Truck Impact on Roadway Safety

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ABSTRACT

A number of aspects connected with the operation and safety of trucks are discussed in this paper. The involvement rate of trucks in road accidents is found to be lower than that of passenger cars and buses; similarly, there is a decreasing trend in accident rate with an increase in gross vehicle weight. In contrast, the fatality rate in truck accidents is found to be higher than that involving passenger cars; also, a tendency exists toward an increase in the relative proportion of fatal accidents with an increase in gross vehicle weight. A multiplicity of injuries in truck-involved accidents is also noticed. It is concluded that the injury and fatality victims in such accidents are more likely to be the passengers and drivers of the other vehicles involved or pedestrians. Finally, a relatively high truck involvement is found in front-rear, side, and single-vehicle accidents.

Road accidents in which trucks are involved generally arouse great public interest and sensitivity, mainly because of their relatively high severity and the heavy economic damage accompanying them. In recent years, this sensitivity appears to have been heightened in light of the fact that trucks have been made larger and passenger cars smaller.

The relatively high severity of accidents involving trucks is a direct result of their basic characteristics, which, according to Neilson et al. (1) are as follows: (a) relatively large mass, resulting in instant velocity changes in smaller vehicles that strike them; (b) high rigidity of structure, resulting in most of the energy loss being dissipated in the collapse of the smaller vehicle; and (c) misalignment of structures, the height of truck structures resulting in damage to the upper and weaker parts of smaller vehicles.

Despite the high severity of truck accidents, the accident rate for trucks may be expected to be lower than that for passenger vehicles. Following are some of the reasons for this apparent anomaly:

1. Trucks record a relatively higher proportion of interurban mileage than do passenger vehicles, a determination that is particularly true for heavy trucks;
2. Trucks register much higher mileage, a fact that influences the creation of a low accident rate (the phenomenon of a low accident rate following high road exposure stems apparently from nonlinear relationships between accidents and exposure);
3. Truck drivers are generally more skilled in driving than are drivers of passenger cars; and
4. Vehicle maintenance of trucks, especially in the large companies, is generally stricter than that of passenger cars.

Despite the existence of a low accident rate for trucks, one may also point to the following reasons that would cause trucks to have a higher accident risk:

1. Driver fatigue: the driving time of truck drivers, both proportionally and in absolute terms, is higher than that of car drivers, and causes a decrease in driver attention span.
2. Structure and maneuverability: tires, brakes, braking distances, stability while braking, jackknifing possibility, power steering, and lashing of freight are among the characteristics creating a high accident risk for trucks.
3. Problems of overloading: the economic temptation to overload trucks creates a decrease in the safety factor of different truck parts.

The typical problems connected with the involvement of trucks in road accidents have been discussed in the literature. Eck (2) analyzed some 600 accidents related to runaway trucks and presented several contributing factors, among which were driver error, equipment failure, and lack of experience with mountain driving. A study by McGee et al. (3) on accident types and contributing factors indicated that truck-accident rates varied inversely with truck weight. Among the effects surveyed were those of roadway geometry, roadside features, and wide loads. A review of the research on truck size and weights by Freitas (4) concluded that the available research on the safety of large trucks is not congruent. One reason is that data in some studies are not consistent, particularly the mix between large combination-trucks, which tend to travel on rural freeways, and smaller single-unit trucks, which tend to travel on urban streets. Another reason is that the quality of the data is sometimes questionable because of the difficulty in calculating accident rates.

Lohman and Waller (5), who analyzed accident characteristics by vehicle weight, discovered that larger trucks were more likely to be involved in single-vehicle crashes than were cars or smaller trucks. Their study also suggested that some truck drivers appeared to encounter difficulties in stopping their vehicles; the use of improved braking systems, with greater braking power and less probability for failure, may therefore be considered as a possible remedy for truck accidents. This point was also discussed in Neilson (1), which is a study of accidents involving heavy-goods vehicles that further demonstrated that trucks, particularly when laden, take a considerably longer distance to stop than do cars.

