VOL. 31, NO. 2 JUNE 1960

# Public Roads

A JOURNAL OF HIGHWAY RESEARCH

PUBLISHED BIMONTHLY BY THE BUREAU OF PUBLIC ROADS, U.S. DEPARTMENT OF COMMERCE, WASHINGTON

Mohawk River Bridge, Interstate Route 87, near Albany, N.Y.

IN THIS ISSUE: Economic costs of motor-vehicle traffic accidents.

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**Published Bimonthly**

*Vol. 31, No. 2* *June 1960*

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Use of funds for printing this publication has been approved by the Director of the Bureau of the Budget, March 28, 1958.


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# IN THIS ISSUE




**U.S. DEPARTMENT OF COMMERCE**
**FREDERICK H. MUELLER, Secretary**

**BUREAU OF PUBLIC ROADS**
**BERTRAM D. TALLAMY, Administrator**
**ELLIS L. ARMSTRONG, Commissioner**

# A Symposium on Traffic Accident Costs

*In this issue, major findings of motor-vehicle accident cost studies conducted in Massachusetts and Utah are discussed. Cost data are classified on the basis of severity of accidents and are further related to the activities of persons involved in accidents, to the highway systems on which the accidents occurred, and to the types of vehicles involved.*

*Placing a dollar value on losses resulting from traffic accidents in no way minimizes the personal tragedy of either traffic fatalities or serious injuries; it is simply a means of identifying and measuring financial losses that in turn can be used as a tool in the planning of both highway safety and highway improvement programs.*

*Of the four articles presented here, three report findings of the Massachusetts accident cost study and the fourth applies to a similar study made in Utah. The findings are based on data from only two States, and whether similar patterns or trends obtain in other States can only be determined when studies now under way or planned for the future are completed. The data presented, however, are believed to be generally indicative of what may be expected in other States of similar characteristics.*

*In this analysis, economic costs are confined specifically to direct costs of traffic accidents. Other direct costs in connection with non-traffic accidents and traffic and non-traffic incidents are excluded. Non-traffic accidents are those involving motion but not occurring on a public roadway. Traffic and non-traffic incidents are mishaps occurring on and off public roadways, not involving motion, and attributable to vandalism, fire, and acts of God.*

*Direct costs are composed of the money value of damage to property; hospitilization; services of physicians, dentists, and nurses; ambulance use; medicine; work time lost; damages awarded in excess of other direct costs; attorneys' services; court fees; and other lesser items.*

*Another large segment of costs borne by the public are indirect costs. Although not a part of this analysis, they must be considered in any total view of accidents. They include such items as loss of future earnings as a result of injuries causing death or permanent disability, overhead cost of motor-vehicle accident insurance as well as certain other types of insurance with accident coverage, property damage indirectly resulting from an accident, illness or death of a person not involved in an accident but traceable thereto, public aid for care of indigent persons injured in motor-vehicle accidents, and expenditures for driver training and other accident prevention activities.*

*The economic costs of motor-vehicle accidents are discussed from four aspects: First, the cost in relation to persons involved in accidents; second, the cost in relation to the road systems; third, the cost in relation to passenger cars and trucks; and fourth, the cost in relation to highway planning and improvement.*

The Economic Cost of Traffic Accidents in Relation to the Human Element *(p. 34) discusses the impact of traffic accidents on the total population of Massachusetts. It shows that if existing traffic accident rates are not reduced, every individual in the entire population of Massachusetts would be in a motor-vehicle accident at least once every 13 years, or 5 times during his life. The article points out, however, that the possibilities of being killed or seriously injured are very slight.*

*Of the 4.8 million residents of Massachusetts in 1953, less than 8 percent were involved in traffic accidents.*

*Of the 45,472 persons injured, 421 were fatally injured, 18,045 were seriously injured, and 27,006 were superficially injured. Injuries sustained in accidents caused 19,405 persons to lose an average of 19 days worktime per person; they hospitalized 6,647 persons for an average of 9.4 days each. Traffic accident injuries permanently reduced to some degree the ability of 2,117 persons to earn a living, and they similarly temporarily affected another 3,514 persons.*

*The total direct cost of traffic accidents in Massachusetts in 1953 was more than $50 million, of which fatal injury accidents cost $1.6 million; nonfatal injury accidents, $28.7 million; and property-damage-only accidents, $19.9 million.*

*This article points up one significant thing—of the total economic loss from traffic accidents, 59 percent was due to property damage alone, and 41 percent to injuries and related costs. The total direct cost of accidents was divided among six major elements: Property damage, $27.6 million; treatment of injuries, $3.4 million; worktime lost, $4.5 million; loss of use of vehicle, $0.4 million; legal and court fees, $5.2 million; and awards and settlements, $9.1 million.*

The Economic Cost of Accidents in Relation to the Highway Systems *(p. 39) evaluates the efficiency of the Massachusetts highway systems from the standpoint of economic losses through automobile accidents. A major finding was that of the 131,536 traffic accidents in Massachusetts during 1953, 87 percent occurred in urban areas. Likewise, 87 percent of the direct costs were from accidents occurring in urban areas.*

*Classified by highway systems, the cost of fatal accidents was $662,810 on the Federal-aid primary system, $227,480 on the Federal-aid secondary system, and $751,460 on local roads not a part of the Federal-aid systems.*

*In the Federal-aid primary system, State highways had a decidedly lower average accident rate than local roads. Conversely, in the Federal-aid secondary system the State highways had a much higher accident rate than local roads.*

*In addition to these general system findings, the article demonstrates that highways with full control of access experienced much lower accident rates, at a given traffic volume, than did those highways where access was not controlled.*

The Economic Cost of Traffic Accidents in Relation to the Vehicle *(page 44) compares the accident experience of passenger cars and trucks registered in Massachusetts. A further comparison is made of trucks grouped by visual classification and by gross weight classification.*

*A significant finding was that the cost of accidents per mile of travel for passenger cars was nearly double that of trucks, with the single exception of cost per mile for fatal accidents. It was also found that both the accident involvement rate and the accident cost per mile for passenger cars increased with the age of the car, but this was not true of trucks.*

*Truck-tractor-semitrailer combinations had the best accident record among the truck groups, on the basis of exposure, with the sole exception of a higher fatal involvement rate and fatal accident cost per mile. Panel and pickup trucks, together with the 2-axle, 6-tire trucks, accounted for 82 percent of the truck registrations, 73 percent of the truck travel, 74 percent of all truck involvements in accidents, and 80 percent of the truck accident costs.*

*An important relation developed with regard to registered gross weight was the decrease of accident cost per mile as the gross weight increased. Both the involvement rate and accident cost per mile of the heaviest group of trucks were the most favorable when compared to those of all other trucks.*

The Economic Cost of Traffic Accidents in Relation to Highway Planning *(p. 49) points up the value of traffic accident cost data to the highway planner in evaluating and scheduling highway improvement.*

*The article also compares the frequencies and costs of traffic accidents in Utah in 1955 with the results found in the 1953 Massachusetts study.* [1] *Despite dissimilarities in geographic characteristics and population densities, the relative distributions of accidents in the two States were quite consistent. As to costs, regardless of severity or type, accidents were more costly in Utah than in Massachusetts.*

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[1] *The Economic Costs of Motor-Vehicle Accidents of Different Types*, by Robie Dunman, PUBLIC ROADS, vol. 30, No. 2, June 1958. The basic data from that article are included in the tables on p. 50 of this issue.

# The Economic Cost of Traffic Accidents in Relation to the Human Element

*BY THE DIVISION OF TRAFFIC OPERATIONS*
*BUREAU OF PUBLIC ROADS*

**Reported by [1] ROBIE DUNMAN**
**Transportation Economis**

EXTENSIVE use of traffic accident cost data developed by the Massachusetts Department of Public Works and by the Massachusetts Registry of Motor Vehicles in cooperation with the U.S. Bureau of Public Roads was made in the Congressional report *The Federal Role in Highway Safety*.[2] These data have also been used as the basis of other reports relating economic costs to accident types, characteristics of the street and highway systems, and to the characteristics of motor vehicles. This article, using data from the same source, relates the economic cost of motor-vehicle traffic accidents to persons.

Comparisons involving passenger cars of Massachusetts registry in 1953 are made of the accident experience of automobile drivers, passengers, pedestrians, and other persons involved in motor-vehicle traffic accidents. The number of accidents, the number of persons involved, the number of persons injured fatally, seriously, and superficially, the number hospitalized, and the number permanently and temporarily disabled are discussed. Equally important, the cost of accidents and injuries is revealed.

Injury rates and injury cost rates, number of persons injured per 100,000 population, and the per capita cost of their injuries show the relative economic importance of the accidents and injuries experienced by each class of persons.

The Massachusetts study of the economic cost of motor-vehicle accidents encompassed the total driving experience of all licensed operators of passenger cars and cargo-carrying vehicles of Massachusetts registry, including those who experienced accidents and those who did not, in the operation of passenger cars during 1953, within or outside the State, and in the operation of cargo-carrying vehicles during 1955. However, the discussion in this article is confined to the accident experience of Massachusetts licensed passenger-car operators and persons in motor-vehicle traffic accidents involving passenger cars on public streets and highways of the State. This article excludes accident experience of truck operators, the number and cost of accidents occurring on private property, and the number and cost of mishaps involving acts of vandalism and acts of God.

Statistical studies of the motor-vehicle accident costs were based on a probability sample designed to be accurate within 10 percent. To determine the number of persons involved in fatal accidents, original accident reports were reviewed and the number of persons reported represents a firm figure. The number of drivers involved in nonfatal injury and property-damage-only accidents was unavoidably slightly inflated because a driver who was involved in more than one accident during the year was counted as one driver each time he was involved in an accident. The number of passengers involved in accidents was estimated on the basis of an average passenger-car occupancy of 1.6 persons. The number of pedestrians and "other" persons nonfatally injured, however, was obtained from the original accident reports.

Costs reflected in this article are direct costs and consist exclusively of the money value of damage to property, injuries to persons, worktime lost, loss of use of vehicle, legal and court costs, damage awards in excess of actual cost, and small miscellaneous items. The number of persons losing worktime includes only those employed in gainful occupations. The number of workdays lost includes time lost for treatment of injuries, for convalescence, and for settlement of claims.

The activity class, "others," used throughout this article, consists of persons using conveyances other than motor-vehicles—such as bicycles, horsedrawn vehicles, and trolley cars.

Physical injury that impaired earning capacity is referred to as disability. The degree of disability as used is a measure of the extent to which persons injured in motor-vehicl traffic accidents were handicapped in makin a living. There are two classes of disability— temporary disability and permanent disabilit Under the temporary disability class, there ar two degrees of disability—total and partia The degree of permanent disability is ex pressed in percentages of 25, 50, 75, and 10(

The data regarding persons permanentl and temporarily disabled as a result of moto vehicle traffic accidents in Massachusett appeared to be incomplete and therefore no usable in this analysis. However, rathe than include no information on this importan part of the problem, an approximation wa derived by applying to the number of person injured in Massachusetts, the percentage o persons injured that were disabled in th State of Utah, where a similar study wa being conducted.

## *Persons in Accidents*

In 1953, the population of Massachusett was 4,773,000. Of this total, 362,280 person were involved in 131,536 motor-vehicle traffi accidents. Table 1 shows the number o accidents and their severity, the number o persons in accidents, the severity of thei injuries, and their activity at the time of th accident.

The most significant point drawn from tabl 1 was the great number of persons involve and the relatively small number of person killed and injured in motor-vehicle traffi accidents. The 362,280 persons involved i

**Table 1.—Number of persons in traffic accidents involving passenger cars, classified b severity of accident and activity**

| Item of comparison | Severity of accident | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Fatal | | Nonfatal injury | | Property-damage-only | | All accidents | |
| | Number | Percent of total | Number | Percent of total | Number | Percent of total | Number | Percent of total |
| Involvements: | | | | | | | | |
| Severity of injuries: | | | | | | | | |
| Persons fatally injured | 421 | 58.6 | ---------- | ------- | ----------- | ------- | 421 | 0.1 |
| Persons nonfatally injured | 168 | 23.4 | 44,883 | 47.9 | ----------- | ------- | 45,051 | 12.4 |
| Persons not injured | 129 | 18.0 | 48,751 | 52.1 | 267,928 | 100.0 | 316.808 | 87.5 |
| Total persons involved | 718 | 100.0 | 93,634 | 100.0 | 267,928 | 100.0 | 362,280 | 100.0 |
| Activity of persons: | | | | | | | | |
| Drivers | 344 | 47.9 | 54,260 | 57.9 | 167,455 | 62.5 | 222,059 | 61.3 |
| Passengers | 206 | 28.7 | 32,556 | 34.8 | 100,473 | 37.5 | 133,235 | 36.8 |
| Pedestrians | 158 | 22.0 | 5,735 | 6.1 | ----------- | ------- | 5,893 | 1.6 |
| Others | 10 | 1.4 | 1,083 | 1.2 | ----------- | ------- | 1,093 | .3 |
| Total persons involved | 718 | 100.0 | 93,634 | 100.0 | 267,928 | 100.0 | 362,280 | 100.0 |
| Accidents: | | | | | | | | |
| Number of accidents | 315 | ------- | 33,270 | ------- | 97,951 | ------- | 131,536 | ------ |
| Persons per accident | 2.3 | ------- | 2.8 | ------- | 2.7 | ------- | 2.7 | ------ |
| Persons injured per accident | 1.9 | ------- | 1.3 | ------- | ----------- | ------- | .3 | ------ |

[1] Presented at the 39th Annual Meeting of the Highway Research Board, Washington, D.C., January 1960.

[2] House Document No. 93, 86th Congress, 1st Session, 1959.

motor-vehicle traffic accidents during 1953 represented one out of every 13 persons, or 7.6 percent of the total population. However, of all the persons involved in motor-vehicle traffic accidents only 45,472, or 12.5 percent, were either fatally or nonfatally injured. The vast majority of persons involved, 316,808 (87.5 percent), experienced no injury whatever.

In the distribution of persons involved in motor-vehicle traffic accidents by their activity at the time of accident, there were more drivers involved in accidents than there were persons in the other three activity classes combined. Of the total persons involved in accidents 61.3 percent were drivers, 36.8 percent were passengers, 1.6 percent were pedestrians, and 0.3 percent were others.

An interesting distribution, presented in figure 1, is the makeup of accidents of different severity. All persons in fatal injury accidents were not killed and all persons in nonfatal injury accidents were not injured. (For example, two cars, each with two occupants, may have collided. One occupant may have been fatally injured, another nonfatally injured, and the other two occupants may have avoided injury entirely.) Of the 718 persons involved in fatal injury accidents, 59 percent were killed, 23 percent were nonfatally injured, and 18 percent sustained no injuries whatever. Of the 93,634 persons involved in nonfatal injury accidents, 48 percent were injured and 52 percent were not injured.

In terms of number of accidents rather than involvement of persons, it may be noted from table 1 that of the 131,536 accidents reported 75 percent were property-damage-only accidents, and only 0.2 percent were fatal injury accidents.

## *Persons Injured and Injury Rates*

In table 2 it is found that only 1 out of 8 persons involved in motor-vehicle accidents was injured and that more than half of those injured were not seriously injured. In terms of numbers, there were 421 persons fatally injured and 45,051 persons nonfatally injured. Of the persons nonfatally injured 27,006 experienced only superficial injuries such as mild shock, bumps, scratches, and bruises. The remaining 18,045 experienced serious injuries such as concussions, fractured bones, internal injuries, deep cuts, and dismemberment of body extremities.

Data from table 2 also indicate that more than 1 out of every 3 persons killed in traffic accidents was a pedestrian. It is significant, too, that more passengers than drivers were killed in traffic accidents, since on the basis of average car occupancy of 1.6 persons, the relative exposure of drivers as compared to that of passengers was in a ratio of 5 to 3. As to the number of persons nonfatally injured in traffic accidents, drivers constituted approximately one-half of the total.

In figure 2, the fatal injury rate—persons fatally injured in traffic accidents per 100,000 population—relates the high incidence of pedestrians and passengers in fatal accidents. Figure 3 shows the rate at which persons in traffic accidents were seriously and superficially injured. This latter chart points up the superficial nature of the majority of traffic accident injuries and also shows that a much higher percentage of drivers were seriously injured than any other activity group. Furthermore, it shows that most pedestrians not fatally injured were only superficially injured.

