A Preliminary Study of Speed as Related to Injury-Producing Automobile Accidents

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This paper examines accident and injury data on 3,203 automobiles involved in injury-producing accidents to determine effects which speed may have on the frequency of dangerous or fatal injuries.

The examination consists of four substudies: (1) the frequency distributions of the cars according to traveling and impact speeds in progressive ranges of 10 mph; (2) the frequency of dangerous or fatal occupant injury in each of the progressive traveling and impact speed ranges; (3) the extent to which rigid control of traveling speed would reduce the frequency of dangerous or fatal injuries; and (4) the influence which factors other than speed (ejection, seat area occupied, site of impact) have on the incidence of dangerous or fatal injuries.

● MOBILITY and speed seem to have become essential requirements of American culture. A network of new highways is being engineered to carry more and more vehicles farther and faster. Yet constantly is heard the cry: "Speed kills .... Slow down and live!" This poses a dilemma: demand for speed and the opposing dread of it. It is strange that this dilemma should exist, because the contention that speed kills never has been actually proven. It is the purpose of this preliminary study to examine data which may throw light on the subject of the relationship between speed and injury or death.

There is little doubt that the high or excessive speed of a traveling automobile can cause an accident; as the speed increases, so does the rate of closure, thereby reducing visual and physical reaction time. The cause of injury, however, is another matter, for all accidents do not necessarily produce injury.

Realistic examination of the relationship between speed and injury or death requires distinction between traveling speed and impact speed. For example, the driver of a car traveling at 60 mph may observe an imminent accident, apply his brakes, and finally strike an object at 40 mph. Thus, a chain of events leading to an injury is created. A particular traveling speed results in an accident involving a particular impact speed; the injury resulting, although related to both the traveling and impact speeds, is more closely related to the latter, whereas the occurrence of the accident is related to the former. This study, therefore, while examining the relationship between speed and death or serious injury, keeps data on traveling speed distinct from those on impact speed.

Automotive Crash Injury Research data are ideally suited for such study. An interstate cooperative program, involving police, highway patrol personnel, physicians and public health authorities in eleven states and one city, produces data through the use of detailed photographs and specially designed accident and injury report forms. Sampling techniques afford reliable and representative data. State police and highway patrols are specially trained by Automotive Crash Injury Research personnel in reporting and photographic procedures. Hospital emergency room staffs and physicians in the areas being sampled are also briefed on the program, and public health or similar authorities act as a control in securing complete, detailed and accurate medical reports. All persons participating in the program are oriented and motivated to the requirements of a study aimed at obtaining complete accounts of the accidents, as well as discovering the specific mechanical and structural causes of injury.

One of the difficulties in dealing with speed data is that speed reporting is largely subjective. Objectivity in this field of study would require speed recording instrumentation in every automobile, or large-scale employment of radar or similar devices. Since neither of these methods is used presently to an extensive degree — nor promises to be in the immediate future — reliance must be placed on the accuracy of speed reporting by police and highway personnel.

These professional accident reporters have had years of experience in estimating speeds through observation of many thousands of traveling cars; they are trained in the proper methods of interpreting accident details and use such evidence as extent of basic car damage, tire condition, skid marks, types of road surface, weather conditions, and related information in determining accident speeds. Recent years have seen the development of tests to measure and improve the accuracy of police and highway personnel in estimating rates of closure. Thus, although most current speed reporting is subjective, attempts are constantly being made to control and minimize subjectivity. Speed data reported to Automotive Crash Injury Research have the additional advantage of support and confirmation through photographic evidence. Experienced accident analysts at the project headquarters at Cornell University Medical College in New York City used detailed pictures of car damage to confirm reported traveling and impact speeds.

Portions of the report which follow deal with what is termed "excessive" speed. Of course, speed limits in one area of the country often differ from those in another because of variations in terrain, road design, traffic density, etc. Nevertheless, an arbitrary definition of excessive speed can be based on the knowledge that large segments of present rural highway systems employ a speed limit of 60 mph. Thus, for purposes of discussion, this study terms speed over 60 mph as excessive.

