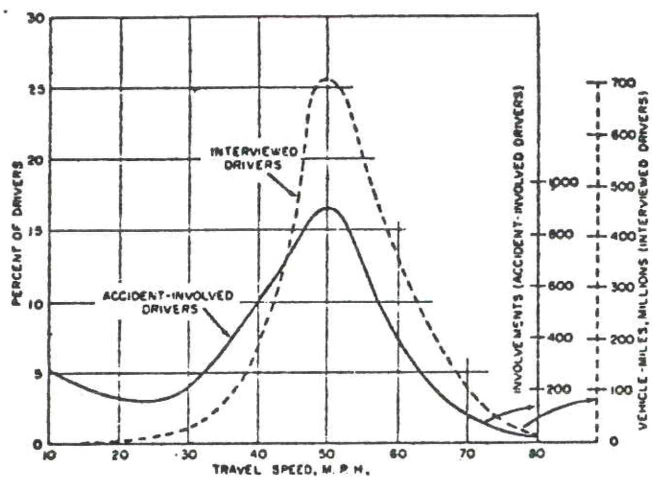
Figure 1. - Travel speeds of accident-involved
and interviewed drivers, day.




represented. That is, at 30 MPH the likelihood of an accident was greater than at 40 MPH. Indeed, the greatest differences occurred at speeds below 25 MPH. Solomon presents other data showing that for all accidents, 24 percent (2404 ÷ 9816) of the vehicles had a travel speed below 23 MPH. This should be considered in view of the fact the lowest speed limit for his data collection sites was 45 MPH. Averaging over roads, the mean speed limit was over 55 MPH. Under these circumstances, it seems clear that the majority of the accident vehicles with speeds below 23 MPH were involved in short term maneuvers such as stopping, preparing to turn, etc. Thus, it appears that the major basis for the conclusion was not associated with undisrupted traffic flow but with other short term activities. This may bode poorly for larger trucks which accelerate and decelerate more slowly than cars and therefore spend more time in these short term, low speed, maneuvers.

Another source of information pertaining to speeds is "The Toll Road Study" (Campbell, et al). This was a comparative analysis of exposure and accidents before and after the onset of the energy crisis. Data were obtained from toll roads in five states. Police accident reports were used for accident data. Speed and exposure data were apparently obtained from existing road records.

They attempted to analyze the effect of the energy crisis in terms of two major components, viz: exposure and vehicle interactions associated with passing (the latter being responsive to both amount of exposure and differences in travel speed among vehicles.) Their data show a 14.7 percent reduction in miles traveled by cars and 1.2 percent increase for large trucks. They also found an overall speed reduction of 7.1 MPH: 8.2 MPH for cars and 4.3 MPH for trucks. Since the trucks previously had a lower mean speed, the effect was a reduction in car - truck speed differentials.

There was a 45 percent reduction in cars in accidents and 17 percent for trucks; for single vehicle accidents, the reductions were 44 and 3 percent, and for multivehicle accidents, 47 and 28 percent respectively. Accident involvement rates dropped 35.6 percent for cars and 17.6 percent for trucks. In car - truck accidents involving sideswipes in passing and rear end collisions, the proportion of "truck into car" accidents (where the truck was apparently approaching from the rear) increased from 45.7 percent to 54.1 percent. This was thought to be the result of an increased number of trucks passing cars due to the reduced speed differential. On this basis, if speed differentials increased, one would expect a reduction of trucks hitting cars in rear end accidents, and an increase in cars "rear ending trucks".

The foregoing suggests (a) the reduced acceleration and deceleration potential of large trucks may create extended exposure in short term maneuvers, and (b) modified speed differentials may influence how trucks are involved in accidents. That trucks may be more conducive to multivehicle accidents due to lower speeds in normal traffic flow seems reasonable, but we found no empirical evidence to support this.

One view, reported by Forsythe, Hanscom, Reiss, Vallette, and Yoo (1975), is that as the speed of a passing car relative to a truck increases, there is less opportunity for the car to experience aerodynamic disturbance and has time for the car driver to be distracted. While such a benefit may, in fact exist, it was not sufficient to preclude the shift in the Toll Road Study toward relatively fewer cars hitting trucks with an increase in relative truck speeds.

Again, it seems eminently reasonable that increased speed differences would increase the accident rate. However, apart from low speed maneuvers, we could not find evidence to this effect.

R.5 Deaths/injuries per ton mile is an acceptable comparison criteria by mode of transportation.

This is not an empirical hypothesis. That is, it's validity cannot be determined through the use of actual data. Rather, the question is whether the expression is a useful measure. We will first discuss ton miles as a unit of exposure, and then the ratio as a whole.

Measures of exposure are appropriate or inappropriate depending on the use to which they are put. Generally speaking, distance traveled, for example, can be used without combination with other measures to quantify service; the more mileage vehicles travel, the more service they provide. However, in safety research, distance traveled is used to measure risk; the more mileage vehicles travel, the greater the opportunity for an accident. This is the usual connotation of the term exposure, and we will use it that way in this duscussion.

