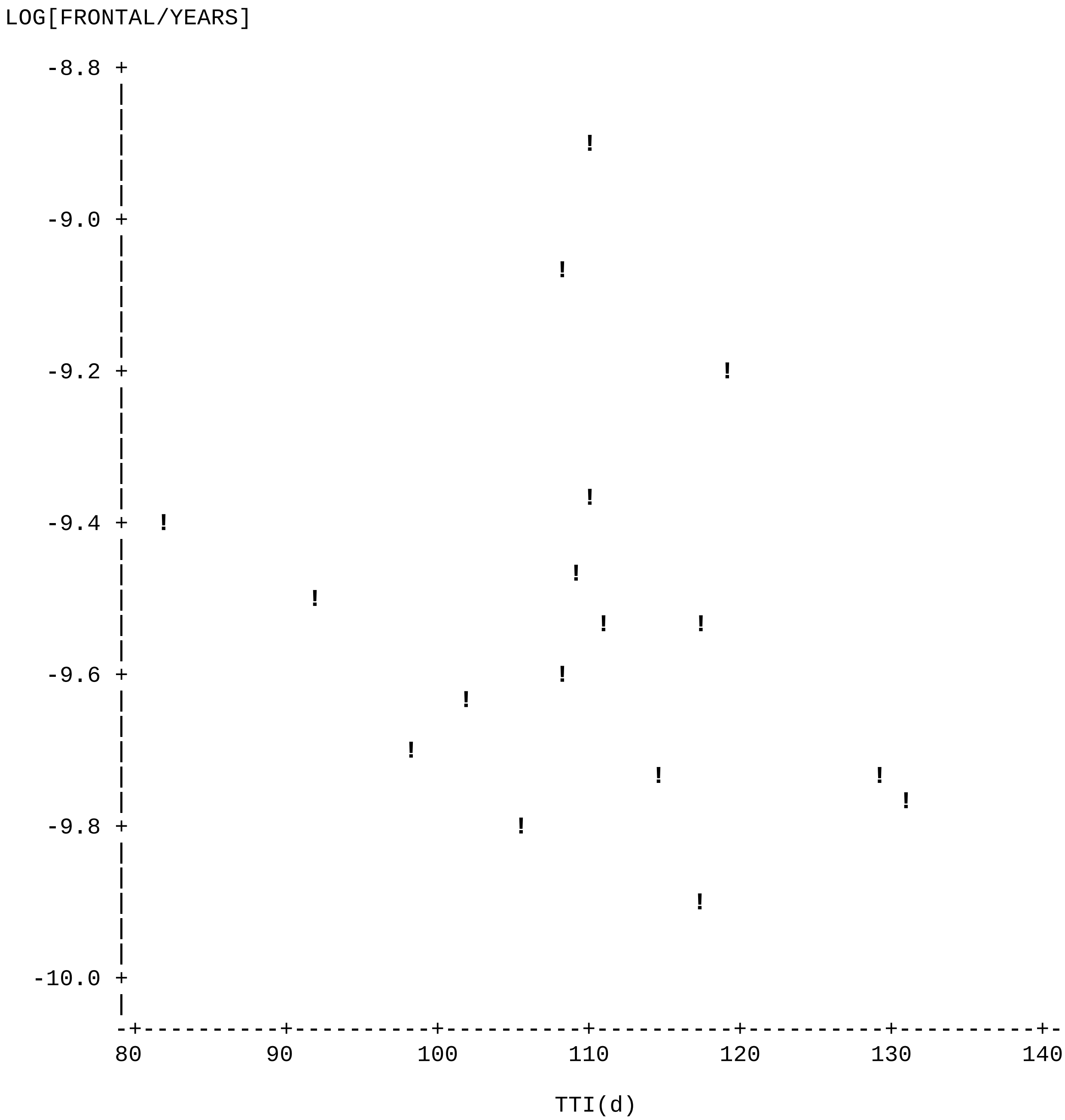


TABLE 7-3

4-DOOR MAKE-MODELS: TTI(d) vs. SIDE IMPACT FATALITY RISK PER 1,000,000 CAR YEARS
(front outboard occupant fatalities in 23 pre-FMVSS 214 make-models with < 10% air bags and < 10% ABS)

TTI(d)	FMVSS 214 Test MY-Make-Model	FARS MY Range	Curb Weight	Side Impact Fatals	Car Years (000)	Fatals / 10^6 Years	Log(Fatals/Years)
40.00	*1988 Lincoln Town Car*	*1981-89*	*4056*	*215*	*8051*	*27*	*-10.53*
50.73	*1988 Chevrolet Caprice*	*1981-90*	*3641*	*630*	*13899*	*45*	*-10.00*
61.79	1989 Plymouth Colt Vista	1984-91	2635	24	628	38	-10.17
65.60	1992 Chevrolet Lumina	1990-91	3262	97	2525	38	-10.17
71.81	1980 AMC Concord	1981-83	3006	65	1006	65	- 9.65
73.50	1988 Oldsmobile Calais	1986-91	2593	132	2264	58	- 9.75
74.80	1990 Pontiac 6000	1989-91	2857	62	1071	58	- 9.76
77.76	1981 Honda Civic	1981	1971	28	786	36	-10.24
77.79	1984 Chevrolet Celebrity	1982-88	2795	985	16957	58	- 9.75
78.22	1988 Ford Taurus	1986-89	3065	479	10976	44	-10.04
78.70	1988 Oldsmobile Delta 88	1986-91	3214	362	6345	57	- 9.77
81.21	1986 Chevrolet Cavalier	1982-86	2406	593	9892	60	- 9.72
82.23	1987 Chevrolet Cavalier	1987-88	2375	182	2603	70	- 9.57
85.62	1988 Hyundai Excel	1986-89	2158	275	4354	63	- 9.67
85.72	1992 Honda Accord	1990-91	2872	154	4184	37	-10.21
88.65	1981 Chevrolet Citation	1981-85	2534	418	5974	70	- 9.57
91.56	1992 Nissan Sentra	1991-92	2277	38	680	56	- 9.79
93.54	1983 Ford Escort	1982-85	2142	424	7699	55	- 9.81
98.00	1988 Ford Escort	1988-90	2319	183	2819	65	- 9.64
102.88	1982 Honda Civic	1982-83	1988	91	1657	55	- 9.81
105.12	1983 Mazda 626	1983-87	2433	144	2846	51	- 9.89
110.44	1981 Plymouth Horizon	1981-89	2213	348	5336	65	- 9.64
118.37	1981 Ford Granada	1981-82	2950	122	2014	61	- 9.71

cars with low fatality rates, as evidenced by a log more negative than -10, are at the lower end of the TTI(d) range. Figure 7-3 graphs the log fatality rate of these 21 models (excluding Town Car and Caprice). The data points generate one small "cloud" at the lower left - i.e., cars with low TTI(d) and a low fatality rate. A larger cloud extends from the mid-left to the right at the top of the graph - higher fatality rates at almost any TTI(d). The two clouds' position along the diagonal will tend to make the overall correlation positive. On the other hand, the wide, chaotic scatter within each cloud will limit the correlation. In fact, the registration-weighted correlation coefficient is .325. Although it is in the "right" direction, it is not statistically significant: the probability of observing a more positive coefficient by chance alone, given 21 data points, is .075.

Table 7-4 and Figure 7-4 present corresponding fatality rates of 4-door cars in purely frontal crashes. Figure 7-4 does not have two well-defined "clouds" as in Figure 7-3, but it perhaps shows a slight tendency of fatality rates increasing as TTI(d) increases, with outliers. The correlation coefficient of TTI(d) with frontal fatality risk is .253, slightly less than its correlation with side impact fatality risk. It is not statistically significant ($p = .134$). The fact that TTI(d) has similar correlation with side and frontal impact fatality risk hardly suggests there is a special relationship between TTI(d) and fatality risk in side impacts of 4-door cars.

7.2 Regression of side impact fatalities per 1,000,000 car years by TTI(d)

Together, the crash and registration data bases drive regression analyses of side impact fatality risk per million vehicle years, by TTI(d) and a few control variables. They are regressions on disaggregate data, using maximum likelihood principles, performed by the LOGIST procedure on the Statistical Analysis System (SAS)[6]. The data points in the regressions can be either a:

"Failure" One case of a fatally injured driver or a right-front (RF) passenger involved in a side impact (IMPACT2 = 2, 3, 4, 8, 9, or 10), or a

"Success" One year of vehicle registration - e.g., if 200,000 cars of a specific make-model-year-body style were registered in a specific calendar year, they supply 200,000 "success" data points to the regression analysis.

This setup differs in several ways from data that would usually be analyzed by the LOGIST procedure. "Successes" are ordinarily discrete cases, similar to the "failures." For example, if a "failure" is an occupant who died in a crash, a "success" could be an occupant who survived a crash of the same type. The definition of one year of registration as a success is arbitrary - it would also have been possible to define it as one month or one day. Nevertheless, this approach makes it possible to use disaggregate regression. The alternative - aggregating the data into cells by make-model, model year and calendar year and performing a regression on the fatality rates in the various cells - is not advantageous when the fatality counts are as small as they are here.

[6] *SAS/STAT® User's Guide, Version 6, Fourth Edition*, Volume 2, SAS Institute, Cary, NC, 1989, pp. 1071-1126.

FIGURE 7-3: 4-DOOR MAKE-MODELS - LOG RATIO OF SIDE IMPACT FATALITIES TO CAR REGISTRATION YEARS, BY TTI(d)
(front outboard occupant fatalities in 21 pre-FMVSS 214 make-models weighing 1900-3299 pounds with < 10% air bags and < 10% ABS)

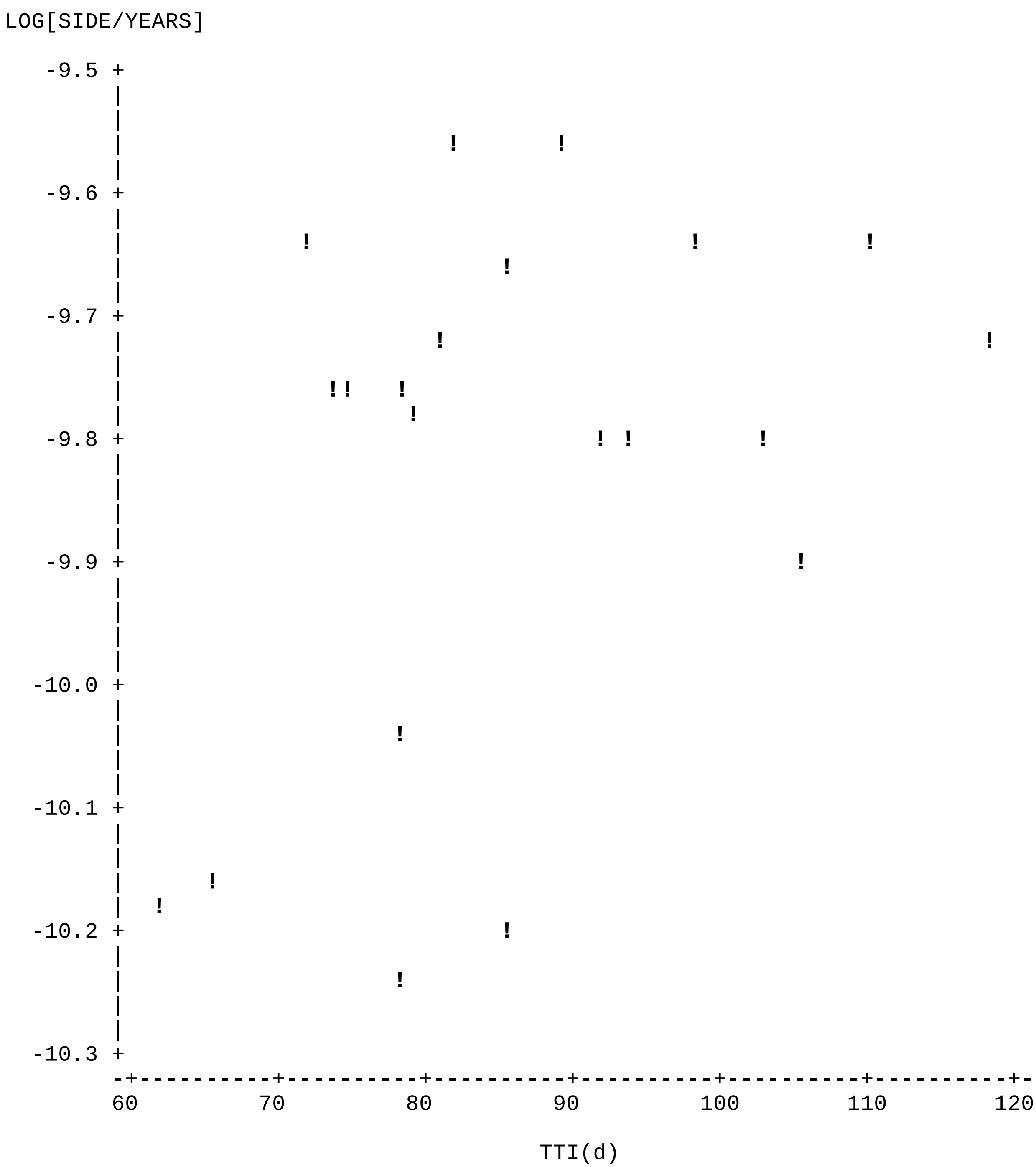
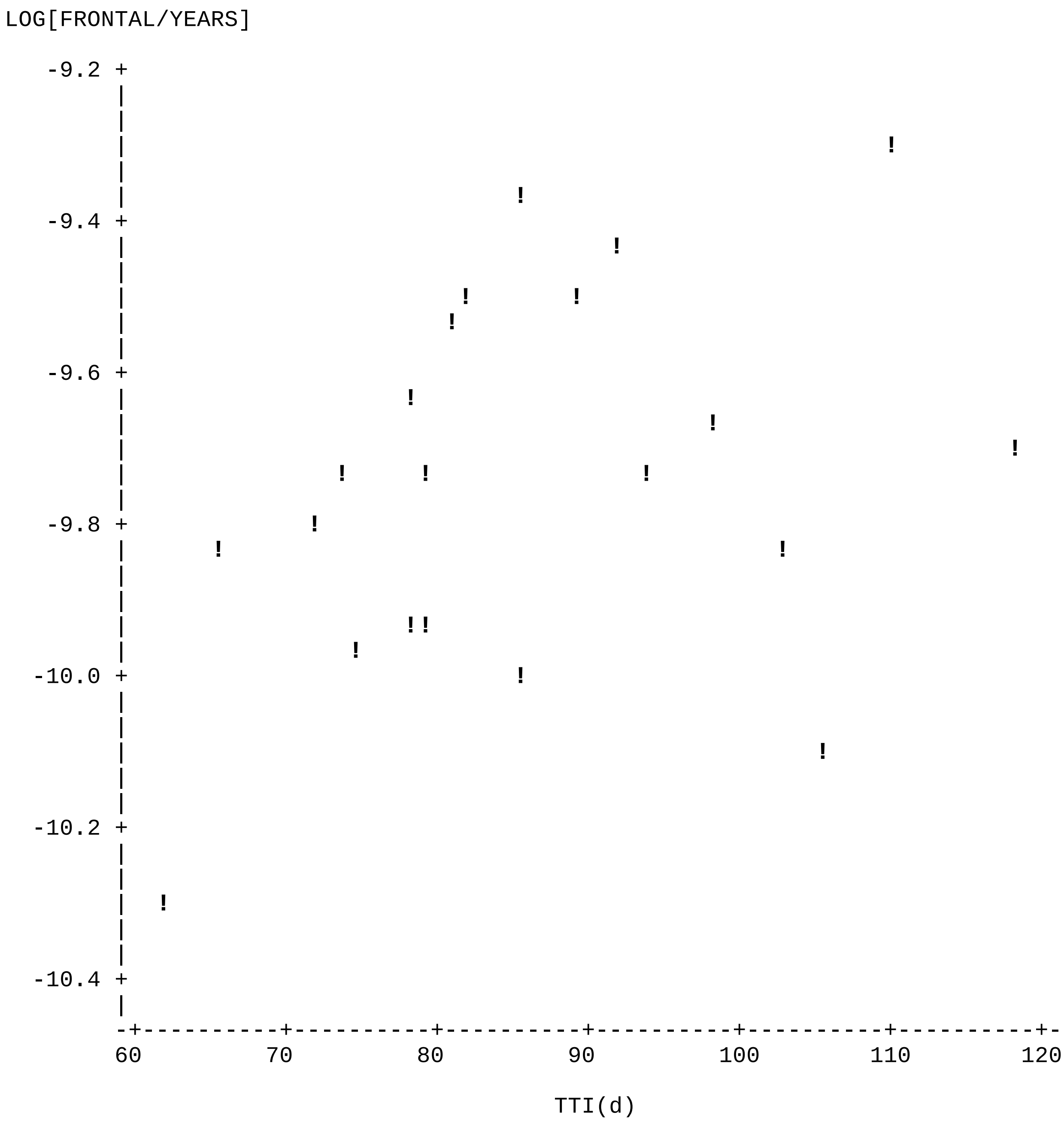


TABLE 7-4

4-DOOR MAKE-MODELS: TTI(d) vs. PURELY FRONTAL FATALITY RISK PER 1,000,000 CAR YEARS
(front outboard occupant fatalities in 23 pre-FMVSS 214 make-models with < 10% air bags and < 10% ABS)

TTI(d)	FMVSS 214 Test MY-Make-Model	FARS MY Range	Curb Weight	Purely Frontal Fatals	Car Years (000)	Fatals / 10^6 Years	Log(Fatals/Years)
40.00	*1988 Lincoln Town Car*	*1981-89*	*4056*	*326*	*8051*	*40*	*- 10.11*
50.73	*1988 Chevrolet Caprice*	*1981-90*	*3641*	*909*	*13899*	*65*	*- 9.64*
61.79	1989 Plymouth Colt Vista	1984-91	2635	21	628	33	- 10.31
65.60	1992 Chevrolet Lumina	1990-91	3262	136	2525	54	- 9.83
71.81	1980 AMC Concord	1981-83	3006	55	1006	55	- 9.81
73.50	1988 Oldsmobile Calais	1986-91	2593	135	2264	60	- 9.73
74.80	1990 Pontiac 6000	1989-91	2857	50	1071	47	- 9.97
77.76	1981 Honda Civic	1981	1971	38	786	48	- 9.94
77.79	1984 Chevrolet Celebrity	1982-88	2795	1111	16957	66	- 9.63
78.22	1988 Ford Taurus	1986-89	3065	527	10976	48	- 9.94
78.70	1988 Oldsmobile Delta 88	1986-91	3214	375	6345	59	- 9.74
81.21	1986 Chevrolet Cavalier	1982-86	2406	706	9892	71	- 9.55
82.23	1987 Chevrolet Cavalier	1987-88	2375	197	2603	76	- 9.49
85.62	1988 Hyundai Excel	1986-89	2158	371	4354	85	- 9.37
85.72	1992 Honda Accord	1990-91	2872	192	4184	46	- 9.99
88.65	1981 Chevrolet Citation	1981-85	2534	444	5974	74	- 9.51
91.56	1992 Nissan Sentra	1991-92	2277	55	680	81	- 9.42
93.54	1983 Ford Escort	1982-85	2142	451	7699	59	- 9.75
98.00	1988 Ford Escort	1988-90	2319	180	2819	64	- 9.66
102.88	1982 Honda Civic	1982-83	1988	90	1657	54	- 9.82
105.12	1983 Mazda 626	1983-87	2433	117	2846	41	- 10.10
110.44	1981 Plymouth Horizon	1981-89	2213	482	5336	90	- 9.31
118.37	1981 Ford Granada	1981-82	2950	122	2014	61	- 9.71

FIGURE 7-4: 4-DOOR MAKE-MODELS - LOG RATIO OF PURELY FRONTAL FATALITIES TO CAR REGISTRATION YEARS, BY TTI(d)
(front outboard occupant fatalities in 21 pre-FMVSS 214 make-models weighing 1900-3299 pounds with < 10% air bags and < 10% ABS)



Disaggregate regression uses many individual observations of side-impact fatalities and registration years to predict the probability of a side-impact fatality per year under any hypothetical combination of the independent variables. The principal independent variable is the TTI(d) score for the front-seat dummy on the FMVSS 214 test. It is entered directly, without any transformations (except the minor test-speed adjustment defined in Section 2.1). Thus, the regression coefficient will indicate the change in the log ratio of fatalities to vehicle years, given a one-unit increase in TTI(d). A positive coefficient for TTI(d) is an effect in the "right" direction: the lower the TTI(d), the lower the side-impact fatality risk.

The only control variables in the analyses are curb weight and vehicle age. Although vehicle age had nonsignificant coefficients in all the regressions of Chapter 5, it could be a more important control variable here: whereas the ratio of side impacts to frontal impacts does not change so much over time, the absolute rate of side impacts per million years can change substantially as a car ages and gets different drivers and exposure patterns. Since cars less than one year old have been excluded from these data, no special variable is needed to indicate brand new cars, as in Chapter 5.

Occupant age, gender, belt use and seating position cannot be control variables because they are unknown or cannot be defined for the vehicle registration years. As in Section 7.1, the data are limited to make-model-year combinations with no ABS or with less than 10 percent optional ABS. Similarly, the data are also limited to combinations with no driver air bags or with less than 10 percent optional driver air bags.

The principal regression for baseline 2-door cars involves 1,104 make-model-MY-CY combinations that experienced 3,615 side impact fatalities in 45,475,254 registration years. That's a total of 45,478,869 data points. The regression generates the following coefficients:

Side Impacts: 2-Door Cars

Variable	DF	Parameter Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square	Standardized Estimate	Odds Ratio
Intercept	1	-11.0506	0.2291	2327.4212	0.0001		
TTI(d)	**1**	**0.00736**	**0.00181**	**16.6276**	**0.0001**	**3.955019**	**1.007**
CURBWT	1	0.000359	0.000037	96.2869	0.0001	8.774489	1.000
VEHAGE	1	-0.0155	0.00517	8.9651	0.0028	-2.729537	0.985

The coefficient for TTI(d) is +.00736. In other words, a one-unit reduction in TTI(d) is associated with a 0.736 percent reduction in the side-impact fatality rate. This is in the right direction and it is statistically significant at the .01 level, as evidenced by the Chi-Square (χ^2) statistic being 16.6276. (For statistical significance at the .05 level, χ^2 must exceed 3.84, and for the .01 level, 6.64.) This TTI(d) coefficient is fairly similar, although slightly weaker than the +.00927 coefficient obtained in Section 5.2 for the corresponding regression of side impacts relative to pure frontals.