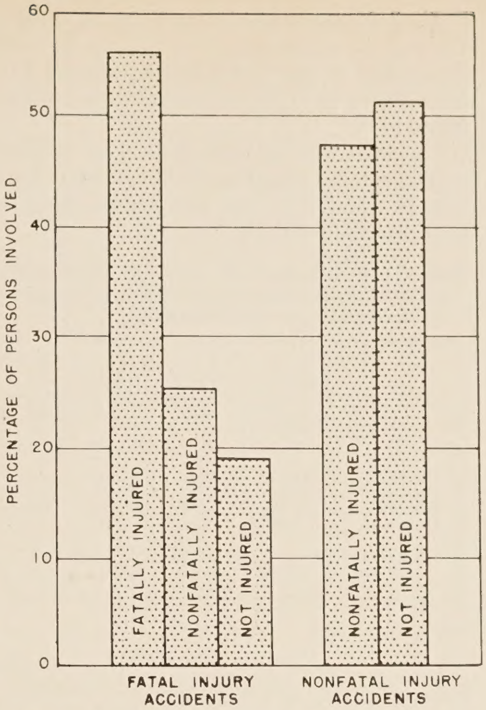


*Figure 1.—Percentage distribution of persons involved in accidents, classified by severity of injury.*

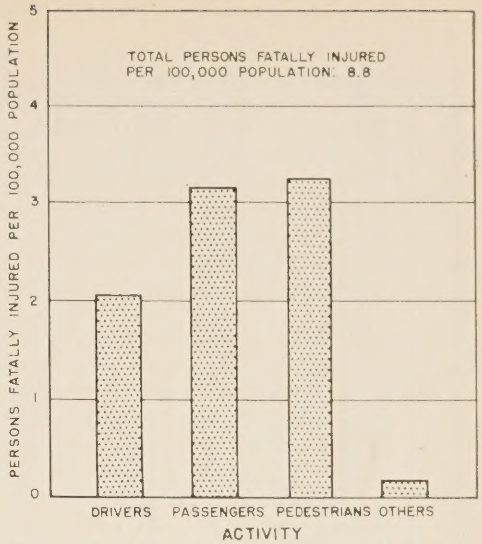


*Figure 2.—Fatal injury rate, classified by activity.*

### Age and sex of persons injured

Table 3 shows the number of persons and the number per 100,000 population in each age and sex group that were injured in traffic accidents, classified by severity of injury. Of every 100,000 persons in the State, 953 were injured in a traffic accident during the year and the majority of those injured were male persons. A total of 25,579 males were fatally and nonfatally injured, or 1,107 males per 100,000 male persons.

Categorized by age groups, more persons from 30 to 39 years of age were injured than in any other age group, and the next largest category was the 20-29 age group. Of all persons injured 43 percent were in these two age groups. However, of more importance from the economic point of view, 70 percent of the persons injured were from 20 to 59 years of age—the ages supplying most of the labor force of the State.

In every age group except one, male persons had a higher fatal injury rate than females; and in the one exception the rate was the same for both sexes. In the 20–29 age group for males and in the 50 and over age groups for both males and females, a relatively high fatal injury rate occurred. The higher rates in the older age groups were believed to have been largely brought about by pedestrian deaths.

Turning to the nonfatal injuries per 100,000 in each age and sex group (table 3), males had a higher rate at every age, with only the youngest age group evidencing a closeness. Males in the 20–39 and 30–39 age groups had the highest injury rate, and females 60 and over had the lowest nonfatal injury rate.

### Persons hospitalized

The number of persons nonfatally injured in traffic accidents that were hospitalized is shown in table 4. One of the most remarkable items derived from the 1953 Massachusetts accident study was evidence of the relatively

**Table 2.—Number of persons in traffic accidents and number per 100,000 population, classified by severity and activity**

| Activity of persons | Persons injured | | | | | Total not injured | Total involved in accidents |
|---|---|---|---|---|---|---|---|
| | Fatally | Nonfatally | | | Total injured | | |
| | | Seriously | Superficially | Total | | | |
| Involvements: | | | | | | | |
| Drivers | 102 | 12, 800 | 9, 434 | 22, 234 | 22, 336 | 199, 723 | 222, 059 |
| Passengers | 151 | 4, 275 | 12, 914 | 17, 189 | 17, 340 | 115, 895 | 133, 235 |
| Pedestrians | 158 | 770 | 3, 775 | 4, 545 | 4, 703 | 1, 190 | 5, 893 |
| Others | 10 | 200 | 883 | 1, 083 | 1, 093 | ---------- | 1, 093 |
| Total persons | 421 | 18, 045 | 27, 006 | 45, 051 | 45, 472 | 316, 808 | 362, 280 |
| Involvements per 100,000 population: | | | | | | | |
| Drivers | 2. 1 | 268 | 198 | 466 | 468 | 4, 184 | 4, 652 |
| Passengers | 3. 2 | 89 | 271 | 360 | 363 | 2, 428 | 2, 791 |
| Pedestrians | 3. 3 | 16 | 79 | 95 | 99 | 25 | 124 |
| Others | . 2 | 5 | 18 | 23 | 23 | ---------- | 23 |
| Total persons | 8. 8 | 378 | 566 | 944 | 953 | 6, 637 | 7, 590 |

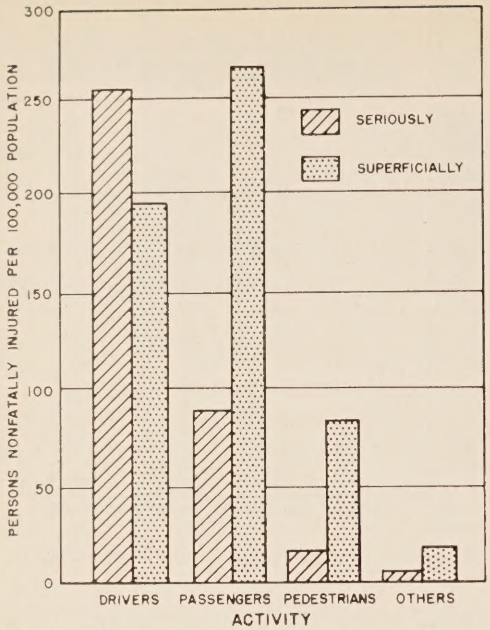


*Figure 3.—Nonfatal injury rate, classified by activity and severity.*

small number of nonfatally injured persons that required hospitalization. Only 15 percent of the persons nonfatally injured spent time in the hospital as a result of their injuries. Table 4 also shows that the 6,647 persons confined to the hospital remained there a total of 62,148 days or an average of 9.4 days per person.

During 1953, of the 45,051 persons nonfatally injured, 16,204, or 35.9 percent were examined in a hospital after the accident. Of those examined, 6,647 were confined while 9,557 persons were released from the hospital immediately after receiving emergency treatment. There were 28,847 persons, or 61.4 percent of all the persons nonfatally injured, that were either treated outside hospitals or received no professional treatment. These figures are additional evidence of the superficial nature of a large majority of traffic accident injuries.

Only 10 percent of the passengers that were injured required hospitalization, as compared with 16 percent of the drivers and 25 percent of the injured pedestrians. Persons in the "other" category that were hospitalized had the highest percentage rate, but the number of persons in this category represented less than 3 percent of the total number of persons injured.

Considered by activity class, over one-half of the persons requiring hospitalization were drivers, one-fourth were passengers, and one-sixth were pedestrians.

**Table 4.—Number of persons nonfatally injured in accidents and time in hospital as the result of such injuries**

| Activity | Total persons nonfatally injured | Persons hospitalized | Days in hospital | Average days in hospital |
|---|---|---|---|---|
| Drivers | 22, 234 | 3, 624 | 33, 804 | 9. 3 |
| Passengers | 17, 189 | 1, 630 | 15, 020 | 9. 2 |
| Pedestrians | 4, 545 | 1, 115 | 10, 580 | 9. 5 |
| Others | 1, 083 | 278 | 2, 744 | 9. 9 |
| Total or average | 45, 051 | 6, 647 | 62, 148 | 9. 4 |

### Worktime lost

The number of nonfatally injured persons losing worktime and the amount of worktime lost as a result of motor-vehicle traffic accidents, shown in table 5, revealed the interesting point that more than one-half of the persons injured did not lose time from work. This situation appeared to be brought about by two factors: First, many injured persons were not members of the labor force, and second, three-fifths of the nonfatal injuries were of a superficial nature. The average number of work days lost per person was 19 days.

Of the 22,234 drivers nonfatally injured, 60 percent lost time from work, whereas a similar comparison for passengers and pedestrians show percentages of 28 and 23, respectively. Of the 19,405 persons losing worktime, drivers accounted for 68 percent; passengers, 25 percent; pedestrians, 6 percent; and others, 1 percent.

## *Persons Disabled*

Table 6 shows the number of persons injured in traffic accidents that were disabled, and the disability rate per 100,000 population. As

**Table 3.—Number of persons injured in accidents and number injured per 100,000 population, classified by age, sex, and severity**

| Age of persons | Males injured | | | Females injured | | | All persons injured | | |
|---|---|---|---|---|---|---|---|---|---|
| | Fatally | Nonfatally | Total | Fatally | Nonfatally | Total | Fatally | Nonfatally | Total |
| Number injured: | | | | | | | | | |
| Under 10 | 25 | 2, 993 | 3, 018 | 12 | 2, 238 | 2, 250 | 37 | 5, 231 | 5, 268 |
| 10–19 | 26 | 3, 070 | 3, 096 | 6 | 1, 694 | 1, 700 | 32 | 4, 764 | 4, 796 |
| 20–29 | 59 | 5, 187 | 5, 246 | 13 | 4, 542 | 4, 555 | 72 | 9, 729 | 9, 801 |
| 30–39 | 25 | 5, 579 | 5, 604 | 7 | 4, 297 | 4, 304 | 32 | 9, 876 | 9, 908 |
| 40–49 | 22 | 3, 668 | 3, 690 | 6 | 2, 741 | 2, 747 | 28 | 6, 409 | 6, 437 |
| 50–59 | 36 | 2, 958 | 2, 994 | 41 | 2, 776 | 2, 817 | 77 | 5, 734 | 5, 811 |
| 60 and over | 75 | 1, 856 | 1, 931 | 68 | 1, 452 | 1, 520 | 143 | 3, 308 | 3, 451 |
| Total | 268 | 25, 311 | 25, 579 | 153 | 19, 740 | 19, 893 | 421 | 45, 051 | 45, 472 |
| Number per 100,000: [1] | | | | | | | | | |
| Under 10 | 5 | 653 | 658 | 3 | 510 | 513 | 4 | 583 | 587 |
| 10–19 | 8 | 965 | 973 | 2 | 546 | 548 | 5 | 759 | 764 |
| 20–29 | 19 | 1, 673 | 1, 692 | 4 | 1, 402 | 1, 406 | 11 | 1, 535 | 1, 546 |
| 30–39 | 7 | 1, 631 | 1, 638 | 2 | 1, 161 | 1, 163 | 4 | 1, 387 | 1, 391 |
| 40–49 | 7 | 1, 207 | 1, 214 | 2 | 818 | 820 | 4 | 1, 003 | 1, 007 |
| 50–59 | 14 | 1, 160 | 1, 174 | 14 | 951 | 965 | 14 | 1, 048 | 1, 062 |
| 60 and over | 23 | 575 | 598 | 17 | 369 | 386 | 20 | 462 | 482 |
| Total | 12 | 1, 095 | 1, 107 | 6 | 801 | 807 | 9 | 944 | 953 |

[1] Number of persons injured per 100,000 in each age and sex group.

**Table 5.—Number of persons nonfatall injured in accidents and worktime los from such injuries**

| Activity | Total persons nonfatally injured | Persons losing worktime | Total work-days lost | Average work-days lost per person |
|---|---|---|---|---|
| Drivers | 22, 234 | 13, 261 | 271, 170 | 20. 4 |
| Passengers | 17, 189 | 4, 880 | 70, 795 | 14. 5 |
| Pedestrians | 4, 545 | 1, 053 | 23, 107 | 21. 9 |
| Others | 1, 083 | 211 | 4, 200 | 20. 0 |
| Total or average | 45, 051 | 19, 405 | 369, 272 | 19. 0 |

mentioned earlier in this article, the distribu tion made according to degree of disabilit was based on percentage data provided b Utah. On this basis, of the 45,051 person nonfatally injured in traffic accidents i Massachusetts, 2,117 were permanently dis abled to some degree, and 3,514 were tempo rarily disabled either totally or partially It is important to note that of all those person nonfatally injured only 225 suffered tota permanent disability, or a rate of less tha 5 persons per 100,000 population.

Table 6 also indicates the relative impor tance of temporary and permanent disabilitie in the overall traffic accident injury picture Numerically, disabilities are relatively smal but from an economic point of view they ac count for a sizeable portion of every acciden direct cost dollar. Considering the perma nently disabled, only a small proportion ha total disability. In contrast, almost 65 per cent of the permanently disabled group wer in the 25-percent disability group.

## *Total Direct Cost of Accidents*

The total direct cost of motor-vehicl traffic accidents is summarized in table 7 b severity of accident and by cost elements In considering the direct cost of motor-vehicl accidents it is necessary to distinguish be tween property damage costs, which ma occur in any type of accident, and property damage-only accidents. Property damag relates to an element of cost of an acciden whereas the property-damage-only acciden refers to the severity class of an acciden where no injuries were sustained. Tota property damage costs of property-damage only accidents amounted to $17,900,000, whic

**Table 6.—Number of persons nonfatall injured and the extent of their disability**

| Degree of disability | Number of persons nonfatally injured [1] | Persons nonfatally injured per 100,000 population |
|---|---|---|
| Permanent disability: | | |
| Total | 225 | 4. 7 |
| 75 percent | 180 | 3. 8 |
| 50 percent | 360 | 7. 5 |
| 25 percent | 1, 352 | 28. 3 |
| Subtotal | 2, 117 | 44. 3 |
| Temporary disability: | | |
| Total | 2, 435 | 51. 0 |
| Partial | 1, 079 | 22. 6 |
| Subtotal | 3, 514 | 73. 6 |
| Total disabled | 5, 631 | 118. 0 |
| Total not disabled | 39, 420 | 826. 0 |
| Total injuries | 45, 051 | 944. 0 |

[1] Distribution of persons according to degree of disability was derived from data provided by the State of Utah, where a similar accident cost study was conducted.

**Table 7.—Total direct cost of traffic accidents by cost elements and severity of accident**

| Cost elements | Severity of accident | | | | All accidents |
|---|---|---|---|---|---|
| | Fatal injury | Nonfatal injury | Total injury | Property-damage-only | |
| | *($1,000)* | *($1,000)* | *($1,000)* | *($1,000)* | *($1,000)* |
| Property damage: | | | | | |
| Vehicle | 238 | 9,352 | 9,590 | 17,722 | 27,312 |
| Other property | 2 | 102 | 104 | 204 | 308 |
| Subtotal | 240 | 9,454 | 9,694 | 17,926 | 27,620 |
| Injury treatment: | | | | | |
| Doctors and dentists | 25 | 2,038 | 2,063 | -------- | 2,063 |
| Hospital | 24 | 1,117 | 1,141 | -------- | 1,141 |
| Ambulance | 2 | 56 | 58 | -------- | 58 |
| Miscellaneous | 3 | 139 | 142 | -------- | 142 |
| Subtotal | 54 | 3,350 | 3,404 | -------- | 3,404 |
| Incidental costs: | | | | | |
| Loss of vehicle use | 6 | 105 | 111 | 248 | 359 |
| Value of time lost | 32 | 4,061 | 4,093 | 473 | 4,566 |
| Legal assistance and court fees | 293 | 4,338 | 4,631 | 558 | 5,189 |
| Damage awards and settlements | 1,017 | 7,380 | 8,397 | 689 | 9,086 |
| Subtotal | 1,348 | 15,884 | 17,232 | 1,968 | 19,200 |
| Total | 1,642 | 28,688 | 30,330 | 19,894 | 50,224 |

as almost twice the property damage costs f total injury accidents. This, however, was o be expected because of the much greater umber of property-damage-only accidents. Vhen all the other elements of costs were considered with the property damage costs, all njury accidents cost 52 percent more than he property-damage-only accidents.

The average accident cost dollar, illustrated in figure 4 for each severity class and for each of the elements of cost, vividly describes the makeup of the $50,224,000 spent on accidents in Massachusetts during 1953. A most significant fact is that the cost of property damage was greater than that of all other elements of accident cost combined. The minor economic role of the treatment of injuries as a cost element is also indicated.