This paper will deal with a number of aspects connected with truck operations, especially in the area of safety. The section that follows contains a discussion on the economic and safety implications of operating single versus double trailers. Succeeding sections make a detailed comparison between trucks and automobiles of accident rates, accident severity, and types of accidents.

One of the aims of the present work was to examine differences in safety performance among various gross vehicle weight (GVW) groups of trucks in Israel. For that reason, a new accident data file had to be constructed. This file was combined from two independent sources: the police accident file and the vehicle registration file. The latter was needed for supplying technical information concerning the vehicles (e.g., vehicle weight). The police accident file identified the vehicles involved in road accidents and provided more accident details.

LARGE-TRUCK COMBINATION OPTIONS

Long combinations of trucks have, for some time, constituted a subject of much controversy. Alongside the economic advantages of these vehicles (e.g., a saving in manpower), there exist doubts concerning the safety implications stemming from the use of combination trucks.

Polus (6) conducted an analysis of the operating costs of heavy-truck combinations in western Canada and evaluated their relative efficiencies. He found that because trucks operate under a variety of conditions, operating costs vary considerably, depending on the commodities carried, the service provided, and the operating conditions experienced. The parameters involved in determining these costs may be characterized as the internal and external factors of the trucking industry. Some of the internal factors include type of commodity; equipment, purchase, and maintenance policies; annual mileage traveled; and vehicle configuration. External factors include such variables as union rules and wage scales, road topography and surface type, climate, and payload and axle-weight limits.

The economic performance of any given truck combination can be compared to a 2-axle truck (or to any other base), and its relative value obtained. Figure 1 shows the relative economic performance of various heavy-vehicle combinations for a given annual mileage, based on payload-to-cost relationships, after comparisons were made with two types: a 2-axle truck (used as the base) and a 5-axle semi-trailer.

The 7-axle Rocky Mountain Double was found to be the most efficient combination--on the average, approximately 24.8 percent more efficient than the 5-axle combination. Similarly, 8-axle triple-trailer trucks were found to be, on the average, approximately 9.6 percent more efficient than semi-trailers.

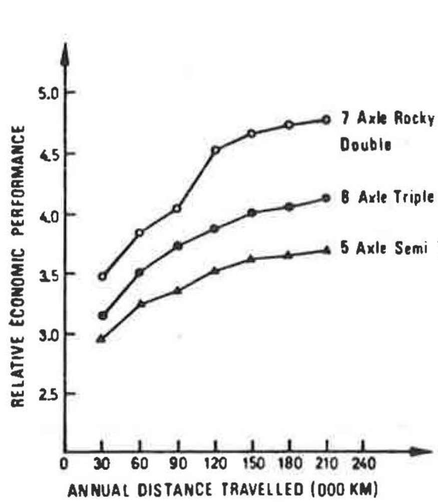

FIGURE 1 Relative economic performance of various heavy-vehicle combinations.

Various trucking companies had previously identified the 7-axle Rocky Mountain Double as the most suitable combination for long-distance freight movement. Company officials pointed particularly to the added flexibility of this type resulting from combining a short trailer with a regular 45-ft (13.6-m) trailer.

The literature contains conflicting evaluations of the safety of double trailers compared to singles. Thus, whereas Winfrey et al. (7) and Scott and O'Day (8) found that doubles have a relatively lower accident rate than do singles, Vallette et al. (9) offered the opposite conclusion. Figure 2, taken from this latter work, shows the accident rate per 100 million vehicle miles. In each weight group, the rate can be seen to be higher for double trucks than for singles. McGee et al. (5) on the other hand, found that the accident rate of the two truck types did not show a clear differentiation by itself. By contrast, in combined terms of distance and weight, double trailers showed a relative advantage in that the accident rate per 100 million ton-miles of travel was higher for the singles (14.7 versus 11.0 for the doubles). Peterson and Grull (10) analyzed the operations of triple-trailer combinations in comparison with doubles and singles during a 1-year field study in Utah. The accident data, though limited, indicated that triples were safer under the conditions in which they were operated.

