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Passive Restraint Systems; The Bag and the Belt

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BACKGROUND

There are only two major passive restraint systems: air bags (or cushions) and automatic belts. Table 7 identifies their relative strengths (many of which are discussed in this chapter), but the important point is that, when used properly, both passive restraint systems are quite effective in reducing the risk of death and serious injury.

Technically, the automatic belt system is quite simple. Most systems in operation consist of a single shoulder belt (a "two-point system") that crosses the rider automatically upon entry into the car, and a padded knee panel below the dashboard to provide added protection. Automatic belts with a lap as well as a shoulder component (a "three-point system") have also been designed. Some systems offer automatic shoulder belts and manual lap belts. Close to half a million automatic belt systems are currently on American roads, almost all of them in VW Rabbits and Chevrolet Chevettes, offered as part of option packages.

Air bags consist of deflated bags situated in the steering wheel (driver) and glove compartment area (passenger) sides which inflate virtually instantaneously when front end or dashboard sensors detect crash forces substantial enough to be harmful. Different systems have different inflation mechanisms, and all include ancillary equipment (e.g., knee restraints to prevent riders from sliding under bags, a readiness monitor, and an indicator light) (28). Altogether, over 10,000 air-bag-equipped cars have accumulated over a billion miles on American roads since they first appeared in 1972.

Table 7.—Relative Strengths of the Two Passive Restraint Systems

Air bag	Automatic belt
Less obtrusive	Less expensive
Less uncomfortable	No chemicals involved
Greater protection in most serious accident situations (particularly when used with manual lap belt)[a]	Potentially greater protection in some accident situations[a]
Less likely to be disconnected	Redeployment following emergency use less expensive

[a]see the discussion of safety and effectiveness below.

This more complex technology has a history which dates back 30 years. In 1952, the first of several patents for automatically inflating air cushions was filed. Federal Government interest dates from 1968, when prototype development became sufficiently advanced to consider large-scale application in the near future. In ***1969,*** the National Highway Safety Bureau (NHSB, predecessor of the National Highway Traffic Safety Administration, NHTSA) announced a proposed rulemaking for an "Inflatable Occupant Restraint System," with an initially proposed effective date of January 1, ***1972.*** This marked the beginning of a longstanding adversarial relationship between automobile manufacturers and the Department of Transportation (DOT) which saw dozens of debates over the effectiveness and cost of passive restraints and delays in implementation of, and changes in, a passive restraint requirement.

Delay and change have occurred during each successive administration, with the Reagan administration's re-examination of the issue being the latest and most radical. The courts, Congress, public interest groups, and the media have all been active participants in the drama. The conflict has made strange bedfellows of such diverse interests as Ralph Nader and the Pacific Legal Foundation (PLF), the latter a public interest group advocating "limited government." In 1977, PLF filed suit in the U.S. Court of Appeals to block the passive restraint rule, claiming that DOT had an "insufficient basis for the air bag decision." The following year, Nader and Public Citizen, the consumer rights group, filed suit in the Court of Appeals seeking a ruling that DOT's scheduled 3-year phase-in of restraints was illegal; plaintiffs wanted all new vehicles to have passive restraints at the same time. The Court of Appeals consolidated the suits of PLF and Nader and Public Citizen. *

Part of the regulatory debate picture has been repeated proposals by automakers to introduce air bags or automatic belts on their own. Each of these proposals has come in response to a proposed passive restraint rulemaking by the Government. As each of the proposed rulemakings was altered or delayed, often because of agency actions, occasionally because of judicial decisions, the automakers' plans were themselves altered, invariably in the direction of limiting introduction of passive restraints.

In 1970, for example, General Motors (GM) informed NHSB that it would provide air bags on all its cars by 1975, introducing the equipment as an option and then converting it to standard equipment. In 1973, GM informed DOT that it was reducing its planned production of air-bag-equipped 1974-75 cars from 1 million to 150,000 units, blaming both tooling difficulties and the Government's standard-setting process. Half a year later, a GM spokesperson told the Insurance Institute for Highway Safety (IIHS) that the figure of 150,000 was probably too high.