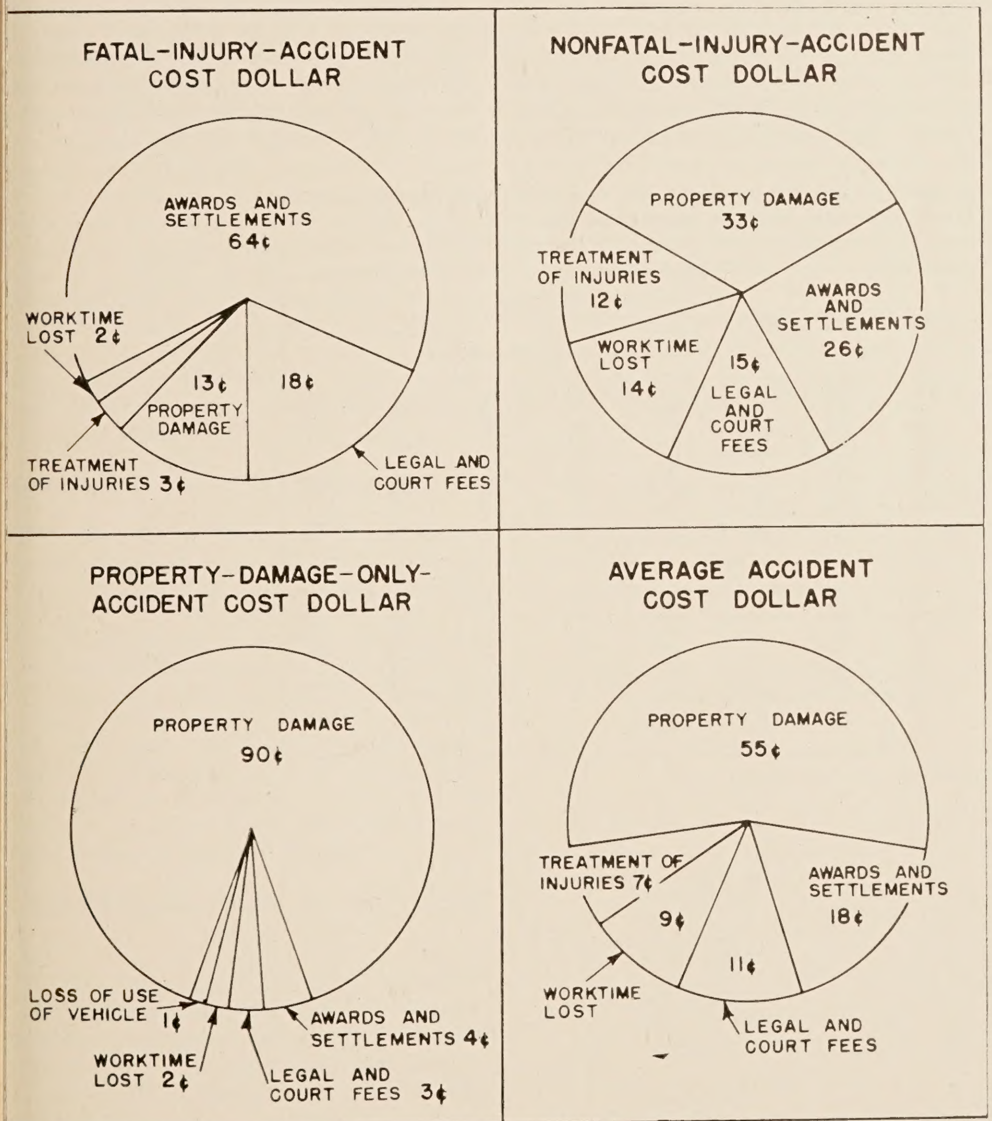


*Figure 4.—Direct cost of traffic accidents shown as fractional parts of a dollar.*

The "fatal injury accident dollar" is representative of the $1,642,000 spent on fatal accidents during 1953. It illustrates the overriding economic importance of damage awards and settlements, which in this instance largely represents the value of human life. The "fatal injury accident dollar" also shows that there is a fairly large element of property damage cost even in this most serious severity class of accident.

The "nonfatal injury accident dollar" represents the $28,688,000 spent on nonfatal injury accidents during the 12-month period. In the breakdown of this cost dollar the work-time loss cost more than the treatment of injuries, and property damage accounted for one-third of the total cost of nonfatal injury accidents. Also, legal and court fees (15 cents out of the dollar) cost more than half as much as awards and settlements (26 cents out of the dollar).

The "property-damage-only accident dollar" is representative of the $19,894,000 spent on property-damage-only accidents during the year. The significant thing about this diagram is that there were elements of cost other than property damage which accounted for 10 cents out of every property-damage-only accident dollar.

**Table 8.—Direct cost of injuries by severity of injury and activity**

| Activity of persons injured | Fatally injured | Nonfatally injured [1] | All persons injured |
|---|---|---|---|
| | *($1,000)* | *($1,000)* | *($1,000)* |
| Drivers | 156 | 11,552 | 11,708 |
| Passengers | 378 | 5,046 | 5,424 |
| Pedestrians | 824 | 2,305 | 3,129 |
| Others | 44 | 331 | 375 |
| Total | 1,402 | 19,234 | 20,636 |

[1] $13,906,000—cost of seriously injured; $5,328,000—cost of superficially injured.

## Cost of injuries by activity

The direct cost to persons fatally and nonfatally injured in motor-vehicle traffic accidents is arrayed in table 8 by activity. The study did not provide a breakdown of costs for seriously and superficially injured persons according to their activity, but in total the amounts were $13,906,000 and $5,328,000, respectively. The $20,636,000 cost of injuries is the total direct cost of fatal and nonfatal accidents, less the cost of property damage incurred in them, as shown in table 7.

Over half of the total traffic accident injury cost was borne by drivers, who experienced approximately twice as much injury cost as passengers. Average injury costs per person involved are calculated to be $524 for drivers, $313 for passengers, $665 for pedestrians, and $343 for all other injured persons.

The average direct cost of injuries sustained by persons in traffic accidents, classified by the severity of injury, is shown in figure 5. The average cost of a fatal injury was $3,300, which was 4 times the amount expended for the serious nonfatal injury, and 17 times the cost for the superficial nonfatal injury. However, this comparison gives an erroneous idea of the economic importance of fatal injuries

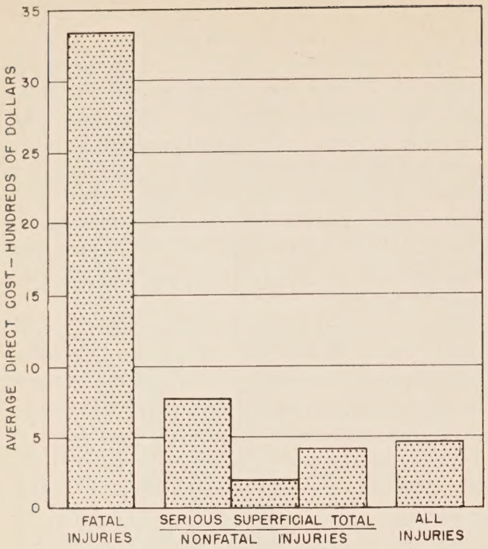


*Figure 5.—Average direct cost of injuries sustained in accidents, according to severity of injury.*

unless the total costs and number of persons are considered. The serious nonfatal injuries, in total, cost almost 10 times as much as fatal injuries. Referring back to table 2, there were 18,045 persons seriously injured, as compared to 421 persons fatally injured.

**Cost of injuries by age and sex**

Table 9 shows the direct cost of injuries to persons in accidents by the severity of their injuries and by their age and sex. It also shows the injury cost rate per 100,000 population for the different groups. Among the important facts observed was that nonfatal injuries, $403,000 per 100,000 persons, cost approximately 14 times as much as fatal injuries, $29,000 per 100,000 persons; and that the cost of injuries to males exceeded the cost of injuries to females by 11.4 percent. In the injuries of males, the nonfatal cost was 10 times as great as the cost of their fatal injuries; while in the injuries of females, the nonfatal injury cost was 23 times as great as the cost of their fatal injuries.

The per capita cost of fatal injuries resulting from motor-vehicle traffic accidents, calculated by dividing injury cost by the number of persons (total population) in each age and sex group, shows that the age groups of 20–29 and over 50 had the highest injury cost rates. The high cost rate in the 20–29 year group would appear to reflect the high injury rate and the greater exposure to accidents of this age group. The extremely high rates for persons over 50 years of age reflects two things: increased earning power that comes with age and experience, and failing physical characteristics that come with age.

The per capita costs of nonfatal injuries resulting from traffic accidents are shown in figure 6, calculated in exactly the same way used for calculating the per capita cost of fatal injuries. The cost of injuries to males generally increased with age—the 40–49 and the over 60 age groups being the only exceptions. The higher value of worktime lost and the slower rate of recovery in the 50–59 age group are clearly reflected in this chart.

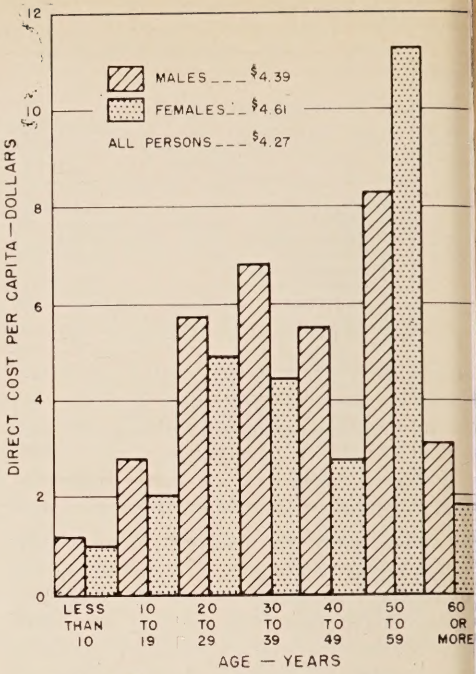


*Figure 6.—Per capita direct cost, within each age and sex group, of nonfatal injuries.*

**Table 9.—Direct cost to persons injured in accidents and costs per 100,000 persons, classified by age, sex, and severity of injury**

| Age of persons | Males injured | | | Females injured | | | All persons injured | | |
|---|---|---|---|---|---|---|---|---|---|
| | Fatally | Non-fatally | Total | Fatally | Non-fatally | Total | Fatally | Non-fatally | Total |
| Cost to persons injured: | *($1,000)* | *($1,000)* | *($1,000)* | *($1,000)* | *($1,000)* | *($1,000)* | *($1,000)* | *($1,000)* | *($1,000)* |
| Under 10 | 112 | 539 | 651 | 50 | 424 | 474 | 162 | 963 | 1, 125 |
| 10–19 | 67 | 739 | 804 | 19 | 619 | 638 | 86 | 1, 356 | 1, 442 |
| 20–29 | 147 | 1, 766 | 1, 913 | 44 | 1, 594 | 1, 638 | 191 | 3, 360 | 3, 551 |
| 30–39 | 96 | 2, 333 | 2, 429 | 10 | 1, 591 | 1, 601 | 106 | 3, 924 | 4, 030 |
| 40–49 | 81 | 1, 678 | 1, 759 | 30 | 905 | 935 | 111 | 2, 583 | 2, 694 |
| 50–59 | 141 | 2, 074 | 2, 215 | 42 | 3, 324 | 3, 324 | 183 | 5, 356 | 5, 539 |
| 60 and over | 370 | 1, 009 | 1, 379 | 193 | 683 | 876 | 563 | 1, 692 | 2, 255 |
| Total | 1, 014 | 10, 136 | 11, 150 | 388 | 9, 098 | 9, 486 | 1, 402 | 19, 234 | 20, 636 |
| Cost to persons per 100,000: [1] | | | | | | | | | |
| Under 10 | 25 | 118 | 142 | 11 | 97 | 108 | 18 | 107 | 125 |
| 10–19 | 21 | 232 | 253 | 6 | 200 | 206 | 14 | 216 | 230 |
| 20–29 | 48 | 570 | 617 | 14 | 492 | 505 | 30 | 530 | 560 |
| 30–39 | 28 | 682 | 710 | 3 | 430 | 433 | 15 | 551 | 566 |
| 40–49 | 27 | 552 | 579 | 9 | 270 | 279 | 17 | 404 | 422 |
| 50–59 | 55 | 814 | 869 | 14 | 1, 124 | 1, 138 | 33 | 979 | 1, 012 |
| 60 and over | 115 | 312 | 427 | 49 | 174 | 223 | 79 | 236 | 315 |
| Total | 44 | 439 | 483 | 16 | 369 | 385 | 29 | 403 | 432 |

[1] Direct cost per 100,000 persons in each age and sex group.

# The Economic Cost of Traffic Accidents in Relation to the Highway Systems

By BERNARD B. TWOMBLY,[1] Traffic Engineer, Massachusetts Department of Public Works

THE traffic accident toll in number of persons killed and injured has been publicized so frequently that many people are quite familiar with the figures and can even relate the details of the latest fatal accident. Few persons, however, have an estimate knowledge of where, on a statewide basis, most of the accidents are occurring, what types are most frequent, and what would be the odds, as measured in number of accidents per 100 million vehicle-miles, of having an accident on Massachusetts streets and highways. Prior to the 1954–55 accident cost study conducted by the Massachusetts Department of Public Works and the Registry of Motor Vehicles in cooperation with the U.S. Bureau of Public Roads, the monetary cost of traffic accidents was purely conjectural.

The purpose of this article is to evaluate the efficiency of the highway systems in Massachusetts from the standpoint of losses through automobile accidents. This article shows what the 1954–55 accident cost study revealed in terms of accident rates and direct costs of accidents on the State highways and local roads in Massachusetts and also points out where special attention should be directed in order to stem the tide of rising accident toll. It is reasonable to expect that the conditions which prevail in Massachusetts are typical of those in many other States.

## *Highway Systems in Massachusetts*

The highway network in Massachusetts can be classified into six major systems whose total extent in 1953 was 24,506 miles. The three general systems consist of the Federal-aid primary system, Federal-aid secondary system, and non-Federal-aid (highways and roads not a part of any Federal-aid system). Within each system two classifications were made: State highways and local roads. A breakdown of total mileage and vehicle-miles traveled on each system during 1953, the year upon which the accident cost study was based, is shown in table 1.

## *Accident Experience on Highways and Roads*

In 1953, there were 1.239 million registered passenger cars and 1.853 million licensed operators in Massachusetts. The vehicle-miles driven in passenger cars during 1953 on the State's highways totalled 11.628 billion. In the same year, there were 131,536 passenger-car accidents which resulted in a direct cost of $50.224 million.

Massachusetts, though densely populated in many sections, still has a low proportion of urban areas when compared with rural areas. Approximately 15 percent of the 8,093 square miles are classed as urban and 85 percent as rural.

From table 2, the basic accident table, it is found that 88 percent of all accidents in the State occurred on urban highways and streets, which consisted of about one-fourth of the State's total mileage. This point is significant when considering density of accidents on the various highway systems. Moreover, two-thirds of all accidents in the State occurred in its 39 cities.

Table 2 also furnishes a comparison of the accident experience on the State highways and local roads. Without considering road mileage and traffic volumes, the 24,562 accidents on the State highways in comparison with the 106,974 accidents on the local road systems clearly show where the chief problem in accident reduction lies.

The Federal-aid primary and secondary systems accounted for 36 percent of the 131,536 accidents. Of the 47,681 accidents on these two systems, 24,080 occurred on State highways and 23,601 on local roads.

In terms of number of accidents classified by severity of accident, the property-damage-only accidents far outweighed the fatal and nonfatal injury accidents. Without the facts it is difficult to realize that 97,951 property-damage-only accidents occurred in one year and that these comprised 75 percent of all accidents. Local systems accounted for 80 percent of the property-damage-only accidents.

### Accident experience rates

The average number of accidents per mile of road on State highways was 11.6 as compared with 4.7 on local roads. The mileage of the State highways was 2,109 miles while mileage of the local roads was 22,397 miles. Thus, the frequency of accidents on State highways was more than double that on local roads, but the State highways constituted only 9 percent of the road mileage in the State.

In the comparisons of motor-vehicle traffic accident rates the efficiencies of the various systems with respect to safety are made evident. Table 3 shows accident rates per 100 million vehicle-miles and is of value since it employs the widely accepted method of comparing accident experience on highways.

The accident rates in table 3 are most revealing. The figures show the following comparisons in accident rates on each system: On the Federal-aid primary system the accident rate (per 100 million vehicle-miles) on the State highways was 432, and 1,211 on local roads. On the Federal-aid secondary system the rates were reversed, with 1,537 accidents per 100 million vehicle-miles on the State highways and 399 on local roads. On the non-Federal-aid highways and roads, with a preponderance of mileage on the local roads, there were 225 accidents per 100 million vehicle-miles on the State highways and 2,107 on local roads.

The reversal of accident rates in the various systems occasioned special study in an at-

**Table 1.—System mileage and vehicle-miles traveled by passenger cars on State highways and local roads in Massachusetts in 1953**

| Highway system | Rural | | Urban | | Total | |
|---|---|---|---|---|---|---|
| | Miles | Million vehicle-miles | Miles | Million vehicle-miles | Miles | Million vehicle-miles |
| Federal-aid primary: | | | | | | |
| State highways | 1,119 | 2,124 | 397 | 1,904 | 1,516 | 4,028 |
| Local roads | 119 | 180 | 333 | 1,253 | 452 | 1,433 |
| Subtotal | 1,238 | 2,304 | 730 | 3,157 | 1,968 | 5,461 |
| Federal-aid secondary: | | | | | | |
| State highways | 359 | 303 | 79 | 131 | 438 | 434 |
| Local roads | 1,301 | 762 | 447 | 801 | 1,748 | 1,563 |
| Subtotal | 1,660 | 1,065 | 526 | 932 | 2,186 | 1,997 |
| Non-Federal-aid: | | | | | | |
| State highways | 141 | 166 | 14 | 48 | 155 | 214 |
| Local roads | 14,987 | 2,350 | 5,210 | 1,606 | 20,197 | 3,956 |
| Subtotal | 15,128 | 2,516 | 5,224 | 1,654 | 20,352 | 4,170 |
| All highways and roads: | | | | | | |
| State highways | 1,619 | 2,593 | 490 | 2,083 | 2,109 | 4,676 |
| Local roads | 16,407 | 3,292 | 5,990 | 3,660 | 22,397 | 6,952 |
| Total | 18,026 | 5,885 | 6,480 | 5,743 | 24,506 | 11,628 |

[1] Presented at the 39th Annual Meeting of the Highway Research Board, Washington, D.C., January 1960.