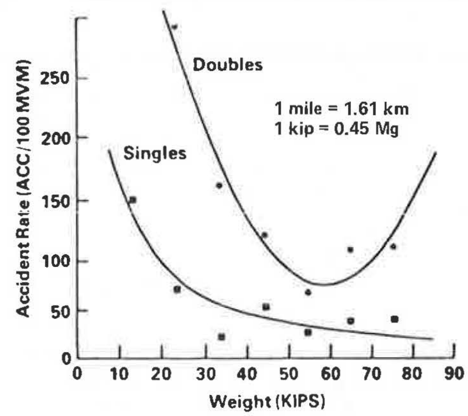

FIGURE 2 Accident rate per 100 million vehicle miles.

Freitas (4), in his review of accident research, gave this evaluation: "It does seem clear that larger and heavier trucks can be operated safely--but under certain conditions, larger trucks do have real safety problems." One of these problems, especially for combination trucks, is presented by an empty vehicle. The extent of the proneness to accident involvement of empty trucks varies from company to company, according to the relative proportion of trips without freight. Indeed, in large companies in which the number of trips without freight is minimal, no differences in accident rate were found between single and combination trailers.

The conclusion to be derived from the facts presented in this section is that in light of the economic advantages inherent in combination trailers, the correct way must be found to operate these trucks such that their alleged safety disadvantages will be minimized. In view of the heavy weight and technological complexity of such trucks, the following elements are necessary: (a) a high level of driver skill; (b) a high level of vehicle maintenance; and (c) an avoidance of trips without freight or, alternatively, the development of appropriate technology for empty-truck transport.

EFFECT OF TRUCK WEIGHT ON ACCIDENT INVOLVEMENT

The various weight groups of the single-unit truck represent a wide range of weight-related mechanical problems and of technologies intended to overcome these problems (number of axles, types of brakes, etc.). Figure 3 shows the road-accident involvement of various weight groups of trucks in Israel. The parameter of road-accident involvement is the average number of accidents per million kilometer of travel for the years 1979-1981. In addition, the accident-involvement rates of passenger vehicles (cars and buses) are presented for comparison. The criteria for defining an accident were the same for cars, trucks, and buses: by law, an accident must be reported to the police whenever it involves an injury or a fatality; it may be reported when it involves only property damage. An accident is counted as such only when reported to the police. Data on this subject indicate the following characteristic trends: (a) passenger cars and buses have a higher accident-involvement rate than any truck weight group; and (b) the accident rate decreases with gross truck weight.

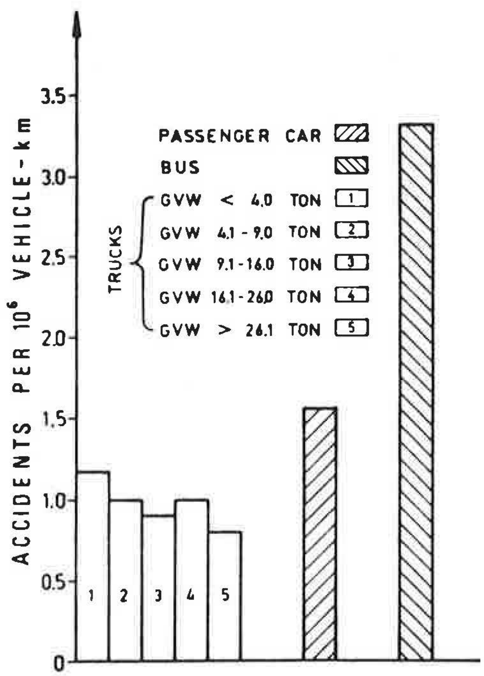

FIGURE 3 Road accident involvement of various weight groups of trucks in Israel.