The strongly positive coefficient for curb weight is about the same as in the regressions of side impacts relative to pure frontals: the heavier 2-door cars are the sportier models and they have higher fatality rates. The significant negative coefficient for vehicle age reflects that older 2-door cars have lower fatality rates per year. As cars get older, their fatality rate per mile increases, but they are driven substantially fewer miles per year. In this case, the annual reduction in mileage overshadows the increase in fatality rates per mile.

It is fair to ask if the 2-door cars with lower TTI(d) specifically have lower **side impact** fatality rates or if they also have generally lower risk in other types of crashes. The relationship between TTI(d) and fatality risk in **purely frontal** crashes can be calibrated by the same regression procedure, except defining a "failure" to be a driver or RF fatality in a purely frontal crash (IMPACT2 = 12 and M_HARM ≠ 1-7) while a "success" is, as above, one year of vehicle registration. The regression coefficients are:

Pure Frontals: 2-Door Cars

Variable	DF	Parameter Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square	Standardized Estimate	Odds Ratio
Intercept	1	-9.1128	0.2148	1800.6667	0.0001		
TTI(d)	**1**	**-0.00190**	**0.00171**	**1.2287**	**0.2677**	**-1.030283**	**0.998**
CURBWT	1	8.793E-7	0.000037	0.0006	0.9813	0.021755	1.000
VEHAGE	1	-0.0282	0.00533	27.9713	0.0001	-5.030957	0.972

It is reassuring that the coefficient for TTI(d) is a nonsignificant -.00190, suggesting there is little relationship between TTI(d) and fatality risk in purely frontal impacts. The difference between the TTI(d) coefficient for side impact fatalities per million years (+.00736) and frontal fatalities per million years (-.00190) is +.00926. Appropriately, that is almost exactly the same as the TTI(d) coefficient in the regression of side impacts relative to pure frontals (+.00927).

As an additional check, fatality rates were computed for a larger control group of crashes including all frontals, rollovers that are not primarily side impacts and pedestrian/bicyclist collisions. In other words, a "failure" is a driver or RF fatality in a frontal crash of any type (IMPACT2 = 11, 12, 1), a driver or RF fatality in a first-harmful-event rollover where the principal impact is not on the side of the car (HARM_EV = 1 and IMPACT2 ≠ 2, 3, 4, 8, 9, 10), or a vehicle involved in a fatal collision with a pedestrian, bicyclist or other non-motorist (M_HARM = 8, 9, 15). The regression coefficients are:

Frontals, Rollovers, Pedestrian/Bicyclist Crashes: 2-Door Cars

Variable	DF	Parameter Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square	Standardized Estimate	Odds Ratio
Intercept	1	-8.6490	0.1466	3478.3617	0.0001		
TTI(d)	**1**	**-0.00105**	**0.00117**	**0.7950**	**0.3726**	**-0.410134**	**0.999**
CURBWT	1	0.000111	0.000025	19.5892	0.0001	1.984197	1.000
VEHAGE	1	-0.0345	0.00361	91.7364	0.0001	-4.445247	0.966

The coefficient for TTI(d) is a negligible -.00105. It is not statistically significant (χ^2 = .795). The analyses suggest that, in 2-door cars, there is a relationship between TTI(d) and fatality risk in side impacts but not in other types of crashes.

A regression of side impact fatalities per year was performed with data on 4-door cars weighing 1900-3299 pounds, with at most 10 percent optional air bags and/or ABS. The regression involved 1,445 make-model-MY-CY combinations that experienced 5,512 side impact fatalities in 92,762,659 registration years. That's a total of 92,767,871 data points. The regression generated the following coefficients:

Side Impacts: 4-Door Cars

Variable	DF	Parameter Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square	Standardized Estimate	Odds Ratio
Intercept	1	-9.4285	0.2104	2008.0894	0.0001		
TTI(d)	**1**	**0.00104**	**0.00141**	**0.5379**	**0.4633**	**0.775121**	**1.001**
CURBWT	1	-0.00019	0.000045	18.6492	0.0001	-4.644582	1.000
VEHAGE	1	0.0108	0.00425	6.4412	0.0112	2.266708	1.011

The coefficient for TTI(d) is +.00104. It is in the "right" direction, but not statistically significant (χ^2 = .54), and it is much weaker than the coefficient in 2-door cars (+.00736). With 4-door cars, the coefficient for curb weight is negative: the heavier the car the lower the fatality rate. That is the more customary pattern for the weight-safety relationship[7].

A regression of purely frontal fatalities per year shows little or no relationship with TTI(d):

[7]Kahane (1997).

Pure Frontals: 4-Door Cars

Variable	DF	Parameter Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square	Standardized Estimate	Odds Ratio
Intercept	1	-9.0077	0.1993	2041.8992	0.0001		
TTI(d)	**1**	**0.00020**	**0.00134**	**0.0214**	**0.8837**	**0.139916**	**1.000**
CURBWT	1	-0.00028	0.000042	43.3448	0.0001	-6.403822	1.000
VEHAGE	1	0.00936	0.00401	5.4554	0.0195	1.877610	1.009

The relationship between TTI(d) and the fatality rate in frontals, rollovers and pedestrian/bicyclist crashes is likewise weak:

Frontals, Rollovers, Pedestrian/Bicyclist Crashes: 4-Door Cars

Variable	DF	Parameter Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square	Standardized Estimate	Odds Ratio
Intercept	1	-8.2171	0.1439	3258.8617	0.0001		
TTI(d)	**1**	**-0.00048**	**0.000969**	**0.2492**	**0.6176**	**-0.261229**	**1.000**
CURBWT	1	-0.0003	0.000031	97.4181	0.0001	-5.233237	1.000
VEHAGE	1	0.00668	0.00289	5.3457	0.0208	1.013193	1.007

In 4-door cars, the analyses suggest there is little relationship between TTI(d) and fatality risk in **any** crash mode.

CHAPTER 8

ANALYSIS PLAN FOR PHASE 2
EFFECT OF FMVSS 214 AND CORRELATION OF TTI(d) WITH ACTUAL FATALITY RISK IN MODEL YEAR 1992-2000 PASSENGER CARS

FMVSS 214 was phased into passenger cars during model years 1994-97. Quite a few make-models received major upgrades to their side structures; others only got energy-absorbing padding; yet others could already meet the standard before 1994 and were not modified at all. In most cases, NHTSA has information specifying what was changed and when. That will allow a "before/after" evaluation of the effect of FMVSS 214 - when enough crash data become available, possibly by 2001. But NHTSA usually does not know how much these changes reduced TTI(d), because the agency tested only a few cars produced immediately before the phase-in. Thus, detailed parametric analyses of correlation between TTI(d) and fatality risk will require additional testing of selected cars of the early-to-mid 1990's.

8.1 What happened in 1994-97?

In 1990, NHTSA's Final Regulatory Impact Analysis for FMVSS 214 described two available strategies for improving TTI(d) scores and meeting the standard: upgraded **structure** such as more rigid door beams, pillars, sills, roof rails and cross members; and **padding**, energy-absorbing material deforms at a safe, controlled rate when impacted by people in crashes. The analysis predicted that 5 percent of cars would need structure plus padding, 59 percent padding only, and 36 percent no change at all in order to lower front-seat TTI(d) just enough to meet FMVSS 214 with no margin of safety (90 in 2-door cars and 85 in 4-door cars)[1]. Of course, if manufacturers wished to do better than these minimum improvements, a substantially higher proportion of cars would need structure plus padding, while fewer would remain unchanged.

Let us first look at what actually happened to passenger cars in model years 1994-97, the phase-in period, to obtain compliance with FMVSS 214 and/or reduce TTI(d). We shall see that the Regulatory Impact Analysis was correct in predicting that structure and padding would be the initial strategies for lowering TTI(d). (More recently, side air bags have supplemented structure and padding for additional performance improvement in some cars, but as of model year 1997 they are not sufficiently numerous for a meaningful statistical analysis of their performance in crashes within the next few years; they are scheduled for a NHTSA evaluation starting in 2002.) However, manufacturers chose to reduce TTI(d) well below the levels permitted by FMVSS 214: in model year 1997 cars, the sales-weighted average TTI(d) was 74 in 2-door cars and 65 in 4-door cars. To achieve those levels, a large percentage of cars got upgraded structures.

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[1] *Final Regulatory Impact Analysis - New Requirements for Passenger Cars to Meet a Dynamic Side Impact Test FMVSS 214*, NHTSA Publication No. DOT HS 807 641, Washington, 1990, pp. IIIC-38 - IIIC-54.

NHTSA has three main sources of information about what happened in model years 1994-97: compliance tests, self-certifications and Information Requests (IR) to the manufacturers.

Compliance tests have been performed for a large number of make-models that were redesigned and/or certified to meet FMVSS 214 (95 tests through MY 1998). They tell us, among other things, the TTI(d) of the front-seat dummy. In many cases, but not always, they were performed in the first model year that a car met FMVSS 214. Without information to the contrary, a compliance test result can be assumed to extend to subsequent and previous model years, as long as the car was certified to meet FMVSS 214 and not redesigned. For the time being, the result may also be assumed to extend to corporate "cousins" of essentially identical design, especially if the manufacturer self-certified the twin at the same time as the tested vehicle - e.g., Ford Taurus to Mercury Sable. (In the future, however, examination of the data could lead to decisions to exclude the corporate cousins, as in Phase 1 of the evaluation.)

Thus, the TTI(d) data base includes a large set of vehicles. Still, there are some make-models that were never tested, or that might have been further modified, unknown to NHTSA, one or more years after the compliance test, or where the result for the specific test vehicle is not really representative - i.e., if the test had been repeated for additional cars, the average might have been higher or lower by more than just 1 or 2.

Self-certification was an opportunity for a manufacturer to inform the public that a 1994, 1995 or 1996 vehicle met FMVSS 214, as part of the phase-in. Usually, the first year of self-certification is the implementation year for modifications to meet FMVSS 214, if there were any. If a model was not self-certified in 1994-96, we can usually assume that it was modified to meet FMVSS 214 in 1997, since all cars had to meet the standard that year. There are gaps, however, in this information. Manufacturers were not obligated to self-certify any specific model, as long as they certified enough models to meet the phase-in schedule. They may have refrained from self-certifying some models that actually met FMVSS 214, especially if they only met it with a small margin for error. Self-certification does not tell us if a model already met the standard before 1994, or if it was modified in 1994.

NHTSA sends Information Requests to the manufacturers, usually but not always for the make-models the agency selects for compliance testing. The manufacturer sends a verbal description, often accompanied by sketches of the specific modifications employed to comply with FMVSS 214 and/or reduce TTI(d) or other test scores. Most IR's are clear whether the modification included substantial redesign of structures, or just padding, or minor structural changes, or nothing. In this report, "substantial" structural upgrades include redesigns or stiffening of door beams, pillars, sills, roof rails and/or cross members; "minor" structural changes are limited, for example, to a small plate near the door latch or a tube to strengthen the seat. Many IR's also specify clearly in what model year the car changed. Some IR's, however, leave room for doubts on both issues.

The three sources can be used to generate a data base, by make-model and model-year, that's rather accurate and complete, at least for the models with high sales, on the current performance level [front-seat-dummy TTI(d)] of each model, and when it achieved that level, and what was done to achieve it. On the other hand, the agency performed only 13 tests of MY 1990-93 cars that were not yet certified to meet FMVSS 214 (as opposed to 95 compliance tests of MY 1994-98 cars certified to meet the standard). The data base will contain only limited information on the level of performance just before the modifications and on the improvement in TTI(d) attributable to the changes.

An investigation of the make-models with the highest sales volumes produced throughout 1993-97 reveals how often, based on model year 1996 registrations, various strategies were used to meet FMVSS 214 or improve performance. Models with unknown changes, or discontinued before 1997, or that did not yet exist in 1993, or with relatively low sales volumes (such as many of the luxury cars) are not included:

	MY 1996 Registrations[2]
SUBSTANTIAL STRUCTURE PLUS PADDING	
Ford Taurus/Mercury Sable 4dr	499,000
Toyota Camry 4dr	330,000
Honda Accord 4dr	329,000
Toyota Corolla/Geo Prizm 4dr	273,000
Saturn 4dr	222,000
Nissan Sentra 4dr	133,000
Ford Mustang 2dr	124,000
Honda Civic 4dr	110,000
GM N Body (Grand Am) 2dr	91,000
VW Jetta 4dr	83,000
Subaru Legacy 4dr	76,000
Mitsubishi Eclipse/Eagle Talon 2dr	59,000
Mazda Protege 4dr	56,000
Toyota Tercel 2dr	45,000
Mitsubishi Galant 4dr	42,000
Lincoln Continental 4dr	27,000
Toyota Celica 2dr	10,000
SUBSTANTIAL STRUCTURE (no padding)	
Chrysler LH Body (Intrepid) 4dr	201,000
Honda Civic 2dr	117,000
Honda Accord 2dr	39,000
Acura Integra 2dr	34,000
SUBTOTAL - STRUCTURE	2,900,000

[2] If 1996 was a "short" model year, 1995 sales are shown instead (GM H Body and Ford Escort/Mercury Tracer 4dr).

PADDING (plus minor structural changes)	
GM H Body (LeSabre) 4dr	318,000
Ford Escort/Mercury Tracer 4dr	315,000
Chevrolet Cavalier/Pontiac Sunfire 2dr	216,000
Ford Thunderbird/Mercury Cougar 2dr	122,000
Mazda 626 4dr	75,000
PADDING (only)	
GM N Body (Grand Am) 4dr	183,000
Chevrolet Cavalier/Pontiac Sunfire 4dr	135,000
Saturn 2dr	49,000
SUBTOTAL - PADDING	1,413,000
NO CHANGE - MET FMVSS 214 BEFORE 1994	
Chevrolet Lumina 4dr	213,000
Pontiac Grand Prix/Buick Regal/Oldsmobile Supreme 4dr	192,000
Mercury Grand Marquis/Ford Crown Victoria 4dr	185,000
Cadillac DeVille 4dr	105,000
Lincoln Town Car 4dr	89,000
Chevrolet Camaro/Pontiac Firebird 2dr[3]	88,000
Ford Probe/Mazda MX6 2dr	36,000
SUBTOTAL - NO CHANGE	908,000

The preceding list comprises 5,221,000 registrations for model year 1996, about two-thirds of the cars registered that year. The 2,900,000 cars that got substantial structural upgrades at some time during 1994-97, in most cases accompanied by padding, far outnumber the 1,413,000 that got mainly padding and the 908,000 that did not change at all. Given that average TTI(d) dropped during 1991-97 from 112 to 74 in 2-door cars and from 78 to 65 in 4-door cars, it is no surprise that many structures were improved. By and large, manufacturers chose substantial upgrades to structure for any car that could not meet FMVSS 214 or was on the borderline. They did not hesitate to install padding in cars that already could have met the standard, and left unchanged primarily those cars that could already pass the test with a large safety margin.

Since just a few cars produced immediately before 1994 were tested, the actual amount of TTI(d) reduction is only known for five make-models that got substantial structural upgrades, and for none that got primarily padding. Thus, it is not possible to compare the effects of structure and padding on TTI(d), or even to estimate a meaningful "average" Δ-TTI(d) for the cars that got structure. The TTI(d) improvements for the five models with improved structure are:

[3] No change for the front-seat occupant

	Before	After	Δ-TTI(d)
SUBSTANTIAL STRUCTURE PLUS PADDING			
Honda Accord 4dr	86	80	6 ?[4]
Toyota Corolla/Geo Prizm 4dr	91	72	19
Nissan Sentra 4dr	92	67	25
SUBSTANTIAL STRUCTURE (no padding)			
Chrysler LH Body (Intrepid) 4dr	79	65	14
Honda Civic 2dr	86	72	14

8.2 Make-model groups for before/after evaluation

Information gleaned from compliance testing, self-certification and IR's tells us pretty clearly what was changed, and when, for most of the make-models with fairly high sales. It is usually unknown how much TTI(d) was reduced. This knowledge almost dictates the analysis plan. We can subdivide the make-models with relatively high sales into three cohorts: substantial structure (in most cases with padding); just padding (sometimes with minor structural changes); and unchanged (a control group). We can definitely perform a before/after evaluation, comparing the side impact fatality or injury risk in cars immediately before and after the transition, separately for the three cohorts. "Side impact fatality risk" could be a ratio of fatalities in side impacts to purely frontal impacts (a control group unaffected by FMVSS 214), as in Chapters 3 to 6. Or it could be a side impact fatality rate per million registration years, as in Chapter 7. But without additional test results for cars produced just before FMVSS 214 certification, we cannot perform a "parametric" evaluation correlating the extent of Δ-TTI(d) with the reduction in fatality risk.

There are three good reasons to organize the data at the make-model level: (1) Statistical before/after analyses are more reliable if they are based on "matched pairs." In other words, if the pre- and post-standard cars are the same make-models, we can have more confidence that any difference in fatality risk is due to FMVSS 214 than if they were different make-models. (2) The implementation date of FMVSS 214 and the number of years of essentially unchanged design before and after the transition vary from model to model and have to be determined one-by-one. We do not have the option just to compare, say, all MY 1997-98 cars to all MY 1995-96 cars, but must define "before" and "after" separately for each model. (3) Installation rates of air bags and ABS - factors that influence fatality risk - also vary from model to model. As explained in Sections 3.2 and 5.1, since air bags reduce fatality risk in pure frontal impacts by about 30 percent and have little effect in side impacts, the presence of air bags ought to increase the ratio of side to frontal fatalities substantially. ABS, associated with a reduction in frontal impacts with other vehicles and an increase in side impacts with fixed objects, will also increase the ratio of side to frontal fatalities. In Chapters 3-7, dealing with older cars, we could simply limit the data to cars without air bags or ABS and not lose too many cases. Here, it is impossible to demand that all

[4]The reduction seems small, given the substantial structural changes described in the Information Request, possibly suggesting nonrepresentative test results for the pre-standard and/or post-standard vehicle - see Appendix B.

cars be consistent on air bags and ABS without losing most of the data. The best we can do is demand consistent installation rates, before and after FMVSS 214, within each individual make-model.

Specifically, the analysis plan focuses on 52 make-model groups of passenger cars with relatively high sales volumes. These are the models that are likely to supply useful quantities of crash data, and they are also the models that have primarily been tested to date. A "make-model group" may consist of a single make-model, or several corporate "cousins" (e.g., Ford Taurus and Mercury Sable) or, in a few cases, one manufacturer's successive offerings in the same general market class (e.g., Ford Tempo and Ford Contour). Appendix B defines and documents each of the 52 groups, starting with No. 1, Ford Taurus/Mercury Sable 4-door and ending with No. 52, Acura Legend 4-door. The numerical ordering of the groups is irrelevant to the analysis plan, but happens to be based on the total 1991-97 sales of the predominant model within each group.

Here is a description, with examples, of the information provided in Appendix B on each make-model group and the way it is used to develop the analysis plan.

The name of the group indicates the constituent make-models and the number of doors. Each group is either all 2-door or all 4-door. The make-models are then identified by two four-digit codes, CG and MM2, as in Section 2.3 and earlier NHTSA evaluations[5], and the applicable model year ranges for each of these codes. Initially, all model years from 1991 through 1997 are considered. The model years of any major redesigns (on a new wheelbase) or minor redesigns (moderate body changes on an existing wheelbase) are specified. They are important, because a TTI(d) result may carry over to subsequent model years, but not beyond either type of redesign. For example, make-model group 1 consists of the 4-door Taurus and Sable, which had codes 1235-1217 and 1235-1417 in 1991-95. After the major redesign of 1996, the codes became 1240-1217 and 1240-1417. There was also a minor redesign, within CG 1217, in 1992.

The next paragraph summarizes test results, self-certification and Information Requests. TTI(d) for the front-seat dummy, speed-adjusted as in Section 2.1 by the formula

$$\text{TTI(d) adjusted} = \text{TTI(d) observed} * (33.54/\text{SPEED})^2$$

is listed for the actual test vehicles and for any other model years the result is believed to carry over. The 1990 and 1996 Taurus were actually tested and had TTI(d) of 77 and 51, respectively. The 1990 result carries over to 1991 and the 1996 result, to 1997, but there is a four-year gap of unknown TTI(d), from the minor redesign of 1992 through 1995, the last year before a major redesign. Self-certification information, as discussed in Section 8.1, is useful for pinpointing the first year that a car met FMVSS 214, although it does not differentiate between cars modified in 1994 and cars that could have met FMVSS 214 even before 1994.

[5]Kahane, C.J., *Relationships between Vehicle Size and Fatality Risk in Model Year 1985-93 Passenger Cars and Light Trucks*, NHTSA Technical Report No. DOT HS 808 570, Washington, 1997, pp. 15-18 and Appendix B.

Information Requests (IR) are the basis for classifying how a car was modified. Let us first look at unequivocal examples. The 1997 Toyota Corolla 4-door (group 4) got B-pillar stiffeners; strengthened cross-members, sills and roof rails; and extensive padding: that's clearly "substantial structure plus padding." The 1997 Ford Escort 4-door (group 5) got extensive padding and a small reinforcement plate in the door structure: that appears to be "padding plus a minor structural change." The 1994 Buick Roadmaster did not receive any modifications and was certified to meet FMVSS 214: "no change - met FMVSS 214 before 1994." Others can be ambiguous: (1) Without a picture, it is not always clear if structural changes are substantial or minor (e.g., group 20, Nissan Altima). (2) IR's for new models are hard to interpret - e.g., the 1995 Mercury Mystique (group 26) is "unmodified"; in fact, it is a new model whose side structure may be substantially upgraded from its predecessor, the 1994 Mercury Topaz. (3) IR's may describe changes without specifying if they were made in that year or a previous year - e.g., Honda Civic 4-door, group 12.

Next, a table shows new-car registrations, by model year, for 1991-97; also, the percent of cars with driver air bags, passenger air bags and ABS, by model year. TTI(d) is recapitulated. Years are shown in *italics* if they will certainly be excluded from the analysis plan because there was a major redesign between those years and the transition to meet FMVSS 214.