In fact, GM built about 10,000 air-bag-equipped cars, all large models, during the 1974-76 model years. The company then canceled production, claiming insufficient consumer demand, a claim which GM officials have acknowledged was based in part on a failure of the company to promote the technology. GM's revising its plans and departing from the air-bag-equipped automobile market followed an earlier court decision overturning a proposed NHSB air-bag rule.

A similar picture emerges in the years since the mid-1970's, with promises of air-bag-equipped vehicles repeatedly made and then scaled back or rescinded (17). Recently, GM announced the termination of its inflatable restraint program, calling the device economically infeasible ***(23).***

Three years ago, the "Big Three" domestic automobile manufacturers and several foreign producers reported to NHTSA that they were working on belt and bag systems and intended to introduce them, as options, on several models within the next few model years (28). Even prior to the rescission of Federal Motor Vehicle Safety Standard (FMVSS) ***208,*** several of the announced intentions had not been realized.

The technology for both bags and belts is developed and available. As is discussed in the section below, when used properly, these technologies are commonly acknowledged to work, to save lives, and prevent disabling injuries. What is less clear is whether the American car rider will wear belts, active or passive, and whether the consumer's car-buying propensity will be reduced as a result of passive-restraint-induced car price increases. This too is examined below.

● **For a detailed chronology of events in air bag development, debate, and rulemaking, see** ***Back,ground Manual) on the Occupant Restraint Issue*** (13).

SAFETY AND EFFECTIVENESS

Following a review of the evidence, William Coleman, Secretary of Transportation in the Ford administration, concluded that passive restraints "are a reliable and effective means of substantially reducing death and injuries on the Nation's highways." If air bags were installed on all cars, Coleman estimated, they "would probably save over twelve thousand lives annually and prevent or reduce in severity over one hundred thousand moderate to critical injuries per year" (13).

The precise quantitative findings can be challenged-for example, recent estimates have placed the life-saving potential of passive restraints in the vicinity of 6,000 to 9,000-but the qualitative conelusion is beyond dispute. All of the quantitative evidence supports it and the logic is impeccable: “The principle behind an occupant restraint is that an occupant is much less likely to be injured or killed in an automobile crash if the crash forces are applied in a controlled way to the strongest parts of the human body” (28). Furthermore, proponents of passive restraints argue, occupant restraints are much more likely to be used if they are automatic (i. e., passive) than if they require action on the part of the occupant, as do today’s manual belts.

Passenger restraint systems are not perfect; they reduce but do not invariably prevent deaths and injuries. Neither belts nor air bags are particularly effective in rear-end collisions, and the two technologies have different merits and liabilities in other types of crashes. In the instance of an impact on the passenger side of a car, for example, belts are effective in keeping the driver from being pitched to the side. Air bags occasionally inflate on side impact, and the passenger-side bag can then protect the driver, but inflation of the bags is uncertain. If the bags do inflate, they shield the driver from flying glass and metal and thereby afford the driver a form of protection that belts cannot offer.

The technology of passive restraints might pose hazards. Concern has been expressed about the toxicity of sodium azide, a chemical in compounds used in many air bag systems to inflate the bags. Testimony has been offered indicating that the chemicals are confined sufficiently so that car occupants are not exposed to them, either before or during deployment of a bag. NHTSA is convinced by the evidence, but is quick to point out that other, nonchemical inflation mechanisms have been developed (13).

Other concerns expressed about bags include fears that inadequately restrained children could slide beneath and be smothered by the bags, or even conceivably be thrown backwards into the rear window. There are worries that air bags might inflate spontaneously without an impact or on minor impact, thereby causing a serious accident (12). Again, the bulk of the evidence is that these are not significant problems. The track record of the more than 10,000 air-bag-equipped cars is quite impressive in this regard (13,28). There may have been isolated incidents, and might be others in the future, but the life-saving and injury-reduction potential of air bags dwarfs these adverse outcomes.

The principal problem with automatic belts is that they can be disconnected. They have to be equipped with a safety release for emergencies. For the person for whom belt-wearing is truly burdensome, passive belts can be actively disengaged either permanently or repeatedly. In effect, the individual converts the passive restraint system into an active nonrestraint system, and effectiveness goes to zero.

