INTRODUCTION

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This morning we heard that there was some potential for a smaller vehicle, primarily because of buyer first cost and fuel economy. Safety did not appear to be a major item of buyer concern. It appears that we can expect a greater number of smaller vehicles in the traffic stream, particularly in and around some of the urban areas as a second vehicle, maybe for some of the younger drivers. If this occurs, what kind of problems can we expect? Our speakers this afternoon will point out some of these problems and maybe raise some additional questions relative to vehicle design. What features should we expect in this vehicle? What features would there be that might improve the safety? Are there some vehicle design features that would improve the compatibility between the vehicle, the driver and the roadway? What are the vehicle problems and how should they be resolved? The roadway, because of its cost, of course is slow to make transitions to accommodate vehicle changes. What are the roadway features that could be a problem with smaller vehicles? Can some of these problems be offset in cheap retrofit of roadway appurtenances? Is there a need for vehicle design and driver education to offset some of the problems? What is the scope of the costs when we talk about roadway revisions? The safety of smaller vehicles has recently been highlighted in the news, pointing out the problem. It appears to be quite a problem when we mix the smaller vehicles with the larger ones. Are there some items that could be taken care of to gear the driver for his operation of the smaller vehicle in the traffic stream? What has been the impact of these smaller vehicles as far as safety? Interwoven into these considerations, of course, are the existing laws, federal requirements, vehicle standards and liability considerations of smaller vehicles. Will there be a change in the vehicle safety standards? Can we expect some changes as far as liability? What approach is the insurance industry taking in this regard? Our speakers this afternoon will address these questions and raise some additional questions that we hope will generate research and answer some of these problems.

DESIGN NOTES FOR A SAFER HALF MEGAGRAM AUTOMOBILE

Dr. Carl Clark, Office of Passenger Vehicle Research, National Highway Traffic Safety Administration

JIM PLINE: Dr. Clark, our first speaker, is a biophysicist. He has taught at the University of Illinois and the University of Pennsylvania. He has also worked for the Library of Congress, has had some involvement in aeromedical research for the X-15 pilots and Mercury astronauts. He is currently working for the National Highway Traffic Safety Administration.

DR. CARL CLARK: May I note that I am speaking as an individual and not necessarily representing the National Highway Traffic Safety Administration policy.

In looking at the various ways of describing the small cars one recognizes that smallness finally gets down to the size of the human body. The dimension of the car, in order to have any crash survivability, gets down to the physics of the deceleration event. The engine power is related more to the attitude on acceleration that is desired than the actual efficiency in going across the road. We're hearing the advertisement for the new Chevrolet, that 12 horsepower will keep you at 50 miles an hour. Many of our cars are still over 100 horsepower. So I am urging that we indeed think of smaller sizes in terms of curb weight. Can we make a half megagram or the 1100 pound car safe. It can be made safer if some attention to these basic physics and biophysics principles are observed.

The Suzuki Alto at about 1100 pounds is near a half megagram. It's a four passenger car not yet available in the United States. The problem of the safety of an automobile falls into two categories; crash avoidance and crash protection. The small automobile crash avoidance aspects depend upon handling properties and braking particularly, and in both of those we can make improvements. It is very significant to note the discussions on the

passive restraint standard. And so, these cars indeed, according to the very minimum federal standards, do not have to observe the crash requirements for dummy survivable loads. To be sold in this country they would still have to observe that 30 mph barrier crash loads will not cause the tearing out of the windshield or leaking of fuel. There are a few standards that still require a crash test. This may change, as a matter of fact, and we are concerned about how the death numbers will increase as very small cars get on the road. The Alto looks as if it complies with all the present standards.

The Dihatsu Cuore is also a half megagram car. It has some problems. The gas tank is in back of the rear wheels and you want to avoid that design today. The steering apparatus is not good. You want to look particularly at the rearward displacement of the steering wheel. These vehicles have the wheels near the front and the steering apparatus gets involved early in a collision. Therefore, I think we need to take a hard look at going to non-mechanical steering control, either hydraulic controls or electronic controls like in the aircraft industry. Why do we need that rod that is a spear coming back at the person?

In the discussion this morning, we didn't really touch on the smaller vehicles. I do want to talk a little bit about the earlier version of the Sebring City Car, a two-passenger electric. It didn't get much over 30-35 miles an hour and it did very poorly in crash tests. The modern version is called the Commut-a-Car. It is handled by a new company, and has a much better bumper system. The front wheel is the first collision contact and it has a rigid steering wheel with no crash protection. A fluke in our standards is that all three-wheeled vehicles are classed by the National Highway Traffic Safety Administration as motorcycles. That isn't in the standard itself, it was a legal decision and, at present, that decision is firm enough that to change it will require a regulation. So, these cars have never had to meet a crash survival test, and, indeed, that's one of the attractions to build three-wheeled cars in the United States. We do have the ability in the National Highway Traffic Safety Administration to do defect investigation and require recall if we see a car that is totally unreasonably unsafe even if no standard is involved. The manufacturer has to certify standard compliance and we can subsequently test for compliance.

