and is a very valid point. The problem that you get into with trying to detect the stability problems is very complicated, however, and well beyond the scope of what we were trying to address in this session. It is certainly a fundamental problem. We will have to weaken the devices; they probably will have to be weaker than what we have projected in the paper; that is, taking the 1,100 and 750 second criteria. But that was, and the question came up earlier, what was the survivable deceleration. The criteria that we now have, as much as anything, is based on the stability of the vehicle after impact. Therefore, we have incorporated some of that thinking into the criteria.

QUESTION: What has or can be done to make utility poles breakaway design?

MR. WOODS: The utility pole area has some real built-in problems. It's obvious we can treat them, we know how to do that, that's not the problem. The problem is, people that work on utility poles have union rules that don't allow them to climb them if they are weakened and that creates a very basic problem. If you put in a weakening mechanism to make it safe, what do you do with the lineman when he goes out for repairs? This is not significant in every state, it is very significant in some states. We do not have a satisfactory mechanism at the present time for these very light vehicles in that respect. We're probably exceeding the mass of the pole--the mass of the pole probably exceeds what we can reasonably hope to be safe for a vehicle of 1,000 or 1,200 pounds which means scaling down the size of the elements drastically, but more practically, get it away from the highway. That's where we're going to push, I think, in the future. We forget sometimes that we give the utilities the privilege of being on our right of way but we don't have to give it. We can take it back and force them to do things or lose their utilities, to make them safe, especially under certain circumstances.

QUESTION: What effect would there be on sign post design?

MR. WOODS: They do have to be substantially weaker, there's no question about that. Probably we're talking about changing the material property in order to achieve the fracture at relatively low energy levels and at the same time resist bending satisfactorily. Probably, also we're going to have to cut the weight down even further. Where we now talk about 3 pounds per foot being the basic single post that's safe, we may have to think in terms of 2 pounds or less. This means we have more vibration problems and several other of the normal installation problems becoming very difficult. The other thing that looks very shaky is the fracture type, the wood supports. Four by six is marginal for a 2,250 pound vehicle, now we pull it down to 1,200 or 1,700 even, and it becomes at best survivable. The injury rate is going up drastically with the smaller vehicles.

In terms of making them more survivable for a 15 degree hit? The logic of the system says you have to yield a little bit in order to get these lateral decelerations down below 5 G's. Maybe the criteria are bad, that's a possibility. Assuming the criteria are good, then it probably would mean adding on to it to allow the vehicle to penetrate slightly, which increases our maintenance costs. We're going exactly the opposite way at the present time. Increased use of concrete to reduce the maintenance costs. Those of you who haven't heard the message yet, the national average metal beam barrier maintenance cost is 50 cents per linear foot per year. The national average concrete barrier maintenance is a penny per foot per year. If you have any reasonable idea what the highway agencies' problems are now money-wise, you understand very quickly why concrete is becoming terribly popular. It's economically feasible.

OPERATOR AND SAFETY PROBLEMS

James O'Day
Highway Safety Research Institute
The University of Michigan

JIM PLINE: Our next speaker is James O'Day, with the Highway Safety Research Institute at the University of Michigan. He's head of the Systems Analysis Division at that agency. He's been involved over the years in accident investigation, processing and analyzing accident data, has frequently written and presented papers on safety of large and small cars, and had a short tour down in Australia as a consultant to them on safety matters.

JIM O'DAY: As Don Woods said, one of the hardest things to do with this kind of problem is to describe distributions out of data that do not exist and that's what I'm going to try to do, too. The only joy in this is by the time the real data exist to prove that I'm wrong, most of you will have forgotten who said it. Listening to this morning's speakers, I'm not sure that safety matters much to anybody anyhow. We'll proceed from there.

Thousand pound cars just don't exist in the United States in quantities large enough to measure anything (in the present accident data) about their safety performance. Let's start with some data on vehicles that do exist and use some sort of a physical model to proceed from that into the future. I want to start by describing two relationships, one a sort of an empirically-derived relationship from accident data, and the other just a physical model that I think you'll all believe. First the empirical data.