The table is used to pinpoint analysis problems due to installation of air bags or ABS. If the FMVSS 214 modifications coincided with a large (20 percent or more) increase in driver air bags or ABS, the model years just before and after the transition must be excluded from the analysis plan, because the ratio of side impacts to pure frontals could be affected by the air bags or ABS in addition to the FMVSS 214 modifications (see Sections 3.2 and 5.1). However, even if the transition years must be excluded from the analysis, we need not drop the make-model group completely. We can take a range of post-standard model years, where air bags and ABS stayed the same, and include them in the "no change" control group cohort (e.g., Nissan Sentra 4-door, group 25). If a make-model was upgraded twice, once to meet FMVSS 214 and a second time to improve performance further, we may be able to include the second transition even though we had to exclude the first (e.g., Toyota Camry 4-door, group 3).

If the transition coincided with a large increase in passenger air bags, we can still retain the transition years in the analysis plan as long as we limit the analysis to driver fatalities (e.g., Honda Accord 4-door, group 2).

Next is the recommended analysis plan: an appraisal of what happened, when it happened, and what ranges of model years should be included as the "before" and the "after" data in the statistical analysis. If the years before and after the original transition to FMVSS 214 cannot be included in the analysis, because of conflict with air bags/ABS or uncertainty about what happened, assignment of subsequent years may be recommended. Table 8-1 summarizes the analysis plan for the 52 make-model groups in Appendix B, showing the type of vehicle change (as defined below), the model year ranges in the analysis, and whether the data should include drivers and right-front (RF) passengers or be limited to drivers.

TABLE 8-1

MAKE-MODEL GROUPS FOR EVALUATING FMVSS 214, PHASE 2
(Preliminary assignments to change groups and model year selection)

Car Group	Change Group	"Before" MY	"After" MY	Include
1. Taurus/Sable 4dr	1SP	1994-95	1996-97	RF+Driver
2. Honda Accord 4dr	1SP	1992-93	1994-97	Driver only*
3. Toyota Camry 4dr	1SP	1995-96	1997	RF+Driver
4. Corolla/Prizm 4dr	1SP	1995-96	1997	RF+Driver
5. Escort/Tracer 4dr	1Pm	1995-96	1997	RF+Driver
6. Chevrolet Lumina 4dr	2a	1995	1996-97	RF+Driver
7. Saturn 4dr	1SP	1994-95	1996-97	RF+Driver
8. GM H Body (LeSabre) 4dr	1Pm	1995-96	1997	RF+Driver
9. GM J Body (Cavalier) 2dr	1Pm	1995-96	1997	RF+Driver
10. Cadillac DeVille 4dr	2a	1994-95	1996-97	RF+Driver
11. GM N Body (Grand Am) 4dr	1P	1996	1997	RF+Driver
12. Honda Civic 4dr	1SP	1995	1996-97	RF+Driver
13. Honda Civic 2dr coupe	1S	1995	1996-97	RF+Driver
14. Chevrolet Corsica 4dr	3	1994	1995-96	RF+Driver
15. Lincoln Town Car 4dr	2a	1994-95	1996-97	RF+Driver
16. GM A Body (Ciera) 4dr	2a	1994	1995-96	RF+Driver
17. GM J Body (Cavalier) 4dr	1P	1996	1997	RF+Driver
18. Ford Mustang 2dr	2t	1996	1997	RF+Driver
19. Nissan Sentra 4dr	2e	1995	1996-97	RF+Driver
20. Nissan Altima 4dr	1u	1995-96	1997	
21. Nissan Maxima 4dr	2t	1995	1996-97	RF+Driver
22. Grand Marquis/Crown Vic 4dr	2a	1994-95	1996-97	RF+Driver
23. Thunderbird/Cougar 2dr	1Pm	1994	1995-96	RF+Driver
24. Chrysler LH (Intrepid) 4dr	1S	1993	1994-95	RF+Driver
25. Ford Escort 2dr	3	1994	1995-96	Driver only*
26. Contour/Mystique 4dr	2e	1996	1997	RF+Driver

*RF passenger cases should be excluded because FMVSS 214 coincided with passenger air bags.

TABLE 8-1 (continued)

MAKE-MODEL GROUPS FOR EVALUATING FMVSS 214, PHASE 2
(Preliminary assignments to change groups and model year selection)

Car Group	Change Group	"Before" MY	"After" MY	Include
27. GM N Body (Grand Am) 2dr	1SP	1996	1997	RF+Driver
28. Camaro/Firebird 2dr	2a	1993-94	1995-97	RF+Driver
29. Caprice/Roadmaster 4dr	2a	1994	1995-96	RF+Driver
30. Mazda 626 4dr	1Pm	1994-95	1996-97	RF+Driver
31. Subaru Legacy 4dr	1SP	1993-94	1995	Driver only*
32. Grand Prix/Regal/Supreme 4dr	2a	1995	1996	RF+Driver
33. Mazda Protege 4dr	2e	1995	1996-97	RF+Driver
34. GM C Body (Park Avenue) 4dr	TBD			
35. Probe/MX6 2dr	2a	1993	1994-96	Driver only*
36. Toyota Tercel 2dr	1SP	1993-94	1995-97	Driver only*
37. VW Jetta 4dr	2e	1995	1996-97	RF+Driver
38. Metro/Swift 2dr	2e	1995	1996-97	RF+Driver
39. Dodge/Plymouth Neon 4dr	1m	1996	1997	
40. Eclipse/Talon 2dr	2t	1996	1997	RF+Driver
41. Honda Accord 2dr	2t	1996	1997	RF+Driver
42. Saturn 2dr	1P	1995-96	1997	RF+Driver
43. Chevrolet Beretta 2dr	3	1994	1995-96	RF+Driver
44. Grand Prix/Regal/Supreme 2dr	3	1995	1996	RF+Driver
45. Acura Integra 2dr	1S	1996	1997	RF+Driver
46. Mitsubishi Galant 4dr	2e	1995	1996-97	RF+Driver
47. Cadillac Seville 4dr	2t	1994-95	1996-97	RF+Driver
48. Lexus ES 4dr	TBD			
49. Toyota Celica 2dr	1SP	1995	1996-97	RF+Driver
50. Lincoln Continental 4dr	1SP	1993-94	1995-97	RF+Driver
51. Plymouth Acclaim/Breeze 4dr	1SP	1994-95	1996-97	Driver only*
52. Acura Legend 4dr	2a	1993	1994-95	RF+Driver

*RF passenger cases should be excluded because FMVSS 214 coincided with passenger air bags.

The type of vehicle change is classified into 11 "change groups" designated by alphanumeric codes:

CARS MODIFIED TO MEET FMVSS 214 AND/OR REDUCE TTI(d)

1SP	substantial structural modifications plus padding, as evidenced by explicit mention of these changes in IR's, or by a reduction in TTI(d) so large that it must have necessitated substantial modification.
1S	substantial structural modifications only
1P	padding only
1Pm	primarily padding, with minor structural modifications
1m	minor structural modifications only
1u	car apparently modified, specifics unknown, will reassign with more information

CARS MEETING FMVSS 214 WITHOUT MODIFICATIONS

2a	"actual" group 2 - models that met FMVSS 214 at all times and/or before 1994, and were not modified in 1994-1997 to reduce TTI(d) - as evidenced by passing TTI(d) scores on pre-1994 vehicles and/or manufacturer statements that they changed nothing, or almost nothing to meet FMVSS 214
2e	"expedient" group 2 - models that were actually modified to meet FMVSS 214, but the transition period cannot be analyzed because the change coincided with driver air bags and/or ABS; so as not to lose these data entirely, we can at least take some post-standard model years and include them in the control group.
2t	"temporary" group 2 - models apparently modified to meet FMVSS 214, but the date and/or extent of the change is unclear; we will reassign them to another group when we get more information, but for now, we can at least take some post-standard model years and include them in the control group.

3	cars that never met FMVSS 214 - generally, make-models discontinued after 1996 and never self-certified; if any pre-1997 cars were tested, TTI(d) always exceeded 85 (4-door) or 90 (2-door).
TBD	unclear if this make/model was changed to meet FMVSS 214 or reduce TTI(d) - will reassign to one of the other groups when we obtain more information

In Appendix B, question marks indicate doubts or ambiguities about these assignments. Appendix B also indicates "non-recommended assignments" that had to be excluded due to conflicts with air bags/ABS or insufficient information.

The three analysis cohorts, "structure," "padding" and "no change" are defined as follows:

STRUCTURE	1SP and 1S
PADDING	1Pm and 1P
NO CHANGE	2a, 2e, 2t and 3

Change groups 1u and TBD are temporarily excluded from the analysis plan until more information is obtained about when or how the cars were modified. At that time, they may be reassigned to the other groups. Similarly the make-models currently in group 2t may be reassigned with more information on the FMVSS 214 transition. Group 1m is excluded, since it is neither structure, nor padding, nor entirely unchanged.

For make-model groups classified 1SP, 1S, 1Pm, 1P, 1m or 1u, the transition year defined in Appendix B is, quite simply, the first model year that cars were modified to meet FMVSS 214 or reduce TTI(d). If the model was never modified (change groups 2a and 3) or if it was not modified in the range of years included in the plan (2e and 2t), the "transition" year could be any of the model years included in the analysis, but it is selected to place between **a** and ½ of the crash cases in the "after" range of model years.

The specific range of model years included in the analysis plan, and their assignment to "before" or "after," as shown in Table 8-1 and Appendix B, must meet the following criteria: (1) TTI(d) is unchanged during the "before" years. (2) TTI(d) is unchanged during the "after" years. (3) Installation rates for driver air bags and ABS are consistent within, and between the "before" and "after" years, differing by no more than 20 percent. (4) Passenger air bag installation rates are consistent, or the analysis is limited to driver fatalities. For make-model groups classified 1SP, 1S, 1Pm, 1P, 1m or 1u, the transition year is the first "after" year and the year before that is the last "before" year. For make-model groups classified 2a, 2e, 2t or 3, TTI(d) is the same "before" and "after": they are a control-group cohort.

When more than one "before" and/or "after" years are available for analysis once all those criteria are satisfied, we do not always include every available year. All ranges are limited to MY 1992 or later, to exclude older cars that might have different crash distributions. To the extent feasible, ranges should be selected to assure that each make-model group has a crash sample of "before" cars as close as possible to **double** its "after" sample. Uniform ratios of "before" and "after" crash cases, by make-model group, assure that the overall "before" and "after" samples have a similar make-model mix (thereby avoiding, for example, a bias due to an overrepresentation of sporty cars in one group or the other). At this time, a target ratio of 2:1 is, heuristically, the best: a smaller ratio would increase sampling error because it would reduce the sample of "before" cars; a larger ratio in many cases cannot be achieved without violating the other criteria.

Δ-TTI(d), as shown in Appendix B, is the reduction in TTI(d) in the transition year. It is always zero in make-models classified 2a, 2e, 2t or 3. It should always be a positive number for make-models classified 1SP, 1S, 1Pm or 1P, but it is mostly unknown since TTI(d) was obtained for only a few 1990-93 models. However, it is unnecessary to know Δ-TTI(d) just to perform a before/after statistical analysis. It is only needed for a parametric analysis that attempts to correlate, by make-model group, the extent of Δ-TTI(d) with the reduction in fatality risk. To perform such analyses, it would be necessary to test additional cars produced just before FMVSS 214. Recommended tests are listed in Appendix B and discussed in Section 8.3.

The analysis plan will be reviewed from time to time, extended to 1998 and later model years as information becomes available, and revised if assessments of the original FMVSS 214 transitions are in error. The model year ranges included for each group will also be revised from time to time, with the goal of approaching a uniform ratio of "before" to "after" cases in each make-model group.

Table 8-2 classifies the make-model groups included in the current analysis plan, by cohort: structure, padding or no change.

The preliminary analysis plan is to generate a 3x2x2 table of driver and right front (RF) passenger fatalities by analysis cohort (structure, padding, no change), impact location (purely frontal, side impact) and model year group ("before," "after"). Side impacts would be defined by IMPACT2 = 2, 3, 4, 8, 9, 10 and purely frontal impacts by IMPACT2 = 12 and M_HARM $\neq$ 1-7, as in Chapters 3-5.   In the structure and padding cohorts, "before" means higher TTI(d) and "after" means lower TTI(d). In the no-change cohort, TTI(d) is the same "before" and "after," as explained in Section 8.2. If Table 8-2 says to include only drivers for a particular make-model, the RF passengers are excluded.

STRUCTURE

	Before	After
Purely frontal fatalities	x_{11}	x_{12}
Side impact fatalities	x_{21}	x_{22}

PADDING

	Before	After
Purely frontal fatalities	y_{11}	y_{12}
Side impact fatalities	y_{21}	y_{22}

NO CHANGE

	'Before'	'After'
Purely frontal fatalities	z_{11}	z_{12}
Side impact fatalities	z_{21}	z_{22}

The effectiveness of FMVSS 214 in cars that got substantially upgraded structure (plus padding, in most cases), is:

TABLE 8-2

MAKE-MODEL GROUPS FOR EVALUATING FMVSS 214 - BY ANALYSIS COHORT
(Preliminary assignments to change groups and model year selection)

Car Group	Change Group	"Before" Pre-Std.214/ Higher TTI(d)	"After" Post-Std.214/ Lower TTI(d)	Include
STRUCTURE				
1. Taurus/Sable 4dr	1SP	1994-95	1996-97	RF+Driver
2. Honda Accord 4dr	1SP	1992-93	1994-97	Driver only*
3. Toyota Camry 4dr	1SP	1995-96	1997	RF+Driver
4. Corolla/Prizm 4dr	1SP	1995-96	1997	RF+Driver
7. Saturn 4dr	1SP	1994-95	1996-97	RF+Driver
12. Honda Civic 4dr	1SP	1995	1996-97	RF+Driver
13. Honda Civic 2dr coupe	1S	1995	1996-97	RF+Driver
24. Chrysler LH (Intrepid) 4dr	1S	1993	1994-95	RF+Driver
27. GM N Body (Grand Am) 2dr	1SP	1996	1997	RF+Driver
31. Subaru Legacy 4dr	1SP	1993-94	1995	Driver only*
36. Toyota Tercel 2dr	1SP	1993-94	1995-97	Driver only*
45. Acura Integra 2dr	1S	1996	1997	RF+Driver
49. Toyota Celica 2dr	1SP	1995	1996-97	RF+Driver
50. Lincoln Continental 4dr	1SP	1993-94	1995-97	RF+Driver
51. Plym Acclaim/Breeze 4dr	1SP	1994-95	1996-97	Driver only*
PADDING				
5. Escort/Tracer 4dr	1Pm	1995-96	1997	RF+Driver
8. GM H Body (LeSabre) 4dr	1Pm	1995-96	1997	RF+Driver
9. GM J Body (Cavalier) 2dr	1Pm	1995-96	1997	RF+Driver
11. GM N Body (Grand Am) 4dr	1P	1996	1997	RF+Driver
17. GM J Body (Cavalier) 4dr	1P	1996	1997	RF+Driver
23. Thunderbird/Cougar 2dr	1Pm	1994	1995-96	RF+Driver
30. Mazda 626 4dr	1Pm	1994-95	1996-97	RF+Driver
42. Saturn 2dr	1P	1995-96	1997	RF+Driver

*RF passenger cases should be excluded because FMVSS 214 coincided with passenger air bags.

TABLE 8-2 (continued)

MAKE-MODEL GROUPS FOR EVALUATING FMVSS 214 - BY ANALYSIS COHORT
(Preliminary assignments to change groups and model year selection)

Car Group	Change Group	"Before" Earlier MY	"After" Later MY	Include
NO CHANGE (during the model years specified)				
6. Chevrolet Lumina 4dr	2a	1995	1996-97	RF+Driver
10. Cadillac DeVille 4dr	2a	1994-95	1996-97	RF+Driver
14. Chevrolet Corsica 4dr	3	1994	1995-96	RF+Driver
15. Lincoln Town Car 4dr	2a	1994-95	1996-97	RF+Driver
16. GM A Body (Ciera) 4dr	2a	1994	1995-96	RF+Driver
18. Ford Mustang 2dr	2t	1996	1997	RF+Driver
19. Nissan Sentra 4dr	2e	1995	1996-97	RF+Driver
21. Nissan Maxima 4dr	2t	1995	1996-97	RF+Driver
22. Grand Marquis/Crown Vic 4dr	2a	1994-95	1996-97	RF+Driver
25. Ford Escort 2dr	3	1994	1995-96	Driver only*
26. Contour/Mystique 4dr	2e	1996	1997	RF+Driver
28. Camaro/Firebird 2dr	2a	1993-94	1995-97	RF+Driver
29. Caprice/Roadmaster 4dr	2a	1994	1995-96	RF+Driver
32. Grand Prix/Regal/Supreme 4dr	2a	1995	1996	RF+Driver
33. Mazda Protege 4dr	2e	1995	1996-97	RF+Driver
35. Probe/MX6 2dr	2a	1993	1994-96	Driver only*
37. VW Jetta 4dr	2e	1995	1996-97	RF+Driver
38. Metro/Swift 2dr	2e	1995	1996-97	RF+Driver
40. Eclipse/Talon 2dr	2t	1996	1997	RF+Driver
41. Honda Accord 2dr	2t	1996	1997	RF+Driver
43. Chevrolet Beretta 2dr	3	1994	1995-96	RF+Driver
44. Grand Prix/Regal/Supreme 2dr	3	1995	1996	RF+Driver
46. Mitsubishi Galant 4dr	2e	1995	1996-97	RF+Driver
47. Cadillac Seville 4dr	2t	1994-95	1996-97	RF+Driver
52. Acura Legend 4dr	2a	1993	1994-95	RF+Driver

*RF passenger cases should be excluded because FMVSS 214 coincided with passenger air bags.

$$1 - [(x_{22} / x_{12}) / (x_{21} / x_{11})]$$

and it ought to be a substantial positive number. The effectiveness of FMVSS 214 in cars that were primarily upgraded with padding is $1 - [(y_{22} / y_{12}) / (y_{21} / y_{11})]$, and our initial expectation is that this should still be positive, but presumably not as large as the effectiveness of structure. The "effectiveness" of FMVSS 214 in cars that remained unchanged, essentially a control group, is $1 - [(z_{22} / z_{12}) / (z_{21} / z_{11})]$, and it ought to be close to zero.

Potential refinements to the initial analysis plan, given sufficient data, include:

- Examination of the data on a make-model by make-model basis. Exclusion of selected make-models in which FMVSS 214 implementation coincided with an extensive redesign that substantially changed the market for that model, resulting in major changes in crash distributions unrelated to FMVSS 214.

- Separate analyses of 2-door and 4-door cars.

- Separate analyses for subgroups of side impacts (compartment and off-center, nearside and farside, single- and multivehicle).

As in Phase 1, this proposed analysis is based on all types of fatal lesions in side impacts. Another approach will be to focus on the type of injuries most associated with TTI(d): thoracic injuries, and especially thoracic injuries due to occupant contact with side interior surfaces. However, the basic FARS data specify neither the body region nor the source of injuries. Data sources include National Automotive Sampling System (NASS), which specifies both, and the FARS Multiple Cause of Death (MCOD) file, which identifies body regions of injuries. The NASS analysis could include nonfatal as well as fatal injuries, and it would be based on injury rates per 100 towaway-involved occupants. NASS and MCOD will need even more time than the basic FARS to accumulate sufficient data.

8.3 Recommended FMVSS 214 tests

A powerful statistical analysis combines the concept of matched pairs with a continuous independent variable. The matched pairs are the "before" and "after" cars within the make-model groups of the preceding section. In each make-model group, the ratio of side impact to purely frontal fatalities [or, alternatively, the ratio of side impact fatalities to registration years, or the ratio of side impact injuries per 100 crash-involved occupants] is calculated "before" and "after" FMVSS 214 - i.e., for the "before" and "after" ranges of model years shown in Table 8-1. The dependent variable is the change in the fatality risk - i.e., the log of the ratio of the "before" and the "after" ratios.

The independent variable is Δ-TTI(d), the reduction in TTI(d) for the "after" model years relative to the "before." The objectives of the analysis are to find out if Δ-TTI(d) is significantly correlated with the magnitude of the fatality reduction, by make-model group, and to calibrate the percentage fatality reduction per unit of Δ-TTI(d).

Unfortunately, Δ-TTI(d) is unknown at this time for most of the make-model groups because few cars were tested in the model years just before FMVSS 214 certification. As stated in Section 8.1, TTI(d) is currently known for cars just before and after the initial FMVSS 214 transition in five make-model groups that got substantial structure, possibly including padding:

	Before	After	Δ-TTI(d)
2. Honda Accord 4dr	86	80	6
4. Toyota Corolla/Geo Prizm 4dr	91	72	19
13. Honda Civic 2dr	86	72	14
19. Nissan Sentra 4dr	92	67	25
24. Chrysler LH Body (Intrepid) 4dr	79	65	14

However, the information on the Nissan Sentra cannot be used in the analysis because the FMVSS 214 transition coincided with the installation of driver and passenger air bags. Δ-TTI(d) observed for the Honda Accord is surprisingly small, given the substantial structural changes described in the Information Request, possibly raising doubts about the accuracy of the "before" and/or "after" test results. That's only three firm data points. We have one additional result. Toyota Camry, although the initial FMVSS 214 transition must be excluded from the analysis because it coincided with a large increase in ABS, was upgraded with additional substantial structure in 1997, and TTI(d) is known before and after that upgrade:

	1994-96	1997	Δ-TTI(d)
3. Toyota Camry 4dr	66	50	16

Δ-TTI(d) is not known for **any** of the make-model groups that only got padding (with or without minor structural revisions).

To make the analysis work, we need at least ten additional data points, preferably more. For example, the correlation analyses of older cars at the make-model level in Section 5.1 were based on 17 data points for 2-door cars and 22 for 4-door cars. At least five of these ten additional data points should be make-models that got primarily padding. That would make a data set with about ten models that got structure and five that got padding: the right mix, since twice as many cars got structure as padding.

Appendix B lists a recommended test for most of the make-model groups - basically all except those that were known to be unchanged (groups 2a and 3), or where the transition cannot be analyzed because it coincided with air bags or ABS (group 2e), or where Δ-TTI(d) is already known. We need to choose a subset of approximately 10 tests, concentrating on those make-model groups that are likely to contribute the most crash data to future analyses, generally the groups with the highest sales volumes, or with historically high crash rates. Two-door as well as 4-door cars should be represented.

Any test program by NHTSA is subject to the availability of funds. Of course, the agency would welcome any test results from the manufacturers or other organizations, submitted as public or confidential information. Those data could really enhance the analysis and enable NHTSA to include additional vehicles.