Table 2.—Motor-vehicle traffic accidents by highway system and severity for passenger cars registered in Massachusetts, 1953

| Highway system | Number of accidents, classified by severity and location | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fatal | | | Nonfatal | | | Property-damage-only | | | Total | | |
| | Rural | Urban | Total | Rural | Urban | Total | Rural | Urban | Total | Rural | Urban | Total |
| Federal-aid primary: | | | | | | | | | | | | |
| State highways | 40 | 33 | 73 | 1,903 | 2,249 | 4,152 | 4,481 | 8,703 | 13,184 | 6,424 | 10,985 | 17,409 |
| Local roads | ------ | 49 | 49 | 15 | 5,216 | 5,231 | ------ | 12,081 | 12,081 | 15 | 17,346 | 17,361 |
| Subtotal | 40 | 82 | 122 | 1,918 | 7,465 | 9,383 | 4,481 | 20,784 | 25,265 | 6,439 | 28,331 | 34,770 |
| Federal-aid secondary: | | | | | | | | | | | | |
| State highways | 24 | 5 | 29 | 576 | 410 | 986 | 3,257 | 2,399 | 5,656 | 3,857 | 2,814 | 6,671 |
| Local roads | ------ | 20 | 20 | 30 | 1,514 | 1,544 | ------ | 4,676 | 4,676 | 30 | 6,210 | 6,240 |
| Subtotal | 24 | 25 | 49 | 606 | 1,924 | 2,530 | 3,257 | 7,075 | 10,332 | 3,887 | 9,024 | 12,911 |
| Non-Federal-aid: | | | | | | | | | | | | |
| State highways | ------ | ------ | ------ | 120 | ------ | 120 | 90 | 272 | 362 | 210 | 272 | 482 |
| Local roads | 26 | 118 | 144 | 1,304 | 19,933 | 21,237 | 4,676 | 57,316 | 61,992 | 6,006 | 77,367 | 83,373 |
| Subtotal | 26 | 118 | 144 | 1,424 | 19,933 | 21,357 | 4,766 | 57,588 | 62,354 | 6,216 | 77,639 | 83,855 |
| All highways and roads: | | | | | | | | | | | | |
| State highways | 64 | 38 | 102 | 2,599 | 2,659 | 5,258 | 7,828 | 11,374 | 19,202 | 10,491 | 14,071 | 24,562 |
| Local roads | 26 | 187 | 213 | 1,349 | 26,663 | 28,012 | 4,676 | 74,073 | 78,749 | 6,051 | 100,923 | 106,974 |
| Total | 90 | 225 | 315 | 3,948 | 29,322 | 33,270 | 12,504 | 85,447 | 97,951 | 16,542 | 114,994 | 131,536 |

Table 3.—Motor-vehicle traffic accident rate by highway system and severity for passenger cars registered in Massachusetts, 1953

| Highway system | Number of accidents per 100 million vehicle-miles, classified by severity and location | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fatal | | | Nonfatal | | | Property-damage-only | | | Total | | |
| | Rural | Urban | Total | Rural | Urban | Total | Rural | Urban | Total | Rural | Urban | Total |
| Federal-aid primary: | | | | | | | | | | | | |
| State highways | 1.88 | 1.73 | 1.81 | 89.59 | 118.11 | 103.07 | 210.96 | 457.09 | 327.30 | 302.40 | 576.94 | 432.17 |
| Local roads | ---- | 3.91 | 3.41 | 8.33 | 416.28 | 365.03 | ------- | 964.16 | 843.65 | 8.33 | 1,384.35 | 1,211.51 |
| Subtotal | 1.73 | 2.59 | 2.23 | 83.24 | 236.45 | 171.81 | 194.48 | 658.34 | 462.64 | 279.42 | 897.40 | 636.67 |
| Federal-aid secondary: | | | | | | | | | | | | |
| State highways | 7.92 | 3.81 | 6.68 | 190.09 | 312.97 | 227.18 | 1,074.91 | 1,831.29 | 1,303.22 | 1,273.26 | 2,148.09 | 1,537.32 |
| Local roads | ---- | 2.49 | 1.27 | 3.93 | 189.01 | 98.78 | ------- | 583.77 | 299.16 | 3.93 | 775.28 | 399.23 |
| Subtotal | 2.25 | 2.68 | 2.45 | 56.90 | 206.43 | 126.69 | 305.82 | 759.12 | 517.37 | 365.07 | 968.24 | 646.56 |
| Non-Federal-aid: | | | | | | | | | | | | |
| State highways | ---- | ---- | ---- | 72.28 | ------ | 56.07 | 54.21 | 566.66 | 169.15 | 126.50 | 566.66 | 225.23 |
| Local roads | 1.10 | 7.34 | 3.64 | 55.48 | 1,241.15 | 536.83 | 198.97 | 3,568.86 | 1,567.03 | 255.57 | 4,817.37 | 2,107.50 |
| Subtotal | 1.03 | 7.13 | 3.45 | 56.59 | 1,205.13 | 512.15 | 189.42 | 3,481.74 | 1,495.29 | 247.05 | 4,694.01 | 2,010.91 |
| All highways and roads: | | | | | | | | | | | | |
| State highways | 2.46 | 1.82 | 2.18 | 100.23 | 127.65 | 112.44 | 301.88 | 546.03 | 410.65 | 404.58 | 675.51 | 525.27 |
| Local roads | .78 | 5.10 | 3.06 | 40.97 | 728.49 | 402.93 | 142.04 | 2,023.85 | 1,132.75 | 183.80 | 2,757.45 | 1,538.75 |
| Total | 1.52 | 3.91 | 2.70 | 67.08 | 510.56 | 286.11 | 212.47 | 1,487.84 | 842.37 | 281.08 | 2,002.33 | 1,131.20 |

tempt to determine the reasons therefor. Comparisons of the number of accidents per mile of highway and the number of accidents per 100 million vehicle-miles were both studied in relation to their respective system mileages. In neither of these possibilities could a definite indication or trend be detected.

There did appear to be a relationship between the number of accidents in terms of vehicle-miles as related to their average traffic volumes. However, this was not sufficiently pronounced to substantiate any definite conclusions as to the reasons for the variation of accident rates in the various highway systems. A possible explanation might be that the priority given, since World War II, to the construction of controlled-access highways on the Federal-aid primary system, and the financial assistance to local governments for the improvement of local roads on the Federal-aid secondary system, have brought about a reduction in the accident rates on those systems.

In any event, the results of the accident cost study point to the need for improvement of local roads on the Federal-aid primary system and State highways on the Federal-aid secondary system, and even greater emphasis should be given to non-Federal-aid local roads with their high accident totals, extensive mileages, and high rate of accidents per 100 million vehicle-miles.

## *Total Direct Cost of Accidents*

The foregoing has been purposely confined to a discussion of accident experience and accident rates on the highway systems. This was done in order to promote a clearer understanding of the accident picture in Massachusetts. It is a fact, however, that an important and integral part of any motor-vehicle accident, and aside from the aspect of personal injury, suffering and inconvenience involved, is the monetary cost incurred.

In this article, dollar values will be confined to direct costs only. The cost of accidents in relation to the highway systems is shown in tables 4 and 5. For those who include among their responsibilities the improvement of accident-prone highways, the overall costs of accidents on the highway systems in table 4 are of special significance. The value of table 5 is that it brings into sharp focus the cost of an accident to the individual or individuals involved. The cost varied from $203, for an average property-damage-only accident, up to $5,499 for an average fatal accident in urban areas.

In 1953, there occurred a total of 131,536 accidents which involved $50.224 million in direct costs. Fatal accidents made up 3 percent, nonfatal injury accidents 57 percent, and property-damage-only accidents 40 percent of the direct cost. In this cost breakdown it is interesting to examine the cost comparisons in the light of what was previously found through accident rate comparisons by again using the highway systems. The costs and rates found below are derived from tables 3–5.

### Federal-aid primary system

On the Federal-aid primary system, State highways had a better accident rate (per 100 million vehicle-miles of travel) than local roads in the ratio of 1 to 3. However, the

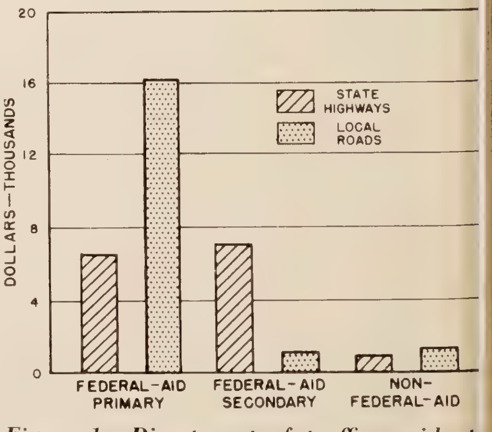


***Figure 1.—Direct cost of traffic accidents per mile of highway in Massachusetts classified by highway system.***

tate highway accident costs exceeded those n the local roads, being $9.9 million and 7.3 million, respectively.

The highest total costs in each subdivision f the Federal-aid primary system were hose incurred in urban nonfatal accidents—hat is, in accidents where nonfatal injuries ere involved; they amounted to almost 8.9 million. State highways and local roads ich showed a total cost of approximately 4.4 million. Also, nonfatal injury accidents urban areas accounted for 52 percent of ne total cost of all accidents on the Federal-id primary system. While property-damage-nly accidents were also very costly in total, both rural and urban areas, these costs ere only slightly more than half of the non-tal total costs.

### 'ederal-aid secondary system

On Federal-aid secondary highways the otal accident cost was only 29 percent of he cost of accidents on the Federal-aid rimary highways. Here again, the dissimi-arity between accident rate comparisons and ost comparisons is worthy of note. In the 'ederal-aid secondary system local roads had comparatively low accident rate and the tate highways experienced a much greater ate, in the ratio of about 1 to 4. Neverthe-ess, the accident costs were in the ratio of nly 2 to 3 on local roads versus State ighways.

Another noteworthy fact is that property-damage-only costs were greater on the secondary system than were those of fatal and nonfatal injury accidents combined.

### Non-Federal-aid highways

The non-Federal-aid highways and roads form the large network of local streets and connecting highways in Massachusetts. Compared with the highways and roads in the Federal-aid systems, they carry far less average daily traffic. The accident rate for the non-Federal-aid highways and roads, expressed in number of accidents per mile of roadway, was less than the Federal-aid highways and roads and yet, they accounted for 69 percent of all accidents and 56 percent of the total accident cost in 1953.

Of the $28.0 million cost of accidents occurring on non-Federal-aid highways and roads, nonfatal injury accidents accounted for almost $16.0 million, property-damage-only accidents accounted for $11.3 million, and fatal accidents accounted for $751,460. Of the total amount, a very large proportion, $26.2 million, was incurred in urban areas. Thus, besides having a high accident rate in terms of accidents per 100 million vehicle-miles on its local road subdivision, accidents occurring on both non-Federal-aid State highways and local roads accounted for 56 percent of the cost of accidents in Massachusetts.

## *Economic Costs and Costs Rates*

As previously noted, the efficiency of a highway in terms of accidents may be obtained by comparing accident rates. This is also true when comparing economic loss expressed in accident cost rates.

An analysis of figure 1, which shows the direct cost of accidents per mile of highway on each highway system, indicates that the highest accident cost per mile of highway, $16,112, was on the Federal-aid primary local roads. The second highest cost was $6,857 per mile on the Federal-aid secondary State highways and the third highest cost, $6,537 per mile, was on the primary State highways. Accident costs per mile on the remaining highways and roads were minor in comparison to the above three. It should be stressed, however, that these costs are average costs only and that costs fluctuate greatly on the many types of roadways in each system. Accident costs per mile, of course, present only one side of the picture and do not reflect the volumes of traffic carried.

The comparison of accident costs per passenger-car-mile, excluding trucks, is shown in figure 2. The cost in dollars per 100 million vehicle-miles has been reduced to fractions of a cent per mile. On the whole, the State highways are costing the motorist an average of 0.28 cent per passenger-car-mile while on the local roads the accident cost per passenger-car-mile is 0.53 cent.

**Table 4.—Direct costs of traffic accidents by highway system and severity for passenger cars registered in Massachusetts, 1953**

| Highway system | Cost of accidents, classified by severity and location | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fatal | | | Nonfatal | | | Property-damage-only | | | Total | | |
| | Rural | Urban | Total | Rural | Urban | Total | Rural | Urban | Total | Rural | Urban | Total |
| Federal-aid primary: | | | | | | | | | | | | |
| State highways | $214, 420 | $179, 750 | $394, 170 | $1, 920, 530 | $4, 428, 550 | $6, 349, 080 | $1, 189, 760 | $1, 976, 520 | $3, 166, 280 | $3, 324, 710 | $6, 584, 820 | $9, 909, 530 |
| Local roads | ------ | 268, 640 | 268, 640 | 28, 800 | 4, 434, 680 | 4, 463, 480 | ------ | 2, 550, 290 | 2, 550, 290 | 28, 800 | 7, 253, 610 | 7, 282, 410 |
| Subtotal | 214, 420 | 448, 390 | 662, 810 | 1, 949, 330 | 8, 863, 230 | 10, 812, 560 | 1, 189, 760 | 4, 526, 810 | 5, 716, 570 | 3, 353, 510 | 13, 838, 430 | 17, 191, 940 |
| Federal-aid secondary: | | | | | | | | | | | | |
| State highways | 83, 700 | 28, 820 | 111, 920 | 528, 500 | 416, 980 | 945, 480 | 655, 220 | 1, 290, 530 | 1, 945, 750 | 1, 267, 420 | 1, 735, 730 | 3, 003, 150 |
| Local roads | ------ | 115, 560 | 115, 560 | 4, 500 | 950, 410 | 954, 910 | ------ | 962, 920 | 962, 920 | 4, 500 | 2, 028, 890 | 2, 033, 390 |
| Subtotal | 83, 700 | 143, 780 | 227, 480 | 533, 000 | 1, 367, 390 | 1, 900, 390 | 655, 220 | 2, 253, 450 | 2, 908, 670 | 1, 271, 920 | 3, 764, 620 | 5, 036, 540 |
| Non-Federal-aid: | | | | | | | | | | | | |
| State highways | ------ | ------ | ------ | 134, 400 | ------ | 134, 400 | 5, 430 | 19, 910 | 25, 340 | 139, 830 | 19, 910 | 159, 740 |
| Local roads | 106, 390 | 645, 070 | 751, 460 | 859, 200 | 14, 980, 900 | 15, 840, 100 | 695, 040 | 10, 548, 680 | 11, 243, 720 | 1, 660, 630 | 26, 174, 650 | 27, 835, 280 |
| Subtotal | 106, 390 | 645, 070 | 751, 460 | 993, 600 | 14, 980, 900 | 15, 974, 500 | 700, 470 | 10, 568, 590 | 11, 269, 060 | 1, 800, 460 | 26, 194, 560 | 27, 995, 020 |
| All highways and roads: | | | | | | | | | | | | |
| State highways | 298, 120 | 207, 970 | 506, 090 | 2, 583, 430 | 4, 845, 530 | 7, 428, 960 | 1, 850, 410 | 3, 286, 960 | 5, 137, 370 | 4, 731, 960 | 8, 340, 460 | 13, 072, 420 |
| Local roads | 106, 390 | 1, 029, 270 | 1, 135, 660 | 892, 500 | 20, 365, 990 | 21, 258, 490 | 695, 040 | 14, 061, 890 | 14, 756, 930 | 1, 693, 930 | 35, 457, 150 | 37, 151, 080 |
| Total | 404, 510 | 1, 237, 240 | 1, 641, 750 | 3, 475, 930 | 25, 211, 520 | 28, 687, 450 | 2, 545, 450 | 17, 348, 850 | 19, 894, 300 | 6, 125, 890 | 43, 797, 610 | 50, 223, 500 |

