SPECIAL ISSUE: CAR SIZE, WEIGHT, AND SAFETY

STATUS REPORT

INSURANCE INSTITUTE FOR HIGHWAY SAFETY

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CAR SIZE AND WEIGHT ARE CRUCIAL

to protecting people in crashes. One way to see how crucial is to crash two cars that have a lot in common other than their size and weight differences. For example, crash a microcar or a minicar with good frontal crashworthiness ratings into a midsize model that earns the same ratings and was manufactured by the same automaker. What happens in the front-to-front collision says a lot about the safety consequences of vehicle size and weight.

The Institute recently crashed a Honda Fit into a Honda Accord, a Smart Fortwo into a Mercedes C class, and a Toyota Yaris into a Toyota Camry (these automakers have micro and minicars rated good for frontal crashworthiness, based on the Institute's 40 mph offset test into a deformable barrier). The car-to-car tests aren't about whether one minicar is more crashworthy than another. Such information is available from the comparative ratings based on the barrier tests.

The new tests of paired cars are about the physics of crashes. Reflecting Newton's laws of motion, the results confirm the lesson that bigger, heavier cars are safer (see facing page). Some minicars earn higher crashworthiness ratings than others, but as a group these cars generally can't protect people in crashes as well as bigger, heavier models.

"There are good reasons people buy minicars," says David Zuby, the Institute's senior vice president for vehicle research. "For starters, they're affordable, and they use less gas. But the safety trade-offs are clear from the results of our new tests."

The midsize Honda Accord's occupant compartment remained intact during this 40 mph frontal collision with the Fit, a minicar. In contrast, there was a lot of intrusion into the Fit's occupant compartment, which compromised the survival space around the driver dummy. Measures recorded on the dummy indicate that the risk of serious injury would be high in a real-world collision similar to this test.

As in the barrier tests the Institute conducts for consumer information, each of the cars in the frontal offset crashes involving pairs of 2009 models from Daimler, Honda, and Toyota were going 40 mph. Researchers rated each car's performance from good to poor based on measured intrusion into the occupant compartment, forces recorded on the Hybrid III driver dummy, and movement of the dummy during the impact. The main difference between these tests and those conducted for consumer information is the car-to-car versus car-into-barrier configuration.

"Sometimes the whole issue of size and weight gets obscured in the quest to buy a car with good safety ratings," Zuby says. "The ratings are important, but frontal ones can be used only to compare cars that are similar in size and weight. You can compare the ratings of the Fit and Yaris, for example, and find they both earn good overall scores. But you can't compare these cars' ratings with those of midsize cars — or with the ratings of cars in any other class, for that matter, because of the effects of vehicle size and weight."

The Institute didn't choose SUVs or pickups, or even large cars, to pair with the minis in the new crash tests. The choice of midsize cars reveals how much influence some extra size and weight can have on crash outcomes.

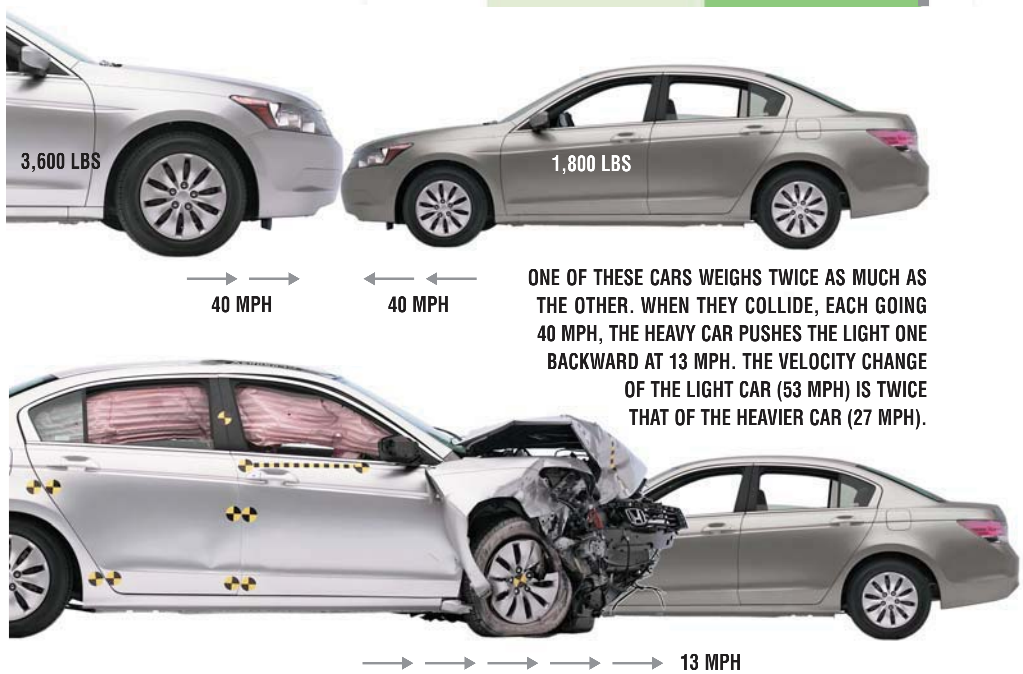
Honda Accord versus Fit: The Accord came through the frontal test without significant downgrades. Measured intrusion at 8 locations in the occupant compartment was in the good range, and all *(continues on p.6)*