Among cars produced just before FMVSS 214 transitions that apparently included substantial upgrades to **structures**, the make-models with the highest priority for testing are:

1. 1994 or 1995 Ford Taurus 4dr
7. 1994 or 1995 Saturn SL1 4dr
12. 1995 Honda Civic 4dr
36. 1993 or 1994 Toyota Tercel 2dr

If additional testing is possible, we might also consider:

27. 1997 or later Pontiac Grand Am 2dr (a compliance test - here, only the "before" is known)
31. 1993 or 1994 Subaru Legacy 4dr
51. 1994 or 1995 Plymouth Acclaim 4dr (for comparison to Plymouth Breeze)

Among the cars produced just before FMVSS 214 transitions that seem to have mainly involved **padding**, the priority make-models are:

5. 1995 or 1996 Ford Escort 4dr
8. 1995 or 1996 Buick LeSabre 4dr
9. 1995 or 1996 Chevrolet Cavalier 2dr
11. 1996 Pontiac Grand Am 4dr
23. 1994 Ford Thunderbird 4dr

If additional testing is possible, we might also consider:

17. 1996 Chevrolet Cavalier 4dr
30. 1994 or 1995 Mazda 626 4dr

Two other make-models, for which it is not quite clear what was changed or when it happened, should be tested so they can be included in future analyses:

18. 1994 or 1995 Ford Mustang 2dr coupe
21. 1993 or 1994 Nissan Maxima 4dr

Finally, it would be desirable to check Δ-TTI(d) for the Honda Accord 4-door, if necessary by retesting a 1992-93 Accord and/or a 1994-96 Accord.

DISCUSSION OF FINDINGS

Although this report generally finds an overall correlation between TTI(d) and fatality risk in actual crashes in the baseline, Phase 1 cars, one contrast clearly emerges from the analyses:

- In 2-door cars of model years 1981-93, pre-FMVSS 214, there is a strong relationship between TTI(d) and overall fatality risk in actual side impacts - the lower the TTI(d), the lower the fatality risk.

- In 4-door cars of model years 1981-93, pre-FMVSS 214, the data show at most a weak relationship between TTI(d) and overall fatality risk in actual side impacts.

Can it really be true that TTI(d) has a strong association with fatality risk in older 2-door cars but not in 4-door cars? If so, why?

The first question is if the strong results for pre-standard 2-door cars are spurious: an artifact of the data or the statistical method. Would we expect the make-models with high TTI(d) to have high fatality rates in side impacts for reasons unrelated to crashworthiness? For example, are they all sporty cars with a high percentage of young male drivers, who have many side impacts with fixed objects? We have already rejected this possibility in our model-by-model review of the data in Section 3.5. The make-models in our study are almost all small economy cars or the 2-door versions of average-sized, non-luxury cars. The only exceptions, Chevrolet Corvette and Ford Mustang, were in the middle of the TTI(d) range, not at either end.

Could the observed effect have been the result of chance alone? Since relatively few distinct make-models were involved, could it be that the models with high TTI(d) just happened to have high fatality rates in the limited FARS data, and the models with low TTI(d), low rates? The strength of the observed relationships and the large number of fatality cases just about rules out pure chance occurrences. It also does not seem a chance occurrence that, throughout Chapters 3-6, the relationship gets stronger in those subsets of crashes where it's intuitively expected: in compartment impacts, nearside impacts, collisions with another passenger car, etc - in 2-door cars but not in 4-door cars.

Could the make-models with the poorest side impact crashworthiness (for real) just happen to have high TTI(d) - but there is no connection between the TTI(d) and the crashworthiness? It's theoretically possible but far-fetched. The statistical relationships between TTI(d) and fatality risk are strong and consistent enough that it is most likely there is a real relationship here - in pre-standard 2-door cars.

The second question, conversely, is if an artifact of the data or the statistical method weakened the results for 4-door cars, masking the real effect of TTI(d). One data factor has been discussed in Sections 3.6 and 5.3: the limited *effective* range of TTI(d) scores. Although the full range of scores is wide, many of the 4-door cars with large FARS samples are concentrated in a narrow range from 77 to 94 (while the 2-door cars are more uniformly distributed across their full range).

Concentration in the middle especially diminishes the power of correlation and regression analyses. Indeed, some of the most positive results for 4-door cars are in Chapter 4: they are not based on either correlation or regression, but compare the fatality rates of just the best and worst performers (although even these results fall somewhat short of statistical significance). The only statistically significant finding in 4-door cars was a correlation analysis in Section 3.6 that included the models Lincoln Town Car and Chevrolet Caprice, widening the effective range of TTI(d), but introducing possible biases by making the data less homogeneous.

In summary, could the weakness of the results in 4-door cars be a statistical problem? Maybe.

One obvious difference between 2-door and 4-door baseline cars is that the 2-door cars have much higher TTI(d). The average TTI(d) is close to 110 in pre-standard 2-door cars, 80 in pre-standard 4-door cars [and about 70 in post-standard cars]. Could there be easy-to-measure benefits in reducing TTI(d) from 130 to 100, say, but only hard-to-detect benefits in reducing from 90 to 60?

This, too, could be more a statistical/data problem than a real difference between 2-door and 4-door cars. It could be that the effect of TTI(d) is about equally strong in relative terms at all TTI(d) - i.e., a reduction of one unit in TTI(d), whether from 110 to 109 or 60 to 59, produces an x percent reduction in thoracic injuries due to contact with side structures. However, at low TTI(d), the absolute rates of thoracic injuries are so much lower that it just becomes more difficult to see statistically significant reductions - especially in FARS analyses based on overall fatality rates, where the thoracic/side surface injuries are pooled with all the other fatal lesions.

Alternatively, the TTI(d)-fatality relationship might really be stronger in relative as well as absolute terms at higher TTI(d). That could explain why the results are stronger for 2-door cars. It would resemble a conclusion in NHTSA's evaluation of the New Car Assessment Program (NCAP): "the data show that cars with poor [frontal] NCAP scores (e.g., above the FMVSS 208 criteria) have significantly elevated fatality risk in head-on collisions, but they do not show a significant difference between the fatality risk of cars with exceptionally good NCAP performance and those with merely average performance."[1] FMVSS 214 has already produced significant benefits by eliminating those vehicles with TTI(d) levels in the 120's and 130's.

Nevertheless, there is nothing in this report, other than different results for 2-door and 4-door cars, to prove that the benefits of reducing TTI(d) are primarily at the high end. If they were, we would expect Figure 3-5, our graph of fatality risk by TTI(d) at the make-model level to show a relationship that gets stronger as TTI(d) gets higher. We would expect a nonlinear trend, flat on the left side and steeply rising on the right. However, the scatter in Figure 3-5 as well as Figures 3-6 - 3-9 is too great for clear-cut answers. None of them shows an unequivocal nonlinear trend. Some look fairly linear, while others could be consistent with a nonlinear pattern. At this time, we can neither embrace nor rule out the hypothesis that the TTI(d)-fatality relationship is stronger in relative as well as absolute terms at higher TTI(d).

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[1]Kahane, C.J., *Correlation of NCAP Performance with Fatality Risk in Actual Head-On Collisions*, NHTSA Technical Report No. DOT HS 808 061, Washington, 1994, p. xviii.

Another evident difference of pre-standard 2-door and 4-door cars is in the design of the side structure. Two-door cars had exceptionally wide doors, with little internal support other than side door beams of 1970-80's construction. They offered little initial resistance to a striking vehicle. The side structure contacts the occupant at high speed, before the striking vehicle engages more rigid structures and transfers significant momentum to the struck vehicle. In 4-door cars, by contrast, the striking vehicle may have been slowed down to a greater extent before the occupant contacts the side structure.

Thus, it is not surprising that baseline 2-door cars had, on the average, higher TTI(d) and higher side-impact fatality rates than 4-door cars. It can also explain why TTI(d) is uncorrelated with curb weight in 2-door cars but strongly decreases in the heavier 4-door cars (see Figure 4-1): only the heavy 4-door cars can quickly slow down the striking vehicle. But it provides no obvious explanation why a reduction of TTI(d) could be highly beneficial in 2-door cars but only have limited effect in 4-door cars.

One possibility is that injury distributions are different in 2-door and 4-door cars. If 2-door cars had an exceptionally high proportion of the type of injury mechanism that is best predicted and modeled by TTI(d) - torso contacts with the side door structure - while 4-door cars primarily had other injury types in side impacts - e.g., head contacts with rails and pillars - it would be easy to see why TTI(d) reductions were more beneficial in 2-door cars. However, National Automotive Sampling System (NASS) data for 1989-94 indicate that occupants of 2-door and 4-door cars have very similar distributions of life-threatening injuries (AIS[2] 4-6): 63 percent of the life-threatening injuries to non-ejected nearside occupants of 2-door cars are torso contacts with the side interior surface, and 62 percent in 4-door cars.

On the other hand, these NASS data show one important difference between baseline 2- and 4-door cars on how the injuries occurred. In the 2-door cars, 52 percent of the life-threatening torso contacts with the side interior surface involved external vehicle crush over 60 centimeters, but in the 4-door cars, only 16 percent. Similarly, in the 2-door cars, 47 percent of these injuries involved vehicle damage that extended into Collision Deformation Classification[3] zone 5 or beyond, but in the 4-door cars, only 21 percent. In other words, extremely severe intrusion of the vehicle's side structure is far more common among the injury cases in the 2-door cars. That is not surprising, given both the vulnerability of the side structures in 2-door cars and the tendency of their [often young] drivers to get involved in more severe crashes. If TTI(d) were a better predictor of fatality risk in cases with extremely severe intrusion than in cases with less severe intrusion, that could explain why a reduction of TTI(d) would be more beneficial in the 2-door cars. But, again, there is no obvious reason why TTI(d) should be a better predictor of fatality risk in cases with extremely severe intrusion than in the cases with less severe intrusion. It's not implausible, but it's not obvious, either. (A further caveat: in the baseline side impact tests, unlike

[2] *The Abbreviated Injury Scale (AIS) - 1990 Revision*, American Association for Automotive Medicine, Des Plaines, IL, 1990.

[3] "Collision Deformation Classification," SAE Recommended Practice No. J224 MAR80 in *1985 SAE Handbook*, Vol. 4, Society of Automotive Engineers, Warrendale, PA, 1985.

the NASS injury cases, average maximum crush was only slightly higher in the 2-door cars than in the 4-door cars.)

Thus, we are unable to conclude unequivocally that TTI(d) has a strong association with fatality risk only in older 2-door cars but not in 4-door cars. Even though the analyses lean strongly in that direction, it is conceivable that data problems are masking some of the effect in 4-door cars. And if the effect is indeed much stronger in older 2-door cars than in older 4-door cars, we are unable to provide a clear-cut explanation of why that should be so, but are only able to point out some differences between 2-door and 4-door cars that might be influential.

The Phase 2 evaluation report will perhaps shed light on some of these issues. More crash data will be available, above all on later-model cars. The inclusion of post-1993 cars that perform very well on the FMVSS 214 test will substantially increase the effective range of TTI(d) in the data, correcting a possible weakness in the current sample of 4-door cars. In addition to overall fatality rates in the basic FARS data, it will be useful to focus on thoracic injuries, especially thoracic injuries due to contact with side surfaces, using the National Automotive Sampling System (NASS) and FARS Multiple Cause of Death (MCOD) files.

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APPENDIX A

SIDE IMPACT FATALITY RISK AND OTHER STATISTICS FOR THREE QUANTILE GROUPS OF TTI(d)

Based on front outboard fatalities at seats without air bags in cars with no ABS or less than 10 percent optional ABS. Includes all FARS cases that match the make-model of a FMVSS 214 test vehicle, same or similar model year (no redesign in the interim). "Side impact fatality risk" is (side impact fatalities) / (purely frontal fatalities). Statistics for 2-door cars are limited to vehicles weighing 1700-3299 pounds. Statistics for 4-door cars limited to vehicles weighing 1900-3299 pounds (however, statistics for Chevrolet Caprice/Lincoln Town Car are also shown on a separate line). Three quantile groups of TTI(d) are lowest 15 percent, middle 70 percent and highest 15 percent. Methods for defining quantile groups are:

- 2-door cars weighing 1700-3299 pounds - based on distribution of TTI(d) for all side and purely frontal fatality cases.
- 2-door cars weighing 1700-3299 pounds - based on distribution of TTI(d) for the fatality cases within each 200 pound class interval of curb weight.
- 4-door cars weighing 1900-3299 pounds - based on distribution of TTI(d) for all side and purely frontal fatality cases.
- 4-door cars weighing 1900-3299 pounds - based on distribution of TTI(d) for the fatality cases within each 200 pound class interval of curb weight.

ANALYSIS NO. 1: 2-DOOR CARS WEIGHING 1700-3299 POUNDS, BASED ON DISTRIBUTION OF TTI(d) FOR ALL SIDE AND PURELY FRONTAL FATALITY CASES

ALL SIDE IMPACTS
2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LT 102	1182	0.807	94.26	2242	35.36	0.426	0.282
102 TO 115	5156	1.067	109.92	2630	30.29	0.359	0.292
GT 115	1572	1.068	123.11	2261	33.62	0.413	0.249

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LT 102	0.000	0.238	0.000	4.46	1986.30	1990.75
102 TO 115	0.000	0.287	0.060	4.71	1986.37	1991.07
GT 115	0.001	0.253	0.008	5.05	1984.64	1989.69

2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS, OCCUPANTS AGE 30-65

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LT 102	405	0.646	94.25	2251	43.49	0.415	0.296
102 TO 115	1560	0.871	110.02	2555	41.63	0.405	0.315
GT 115	549	0.961	123.36	2291	43.08	0.446	0.257

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LT 102	0.000	0.165	0.000	4.92	1986.12	1991.04
102 TO 115	0.000	0.201	0.055	4.92	1986.43	1991.34
GT 115	0.002	0.189	0.015	5.25	1984.82	1990.07

*SIDE = (side impact fatalities) / (purely frontal fatalities)

NEARSIDE COMPARTMENT IMPACTS
2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LT 102	903	0.381	94.18	2242	35.01	0.415	0.282
102 TO 115	3824	0.533	109.92	2615	30.77	0.365	0.301
GT 115	1179	0.551	123.17	2266	34.15	0.406	0.242

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LT 102	0.000	0.249	0.000	4.51	1986.30	1990.81
102 TO 115	0.000	0.298	0.058	4.69	1986.46	1991.15
GT 115	0.002	0.266	0.008	4.99	1984.67	1989.66

2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS, OCCUPANTS AGE 30-65

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LT 102	325	0.321	94.25	2253	43.80	0.412	0.298
102 TO 115	1192	0.429	110.01	2532	41.97	0.416	0.328
GT 115	421	0.504	123.43	2299	43.15	0.439	0.245

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LT 102	0.000	0.163	0.000	4.93	1986.09	1991.01
102 TO 115	0.000	0.211	0.054	4.89	1986.56	1991.45
GT 115	0.002	0.204	0.014	5.25	1984.85	1990.10

*SIDE = (side impact fatalities) / (purely frontal fatalities)

ALL SIDE IMPACTS BY ANOTHER VEHICLE
2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LT 102	707	0.948	94.21	2250	37.78	0.467	0.313
102 TO 115	2562	1.013	110.00	2548	32.22	0.427	0.347
GT 115	895	1.162	123.59	2245	35.59	0.453	0.296

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LT 102	0.000	0.243	0.000	4.41	1986.17	1990.57
102 TO 115	0.000	0.289	0.047	4.70	1986.43	1991.13
GT 115	0.001	0.260	0.009	5.04	1984.58	1989.62

2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS, OCCUPANTS AGE 30-65

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LT 102	250	0.748	94.12	2260	44.04	0.432	0.328
102 TO 115	885	0.817	110.13	2480	42.30	0.447	0.338
GT 115	317	1.156	124.26	2236	43.80	0.492	0.284

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LT 102	0.000	0.180	0.000	4.83	1985.98	1990.81
102 TO 115	0.000	0.216	0.041	4.74	1986.49	1991.23
GT 115	0.001	0.186	0.019	5.21	1984.64	1989.84

*SIDE = (side impact fatalities) / (purely frontal fatalities)

NEARSIDE COMPARTMENT IMPACTS BY ANOTHER VEHICLE
2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LT 102	528	0.455	94.23	2250	36.72	0.441	0.303
102 TO 115	1956	0.537	109.99	2533	32.23	0.422	0.355
GT 115	682	0.647	123.55	2253	35.61	0.446	0.284

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LT 102	0.000	0.246	0.000	4.43	1986.23	1990.65
102 TO 115	0.000	0.303	0.045	4.71	1986.53	1991.23
GT 115	0.002	0.280	0.010	4.96	1984.64	1989.59

2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS, OCCUPANTS AGE 30-65

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LT 102	199	0.392	94.27	2264	44.22	0.422	0.327
102 TO 115	696	0.429	110.12	2463	42.43	0.444	0.349
GT 115	241	0.639	124.25	2252	43.56	0.494	0.274

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LT 102	0.000	0.176	0.000	4.80	1985.97	1990.77
102 TO 115	0.000	0.226	0.043	4.73	1986.62	1991.35
GT 115	0.001	0.212	0.021	5.21	1984.73	1989.93

*SIDE = (side impact fatalities) / (purely frontal fatalities)

ALL SIDE IMPACTS BY A PASSENGER CAR

2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LT 102	328	0.918	94.34	2267	38.41	0.470	0.290
102 TO 115	1116	0.996	110.04	2566	33.22	0.426	0.328
GT 115	410	1.330	123.54	2221	36.26	0.471	0.259

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LT 102	0.000	0.247	0.000	4.22	1985.91	1990.12
102 TO 115	0.000	0.312	0.054	4.49	1986.30	1990.79
GT 115	0.001	0.288	0.012	4.65	1984.37	1989.01

2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS, OCCUPANTS AGE 30-65

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LT 102	121	0.704	94.08	2274	43.88	0.471	0.298
102 TO 115	407	0.817	110.19	2500	42.40	0.455	0.310
GT 115	147	1.333	124.12	2208	43.95	0.537	0.211

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LT 102	0.000	0.182	0.000	4.32	1985.89	1990.21
102 TO 115	0.000	0.229	0.039	4.57	1986.23	1990.79
GT 115	0.001	0.218	0.027	4.82	1984.35	1989.16

*SIDE = (side impact fatalities) / (purely frontal fatalities)

NEARSIDE COMPARTMENT IMPACTS BY A PASSENGER CAR
2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LT 102	246	0.439	94.14	2272	38.13	0.447	0.285
102 TO 115	837	0.497	110.05	2545	33.12	0.436	0.333
GT 115	301	0.710	123.68	2221	36.24	0.472	0.262

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LT 102	0.000	0.264	0.000	4.24	1985.80	1990.03
102 TO 115	0.000	0.327	0.053	4.46	1986.40	1990.86
GT 115	0.001	0.319	0.017	4.40	1984.44	1988.83

2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS, OCCUPANTS AGE 30-65

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LT 102	97	0.366	93.89	2276	44.32	0.464	0.320
102 TO 115	320	0.429	110.19	2467	42.56	0.472	0.319
GT 115	105	0.667	124.11	2227	43.41	0.562	0.200

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LT 102	0.000	0.186	0.000	4.36	1985.75	1990.11
102 TO 115	0.000	0.244	0.044	4.48	1986.38	1990.84
GT 115	0.002	0.267	0.038	4.63	1984.50	1989.11

*SIDE = (side impact fatalities) / (purely frontal fatalities)

ANALYSIS NO. 2: 2-DOOR CARS WEIGHING 1700-3299 POUNDS, BASED ON DISTRIBUTION OF TTI(d) FOR THE FATALITY CASES WITHIN EACH 200 POUND CLASS INTERVAL OF CURB WEIGHT

ALL SIDE IMPACTS
2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LOW 15% IN ITS WTGP	1209	0.898	100.22	2489	33.22	0.390	0.280
MID 70% IN ITS WTGP	5533	1.044	110.62	2502	30.79	0.374	0.287
HI 15% IN ITS WTGP	1168	1.071	118.56	2496	34.47	0.398	0.262

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LOW 15% IN ITS WTGP	0.000	0.262	0.007	4.55	1986.07	1990.61
MID 70% IN ITS WTGP	0.000	0.281	0.053	4.74	1986.14	1990.88
HI 15% IN ITS WTGP	0.002	0.246	0.020	4.92	1985.34	1990.26

2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS, OCCUPANTS AGE 30-65

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LOW 15% IN ITS WTGP	413	0.721	99.76	2500	42.01	0.390	0.281
MID 70% IN ITS WTGP	1697	0.877	110.98	2417	42.05	0.421	0.306
HI 15% IN ITS WTGP	404	0.870	118.78	2532	43.32	0.421	0.292

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LOW 15% IN ITS WTGP	0.000	0.174	0.002	5.12	1985.69	1990.80
MID 70% IN ITS WTGP	0.000	0.203	0.048	4.96	1986.19	1991.14
HI 15% IN ITS WTGP	0.002	0.171	0.027	5.01	1985.71	1990.71

*SIDE = (side impact fatalities) / (purely frontal fatalities)

NEARSIDE COMPARTMENT IMPACTS
2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LOW 15% IN ITS WTGP	898	0.410	99.89	2470	33.33	0.388	0.281
MID 70% IN ITS WTGP	4140	0.529	110.63	2489	31.16	0.377	0.293
HI 15% IN ITS WTGP	868	0.539	118.54	2505	35.27	0.392	0.258

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LOW 15% IN ITS WTGP	0.000	0.268	0.007	4.56	1986.08	1990.63
MID 70% IN ITS WTGP	0.000	0.295	0.051	4.73	1986.20	1990.92
HI 15% IN ITS WTGP	0.002	0.251	0.017	4.89	1985.49	1990.38

2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS, OCCUPANTS AGE 30-65

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LOW 15% IN ITS WTGP	322	0.342	99.44	2479	42.59	0.394	0.276
MID 70% IN ITS WTGP	1309	0.448	111.02	2396	42.24	0.425	0.316
HI 15% IN ITS WTGP	307	0.421	118.52	2555	43.75	0.430	0.290

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LOW 15% IN ITS WTGP	0.000	0.180	0.000	5.16	1985.62	1990.78
MID 70% IN ITS WTGP	0.000	0.209	0.047	4.93	1986.30	1991.23
HI 15% IN ITS WTGP	0.003	0.189	0.026	4.97	1985.82	1990.79