When computing accident rates, for example, the normal procedure is to divide the number of accidents by the exposure - the distance traveled. However, many things other than distance influence the risk of an accident. Examples are driver age, vehicle type, traffic, roadway conditions, etc. Even time elapsed is relevant. (Consider a stopped vehicle in the middle of an expressway - its distance traveled is nil, but its risk of an accident certainly is not.) Generally speaking, in studying the accident risk of two or more different groups of vehicles, the purpose of the exposure measure is to normalize accident frequencies so that they reflect only variables of interest, not extraneous effects. For example, in comparing accident rates for cars and trucks, we may want to match the kind of situations in which they travel, as well as the distance traveled. Thus, exposure has two components, amount of exposure and quality of exposure. Generally speaking, the amount of exposure is treated numerically to create a ratio (the accident rate), while quality of exposure is treated either experimentally by sampling, or statistically by grouping and matching after data collection.

Thus in considering ton miles as a measure of exposure we consider the following criteria:

(a) Is it a measure of service or risk of an accident?

(b) Will it help normalize vehicle accident frequencies; i.e. does it remove extraneous factors from the comparison of two rates?

(c) Is it a measure of amount of exposure or quality of exposure?

Is ton miles a measure of service or risk? It appears to be a bit of both. As a measure of risk, however, it is somewhat lacking. Consider the test: Does doubling the ton miles double the risk of an accident? The answer is yes if tons are held constant and miles are doubled. But if miles are held constant and tons are doubled, we probably can't expect a doubling of the risk. Thus, ton miles is not an acceptable measure of amount of exposure.

Will ton miles remove the effects of extraneous variables from accident frequency comparisons? The discussion above suggests it will, in fact, introduce extraneous effects. Suppose fleet A of large trucks has exactly the same amount and quality of exposure as fleet B, except that fleet B uses larger trucks carrying twice the tonnage. Suppose that fleet B has twenty percent more accidents in a year. Using accident frequency divided by mileage, B has a twenty percent higher accident rate, but if ton miles is the denominator, fleet B has a forty percent lower accident rate. As noted earlier, this latter comparison may make economic sense, but to imply that fleet B is safer would be misleading. Thus even applied within a single mode of transportation, ton miles is problematic as a unit of exposure.

Is ton miles a quantitative or qualitative measure of exposure? Certainly the mileage component is quantitative. But, it's not clear that tonnage is a quantitative measure, or at least a measure which is solely quantitative. As we increase weight, say payload capacity, from motorcycles to triple bottoms, there are not only quantitative changes but also qualitative ones. Among the many quantitative dimensions are: two wheels to multi-axle, a solid vehicle to compound articulation, one useful on a wide variation of terrain to one limited to certain roads, etc. Again, ton miles as a divisor for accident frequencies breaks down, at least within one general mode of transportation.

Ton miles, then, would appear to be an unacceptable measure of exposure for traffic safety purposes. It is a better measure of service than risk. It will introduce distortions into accident rates. It has important qualitative as well as quantitative components.

In three basic ways, then, ton miles is an unsatisfactory measure of exposure.

There remains the possibility that ton miles is a valid measure of service, and that death per ton miles is a useful ratio of safety costs to amount of service. This might be fruitful but only under certain circumstances. Again the problem resides in the denominator. Ton miles can be considered an appropriate measure of service only if the cargo for the various transportation modes is of similar value. To compare airplanes to trains in terms of ton miles, we must assume that transporting a ton of people 1000 miles is equal in the amount of service performed to transporting a ton of beef the same distance. Without stating which service is the greater, it can be said that there is not reason to believe they are equal.

Secondly, it is only useful to compare modes of transportation when one can replace the other. For example, the comparison of ship-miles to train-miles serves little function in selecting transportation to

Hawaii. Indeed, one wonders if the comparison of truck accident rates to car accident rates is a useful pursuit when one cannot replace the other.

R.6 Trucks are inherently more unsafe because they are driven many more miles than other vehicles.

In responding to this hypothesis, the view that increased exposure is conducive to greater accident involvement is accepted.* Therefore, the hypothesis raised the question of how a group of vehicles should be judged in terms of "safety".

Before proceeding, an operational value is assigned to the word "safe". Either of two general meanings seems appropriate: (a) A group of vehicles is unsafe if remedial action is required. (b) A group of vehicles is unsafe if, in terms of accident-related considerations, another vehicle type is preferred.

What are the bases for judging the safety of a type of vehicle? There seem to be three relevant measures: (a) The portion of the total accident picture accounted for by that type of vehicle; (b) the average number of accident involvements per vehicle; and (c) the accident involvement rate.**

Taking "unsafe" to refer to the need for acting to improve the performance of a type of vehicle, the appropriate measure is the magnitude of the safety problem in comparison to other vehicles. For example, data used elsewhere from Accident Facts showed trucks were involved in 13.5

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*It is also possible that greater exposure is conducive to vehicle defects. Discussion of hypothesis M.4, showed the comparison between cars and trucks with regard to defects was inconclusive due to the lack of appropriate comparative data.