Injury or fatality to occupants of a crashed car results from a variety of things that happen. Carl mentioned the 30G level as an important severity you don't want to exceed, but, many fatalities occur because of an interaction with some part of the body with some part of the vehicle at much less than 30G's. There are lots of things that happen to cause serious injuries and accidents. There have been a lot of crash severity measures tried over the years in accident investigation and in vehicle testing, vehicle design. Many of these correlate more or less well with the probability of occupant injury. Years ago, we used traveling speed because that was what police reported on their accident reports--we'd look at accidents and find out how many people survived or didn't survive for crashes that happened at a 30 mile an hour traveling speed or whatever. A severity estimate closely associated with traveling speed which was used in analysis was the barrier equivalent velocity or BEV. The barrier equivalent velocity would be the equivalent speed of hitting a barrier with the car in a frontal direction. We have also used measurements of the vehicle damage extent and developed a relationship between inches of crush and speed of impact. All of these quantities have been used to estimate crash severity.

Over the past several years, the use of this quantity that Carl mentioned, called Delta-V, has come into prominence. Delta-V is essentially the change in velocity during the crash or crunch phase of an accident. Again, you can think of it pretty much as the same thing as a barrier equivalent velocity for a vehicle that's going into a solid barrier, i.e., it's about equal to the traveling speed in that case. If you hit something hard at 30 miles an hour, your Delta-V will be 30 miles an hour, since in a hundred milliseconds or so, you will be at zero miles an hour. All of these measures are roughly equivalent, although some predict injury better than others.

The Delta-V turns out to be moderately easy to estimate from damage measurements. There are some questions about the precision of Delta-V, but we'll not worry about that for the moment. There are now quite a lot of accident data available for which a value of Delta-V has been estimated for each crash-involved vehicle. One of the most useful results of NHTSA's National Crash Severity Study (NCSS) program was the determination of a relationship between fatality rate for car occupants and Delta-V. Figure 1 shows the approximate relationship. At zero miles an hour, nobody is killed. At Delta-V of 20 miles per hour, about one percent of the occupants of frontally crashed passenger cars die. At 30 miles per hour, the fatality rate is about eight percent (everybody does not die given a 30 mile an hour crash). At about 40 miles an hour the fatality rate is around 17 percent and at 50 miles an hour it's close to 50 percent. It is curved upward rather than linear.

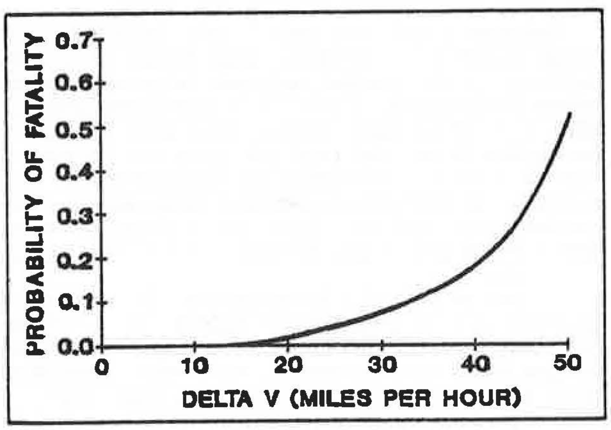

FIGURE 1
Probability of Fatality for Occupants of Towed Passenger Cars Versus Delta-V
SOURCE: NCSS Statistics