*SIDE = (side impact fatalities) / (purely frontal fatalities)

ALL SIDE IMPACTS BY ANOTHER VEHICLE
2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LOW 15% IN ITS WTGP	619	1.043	98.57	2404	35.50	0.462	0.344
MID 70% IN ITS WTGP	2915	0.992	110.83	2427	32.89	0.436	0.328
HI 15% IN ITS WTGP	630	1.218	118.99	2484	36.93	0.432	0.327

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LOW 15% IN ITS WTGP	0.000	0.237	0.003	4.42	1985.99	1990.41
MID 70% IN ITS WTGP	0.000	0.289	0.040	4.78	1986.13	1990.91
HI 15% IN ITS WTGP	0.002	0.251	0.017	4.77	1985.34	1990.11

2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS, OCCUPANTS AGE 30-65

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LOW 15% IN ITS WTGP	215	0.792	98.12	2375	43.33	0.447	0.353
MID 70% IN ITS WTGP	1015	0.839	111.14	2370	42.57	0.449	0.314
HI 15% IN ITS WTGP	222	1.114	119.29	2488	44.19	0.486	0.342

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LOW 15% IN ITS WTGP	0.000	0.177	0.000	5.03	1985.74	1990.78
MID 70% IN ITS WTGP	0.000	0.215	0.035	4.82	1986.13	1990.95
HI 15% IN ITS WTGP	0.002	0.176	0.027	4.88	1985.64	1990.52

*SIDE = (side impact fatalities) / (purely frontal fatalities)

NEARSIDE COMPARTMENT IMPACTS BY ANOTHER VEHICLE
2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LOW 15% IN ITS WTGP	443	0.462	98.46	2395	34.81	0.440	0.348
MID 70% IN ITS WTGP	2243	0.533	110.77	2416	32.71	0.430	0.329
HI 15% IN ITS WTGP	480	0.690	118.89	2496	37.35	0.425	0.323

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LOW 15% IN ITS WTGP	0.000	0.248	0.005	4.47	1986.07	1990.53
MID 70% IN ITS WTGP	0.000	0.303	0.038	4.76	1986.21	1990.96
HI 15% IN ITS WTGP	0.002	0.260	0.017	4.74	1985.46	1990.20

2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS, OCCUPANTS AGE 30-65

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LOW 15% IN ITS WTGP	166	0.383	98.05	2367	43.59	0.434	0.355
MID 70% IN ITS WTGP	801	0.451	111.14	2355	42.58	0.442	0.321
HI 15% IN ITS WTGP	169	0.610	118.63	2535	44.28	0.509	0.343

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LOW 15% IN ITS WTGP	0.000	0.181	0.000	5.11	1985.61	1990.73
MID 70% IN ITS WTGP	0.000	0.223	0.037	4.80	1986.26	1991.06
HI 15% IN ITS WTGP	0.002	0.201	0.030	4.81	1985.84	1990.65

*SIDE = (side impact fatalities) / (purely frontal fatalities)

ALL SIDE IMPACTS BY A PASSENGER CAR
2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LOW 15% IN ITS WTGP	287	0.993	99.05	2427	34.47	0.446	0.352
MID 70% IN ITS WTGP	1292	1.003	110.74	2440	34.36	0.445	0.299
HI 15% IN ITS WTGP	275	1.350	119.61	2433	37.26	0.433	0.291

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LOW 15% IN ITS WTGP	0.000	0.244	0.007	4.27	1985.71	1989.97
MID 70% IN ITS WTGP	0.000	0.307	0.043	4.53	1986.01	1990.54
HI 15% IN ITS WTGP	0.002	0.295	0.029	4.42	1984.94	1989.36

2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS, OCCUPANTS AGE 30-65

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LOW 15% IN ITS WTGP	105	0.750	98.31	2381	42.94	0.457	0.343
MID 70% IN ITS WTGP	474	0.866	111.00	2395	42.76	0.470	0.276
HI 15% IN ITS WTGP	96	1.182	120.25	2417	44.25	0.521	0.271

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LOW 15% IN ITS WTGP	0.000	0.152	0.000	4.51	1985.73	1990.25
MID 70% IN ITS WTGP	0.000	0.230	0.034	4.56	1985.91	1990.46
HI 15% IN ITS WTGP	0.002	0.229	0.042	4.75	1985.04	1989.79

*SIDE = (side impact fatalities) / (purely frontal fatalities)

NEARSIDE COMPARTMENT IMPACTS BY A PASSENGER CAR

2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LOW 15% IN ITS WTGP	207	0.438	98.56	2415	34.65	0.440	0.367
MID 70% IN ITS WTGP	973	0.509	110.66	2427	33.99	0.452	0.298
HI 15% IN ITS WTGP	204	0.744	119.72	2434	38.03	0.422	0.304

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LOW 15% IN ITS WTGP	0.000	0.266	0.010	4.33	1985.59	1989.92
MID 70% IN ITS WTGP	0.000	0.324	0.042	4.45	1986.08	1990.52
HI 15% IN ITS WTGP	0.002	0.319	0.029	4.27	1985.15	1989.42

2-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1700-3299 POUNDS, OCCUPANTS AGE 30-65

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
LOW 15% IN ITS WTGP	83	0.383	97.85	2347	43.57	0.458	0.373
MID 70% IN ITS WTGP	367	0.445	110.83	2375	42.73	0.485	0.278
HI 15% IN ITS WTGP	72	0.636	119.52	2466	44.14	0.542	0.292

TTI(d) Group	ABS	RFPASS	CONVRTBL	VEHAGE	MY	CY
LOW 15% IN ITS WTGP	0.000	0.145	0.000	4.66	1985.60	1990.27
MID 70% IN ITS WTGP	0.000	0.251	0.038	4.43	1986.04	1990.46
HI 15% IN ITS WTGP	0.002	0.278	0.056	4.57	1985.42	1989.99

*SIDE = (side impact fatalities) / (purely frontal fatalities)

ANALYSIS NO. 3: 4-DOOR CARS WEIGHING 1900-3299 POUNDS - BASED ON DISTRIBUTION OF TTI(d) FOR ALL SIDE AND PURELY FRONTAL FATALITY CASES

ALL SIDE IMPACTS
4-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1900-3299 POUNDS

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
CAPRICE & TOWN CAR	2239	0.678	47.91	3750	56.66	0.389	0.331
LT 78	3257	0.901	75.75	2803	50.68	0.488	0.360
78 TO 95	6971	0.888	84.26	2581	46.63	0.479	0.375
GT 95	2059	0.872	107.44	2337	44.44	0.487	0.379

TTI(d) Group	ABS	RFPASS	STAWAGON	VEHAGE	MY	CY
CAPRICE & TOWN CAR	0.000	0.237	0.000	6.04	1985.08	1991.12
LT 78	0.001	0.265	0.154	5.47	1986.22	1991.69
78 TO 95	0.004	0.273	0.171	5.05	1986.08	1991.12
GT 95	0.000	0.235	0.102	5.27	1985.10	1990.37

4-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1900-3299 POUNDS, OCCUPANTS AGE 30-65

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
CAPRICE & TOWN CAR	942	0.589	47.32	3772	49.09	0.383	0.283
LT 78	1361	0.727	75.64	2802	45.81	0.514	0.334
78 TO 95	2883	0.692	84.44	2567	45.97	0.497	0.355
GT 95	827	0.767	107.49	2330	45.22	0.496	0.363

TTI(d) Group	ABS	RFPASS	STAWAGON	VEHAGE	MY	CY
CAPRICE & TOWN CAR	0.000	0.149	0.000	5.62	1985.00	1990.62
LT 78	0.001	0.206	0.192	5.17	1986.13	1991.29
78 TO 95	0.004	0.215	0.207	4.83	1986.05	1990.88
GT 95	0.000	0.172	0.102	5.08	1985.03	1990.10

*SIDE = (side impact fatalities) / (purely frontal fatalities)

ANALYSIS NO. 4: 4-DOOR CARS WEIGHING 1900-3299 POUNDS - BASED ON DISTRIBUTION OF TTI(d) FOR THE FATALITY CASES WITHIN EACH 200 POUND CLASS INTERVAL OF CURB WEIGHT

ALL SIDE IMPACTS

4-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1900-3299 POUNDS

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
CAPRICE & TOWN CAR	2239	0.678	47.91	3750	56.66	0.389	0.331
LOW 15% IN ITS WTGP	1862	0.815	77.30	2600	45.11	0.476	0.350
MID 70% IN ITS WTGP	8608	0.904	84.98	2593	47.97	0.488	0.371
HI 15% IN ITS WTGP	1817	0.897	98.99	2624	46.59	0.462	0.396

TTI(d) Group	ABS	RFPASS	STAWAGON	VEHAGE	MY	CY
CAPRICE & TOWN CAR	0.000	0.237	0.000	6.04	1985.08	1991.12
LOW 15% IN ITS WTGP	0.000	0.253	0.176	5.11	1986.41	1991.51
MID 70% IN ITS WTGP	0.002	0.268	0.171	5.21	1985.92	1991.12
HI 15% IN ITS WTGP	0.006	0.259	0.054	5.26	1985.63	1990.88

4-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1900-3299 POUNDS, OCCUPANTS AGE 30-65

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
CAPRICE & TOWN CAR	942	0.589	47.32	3772	49.09	0.383	0.283
LOW 15% IN ITS WTGP	808	0.619	77.18	2607	45.47	0.512	0.311
MID 70% IN ITS WTGP	3528	0.731	85.06	2584	45.94	0.499	0.352
HI 15% IN ITS WTGP	735	0.738	99.09	2607	45.53	0.501	0.388

TTI(d) Group	ABS	RFPASS	STAWAGON	VEHAGE	MY	CY
CAPRICE & TOWN CAR	0.000	0.149	0.000	5.62	1985.00	1990.62
LOW 15% IN ITS WTGP	0.000	0.192	0.223	5.00	1986.30	1991.29
MID 70% IN ITS WTGP	0.002	0.211	0.204	4.98	1985.86	1990.83
HI 15% IN ITS WTGP	0.006	0.197	0.057	4.85	1985.70	1990.55

*SIDE = (side impact fatalities) / (purely frontal fatalities)

NEARSIDE COMPARTMENT IMPACTS
4-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1900-3299 POUNDS

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
CAPRICE & TOWN CAR	1837	0.377	47.92	3749	56.67	0.383	0.322
LOW 15% IN ITS WTGP	1465	0.428	77.43	2594	45.18	0.476	0.345
MID 70% IN ITS WTGP	6672	0.475	84.95	2595	48.04	0.477	0.372
HI 15% IN ITS WTGP	1407	0.469	99.02	2623	46.38	0.461	0.392

TTI(d) Group	ABS	RFPASS	STAWAGON	VEHAGE	MY	CY
CAPRICE & TOWN CAR	0.000	0.234	0.000	6.12	1985.05	1991.16
LOW 15% IN ITS WTGP	0.000	0.265	0.173	5.05	1986.40	1991.45
MID 70% IN ITS WTGP	0.003	0.276	0.175	5.18	1985.95	1991.13
HI 15% IN ITS WTGP	0.006	0.271	0.053	5.19	1985.66	1990.85

4-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1900-3299 POUNDS, OCCUPANTS AGE 30-65

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
CAPRICE & TOWN CAR	785	0.324	47.38	3769	49.05	0.380	0.275
LOW 15% IN ITS WTGP	662	0.327	77.35	2598	45.50	0.505	0.301
MID 70% IN ITS WTGP	2803	0.375	85.00	2588	45.84	0.490	0.355
HI 15% IN ITS WTGP	584	0.381	98.90	2615	45.86	0.500	0.370

TTI(d) Group	ABS	RFPASS	STAWAGON	VEHAGE	MY	CY
CAPRICE & TOWN CAR	0.000	0.146	0.000	5.72	1984.95	1990.66
LOW 15% IN ITS WTGP	0.000	0.198	0.218	4.88	1986.27	1991.13
MID 70% IN ITS WTGP	0.002	0.216	0.203	4.98	1985.90	1990.88
HI 15% IN ITS WTGP	0.007	0.219	0.051	4.88	1985.75	1990.63

*SIDE = (side impact fatalities) / (purely frontal fatalities)

ALL SIDE IMPACTS BY ANOTHER VEHICLE
4-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1900-3299 POUNDS

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
CAPRICE & TOWN CAR	1358	0.889	47.95	3748	58.77	0.432	0.372
LOW 15% IN ITS WTGP	1191	1.026	77.05	2621	47.79	0.507	0.390
MID 70% IN ITS WTGP	5625	1.120	85.15	2586	50.26	0.527	0.408
HI 15% IN ITS WTGP	1137	1.090	99.38	2616	48.92	0.499	0.419

TTI(d) Group	ABS	RFPASS	STAWAGON	VEHAGE	MY	CY
CAPRICE & TOWN CAR	0.000	0.267	0.000	6.00	1985.02	1991.01
LOW 15% IN ITS WTGP	0.000	0.262	0.184	5.16	1986.42	1991.58
MID 70% IN ITS WTGP	0.002	0.279	0.178	5.21	1985.83	1991.03
HI 15% IN ITS WTGP	0.005	0.266	0.061	5.29	1985.51	1990.80

4-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1900-3299 POUNDS, OCCUPANTS AGE 30-65

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
CAPRICE & TOWN CAR	552	0.741	47.37	3769	49.76	0.428	0.326
LOW 15% IN ITS WTGP	505	0.753	77.14	2617	45.49	0.537	0.339
MID 70% IN ITS WTGP	2306	0.878	85.23	2576	46.61	0.548	0.388
HI 15% IN ITS WTGP	454	0.838	99.51	2599	45.86	0.531	0.379

TTI(d) Group	ABS	RFPASS	STAWAGON	VEHAGE	MY	CY
CAPRICE & TOWN CAR	0.000	0.170	0.000	5.61	1984.83	1990.43
LOW 15% IN ITS WTGP	0.000	0.206	0.236	5.03	1986.28	1991.30
MID 70% IN ITS WTGP	0.002	0.232	0.214	4.92	1985.80	1990.71
HI 15% IN ITS WTGP	0.006	0.205	0.064	4.82	1985.58	1990.40

*SIDE = (side impact fatalities) / (purely frontal fatalities)

NEARSIDE COMPARTMENT IMPACTS BY ANOTHER VEHICLE
4-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1900-3299 POUNDS

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
CAPRICE & TOWN CAR	1100	0.530	47.95	3748	58.62	0.430	0.365
LOW 15% IN ITS WTGP	915	0.556	77.18	2618	47.91	0.508	0.391
MID 70% IN ITS WTGP	4286	0.616	85.13	2587	49.85	0.515	0.409
HI 15% IN ITS WTGP	867	0.594	99.45	2612	48.07	0.501	0.415

TTI(d) Group	ABS	RFPASS	STAWAGON	VEHAGE	MY	CY
CAPRICE & TOWN CAR	0.000	0.266	0.000	6.10	1985.01	1991.10
LOW 15% IN ITS WTGP	0.000	0.279	0.184	5.07	1986.44	1991.51
MID 70% IN ITS WTGP	0.003	0.288	0.183	5.16	1985.86	1991.02
HI 15% IN ITS WTGP	0.005	0.283	0.059	5.25	1985.52	1990.77

4-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1900-3299 POUNDS, OCCUPANTS AGE 30-65

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
CAPRICE & TOWN CAR	458	0.445	47.40	3767	49.72	0.437	0.321
LOW 15% IN ITS WTGP	403	0.399	77.32	2608	45.60	0.529	0.333
MID 70% IN ITS WTGP	1802	0.467	85.16	2583	46.30	0.536	0.390
HI 15% IN ITS WTGP	358	0.449	99.54	2604	46.31	0.531	0.355

TTI(d) Group	ABS	RFPASS	STAWAGON	VEHAGE	MY	CY
CAPRICE & TOWN CAR	0.000	0.175	0.000	5.68	1984.83	1990.49
LOW 15% IN ITS WTGP	0.000	0.213	0.233	4.81	1986.28	1991.09
MID 70% IN ITS WTGP	0.002	0.235	0.213	4.95	1985.84	1990.78
HI 15% IN ITS WTGP	0.006	0.237	0.067	4.86	1985.55	1990.41

*SIDE = (side impact fatalities) / (purely frontal fatalities)

ALL SIDE IMPACTS BY A PASSENGER CAR
4-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1900-3299 POUNDS

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
CAPRICE & TOWN CAR	506	0.698	48.01	3745	60.30	0.443	0.336
LOW 15% IN ITS WTGP	477	0.971	77.31	2604	48.10	0.503	0.363
MID 70% IN ITS WTGP	2439	0.985	85.73	2565	51.24	0.533	0.407
HI 15% IN ITS WTGP	482	0.944	99.49	2582	49.77	0.485	0.398

TTI(d) Group	ABS	RFPASS	STAWAGON	VEHAGE	MY	CY
CAPRICE & TOWN CAR	0.000	0.277	0.000	5.80	1985.04	1990.83
LOW 15% IN ITS WTGP	0.000	0.308	0.201	4.79	1986.32	1991.10
MID 70% IN ITS WTGP	0.002	0.310	0.186	4.88	1985.68	1990.56
HI 15% IN ITS WTGP	0.005	0.280	0.058	4.96	1985.57	1990.53

4-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1900-3299 POUNDS, OCCUPANTS AGE 30-65

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
CAPRICE & TOWN CAR	223	0.593	47.60	3758	51.24	0.426	0.287
LOW 15% IN ITS WTGP	200	0.695	77.29	2615	45.48	0.535	0.300
MID 70% IN ITS WTGP	1025	0.817	86.02	2553	46.88	0.567	0.374
HI 15% IN ITS WTGP	197	0.655	99.05	2567	46.50	0.518	0.371

TTI(d) Group	ABS	RFPASS	STAWAGON	VEHAGE	MY	CY
CAPRICE & TOWN CAR	0.000	0.184	0.000	5.30	1984.74	1990.04
LOW 15% IN ITS WTGP	0.000	0.250	0.240	4.53	1986.39	1990.92
MID 70% IN ITS WTGP	0.002	0.278	0.222	4.53	1985.65	1990.17
HI 15% IN ITS WTGP	0.006	0.228	0.061	4.84	1985.47	1990.31

*SIDE = (side impact fatalities) / (purely frontal fatalities)

NEARSIDE COMPARTMENT IMPACTS BY A PASSENGER CAR
4-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1900-3299 POUNDS

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
CAPRICE & TOWN CAR	418	0.403	47.98	3746	60.20	0.450	0.323
LOW 15% IN ITS WTGP	370	0.529	77.11	2624	49.26	0.519	0.376
MID 70% IN ITS WTGP	1920	0.562	85.65	2566	50.67	0.524	0.414
HI 15% IN ITS WTGP	367	0.480	99.48	2573	48.27	0.499	0.401

TTI(d) Group	ABS	RFPASS	STAWAGON	VEHAGE	MY	CY
CAPRICE & TOWN CAR	0.000	0.278	0.000	5.87	1985.09	1990.95
LOW 15% IN ITS WTGP	0.000	0.338	0.200	4.71	1986.42	1991.13
MID 70% IN ITS WTGP	0.002	0.319	0.194	4.86	1985.73	1990.59
HI 15% IN ITS WTGP	0.006	0.308	0.057	4.96	1985.55	1990.50

4-DOOR CARS W/O AIR BAGS OR ABS WEIGHING 1900-3299 POUNDS, OCCUPANTS AGE 30-65

TTI(d) Group	N	SIDE*	TTI(d)	CURBWT	AGE	FEMALE	BELT
CAPRICE & TOWN CAR	190	0.357	47.51	3762	51.52	0.453	0.289
LOW 15% IN ITS WTGP	162	0.373	77.40	2615	46.52	0.556	0.309
MID 70% IN ITS WTGP	824	0.461	85.82	2561	46.60	0.553	0.385
HI 15% IN ITS WTGP	161	0.353	98.74	2573	46.74	0.516	0.348

TTI(d) Group	ABS	RFPASS	STAWAGON	VEHAGE	MY	CY
CAPRICE & TOWN CAR	0.000	0.189	0.000	5.15	1984.77	1989.91
LOW 15% IN ITS WTGP	0.000	0.259	0.241	4.40	1986.40	1990.80
MID 70% IN ITS WTGP	0.002	0.282	0.226	4.59	1985.71	1990.29
HI 15% IN ITS WTGP	0.007	0.273	0.062	4.91	1985.53	1990.43

*SIDE = (side impact fatalities) / (purely frontal fatalities)

APPENDIX B

MAKE-MODEL GROUPS FOR FMVSS 214 EVALUATION, PHASE 2

52 make-model groups of passenger cars with high sales volumes are defined for Phase 2 of the FMVSS 214 evaluation. A group may consist of one make-model or several corporate "twins" (e.g., Ford Taurus and Mercury Sable) or, in a few cases, successive offerings in the same general market class (e.g., Ford Tempo and Ford Contour). Information listed for each group includes:

- CG-MM2-MY: applicable car group, make-model codes and their model year ranges
- Redesigns: model years of major redesigns (new wheelbase) or minor redesigns (moderate body changes on an existing wheelbase), if any
- TTI(d): test results (speed-adjusted), and the model years they are believed to carry over
- Self-certification: in model years 1994, 1995 and/or 1996 only, manufacturers could certify that a car met FMVSS 214. Notes: all cars had to meet FMVSS 214 in MY 1997; self-certification did not exist before 1994, though some cars could have met FMVSS 214.
- Information Request (IR): manufacturers' descriptions of specific vehicle modifications related to FMVSS 214, requested by NHTSA in conjunction with compliance tests.
- Sales by model year
- Percent of cars with driver air bags, passenger air bags and ABS, by model year
- TTI(d) by model year (adjusted for test speed - see Section 2.1)
- Analysis problems: e.g., (1) before/after analysis not advisable because FMVSS 214 compliance coincided with a large increase in driver air bags or ABS, or (2) analysis must be limited to driver fatalities, because FMVSS 214 compliance coincided with a large increase in passenger air bags
- "Change" groups (recommended assignment for analysis purposes):

  1. CARS MODIFIED TO MEET FMVSS 214 AND/OR REDUCE TTI(d)
  1SP substantial structural modifications plus padding
  1S substantial structural modifications only
  1P padding only
  1Pm primarily padding, with minor structural modifications
  1m minor structural modifications only
  1u car apparently modified, specifics unknown, will reassign with more information

2. CARS MEETING FMVSS 214 WITHOUT MODIFICATIONS (control group)

2a "actual" group 2 - models that met FMVSS 214 at all times and/or before 1994, and were not modified in 1994-1997 to reduce TTI(d) - as evidenced by passing TTI(d) scores on pre-1994 vehicles and/or manufacturer statements that they changed nothing to meet FMVSS 214

2e "expedient" group 2 - models that were actually modified to meet FMVSS 214, but the transition period cannot be analyzed because the change coincided with driver air bags and/or ABS; so as not to lose these data entirely, we can at least take some post-standard model years and include them in the control group.