**Because the hypothesis emphasizes exposure, it has been assumed that the issue is accident occurrence, not accident severity.

percent of reported accidents, while cars were involved in 82.0 percent. It seems rational that safety resources be applied to these problems in amounts commensurate with these percentages or other values that reflect that part of the accident problem associated with each type of vehicle. Not only do cars show the greatest need but, for example, a five percent improvement will result in greater absolute benefit for cars than trucks.

There are precedents for establishing the need for remedial action in terms of magnitude of the problem as opposed to accident rates (accident per vehicle, or accidents per vehicle mile). For example, it is unlikely that accident rates for bicycles have increased, and yet relevant safety efforts have. This is in response to increased bicycle usage and resultant involvement in accidents. Similarly if trucks show an increase in accident frequency, irrespective of rates, then a commensurate increase in remedial effort is indicated.

Regarding the type of vehicle that can be expected to show greater safety in comparing several types of vehicles, the proper measure is the accident rate. If motor vehicles are needed to move goods, the distances to be traveled are more or less fixed. Since trucks will travel no further than cars in performing this service, it is inappropriate to choose cars due to their history of fewer accidents per vehicle, but only if the rate per vehicle mile is less. Thus, the appropriate measure is the accident rate, which takes exposure into account.

There is one further, and perhaps overriding, point. It has been indicated that in choosing vehicles, the proper safety measure is the accident involvement rate, but the process of making such a comparison is useful only if the vehicles are interchangeable for the function needed. That is, since cars cannot, in most instance, serve the functions required of trucks, a comparison of accident rates (although it has been done in this report in response to specific hypotheses) appears to be largely academic.

The exception to this would be the setting of insurance rates for drivers of trucks versus cars. In this instance, expected accidents per vehicle, not per vehicle mile, is an appropriate criterion.

Thus, using three classes of operational meaning for the term "unsafe", each of them requires a different criterion measure. For the allocation of safety efforts by the government, the proportion of total loss is appropriate.* For selecting vehicles, the accident rate is a meaningful measure; however, this is useful only when interchangeable vehicles are compared. For insurance purposes, accidents per vehicle is the proper measure.

Since, therefore, a vehicle can be "unsafe" in one sense, but not another, a more discriminating use of the term would be advantageous.

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*For the purposes of simplifying this discussion, it has been assumed that benefits are proportional to effort expended; this is often untrue. However, the proportion of total loss does provide a valid measure of need.

## Miscellaneous Hypotheses

M.1 With the energy crisis have come two distinct movements: More smaller economical cars and larger heavier trucks on the roads. With this increasingly adverse mix, the safety problem cannot get better.

This hypothesis has two components: (a) the effect of truck size on the precipitation of accidents, and (b) the effect of an increasing truck to car mass ratio when a truck and car collide.

Regarding the first component, in the discussion of accident rates (cf. R.2), a consensus of the results showed no difference in accident rates for cars and trucks. Furthermore, the results were so variable as to preclude any conclusive comparison. While these results allow the possibility that increasing truck size will lead to more accidents, they do not form a basis for it. Finally, no studies were found on the comparative effects of very large trucks; however, Solomon's data on trucks with six or more tires versus those with four, and the Voorhees data on combination units versus single units both showed lower rates for the larger trucks.

Regarding the effect of the truck to car mass ratio upon accident severity, this appears to be a controversial area. Interestingly, the two viewpoints can be based on the same data. The following table was used by Mela (1975). It shows the number of people killed in truck - car accidents who were not truck occupants. The third column is the ratio of the number killed to the number of accidents. We are interested in this ratio as a function of truck size (i.e., actual weight of the vehicle plus load).

FATALITY RATES IN CAR-TRUCK ACCIDENTS

(1973 and 1974 EDITED)

| Weights (in Pounds) | Number of Accidents | Number of Others Killed | Fatality Rate |
|---|---|---|---|
| 1- 5,000 | 200 | 4 | .020 |
| 5,001-10,000 | 551 | 21 | .038 |
| 10,001-15,000 | 958 | 79 | .082 |
| 15,001-20,000 | 905 | 44 | .049 |
| 20,001-25,000 | 1,878 | 178 | .095 |
| 25,001-30,000 | 2,667 | 321 | .120 |
| 30,001-35,000 | 1,087 | 108 | .099 |
| 35,001-40,000 | 803 | 100 | .125 |
| 40,001-45,000 | 811 | 96 | .118 |
| 45,001-50,000 | 769 | 96 | .125 |
| 50,001-55,000 | 888 | 108 | .122 |
| 55,001-60,000 | 1,042 | 142 | .136 |
| 60,001-65,000 | 1,257 | 155 | .123 |
| 65,001-70,000 | 2,190 | 273 | .125 |
| 70,001-75,000 | 3,124 | 449 | .144 |
| Over 75,000 | 573 | 94 | .164 |
| | 19,704 | 2,277 | |