**Table 5.—Direct costs per traffic accident by highway system and severity for passenger cars registered in Massachusetts, 1953**

| Highway system | Cost per accident, classified by severity and location | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fatal | | | Nonfatal | | | Property-damage-only | | | Total | | |
| | Rural | Urban | Total | Rural | Urban | Total | Rural | Urban | Total | Rural | Urban | Total |
| Federal-aid primary: | | | | | | | | | | | | |
| State highways | $5, 361 | $5, 447 | $5, 400 | $1, 009 | $1, 969 | $1, 529 | $266 | $227 | $240 | $518 | $599 | $569 |
| Local roads | ---- | 5, 482 | 5, 482 | 1, 920 | 850 | 853 | ---- | 211 | 211 | 1, 920 | 418 | 419 |
| Subtotal | 5, 361 | 5, 468 | 5, 433 | 1, 016 | 1, 187 | 1, 152 | 266 | 218 | 226 | 521 | 488 | 494 |
| Federal-aid secondary: | | | | | | | | | | | | |
| State highways | 3, 488 | 5, 644 | 3, 859 | 918 | 1, 017 | 959 | 201 | 538 | 344 | 329 | 617 | 450 |
| Local roads | ---- | 5, 778 | 5, 778 | 150 | 628 | 618 | ---- | 206 | 206 | 150 | 327 | 326 |
| Subtotal | 3, 488 | 5, 751 | 4, 642 | 880 | 711 | 751 | 201 | 319 | 282 | 327 | 417 | 390 |
| Non-Federal-aid: | | | | | | | | | | | | |
| State highways | ---- | ---- | ---- | 1, 120 | ---- | 1, 120 | 60 | 73 | 70 | 666 | 73 | 331 |
| Local roads | 4, 092 | 5, 467 | 5, 218 | 659 | 752 | 746 | 149 | 184 | 181 | 276 | 338 | 334 |
| Subtotal | 4, 092 | 5, 467 | 5, 218 | 698 | 752 | 748 | 147 | 184 | 181 | 290 | 337 | 334 |
| All highways and roads: | | | | | | | | | | | | |
| State highways | 4, 658 | 5, 473 | 4, 962 | 994 | 1, 822 | 1, 413 | 236 | 289 | 268 | 451 | 593 | 532 |
| Local roads | 4, 092 | 5, 504 | 5, 332 | 662 | 7, 639 | 759 | 149 | 190 | 187 | 280 | 351 | 347 |
| Total | 4, 495 | 5, 499 | 5, 212 | 880 | 860 | 862 | 204 | 203 | 203 | 388 | 381 | 382 |


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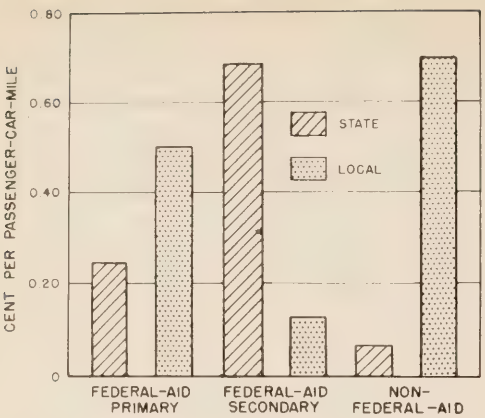


*Figure 2.—Accident costs per passenger-car-mile on State highways and local roads in Massachusetts in hundredths of a cent.*

### Costs by type of accident

A breakdown of the number of accidents which occurred in Massachusetts in 1953 appears in table 6. Of the total accidents, 84 percent involved collisions of two or more motor vehicles, whereas 16 percent involved only one vehicle. In the former grouping, over 48 percent of the accidents were angle collisions. Rear-end collisions accounted for the next highest percentage, 20 percent, of the collisions with other vehicles. "Other" collisions, which included turning movements, parking maneuvers, and backing in traffic lanes, accounted for 12 percent of the collisions with other vehicles. Accidents involving only one motor vehicle included collisions with pedestrians, fixed objects, other objects (bicycles, scooters, etc.), and non-collision accidents.

By comparing the types of collisions on the State highways and local roads, it is interesting to note that rear-end collisions retained about the same proportion to the total collisions, 17 percent on State highways and 17 percent on local roads, but angle collisions were more prevalent on the local roads, 44 percent, whereas on State highways they accounted for only 23 percent of the accidents. Vehicle-pedestrian collisions accounted for only 2 percent of the collisions on State highways and 5 percent on local roads. Collisions with fixed objects were in about equal proportion, 6 percent on State highways and 5 percent on local roads.

The costs of the various types of accidents are shown in tables 7 and 8. Table 7 shows total costs and table 8 shows the accident cost rate per 100 million vehicle-miles of travel. The highest cost rate of accidents occurring on the State highways applied to head-on collisions. Rear-end and angle collisions had the next highest cost rates. On local roads the order of cost rates was angle collisions highest, rear-end second, and head-on collisions third.

Except for head-on collisions, sideswipe collisions involving two vehicles moving in opposite directions, single-car collisions with other objects, and non-collisions, the direct cost rates of accidents occurring on local roads were higher than the respective type of collision on State highways. In total costs, only the sideswipe (opposite direction) and non-collision accidents had a greater cost on State highways.

In the Federal-aid primary system, reducing the cost rate of accidents per 100 million vehicle-miles to a cost rate per passenger-car-mile, the total cost for all types of accident on the State highways was 0.24 cent pe passenger-car-mile while the local road cos rate was 0.50 cent per passenger-car-mile.

The highest cost rate for all types of acci- dents occurring on the Federal-aid secondar highways and roads was the rear-end col-

**Table 6.—Motor-vehicle traffic accidents by type of accident and highway system fo passenger cars registered in Massachusetts, 1953**

| Type of accident | Federal-aid primary | | Federal-aid secondary | | Non-Federal-aid | | All highways and roads | | |
|---|---|---|---|---|---|---|---|---|---|
| | State highways | Local roads | State highways | Local roads | State highways | Local roads | State highways | Local roads | Total |
| Two or more car collisions: | | | | | | | | | |
| Head-on | 2, 306 | 1, 462 | 631 | 514 | 15 | 7, 751 | 2, 952 | 9, 727 | 12, 679 |
| Rear-end | 3, 403 | 3, 395 | 864 | 1, 273 | 15 | 13, 363 | 4, 282 | 18, 031 | 22, 313 |
| Angle | 4, 367 | 7, 726 | 1, 276 | 2, 000 | 15 | 34, 484 | 5, 658 | 47, 210 | 52, 868 |
| Sideswipe (same direction) | 1, 281 | 1, 070 | 150 | 151 | ------- | 4, 397 | 1, 431 | 5, 618 | 7, 049 |
| Sideswipe (opposite direction) | 433 | 226 | 15 | 90 | ------- | 708 | 448 | 1, 024 | 1, 472 |
| Others | 2, 129 | 1, 333 | 1, 086 | 1, 050 | 181 | 10, 570 | 3, 396 | 9, 953 | 13, 349 |
| Total | 13, 919 | 15, 212 | 4, 022 | 5, 078 | 226 | 71, 273 | 18, 167 | 91, 563 | 109, 730 |
| One-car collision with: | | | | | | | | | |
| Pedestrians | 201 | 327 | 248 | 283 | 30 | 4, 759 | 479 | 5, 369 | 5, 848 |
| Fixed objects | 745 | 734 | 679 | 726 | 15 | 4, 361 | 1, 439 | 5, 821 | 7, 260 |
| Other objects | 1, 751 | 875 | 1, 146 | 153 | 181 | 2, 358 | 3, 078 | 3, 386 | 6, 464 |
| Non-collision accidents | 792 | 213 | 577 | ------ | 30 | 622 | 1, 399 | 835 | 2, 234 |
| Total | 3, 489 | 2, 149 | 2, 650 | 1, 162 | 256 | 12, 100 | 6, 395 | 15, 411 | 21, 806 |
| All accidents | 17, 408 | 17, 361 | 6, 672 | 6, 240 | 482 | 83, 373 | 24, 562 | 106, 974 | 131, 536 |

**Table 7.—Direct costs of traffic accidents by type of accident and highway system fo passenger cars registered in Massachusetts, 1953**

| Type of accident | Federal-aid primary | | Federal-aid secondary | | Non-Federal-aid | | All highways and roads | | |
|---|---|---|---|---|---|---|---|---|---|
| | State highways | Local roads | State highways | Local roads | State highways | Local roads | State highways | Local roads | Total |
| Two or more car collisions: | | | | | | | | | |
| Head-on | $3, 857, 550 | $958, 730 | $312, 490 | $288, 060 | $36, 950 | $3, 513, 630 | $4, 206, 990 | $4, 760, 420 | $8, 967, 410 |
| Rear-end | 1, 745, 000 | 2, 140, 330 | 761, 900 | 490, 670 | 20, 400 | 5, 561, 050 | 2, 527, 300 | 8, 192, 050 | 10, 719, 350 |
| Angle | 1, 496, 100 | 2, 503, 180 | 528, 530 | 658, 060 | 16, 500 | 11, 973, 340 | 2, 041, 130 | 15, 134, 580 | 17, 175, 710 |
| Sideswipe (same direction) | 487, 980 | 221, 920 | 83, 310 | 39, 640 | ----- | 1, 104, 170 | 571, 290 | 1, 365, 730 | 1, 937, 020 |
| Sideswipe (opposite direction) | 339, 850 | 97, 100 | 43, 500 | 33, 040 | ----- | 186, 460 | 383, 350 | 316, 600 | 699, 950 |
| Others | 452, 570 | 293, 600 | 465, 170 | 186, 600 | 5, 430 | 912, 600 | 923, 170 | 1, 392, 800 | 2, 315, 970 |
| Total | 8, 379, 050 | 6, 214, 860 | 2, 194, 900 | 1, 696, 070 | 79, 280 | 23, 251, 250 | 10, 653, 230 | 31, 162, 180 | 41, 815, 410 |
| One-car collision with: | | | | | | | | | |
| Pedestrians | 150, 250 | 268, 980 | 55, 220 | 62, 710 | 31, 500 | 2, 799, 550 | 236, 970 | 3, 131, 240 | 3, 368, 210 |
| Fixed objects | 547, 850 | 670, 290 | 225, 310 | 145, 710 | 35, 400 | 1, 395, 380 | 808, 560 | 2, 211, 380 | 3, 019, 940 |
| Other objects | 122, 350 | 93, 520 | 194, 170 | 128, 900 | 10, 860 | 135, 150 | 327, 380 | 357, 570 | 684, 950 |
| Non-collision accidents | 710, 030 | 34, 760 | 333, 550 | ------- | 2, 700 | 253, 950 | 1, 046, 280 | 288, 710 | 1, 334, 990 |
| Total | 1, 530, 480 | 1, 067, 550 | 808, 250 | 337, 320 | 80, 460 | 4, 584, 030 | 2, 419, 190 | 5, 988, 900 | 8, 408, 090 |
| All accidents | 9, 909, 530 | 7, 282, 410 | 3, 003, 150 | 2, 033, 390 | 159, 740 | 27, 835, 280 | 13, 072, 420 | 37, 151, 080 | 50, 223, 500 |

**Table 8.—Direct costs of traffic accidents per 100 million vehicle-miles by highway system and type of accident for passenger cars registered in Massachusetts, 1953**

| Type of accident | Federal-aid primary | | Federal-aid secondary | | Non-Federal-aid | | State highways | Local roads | Total |
|---|---|---|---|---|---|---|---|---|---|
| | State highways | Local roads | State highways | Local roads | State highways | Local roads | | | |
| Two or more car collisions | | | | | | | | | |
| Head-on | $95, 768 | $66, 904 | $72, 002 | $18, 430 | $17, 266 | $88, 818 | $89, 970 | $68, 476 | $77, 119 |
| Rear-end | 43, 322 | 149, 360 | 175, 553 | 31, 393 | 9, 533 | 140, 573 | 54, 048 | 117, 837 | 92, 186 |
| Angle | 37, 142 | 174, 681 | 121, 781 | 42, 102 | 7, 710 | 302, 663 | 43, 651 | 217, 701 | 147, 710 |
| Sideswipe (same direction) | 12, 115 | 15, 486 | 19, 196 | 2, 536 | ------- | 27, 911 | 12, 218 | 19, 645 | 16, 658 |
| Sideswipe (opposite direction) | 8, 437 | 6, 776 | 10, 023 | 2, 114 | ------- | 4, 713 | 8, 198 | 4, 554 | 6, 020 |
| Others | 11, 236 | 20, 489 | 107, 182 | 11, 939 | 2, 538 | 23, 069 | 19, 743 | 20, 035 | 19, 917 |
| Total | 208, 020 | 433, 696 | 505, 737 | 108, 514 | 37, 047 | 587, 747 | 227, 828 | 448, 248 | 359, 610 |
| One-car collision with | | | | | | | | | |
| Pedestrians | 3, 730 | 18, 770 | 12, 723 | 4, 012 | 14, 720 | 70, 767 | 5, 068 | 45, 041 | 28, 966 |
| Fixed objects | 13, 601 | 46, 775 | 51, 915 | 9, 322 | 16, 542 | 35, 273 | 17, 292 | 31, 809 | 25, 971 |
| Other objects | 3, 038 | 6, 526 | 44, 740 | 8, 247 | 5, 075 | 3, 416 | 7, 001 | 5, 143 | 5, 891 |
| Non-collision accidents | 17, 627 | 2, 426 | 76, 855 | ------- | 1, 261 | 6, 419 | 22, 375 | 4, 153 | 11, 481 |
| Total | 37, 996 | 74, 497 | 186, 233 | 21, 581 | 37, 598 | 115, 875 | 51, 736 | 86, 146 | 72, 309 |
| All accidents | 246, 016 | 508, 193 | 691, 970 | 130, 095 | 74, 645 | 703, 622 | 279, 564 | 534, 394 | 431, 919 |

**Table 9.—Accident rates and costs on State highways in Massachusetts comparing controlled-access highways and highways with no control of access, 1957**

| Sections of State highway | Miles studied | Average daily traffic | Severity of accidents: Fatal | Nonfatal | Property-damage-only | Total | Accident rate [1] | Direct costs per mile |
|---|---|---|---|---|---|---|---|---|
| Controlled access: | | | | | | | | |
| Route 128 (Wellesley to Lynnfield) | 24.6 | 32,200 | 3 | 254 | 211 | 468 | 161.7 | $30,100 |
| Route 15 (Sturbridge to Holland) | 6.7 | 15,700 | 2 | 26 | 17 | 45 | 117.2 | 13,900 |
| Route 2 (Concord to Westminster) | 29.4 | 7,600 | 4 | 43 | 58 | 105 | 128.7 | 7,250 |
| Route 1 (Danvers to Salisbury) | 21.6 | 15,500 | 5 | 86 | 68 | 159 | 130.1 | 14,800 |
| Total | 82.3 | [2] 17,700 | 14 | 409 | 354 | 777 | 146.2 | ..... |
| Uncontrolled access: | | | | | | | | |
| Route 1 (Revere to Peabody) | 7.8 | 30,900 | 3 | 213 | 109 | 325 | 370.5 | 79,700 |
| Route 20–1 (Northboro to Weston) | 20.5 | 8,200 | 1 | 72 | 68 | 141 | 230.2 | 9,700 |
| Route 20–2 (Northboro to Auburn) | 15.9 | 8,600 | 2 | 122 | 82 | 206 | 412.7 | 21,600 |
| Route 9 (Brookline to Framingham) | 19.9 | 30,400 | 6 | 572 | 339 | 917 | 415.3 | 78,500 |
| Total | 64.1 | [2] 17,900 | 12 | 979 | 598 | 1,589 | 378.4 | ..... |

[1] Accidents per 100 million vehicle miles. [2] Weighted average.

sions on State highways. Angle collisions, which had the highest cost rate on the system's local roads, had the second highest rate on the State highways. "Other" collisions had the third highest rate on State highways while on the local roads head-on collisions were third.

Accident cost rates for all types of accidents on the secondary system's State highways greatly exceeded the rate of costs on the local roads. In terms of cost per passenger-car-mile, all costs in the Federal-aid secondary system on State highways were 0.69 cent as compared with 0.13 cent on the local roads.

By type of accident, the highest costs per 100 million vehicle-miles on State highways not on any Federal-aid system were the head-on collisions, collisions with fixed objects, and pedestrian accidents. On the local roads the angle collisions accounted for 43 percent of the total direct cost of accidents occurring on these roads. The cost rate amounted to $302,663 per 100 million vehicle-miles. This very high rate exceeded the rate for all other types of accidents occurring on any highway system by a wide margin. In comparing costs in each of the two highway classifications not a part of any Federal-aid system, it should be stressed that there were only 155 miles of State highways while there were 20,197 miles of local roads.

The cost per passenger-car-mile on the non-Federal-aid highways and roads was 0.07 cent on the State highways while the cost per passenger-car-mile on the local roads was 0.70 cent.

### *Costs on Selected Highways*

In the analysis of the accident records and direct costs on the six highway systems, a general picture has been obtained on a Statewide basis. In order also to gain an impression of the costs on specific sections of highways it is of interest to consider the results of an accident cost study made in Massachusetts during 1957. This study was based on the accidents reported to the Registrar of Motor Vehicles in 1955. The purpose of the study was to determine the direct costs of accidents on two types of State highways; namely, those having no control of access and those on which access was controlled. Four highways were selected of the former type and they included 2-, 3-, 4-, and 6-lane highway. Five highways of the latter type were selected and each were 4-lane divided highways which had been opened to traffic since June 1952. As part of the study, two curves, shown in figure 3, were prepared by plotting the yearly accident cost per mile against the average daily traffic volume for each of the nine sections of highway. The costs used were based on the results of the Massachusetts accident cost study and consisted of direct costs only. The results showed a yearly saving in cost of accidents per mile of highway of $18,000 at 10,000 vehicles per day and $68,000 at 25,000 vehicles per day on the controlled-access roads.

It is pointed out, however, that since this was an initial study, future research might alter the results obtained. Since this study was completed, a new comparison of accident costs on eight of the nine highways has been made available and is included here in table 9. The accident data used in this table were those submitted in 1957. A comparison of the results in accident costs per mile with the curves on figure 3 proved to be of special interest since volumes on the highways had changed since 1955. On one highway section, Route 20–2, the so-called Southwest Connection, volumes had decreased substantially because of the opening of the Massachusetts Turnpike. Despite this volume decrease, however, the yearly accident cost per mile was in close agreement with the curve in figure 3.