A common worry expressed about belts (manual or automatic) is that they may prevent a person from being thrown from a car in an accident in which remaining within the car would prove to be more damaging. This outcome might occur in rare instances, but the opposite outcome is much more probable—i.e., an unrestrained occupant is much more likely to be injured or killed by being thrown from (or around) the car than by being restrained within it.

In the remainder of this section, the evidence on the effectiveness of belts and bags in reducing death and injury is presented and discussed. The following caveats should be kept in mind in interpreting the data:

1. Air-bag field experience relates virtually exclusively to large-size and luxury cars, principally the GM vehicles produced in the ***1974-76*** model years. Whether this experience generalizes directly to all cars (with almost all new cars much smaller than these) remains to be seen.

2. Automatic belt experience in the VW Rabbit, the source of most relevant data, might not typify general experience once all cars were so equipped. Small-car buyers in the late 1970’s exhibited a greater propensity to buckle up than did the average driver of the period: whereas average drivers buckled up only 10 to 15 percent of the time, owners of Rabbits with manual (active) belt systems wore their belts 34 percent of the time (28). Thus, in a world of passive seatbelts, there would be reason to expect a disconnect rate

in the general population greater than that of automatic-belt Rabbit owners, particularly since DOT policy could not require the kind of interlock device found in automatic-belt Rabbits (23).

3. Related to the above point, current users of passive restraint systems represent a largely self-selected group. It is possible that their motivation, particularly their concern about driving safety, differs enough from that of the overall population to invalidate generalizations based on their experience. Mitigating this concern are studies which control for accident severity before assessing the effectiveness of the restraint systems. Also, in the VW case, the passive belts were part of a luxury option package, one sufficiently expensive that it seems unlikely that people would buy the package simply to get the belts. Furthermore, evidence from claims data indicates almost identical rates of accident claims and size of damage awards for Rabbit owners with and without passive belts (3). Nevertheless, it should be recognized that victims of serious crashes are less often restrained than nonvictims (41), so the average effectiveness of restraints in a mandatory system may be less than that observed with voluntary experience. *

Subject to these caveats, the evidence is strong that both air bags and automatic belts are very effective devices for reducing death and serious injury. Different studies have employed different data bases, estimating techniques, and measures of health outcomes, making direct comparability difficult.

The most effective restraint system is the air bag combined with use of a (manual) lap belt. In 1977, NHTSA estimated this combination to be ***66*** percent effective in reducing fatalities, with the bag alone rated as ***40*** percent effective. * NHTSA estimated the effectiveness of seatbelts, when worn, at 50 to 60 percent (3). Other estimates of effectiveness range from 25 percent (12) to 79 percent (12) for the air bag and from 28 percent (12) to 72 percent (13) for seatbelts. However, with both the lowest and highest figures, biases may be exaggerating the estimates. * * From the entirety of the studies, a figure in the vicinity of 50 percent seems reasonable for both passive restraint technologies when used properly.

While the effectiveness ratios are close to each other, air bags rank distinctly higher as life-saving devices for one simple reason: they are used when needed. Disconnect rates for passive belts might run ***30*** to ***40*** percent, conceivably much higher, and almost certainly would exceed 20 percent (VW Rabbit experience being estimated at 22 percent).

Many of the studies share the finding that passive restraint effectiveness decreases with a decrease in injury severity, particularly as one moves to the most minor accidents. Automatic belts and air bags are most effective in protecting against fatal and life-threatening accidents, less so but still highly effective for severe but not life-threatening accidents, less effective for moderate injuries, and least effective for minor injuries. * * *

NHTSA, for example, estimated that belt effectiveness drops 1 to ***5*** percentage points as one moves from life-threatening to non-life-threatening but severe injuries, another 1 to 5 points

‘A related view is that greater protection from equipment may cause drivers to drive with greater abandon, since they feel “safer.” Peltzman (35) advanced this view in an article in which he claimed that automobile safety regulations had led to a redistribution, rather than reduction, in highway deaths, with occupant deaths falling and pedestrian deaths rising. Peltzman's work has been criticized on both empirical and theoretical grounds (38).

*In studies of air bag deployments, 16 or 17 percent of occupants were wearing manual lap belts (24).

**For example, Huelke and O’Day (12) examined rural accidents and relied on a team of medical and other experts to estimate the probability of occupant survival with different kinds of restraints. Rural accidents tend to be more severe than average, which may produce a downward bias in the authors’ estimates (3).