Source: BMCS Truck Accident File

Using these data, it has been argued that the fatality rate increases with truck size; it clearly does. However, if one line is drawn to separate the 25,000 pound truck from the 25,001 pound trucks, and another separates the 70,000 pound trucks from the larger ones, some things become evident. In particular, the fatality rates for trucks in the 25,001 to 70,000 pound range are essentially constant. Below that range, the fatality rate increased, with one exception, with increasing truck size. For trucks over 70,000 pounds the fatality rate, once again, increased with truck size.*

Thus, it is evident that the fatality rate increased with the size of smaller trucks, and that it was constant for the majority range from 25,001 pounds to 70,000 pounds. Under these circumstances, is it believable that it increased for trucks over 70,000 thousand pounds or is this part of the curve misleading?

The apparent arguments against an increase include: (a) The fatality rate leveled off at 25,000 pounds and stayed that way for almost 50,000 pounds, why should it increase thereafter? (b) There are only two data points showing the final increase, and one of them is based on a relatively small number of observations. The change in slope in the 15,001 to 20,000 pound range shows anomalies can occur. (c) Picture yourself driving a car into a truck; do you really think you'd be better off if the truck weighed only 40,000 pounds instead of 75,000 pounds? Or, as Grime (1971) argues on theoretical grounds: for any fixed relative impact speed in a two vehicle collision, the change in speed ($\Delta V$) of the smaller vehicle changes less as the mass ratio grows larger. He shows that increasing the mass ratio above 4 to 1 has practically no effect on $\Delta V$. (d) These data reflect only the effects of truck size; speed is nowhere accounted for. It is certainly possible that the fatality ratio increased for trucks over 70,000 pounds because such trucks are practically never driven on low speed roads.

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*This change in slope was shown by Herzog using the parent sample for these data.

The arguments for an increased fatality rate include: (a) In comparing 2,190 trucks in the 65,001 to 70,000 pound range to 3,124 trucks in the 70,001 to 75,000 pound range, the fatality ratio increased 15 percent. There are too many observations to ignore this. Furthermore, the fatality rate continued to increase for truck weights above 75,000 pounds. (b) A line fit to all the data points has an increasing slope. Therefore, consider only the very heavy trucks or all of the trucks; in either case the fatality rate increased with truck size. (c) If the largest trucks more often travel at speeds below that of surrounding traffic, relative impact speed in car-truck accidents could be higher, thereby inducing greater severity.

In summary, it is our judgment that the statistical arguments tend to support the view of increased fatalities with increasing truck size. This is based directly on the observed increase for very large trucks and the relatively large number of observations for these trucks. On the other hand, Grime's use of momentum equations persuasively argues the opposing view. Finally, the speed related effects may be twofold. The largest trucks may be exposed to higher speed conditions and may be in accidents involving greater relative impact speeds; the former is attributable to the conditions in which they travel, and the latter to limited acceleration capability. Thus, it is felt that a resolution of the problem will be achieved only through further study of the mass ratio/fatality relationship using analyses which include the effects of other accident factors, particularly impact speed and relative impact speed.

While this discussion has not included reduced car size, it is assumed that regarding impact characteristics, reduced car size is essentially equivalent to increased truck size.

M.2 The better safety performance of smaller trucks (pick-ups, vans, etc.), which constitute about 96 percent of the total number of trucks, completely obscures the safety performance of combination trucks.

M.3 Comparatively little information has been developed on the unique safety performance of truck combinations.

These two hypotheses are concerned with the availability of safety information for truck combinations, and are therefore discussed together. Clearly, whenever hypothesis M.2 is correct, so is M.3; that is, if smaller trucks are not separated from large ones, no information will be obtained regarding the large ones.

It should be noted that M.2 assumes better safety performance by small trucks than large ones. Although this point was not explicitly studied, there is evidence that this is not true in all respects.

It is undeniable that if large and small trucks are lumped together for analysis, the smaller vehicles will obscure the performance of the larger ones. On the other hand, data do exist for large trucks alone, and it appears likely that more will become available. Thus, the problem in M.2 seems to refer to the lack of carefully stated results in which the type of truck involved is not clearly stated.

Just how much data pertaining to truck combinations is available has not been assessed. It is recommended that the need for data be established somewhat along the lines described in the discussion of truck safety criteria (R.6). One point, however, is clear. There appears to be no sample of truck accident data which is reasonably representative of the entire country and that contains a specification of truck type.

M.4 Trucks are more likely to be reported as having safety defects than cars. The Department of Transportation's Bureau of Motor Carrier Safety inspects about 30,000 trucks each year, and has listed the most numerous safety violations as follows (in descending order): (a) lighting, (b) brakes, (c) tires, (d) exhaust, (e) safety appliances.