The first trend also exists in other countries. Wolf (11) found that in respect to general accident-involvement rate, the truck system has the best safety record: 1,510 accidents per 100 million vehicle miles, compared with 3,000 for cars and 4,310 for buses. Vallette et al. (9) also found that the accident rate changes inversely with truck weight and that this tendency occurs both for single- and double-unit trucks. Accident statistics from Canada based on the Provincial highway system and data base of Saskatchewan, are given in Table 1 and offer the following principal features:

1. The accident rate for large semi-trailers and trailers (5 axles or more) is lower than the rate of accidents either for passenger cars or for all other categories of vehicles.
2. The rate of accidents for passenger cars is lower than that for pickup vehicles.
3. The 3-axle, semi-trailer (power units only or small trailers) has the highest accident rate of all vehicles. This indicates, perhaps, careless driving, compounded by possible speed-limit violations and lack of stability.
4. The rate of accidents for single-unit trucks is higher than that for 5 or more axles, but lower than the rate for passenger cars.

TABLE 1 Number and Rate of Accidents on the Provincial Highway System in Saskatchewan, Canada, by Type of Vehicle, in 1980

Type of Vehicle	Estimated 1980 Highway Travel: Total Highway Travel (km: 10^6)	Percent of Total Highway Travel	Accidents[a]: Total	Total (%)	Accident Rate (accidents per 10^6 vehicle km)
Passenger cars	3,061.05	57.9	4,321	54.9	1.412
Pickups[b]	1,501.45	28.4	2,360	30.0	1.572
Single-unit trucks	243.19	4.6	309	3.9	1.271
Semi-trailers:					
3-axle combinations	15.86	0.3	118	1.5	7.440
5 or more axles	380.65	7.2	409	5.2	1.074
Others[c]	63.44	1.2	295	3.8	4.650
Total[d]	5,286.79	100.0	7,864	100.0	

[a]Includes fatal, injury, and property-damage accidents.
[b]Includes all panels of light trucks with single wheels on rear axle.
[c]Includes emergency vehicles, construction equipment, motorcycles, farm equipment, motor homes, snowmobiles, and buses.
[d]Totals may not sum due to rounding.

It is possible to distinguish in statistics from South Africa, as in data from Israel, the United States, and Canada, that the accident rate for passenger cars is higher than that for trucks. Accident involvement data on South African roads are given in Table 2. As can be seen, the rate in 1981 for petrol and diesel trucks was 7.14 and 9.71 accidents per million km, respectively, whereas the accident rate for passenger cars was 15.19 per million km.

The distinction between truck groups correlates with the type of engine (e.g., the petrol engine characterizing lighter trucks, and the diesel engine of the heavier vehicles). It should be noted that there is an extensive weight group (up to 12 tons inclusive) of trucks that can be equipped with either petrol or diesel engines. The fact that the South African data show the accident-involvement rate of diesel-driven trucks to be higher than that of petrol-driven vehicles indicates the possibility that heavy vehicles in that country are involved in more accidents than are light trucks.

In summary, it may be said that despite the physical dimensions and the technological problems of heavy vehicles, it is not possible to point to a higher accident involvement with an increase in the dimensions and weight of trucks. On the contrary, there is much evidence that the accident rate for trucks is lower than that for passenger cars, and that there is a decreasing trend in accident rate with an increase in GVW.

EFFECT OF TRUCK WEIGHT ON ACCIDENT SEVERITY

The weight of a truck involved in a road accident constitutes a significant factor in the severity of

TABLE 2 Accident Involvement on South African Roads

	1980			1981		
Vehicle Type	Total Travel (million km)	Total Accidents	Accident Rate	Total Travel (million km)	Total Accidents	Accident Rate
Motor cars, station wagons, and taxis	28,784	385,570	13.39	29,731	451,576	15.19
Light trucks (petrol-driven)	9,982	62,178	6.22	10,424	74,390	7.14
Heavy trucks[a] (diesel-driven)	4,033	32,840	8.14	4,282	41,564	9.71

[a]Includes single-unit and articulated vehicles.

the accident because of the effect of a heavy mass on the speed change of the vehicle that crashes with the truck. Figure 4 shows the percentage of fatal accidents of the total number of accidents in which trucks of a certain weight group were involved. For comparison, statistics are also presented for passenger cars and buses. The principal finding is a rise in the relative proportion of fatal-accident involvement with an increase in truck weight. In other words, the heavier the truck, the more the risk grows that when the truck is involved in an accident, it will be a fatal one. In addition, the relative proportion of fatal accidents in which trucks were involved is higher than that in which passenger vehicles were associated.