● **As discussed in ch. 2, automobile accidents are categorized according to the Abbreviated Injury Scale (AIS), which runs from minor injuries (AIS 1) to fatalities (AIS 6). Attempts to utilize injury data in a comparative framework often involve manipulating AIS codes (e.g., using the root mean square of the AIS). More recently, in an attempt to combine the effects of the severity and number of injuries, an Injury Severity Score (ISS) was developed. The ISS has been shown to be highly correlated with the probability of death, length of hospitalization, and extent of disability (24).

moving to moderate injuries, and 20 to 27 points to minor injuries (3). For air bags, NHTSA estimated more precipitous drops, by 10 to 20 percentage points moving to the severe-but-not-life-threatening category, 8 to 13 points to moderate, and 8 to 22 points for minor. The air bag's effectiveness, without a lap belt worn, is rated at close to zero for minor injuries, since the bag will rarely deploy.

Mohan, Zador, and O'Neill (24), provide support for this general finding. In their assessment of the mean Injury Severity Score (ISS) for the two restraint systems and unrestrained occupants by Vehicle Deformation Index (VDI), * Mohan, et al., found that for high VDISs (considerable vehicle deformation), both restraint systems performed well: lap / shoulder belts resulted in an average ISS 55 percent below that of the no-restraint situation, and air bags scored an ISS ***66*** percent below the no-restraint condition. Both of these differences were statistically significant. While the small difference between the two restraint systems was not statistically significant, it was consistent with laboratory test data indicating the superiority of air bags in severe frontal crashes.

Mohan and colleagues found that for lower VDIs (less vehicle deformation), belts continued to show a considerably lower mean ISS than no restraints; air bags, however, did not. The authors explain this, at least in part, as an artifact of the accident-designation process: an accident was recorded as involving an air-bag- equipped vehicle only when an air bag deployed; at low VDIs, deployment might indicate a stronger-than-average crash force for the VDI class. Regardless of the explanation, however, the data are consistent with the finding that relative restraint effectiveness decreases with decreasing accident severity, and that air bag effectiveness decreases more rapidly —i.e., an occupant is better off wearing a seatbel in a minor accident but perhaps better off being in an air-bag-equipped car in a severe crash. And, again, wearing a belt in an air-bag-equipped vehicle is the safest form of restraint.**

From the relationship between probability of death and IS, Mohan and colleagues estimated the expected number of deaths per 1,000 occupants in cars in frontal crashes with VDIsof 3 to 5. Their estimates, given in percentage terms above, constitute very high estimates of belt and bag effectiveness. Nevertheless, it seems worth presenting these striking numbers: for 1,000 unrestrained occupants, the estimated deaths total 19.4; for 1,000 lap / shoulder-belt-restrained occupants, deaths equal 5.4; and for 1,000 air-bag-restrained occupants (16 percent also wearing a lap belt), the figure is 4.0 The authors caution that these estimates apply only to full-size and luxury cars. I would caution, further, that they *are* estimates, based on a general correlation between an index and an extreme outcome—death.

The different technologies have comparative advantages in the specific injury protection they confer. Table 8 presents data on the root mean square Abbreviated Injury Scale (AIS) ratings, by body region and restraint system, for occupants in frontal crashes with VDIsf 3 to 5. The data show that both air bags and lap / shoulder belts provide greater protection for all body regions (with one exception) than no restraint.

Air bags are particularly effective in reducing head and neck injuries (by 58 percent compared with no restraint) and have their greatest advan-

Table 8.—Root Mean Square AIS Ratings for Occupants in Frontai Crashes With VDis 3-5 by Body Region and Restraint System

	Restraint system		
Body region	Air bag[a]	Lap/shoulder belt	None
Head and neck	0.5	0.7	1.2
Face	0.7	0.8	1.2
Chest	0,8	0.8	1.4
Abdominal or pelvic region	0.3	0.8	0.5
Extremities and pelvic girdle	1.1	1.2	1.8

approximately 16-percent lap belt use.