SIZE

When a car crashes into a solid barrier, the outcome depends in part on the size of the front end. If one car's front end is long enough to crush twice as much as another car's in a barrier crash at the same speed, its restrained occupants will experience half as much force as the people in the smaller car because it takes them twice as long to stop.

WEIGHT

When two cars going the same speed crash front to front, the outcome depends in part on the cars' relative weights. The heavier car will push the lighter car backward during the impact, which means the velocity change of the heavier car will be much less than that of the lighter car. If the lighter car weighs half as much as the heavier car, the forces on its occupants will be twice as great.



PHYSICS

DICTATE CRASH OUTCOMES

The poor performance of all three micro and minicars in frontal impacts with midsize cars (see p. 1) isn't surprising. It reflects the laws of the physical universe, specifically principles related to force and distance.

Although the physics of frontal car crashes usually are described in terms of what happens to the vehicles, injuries depend on the forces that act on the occupants — and these forces are affected by two key physical factors. One is the weight of a crashing vehicle, which determines how much its velocity will change during impact. The greater the change in velocity, the greater the forces on the people inside and the higher the risk of injury.

The second physical factor affecting injury likelihood is vehicle size, specifically the distance from the front of a vehicle to its occupant compartment. The longer this is, the lower the forces on the occupants, provided vehicle designers take advantage of the extra length.

These two factors, size and weight, have separate effects, but they're highly correlated. In theory the lighter weights of smaller cars could be offset by increasing the sizes of their front ends, keeping weight down by using materials like aluminum, plastic, or titanium. But this typically doesn't occur because such materials cost so much.

Characteristics including the stiffness of a vehicle's front end also influence the outcomes of crashes. However, size and weight are the basic influences.

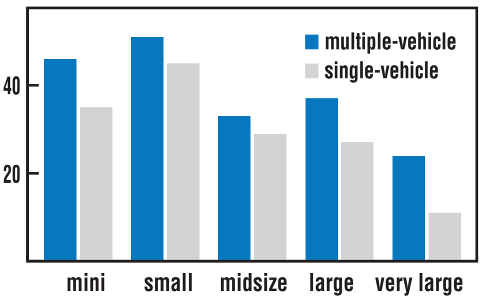
Size and weight affect injury likelihood in all kinds of crashes. In a collision involving two vehicles that differ in size and weight, the people in the smaller, lighter vehicle will be at a disadvantage. The bigger, heavier vehicle will push the smaller, lighter one backward during the impact. This means less force on the occupants of the heavier vehicle and more on the people in the lighter vehicle. Greater force means greater risk, so the people in the smaller, lighter vehicle are more likely to be injured.

Crash statistics confirm this. The death rate in 1-3-year-old minicars involved in multiple-vehicle crashes during 2007 was almost twice as high as the rate in very large cars.

"Some minicars are definitely more crashworthy than others," says David Zuby, Institute senior vice president for vehicle research. "So it pays to compare their safety ratings. But as a group minicars do a comparatively poor job of protecting people in crashes, simply because they're smaller and lighter. In collisions with bigger vehicles, the forces acting on the smaller one are higher, and there's less distance from the front of a small car to the occupant compartment to 'ride down' the impact. These and other factors increase injury likelihood."

Fatality risk in minicars is high in single- as well as multiple-vehicle crashes. The death rate per million 1-3-year-old minis in single-vehicle crashes during 2007 was 35 compared with 11 per million for very large cars. Even in midsize cars, the death rate in single-vehicle crashes was 17 percent lower than in minicars.