The BMCS (1972) report on safety road checks, gives information on truck defects as determined in their roadside inspections of trucks in use. Two critical definitions are: (a) A unit is "a truck, truck-tractor, trailer, or semitrailer, whether alone or a component in a combination vehicle" (e.g., a double bottom contains three units); and (b) An out-of-service defect is one "of such type and degree as to render a vehicle imminently hazardous to operate until repaired." (The unit was not allowed to continue until it was repaired.)

The report cautions the reader that vehicles chosen for inspection were selected from passing traffic because of their apparent lack of maintenance. As such, they do not comprise a representative sample of commercial vehicles; that is, the samples contain an overrepprestation of defects.

The following data apply to 1971. 37,882 units were inspected; 9005 (23.8 percent) of them had out-of-service defects. A total of 56,985 defects were found, 11,973 of them were out-of-service defects. Of these, the most frequent were: brake system (61.9%), lights (12.1%), wheels (5.6%), exhaust system (5.1%), tires (4.8%), suspension systems (2.1%), fuel system (2.1%), and steering mechanism (2.0%). Of all 56,985 defects found, the most frequent were: brake system (34.2%), lights (27.5%), tires (7.5%), wheels (5.0%), and suspension systems (3.8%). We found no comparable information source for cars.

The remainder of the data presented here reflects defects among accident vehicles. The BMCS (1975) reported defects among 30,911 trucks in accidents reported to them in 1973. Their data contained 2051 mechanical defects. If we assume no more than one defect per vehicle, this yields a vehicle defect rate of 6.6%. Among the defects 27.3 percent were associated with wheels and tires, 26.4 percent with brakes, 6.0 with steering mechanisms, 4.2 percent with couplings, 3.9 percent with the fuel system, and 3.3 percent with suspension systems. It appears that accident reports filed by owners with the BMCS give considerably different information than police reports and the roadside inspections. For example, in the BMCS accident file, lights constituted only 1.3 percent of the defects, whereas in the BMCS road inspection they were 27.5 percent of all defects, and 12.1 percent of the out-of-service defects. In the accident file, brakes constituted 26.4 percent of the total, but 34.2 percent of the roadside defects and 61.9 percent of the out-of-service defects.

In order to compare cars to trucks with respect to defects, we referred to accident data. Information from three different studies is tabulated below. The first column gives the total number of vehicles in the sample, the second column lists the number which were found defective by the police; the number in parenthesis is the percent of the total vehicles which was defective. Following that are the percentages of defect types, given a defect. The last column specifies the percentage of vehicles where the presence of a defect was unknown.

Regarding the proportion of vehicles which were defective, the first two studies show trucks were more likely to have reported defects than were cars. The Scott and O'Day data showed much smaller differences; in fact, for the multivehicle accidents, trucks had fewer defects than cars. Scott and O'Day gave reported defects (without the specific type of defect) for Indiana, Ohio, and Pennsylvania combined. The percentages were: cars-single vehicle-14.3, trucks-single vehicle-23.5; and for multivehicle accidents, cars-2.9, trucks-3.1. Again, the difference between cars and

## Vehicle Defects in Accidents

| | N | Defective Vehicles | Distribution of Defects (in percent) Brakes | Lights | Steering | Tires | Other | Unknown |
|---|---|---|---|---|---|---|---|---|
| Source: Ernst and Ernst | | | | | | | | |
| Cars | 5821 | 115 (2.0) | 45 | 8 | 3 | 23 | 21 | - |
| Trucks | 5729 | 510 (8.9) | 41 | 9 | 5 | 18 | 26 | - |
| Source: Lohman and Waller | | | | | | | | |
| Cars | 218730 | 8530 (3.9) | 28 | 8 | 5 | 49 | 10 | 20 |
| Trucks | 5653 | 452 (8.0) | 55 | 6 | 6 | 13 | 19 | 16 |
| Source: Scott and O'Day* - Single Vehicle Accidents (Indiana) | | | | | | | | |
| Cars | 2285 | 379 (16.6) | 3 | 1 | 2 | 94 | 0 | - |
| Trucks | 404 | 80 (19.8) | 10 | 1 | 9 | 80 | 0 | - |
| Source: Scott and O'Day* - Multivehicle Accidents (Indiana) | | | | | | | | |
| Cars | 1912 | 65 (3.4) | 12 | 18 | 3 | 71 | 0 | - |
| Trucks | 462 | 8 (1.8) | 38 | 38 | 0 | 25 | 0 | - |

*Only percentages were given in the text and the total N was assumed from another portion of the text; thus, the first two columns maybe in error but all percentages should be reasonably correct. The single vehicle and multivehicle data were presented separately; they were not combined here due to these considerations.

trucks was small for multivehicle accidents. These accident data suggest that among accident vehicles, trucks are more likely to have defects than are cars; however, the variability of the data and the fact that they were collected by police accident investigations imply a requirement for caution in using these data.

Regarding the type of defect, the major problems were brake systems and tires. The Ernst and Ernst data, and the Lohman and Waller truck data showed brakes to be the greater problem; the remainder of the data (aside from the last row with very limited observations) showed tires to be the greatest problem.