The HM vehicle is an enclosed motorcycle weighing about 600 pounds. It is basically a one place vehicle, a three wheeler. We have done quite a study of three wheeled vehicle dynamic safety and you'll see a film of that in a moment. This does have room for another passenger in back of the front passenger, and gets something like 78 miles to the gallon. It meets the legal requirements at the present time to be on the road.

This is Jim Beatty's enclosed motorcycle. Jim Beatty is an aerodynamicist and was particularly interested in making the 0.25 drag coefficient vehicle. This is actually a rear-drive motorcycle engine and a strengthened frame with a roll bar. He has paid attention to crash protection. He has beverage cans packaged in plastic in the nose and probably has quite significant crash protection. The two outrigger wheels do not both touch at once, but they give stability.

We have these smaller vehicles coming along and I think they'll just be in a niche of the market. I think they can probably comply with our standards. We are concerned as to whether our standards are really adequate and yet this is a period in which we probably will not have very many new regulations to strengthen the standards. The standard car in either a barrier or a crash test was not so good a few years ago. It is now a lot better. It is interesting that Jim Ryan in 1957 proposed that bumpers don't have to meet 5, 10 or 1-1/2 miles per hour test as the industry is now arguing, but indeed could stop us at 30 or 40 miles per hour without significant injury. That concept was developed in the old safety car designs. The AMF Safety Car looks horrendous with the early version of the air bag flying out the windows and all that stuff. With hydraulic bumpers the load can be attenuated so that the frame and the interior passenger compartment in a 50 mile an hour crash will receive only 40 G's. In crash protection, what you need first is a structure. Both AMF and Fairchild Safety Cars were over-designed but the message is that bumper attenuation can protect us. We haven't adequately dealt with the compatibility issue at all in American regulations. The heavier cars with load attenuation can take up a greater proportion of the load and thereby provide protection for the smaller car. This is something in front of us that we need to think about. So far, we're having trouble specifying sufficient safety requirements for the individual car but eventually the mix and the possibilities of load attenuation for the bigger car must be considered. If we would begin to deal with the compatibility issue we could do a lot in this area.

The first message that comes out of this is that the small car should not just be small; it can be lightweight but it also should have a crush capability. Because of the three-wheeled vehicle exemption from our dummy crash tests, a number of three-wheeled vehicles have been built. We have been concerned and have tested the dynamic stability of these, which is more a crash avoidance feature. You bring them up to increasing speed in a constant radius turn and determine the speed at which they either skid out or begin to lift a wheel. The three-wheel design can be less stable than a four-wheel design of the same weight, but a three-wheeled car that is well designed can be more stable than some of the four-wheeled cars that we now have.

There is an 1100 or 1200 pound car put together by the University of Washington, mainly constructed by the students, but using crush protection concepts. The front end has foam-filled material and honeycombed material. It provides passenger survivability at 40 miles per hour with not more than 30 or 40 G.

The potential of a good belt system begins to fade out at around 30 miles an hour or 30 G. You begin to overload the chest. An air bag can distribute the load so that you do have the possibility to make design speed, that is 55 mile per hour crashes, survivable by allowing the right amount of crush distance. I would settle for 30 miles an hour barrier crash survivability without injury today. At thirty miles an hour, you can design a controlled collapse of the front end so objects do not penetrate the passenger compartment. With the combination of perhaps two feet of crush area and no more than 30 G in the passenger compartment and a good restraint in the passenger area, you should live, in fact emerge without injury from a 30 mile an hour crash. My own research design is that we should emerge, without injury, from 55-mile per hour crashes. My conclusion in looking at the data is that we have the technical know-how today to perhaps get rid of some

80 percent of the deaths on the highway by the information we now have. We know how to build these cars. The questions have been, "Are they too expensive? Are they too different from what the public expects?" The National Highway Traffic Safety Administration is hoping to convince the public to fasten up their belts. Certainly if they would do so their chance of death would be cut in half. I still feel that car design is where we must also look; doing something about the design to provide protection in spite of the public.