2t "temporary" group 2 - models apparently modified to meet FMVSS 214, but the date and/or extent of the change is unclear; we will reassign them to another group when we get more information, but for now, we can at least take some post-standard model years and include them in the control group.

3. CARS THAT NEVER MET FMVSS 214 (control group) - generally, make-models discontinued after 1996 or 1995 and never self-certified; if any pre-1997 cars were tested, TTI(d) always exceeded 85 (4-door) or 90 (2-door).

TBD Unclear if this make/model was changed to meet FMVSS 214 or reduce TTI(d) - will reassign to one of the other groups when we obtain more information

! Transition year: change group 1 - first MY meeting FMVSS 214 or with reduced TTI(d); change groups 2 and 3 - MY arbitrarily selected so about half the data are on either side

! Δ-TTI(d): reduction in TTI(d) in the transition year; always 0 in change groups 2 and 3

! Before & After years: MY ranges proposed for the analysis before and after the transition year; air bags and ABS need to be consistent within and between both ranges

! Recommended FMVSS 214 tests, usually on pre-standard cars, to ascertain or confirm Δ-TTI(d)

Group 1: Taurus/Sable 4dr

Car group-make-model codes and applicable model years:
1235-1217 1991-95 Ford Taurus
1235-1417 1991-95 Mercury Sable
1240-1217 1996- Ford Taurus
1240-1417 1996- Mercury Sable
Major redesign: 1996, Minor redesign: 1992

TTI(d): 1990-91=77 (test vehicle = 1990 Taurus), 1992-95=unknown, 1996-97=51 (test vehicle = 1996 Taurus)
Self-certification: begins in 1996; no claims for 1994-95
IR: 1996 Taurus got structural reinforcements in the body side structure, energy absorbing foam in the door panels...(no picture; not necessarily informative since this was major redesign)

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	357,659	100	0	15	77
1992	443,615	100	19	25	U
1993	536,756	100	59	41	U
1994	437,352	100	100	58	U
1995	485,613	100	100	60	U
1996	499,052	100	100	60	51
1997	498,602	100	100	55	51

Recommended Assignment: Change group=1SP? (Definite major reduction in TTI(d); definite padding; probably substantial structure; but not clear if it was in 1996 [more likely] or 1992 [less likely])
Transition year=1996? Δ-TTI(d)=26?
Before=1994-95 After=1996-97 (air bags and ABS are consistent throughout 1994-97)
Recommended test=1994-95 Ford Taurus or Mercury Sable to confirm if major change was in 1996, not 1992 and to ascertain Δ-TTI(d)

Group 2: Honda Accord 4dr

Car group-make-model codes and applicable model years:
3718-3732 1991-93 Honda Accord
3726-3732 1994- Honda Accord
Major redesign: 1994

TTI(d): 1991-93=86 (test vehicle = 1992 Accord), 1994-97=80 (test vehicle = 1994 Accord)
Self certification: begins in 1994
IR: 1994 Accord got major structural changes including A and B pillar stiffeners, horizontal cross-members, stronger beams, some padding,...(not necessarily informative since this was major redesign)

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	339,301	4	0	6	86
1992	564,596	100	0	34	86
1993	260,304	100	6	45	86
1994	316,194	100	100	53	80
1995	263,640	100	100	54	80
1996	329,484	100	100	37	80
1997	303,117	100	100	30	80

Analysis problem: may need to limit analysis to drivers since 214 coincided with RF air bag installation
Recommended Assignment: Change group=1SP? (IR clearly describes substantial structure & padding, but the surprisingly small reduction in TTI(d) leaves some doubt about the extent of the changes; indeed, 80 is a surprisingly high score for a fairly large 4-door sedan that meets FMVSS 214)
Transition year=1994 Δ-TTI(d)=6?
Before=1992-93 After=1994-97 (driver air bags and ABS are consistent throughout 1992-97)
Recommended test=probably none needed; might retest 94-97 model - is TTI(d) as high as 80 upon retest?

Group 3: Toyota Camry 4dr

Car group-make-model codes and applicable model years:
4920-4940 1991 Toyota Camry - not applicable
4928-4940 1992-96 Toyota Camry
4936-4940 1997- Toyota Camry
Major redesigns: 1992, 1997

TTI(d): 1992-93=unknown, 1994-96=66 (test vehicle = 1994 Camry), 1997 = 50 (test vehicle = 1998 Camry)
Self-certification: begins in 1994
IR: 1994 Camry got major structural changes including A and B pillar stiffeners, horizontal cross-members, extensive padding,...
IR: “1998" Camry got reinforced rocker panel, B-pillar, front floor cross member, roof side rail, horizontal roof reinforcement, an additional side door beam, and padding in two places (it is not clear whether all of these are beyond to the 1994 changes, or merely a recapitulation of those changes; at a minimum, the horizontal roof reinforcement and additional side door beam are new). Presumably, these changes were already present in the redesigned 1997 Camry.

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	*250,185*	*0*	*0*	*8*	*N/A*
1992	276,341	100	0	28	U
1993	312,641	100	0	22	U
1994	298,821	100	100	82	66
1995	284,657	100	100	82	66
1996	330,247	100	100	86	66
1997	410,670	100	100	88	50?

Analysis problem: the 1993-94 transition will have to be excluded from the analysis because FMVSS 214 coincided with a major increase in ABS as well as RF air bags; however, we can still analyze the effect of the TTI(d) reduction in the 1997 redesign
Recommended Assignment: Change group=1SP? (The IR lists substantial structure and padding for 1998 - presumably already there in 1997 - but there is some question if all of those items are changes from 1994-96; there was a fairly large reduction in TTI(d))
Transition year=1997 Δ-TTI(d)=16?
Before=1995-96 After=1997 (air bags and ABS are consistent throughout 1995-97)
Recommended test=none needed, but confirm that 1998 test result is valid retroactive to 1997

Group 4: Corolla/Prizm 4dr

Car group-make-model codes and applicable model years:
4919-2032 1991-92 Geo Prizm - not applicable
4919-4932 1991-92 Toyota Corolla - not applicable
4930-2032 1993- Geo Prizm
4930-4932 1993- Toyota Corolla
Major redesign: 1993

TTI(d): 1993-96=91 (test vehicle = 1993 Corolla), 1997=72 (test vehicle = 1997 Corolla)
Self-certification: no claims for 1994-96
IR: 1997 Corolla got major structural changes including B pillar stiffener, horizontal cross-members, sill & roof rail strengthening, extensive padding,...

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	*280,121*	*0*	*0*	*0*	*N/A*
1992	*292,059*	*0*	*0*	*0*	*N/A*
1993	269,320	100	0	11	91
1994	301,603	100	100	13	91
1995	305,656	100	100	13	91
1996	273,115	100	100	19	91
1997	284,871	100	100	24	72

Recommended Assignment: Change group=1SP (Substantial structure and padding with large reduction in TTI(d))
Transition year=1997 Δ-TTI(d)=19
Before=1995-96 After=1997 (air bags and ABS are consistent throughout 1994-97)
Recommended test=none needed

Group 5: Escort/Tracer 4dr

Car group-make-model codes and applicable model years:
4117-1213 1991- Ford Escort
4117-1436 1991- Mercury Tracer
Major redesign: none, Minor redesign: 1997

TTI(d): 1991-96=unknown, 1997=62 (test vehicle = 1997 Escort)
Self-certification: no claims for 1994-96
IR: 1997 Escort got minor structural changes including a small reinforcement plate in the door structure, and extensive padding,...

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	235,805	0	0	0	U
1992	128,896	0	0	0	U
1993	368,984	0	0	0	U
1994	235,685	100	0	1	U
1995	315,107	100	100	< 1	U
1996	71,609	100	100	< 1	U
1997	425,613	100	100	1	62

Recommended Assignment: Change group=1Pm? (Padding with minor structural modifications; unknown reduction in TTI(d))
Transition year=1997 Δ-TTI(d)=?
Before=1995-96 After=1997 (air bags and ABS are consistent throughout 1995-97)
Recommended test=1995-96 Ford Escort 4dr, to ascertain Δ-TTI(d)

Group 6: Chevrolet Lumina 4dr

Car group-make-model codes and applicable model years:
1859-2020 1991- Chevrolet Lumina
Major redesign: none, Minor redesign: 1995

TTI(d): 1991-94=66 (test vehicle = 1992 Lumina), 1995-96=67? 1997=67 (test vehicle = 1997 Lumina)
Self-certification: begins in 1995; no claim for 1994
IR: 1995 Lumina (4-door?) got negligible structural change consisting of a redesigned B-pillar to rocker panel joint, no front-seat padding
IR: 1997 Lumina got negligible structural change consisting of a redesigned B-pillar to rocker panel joint, no front-seat padding. GM sent exactly the same documentation for both IR's. The change was most likely made in 1995, not 1997, and the 1997 test result is probably valid retroactive to 1995

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	150,522	0	0	0	66
1992	189,922	0	0	61	66
1993	184,053	0	0	64	66
1994	70,760	0	0	62	66
1995	233,999	100	100	62	67?
1996	213,070	100	100	43	67?
1997	260,090	100	100	65	67

Recommended Assignment: Change group=2a (Always met 214; negligible change in 1995)
"Transition year"=1996 Δ-TTI(d)=0
"Before"=1995 "After"=1996-97 (air bags and ABS are consistent throughout 1995-97)
Recommended test=none needed

Group 7: Saturn 4dr

Car group-make-model codes and applicable model years:
1862-2401 1991- Saturn SL sedan
1862-2403 1993- Saturn SL wagon
Major redesign: none, Minor redesign: 1996

TTI(d): 1991-95=unknown, 1996=70 (test vehicle = 1996 Saturn SL1), 1997=76 (test vehicle = 1997 Saturn SL2)
Self certification: begins in 1996; no claims for 1994-95
IR: 1996 Saturn got major structural reinforcements in the A, B and C pillars, cross-members, beams, rocker panels, plus extensive padding
IR: 1997 Saturn is unchanged from 1996

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	39,133	0	0	0	U
1992	124,985	3	0	13	U
1993	174,749	100	0	16	U
1994	191,916	100	100	23	U
1995	220,034	100	100	27	U
1996	221,577	100	100	38	70
1997	248,708	100	100	37	76

Recommended Assignment: Change group=1SP? (Substantial structural modifications plus padding, but unknown reduction in TTI(d))
Transition year=1996 Δ-TTI(d)=?
Before=1994-95 After=1996-97 (air bags and ABS are consistent throughout 1994-97)
Recommended test=1994-95 Saturn SL1, to ascertain Δ-TTI(d)

Group 8: GM H Body (LeSabre) 4dr

Car group-make-model codes and applicable model years:
1852-1802 1991- Buick LeSabre
1852-2102 1991- Olds Delta 88
1852-2202 1991- Pontiac Bonneville
Major redesign: none, Minor redesign: 1992

TTI(d): 1991=79 (test vehicle = 1988 Olds Delta 88), 1992-96=unknown 1997=68 (test vehicle = 1997 Buick LeSabre)
Self-certification: no claims for 1994-96
IR: 1997 LeSabre got thorax and pelvic padding, armrest force deflection characteristics modified, and the side ring structure redesigned

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	169,423	1	0	7	79
1992	372,787	100	6	50	U
1993	294,053	100	7	100	U
1994	297,383	100	100	100	U
1995	318,192	100	100	100	U
1996	170,304	100	100	100	U
1997	376,901	100	100	100	68

Recommended Assignment: Change group=1Pm? (Padding with minor structural modifications; moderate reduction in TTI(d), but not clear if it was in 1997 [more likely] or 1992 [less likely])
Transition year=1997? Δ-TTI(d)=?
Before=1995-96 After=1997 (air bags and ABS are consistent throughout 1994-97)
Recommended test=1995-96 Buick LeSabre, to ascertain Δ-TTI(d)

Group 9: GM J Body (Cavalier) 2dr

Car group-make-model codes and applicable model years:
1848-2016 1991-94 Chevrolet Cavalier
1848-2216 1991-94 Pontiac Sunbird
1866-2016 1995- Chevrolet Cavalier
1866-2216 1995- Pontiac Sunfire
Major redesign: 1995

TTI(d): 1991-94=unknown, 1995-96=unknown, 1997=79 (test vehicle = 1997 Cavalier)
Self-certification: no claims for 1994-96
IR: 1997 Cavalier got minor structural changes (modified door beam, rear structural brace on roof rail to limit intrusion) and extensive padding

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	220,435	0	0	0	U
1992	170,464	0	0	100	U
1993	167,018	0	0	100	U
1994	199,682	0	0	100	U
1995	112,591	100	100	100	U
1996	216,484	100	100	100	U
1997	260,690	100	100	100	79

Recommended Assignment: Change group=1Pm? (Padding with minor structural modifications; unknown reduction in TTI(d))
Transition year=1997 Δ-TTI(d)=?
Before=1995-96 After=1997 (air bags and ABS are consistent throughout 1995-97)
Recommended test=1995-96 Chevrolet Cavalier, to ascertain Δ-TTI(d)

Group 10: Cadillac DeVille 4dr

Car group-make-model codes and applicable model years:
1860-1903 1991-93 Cadillac DeVille
1864-1903 1994- Cadillac DeVille
Major redesign: 1994

TTI(d): 1991-93=unknown, 1994-97=52 (test vehicle = 1994 DeVille)
Self-certification: begins in 1994
IR: 1994 Cadillac DeVille did not receive any modifications to meet 214 (not necessarily informative since this was major redesign)

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	130,685	100	0	100	U
1992	124,022	100	0	100	U
1993	119,950	100	0	100	U
1994	111,494	100	100	100	52
1995	103,207	100	100	100	52
1996	105,193	100	100	100	52
1997	106,806	100	100	100	52

Recommended Assignment: Change group=2a (Always met 214)
"Transition year"=1996 Δ-TTI(d)=0
"Before"=1994-95 "After"=1996-97 (air bags and ABS are consistent throughout 1994-97)
Recommended test=none needed

Group 11: GM N Body (Grand Am) 4dr

Car group-make-model codes and applicable model years:
1854-1817 1991- Buick Skylark
1854-2117 1991 Olds Calais
1854-2121 1992- Olds Achieva
1854-2202 1991- Pontiac Grand Am
Major redesign: none, Minor redesign: 1992

TTI(d): 1991=74 (test vehicle = 1988 Olds Calais), 1992-96=unknown 1997=70 (test vehicle = 1997 Pontiac Grand Am)
Self-certification: no claims for 1994-96
IR: 1997 Grand Am got thorax and pelvic padding, but no structural changes

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	199,132	0	0	0	74
1992	194,660	0	0	100	U
1993	214,547	0	0	100	U
1994	218,575	100	0	100	U
1995	237,225	100	0	100	U
1996	182,837	100	100	100	U
1997	268,083	100	100	100	70

Analysis problem: may need to limit analysis to drivers if MY<96 is included (no RF air bags)
Recommended Assignment: Change group=1P? (Padding only; little reduction in TTI(d), unless it had gone up in 1992)
Transition year=1997? Δ-TTI(d)=?
Before=1996 After=1997 (air bags and ABS are consistent throughout 1996-97)
Recommended test=1996 Pontiac Grand Am 4-door, to ascertain Δ-TTI(d)

Group 12: Honda Civic 4dr

Car group-make-model codes and applicable model years:
3723-3731 1992- Honda Civic
Major redesign: 1992, Minor redesign: 1996

TTI(d): 1992-96=unknown, 1997=58 (test vehicle = 1997 Civic)
Self-certification: begins in 1996; no claims for 1994-95
IR: 1997 Civic got major structural reinforcements in the A and B pillars, cross-members, beams, sills, plus some padding. IR does not say these are carryovers from 1996, but presumably they were.

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1992	125,461	100	0	3	U
1993	104,232	100	0	3	U
1994	92,147	100	100	41	U
1995	135,277	100	100	14	U
1996	109,890	100	100	6	58?
1997	170,718	100	100	8	58

Recommended Assignment: Change group=1SP? (Substantial structure plus padding; unknown reduction in TTI(d))
Transition year=1996(based on self-certification) Δ-TTI(d)=?
Before=1995 After=1996-97 (air bags and ABS are consistent throughout 1995-97)
Recommended test=1995 Honda Civic 4dr sedan, to ascertain Δ-TTI(d); also confirm change was in 1996, not 1997

Group 13: Honda Civic 2dr coupe

Car group-make-model codes and applicable model years:
3723-3731 1993- Honda Civic
Major redesign: 1993, Minor redesign: 1996

TTI(d): 1993-95=86 (test vehicle = 1993 Civic), 1996-97=72 (test vehicle = 1998 Civic)
Self-certification: no claims for 1994-96
IR: “1998" Honda Civic Coupe got substantial structural modifications including A- and B-pillar stiffeners, two cross-member reinforcements and an upgraded beam. No mention of padding. These modifications were undoubtedly already on the 1997 and probably on the 1996.

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1993	78,606	100	0	3	86
1994	95,967	100	100	41	86
1995	141,248	100	100	14	86
1996	117,321	100	100	6	72?
1997	152,295	100	100	8	72

Recommended Assignment: Change group=1S (Substantial structural modifications without padding; fairly large reduction in TTI(d))
Transition year=1996? Δ-TTI(d)=14
Before=1995 After=1996?-1997 (air bags and ABS are consistent throughout 1995-97)
Recommended test=none, but find out if change was in 1996 or 1997

Group 14: Chevrolet Corsica 4dr

Car group-make-model codes and applicable model years:
1856-2019 1991-96 Chevrolet Corsica
Major redesign: none, Minor redesign: none

TTI(d): 1991-96=unknown
Self-certification: no claims for 1994-96
IR: none

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	160,343	100	0	0	U
1992	118,768	100	0	100	U
1993	126,687	100	0	100	U
1994	134,501	100	0	100	U
1995	126,150	100	0	100	U
1996	127,501	100	0	100	U

Recommended Assignment: Change group=3? (No vehicle modifications; probably never met 214 up through 1996)
“Transition year”=1995 Δ-TTI(d)=0
“Before”=1994 “After”=1995-96 (air bags and ABS are consistent throughout 1994-96)
Recommended test=1995-96 Chevrolet Corsica to see if it met FMVSS 214

Group 15: Lincoln Town Car 4dr

Car group-make-model codes and applicable model years:
1230-1301 1991- Lincoln Town Car
Major redesign: none, Minor redesign: none

TTI(d): 1991-93=unknown (TTI(d) was 40 in 1988 Lincoln Town Car), 1994-97=64 (test vehicle = 1994 Town Car)
Self-certification: begins in 1994
IR: 1994 Lincoln Town Car had minor changes related to FMVSS 214 (3 electrical connectors moved from the inner to the outer door panel)

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	116,913	100	0	100	U
1992	104,566	100	100	100	U
1993	142,555	100	100	100	U
1994	111,236	100	100	100	64
1995	106,691	100	100	100	64
1996	88,983	100	100	100	64
1997	91,005	100	100	100	64

Recommended Assignment: Change group=2a (Always met 214)
“Transition year”=1996 Δ-TTI(d)=0
“Before”=1994-95 “After”=1996-97 (air bags and ABS are consistent throughout 1994-97)
Recommended test=none needed

Group 16: GM A Body (Ciera) 4dr

Car group-make-model codes and applicable model years:
1850-1817 1991-96 Buick Century
1850-2117 1991-96 Olds Cutlass Ciera
1850-2217 1991 Pontiac 6000
Major redesign: none, Minor redesign: none

TTI(d): 1991-96=75 (test vehicle = 1990 Pontiac 6000)
Self-certification: no claims for 1994-96
IR: none

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	244,731	0	0	0	75
1992	239,595	0	0	0	75
1993	258,509	62	0	0	75
1994	260,382	100	0	100	75
1995	237,003	100	0	100	75
1996	208,808	100	0	100	75

Recommended Assignment: Change group=2a (Always met 214)
“Transition year”=1995 Δ-TTI(d)=0
“Before”=1994 “After”=1995-96(air bags and ABS are consistent throughout 1994-96)
Recommended test=none needed

Group 17: GM J Body (Cavalier) 4dr

Car group-make-model codes and applicable model years:
1848-2016 1991-94 Chevrolet Cavalier - not applicable
1848-2216 1991-94 Pontiac Sunbird - not applicable
1866-2016 1995- Chevrolet Cavalier
1866-2216 1995- Pontiac Sunfire
Major redesign: 1995

TTI(d): 1991-94=unknown [TTI(d) was 83 in 1987-88], 1995-96=unknown, 1997-98=84 (test vehicle = 1998 Chevrolet Cavalier)
Self-certification: no claims for 1994-96
IR: “1998" Chevrolet Cavalier 4-door sedan got extensive padding, no structural modifications. Presumably that’s retroactive to 1997.