In comparing defect type for trucks versus cars, the Ernst and Ernst data in particular, show little difference. In the Lohman and Waller data, trucks had more brake defects and fewer tire problems. The Scott and O'Day data tend to agree. Aside from the general predominance of reported problems with brakes and tires for trucks and cars, it appears no further conclusions can be drawn regarding defect type.

Summarizing, the most frequent sources of defects were brakes and the combination of wheels and tires. The BMCS roadside data shows truck brake systems to be most often defective; brakes were also found to be frequently defective in the BMCS accident data, but no more so than the combination of wheels and tires. The car versus truck comparisons reflected the same problems with no consistent differences between the two vehicle types. In the BMCS roadside data, lights constituted over 25 percent of all defects, but only 12 percent of the out-of-service defects. In the accident data, lights were reported as defective for one to nine percent of the trucks. There was little difference between car and trucks regarding defective lights.

Generally speaking, then, vehicle defect data and conclusions must be viewed with caution. The BMCS roadside data is undoubtedly the most sensitive to defects, but generalization is not justified because of the selection process. These data also demonstrate the shifts in reported defects which result from different defect criteria. Regarding the accident data, it is likely that they suffer from both insensitivity to defects and a multiplicity of criteria for reporting them.

M.5 The crashworthiness of tractors has decreased since the hood and extra distance between the driver and the front bumper are now gone.

Only one empirical study of this hypothesis could be found (Stern, 1966). This involved the comparison of 108 cabs with a "conventional" configuration to 96 cab over engine power units. These 204 units were obtained from North Dakota and Oklahoma, the Interstate Commerce Commission (then), and members of the American Trucking Association. Clearly, no particular population was represented by this sample. Stern presented the following table.

Percent Distribution of Driver's Degree of Injury by Type of Power Unit

| | Degree of Injury | | | | | | |
|---|---|---|---|---|---|---|---|
| Power Unit | None | Minor | Non-Dangerous | Dangerous | Fatal | Total | Total Cases |
| Conventional | 12.0 | 24.1 | 42.6 | 6.5 | 14.8 | 100.0 | 108 |
| Cab Over Engine | 7.3 | 35.4 | 36.4 | 8.3 | 12.5 | 100.0 | 96 |

$X^2_{(4)} = 4.31$ N.S.

The results were not statistically significant, and a comparison of the injury proportions failed to show any kind of meaningful trend. This should not be taken to mean there is no difference between the two types of cabs. The sample was not large and no controls were provided for impact characteristics. Nonetheless, given 204 accidents, as they occurred in the real world, no differences were found.

M. 6 Trucking is the most costly, in terms of lives, of all the freight modes, four times more costly than railroads, which are the next most costly.

We could find no single reference to verify this hypothesis. Even within references, several different sources are used. Hence, in comparing the figures which follow, one must recognize that they provide only the roughest of guidelines. In compliance with M.6, we have attempted, where possible, to restrict the scope of injury to vehicles whose main function was to carry freight, rather than people. It was assumed that all trucks were carriers of freight; airplanes and boats were limited to cargo carriers; we could find no information allowing the separation of freight and personnel carriers for trains. The data presented apply to the year 1973.

Accident Facts specifies 4800 tractor trailers and other truck combinations were in fatal accidents. Assuming, rather arbitrarily, 1.2 deaths per fatal accident, this gives approximately 5,600 deaths in accidents involving truck combinations in 1973.

For the same year, Gay (1975) gave the number of deaths for other transportation modes. For all railroad accidents, 1916 deaths were specified. (According to the Federal Railroad Commission (1972), some 200 of these fatalities involved grade crossing collisions with trucks). Combining domestic and international air carriers plus general avaition accidents, there were 1638 deaths; however, 1411 of these were attributed to general aviation, practically none of which is associated with freight. The number of deaths associated with air cargo carriers was 10, all of which involved operations outside the U.S or between the U.S. and other countries.

Gay specifies 2663 deaths associated with water transportation. Of these, 1852 were associated with private or commercial passenger craft. Only 293 were assoicated with cargo carriers.

Thus, the most appropriate figures were: trucks-5600, rail-1916, air-10, and marine-293; again, the figure for railroads is an over-estimate in that it includes trains used primarily for passenger service.

These figures show a truck to rail fatality ratio of at least three to one. It should not be argued on the basis of data presented here that traveling in a truck is more dangerous than traveling by air, water, or rail; this view would require normalization with exposure data. But these data do suggest that a greater effort is needed to improve the safety performance of trucks than other freight modes.