On the other highways, accident costs per mile were also quite consistent with the curves with only one notable exception. In the volume range above 25,000 average daily

(Continued on page 52)

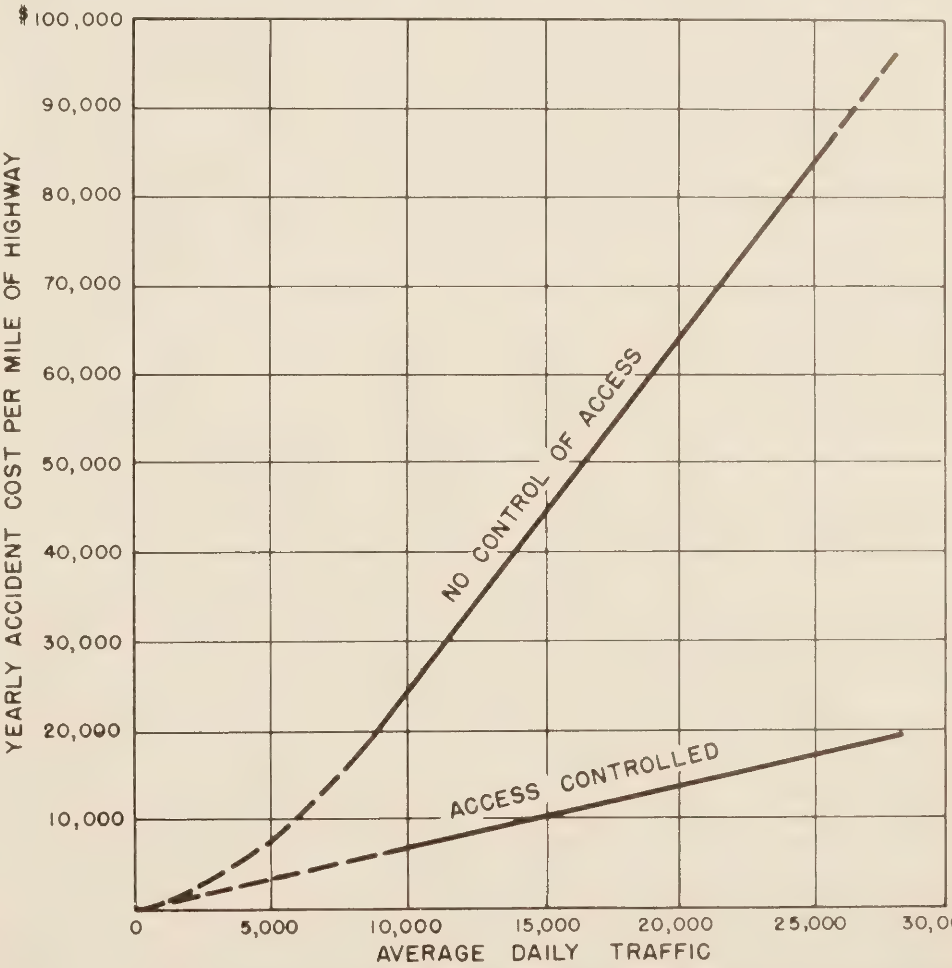


*Figure 3.—Accident costs on Massachusetts highways with no control of access and with access controlled. Data based on 1955 accidents and traffic volumes.*

# The Economic Cost of Traffic Accidents in Relation to the Vehicle

*BY THE DIVISION OF TRAFFIC OPERATIONS*
*BUREAU OF PUBLIC ROADS*

**Reported by [1] JAMES F. McCARTHY**
**Transportation Economis**

THIS article discusses traffic accidents in Massachusetts and their resulting economic costs. The study applies only to vehicles of Massachusetts registry that were involved in traffic accidents within the State. The data for passenger cars are for the year 1953, and for trucks for the year 1955.

The purpose of this article is to present the cost of accidents in relation to the vehicle in a way that will aid those interested in pinpointing where prevention efforts should be centered, as well as those engaged in the economic analysis of highway improvements. The intent is not to fix responsibility for accidents by type of vehicle but rather to show what kinds of vehicles were involved and the extent of involvement in terms of cost.

Involvement and cost data are analyzed separately for passenger cars and trucks by age of vehicle and severity of accident. Further analyses are made of trucks involved in accidents and their direct costs in relation to the registered gross weight and type of truck. Comparisons are made throughout the article on the basis of the involvement per 100 million vehicle-miles of travel and the accident cost per vehicle-mile.

An involvement is one vehicle in one accident. For example, in the passenger car study, if a passenger car struck a pedestrian there was one involvement in one accident. If two passenger cars collided, there were two involvements in one accident. Also, in the passenger car study, if a passenger car collided with a truck this was one passenger car involvement in one accident. The truck involvement was not included in the passenger car study.

[1] Presented at the 39th Annual Meeting of the Highway Research Board, Washington, D.C., January 1960.

## *Overall Accident Experience*

There were 1,239,596 passenger cars registered in Massachusetts during 1953 and 179,610 trucks registered in 1955. Table 1 shows that passenger cars traveled 11.6 billion vehicle-miles as compared to 2.0 billion vehicle-miles for trucks, or a ratio of about 6 to 1. The direct cost of passenger car accidents was $50.2 million, whereas truck accident costs amounted to $4.8 million. Thus, the cost attributable to trucks was about one-tenth of that for passenger cars.

In addition to the direct costs of traffic accidents just mentioned, there were other direct costs in connection with non-traffic accidents, traffic incidents, and non-traffic incidents that are not included in this article. Non-traffic accident involvements—accidents involving motion but not occurring on a public roadway—resulted in direct costs of $2.7 million for passenger cars and $327,000 for trucks. Traffic and non-traffic incidents—mishaps not involving motion and usually involving vandalism, fire, or acts of God—resulted in direct costs of $4.7 million for passenger cars and $865,000 for trucks. The present analysis is confined to the $50.2 million for passenger cars and $4.8 million for trucks which comprised the direct costs of motor-vehicle traffic accidents.

A comparison is made in figure 1 of the direct cost of traffic accidents on the basis of vehicle-miles of travel for passenger cars and trucks. It is immediately evident that trucks had an appreciably lower accident cost per mile of travel. In the case of all accidents, the truck cost per mile of travel was 0.23 cent, and the comparable cost for passenger cars was 0.43 cent. For nonfatal injury and property-damage-only accidents, the

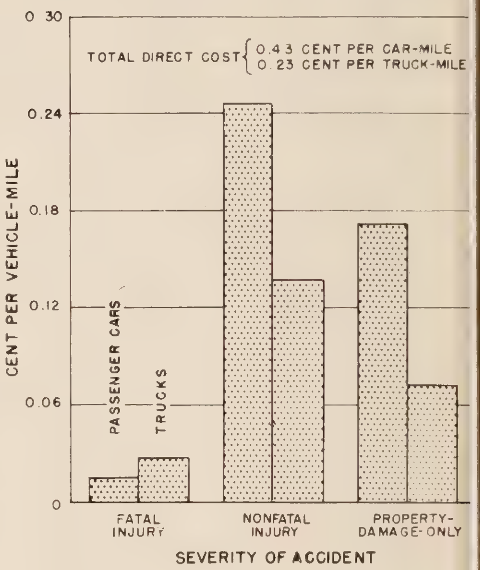


***Figure 1.—Direct cost of traffic accident in Massachusetts per passenger-car-mil of travel during 1953, and per truck-mil of travel during 1955, classified by severit of accident.***

passenger car cost per mile was approximatel double that of trucks. Only for fatal injur accidents was the rate for trucks higher, bein 0.014 cent for passenger cars and 0.027 cer for trucks for each mile of vehicle operatioi

From the data given in tables 2 and 3, comparison can be made of the average co per involvement of passenger cars and truck The high cost per involvement in fatal injur accidents—$4,800 for passenger cars an $6,800 for trucks—completely overshadow the cost per involvement of other types accidents, but fatal injury accidents repr sented less than one-half of one percent of a accidents and only 3 percent of the total cos The average cost for all involvements—$22 for passenger cars and $166 for trucks—wa heavily influenced by the less costly propert damage-only involvements, which accounte for three-fourths of all accidents.

## *Age of Vehicles*

The number of cars and trucks involved i accidents and the involvement rates by ag of car and truck and severity of accident a summarized in table 2. For purposes orientation on involvements and accident

**Table 1.—Number of motor vehicles registered in Massachusetts (passenger cars, 1953, and trucks, 1955) and their travel, classified by age of vehicle**

| | Age of passenger cars registered in 1953 | | | | | Age of trucks registered in 1955 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Under 2 years | 2–4 years | 4–8 years | 8 years and over | Total | Under 2 years | 2–4 years | 4–8 years | 8 years and over | Total |
| Number of vehicles | 257,852 | 333,947 | 356,030 | 291,767 | 1,239,596 | 27,074 | 27,343 | 67,913 | 57,280 | 179,610 |
| Percent of total | 20.8 | 26.9 | 28.7 | 23.6 | 100.0 | 15.1 | 15.2 | 37.8 | 31.9 | 100.0 |
| Vehicle travel: | | | | | | | | | | |
| Total mileage (million miles) | 3,331 | 3,390 | 3,143 | 1,764 | 11,628 | 355 | 396 | 795 | 495 | 2,041 |
| Percent of total | 28.6 | 29.2 | 27.0 | 15.2 | 100.0 | 17.4 | 19.4 | 39.0 | 24.2 | 100.0 |
| Average annual travel (miles) | 12,918 | 10,151 | 8,828 | 6,046 | 9,380 | 13,102 | 14,472 | 11,705 | 8,637 | 11,358 |

**Table 2.—Number of cars and trucks involved in traffic accidents, and the rate per 100 million vehicle-miles, classified by age and severity**

| Age of motor vehicle | Motor vehicles involved in— | | | | | | | | Number of motor vehicles per 100 million vehicle-miles of travel involved in— | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fatal injury accidents | | Nonfatal injury accidents | | Property-damage-only accidents | | All accidents | | Fatal injury accidents | Nonfatal injury accidents | Property-damage-only accidents | All accidents |
| | Number | Percent of total | Number | Percent of total | Number | Percent of total | Number | Percent of total | | | | |
| Passenger cars: | | | | | | | | | | | | |
| Under 2 years | 66 | 19.2 | 10,403 | 19.2 | 31,162 | 18.6 | 41,631 | 18.7 | 2.0 | 312 | 936 | 1,250 |
| 2–4 years | 94 | 27.3 | 15,311 | 28.2 | 47,375 | 28.3 | 62,780 | 28.3 | 2.8 | 452 | 1,397 | 1,852 |
| 4–8 years | 101 | 29.4 | 16,762 | 30.9 | 51,927 | 31.0 | 68,790 | 31.0 | 3.2 | 533 | 1,652 | 2,189 |
| 8 years and over | 83 | 24.1 | 11,784 | 21.7 | 36,991 | 22.1 | 48,858 | 22.0 | 4.7 | 668 | 2,097 | 2,770 |
| Total | 344 | 100.0 | 54,260 | 100.0 | 167,455 | 100.0 | 222,059 | 100.0 | 3.0 | 467 | 1,440 | 1,910 |
| Trucks: | | | | | | | | | | | | |
| Under 2 years | 19 | 23.2 | 705 | 15.6 | 4,080 | 16.9 | 4,804 | 16.7 | 5.4 | 200 | 1,150 | 1,355 |
| 2–4 years | 13 | 15.9 | 959 | 21.3 | 4,749 | 19.6 | 5,721 | 19.9 | 3.3 | 242 | 1,200 | 1,466 |
| 4–8 years | 28 | 34.1 | 1,881 | 41.7 | 9,395 | 38.8 | 11,304 | 39.2 | 3.5 | 237 | 1,182 | 1,442 |
| 8 years and over | 22 | 26.8 | 964 | 21.4 | 5,981 | 24.7 | 6,967 | 24.2 | 4.4 | 195 | 1,209 | 1,408 |
| Total | 82 | 100.0 | 4,509 | 100.0 | 24,205 | 100.0 | 28,796 | 100.0 | 4.0 | 223 | 1,186 | 1,412 |

22,059 passenger cars were involved in 31,536 accidents in 1953. This total was omprised of 344 involvements in 315 fatal ccidents, 54,260 involvements in 33,270 nontal injury accidents, and 167,455 involveents in 97,951 property-damage-only accients.

In contrast, 28,796 trucks were involved in 7,041 accidents during 1955. Classified by verity there were 82 truck involvements in 7 fatal accidents, 4,509 involvements in 344 nonfatal injury accidents, and 24,205 volvements in 22,648 property-damageuly accidents. The ratio of truck involveents to accidents was almost 1.1 to 1 28,796 to 27,041), whereas the corresponding atio for passenger cars involved in accidents as 1.7 to 1 (222,059 to 131,536).

**ccident involvement rates**

When the age of passenger cars and trucks volved in accidents was compared, dismilar results were found. The accident volvement rate of passenger cars, on the asis of involvements per 100 million vehicleiles, increased steadily with age—passenger rs 8 years and older had an involvement te of more than double that for cars under years of age. This influence of age on the volvement rates can be construed as a rong argument for vehicle inspection even iough there are contributory factors other an mechanical condition. With respect to ccident involvement rates of trucks, there was no apparent trend with age. Except for vehicles under 2 years of age, the involvement rate for passenger cars was higher than that for trucks. In the age group under 2 years, the truck rate exceeded the passenger car rate by only a narrow margin.

The influence of the age of the vehicle with respect to all accidents holds for each of the severity classes except for the fatal injury accidents. Throughout the article it will be seen that this class of accident severity has distinct characteristics in relation to nonfatal injury and property-damage-only accidents.

Just as for all accidents, the fatal involvement rate per 100 million vehicle-miles for passenger cars increased with age. When trucks under 2 years of age are ignored, the fatal involvement rate for trucks also increased with age. For vehicles less than 2 years of age, the fatal rate for trucks was almost 3 times that for passenger cars. For other than the newest vehicle group, the fatal involvement rates for passenger cars and trucks did not differ significantly.

**Accident cost rates**

The relationship between accident cost per million vehicle-miles and age of vehicle for each severity class of accident and for all accidents is shown in table 3 for passenger cars and trucks. A comparison of the costs for the two types of vehicles demonstrates the greater cost per mile of passenger car accidents. Although not as pronounced as the influence of age on accident involvement rates, the cost per million vehicle-miles for passenger cars tended to increase with age for all accidents, for the fatal injury accident, and for the nonfatal injury accident. The cost per million vehicle-miles for property-damage-only accidents dropped off for the older vehicles for both passenger cars and trucks. This undoubtedly reflected the reduced value of the older vehicles involved.

The fact that the total direct cost of nonfatal injury accidents constituted almost 60 percent of the total cost of all accidents for both passenger cars and trucks has a great influence on the pattern of cost per million vehicle-miles for all accidents.

## *Visual Classification of Trucks*

It was not practical to classify passenger cars by different body styles or weight. However, trucks were studied first by visual classification and second by registered weight. In the visual classification, trucks were grouped as follows: 2-axle, 4-tire panel and pickup trucks; all other 2-axle, 4-tire trucks; 2-axle, 6-tire trucks; 3-axle trucks; and truck-tractor-semitrailer combinations. The truck-tractor-semitrailer combinations, ranging from 3- to 5-axle units, were treated as a single classification. Truck and full trailer combinations are illegal in Massachusetts and therefore were not represented in the study.