The 30G "squarewave" crush distance to stop from 30 miles an hour is a foot, but in a typical oscillating pulse car crash the used crush is nearly two feet. So even little cars should have something like two feet of crushable material if they're going to be made by a reasonable manufacturer today. To a significant extent the fuel economy is a function to a significant extent of the engine horsepower. My own recommendation is that we pay much more attention to being patient on the highway and not using the greater horsepower. We should not expect high acceleration, and design the roads accordingly. Certainly, we ought to make more one way streets to reduce the chance of head-on accidents. The feeling that you have to get there so quickly is a social ill within our country. We can begin to pay attention to not having to hurry quite so much and use a mere 20 to 15 horsepower for our motor vehicles. They can, indeed, be big enough to survive the crash loads and yet not so heavy that we get at least 40 miles to the gallon. I do stress, again, that the present motor vehicle safety standards will not make these micro-mini cars, the half megagram cars, as safe as the present large cars. I hope we will pay attention to requiring a dynamic test at some future date.

I do see the communications to the car being very significant in crash avoidance. Micro electronics are now appearing. We have computers taking care of the engine. They could begin to interactively tell us where our next turnoff is and all kinds of other things that we want to know about where we're headed that contribute so significantly to accidents. In the same way, once you have the computer on board the functions of the radar detection of an impending impact can be put in that same computer thus eliminating a major part of the cost of a radar system. One of the estimates is that automobile radar, if you didn't have to pay for the computer, might be as little as $25.00, molded into the front grille of the automobile. The radar brake is certainly a feasible device. My own expectation is that we can begin to design cars that just plain cannot crash. That should be our goal. People will say, "That's much too expensive", and what I'm saying is let's do the research to cut the expense. These little cars are coming, and let's make them safer than they will be if we don't pay attention to these basic principles.

DISCUSSION:

QUESTION: How does the small car respond to crosswinds?

DR. CLARK: We did pay attention to the crosswind sensitivity in the tests of these three-wheeled vehicles. NHTSA has large fans that can create significant winds of 30 miles per hour. What you want to make is the center of pressure for the side load very close to the center of gravity. Mr. Walter Korff is one of the experts on how to make the little cars so that they're not sensitive to crosswinds by putting the center of aerodynamic pressure at the center of gravity. He also was involved in one of the high speed Bonneville Salt Flat designs that got aerodynamic drag down below .2. My view of reasonable safety is that we have the technology to save 80 percent of the 150 people we're killing every day. Eighty percent, and we're not using it, so somebody's not doing a reasonable job. We should examine dollar trade-offs. The societal cost of accidents, which we estimate at about 50 billion dollars a year approximate each year the cost of new cars. The average societal costs due to accidents equal the cost of the car. If we take a significant chunk of that cost of accidents and put it into safety so that we didn't have the accidents, we'd come out ahead. The problem is that the manufacturers at present, in product liability settlements, pay probably less than one percent and maybe as low as 0.1 percent of the societal cost of accidents. They see the cost of safety but they don't see the benefits of it. I've suggested, actually, within the agency that we might be better off to abolish all of our standards and simply require that the manufacturers pay for all the costs of injury. You would then have no insurance, injury insurance, on your car, so you probably, over the life of the car wouldn't pay too much more than you're now paying, and yet all the money to pay for safety would be in the same pocket that is paying for the car design. I think you would see that the numbers of deaths would go down at least half, and probably 80 percent is what I surmise.

QUESTION: How good is the air bag restraint system?

DR. CLARK: I thought I invented the air bag restraint when I was at the Martin Aircraft Company in 1962. I was developing an air bag design for astronauts landing on the moon. I had the first government contract on air bags, and worked on air bag restraint for airplanes, and then finally did the initial public work on air bag restraint for automobiles. We don't know the acceleration level that is survivable or that which would produce what I call a "soft death". In fact, I wrote in the book, "Human Factors in Technology" a chapter on "Acceleration and Body Distortion", and I said that it is not the force but the distortion due to the force that is lethal. If you examine the effect of acceleration, if it's indeed a uniform acceleration over the entire body, it's a uniform load and is not distortion. If there are differential compression capabilities, the lungs for example, you can have differential compression and can get distortion there, but basically, if you have a uniform loading such as an air bag provides you can, probably, as a healthy person, stand up to 200 G. In fact, there are reports on the survivability of people who fell out of 15-story buildings and got up and walked away. They survive by hitting soft dirt and sinking in five inches with a well-distributed load. There are also people who hit the tops of cars flat and dent the car and survive. These are very high G levels, but they're well distributed, so there's little distortion. By no means is 30 G the limit. The real problem is the distribution of the load. This is the problem with the one and seven-eighths inch wide seat belt. At 30 miles per hour, in a barrier crash, the 30 year old male begins to break his ribs; the 50 year old male at 30 miles per hour is perhaps breaking 10 or 12 ribs. The 30 mph barrier crash load is not

something you walk away from if you are an older person wearing safety belts. In an air bag there is a broadly distributed load and no problem.