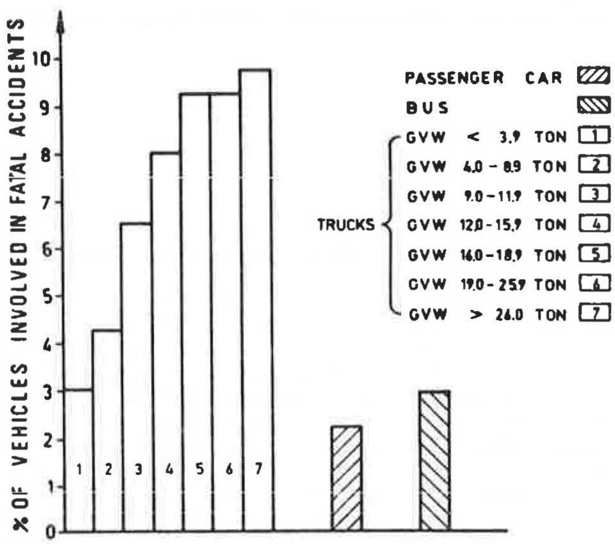

FIGURE 4 Percentage of fatal accidents of the total number of accidents involving trucks of a particular weight.

The increasing risk of a fatal accident with vehicle weight increase is expressed, also, in the overall probability of such an accident with each kilometer traveled. Figure 5 shows the rates of fatal accidents involving trucks, passenger cars, and buses. A trend can be discerned of an increase in fatal-accident involvement with an increase in truck weight. It should be noted that the involvement rates of trucks are higher than those of passenger cars but lower than those of buses.

Another parameter reflecting accident results is the average number of injuries per vehicle involved in an accident. Figure 6 shows these rates for trucks, buses, and passenger cars. As can be seen, except for the 4.0- to 8.9-ton weight group, the average number of injuries occurring in truck-involved accidents is greater than that of passenger cars and buses. In addition, then, to the fatal nature of truck accidents, there is an aspect of a multiplicity of injuries in truck-involved accidents. This phenomenon is all the more striking in view of the fact that the number of passengers in a truck is generally lower than in any other vehicle.

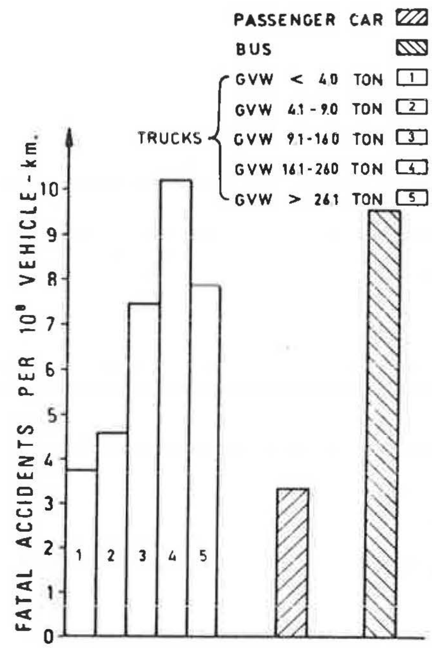

FIGURE 5 Rates of fatal accidents involving trucks, passenger cars, and buses.

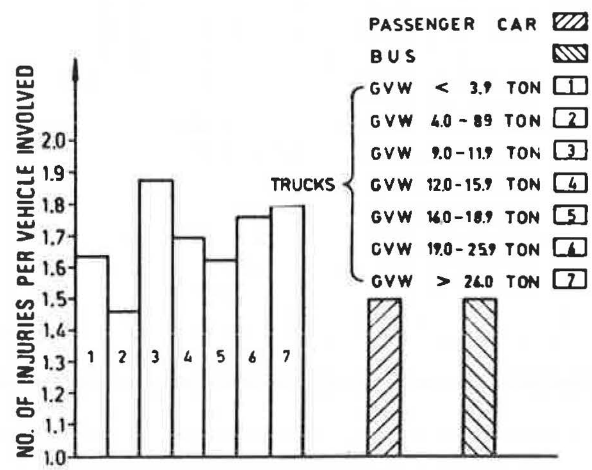

FIGURE 6 Injury rates for trucks, buses, and passenger cars.