**Table 3.—Total direct cost of traffic accidents involving passenger cars and trucks, and the accident cost per million vehicle-miles, classified by age and severity**

| Age of motor vehicle | Accident costs | | | | | | | | Accident costs per million vehicle-miles of travel | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fatal injury | | Nonfatal injury | | Property-damage-only | | All accidents | | Fatal injury | Nonfatal injury | Property-damage-only | All accidents |
| | Amount | Percent of total | Amount | Percent of total | Amount | Percent of total | Amount | Percent of total | | | | |
| Passenger cars: | | | | | | | | | | | | |
| Under 2 years | $343,730 | 20.9 | $5,572,710 | 19.4 | $4,388,040 | 22.0 | $10,304,480 | 20.5 | $103 | $1,673 | $1,317 | $3,093 |
| 2–4 years | 507,170 | 30.9 | 8,695,640 | 30.3 | 7,264,870 | 36.5 | 16,467,680 | 32.8 | 150 | 2,565 | 2,143 | 4,858 |
| 4–8 years | 462,820 | 28.2 | 8,015,350 | 28.0 | 6,001,250 | 30.2 | 14,479,420 | 28.8 | 147 | 2,550 | 1,910 | 4,607 |
| 8 years and over | 328,030 | 20.0 | 6,403,750 | 22.3 | 2,240,140 | 11.3 | 8,971,920 | 17.9 | 186 | 3,631 | 1,270 | 5,087 |
| Total | 1,641,750 | 100.0 | 28,687,450 | 100.0 | 19,894,300 | 100.0 | 50,223,500 | 100.0 | 141 | 2,467 | 1,711 | 4,319 |
| Trucks: | | | | | | | | | | | | |
| Under 2 years | 136,700 | 24.5 | 266,300 | 9.6 | 290,560 | 20.1 | 693,560 | 14.5 | 385 | 751 | 819 | 1,955 |
| 2–4 years | 81,820 | 14.6 | 541,170 | 19.6 | 273,330 | 18.9 | 896,320 | 18.8 | 207 | 1,368 | 691 | 2,265 |
| 4–8 years | 206,370 | 36.9 | 1,526,680 | 55.1 | 612,510 | 42.4 | 2,345,560 | 49.1 | 260 | 1,920 | 771 | 2,951 |
| 8 years and over | 133,950 | 24.0 | 435,020 | 15.7 | 269,180 | 18.6 | 838,150 | 17.6 | 271 | 879 | 544 | 1,694 |
| Total | 558,840 | 100.0 | 2,769,170 | 100.0 | 1,445,580 | 100.0 | 4,773,590 | 100.0 | 274 | 1,357 | 709 | 2,340 |

## 2-axle trucks

Table 4 contains the travel characteristics and accident involvement rates for trucks. During 1955 there were 179,610 trucks registered in Massachusetts. The largest single group was the 2-axle, 4-tire panel and pickup trucks, which accounted for 43 percent of the total truck population and 37 percent of the total truck-miles of travel. Of almost equal magnitude were the 2-axle, 6-tire single-unit trucks. Together these two groupings constituted over 82 percent of the total number of trucks and 73 percent of the mileage traveled by trucks. The combination units, although representing less than 6 percent of the number of trucks, accounted for almost 17 percent of the truck-miles traveled.

The second group of trucks, other 2-axle, 4-tire trucks, had a disproportionate share of the accident involvements and direct costs, considering the number registered and miles traveled by this class. They generally had the highest involvement and cost rates (tables 4 and 5) of any truck group. There were 18,350 trucks of this group registered in Massachusetts during 1955. This number represented 10 percent of the truck registrations and 8 percent of the truck mileage. On the other hand, this group had 12 percent of the accident involvements, and 11 percent of the direct costs.

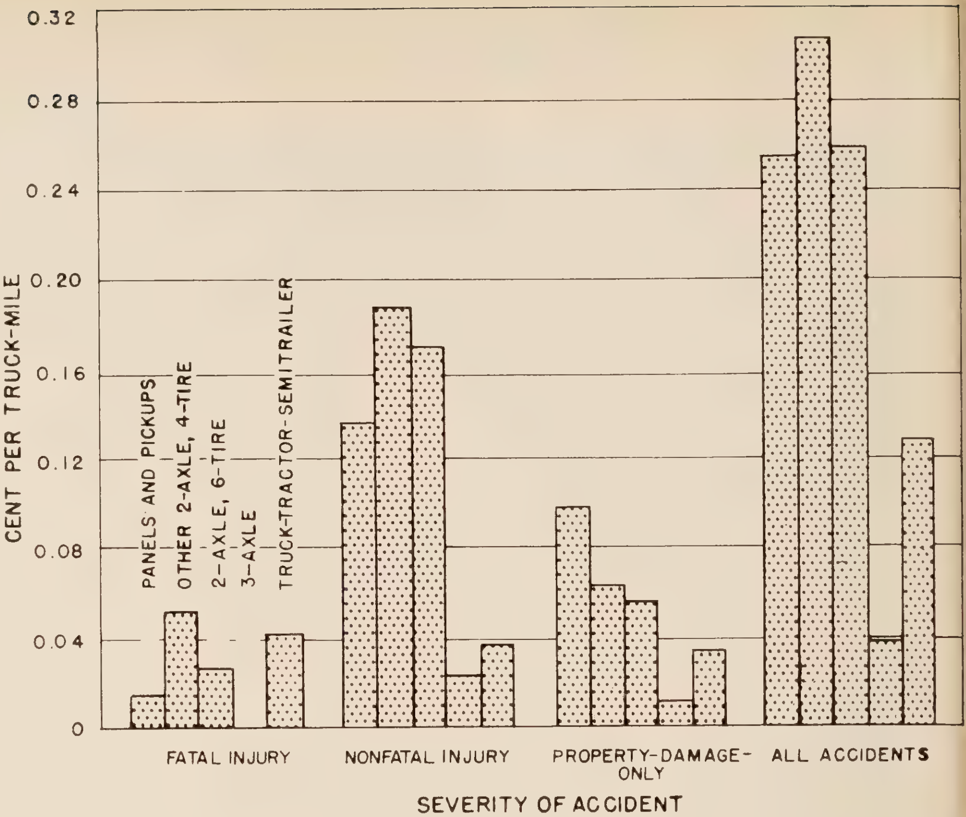


*Figure 2.—Comparison of accident costs per mile of travel by visual classification of trucks and severity of accident.*

The accident involvement rate per 100 million miles of travel for the "other" 2-axle, 4-tire trucks was 8.4 for fatal injury, 238 for nonfatal injury, and 1,867 for property-damage-only accidents. The involvement rate for this group in all accidents was 2,114, which was 50 percent greater than the average rate of 1,412 for all trucks. The fatal injury involvement rate was more than 3 times that of 2-axle, 4-tire panel and pickup trucks.

Figure 2 compares the accident cost per mile of travel by truck group and severity. The accident cost per mile for "other" 2-axle, 4-tire trucks was 0.05 cent for fatal injury, 0.19 cent for nonfatal injury, and 0.07 cent for property-damage-only accidents or a total cost of 0.31 cent per mile. The cost rate for the fatal injury accidents was more than 3 times the cost rate for panels and pickups and twice the average cost rate of 0.03 cent for fatal injury accidents for all trucks. The nonfatal injury rate for other 2-axle, 4-tire trucks was 40 percent greater than the average nonfatal injury cost rate of 0.14 cent for all trucks. Only for property-damage-only accident involvements was the cost rate less than the average for all trucks. The total cost rate for this truck group was 32 percent greater than the average cost rate of 0.23 cent for all trucks. (The average cost rates for all trucks are shown in the totals in table 5.)

Panels and pickups and the 2-axle, 6-tire trucks appeared generally to have about the same accident involvement rate and cost per mile. For all accidents, the involvement rates were 1,444 and 1,430, respectively. In figure 2 the accident cost per mile of travel is shown to be 0.255 cent for panels and pickups and 0.259 cent for 2-axle, 6-tire trucks; these two groups of vehicles which constituted 82 percent of the total registrations accounted for 80 percent of the total direct cost of truck accidents.

Considering the fatal injury accidents, the involvement rate per 100 million truck-miles for the panel and pickup trucks was 2.5 which was considerably less than the average rate of 4.0 for all trucks. The involvement rate for the 2-axle, 6-tire trucks in fatal accidents was 4.1 and was the third highest of the five vehicle types.

## 3-axle trucks

The fourth grouping of trucks, 3-axle trucks consisted of less than 2 percent of all trucks registered and accounted for the same percentage of the total number of accidents. The total cost of accidents for this group was only 0.4 percent of the total cost of accidents for all trucks.

The number of 3-axle trucks involved in accidents per 100 million miles of travel was 992. Classified by severity, the involvement rate was 1.9 for 3-axle trucks in fatal injury accidents, 86 in nonfatal injury accidents, and 904 in the property-damage-only accidents. These involvement rates were, in general, the lowest rates for any of the five truck groupings.

**Table 4.—Number of trucks registered in Massachusetts during 1955, vehicle travel, involvement in accidents, and the accident involvement rate per 100 million truck-miles, by visual classifications and severity**

| Truck groups | Number of trucks | Vehicle travel: Total mileage (thousands) | Vehicle travel: Average annual mileage | Trucks involved in— Fatal injury accidents: Number | Fatal injury accidents: Percent of total | Nonfatal injury accidents: Number | Nonfatal injury accidents: Percent of total | Property-damage-only accidents: Number | Property-damage-only accidents: Percent of total | All accidents: Number | All accidents: Percent of total | Accident involvement rate per 100 million truck-miles: Fatal injury | Nonfatal injury | Property-damage-only | All accidents |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Single-unit trucks: | | | | | | | | | | | | | | | |
| Panel and pickup | 77,180 | 758,139 | 9,823 | 19 | 23.2 | 1,982 | 43.9 | 8,946 | 36.9 | 10,947 | 38.0 | 2.5 | 261 | 1,180 | 1,444 |
| Other 2-axle, 4-tire | 18,350 | 165,866 | 9,039 | 14 | 17.1 | 395 | 8.8 | 3,097 | 12.8 | 3,506 | 12.2 | 8.4 | 238 | 1,867 | 2,114 |
| 2-axle, 6-tire | 70,670 | 727,412 | 10,293 | 30 | 36.6 | 1,683 | 37.3 | 8,691 | 35.9 | 10,404 | 36.1 | 4.1 | 231 | 1,195 | 1,430 |
| 3-axle | 3,220 | 52,206 | 16,213 | 1 | 1.2 | 45 | 1.0 | 472 | 2.0 | 518 | 1.8 | 1.9 | 86 | 904 | 992 |
| Truck-tractor-semitrailer | 10,190 | 336,473 | 33,020 | 18 | 21.9 | 404 | 9.0 | 2,999 | 12.4 | 3,421 | 11.9 | 5.3 | 120 | 891 | 1,017 |
| Total | 179,610 | 2,040,096 | 11,358 | 82 | 100.0 | 4,509 | 100.0 | 24,205 | 100.0 | 28,796 | 100.0 | 4.0 | 221 | 1,186 | 1,412 |

**Table 5.—Total direct cost of traffic accidents involving trucks and the accident cost per million truck-miles, by visual classification and severity**

| Truck group | Accident costs | | | | | | | | Accident cost per million truck-miles of travel | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fatal injury | | Nonfatal injury | | Property-damage-only | | All accidents | | | | | |
| | Amount | Percent of total | Amount | Percent of total | Amount | Percent of total | Amount | Percent of total | Fatal injury | Nonfatal injury | Property-damage-only | All accidents |
| Single-unit trucks: | | | | | | | | | | | | |
| Panel and pickup | $114, 510 | 20. 5 | $1, 050, 880 | 37. 9 | $767, 860 | 53. 1 | $1, 933, 250 | 40. 5 | $151 | $1, 386 | $1, 013 | $2, 550 |
| Other 2-axle, 4-tire | 88, 320 | 15. 8 | 315, 710 | 11. 4 | 107, 340 | 7. 4 | 511, 370 | 10. 7 | 532 | 1, 903 | 647 | 3, 083 |
| 2-axle, 6-tire | 210, 260 | 37. 6 | 1, 256, 550 | 45. 4 | 414, 470 | 28. 7 | 1, 881, 280 | 39. 4 | 289 | 1, 727 | 570 | 2, 586 |
| 3-axle | -------- | ------ | 13, 410 | 0. 5 | 6, 360 | 0. 5 | 19, 770 | 0. 4 | ------ | 257 | 122 | 379 |
| Truck-tractor-semitrailer | 145, 750 | 26. 1 | 132, 620 | 4. 8 | 149, 550 | 10. 3 | 427, 920 | 9. 0 | 433 | 394 | 444 | 1, 272 |
| Total | 558, 840 | 100. 0 | 2, 769, 170 | 100. 0 | 1, 445, 580 | 100. 0 | 4, 773, 590 | 100. 0 | 274 | 1, 357 | 709 | 2, 340 |

der consideration. Similarly, the cost in nts per mile (fig. 2) was the lowest for any the five groups of trucks in all severity sses. These cent-per-mile rates were 0.03 nt for nonfatal injury, 0.01 cent for prop-y-damage-only, and 0.04 cent for all acci-nts. There were no direct costs reported connection with the single reported involve-nt in a fatal accident of a 3-axle truck.

**uck combinations**

The data for the fifth truck group, the ack-tractor-semitrailer combinations (here-after referred to as combinations) offered a dy of contrasts. Although only 5.7 percent the total trucks registered, the combinations re responsible for 12 percent of all traffic cidents involving trucks, and 9 percent of e total direct cost. On the other hand, the mbinations accounted for over 16 percent the total truck travel, and their rates of volvement and cost per mile for all classes severity except the fatal injury accidents re below the average values for all trucks.

The breakdown of the cost of accidents for mbinations by severity class indicated that tal injury accidents accounted for 34 per-nt, nonfatal injury accidents 31 percent, and operty-damage-only accidents 35 percent of e total costs incurred. In contrast, con-dering the total direct cost for all truck acci-nts, fatal injury accidents accounted for less an 12 percent of the total cost and nonfatal jury accidents and property-damage-only cidents accounted for 58 percent and 30 per-nt, respectively.

Combinations had the second highest cost r fatal injury accidents. The average cost a fatal injury accident for this truck group was $8,100 as compared to an average cost of $6,450 for single-unit trucks. In addition to higher costs for fatal injury accidents, 1 out of every 190 combination involvements was fatal, whereas only 1 in every 409 involvements for single-unit trucks was fatal.

When viewed with consideration given to exposure in terms of truck-miles of travel, the higher percentages of truck combination involvements and costs are somewhat modified. The involvement rate for all accidents was 1,017 per 100 million miles of travel for combinations. Classified by severity this rate was 5.3 for fatal injury, 120 for nonfatal injury, and 891 for property-damage-only accident involvements per 100 million miles of travel. The cost of all accidents per mile of travel was 0.13 cent. By severity of accidents the cost rate was about the same, 0.04 cent for each class of severity.

From table 4 and figure 2 it appears that the truck combination involvement and cost rates were well below those of single-unit trucks for nonfatal injury and property-damage-only accidents. However, this was not so with regard to the fatal involvement and cost rates, as these rates for the truck combinations were considerably higher than the rates of single-unit trucks. The fatal involvement rate per 100 million miles was 5.3 for truck combinations, and 3.8 for all single-unit trucks. The cost of fatal accidents per mile of travel was 0.04 cent for the combinations compared to 0.02 cent for all single-unit trucks.

It becomes apparent from the foregoing discussion that any total view of trucks involved in accidents and their costs is predominately weighted by the number of panel and pickup trucks and 2-axle, 6-tire trucks, which dominated the total registrations, truck mileage, accident involvement, and cost rates. The combinations did play a rather important part in the total accident cost in relation to the number registered, but the large average annual mileage of this group tends to offset their disproportionate costs when viewed on an exposure basis.

## *Weight Classification of Trucks*

The discussion up to this point has considered the relationship of truck and passenger car accident costs, and the variation of truck accident costs with age of vehicle and the visual classification of trucks. Another relationship of interest, particularly for economic analysis, is that which exists between accident costs and the weight classification of trucks—registered gross vehicle weights—as shown in table 6.

Of the 179,610 trucks registered during 1955 in Massachusetts, 56 percent had a gross vehicle weight under 8,500 pounds; 20 percent had weights between 8,500 and 16,500 pounds; 11 percent had weights between 16,500 and 24,500 pounds; 5 percent between 24,500 and 36,500 pounds; and 8 percent had gross weights of 36,500 pounds and over.

In addition to the registration data, table 6 indicates the truck travel for each registered gross vehicle weight group. It is important to note that the annual average mileage increased with registered weight. The increase between the last two weight groups is particularly significant. Trucks in the heaviest weight group traveled more miles in a year

**able 6.—Number of trucks registered in Massachusetts during 1955, vehicle travel, involvement in accidents, and the accident involvement rate per 100 million truck-miles, classified by gross weight and severity**

| Gross vehicle weight (pounds) | Number of trucks | Vehicle travel | | Trucks involved in —[1] | | | | | | | | Accident involvement rate per 100 million truck-miles | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total mileage (thousands) | Average annual mileage | Fatal injury accidents | | Nonfatal injury accidents | | Property-damage-only accidents | | All accidents | | Fatal injury | Nonfatal injury | Property-damage-only | All accidents |
| | | | | Number | Percent of total | Number | Percent of total | Number | Percent of total | Number | Percent of total | | | | |
| Under 8,500 | 100, 940 | 949, 636 | 9, 408 | 41 | 50. 0 | 2, 662 | 59. 1 | 11, 001 | 45. 5 | 13, 704 | 47. 6 | 4. 3 | 280 | 1, 158 | 1, 443 |
| 8,500–16,500 | 36, 340 | 333, 960 | 9, 190 | 13 | 15. 8 | 722 | 16. 0 | 4, 998 | 20. 6 | 5, 733 | 19. 9 | 3. 9 | 216 | 1, 497 | 1, 717 |
| 16,500–24,500 | 19, 050 | 224, 139 | 11, 766 | 7 | 8. 5 | 416 | 9. 2 | 3, 289 | 13. 6 | 3, 712 | 12. 9 | 3. 1 | 186 | 1, 467 | 1, 656 |
| 24,500–36,500 | 9, 540 | 132, 603 | 13. 900 | 4 | 4. 9 | 245 | 5. 4 | 2, 084 | 8. 6 | 2, 333 | 8. 1 | 3. 0 | 185 | 1, 572 | 1, 759 |
| 36,500 and over | 13, 740 | 399, 758 | 29, 094 | 13 | 15. 9 | 387 | 8. 6 | 2, 562 | 10. 6 | 2, 962 | 10. 3 | 3. 3 | 97 | 641 | 741 |
| Total | 179, 610 | 2, 040, 096 | 11, 358 | 82 | 100. 0 | 4, 509 | 100. 0 | 24, 205 | 100. 0 | 28, 796 | 100. 0 | 4. 0 | 221 | 1, 186 | 1, 412 |

[1] There were 352 trucks involved in accidents of which the weights were unknown. These included: 4 trucks involved in fatal accidents; 77 in nonfatal accidents; and 271 in property-dam age-only accidents.