BASIC DATA FOR STUDY

Each of the 3,203 passenger automobiles studied was involved in an injury-producing accident during the period from 1953 to 1956 inclusive, and contained at least one injured person. Every type of accident is represented, and the total sample closely resembles national registrations of passenger automobiles in terms of makes, models, and years of manufacture.

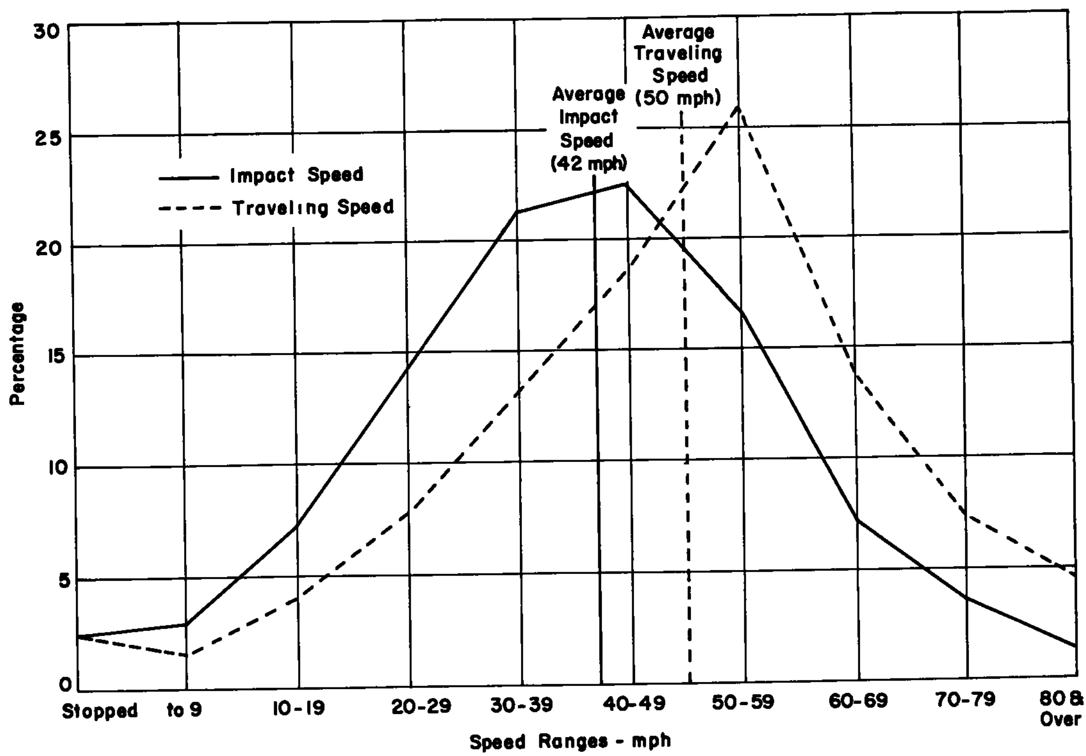

Figure 1. Distribution of reported traveling and impact speeds among 3,203 cars in injury-producing accidents.