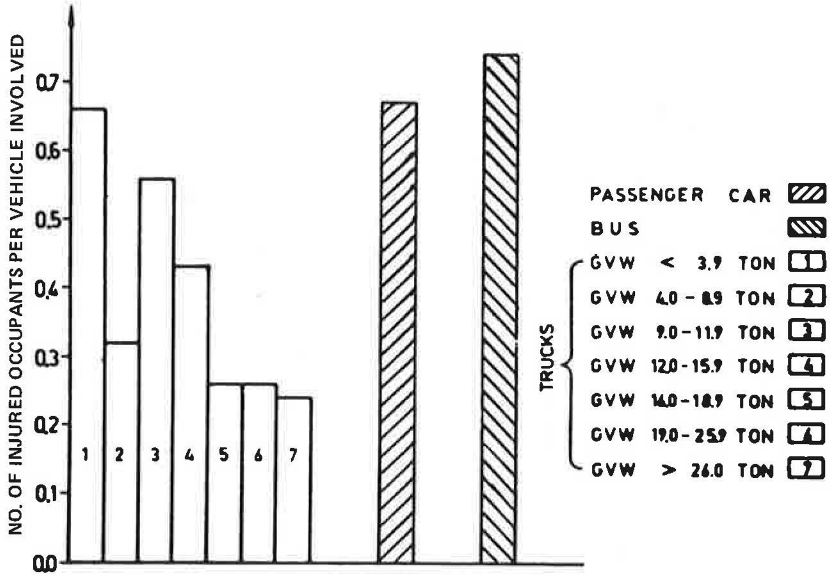

FIGURE 7 Average number of occupants per 1,000 vehicles involved in accidents, by vehicle type.

It may be concluded that the injuries and fatalities are passengers and drivers of the other vehicles or pedestrians.

To examine this phenomenon in more detail, a calculation was made of the average number of vehicle occupants injured per 1,000 vehicles involved in accidents, according to the type of vehicle in which the injured person was riding. Figure 7 shows these data. It can be seen that more car and bus occupants than truck riders are injured. Similarly, the heavier the weight of the truck, the smaller the number becomes of injured truck occupants. These facts highlight the protection that the truck affords its driver and passengers. As mentioned, however, there is a greater chance of the truck's injuring, and injuring more severely, other road users.

GEOGRAPHICAL DISPERSION OF ACCIDENTS

The geographical dispersion of road accidents in which trucks are involved is said to coincide, on the one hand, with the roads on which trucks have great exposure and, on the other hand, with the areas at which they meet with typical problems. In accordance with these two influences, one can expect a relatively high percentage of truck accidents to take place on the upgrades, interchanges and intersections, curves, and downgrades of interurban roads.

Despite the fact that there are no exact statistics reflecting the mileage distribution of trucks between urban and nonurban roads, it is reasonable to assume that the heavier the truck, the greater its relative mileage proportion outside the urban area. Accordingly, an increase may be expected in the relative proportion of accidents on interurban roads with the increase in truck weight.