Keep that curve in mind for just a moment, and let me go on to the physical model. Let's consider two vehicles of exactly the same weight and structure which run head-on into each other, each traveling at 20 miles an hour. When they hit, given that they're the same weight and structure, they're going to both stop over whatever this crush phase happens to be. The length of the crush phase depends on the structure of the car, but in some short period of time they're going to go from 20 miles an hour to zero. Looking at the curve of Figure 1 and looking at 20 miles an hour, on the average in each of those cars one person out of a hundred would sustain a fatal injury; I would then expect two fatal injuries in a hundred such (two-vehicle) crashes. Now let us assume that the two vehicles are of very different masses--say a 3,000 pound passenger car and a Michigan Special--we have a truck in Michigan that legally operates at 165,000 pounds--each going 20 miles an hour. When they hit each other head-on momentum will be conserved as you saw in the movie that Carl showed. The heavier vehicle is going to continue to go forward, and the lighter vehicle is going to back up. Now, the Delta-V for the lighter car is going to be the 20 miles an hour that he would have had if he would have stopped plus about 18.5 miles an hour that he gets from the truck. The Delta-V that the truck sees is only 1.5 miles an hour. Now, I look on the curve at 38.5 miles an hour and I find that in that car I'm up very close to 0.16 probability of fatality in the car, so that in a hundred such accidents--16 people will die.

Now, we won't usually be running into 165,000 pound vehicles. Let's go back to something that is more reasonable, like a 1,000 pound car (which is the one we are talking about today) running into a car that is the average of the passenger car weight of the present population--about 3,200 pounds. When those two cars run into each other, the bigger car is going to see a Delta-V of about 8 miles an hour. Now that's only about a three to one ratio, and yet the smaller car (with Delta-V = 32 mph) is getting close to the Delta-V it would see when hitting a tractor-trailer. When the disparity between the vehicle weights gets up to three to one you're not going to be much worse off by hitting something larger.

Now, for a long time in the United States, the passenger car population looked like kind of a normal distribution that centered somewhere around 3,300 pounds and dropped off to about 2,500 and up to about 4,500 with a little bump or the Volkswagen Beetles at 1,700 or 1,800 pounds. But most of the vehicles were in this relatively narrow weight range (2,500-3,500 pounds) so that when they ran at each other they did not have a two to one ratio to worry about. As we began to get smaller cars into the population and began to look at two to one ratios (from about 4,000 to 2,000 pounds), a car in this population which weighs 2,000 pounds is about twice as likely to have a fatality (given that it will hit a variety of larger cars) than will a car that weighs 4,000 pounds. If we go now to a group of 1,000 pound cars, these 1,000 pound cars will be competing with a very large group of cars that weigh between 2,000 and 4,000 pounds plus a group of larger vehicles (pickup trucks and vans) in the more than 4,000 pound class. Incidentally, about 20 percent of the total vehicle miles in the United States are put on by those pickup trucks and vans, so that they are not a small proportion. The chance of one of these 1,000 pound cars running into a truck is substantial.

If other things are equal, and we bring in a group of these 1,000 pound cars and put them into the normal population and have them do the things that everybody else wants to do, go on all the roads that they would like to travel on, etc., they'll probably be in about as many accidents per vehicle mile as the larger cars. We should expect to see a substantial increase in the fatality rate for these vehicles.

Things are not likely to be equal, for a number of reasons. Very light cars could be restricted by operator choice to primarily urban travel. The worst place that these cars could go is out on two-lane rural roads where there will be head-on traffic and high-speed intersections. If the operators of small cars choose to stay on lower speed roads, the estimate of increased fatalities would be too high. I looked several years ago at the possibility of a small electric car coming into the population and tried to estimate the safety consequences. We concluded that it was probably going to be a safer car per mile traveled than larger cars because it would be operated entirely in urban areas. It was a restricted range vehicle that just was not going to get out on high-speed roads as frequently as normal cars do.

It's quite possible that the micro-mini car or the very small car could be so much improved in its interior protection that it would overcome at least part of this momentum imbalance. Carl has talked about ways of doing this. The best estimates for the current car population and improvements from belting or air bags, I think are not in the 80 percent range (reduction in the chance of fatality), but more probably in the 30 percent range. That is my judgment from the current designs and the current price structures; the addition of air bags or full usage of belts would probably result in something like a 30 percent reduction in the probability of fatality. That's probably not enough to overcome the weight disadvantage.

If Charles Lave was correct this morning, in estimating that young people are going to buy these cars, there is a slight positive advantage because young people are substantially less susceptible to injury, and, when injured, they recover more quickly. If the population of these micro-mini cars turned out to be primarily young people, things would not be as bad as if they were all 55 year olds who would be more easily injured.