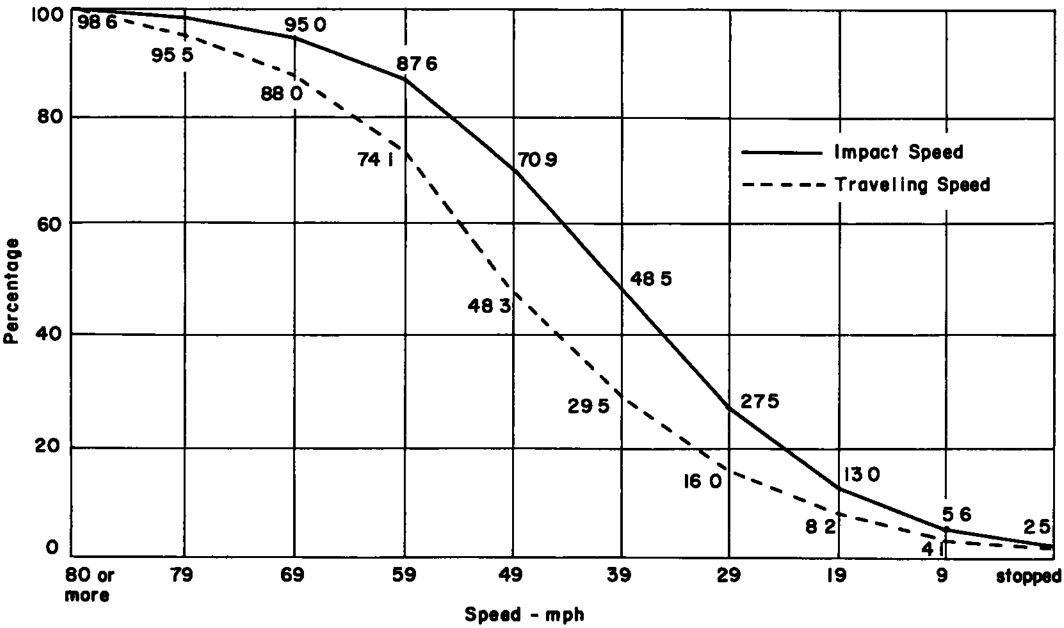

Figure 2. Percentage of cars traveling or impacting at or below a specified speed.

The 3,203 cars carried 7,154 occupants, or 2.3 persons per car. Among the 7,154 occupants, various degrees of injury were sustained in the following proportions:

No injury	25%
Minor injury (bruises, minor lacerations, etc.)	46%
Non-dangerous injury (severe lacerations, fracture, etc.)	20%
Dangerous injury (internal, brain injuries, etc.)	5%
Fatal injury (death instantaneous or within 24 hr after accident	4%

The last two injury classifications (dangerous injury and fatal injury), totaling 9 percent of the occupants, are used in this study as a measure of the effect of speed in injury-producing automobile accidents.

REPORTED TRAVELING AND IMPACT SPEEDS

Figure 1 shows distribution of the 3,203 cars according to both reported traveling[1] and impact[2] speed. It will be seen immediately that the greatest proportion of these cars was traveling at speeds in the 50- to 59-mph range, and impacted in the range of 40 to 49 mph. The average traveling speed was 50 mph and the average impact speed 42 mph.

The basic regularity of the distribution curves in Figure 1 establishes an important fact. The majority of injury-producing accidents are not associated with the higher speed ranges, as popular opinion would have one believe. Cars in injury-producing accidents appear in all ranges of speed and arrange themselves in the typical bell-shaped distribution curve.

In Figure 2 the speed data are presented in cumulative fashion, showing that 16 percent of the cars traveled at 29 mph or less, 29.5 percent traveled at 39 mph or less, 48.3 percent traveled at 49 mph or less, etc. Combining the cars which traveled at

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[1] Traveling speed: the speed of the car before involvement in the accident.

[2] Impact speed: the speed at which the major impact occurred between the car and objects or other cars or vehicles.

the most common speed (50 to 59 mph, as shown in Figure 1, with all the cars which traveled at lesser speeds, a total of 74.1 percent of the 3,203 cars were moving at speeds under 60 mph before becoming involved in injury-producing accidents.

Similar consideration of impact speed tells much the same story. The bulk of the cars impacted in the lower speed ranges. The cars impacting at the most common impact speed (40 to 49 mph, as shown in Figure 1), and all the cars impacting at lower speeds, comprise a total of 70.9 percent of the 3,203 cars.