POTENTIAL IMPACT OF THE MICROVEHICLE ON ROADWAY FACILITIES

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Paul Dexler, in a July 1981 Motor Trend Magazine article (1), says, "The Micros Are Coming." For those of us in the highway research field, this means we are already behind. To have the information necessary to guide designers when the micros are in wide use, several years and millions of dollars of research will be needed.

This paper explores the potential impact of micros on highway design. An attempt has been made to present logical and reasonable projections for changes in design which can be expected should the microvehicle become a significant part of the traffic stream.

Before evaluating the potential impact of microvehicles, it was necessary to define the basic design characteristics of a microvehicle. Based on the data provided by Dexler, the following summary statistics are given for minivehicles and microvehicles. These data form a basis for selecting a design microvehicle.

For the purposes of this paper, the values listed in Table 1 for the microvehicle will be used as the design microvehicle. It probably represents the low side of the microsize vehicles that can be expected in the next decade and therefore may well be the logical microcar design vehicle.

Driver eye height for the design microvehicle can be estimated from the vehicle height. The Society of Automotive Engineers (2) suggests that a driver's eyes will typically be approximately 10 in. (25.4 cm) below the roof of the vehicle. From Table 1, microvehicle height is approximately 53 in. (134.6 cm). The eye height then would be approximately 43 in. (109.2 cm), or 3.58 ft. (1.1 m). This eye height is remarkably similar to the eye height of minivehicles and the design eye height that has been tentatively adopted for the new AASHTO highways and street design policy. Therefore, the problem of driver visibility from the microvehicle would not be expected to be any different than for the present minivehicles.

The design microvehicle is 6 in. (15.2 cm) narrower and approximately 2 ft. (0.61 m) shorter than the present minisize vehicles. The doors on the microvehicle will probably need to be essentially the same size of those on the minisize vehicles. A recent study (3) indicated that the partially open position of minivehicles is about 47 in. (119.4 cm) wider than the closed door width, and the fully open position is about 83 in. (210.8 cm) wider. Thus the two-door open design microvehicle dimensions are 102 in. (259.1 cm) or 8.5 ft. (2.6 m) partially open and 138 in. (350.5 cm) or 11.5 ft. (3.5 m) fully open.

These basic dimensions permit an evaluation of the future needs of highway design features to accommodate the microvehicle.

Geometric Design

Stopping Sight Distance

The basic microvehicle design characteristics previously summarized suggest that a 3.5 ft. (1.1 m) eye height would be appropriate, since AASHTO has already adopted an eye height of 3.5 ft. (1.1 m) as the basic design eye height for the future. General application of this criterion would appear to satisfy the stopping sight distance needs of microvehicle drivers.

Passing Sight Distance

An eye height and object height of 3.5 ft. (1.1 m) previously adopted by AASHTO would appear to provide a relatively safe passing sight distance for the microvehicle driver. The lack of adequate visibility of restrictive pavement markings and the changes in acceleration characteristics of the smaller vehicles will probably be far more significant. No additional changes in the passing sight distance criteria are seen to be necessary to accommodate the microvehicle.

Lane Widths

Lane width requirements for the microvehicle for low-speed operation could be as narrow as 7 ft. (2.1 m) -- a vehicle 5 ft. (1.5 m) wide plus 1 ft. (.31 m) clearance on each side. It is, however, very doubtful that microvehicles will ever make up a majority of the traffic stream. The compact will probably be the least size of vehicle on which lane width will be predicated. Thus an 8 ft. (2.4 m) lane in the absence of trucks or buses is the least probable lane width that can be effectively operated. For high-speed operation (i.e., over 35 mph (56.3 km/h)) a 2 ft. (0.61 m) clearance on each side of the vehicle is needed for normal tracking. Thus 10 ft. (3.1 m) as a minimum should be used. Where trucks or buses are present in substantial percentages, the lane width would be dictated by the maximum 8 ft. (2.4 m) truck width. For low-speed operations (i.e., 30 mph (48.3 km/h) or under) a width of 10 ft. (3.1 m) is acceptable. For high-speed operations 11 or 12 ft. (3.4 or 3.7 m) will need to be provided.

TABLE 1. TYPICAL DIMENSIONS FOR MINI AND MICROVEHICLES (after Dexler (1))

VEHICLE TYPE	VEHICLE LENGTH (in.)	VEHICLE WIDTH (in.)	VEHICLE HEIGHT (in.)	VEHICLE WHEEL BASE (in.)	VEHICLE WEIGHT (in.)	WHEEL TRACK (in.)
MINI	148	61	53.6	89.5	1630	52.5
MICRO	126	55	53.0	81.5	1200	48.0
DIFFERENCE	22	6	.6	8.0	430	4.5

Metric Conversions: 1 in. = 2.54 cm
1 lb_m = .454 kg