Figure 8 shows the breakdown of accidents on interurban roads in Israel according to various truck weights. As might have been expected, the accident percentage rises with the increase in truck weight. In each weight group, moreover, the relative proportion of accidents is higher for trucks than for passenger cars and buses. The relatively high percentage of accidents in interurban areas may explain some of the severity of accidents involving heavy vehicles. As is well known, interurban roads are characterized

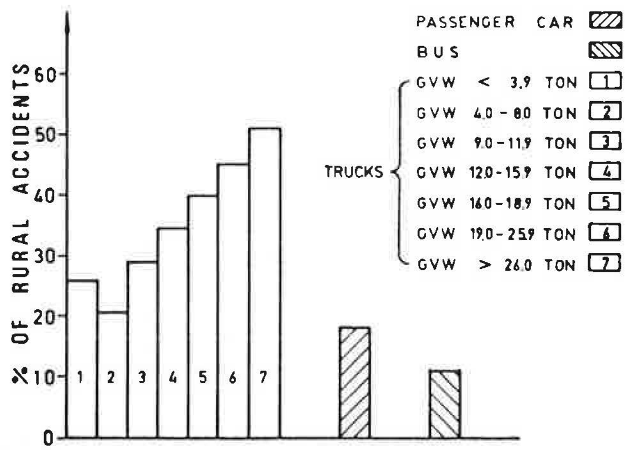

FIGURE 8 Breakdown of accidents on interurban roads in Israel according to various truck weights.

by higher travel speeds, leading to more severe accidents, than urban roads.

The high risk of truck accidents at intersections and interchanges stems from the long stopping distances of trucks, their difficulty in maneuvering in small radii, and their inability to develop high accelerations. Indeed, Vallette et al. (9) reported that 16 percent of truck accidents take place in the area of interchanges. Figure 9 shows the percentage of accidents at interurban intersections in Israel of the total number of interurban truck accidents, according to various weight groups. From these data, however, no trend or greater tendency to accidents at intersections can be distinguished for trucks relative to other types of vehicles.

TYPES OF ACCIDENTS

The characteristic problems of trucks expose them to certain types of accidents. One of the most common types of accidents in which a high truck involvement may be expected is the rear-end collision. Figure 10

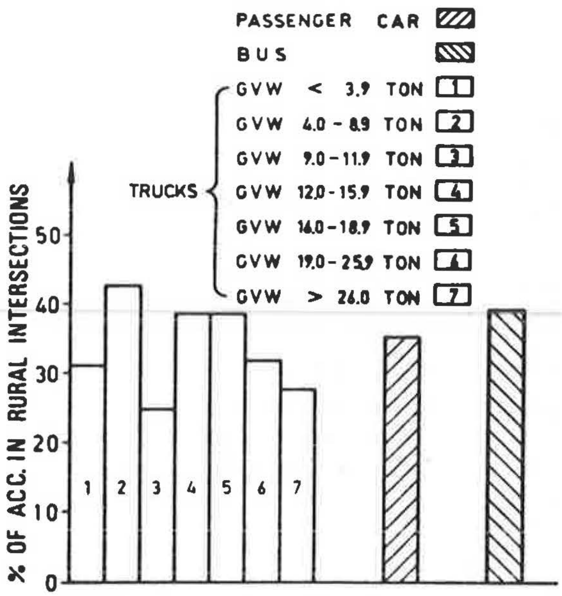

FIGURE 9 Percentage of accidents at interurban intersections in Israel.

shows the distribution of the types of accidents in Israel in which trucks were involved from 1979-1982. As can be seen, all categories of rear-end accidents account for as much as 35 percent of all truck-involved accidents. Trucks are exposed to this type both at intersections and on grades. At intersections, the problem stems from the stopping difficulties of trucks. On upgrades, trucks are prone to being rear-ended by overtaking vehicles; on downgrades, a truck may rear-end a slower-moving vehicle. Another type of accident in which one may expect a high involvement of trucks is a side-to-side collision. These are created on account of the dimensions of trucks and their special difficulties on curves.

As can be seen from the data shown in Figure 10, heavy vehicles are involved in relatively more rear-end collisions, and single-vehicle accidents than are passenger cars. The high involvement of buses in single-vehicle accidents stems from injuries to passengers while boarding or alighting or to inside passengers as a result of the sudden braking of the bus.