# DATA CHARACTERISTICS

The following is a summary of data sources used in the various reports reviewed. Many of the reports are excluded here because (1) they rely on a multitude of data sources, (2) they were not based on original research and contained little description of the way in which data were collected, (3) only non-empirical information were used, and/or (4) they provided primarily background information. Therefore, excluded from this summary are primarily tabular reports using a variety of data sources (Accident Facts, Gay, Mela, MVMA), other tabular reports (the two BMCS references, and the Federal Railroad Administration report), studies providing ancillary information (Herzog, and the two Perchonok reports), and reports used for non-empirical information (Forsythe, Grime). The data sources which are described are from reports of original research providing major application to the hypotheses under study.

In all instances, only data discussed in this report are included; thus, the specifications may, or may not, apply to the complete referenced study. Furthermore, many of these studies provided information related to several hypotheses. In such instances, subsets of the full samples may have been used; when necessary, we described the nature of the subsets in the text.

The language in following specifications needs some explanation. The phrases "not specified" and "no restrictions specified" both denote incomplete data specifications in any given report. The difference between the two is based on a somewhat subjective assessment. If there was some reason to believe that a sample may have been equivalent to the population, then we noted "no restrictions specified". If the suggestion of equivalence was absent, we noted "not specified". In either instance, these assessments were usually invoked when a report indicated, for example, that "accidents were based on state accident files" without stating whether all such accidents were included. If the full file was used, we noted "no restrictions". When it was clear that no coherent population was represented, we noted "not a probability sample".

Regarding accident data sources, we attempted to be as specific as the information allowed. For example, state accident files might include accidents reported by police or by drivers; the use of police reports was noted if, and only if, the research report so stated.

TITLE: Fatal Tractor Trailer Crashes: Considerations in Setting Standards

AUTHOR(S): Baker, Wong, and Masemore

| | |
|---|---|
| Data Collection Period | 1970 - 1973 |
| Data Collection Location | Maryland |
| Accident Data Source | Police and medical examiner reports |
| Exposure Data Source | Not applicable |
| Type of Sample | Not specified; in multi-vehicle accidents, apparently only one "other" vehicle was included. |
| Truck Types | Tractor trailers |
| No. of Trucks in Accidents | 150 |
| No. of Accidents | 150 |
| No. of Other Accident Vehicles | 131 cars |
| No. of Trucks Exposed | Not applicable |
| Accident Severity | Fatal only |
| Road Type | No restrictions specified |

TITLE: Highway Safety Effects on the Energy Crisis on U.S. Toll Roads

AUTHOR(S): Campbell, Scott, Tolkin

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|---|---|
| Data Collection Period | January - October, 1973 and 1974 |
| Data Collection Location | Kansas, Maine, New York, Ohio, Pennsylvania |
| Accident Data Source | Coded police reports |
| Exposure Data Source | Volume: toll ticket records; speed: toll road or state surveys* |
| Type of Sample | Accidents: No restriction specified, but pedestrian accidents deleted.<br>Speeds: Unique to each state<br>Volume: No restrictions specified |
| Truck Types | Tractor trailers** |
| No. of Trucks in Accidents | 2,945 |
| No. of Accidents | 15,555 (in 24 month period) |
| No. of Other Accident Vehicles | 12,151 cars |
| No. of Trucks Exposed | 26,027 |
| Accident Severity | No restrictions specified |
| Road Type | 1,479 miles of toll road. Mainline only -- not ramps, toll booth areas, service plazas, etc. Said to include 29% of all U.S. toll road travel. |

* Insufficient speed data in Pennsylvania. Surrogate freeway used in 1973 Kansas data.

** For exposure data, vehicle toll codes were combined to estimate volume for large trucks. In Maine and Kansas, straight trucks could not be removed from exposure data; the porportion of straight trucks was thought to be small, and total trucks from these two states constituted only 21 percent of the full sample.

TITLE: Accident Experience on the New Jersey Turnpike

AUTHOR(S): Crosby

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|---|---|
| Data Collection Period | 1952 - 1957 |
| Data Collection Location | New Jersey Turnpike |
| Accident Data Source | New Jersey Turnpike Authority |
| Exposure Data Source | New Jersey Authority |
| Type of Sample | Accidents: No restrictions<br>Exposure: Actual distance accumulated; no restrictions specified. |
| Truck Types | Trucks with two axles and dual tires, or with three or more axles. |
| No. of Trucks in Accidents | 1,698 |
| No. of Accidents | 6,048 |
| No. of Other Accident Vehicles | 9,086 |
| No. of Trucks Exposed | 16,233,680 |
| Accident Severity | No restrictions |
| Road Type | Toll road |

TITLE: Truck Accident Study

AUTHOR(S): Ernst and Ernst

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|---|---|
| Data Collection Period | 1965 |
| Data Collection Location | California, Colorado, Connecticut, Florida, Illinois, Minnesota, Ohio, Pennsylvania, Texas, Virginia* |
| Accident Data Source | Police reported truck accidents from state files |
| Exposure Data Source | Not applicable |
| Type of Sample | 5 States -- systematic sample; 5 states -- cluster sample. Sample size for each state proportionate to estimated total number of truck accidents. |
| Truck Types | Trucks categorized as pickup, panel, straight truck, tractor trailer, tractor and two trailers. |
| No. of Trucks in Accidents | 2,184 combination trucks<br>3,170 straight trucks (excluding pickups and panels) |
| No. of Accidents | 10,000 |
| No. of Other Accident Vehicles | 1,075 cars in accidents with combination trucks<br>2,046 cars in accidents with straight trucks |
| No. of Trucks Exposed | Not applicable |
| Accident Severity | No restrictions specified* |
| Road Type | No restrictions specified* |

* 5 states -- rural only, 1 state -- urban injury accidents, and all rural accidents, 4 states -- no severity or locale restrictions.