DRIVER DEATHS PER MILLION 1-3-YEAR-OLD CARS REGISTERED, 2007



Driver death rates decline fairly consistently as vehicle size increases. This doesn't mean drivers have to choose the heaviest vehicles on the road to reap safety benefits. New crash tests demonstrate that midsize cars afford a lot more protection than minicars from the same manufacturer (see p.1). The overall driver death rate in midsize cars is 23 percent lower than in minicars.

"The lower death rates in single-vehicle crashes of larger cars are because many objects that vehicles hit aren't solid, and big, heavy vehicles have a better chance of moving or deforming the objects they strike. This dissipates some of the energy of the impact," Zuby explains.

Insurance claims filed for injuries under personal injury protection coverage also are higher for minis than for midsize cars. Overall losses, which reflect both claim frequency and severity, are 193 for 4-door minis versus 147 for 4-door midsize cars (100 is the average for all cars).

FUEL ECONOMY AND SAFETY CAN BE ACHIEVED AT THE SAME TIME

One reason people buy smaller cars is to conserve fuel. The price of gasoline skyrocketed last year, and there's no telling what the price at the pump might be next week. Meanwhile, the gears are turning to hike federal fuel economy requirements to address environmental concerns.

The conflict is that smaller vehicles use less fuel but do a relatively poor job of protecting their occupants in crashes (see p.3). Thus, fuel conservation policies have tended to conflict with motor vehicle safety policies. But they don't have to.

"The key going forward will be for consumers and policymakers to recognize the potential conflict and make choices that serve safety as well as fuel economy. The first step is to look at the consequences of past policies and choose future ones that serve both goals instead of setting the two at odds," says Institute president Adrian Lund.

Fuel economy at the expense of safety: More than 30 years have elapsed since Congress enacted the Energy Policy and Conservation Act of 1975, which required automakers to build cars that use less fuel. The result during the first 15 or so years of this law was to improve the overall fuel economy of the US car fleet by about 75 percent.

The main way automakers achieved this was by reducing car weights. For example, Chrysler stopped making big cars altogether. By 1985 cars were an average of 500 pounds lighter than they would have been without the federal requirements.

The downside was to increase fatality risk in crashes. Multiple studies document this, including Institute research comparing deaths in Ford and General Motors cars before and after they were downsized during 1977-86 (see *Status Report*, Sept. 8, 1990; on the web at iihs.org). The finding was a 23 percent increase in deaths per 10,000 registered cars.

Subsequent research documents the continuing price in terms of lives. For example, the National Research Council concluded in 2002 that 1,300 to 2,600 additional crash deaths occurred in 1993 because of vehicle weight reductions to comply with federal standards (see *Status Report*, April 6, 2002; on the web at iihs.org).

A problem with the current structure of fuel economy standards for cars is that the target of 27.5 miles per gallon is applied to an automaker's whole fleet, no matter the mix of cars an individual automaker sells. This encourages manufacturers to sell more smaller, lighter cars to offset the fuel consumed by their bigger, heavier models. Sometimes automakers even sell the smaller — and less safe — cars at a loss to ensure compliance with fleetwide requirements.

"What's needed instead is to restructure fuel economy standards for cars the same as the government has done for other kinds of passenger vehicles," Lund advises.

In 2006 the National Highway Traffic Safety Administration adopted a fuel economy system for SUVs, pickup trucks, and vans that mandates lower fuel consumption as vehicles get smaller and lighter, thus removing the incentive for automakers to downsize their lightest vehicles to comply (see *Status Report*, April 22, 2006; on the web at iihs.org). The result is to force the auto manufacturers to use vehicle and engine technologies to improve fuel economy. By 2011 all SUVs, pickup trucks, and vans will have to comply.

However, the same plan doesn't yet apply to cars, which still are subject to a fleetwide fuel economy standard. The Bush administration proposed a size-based standard for cars, like the other passenger vehicles, but left it to the current administration to carry through. Now the Obama administration says it's boosting the fuel economy standard for cars, beginning with 2011 models, and this will be accomplished under a size-based system.

On a separate front, California officials are trying to improve air quality by setting more stringent emissions limits than the federal government requires. The state's carbon emissions limit is structured so that vehicles of all sizes would be held to a single average, which conflicts with occupant safety goals.

A US Court of Appeals is considering whether federal fuel economy standards preempt California's emissions standard, and the Institute has filed a brief opposing the state. The problem, the Institute told the court, is that "the easiest, cheapest, and quickest way for automakers to meet a significant reduction in an overall fleet average of carbon emissions is to downsize to reduce fuel consumption," which costs lives in crashes. Lund adds that if a state does succeed in preempting federal fuel economy or emissions standards, it should ensure that its programs don't have negative consequences for people in crashes.