OCCURRENCE OF DANGEROUS OR FATAL INJURIES AS RELATED TO SPEED

Figure 3 shows what proportion of the persons traveling or impacting at successive speed ranges suffered dangerous or fatal injury. Such injuries were sustained by 9 percent of the occupants of cars studied. These two grades of injury (representing trauma which placed car occupants either on hospital "critical" lists or in morgues within 24 hr) are used in this study to measure the effect of speed in automobile accidents; they reflect the severest aspect of injury. Measuring the effect of automobile accidents by the occurrence of fatal injuries only, while dramatic, illustrates merely a portion of the problem. That large segment of the population which is injured to a dangerous degree also represents a major problem. The loss of manpower and dollars through hospitalization, treatment, and often permanent disability has become a critical matter not only to industry, but also to the military services and the medical profession. Injuries of lesser degree — those of a painful, disfiguring, or disabling nature — are, of course, also important, but are omitted from this study for purposes of simplicity.

Analysis of the data shows that as traveling and impact speeds increase, there is a steady and statistically significant increase in the frequency of dangerous or fatal injury. However, as Figure 3 indicates, any increases of injury are small in speed ranges up to and including 40 to 49 mph. From the 50- to 59-mph range, and progres-

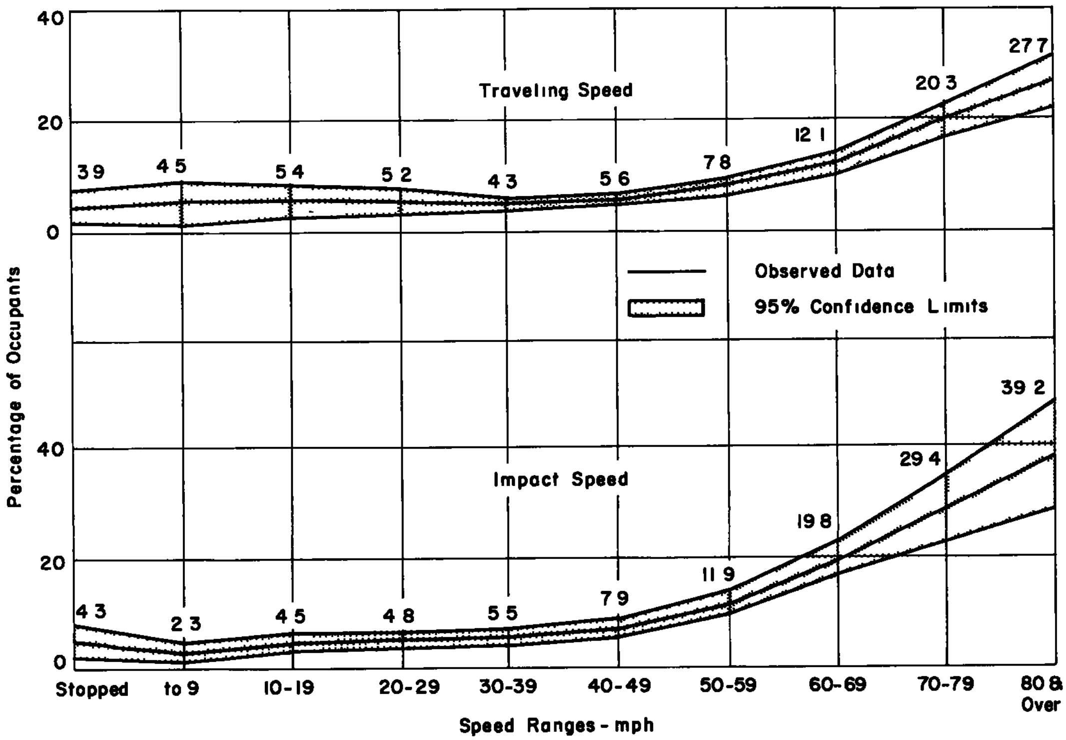

Figure 3. Frequency of dangerous or fatal injury according to progressively higher ranges of traveling and impact speeds.

sing upward through the higher traveling or impact speeds, the increases in frequency of dangerous or fatal injury become more marked. They culminate in an incidence of these injuries among nearly 28 percent of the persons traveling at or above 80 mph, and among approximately 40 percent of the persons in cars impacting at or above this speed.