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	*170,852*	*0*	*0*	*0*	*U*
1992	*106,901*	*0*	*0*	*100*	*U*
1993	*141,723*	*0*	*0*	*100*	*U*
1994	*146,923*	*0*	*0*	*100*	*U*
1995	85,524	100	100	100	U
1996	135,261	100	100	100	U
1997	188,744	100	100	100	84

Recommended Assignment: Change group=1P? (Padding only; unclear what happened to TTI(d))
Transition year=97 Δ-TTI(d)=?
Before=1996 After=1997 (air bags and ABS are consistent throughout 1996-97)
Recommended test=1996 Chevrolet Cavalier, to ascertain Δ-TTI(d)

Group 18: Ford Mustang 2dr

Car group-make-model codes and applicable model years:
1227-1203 1991-93 Ford Mustang
1238-1203 1994- Ford Mustang
Major redesign: 1994

TTI(d): 1988-93=110 (test vehicle = 1988 Mustang convertible), 1994-95=unknown, 1996-97=59 (test vehicle = 1996 Mustang coupe)
Self-certification: begins in 1996; no claims for 1994-95
IR: 1996 Mustang got moderate structural revisions in the door beams, door inner belts and a cross-car member, energy absorbing foam in the door trim panels (no picture); since these changes sound pretty small for a 51 TTI(d) reduction, it is plausible that a large reduction took place with the major redesign of 1994, and a smaller reduction in 1996

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	84,346	100	0	0	110
1992	68,279	100	0	0	110
1993	104,981	100	0	0	110
1994	118,977	100	100	55	U
1995	158,342	100	100	50	U
1996	123,588	100	100	50	59
1997	85,692	100	100	51	59

Analysis problem: If principal TTI(d) reduction was in 1994, must exclude because coincided with major ABS change
Recommended Assignment: Change group=1SP? (Large reduction in TTI(d) between 1993 and 1996, but not clear if it was in 1994 [more likely] or 1996 [less likely])
Transition year=TBD Δ-TTI(d)=?
Before=TBD After=TBD (air bags and ABS are consistent throughout 1994-97)
Recommended test=1994-95 Ford Mustang, to ascertain Δ-TTI(d) from 1993 to 1994 and from 1995 to 1996

Note: temporarily, as long as the performance of the 1994-95 Mustang is unknown, we may include the 1996-97 Mustang in the analysis as part of the “no change” control group.
Recommended Assignment: Change group=2t (Met FMVSS 214 with unchanged TTI(d) in the model years specified)
“Transition year”=1997 Δ-TTI(d)=0
“Before”=1996 “After”=1997 (air bags and ABS are consistent throughout 1996-97)

Group 19: Nissan Sentra 4dr

Car group-make-model codes and applicable model years:
3524-3543 1991-94 Nissan Sentra
3536-3543 1995- Nissan Sentra
Major redesign: 1995

TTI(d): 1991-94=92 (test vehicle = 1992 Nissan Sentra), 1995-97=67 (test vehicle = 1996 Nissan Sentra)
Self certification: MY 1995-96, no claim for 1994
IR: 1995 Sentra got major structural changes including A pillar, B pillar and sill reinforcement, substantial padding,...(not necessarily informative since this was major redesign)

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	59,851	0	0	3	92
1992	68,230	0	0	1	92
1993	120,349	33	0	1	92
1994	158,952	17	0	1	92
1995	84,751	100	100	3	67
1996	132,604	100	100	1	67
1997	115,226	100	100	1	67

Analysis problem: the 1994-95 transition will have to be excluded from the analysis because FMVSS 214 coincided with driver and RF air bag installation; however, we can still analyze MY 1995-97 cars as part of the control group with unchanged TTI(d)
Non-Recommended Assignment: Change group=1SP (substantial structural modifications plus padding; large TTI(d) reduction)
Transition year=1995 Δ-TTI(d)=25
Before=N/A After=N/A (air bags coincided with FMVSS 214)

Recommended Assignment: Change group=2e (Met FMVSS 214 with unchanged TTI(d) in the model years specified)
“Transition year”=1996 Δ-TTI(d)=0
“Before”=1995 “After”=1996-97
Recommended test=none needed

Group 20: Nissan Altima 4dr

Car group-make-model codes and applicable model years:
3532-3547 1993- Nissan Altima
Major redesign: none, Minor redesign: none

TTI(d): 1993-96=unknown, 1997=71 (test vehicle = 1997 Nissan Altima) [69 for 1998 Altima]
Self-certification: no claims for 1994-96
IR: 1997 Altima had certain door structure, body structure in the area of the door and interior components redesigned (no picture, unclear if these were moderate or minor changes)
IR: 1998 Altima - same comments as 1997 Altima

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1993	132,056	100	0	18	U
1994	139,692	100	100	14	U
1995	160,261	100	100	8	U
1996	88,750	100	100	4	U
1997	216,047	100	100	8	71

Recommended Assignment: Change group=1u (Vehicle modifications of unknown magnitude with unknown reduction in TTI(d))
Transition year=1997 Δ-TTI(d)=?
Before=1995-96 After=1997 (air bags and ABS are consistent throughout 1995-97)
Recommended test=1995-96 Nissan Altima, to ascertain Δ-TTI(d)

Group 21: Nissan Maxima 4dr

Car group-make-model codes and applicable model years:
3525-3539 1991-94 Nissan Maxima
3534-3539 1995- Nissan Maxima
Major redesign: 1995

TTI(d): 1991-94=unknown, 1995-97=64 (test vehicle = 1995 Nissan Maxima) [54 for 1998 Maxima]
Self-certification: MY 1995-96; no claim for MY 1994
IR: 1998 Maxima got reinforcements of the sill and the A- and B-pillars plus padding

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	88,603	0	0	25	U
1992	83,049	45	0	30	U
1993	84,714	99	0	20	U
1994	63,338	100	0	17	U
1995	149,602	100	100	35	64
1996	154,149	100	100	27	64
1997	110,618	100	100	30	64

Analysis problem: may need to limit analysis to drivers since 214 coincided with RF air bag installation
Recommended Assignment: Change group=TBD (Unknown modifications, unknown reduction in TTI(d))
Transition year=1995 Δ-TTI(d)=?
Before=1993-94 After=1995-97 (driver air bags and ABS are consistent throughout 1993-97)
Recommended test=1993-94 Nissan Maxima, to ascertain Δ-TTI(d)

Note: temporarily, as long as the performance of the 1993-94 Maxima and the extent of the 1995 modifications are unknown, we may include the 1995-97 Maxima in the analysis as part of the "no change" control group.
Recommended Assignment: Change group=2t (Met FMVSS 214 with unchanged TTI(d) in the model years specified)
"Transition year"=1996 Δ-TTI(d)=0
"Before"=1995 "After"=1996-97 (air bags and ABS are consistent throughout 1995-97)

Group 22: Grand Marquis/Crown Victoria 4dr

Car group-make-model codes and applicable model years:
1228-1216 1991- Ford Crown Victoria
1228-1416 1991- Mercury Grand Marquis
Major redesign: none, Minor redesign: 1994?

TTI(d): 1992-93=41 (test vehicle = 1992 Ford Crown Victoria), 1994-96=unknown, 1997=50 (test vehicle = 1997 Ford Crown Victoria)
Self-certification: MY 1994-96
IR: 1997 Ford Crown Victoria did not receive any modifications to meet 214 and is a carryover from MY 1995 [sic]

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	141,049	100	0	0	U
1992	266,663	100	8	30	41
1993	169,010	100	67	43	41
1994	184,508	100	100	51	U
1995	179,350	100	100	49	50?
1996	184,979	100	100	55	50?
1997	204,830	100	100	52	50

Recommended Assignment: Change group=2a (Always met FMVSS 214; no modifications)
“Transition year”=1996 Δ-TTI(d)=0
“Before”=1994-95 “After”=1996-97 (air bags and ABS are consistent throughout 1994-97)
Recommended test=none needed

Group 23: Thunderbird/Cougar 2dr

Car group-make-model codes and applicable model years:
1237-1204 1991- Ford Thunderbird
1237-1404 1991- Mercury Cougar
Major redesign: none, Minor redesign: none

TTI(d): 1991-94=unknown, 1995-97=71 (test vehicle = 1995 Ford Thunderbird)
Self-certification: MY 1995-96; no claim for 1994
IR: 1995 Thunderbird got structural reinforcement in the body side structure, padding in the door trim panel (no picture, unclear if these were moderate or minor changes)

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	134,755	0	0	11	U
1992	116,765	0	0	12	U
1993	206,370	0	0	15	U
1994	187,233	100	100	27	U
1995	172,165	100	100	40	71
1996	122,494	100	100	36	71
1997	87,629	100	100	33	71

Recommended Assignment: Change group=1Pm? (Padding plus unspecified modification of the side structure, probably minor since it doesn’t mention pillars, cross-members, etc.; unknown reduction in TTI(d))
Transition year=1995 Δ-TTI(d)=?
Before=1994 After=1995-96 (air bags and ABS are consistent throughout 1994-96)
Recommended test=1994 Ford Thunderbird, to ascertain Δ-TTI(d)

Group 24: Chrysler LH (Intrepid) 4dr

Car group-make-model codes and applicable model years:
625-641 1993- Chrysler Concorde
625-741 1993- Dodge Intrepid
625-1041 1993- Eagle Vision
Major redesign: none, Minor redesign: none

TTI(d): 1993=79 (test vehicle = 1993 Dodge Intrepid), 1994-97=65 (test vehicle = 1994 Dodge Intrepid), [1998=51 (test vehicle = 1998 Dodge Intrepid)]
Self-certification: 1994-96
IR: 1994 Intrepid had modified beams, C pillar, roof bow, reinforced sills to strengthen the B-pillar, cross-member (no picture, but sounds substantial from the long list of changes); no mention of padding
IR: 1998 Intrepid has additional reinforcement of the B-pillar and a redesigned beam

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1993	142,475	100	100	62	79
1994	214,466	100	100	69	65
1995	173,548	100	100	49	65
1996	201,144	100	100	57	65
1997	218,309	100	100	50	65

Recommended Assignment: Change group=1S? (Apparently substantial structural modifications without padding; moderately large reduction in TTI(d))
Transition year=1994 Δ-TTI(d)=14
Before=1993 After=1994-95 (air bags and ABS are consistent throughout 1993-95)
Recommended test=none needed

Group 25: Ford Escort 2dr

Car group-make-model codes and applicable model years:
4117-1213 1991-96 Ford Escort
Major redesign: none

TTI(d): 1991-96=unknown, [1998=76 (test vehicle = 1998 Ford Escort ZX2 coupe)]
Self-certification: no claims for 1994-96
IR: 1998 Escort ZX2 coupe got a side impact bar and extensive padding

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	173,417	0	0	0	U
1992	43,701	0	0	0	U
1993	128,986	0	0	0	U
1994	85,432	100	0	1	U
1995	102,299	100	100	< 1	U
1996	63,384	100	100	< 1	U

Analysis problem: may need to limit analysis to drivers if MY 94 is included (no RF air bags)
Recommended Assignment: Change group=3 (Presumably never met FMVSS 214; model was produced up to 1996 and temporarily discontinued in 1997)
"Transition year"=1995 or 1996 Δ-TTI(d)=0
"Before"=1994 or 1995 "After"=1995-96 or 1996 (air bags and ABS are consistent throughout 1995-96; driver air bags and ABS are consistent through 1994-96)
Recommended test=1995-96 Ford Escort 2dr to see if it met FMVSS 214

Group 26: Tempo/Contour/Topaz/Mystique 4dr

Car group-make-model codes and applicable model years:
1234-1215 1991-94 Ford Tempo
1234-1415 1991-94 Mercury Topaz
1239-1235 1995- Ford Contour
1239-1437 1995- Mercury Mystique
Major redesign: 1995

TTI(d): 1991-94=unknown, 1995-97=60 (test vehicle = 1995 Mercury Mystique)
Self-certification: MY 1995-96 Contour/Mystique; no claim for Tempo/Topaz
IR: 1995 Mercury Mystique did not receive any modifications to meet 214 (however, this is misleading because it is a new design with a new name, and should not be construed to suggest that it has the same side structure as Tempo/Topaz)

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	235,029	1	0	0	U
1992	212,959	5	0	0	U
1993	203,667	7	0	0	U
1994	150,196	8	0	0	U
1995	237,744	100	100	19	60
1996	211,887	100	100	45	60
1997	130,977	100	100	40	60

Analysis problem: Tempo-to-Contour transition cannot be analyzed since air bags, ABS introduced at the same time as FMVSS 214; however, we can still analyze MY 1995-97 Contour/ Mystique as part of the control group with unchanged TTI(d)
Non-Recommended Assignment: Change group=TBD (unknown modifications and large TTI(d) reduction)
Transition year=1995 Δ-TTI(d)=TBD
Before=N/A After=N/A (air bags coincided with FMVSS 214)

Recommended Assignment: Change group=2e (Met FMVSS 214 in the years included in the analysis)
“Transition year”=1997 Δ-TTI(d)=0
“Before”=1996 “After”=1997 (air bags and ABS are consistent throughout 1996-97)
Recommended test=none needed

Group 27: GM N Body (Grand Am) 2dr

Car group-make-model codes and applicable model years:
1854-1817 1991- Buick Skylark
1854-2117 1991 Olds Calais
1854-2121 1992- Olds Achieva
1854-2202 1991- Pontiac Grand Am
Major redesign: none, Minor redesign: 1992

TTI(d): 1991=111 (test vehicle = 1988 Olds Calais), 1992-96=109 (test vehicle = 1993 Olds Achieva), 1997=unknown, but has to be 90 or less
Self-certification: no claims for 1994-96
IR: none

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	112,519	0	0	0	111
1992	113,330	0	0	100	109
1993	104,044	0	0	100	109
1994	111,467	100	0	100	109
1995	121,126	100	0	100	109
1996	90,524	100	100	100	109
1997	78,054	100	100	100	< 90

Analysis problem: may need to limit analysis to drivers if MY<96 is included (no RF air bags)
Recommended Assignment: Change group=1SP? (Vehicle modifications unknown, but a reduction in TTI(d) of 19 or more suggests substantial changes)
Transition year=1997? Δ-TTI(d)=19 or more?
Before=1996 After=1997 (driver air bags and ABS are consistent throughout 1996-97)
Recommended test=none needed (except compliance test on 1997 or later Pontiac Grand Am)

Group 28: Camaro/Firebird 2dr

Car group-make-model codes and applicable model years:
1849-2009 1991- Chevrolet Camaro
1849-2209 1991- Pontiac Firebird
Major redesign: none, Minor redesign: 1993

TTI(d): 1991-92=unknown, 1993-94=unknown, 1995-96=82 (test vehicle = 1995 Chevrolet Camaro coupe), 1997=70 (test vehicle = 1997 Chevrolet Camaro convertible)
Self-certification: MY 1995-96 coupe only; no claim for 1994, or for convertible in 1995-96
IR: 1995 Camaro unchanged from 1994 except padding added to rear armrests
IR: 1997 Camaro convertible unchanged in the front; changes to rear side include addition of structural brackets to rear wheel houses, padding,...

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	129,671	100	0	0	U
1992	87,725	100	0	0	U
1993	49,492	100	100	100	U
1994	158,966	100	100	100	U
1995	165,291	100	100	100	82
1996	88,320	100	100	100	82
1997	76,212	100	100	100	82/70

Recommended Assignment: Change group=2a? (Since there were apparently no modifications that would affect front-seat TTI(d), we may presume the 1993-94 Camaro/Firebird already met FMVSS 214 for front-seat occupants)
“Transition year”=1995 Δ-TTI(d)=0?
“Before”=1993-94 After=1995-97 (air bags and ABS are consistent throughout 1993-97)
Recommended test=1993-94 Chevrolet Camaro (to confirm front-seat performance similar to 1995-97)

Group 29: Caprice/Roadmaster 4dr

Car group-make-model codes and applicable model years:
1839-1804 1992-96 Buick Roadmaster sedan
1839-2002 1991-96 Chevrolet Caprice sedan
Major redesign: none, Minor redesigns: 1991, 1993

TTI(d): 1991-92=unknown, 1993-96=46 (test vehicle = 1994 Buick Roadmaster), [1988-90=45 (test vehicle = 1988 Chevrolet Caprice)]
Self-certification: MY 1994-96
IR: 1994 Buick Roadmaster did not receive any modifications to meet 214

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	141,663	100	0	100	U
1992	124,645	100	0	100	U
1993	87,176	100	0	100	46
1994	99,064	100	100	100	46
1995	87,647	100	100	100	46
1996	76,889	100	100	100	46

Recommended Assignment: Change group=2a (Always met FMVSS 214)
“Transition year”=1994 Δ-TTI(d)=0
“Before”=1994 “After”=1995-96 (air bags and ABS are consistent throughout 1994-96)
Recommended test=none needed

Group 30: Mazda 626 4dr

Car group-make-model codes and applicable model years:
4113-4137 1991-92 Mazda 626 - not applicable
4121-4137 1993- Mazda 626
Major redesign: 1993

TTI(d): 1991-92=unknown, 1993-95=unknown, 1996-97=61 (test vehicle = 1996 Mazda 626)
Self-certification: MY 1996; no claims for MY 1994-95
IR: 1996 Mazda 626 got minor-moderate structural changes including small reinforcements in the B pillar and some door panels, plus extensive padding

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	*72,402*	*0*	*0*	*9*	*N/A*
1992	*25,755*	*0*	*0*	*10*	*N/A*
1993	76,466	100	0	16	U
1994	80,114	100	100	20	U
1995	103,813	100	100	11	U
1996	75,244	100	100	14	61
1997	74,028	100	100	13	61

Recommended Assignment: Change group=1Pm? (Padding plus apparently minor structural modifications; unknown reduction in TTI(d))
Transition year=1996 Δ-TTI(d)=?
Before=1994-95 After=1996-97 (air bags and ABS are consistent throughout 1994-97)
Recommended test=1994-95 Mazda 626, to ascertain Δ-TTI(d)

Group 31: Subaru Legacy 4dr

Car group-make-model codes and applicable model years:
4809-4834 1991-94 Subaru Legacy
4812-4834 1995- Subaru Legacy
Major redesign: 1995

TTI(d): 1991-94=unknown, 1995-97=57 (test vehicle = 1995 Subaru Legacy wagon), [1998=70 (test vehicle = 1998 Subaru Legacy L sedan)]
Self-certification: MY 1995-96; no claims for MY 1994
IR: 1995 Subaru Legacy wagon got substantial structural changes including stiffeners for all pillars, redesigned beams, a stronger roof, stronger seats, stronger cross-members, plus extensive padding
IR: 1998 Subaru Legacy L sedan got substantial structural changes including stiffeners for all pillars, redesigned beams, a stronger roof, stronger seats, stronger cross-members, plus extensive padding; since these items resemble the description for the 1995 Legacy, they were probably implemented in 1995, not 1998.

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	64,639	0	0	29	U
1992	68,600	9	0	50	U
1993	69,584	100	0	18	U
1994	39,063	100	0	28	U
1995	73,776	100	100	38	57
1996	75,998	100	100	98	57
1997	108,365	100	100	92	57

Analysis problem: may need to limit analysis to drivers since 214 coincided with RF air bag installation
Recommended Assignment: Change group=1SP (substantial structural modifications plus padding; unknown reduction in TTI(d))
Transition year=1995 Δ-TTI(d)=?
Before=1993-94 After=1995 (driver air bags and ABS are consistent throughout 1993-95)
Recommended test=1993-94 Subaru Legacy, to ascertain Δ-TTI(d)

Group 32: Grand Prix/Regal/Supreme 4dr

Car group-make-model codes and applicable model years:
1859-1820 1991-96 Buick Regal
1859-2120 1991- Olds Supreme
1859-2220 1991-96 Pontiac Grand Prix
Major redesign: none, Minor redesign: 1993

TTI(d): 1991-92=unknown, 1993-97=69 (test vehicle = 1994 Buick Regal)
Self-certification: Buick Regal MY 1994-96; Olds Supreme and Pontiac Grand Prix 1995-96 only
IR: 1994 Buick Regal did not receive any modifications to meet 214

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	217,147	0	0	5	U
1992	190,229	0	0	33	U
1993	179,685	100	0	43	69
1994	208,896	100	40	86	69
1995	216,449	100	100	88	69
1996	192,431	100	100	87	69
1997	46,431	100	100	100	69

Analysis problem: may need to limit analysis to drivers if MY<95 is included (no RF air bags)
Recommended Assignment: Change group=2a (Always met FMVSS 214)
"Transition year"=1996 Δ-TTI(d)=0
"Before"=1995   "After"=1996 (air bags and ABS are consistent throughout 1995-96)
Recommended test=none needed

Group 33: Mazda Protege 4dr

Car group-make-model codes and applicable model years:
4117-4135 1991-94 Mazda Protege
4123-4135 1995- Mazda Protege
Major redesign: 1995

TTI(d): 1991-94=unknown, 1995-97=61 (test vehicle = 1995 Mazda Protege)
Self-certification: Beginning August 5, 1994 (presumably MY 1995 & onwards)
IR: 1995 Mazda Protege got major structural changes including B pillar stiffener, sill reinforcement, stronger cross-members, plus extensive padding

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	60,726	0	0	0	U
1992	67,637	0	0	0	U
1993	68,017	0	0	0	U
1994	89,194	0	0	0	U
1995	74,813	100	100	5	61
1996	55,939	100	100	2	61
1997	44,469	100	100	1	61

Analysis problem: the 1994-95 transition will have to be excluded from the analysis because FMVSS 214 coincided with driver and RF air bag installation; however, we can still analyze MY 1995-97 cars as part of the control group with unchanged TTI(d)
Non-Recommended Assignment: Change group=1SP (substantial structural modifications plus padding; unknown TTI(d) reduction)
Transition year=1995 Δ-TTI(d)=?
Before=N/A After=N/A (air bags coincided with FMVSS 214)

Recommended Assignment: Change group=2e (Met FMVSS 214 with unchanged TTI(d) in the model years specified)
“Transition year”=1996 Δ-TTI(d)=0
“Before”=1995 “After”=1996-97
Recommended test=none needed

Group 34: GM C Body (Park Avenue) 4dr

Car group-make-model codes and applicable model years:
1852-1803 1991- Buick Park Avenue
1852-2103 1991- Olds 98/Regency
Major redesign: none

TTI(d): 1991-97=unknown
Self-certification: no claims for 1994-96
IR: none

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	147,126	100	0	100	U
1992	104,813	100	0	100	U
1993	67,911	100	0	100	U
1994	83,602	100	100	100	U
1995	81,878	100	100	100	U
1996	60,267	100	100	100	U
1997	62,069	100	100	100	U

Recommended Assignment: Change group=TBD
Transition year=TBD Δ-TTI(d)=TBD
Before=TBD After=TBD (air bags and ABS are consistent throughout 1994-97)
Recommended test=TBD

Group 35: Probe/MX6 2dr

Car group-make-model codes and applicable model years:
4115-1218 1991-92 Ford Probe - not applicable
4115-4144 1991-92 Mazda MX6 - not applicable
4121-1218 1993- Ford Probe
4121-4144 1993- Mazda MX6
Major redesign: 1993

TTI(d): 1991-92=unknown, 1993-96=82 (test vehicle = 1993 Ford Probe), 1997=81 (test vehicle = 1997 Ford Probe)
Self-certification: no claims for 1994-96
IR: 1997 Ford Probe added padding to the door panels and had the window regulator motor revised

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	*95,256*	*0*	*0*	*2*	*N/A*
1992	*45,820*	*0*	*0*	*3*	*N/A*
1993	157,451	100	0	34	82
1994	102,565	100	100	37	82
1995	73,708	100	100	26	82
1996	36,139	100	100	29	82
1997	10,292	100	100	17	81

Analysis problem: may need to limit analysis to drivers if MY 93 is included (no RF air bags)
Recommended Assignment: Change group=2a (Always met FMVSS 214)
"Transition year"=1994 Δ-TTI(d)=0
"Before"=1993   "After"=1994-96 (driver air bags and ABS are consistent throughout 1994-97)
Recommended test=none needed

Group 36: Toyota Tercel 2dr

Car group-make-model codes and applicable model years:
4925-4938 1991- Toyota Tercel
Major redesign: none, Minor redesigns: 1992, 1995

TTI(d): 1991-94=unknown, 1995-97=62 (test vehicle = 1995 Toyota Tercel)
Self-certification: starting September 1994 (presumably MY 1995)
IR: 1995 Toyota Tercel got major structural changes including B-pillar stiffener, a second beam, stronger cross-members, plus extensive padding

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	57,120	0	0	0	U
1992	71,380	0	0	0	U
1993	70,500	100	0	< 1	U
1994	58,411	100	0	< 1	U
1995	55,496	100	100	10	62
1996	45,049	100	100	12	62
1997	36,891	100	100	11	62

Analysis problem: may need to limit analysis to drivers since 214 coincided with RF air bag installation
Recommended Assignment: Change group=1SP (substantial structural modifications and padding; unknown reduction in TTI(d))
Transition year=1995 Δ-TTI(d)=?
Before=1993-94 After=1995-97 (driver air bags and ABS are consistent throughout 1993-97)
Recommended test=1993-94 Toyota Tercel 2dr, to ascertain Δ-TTI(d)

Group 37: VW Jetta 4dr

Car group-make-model codes and applicable model years:
3006-3040 1991- VW Jetta
Major redesign: none, Minor redesign: 1993

TTI(d): 1991-94=unknown, 1995-97=72 (test vehicle = 1998 VW Jetta without side air bags tested by VW) [1998 Jetta with side air bags had TTI(d)=52]
Self-certification: beginning September 1, 1994 (presumably MY 1995)
IR: 1998 VW Jetta is identical to previous model years [presumably back to 1995] incorporating stiff B-pillars, sills, door impact beams and padding. Without side air bags that became optional in 1998, VW claims a TTI(d) of 72.