SUMMARY AND CONCLUSIONS

This paper has discussed a number of aspects connected with the operations and safety of trucks, the

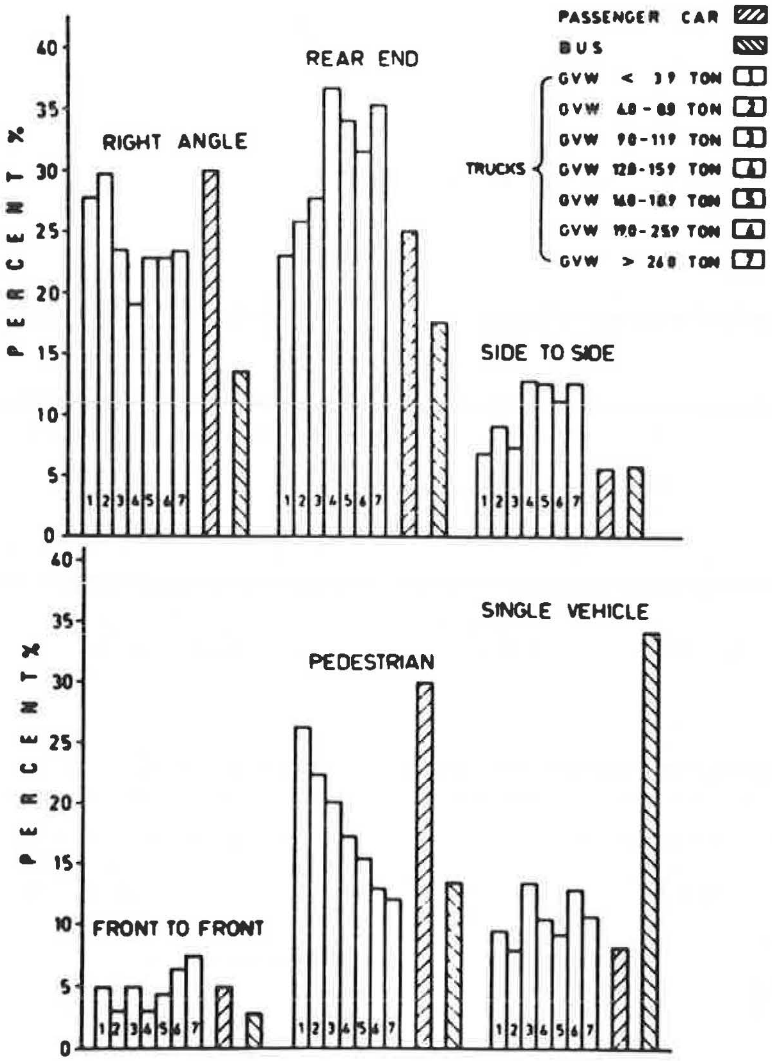

FIGURE 10 Distribution of type of truck accident in Israel from 1979 to 1982.

accidents involving which are associated with heavy economic damage and severity. As a direct result of their weight, structure, and operational characteristics, trucks were seen to be prone to certain types of road accidents--front-rear, side, and single vehicle--on certain geographical elements of the road such as intersections, grades, and curves.

From the data that were processed and surveyed for this study, the following conclusions may be drawn:

1. Long combination trucks, such as doubles and triples, have economic advantages over single-unit trucks; the advantage is expressed in indices of relative economic efficiency;
2. There are conflicting evaluations of the safety of double and triple trailers compared to singles, although most studies suggest that longer combinations have good safety records;
3. In relative terms of involvement (accidents per million kilometer of travel), passenger cars and buses are involved in more accidents than are trucks;
4. A decreasing trend in accident rate exists with increasing GVW;
5. An accident in which a heavy truck is involved will, in all probability, be more fatal than an accident involving a light truck;
6. The number of injuries in an accident involving a truck is greater than in accidents in which no trucks are involved. On the other hand, injuries to truck occupants are lower than they are to passengers in cars and buses; further, there exists a decreasing injury tendency with GVW. Specifically, when trucks are involved in an accident, the victim is more likely to be someone other than the truck driver;
7. The heavier the weight of a truck, the greater the relative proportion of interurban accidents in which it is likely to be involved; and
8. Relative to passenger cars, trucks are involved in more front-rear, side, and single-vehicle-type accidents.

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