SOURCE: D. Mohan, at al., "Air Bags and Lap/Shoulder Belts—A Comparison of Their Effectiveness in Real World, Frontal Crashes" (Washington, D. C.: Insurance Institute for Highway Safety, 1976).

● **The VDI is exactly what the name suggests-an index of the severity of damage to the body of a vehicle.**

● ***A GM study in** 1976 **concluded that air bags' effectiveness in reducing injuries ranged from only** 6 to 20 percent. An **NHTSA critique of the study identified two potential sources of serious** bias **that led NHTSA to conclude that the data supported an effectiveness estimate of from 30 to 60 percent (28). GM has defended the methodology of its study [D. Martin, General Motors, personal communication, 1982].**

tage over belts in the abdominal and pelvic regions, where belts actually perform worse than no restraint at all (though the injury severity level is not great). Belts are less effective than bags in all regions except the chest area, where they confer equal protection.

The most serious injuries occur to the extremities and pelvic girdle, with both restraint systems affording relatively less protection than in most other areas. While bags dominate belts in this analysis, it must be remembered that in the minor accidents not recorded in this table (VDIs less than 3) in which air bags do not deploy, the unbelted occupant of an air-bag-equipped car generally receives no additional protection, while the belted occupant does.

Most of the estimates presented above have been based on actual accident data; some have derived from laboratory tests and theoretical analysis. In most, though not all, attempts have been made to correct for sources of bias, differences in types of drivers, and so on. Nevertheless, it seems useful to close this consideration by presenting some unadjusted on-the-road data, numbers in the simplicity of which lies clarity.

With regard to passive belts, experience with the VW Rabbit is considerable. From 1975 through early 1981, VW produced 400,000 cars with automatic belts satisfying the requirements of FMVSS 208. These cars have averaged 0.78 deaths per 100 million vehicle-miles, compared with a national average of 2.4—a 68 percent reduction in the death rate (14). In an earlier comparison of accident-death experience in Rabbits with automatic v. manual belts, there were 51 percent fewer deaths per 1,000 car-years with the former than with the latter (28). Since some of the automatic belts were disconnected (an estimated 22 percent) and many of the manual belts were being used (about 34 percent), this difference provides an underestimate of, or at least a lower bound on, the life-saving potential of passive belt systems. *

With regard to air bags, almost all of the experience clusters at the other end of the car line: full-size and luxury cars, primarily the 10,000 to 12,000 produced by GM between ***1974*** and 1976. By 1979 these cars had accumulated over 700 million miles of driving on American roads. Statistical expectations for deaths and moderate to critical injuries would have been 10 and 124, respectively, yet experience showed half of these figures: 5 occupants of air-bag-equipped cars had died and ***62*** had received moderate to critical injuries. There had been some 200 air-bag deployments and only two known deployment failures, one attributable to a mechanic's mistakenly disconnecting the mechanism (28).

Finally, while fatality and injury data constitute the bottom line, it is interesting to note that passive restraints may be beginning to pass another acid test—i.e., their effect on automobile insurance. Beginning in the late 1970's, a few insurance companies, including Nationwide and Allstate, offered owners of passive-restraint-equipped vehicles reductions of approximately 30 percent on the portion of car insurance premiums applicable to medical (Medpay) or personal injury protection (PIP) coverage. Nationwide has estimated insurance savings of roughly $20 per year for a car equipped with automatic belts. Over the lifetime of the car, this translates into a present value of $150 (33). A Highway Loss Data Institute study found reductions in Medpay and PIP claims of from ***20*** to ***27*** percent when comparing VW Rabbits with and without passive belts ***(13).*** These market data support the accident data findings that passive restraints are an effective means of reducing death and disability.

● Once again, it is important to keep in mind potential differences by car size, etc. However, the VW data suggest an incremental belt usage of 44 percentage points (78 percent of automatic belt owners not disconnecting their belts minus 34 percent of manual belt owners wearing their belts). The national disconnect rate under a mandatory system would have to exceed 45 percent, given manual belt usage in the vicinity of 11 percent, for incremental belt usage to fall below that of the Rabbit (5s – 11 = 44). Some participants in the passive restraint debate believe that such a disconnect rate would be exceeded.