Well, where do we go from here? Safety wise, it seems to me that bringing a 1,000 pound car into the current United States population and road systems is inviting a kind of safety disaster. We seem to have three approaches to countermeasures for avoiding such disasters, and they operate kind of at three succeedingly difficult levels. The first one that everybody thinks about is education. Let's tell everybody to watch out for the little cars, let's put it in the drivers' education courses, we'll educate and tell Sonny when he goes out at night, "Take the big car if you're going to drink." We know the little car will be more dangerous to its occupants, and education and informing people may do some good. The second kind of countermeasure is to change the vehicle system to reduce the chance of an accident. This morning Pat Waller mentioned the possibility of painting all the micro-mini cars day-glo orange or red, and that is not a bad suggestion. We've done some work that shows that day-glo colored motorcycles are much more visible and less likely to be struck by a passenger car.

Finally, when things get bad enough, and we've decided neither one of these solutions is adequate, we had better think about the possibility of separating vehicles on the highway when they are not physically compatible with each other. I know Don said this is going to be a very difficult thing to do and the society is not going to accept it. But there is some acceptance of such a countermeasure now, and there may be more in the future. The New Jersey turnpike has separated lanes for trucks and cars over much of its length now. Although cars are permitted in the truck lane, there are car lanes that trucks are not allowed to enter. If you travel on the New Jersey turnpike in a car, you can choose to avoid the trucks. Better yet, if you go to New Jersey, take the Garden State Parkway which allows only cars and let the trucks take the turnpike. They go almost the same place and you can travel much more comfortably and safely in an environment with only cars. Another example of positive separation is that we've put sidewalks into almost all of our cities for pedestrians. Years ago people walked in the street, but when the frequency of interaction between cars and pedestrians or maybe even between horses and pedestrians got so big that it was a problem, we put the pedestrians in a separate place. We have pedestrian overpasses and underpasses; we've physically separated most of the pedestrians from the vehicles. We have railroad rights-of-way; we put railroad trains on tracks and have grade-separated crossings that preclude the possibility of cars from getting into the way of railroad trains and vice versa. We have bicycle paths in lots of cities, and bicycle lanes on the streets marked to tell cars to stay out of these lanes. There are many Moped lanes in Europe serving the same purpose. I suggest that the highway engineering fraternity ought to think long and hard about what is going to happen when and if a substantial proportion of the United States car population is in this 1,000 pound class and has to survive in traffic with an average weight of 3,000 pounds or more. Otherwise, the little guy is going to be in trouble. Traffic engineers believe that this will be a bigger social and political problem than an engineering problem. The prospect of such changes deserves thought at this point because, if the micro-mini cars are as susceptible to damage as the physical model suggests, the public will demand such changes sooner or later. They're going to say "Get the big cars off my road, because I drive a little car. Do something to make me safer." It has been done for the bicycles, the pedestrians, and the Mopeds, and it may have to be done for the micro-minis. I think as a last piece of advice, we had some talk this morning about safety matter and insurance and how the economics of insurance is related to it. If the environment does not change, perhaps you should take the money that you save in buying and operating a micro-mini and buy term insurance on your life.

DISCUSSION:

JIM PLINE: I've got one. As a traffic engineer, we can hardly afford to build and maintain what we've got; we can't build separate facilities, so I guess we'll have to kind of check that out won't we?

JAMES O'DAY: I'm sure you will.

LAWS, STANDARDS AND LIABILITY

Andrew Hricko, General Counsel
Insurance Institute for Highway Safety

JIM PLINE: Our cleanup hitter this afternoon is Andrew Hricko from the Insurance Institute for Highway Safety. He is the General Counsel and Secretary Treasurer for the Insurance Institute in Washington, D.C. He has been with that organization since 1964. Prior to working for them, he was Senior Attorney in the Legal Division of the Board of Governors for the Federal Reserve System and has also served as Assistant Attorney General for Pennsylvania.

ANDREW HRICKO: The case law relating to the mini and micro type vehicles is quite new and quite limited. However, using the principles of law applicable to products in general, I've come to