TITLE: Trucks: An Analysis of Accident Characteristics by Vehicle Weight

AUTHOR(S): Lohman and Waller

| | |
|---|---|
| Data Collection Period | 1973 |
| Data Collection Location | North Carolina |
| Accident Data Source | Department of Motor Vehicles |
| Exposure Data Source | Not applicable |
| Type of Sample | Not specified |
| Truck Types | At least three axles and tractor trailers |
| No. of Trucks in Accidents | 5,653 |
| No. of Accidents | Not specified |
| No. of Other Accident Vehicles | 218,730 cars |
| No. of Trucks Exposed | Not applicable |
| Accident Severity | No restrictions specified |
| Road Type | No restrictions specified |

TITLE: Trucks in Rural Injury Producing and Property Damage Utah Accidents

AUTHOR(S): Schotz and Robinson

| | |
|---|---|
| Data Collection Period | September 1965 - August 1967 |
| Data Collection Location | Rural Utah |
| Accident Data Source | Utah Highway Patrol reports with photographs |
| Exposure Data Source | Not applicable |
| Type of Sample | Not a probability sample |
| Truck Types | Tractor trailers |
| No. of Trucks in Accidents | 357 |
| No. of Accidents | Apparently 357 |
| No. of Other Accident Vehicles | 134 cars |
| No. of Trucks Exposed | Not applicable |
| Accident Severity | No restrictions specified |
| Road Type | Rural |

TITLE: Statistical Analysis of Truck Accident Involvements*

AUTHOR(S): Scott and O'Day

| | |
|---|---|
| Data Collection Period | Pennsylvania (1967 to June 1969), Ohio (1966-June 1970), Indiana (1966-1970) |
| Data Collection Location | Indiana, Ohio, Pennsylvania |
| Accident Data Source | State or turnpike accident records |
| Exposure Data Source | Toll ticket records |
| Type of Sample | Exposure: Not clearly specified<br>Accidents: All accidents in the source files |
| Truck Types | Tractor trailers** |
| No. of Trucks in Accidents | 4,478 |
| No. of Accidents | 20,155 |
| No. of Other Accident Vehicles | 21,719 cars |
| No. of Trucks Exposed | Not explicitly stated |
| Accident Severity | No restrictions specified |
| Road Type | Turnpikes, mainline only |

* While Scott and O'Day used a number of data sources, and several of them were included in the text of this report, our major emphasis was on the turnpike data described here.

**For exposure data, vehicle toll codes were combined to estimate volume for combination trucks.

TITLE: Accidents on Main Rural Highways

AUTHOR(S): Solomon

| | |
|---|---|
| Data Collection Period | 3 to 4 years ending June 30, 1958 |
| Data Collection Location | Arizona, California, Connecticut, Iowa, Minnesota, Missouri, Montana, New Jersey, North Carolina, Oregon, Virginia |
| Accident Data Source | State accident records |
| Exposure Data Source | Volume: spot checks; exposure: section length x volume; speed: spot checks |
| Type of Sample | All reported accidents. Road segments chosen for speeds "representative" of general area. Exposure and driver interview sampling not described. |
| Truck Types | (a) 6 or more tires, and (b) [separately] 4 tires |
| No. of Trucks in Accidents | (a) 1,262; (b) 801; 908 combination trucks |
| No. of Accidents | Approximately 10,000 accident vehicles |
| No. of Other Accident Vehicles | 7,608 cars |
| No. of Trucks Exposed | Not explicitly stated |
| Accident Severity | No restrictions |
| Road Type | 600 miles of rural roads; speed limits 45 mph to reasonable and proper; 2 and 4 lane main highways; no freeways. |

TITLE: A Preliminary Report on Trucks in Injury Producing Accidents

AUTHOR(S): Stern

| | |
|---|---|
| Data Collection Period | 1963-1965 |
| Data Collection Location | Scattered in U.S. |
| Accident Data Source | State police in North Dakota and Oklahoma. Interstate Commerce Commission, American Trucking Association |
| Exposure Data Source | Not applicable |
| Type of Sample | Not a probability sample |
| Truck Types | Tractor trailers |
| No. of Trucks in Accidents | 204 |
| No. of Accidents | Not specified |
| No. of Other Accident Vehicles | Not applicable |
| No. of Trucks Exposed | Not applicable |
| Accident Severity | Injury accidents |
| Road Type | Rural |

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