The finding of correlation between the occurrence of dangerous or fatal injury and increasing speeds must be viewed with caution and interpreted in terms of how many cars or people are involved. For example, only 4½ percent of the cars were traveling at or above 80 mph, and no more than 25 percent were traveling at or above 60 mph.

Ignoring the important fact that high speeds are infrequent, the differences in risk of dangerous or fatal injury can be examined according to whether the speed was above or below an arbitrarily selected limit. In such an examination, impact speed need not be used, since the consequences of traveling at a given speed are being studied.

Because the most commonly reported traveling speed in injury-producing accidents is in the 50 to 59 mph range, 60 mph is used arbitrarily as the dividing line and one can proceed to observe the frequency of dangerous or fatal injury among persons who traveled above or below this speed.

About 6 percent of the occupants of cars traveling at speeds up to 60 mph sustained such injuries; above this speed the toll was in the order of 17 percent. Thus, it might be said generally that traveling above 60 mph may result in more than doubling the risk of dangerous or fatal injury.

The findings at this point must be treated with reservation. What has been discussed has been risk without regard to frequency. Further, there exists a distinct possibility that factors other than (or concomitant with) speed act to create dangerous or fatal injury. Simultaneous consideration of risk and frequency can be accomplished by means of "expectancies."

OCCURRENCE AND EXPECTANCY OF DANGEROUS OR FATAL INJURY AS RELATED TO SPEED REGULATION

For purposes of discussing speed regulation, "excessive" speed, as used in this study, is an arbitrary term referring to traveling speeds of 60 mph or over. Although the findings thus far emphasize the need for public education concerning the hazards of excessive speed, it should be repeated that only 25 percent of the cars in this study of injury-producing accidents were reported to have been traveling at excessive speed before involvement in the accidents. Thus, it appears that efforts to regulate speed cannot be expected to solve the total problem of dangerous or fatal injuries in automobile accidents. Obviously, any reduction in the frequency and severity of injury is immediately desirable, and the data herein presented clearly indicate that speed regulation can produce some improvement in the injury picture. However, speed should not be regarded as the sole and exclusive agent responsible for injury or death — the facts do not justify such a view. Nor should the discovery of a correlation between speed and injury lead to disregard of other factors which may be even more significantly responsible for injury. Although the risk of a dangerous or fatal injury increases markedly at the top speeds, both the risk and the frequency distribution of dangerous and fatal injuries must be taken into account in answering the vital question: "To what extent can rigid control of traveling speed reduce the current toll on the highway?"

To provide an answer to this question, the method of "expected values" has been used. In essence, the purpose of this method is to secure a gross estimate of what would have happened had rigid speed controls been enforced during the time when these data were collected. The procedure entails certain assumptions: (1) every vehicle traveling above the specified "rigid speed limit" would have, instead, been traveling at that speed; (2) the risks for the individuals "moved down" by this rigid speed limit would have been the same as the risks of the individuals actually traveling at this limit in the study; (3) other factors would not have changed. For example, the reduction in speed would not have changed anything about the accident and there would have been the same number of people, cars, types of accident, etc. Under these assumptions, it is possible to gain a gross estimate of the percentage of dangerous or fatal injuries which would

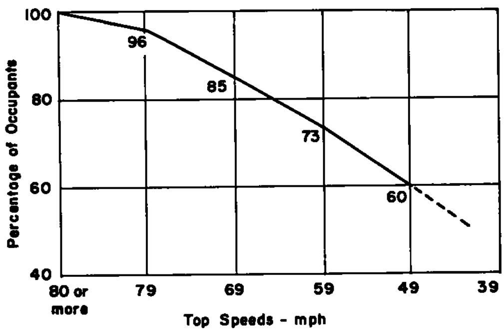

Figure 4. Expected percentage of dangerous or fatal injury at specified top speeds.

have occurred if the speed had been rigidly controlled to a specified limit.