Travel speeds affect both: Setting higher federal fuel economy targets isn't the only way to conserve fuel. How about lowering speed limits? Going slower uses less fuel to cover the same distance. There's a big safety bonus, too, that's evident in the experience of the 1970-80s (see *Status Report*, Nov. 22, 2003; on the web at iihs.org).

Goaded by federal lawmakers, every state adopted 55 mph speed limits on interstate highways in 1974. The impetus was the 1973 oil embargo, and the idea was to conserve fuel by slowing down motorists until automakers could build cars that use less gas. The immediate effect was to save thousands of barrels of fuel per day — and thousands of lives. In fact, highway deaths declined about 20 percent the first year, from 55,511 in 1973 to 46,402 in 1974. The National Research Council estimated that most of the reduction was due to the lower speed limit, and the rest was because of reduced travel. By 1983 the national maximum 55 mph limit still was saving 2,000 to 4,000 lives annually.

With the oil crisis a thing of the past by the middle of the 1980s, Congress lifted pressure on states to retain 55. Speed limits began going up in 1987, and so did occupant deaths in crashes. Fifteen to 30 percent increases were documented.

"The national maximum speed limit was adopted to save fuel, but it turned out to be one of the most dramatic safety successes in motor vehicle history," Lund points out. "The political will to reinstate it probably is lacking, but if policymakers want a win-win approach, this is it. It saves fuel and lives at the same time."

More good choices going forward: Another way to serve both safety and fuel economy would be to curtail the horsepower race. Only a few cars used to be capable of 300 horsepower, but now many cars match this. Average horsepower is 70 percent higher than it was in the mid-1980s, and some of today's high-performance cars surpass the power of even the muscle cars of the 1960-70s. If an automaker were forced to use engine-enhancing technology to improve fuel efficiency instead of to boost performance, safety would improve, too, because vehicles with souped-up horsepower are associated with increased injury risk (see *Status Report*, April 22, 2006; on the web at iihs.org).

"Drivers don't have to wait for the government to act. They can simply choose to drive slower or choose to buy cars that aren't the smallest ones available but still earn kudos for fuel economy," Lund points out. For example, the Honda Civic Hybrid and Toyota Prius, also a hybrid, get better gas mileage than the Smart Fortwo. Even the Volkswagen Jetta with a diesel engine does almost as well.

There are other ways, both individual and societal, to serve fuel economy and safety simultaneously. For example, roundabouts serve both at intersections (see *Status Report*, June 9, 2008; on the web at iihs.org). The key going forward is to keep the potential conflict between safety and fuel conservation in mind so that policies designed to serve one don't inadvertently compromise the other.

ONE OF THESE CARS IS BIGGER THAN THE OTHER, but this doesn't mean their fuel economy necessarily varies by as much as their size difference suggests. Some models that are classified as small or even midsize get as many miles to the gallon, or almost as many, as cars classified as minis. The safety plus is that death rates are lower in the larger cars (see chart, facing page). So driving a relatively big car that's also economical on fuel is one way to serve both safety and fuel conservation. Another way is for state and local officials to set and enforce lower speed limits. Going slower uses less gas to cover the same distance, and it reduces both crash likelihood and the severity of the crashes that occur.

SMART INTO C CLASS: POOR

The space around the driver dummy in the Smart Fortwo collapsed during a 40 mph frontal offset crash test into a Mercedes C class. Multiple injuries, including to the head, would be likely for a real-world driver of a Smart in a similar collision. This outcome contrasts with the Smart's performance in the Institute's frontal offset barrier test that's run at the same 40 mph speed. In the barrier test, the Smart earned a good rating overall, while it rates poor in the collision with the C class.

(continued from p. 2) except one measure of injury likelihood recorded on the driver dummy's head, neck, chest, and both legs also were good. Only the value recorded on the left foot veered from good into the acceptable range (values are based on thresholds indicating injury likelihood).

In contrast, a number of injury measures on the dummy in the Fit were less than good. Forces on the left lower leg and right upper leg were in the marginal range, while the measure on the right tibia was poor. These indicate a high risk of leg injury in a real-world crash of similar severity. In addition, the dummy's head struck the steering wheel through the airbag.

Intrusion into the Fit's occupant compartment was extensive at 6 of 8 measured locations, warranting a marginal rating for the structure. Overall, the Fit is rated poor in this front-to-front test, despite its good crashworthiness rating based on the Institute's offset barrier test. The Accord earns good ratings for performance in both tests.