COSTS OF PASSIVE RESTRAINTS

Estimates of the costs of passive restraint systems are abundantly available, but determination of the likely true costs remains a challenge. Most of the estimates come from the automobile companies, and according to one nonindustry analyst, these companies (33):

> . . . have a very strong incentive to engage in strategic estimates of costs. If the estimated costs are high enough, they may well persuade [NHTSA] to rescind the rule [FMVSS 208].

For some observers, both leaked company documents and analytical work have raised questions about the validity of manufacturers' estimates.

During hearings leading to the l-year delay in implementing FMVSS 208, Ford and GM provided estimates of incremental automatic belt cost which averaged $114, including $88 for manufacturers' cost, $20 for markup, and $6 for incremental fuel costs (additional fuel consumed as a result of installation of the technology). Nordhaus (33) has argued that these estimates are inconsistent with the companies' estimates of their investment programs. He believes that a reasonable estimate for the true incremental cost to the consumer would be $60, instead of the $88 cited by GM. Nordhaus' figure is not inconsistent with earlier NHTSA and GM estimates based on incremental costs in Rabbits and Chevettes, which run (in 1981 dollars), from $42 to $85. GM points out, however, that automatic belt systems for large cars would be more expensive than those designed for small cars. * In terms of annual costs (i.e., amortizing and depreciating over the life of the car), the small-car range becomes $8.25 to $15.45 (3) (figures updated to 1981 dollars).

The costs of air bags are still less clear.** At one point, GM claimed that it would sell air bags for an incremental cost of from $290 to $325, assuming mass production. More recently, the company estimated large-volume consumer costs in excess of $600 per car. Ford's estimates have also varied. In 1976, Ford estimated a consumer cost of close to $400, but a recently leaked internal memorandum placed the figure at from $425 to $1,150. The same source indicated that for both Ford and GM, manufacturer cost would run only $135 to $140 (2). other cost estimates by manufacturers range from $150 to $280. DOT developed an estimate of $190 (13,28).

Put together, these figures suggest that incremental consumer cost for the basic air bag systems probably would run from $250 to $425. Annual costs would range from $55 to $115. In addition, for those air bags deployed in vehicles which were not demolished, costs of reinstallation would become relevant. Such costs would certainly exceed initial installation costs under conditions in which air bags would be mass-produced standard equipment. However, such costs would apply to a very minor proportion of vehicles, since only a small percentage of air bags would ever deploy during the lives of the vehicles.

The variation in air bag cost estimates may represent some strategic gaming, as Nordhaus (33) suggests, but it also reflects several technical changes and uncertainties. Of fundamental importance is the question of scale. Several analyses emphasize the great economies to be realized from large-scale production. Ford estimated a ***200***-percent difference in per-unit manufacturer cost between producing a total volume of 885,000 cars and a volume of only ***200,000*** cars ***(2).*** In 1980, GM estimated a consumer cost of $1,100 based on a volume of 100,000 units, falling to between $650 and $700 if 400,000 units were produced. *

A separate estimate, based on quotations of components, found that the cost of a driver bag and inflator module would be 25 percent of its base cost (which assumed 13,000 units) if 900,000 units were purchased (28). Similarly, a passenger bag and inflator module would fall to 33 percent of base cost at the high volume. Some components, such as sensors and diagnostic parts, are not so sensitive to the scale, but the fact remains that the cost of an air bag system would be very dependent on the number produced and sold (28).

*** Personal communication, 1982. Manufacturers' estimates in 1978 (updated to 1981 dollars) ranged from $84 to $140, depending on comfort and convenience features (28).**

**** All of the dollar figures in the remainder of this section are updated from their original sources to 1981 prices.**

*** D. Martin, General Motors, personal communication, 1982.**

The costs discussed above are direct costs attributable to manufacture and installation of the passive restraint systems, plus small items of indirect cost (e.g., additional fuel consumption). Ignored in these numbers is the potential direct monetary benefit the owner of a passive-restraint-equipped vehicle might derive from lower insurance premiums. As noted above, the present discounted value of this benefit over the life of a typical car will total is $l50 (33), a considerable offset to the incremental cost incurred by the consumer. Indeed, in the case of the automatic belt, the insurance savings outweigh the incremental price of the belt, implying that the purchaser of a passive-belt-equipped car could end up ***saving*** at least $35 over the life of the car (33).