The expected percentages (Figure 4) show that if the speed limit had been rigidly fixed at 79 mph (either by a miraculous 100 percent enforcement or by some engineering device such as a governor), 96 percent of the injuries would still have occurred. If the limit had been set at 69 mph, 85 percent of the injuries would nevertheless have occurred. Lowering the limit to 59 mph, 73 percent would have been involved. Even if the rigid speed limit had been reduced to 49 mph, there would have resulted an essentially limited reduction in the number of dangerous or fatal injuries, for 60 percent of the dangerous or fatal injuries still would have occurred. Hence, although rigid speed control of the top speeds would be expected to produce some improvement in the injury picture, there is a definite limit to the amount of improvement that can be achieved by absolute speed regulation.

OTHER FACTORS INFLUENCING INJURY

The data thus far have clearly indicated that speed is not the sole element in producing dangerous or fatal injuries. Further, speed control offers only partial solution to the problem of these injuries. Of course, there is no injury if there is no accident, and excessive speed does have a bearing on whether or not an automobile accident occurs. Thus, speed control would seem to imply accident rather than injury prevention.

The data make it apparent that conditions other than (or together with) speed act to produce dangerous or fatal injuries. Study of injury-producing accidents has isolated several primary factors as affecting both the occurrence and seriousness of injury in automobile accidents. One of these factors is the phenomenon of ejection, which takes place most frequently when doors open under impact conditions. The consequence of doors opening (front doors open in about 50 percent of cars in injury-producing accidents[3]) is that ejection occurs among approximately 13 percent of the total car occupants. The profound effects of ejection on injury are shown in Table 1, which shows that dangerous or fatal injuries were sustained by five times as many ejectees as non-ejectees; that is, ejection multiplies the risk of dangerous or fatal injury by five.

TABLE 1

RISK OF INJURY AS RELATED TO EJECTION OR NON-EJECTION

	Percentage of Occupants with			
	Mod thru Fatal Injury	Severe thru Fatal Injury	Dangerous or Fatal Injury	Fatal Injury
Non-ejectees	23 9	9 9	5 5	2 6
Ejectees	49 9	36 4	26 6	13 3
Injury ratio, ejectees to non-ejectees	2.1·1	3 7.1	4 8 1	5.1 1

Another factor bearing upon the production of dangerous or fatal injuries relates to the specific areas of the car occupied by passengers. Table 2 shows the frequency of dangerous or fatal injury among the occupants of various seat-areas. Although the problem of injury as a function of seat-area occupied is a subject for further and more thorough study, Table 2 clearly shows that the likelihood of receiving a dangerous or fatal injury is widely different among the occupants of various seats. These differences are statistically significant. Generally speaking, the entire rear seat area is less dangerous than the front seat area. Further, the dangerous or fatal injury potential of the right front seat is somewhat (although not remarkably) greater than that of the driver's seat.

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[3] Automotive Crash Injury Research, "A Study of Automobile Doors Opening under Crash Conditions," T. R. 2. New York, Cornell University Medical College, August 1, 1954. Subsequent study with a greater number of cases has confirmed the findings of this report.

TABLE 2

RISK OF DANGEROUS OR FATAL INJURY ACCORDING TO SEAT-AREA OCCUPIED

Seat Area Occupied	Percentage of Occupants with Dangerous or Fatal Injury
	%
Driver[a]	7.5[a]
Center front	4.9
Right front	10.4
Left rear	4.7
Center rear	5.2
Right rear	6.4

[a] Since the Automotive Crash Injury Research sample is one of injury-producing accidents, a driver alone in a car must be injured to get into the sample. To eliminate bias overemphasizing driver injury, this table shows frequency of injury among drivers who were accompanied by passengers.