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	43,154	0	0	1	U
1992	58,782	0	0	0	U
1993	6,529	0	0	0	U
1994	45,520	46	46	10	U
1995	77,592	100	100	12	72
1996	82,621	100	100	7	72
1997	76,406	100	100	11	72

Analysis problem: the 1994-95 transition will have to be excluded from the analysis because FMVSS 214 coincided with driver and RF air bag installation; however, we can still analyze MY 1995-97 cars as part of the control group with unchanged TTI(d)
Non-Recommended Assignment: Change group=1SP (substantial structural modifications plus padding; unknown TTI(d) reduction)
Transition year=1995 Δ-TTI(d)=?
Before=N/A After=N/A (air bags coincided with FMVSS 214)

Recommended Assignment: Change group=2e (Met FMVSS 214 with unchanged TTI(d) in the model years specified)
“Transition year”=1996 Δ-TTI(d)=0
“Before”=1995 “After”=1996-97
Recommended test=none needed

Group 38: Metro/Swift 2dr

Car group-make-model codes and applicable model years:
5303-2034 1991-94 Geo Metro
5303-5334 1991-94 Suzuki Swift
5304-2034 1995- Geo Metro
5304-5334 1995- Suzuki Swift
Major redesign: 1995

TTI(d): 1991-94=unknown, 1995-97=83 (test vehicle = 1995 Geo Metro)
Self-certification: MY 1995-96; no claim for MY 1994
IR: 1996 Geo Metro 3-door is a carryover from MY 1995; no changes for 1996 (from this it is unclear if anything was done in 1995)

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	67,334	16	0	0	U
1992	75,709	11	0	0	U
1993	63,299	1	0	0	U
1994	72,954	0	0	0	U
1995	46,835	100	100	6	83
1996	46,314	100	100	2	83
1997	40,625	100	100	2	83

Analysis problem: the 1994-95 transition, whatever it may have been, will have to be excluded from the analysis because FMVSS 214 coincided with driver and RF air bag installation; however, we can still analyze MY 1995-97 cars as part of the control group with unchanged TTI(d)
Recommended Assignment: Change group=2e (Met FMVSS 214 with unchanged TTI(d) in the model years specified)
"Transition year"=1996 Δ-TTI(d)=0
"Before"=1995 "After"=1996-97
Recommended test=none needed

Group 39: Dodge/Plymouth Neon 4dr

Car group-make-model codes and applicable model years:
627-720 1995- Dodge Neon
627-920 1995- Plymouth Neon
Major redesign: none

TTI(d): 1995-96=unknown, 1997=69 (test vehicle = 1997 Dodge Neon)
Self-certification: no claims for 1994-96
IR: 1997 Dodge Neon got seat back tubes, B-pillar brackets, and modifications to the console and seat structure (no picture, unclear if these were moderate or minor changes)

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1995	314,855	100	100	28	U
1996	166,284	100	100	6	U
1997	164,087	100	100	4	69

Recommended Assignment: Change group=1m? (Minor structural modifications, unless the B-pillar bracket is something bigger than it sounds; no mention of padding; unknown reduction in TTI(d))
Transition year=1997 Δ-TTI(d)=?
Before=1996 After=1997 (air bags and ABS are consistent throughout 1996-97)
Recommended test=1996 Dodge Neon, to ascertain Δ-TTI(d)

Group 40: Eclipse/Talon 2dr

Car group-make-model codes and applicable model years:
5212-1037 1991-94 Eagle Talon
5212-5237 1991-94 Mitsubishi Eclipse
5219-1037 1995- Eagle Talon
5219-5237 1995- Mitsubishi Eclipse
Major redesign: 1995

TTI(d): 1991-94=unknown, 1995=unknown, 1996-97=86 (test vehicle = 1996 Mitsubishi Eclipse)
Self-certification: begins at the end of May 1995; that might be the beginning of MY 1996 (early introduction) or the middle of MY 1995, but certainly does not sound like the beginning of MY 1995
IR: 1995 [sic] Mitsubishi Eclipse got reinforcements to the B pillar and cross-member, plus some padding; does not specify if this applied to all MY 1995 cars or just some of them

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	82,714	0	0	10	U
1992	82,785	0	0	7	U
1993	74,467	0	0	14	U
1994	58,630	0	0	6	U
1995	95,556	100	100	14	U
1996	59,146	100	100	8	86
1997	64,823	100	100	9	86

Analysis problem: if all MY 1995 cars met FMVSS 214, the 1994-95 transition will have to be excluded from the analysis because it coincided with driver and RF air bag installation; however, if no MY 1995 cars met FMVSS 214, there would be no problem analyzing 1996-97 vs. 1995; until this is resolved, we can still analyze MY 1996-97 cars as part of the control group with unchanged TTI(d)
Recommended Assignment: Change group=1SP? (Substantial structural modifications plus padding; unknown when implemented; unknown reduction in TTI(d))
Transition year=TBD Δ-TTI(d)=?
Before=TBD After=TBD (air bags and ABS are consistent throughout 1995-97)
Recommended test=1995 Eclipse, but only if we find out none of them met FMVSS 214

Note: temporarily, as long as the performance of the 1995 Eclipse is unknown, we may include the 1996-97 Eclipse in the analysis as part of the “no change” control group.
Recommended Assignment: Change group=2t (Met FMVSS 214 with unchanged TTI(d) in the model years specified)
“Transition year”=1997 Δ-TTI(d)=0
“Before”=1996 “After”=1997 (air bags and ABS are consistent throughout 1996-97)

Group 41: Honda Accord 2dr

Car group-make-model codes and applicable model years:
3718-3732 1991-93 Honda Accord
3726-3732 1994- Honda Accord
Major redesign: 1994

TTI(d): 1991-93=unknown, 1994-95=unknown, 1996-97=72 (test vehicle = 1996 Honda Accord)
Self certification: begins in 1994
IR: 1996 Accord got reinforcements to the A pillar, horizontal cross-members, rear wheel arch, and a redesigned beam (Do these changes date back to 1994? If they are only for 1996, on what basis did Honda self-certify for 1994-95?)

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	71,451	4	0	6	U
1992	63,159	100	0	34	U
1993	40,938	100	6	45	U
1994	57,607	100	100	53	72?
1995	43,928	100	100	54	72?
1996	39,139	100	100	37	72
1997	37,521	100	100	30	72

Analysis problem: if the MY 1996 score is also valid for 1994-95, the analysis will need to be limited to drivers since FMVSS 214 coincided with RF air bag installation; however, if 1996 is the transition year, there would be no problem analyzing 1996-97 vs. 1994-95; until this is resolved, we can still analyze MY 1996-97 cars as part of the control group with unchanged TTI(d)
Recommended Assignment: Change group=1S (Substantial structural modifications without padding; unknown when implemented; unknown reduction in TTI(d))
Transition year=TBD Δ-TTI(d)=?
Before=TBD After=TBD (air bags and ABS are consistent throughout 1995-97)
Recommended test=Find out if 1996 score is valid for 1994-95; if yes, test 1992-93 Honda Accord 2-door; if no, test 1994-95 Honda Accord 2-door

Note: temporarily, as long as the performance of the 1994-95 2-door Accord is unknown, we may include the 1996-97 2-door Accord in the analysis as part of the “no change” control group.
Recommended Assignment: Change group=2t (Met FMVSS 214 with unchanged TTI(d) in the model years specified)
“Transition year”=1997 Δ-TTI(d)=0
“Before”=1996 “After”=1997 (air bags and ABS are consistent throughout 1996-97)

Group 42: Saturn 2dr

Car group-make-model codes and applicable model years:
1861-2402 1991-96 Saturn SC coupe
1862-2402 1997- Saturn SC coupe
Major redesign: 1997

TTI(d): 1991-96=unknown, 1997=68 (test vehicle = 1998 Saturn SC2)
Self-certification: no claims for 1994-96
IR: 1997 [sic] Saturn SC2 received extensive reinforcements and a high-strength beam on the rear quarter panel; in the door area they added padding but it's not clear there were any structural modifications

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	9,156	0	0	0	U
1992	26,131	14	0	13	U
1993	49,314	100	0	16	U
1994	55,201	100	0	23	U
1995	58,252	100	100	27	U
1996	49,109	100	100	38	U
1997	71,447	100	100	37	68

Recommended Assignment: Change group=1P? (padding only, apparently, in the front-seat area; unknown reduction in TTI(d))
Transition year=1997 Δ-TTI(d)=?
Before=1995-96 After=1997 (air bags and ABS are consistent throughout 1995-97)
Recommended test=1995-96 Saturn SC, to ascertain Δ-TTI(d)

Group 43: Chevrolet Beretta 2dr

Car group-make-model codes and applicable model years:
1856-2019 1991-96 Chevrolet Beretta
Major redesign: none, Minor redesign: 1994

TTI(d): 1991-96=unknown
Self-certification: no claims for 1994-96
IR: none

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	61,648	100	0	0	U
1992	44,928	100	0	100	U
1993	37,448	100	0	100	U
1994	61,030	100	0	100	U
1995	69,095	100	0	100	U
1996	41,799	100	0	100	U

Recommended Assignment: Change group=3? (No vehicle modifications; probably never met 214 up through 1996)
"Transition year"=1995 Δ-TTI(d)=0
"Before"=1994 "After"=1995-96 (air bags and ABS are consistent throughout 1994-96)
Recommended test=1995-96 Chevrolet Beretta to see if it met FMVSS 214

Group 44: Grand Prix/Regal/Supreme 2dr

Car group-make-model codes and applicable model years:
1859-1820 1991-96 Buick Regal
1859-2120 1991- Olds Supreme
1859-2220 1991-96 Pontiac Grand Prix
Major redesign: none, Minor redesign: 1992

TTI(d): 1991=117 (test vehicle = 1988 Buick Regal), 1992-97=unknown
Self-certification: no claims for 1994-96
IR: none

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	84,722	0	0	4	117
1992	85,734	0	0	31	U
1993	79,170	100	0	38	U
1994	105,951	100	45	85	U
1995	102,652	100	100	79	U
1996	65,588	100	100	73	U
1997	10,914	100	100	100	U

Recommended Assignment: Change group=3? (probably never met 214 up through 1996; most of these cars were discontinued in 1997)
“Transition year”=1996 Δ-TTI(d)=0
“Before”=1995 “After”=1996 (air bags and ABS are consistent throughout 1995-97)
Recommended test=none needed

Group 45: Acura Integra 2dr

Car group-make-model codes and applicable model years:
3717-5431 1991-93 Acura Integra 2dr
3722-5431 1994- Acura Integra 2dr
Major redesign: 1994

TTI(d): 1991-97=unknown
Self-certification: no claims for 1994-96
IR: 1997 Integra got major structural reinforcements in all pillars, cross-members, beams and sills; no mention of padding

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	62,584	0	0	34	U
1992	40,568	0	0	30	U
1993	29,483	0	0	27	U
1994	58,662	100	100	85	U
1995	51,030	100	100	89	U
1996	33,540	100	100	90	U
1997	20,009	100	100	90	U

Recommended Assignment: Change group=1S (Substantial structural modifications; no padding; unknown reduction in TTI(d))
Transition year=1997 Δ-TTI(d)=?
Before=1996 After=1997 (air bags and ABS are consistent throughout 1996-97)
Recommended tests=1997 Acura Integra 2dr (compliance test), 1996 Acura Integra 2dr, to ascertain Δ-TTI(d)

Group 46: Mitsubishi Galant 4dr

Car group-make-model codes and applicable model years:
5209-5234 1991-93 Mitsubishi Galant
5218-5234 1994- Mitsubishi Galant
Major redesign: 1994

TTI(d): 1991-93=unknown, 1994=65 (test vehicle = 1994 Mitsubishi Galant), 1995-97=76 (test vehicle = 1995 Mitsubishi Galant)
Self certification: begins in MY 1994
IR: 1994 Galant got reinforcements to the B pillar, horizontal cross-members, sills, and a redesigned beam, plus extensive padding
IR: 1995 Galant got reinforcements to the B pillar, horizontal cross-members, sills, and a redesigned beam, plus extensive padding (presumably this is not new, but carryover from 1994 Galant, since it is exactly the same as the previous IR)

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	38,219	0	0	6	U
1992	27,161	0	0	8	U
1993	9,581	0	0	4	U
1994	54,801	100	100	18	65
1995	78,633	100	100	7	76
1996	42,478	100	100	5	76
1997	41,723	100	100	4	76

Analysis problem: the 1993-94 transition will have to be excluded from the analysis because FMVSS 214 coincided with driver and RF air bag installation; however, we can still analyze MY 1995-97 cars as part of the control group with unchanged TTI(d)
Non-Recommended Assignment: Change group=1SP (substantial structural modifications plus padding; unknown TTI(d) reduction)
Transition year=1994 Δ-TTI(d)=?
Before=N/A After=N/A (air bags coincided with FMVSS 214)

Recommended Assignment: Change group=2e (Met FMVSS 214 with unchanged TTI(d) in the model years specified)
"Transition year"=1996 Δ-TTI(d)=0
"Before"=1995 "After"=1996-97 (air bags and ABS are consistent throughout 1995-97)
Recommended test=none needed

Group 47: Cadillac Seville 4dr

Car group-make-model codes and applicable model years:
1855-1914 1991 Cadillac Seville - not applicable
1863-1914 1992- Cadillac Seville
Major redesign: 1992, Minor redesign: 1994

TTI(d): 1991=unknown, 1992-97=unknown
Self certification: begins in 1994
IR: none

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	*24,669*	*100*	*0*	*100*	*N/A*
1992	38,707	100	100	100	U
1993	47,105	100	100	100	U
1994	56,779	100	100	100	U
1995	34,520	100	100	100	U
1996	32,821	100	100	100	U
1997	31,932	100	100	100	U

Recommended Assignment: Change group=TBD (unknown if vehicle was modified in 1994 to meet FMVSS 214 or reduce TTI(d))
Transition year=TBD Δ-TTI(d)=TBD
Before=TBD After=TBD (air bags and ABS are consistent throughout 1992-97)
Recommended test=TBD

Note: temporarily, as long as the performance of the 1993 Seville and the extent of the 1994 modifications, if any, are unknown, we may include the 1994-97 Seville in the analysis as part of the “no change” control group.
Recommended Assignment: Change group=2t (Met FMVSS 214 with unchanged TTI(d) in the model years specified)
“Transition year”=1996 Δ-TTI(d)=0
“Before”=1994-95 “After”=1996-97 (air bags and ABS are consistent throughout 1994-97)

Group 48: Lexus ES 4dr

Car group-make-model codes and applicable model years:
4920-5931 1991 Lexus ES-250 - not applicable
4928-5931 1992-96 Lexus ES-300
4936-5931 1997- Lexus ES-300
Major redesigns: 1992, 1997

TTI(d): 1991-97=unknown
Self-certification: no claims for 1994-96
IR: none

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	*16,932*	*100*	*0*	*100*	*N/A*
1992	36,273	100	0	100	U
1993	38,368	100	0	100	U
1994	35,804	100	100	100	U
1995	37,300	100	100	100	U
1996	40,499	100	100	100	U
1997	58,763	100	100	100	U

Recommended Assignment: Change group=TBD (possible change in MY 1997)
Transition year=TBD Δ-TTI(d)=TBD
Before=TBD After=TBD (air bags and ABS are consistent throughout 1994-97)
Recommended test=TBD

Group 49: Toyota Celica 2dr

Car group-make-model codes and applicable model years:
4924-4933 1991-93 Toyota Celica - not applicable
4933-4933 1994- Toyota Celica
Major redesign: 1994

TTI(d): 1991-93=unknown, 1994-95=unknown, 1996-97=60 (test vehicle = 1997 Toyota Celica)
Self-certification: MY 1996; no claims for MY 1994-95
IR: 1996 Celica got a reinforced B pillar and center cross member, plus extensive padding
IR: 1997 Celica hatchback got a reinforced B pillar and center cross member, plus extensive padding (presumably this is not new, but carryover from 1996 Celica, since it is exactly the same as the previous IR)

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	*109,886*	*100*	*0*	*5*	*N/A*
1992	*43,132*	*100*	*0*	*6*	*N/A*
1993	*26,469*	*100*	*100*	*12*	*N/A*
1994	33,866	100	100	9	U
1995	24,525	100	100	11	U
1996	10,049	100	100	21	60?
1997	13,763	100	100	22	60

Recommended Assignment: Change group=1SP (substantial structural modifications plus padding; unknown reduction in TTI(d))
Transition year=1996 Δ-TTI(d)=?
Before=1995 After=1996-97 (air bags and ABS are consistent throughout 1994-97)
Recommended test=1995 Toyota Celica, to ascertain Δ-TTI(d)

Group 50: Lincoln Continental 4dr

Car group-make-model codes and applicable model years:
1236-1305 1991- Lincoln Continental
Major redesign: none, Minor redesign: 1995

TTI(d): 1991-93=98 (test vehicle = 1988 Lincoln Continental), 1994-97=unknown
Self-certification: begins in MY 1995; no claim for 1994
IR: 1995 Continental got "structural reinforcement in the body structure," redesigned beams, padding (no picture, unclear if these were major or moderate changes, but were probably major since pre-214 TTI(d) was 98)

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	50,215	100	0	100	98
1992	38,187	100	100	100	98
1993	24,665	100	100	100	98
1994	48,949	100	100	100	98
1995	31,511	100	100	100	< 85
1996	27,321	100	100	100	< 85
1997	34,493	100	100	100	< 85

Recommended Assignment: Change group=1SP (substantial structural modifications plus padding; TTI(d) reduction at least 13)
Transition year=1995? Δ-TTI(d)=13+
Before=1993-94 After=1995-97 (air bags and ABS are consistent throughout 1992-97)
Recommended test=none needed (except compliance test on 1995 or later Lincoln Continental)

Group 51: Plymouth Acclaim/Breeze 4dr

Car group-make-model codes and applicable model years:
622-919 1991-95 Plymouth Acclaim
626-938 1996- Plymouth Breeze
Major redesign: 1996

TTI(d): 1991-94=unknown, 1995-97=60 (test vehicle = 1995 Chrysler Cirrus)
Self-certification: MY 1995-96 Dodge Stratus; no claim for Plymouth Breeze (probably an error) or Spirit/Acclaim
IR: 1995 Dodge Stratus got reinforcements to all pillars, upper door belt, sill and floor pan plus extensive padding (no picture)

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991 (Acclaim)	112,671	100	0	2	U
1992 (Acclaim)	69,169	100	0	3	U
1993 (Acclaim)	68,787	100	0	4	U
1994 (Acclaim)	60,427	100	0	5	U
1995 (Acclaim)	22,677	100	0	0	U
1996 (Breeze)	45,630	100	100	16	60
1997 (Breeze)	70,579	100	100	16	60

Analysis problems: may need to limit analysis to drivers since FMVSS 214 coincided with RF air bag installation; Dodge Spirit and Stratus, as well as Chrysler Cirrus, although they are of similar design, are omitted from this group because Cirrus and Stratus have too much ABS.
Recommended Assignment: Change group=1SP (substantial structural modifications plus padding; unknown reduction in TTI(d))
Transition year=1996 Δ-TTI(d)=?
Before=1994-95 Plymouth Acclaim After=1996-97 Plymouth Breeze (driver air bags and ABS are consistent throughout 1994-97)
Recommended test=1994-95 Plymouth Acclaim, to ascertain Δ-TTI(d)

Group 52: Acura Legend 4dr

Car group-make-model codes and applicable model years:
3721-5432 1991-95 Acura Legend 4dr
Major redesign: 1991

TTI(d): 1991-95=71 (test vehicle = 1993 Acura Legend)
Self-certification: no claims for 1994-95
IR: none

MY	Sales	Drv Air Bags	RF Air Bags	ABS	TTI(d)
1991	53,199	100	36	100	71
1992	39,271	100	94	100	71
1993	31,666	100	100	100	71
1994	28,840	100	100	100	71
1995	19,138	100	100	100	71

Recommended Assignment: Change group=2a (Always met FMVSS 214)
“Transition year”=1994 Δ-TTI(d)=0
“Before”=1993 “After”=1994-95 (air bags and ABS are consistent throughout 1993-95)
Recommended test=none needed