Mercedes C class versus Smart: After striking the front of the C class, the Smart went airborne and turned around 450 degrees. This contributed to excessive movement of the dummy during rebound — a dramatic indication of the Smart's poor performance but not the only one. There was extensive intrusion into the space around the dummy from head to feet. The instrument panel moved up and toward the dummy. The steering wheel was displaced upward. Multiple measures of injury likelihood, including those on the dummy's head, were poor, as were measures on both legs.

"The Smart is the smallest car we tested, so it's not surprising that its performance looked worse than the Fit's. Still both fall into the poor category, and it's hard to distinguish between poor and poorer," Zuby says. "In both the Smart and Fit, occupants would be subject to high injury risk in crashes with heavier cars."

In contrast, the C class held up well, with little to no intrusion into the occupant compartment. Nearly all measures of injury likelihood were in the good range, though the measure on the head was downgraded to acceptable because the dummy's head struck the B-pillar hard. Still, this was a good performance overall.

Toyota Camry versus Yaris: There was far more intrusion into the compartment of the Yaris than the Camry. The minicar's door was largely torn away. The driver seats in both cars tipped forward, but only in the Yaris did the steering wheel move excessively.

Similar contrasts characterize the measures of injury likelihood recorded on the dummies. The heads of both struck the cars' steering wheels through the airbags, but only the head injury measure on the dummy in the Yaris rated poor. There was extensive force on the neck and right leg plus a deep gash at the right knee of the dummy in the minicar.

Like the Smart and Fit, the Yaris earns an overall rating of poor in the car-to-car test. The Camry is acceptable, which doesn't match its good rating in the Institute's 40 mph barrier test, despite the similar speed and offset configuration (see facing page). Still the midsize car fared much better than the mini.

Laws of physics prevail: Some proponents of mini and small cars claim they're as safe as bigger, heavier cars. But the claims don't hold up. For example, there's a claim

that the addition of safety features to the smallest cars in recent years reduces injury risk, and this is true as far as it goes. Airbags, advanced belts, electronic stability control, and other features are helping. The same features have been added to cars of all sizes, though, so the smallest cars still don't match bigger ones in terms of occupant protection.

Would hazards be reduced if all passenger vehicles were as small as the smallest ones? Yes, this would help in vehicle-to-vehicle crashes, but occupants of smaller cars are at increased risk in all kinds of crashes, not just collisions with heavier passenger vehicles. Almost half of all crash deaths in minicars occur in single-vehicle crashes, and these deaths wouldn't be reduced if all cars became smaller and lighter. In fact, the result would be to afford less occupant protection fleetwide in single-vehicle crashes.

Yet another claim is that minicars are easier to maneuver than big cars, so their drivers can avoid crashes in the first place. Insurance claims experience says otherwise. The frequency of claims filed for crash damage is higher for mini 4-door cars than for midsize ones.

There's no getting around the laws of the physical universe. The Institute's new crash tests confirm this — again.

YARIS IN BARRIER TEST: GOOD

YARIS INTO CAMRY: POOR

BARRIER TEST VS. CAR TO CAR: Car-to-car crash tests often are more demanding than the front-into-barrier tests the Institute conducts for consumer information (go to iihs.org/ratings). A basic reason is that the barrier test mimics a frontal crash between identical cars — a Toyota Yaris into a Yaris, for example. Because the midsize Toyota Camry weighs more than the Yaris, it inflicted more force on the minicar, compared with a barrier test.

Drivers of minicars aren't likely to confine their crash experience to other minis. As the smallest cars on the road, they're far more likely to collide with bigger, heavier vehicles. This is when the safety consequences resemble those in the crash with the Camry — or worse.

Another consideration is that, while the Institute's barrier approximates the front of another car, it can't be designed to mimic the various fronts of hundreds of different cars. This helps explain why the Camry performed worse in the test with the Yaris than in the barrier impact that approximated a crash with another Camry — something about the Yaris' front end was more difficult to manage.

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SPECIAL ISSUE

CAR SIZE & WEIGHT, AGAIN: The new series of crashes involving mini and midsize cars isn't the Institute's first foray into testing to demonstrate vehicle size and weight effects in frontal crashes. The first time was in 1971, and the test series featured an AMC Gremlin (above left) then known as an economy car, crashing into AMC's large Ambassador model.

The Insurance Institute for Highway Safety is a nonprofit scientific and educational organization dedicated to reducing deaths, injuries, and property damage from crashes on the nation's highways. The Institute is wholly supported by auto insurers:

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