Another influence on the occurrence of dangerous or fatal injury is the area of the car sustaining the principal crash impact. To examine this influence, it was necessary to study the frequency of injury among occupants with respect to their proximity to the site of impact. Table 3 shows the wide variations in injury frequency occurring according to interaction of (1) the location of the impact, (2) the seat occupied, and (3) the closeness of the seat-area to the impact site. The data show that being near the impact site produces the greatest likelihood of dangerous or fatal injury, regardless of seat-area occupied; further, the incidence of the injury will vary as a function either of the site of impact or the seat-area occupied.

It becomes increasingly clear that injury is concomitant with many accident factors related to engineering and design. Ejection, the force localization dictated by objects in a given seat-area, and the energy-absorbing qualities of various exterior portions of the car are all subject to effective control through engineering. Of course, it should be realized that such factors, controllable by engineering, relate to one another. Similarly, each of these factors is also related, in some degree, to speed. For example, clinical observation shows that ejection increases as speed increases, or that in a given seat-area, the frequency of injury will increase as speed does. However, an all-important reservation is that dangerous or fatal injuries increase appreciably from one high-speed range to the next, starting only at the traveling speed range of 50 to 59 mph. In the lower traveling speed ranges, although there are increases in risk of dangerous or fatal injury, these increases are rather small. Further, although nearly 75 percent of the cars were traveling under 60 mph, approximately as many dangerous or fatal injuries were sustained among the persons traveling below 60 mph as were sustained by those traveling in excess of 60 mph.

Apparently the injuries occurring in lower speed ranges are largely a function of car design, while injuries in the higher speed ranges are a function of both speed and automotive design. Thus, the path for correction is shown by the basic indications of the data: Speed affects dangerous or fatal injury in a relatively small proportion of the cars; design engineering affects this grade of injury in all of the cars and in all of the speed ranges. Efforts to reduce dangerous or fatal injuries in automobile accidents must take both these factors into account.

TABLE 3

RISK OF DANGEROUS OR FATAL INJURY ACCORDING TO OCCUPANTS'[a] PROXIMITY TO CRASH IMPACT SITE

Relation between Occupant and Crash Impact Site	Area of Car Sustaining Principal Impact	Percentage of Occupants with Dangerous or Fatal Injury	
		Drivers	Right Front Seat Passenger
		%	%
Opposite impact site	Front	5 6	7 4
At or near impact site	Side	16 7	20 0
Opposite impact site	Side	2 0	8 5
No strict relationship (car rolled over)	Top	3 1	4 5

[a] Based on non-ejected occupants of cars involved in injury-producing accidents

SUMMARY

A study of the reported impact and traveling speeds of 3,203 cars in injury-producing accidents, and correlation with injury data on the 7,154 occupants of these cars revealed that:

1. Although each car contained at least one injured person, approximately 75 percent of the cars were traveling at speeds under 60 mph and about 70 percent involved impact speeds under 60 mph.

2. There is a statistically significant correlation between increases in both traveling and impact speed and the frequency of dangerous or fatal injury. In each of the 10-mph speed ranges through 59 mph, the increases in frequency of dangerous or fatal injury are slight; beyond 59 mph the increases rise sharply. Traveling above 59 mph (represented by 25 percent of the cars) more than doubles the risk of dangerous or fatal injury.

3. Top speed limits imposed by enforcement or mechanical devices afford relatively limited reduction in the expectancy of dangerous or fatal injuries in injury-producing accidents; a strict enforcement of a top traveling speed of 49 mph would still result in the occurrence of 60 percent of the dangerous or fatal injuries.

4. Many factors other than speed operate to produce injury in automobile accidents. Acting independently, interdependently, or together with speed, are such accident factors as ejection, seat-area occupied, and site of crash impact.

5. Dangerous or fatal injury in low-speed ranges appears to be largely a function of car design, while such injuries in the higher-speed ranges apparently correlate with both speed and car design.

6. Control of excessive speed without simultaneous control of car design imposes limitation on the extent of reduction of dangerous or fatal injuries in injury-producing automobile accidents.