**Table 7.—Total direct cost of traffic accidents involving trucks and the accident cost per million truck-miles, classified by gross weight and severity**

| Gross vehicle weight (pounds) | Accident costs | | | | | | | | Accident cost per million truck-miles of travel | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fatal injury | | Nonfatal injury | | Property-damage-only | | All accidents | | Fatal injury | Nonfatal injury | Property damage-only | All accidents |
| | Amount | Percent of total | Amount | Percent of total | Amount | Percent of total | Amount | Percent of total | | | | |
| Under 8,500 | $268,040 | 48.0 | $1,915,460 | 69.1 | $872,060 | 60.3 | $3,055,560 | 64.0 | $282 | $2,017 | $918 | $3,218 |
| 8,500-16,500 | 130,990 | 23.4 | 378,530 | 13.7 | 242,910 | 16.8 | 752,430 | 15.8 | 392 | 1,133 | 727 | 2,253 |
| 16,500-24,500 | 19,990 | 3.6 | 209,950 | 7.6 | 126,920 | 8.8 | 356,860 | 7.5 | 89 | 937 | 566 | 1,592 |
| 24,500-36,500 | 46,900 | 8.4 | 71,600 | 2.6 | 73,110 | 5.0 | 191,610 | 4.0 | 354 | 540 | 551 | 1,445 |
| 36,500 and over | 78,310 | 14.0 | 143,270 | 5.2 | 122,160 | 8.5 | 343,740 | 7.2 | 196 | 358 | 306 | 860 |
| Unknown | 14,610 | 2.6 | 50,360 | 1.8 | 8,420 | 0.6 | 73,390 | 1.5 | ------ | ------ | ------ | ------ |
| Total | 558,840 | 100.0 | 2,769,170 | 100.0 | 1,445,580 | 100.0 | 4,773,590 | 100.0 | 274 | 1,357 | 709 | 2,340 |

in total than those in any other group except those registered under 8,500 pounds.

Light trucks have often been compared to passenger cars because of many similar vehicle characteristics. One of these similarities is average annual travel per vehicle. The average annual travel of passenger cars and light trucks was approximately equal. Passenger cars averaged 9,380 miles of travel annually and light trucks averaged 9,408 miles. By comparing the involvement rate of 1,910 per 100 million vehicle-miles for passenger cars with the involvement rate of 1,443 for light trucks it may be seen that passenger cars were involved in 32 percent more accidents on a mileage basis.

Table 6 also contains the accident involvements and the involvement rate per 100 million miles of travel for each gross weight group. Table 7 contains the accident costs and cost rate per million truck-miles of travel for each weight group. When the proportion of heavy trucks involved in accidents is compared with the proportion of heavy trucks in the total truck registrations, the comparison presents a somewhat unfavorable picture for heavy trucks. For example, trucks with a gross vehicle weight of 36,500 pounds and over represented less than 8 percent of the total trucks registered in Massachusetts and over 10 percent of the trucks involved in accidents. In terms of accident costs, however, the heaviest trucks accounted for only 7 percent of the total accident costs.

### Accident involvement rates

The involvement rates for fatal injury accidents appeared generally to decrease with registered weight over the range covered by the first three groups and then tended to level off. The proportion of trucks in the heaviest group involved in fatal injury accident was high in comparison to the proportion of trucks in the other groups. This group had one vehicle in fatal accidents for every 30 vehicles in nonfatal accidents. On an exposure basis, the heaviest truck group had a favorable involvement rate of 3.3 per 100 million miles of travel, as compared to a rate of 4.0 for the remainder of the trucks.

In the case of nonfatal injury accidents, the involvement rates decreased with registered weight. However, for the property-damage-only accidents the tendency was for an increase with weight excepting the heaviest group vehicles. For these trucks, 36,500 pounds and over, the rate dropped off sharply to less than half that for the other weight groups combined.

The involvement rate for all accidents, regardless of severity, was 741 for the heaviest trucks and 1,554 for all other trucks.

### Accident cost rates

Accident cost rates per mile of travel are shown in figure 3. The heaviest trucks had the most favorable cost rates among the weight groups. For nonfatal injury accidents the cost rate of 0.04 cent per mile for the heaviest trucks was about one-fourth of the cost rate of 0.16 for all other trucks in accident of comparable severity. The property-dam age-only cost rate was 0.03 cent per mile fo the heaviest trucks and 0.08 for all othe trucks. The cost rate for all accidents wa 0.09 cent per mile for the heaviest trucks which was one-third of the cost rate of 0.2 cent for all other trucks.

A most significant finding of the report i the very definite decrease of accident cost pe mile of travel with increase of registered gros vehicle weight. This is the first time suc data have become available. With referenc to the results for all accidents the cost rat ranges from 0.32 cent per mile for the lightes group to 0.09 cent per mile for the heavies group of trucks.

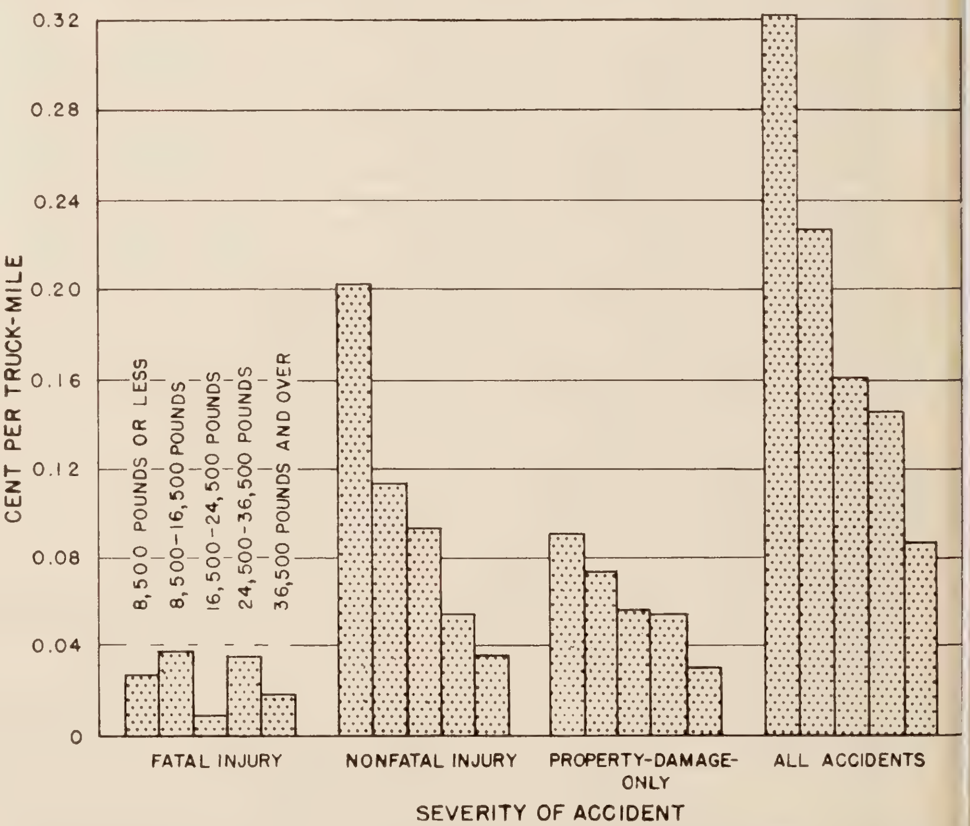


*Figure 3.—Comparison of accident costs per mile of travel by gross vehicle weight and severity of accident.*

# The Economic Cost of Traffic Accidents n Relation to Highway Planning

## and a Comparison of Accident Costs in Utah and Massachusetts

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TODAY, highway planners are seeking more scientific methods of evaluating xisting highways and designing and programg new facilities. The highway administraor and planner realize as never before the nportance of engineering tools that will ermit them to schedule construction on the asis of need, allocate highway funds on a riority basis, select additions to the highway ystems, change system classifications, select roper alternate routes or locations, and to ope effectively with public and private roups having vested interests in the processes f planning and programing.

Some States have employed sufficiency atings to assist them in accomplishing these bjectives. This method simply assigns a oint rating to each section of road according o its ability to provide traffic service in a afe and efficient manner. Other States have mployed economic analyses using factors such s highway costs, revenues, and benefits. n the main, this approach has been simplified o include only the benefit quotient which eflects primarily a savings to the motorvehicle user in operating cost and time through mproved alinement. Some States use both approaches.

In the methods generally in use, one imortant factor is too often omitted—traffic ccident rates. Some States incorporate accilent rates in their sufficiency ratings, but nore do not. It is known that sections of ighway having a good adequacy rating, as rovided by the sufficiency rating system, ometimes may have a high traffic accident requency.

Traffic accident rates normally are not inluded in economic analyses of the cost-benefit variety at all. The principal reason for the omission has been the unreliability of traffic accident data. Too many accidents are not reported; and for those that are, the reports often do not clearly indicate where the accidents occurred. But one of the greatest deterrents has been the lack of information on accident costs related to the types of vehicles, classes of highways, roadway features, types of accidents, and severity of accidents.

[1] Presented at the 39th annual meeting of the Highway Research Board, Washington, D.C., January 1960.

### *Application of Accident Cost Factor*

Traffic accident data should be one of the highway planner's most important tools to justify street and highway improvements. Just to illustrate this point, a traffic accident study was made on State Street in Salt Lake City. The study section, 17 blocks in length, carried over 30,000 vehicles daily. During a 3-year period, more than 1,000 traffic accidents occurred on this street, and over 700 of them took place at intersections. The street is a 6-lane divided roadway with parallel parking on each side.

It is estimated that had this traffic been carried on a street of freeway design, slightly more than 200 accidents would have been expected instead of 1,000. An Interstate System improvement is being planned to parallel State Street, and the portion paralleling the 17-block study section is expected to carry 100,000 vehicles daily by 1975.

According to the Utah accident cost study, the direct cost for passenger-car accidents occurring on major urban arteries was 0.49 cent per vehicle-mile. Using Utah study data, it was estimated that the direct cost of accidents on the Interstate System would be only 0.13 cent per freeway vehicle-mile. Thus, there would be a savings in accident costs of 0.36 cent per vehicle-mile on streets of freeway design. Based on an estimated traffic volume of 100,000 vehicles daily by 1975, the savings in accident costs would approach $330,000 annually.

The significant point is that an accident cost savings of such magnitude should not be overlooked in justifying an investment of $20 million, as would be required in constructing a freeway parallel to State Street. Furthermore, the savings figure is on the conservative side because it does not include indirect costs relating to traffic accidents.

In this analysis, the reduction in traffic accidents on freeways was based upon the California study [2] which indicated that there were five times fewer accidents on their freeways than on local streets. In addition, in the analysis, the accidents expected on the freeway were distributed as to type in accordance with those happening on the Detroit Expressway. This was done in order to isolate those types of accidents that could not occur on a freeway.

[2] *The Economy of Freeways*, by Lloyd Aldrich. City of Los Angeles, Street and Parkway Design Division, June 1953.

### *Utah and Massachusetts Results Compared*

The Utah State Road Commission has completed a study of the passenger-car phase of traffic accident costs. It was based upon passenger cars registered by the Utah State Motor Vehicle License Bureau in 1955. A sample was selected from the registration list, a universe of 268,000 passenger cars. The registration sample was deemed to be of sufficient size to satisfactorily approximate the general accident experience of the motoring public, but in order to obtain more detailed information on fatal and nonfatal injury accidents the State's accident files were sampled at a much higher rate than the registration list.

Only a small portion of the data collected in the Utah accident cost study is reported here, in tables 1–4, to provide a comparison of the number of traffic accidents and their costs in Utah and Massachusetts.[3] When comparing the values for the two States, it must be kept in mind that the base year of the Utah study was 1955, and for the Massachusetts study it was 1953. Since only a two-year difference was involved, no attempt was made to adjust the data to a common year.

The size of Utah is 82,346 square miles, whereas in Massachusetts the area is 7,867 square miles. In 1955, Utah had a population of 797,000; there were 268,000 registered passenger cars, 455,000 licensed drivers, 31,400 miles of highways and streets, and 2,523 million vehicle-miles of travel. During 1953, there were 4,773,000 persons living in Massachusetts, 1,239,000 registered passenger cars, 1,858,000 licensed drivers, 24,500 miles of highways and streets, and 11,628 million vehicle-miles of travel.

[3] A discussion of the Massachusetts data may be found in the article *The Economic Costs of Motor-Vehicle Accidents of Different Types*, by Robie Dunman, PUBLIC ROADS, vol. 30, No. 2, June 1958.

**Table 1.—Comparison of the number of motor-vehicle traffic accidents involving passenger cars in Utah during 1955 and in Massachusetts during 1953**

| Item of comparison | Number of accidents | | Percent of total | | Number of residents per accident | | Number of registered passenger cars per accident | | Number of licensed operators per accident | | Number of accidents per 100 million vehicle-miles of travel | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Utah | Mass. | Utah | Mass. | Utah | Mass. | Utah | Mass. | Utah | Mass. | Utah | Mass. |
| Severity of accident: | | | | | | | | | | | | |
| Fatal injury | 77 | 315 | 0.2 | 0.2 | 10,350 | 15,152 | 3,481 | 3,933 | 5,909 | 5,898 | 3.1 | 2.7 |
| Nonfatal injury | 9,048 | 33,270 | 19.0 | 25.3 | 88 | 143 | 30 | 37 | 50 | 56 | 359 | 286 |
| Property-damage-only | 38,453 | 97,951 | 80.8 | 74.5 | 21 | 49 | 7 | 13 | 12 | 19 | 1,524 | 842 |
| All accidents | 47,578 | 131,536 | 100.0 | 100.0 | 17 | 36 | 6 | 9 | 10 | 14 | 1,886 | 1,131 |
| Type of accident: | | | | | | | | | | | | |
| Passenger-car collision with— | | | | | | | | | | | | |
| Other motor vehicles | 29,044 | 109,730 | 61.0 | 83.4 | 27 | 44 | 9 | 11 | 16 | 17 | 1,151 | 943 |
| Pedestrians | 1,792 | 5,848 | 3.8 | 4.5 | 445 | 809 | 150 | 210 | 254 | 315 | 71 | 51 |
| Fixed objects | 741 | 7,260 | 1.5 | 5.5 | 1,076 | 654 | 362 | 170 | 614 | 255 | 29 | 63 |
| Other objects | 11,921 | 6,464 | 25.1 | 4.9 | 67 | 746 | 22 | 194 | 38 | 290 | 473 | 55 |
| Non-collision accidents | 4,080 | 2,234 | 8.6 | 1.7 | 195 | 2,170 | 66 | 563 | 112 | 845 | 162 | 19 |
| All accidents | 47,578 | 131,536 | 100.0 | 100.0 | 17 | 36 | 6 | 9 | 10 | 14 | 1,886 | 1,131 |

**Table 2.—Comparison of direct costs of motor-vehicle traffic accidents involving passenger cars in Utah during 1955 and in Massachuse[tts] during 1953**

| Item of comparison | Total direct cost | | Percent of total | | Total direct cost: Per accident | | Per capita | | Per passenger car registered | | Per licensed operator | | Per mile of road | | Per 100 millio[n] vehicle-miles of travel | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Utah | Mass. | Utah | Mass. | Utah | Mass. | Utah | Mass. | Utah | Mass. | Utah | Mass. | Utah | Mass. | Utah | Mass[.] |
| Severity of accident: | *($1,000)* | *($1,000)* | | | | | | | | | | | | | *($1,000)* | *($1,00[0])* |
| Fatal injury | 284 | 1,642 | 1.2 | 3.3 | $3,690 | $5,213 | $0.36 | $0.34 | $1.06 | $1.32 | $0.62 | $0.88 | $9 | $67 | 11 | 14 |
| Nonfatal injury | 11,559 | 28,688 | 49.5 | 57.1 | 1,277 | 862 | 14.50 | 6.01 | 43.13 | 23.15 | 25.40 | 15.44 | 368 | 1,171 | 458 | 247 |
| Property-damage-only | 11,506 | 19,894 | 49.3 | 39.6 | 299 | 203 | 14.44 | 4.17 | 42.93 | 16.06 | 25.29 | 10.71 | 366 | 812 | 456 | 171 |
| All accidents | 23,349 | 50,224 | 100.0 | 100.0 | 491 | 382 | 29.30 | 10.52 | 87.12 | 40.53 | 51.31 | 27.03 | 743 | 2,050 | 925 | 432 |
| Type of accident: | | | | | | | | | | | | | | | | |
| Passenger-car collision with— | | | | | | | | | | | | | | | | |
| Other motor vehicles | 17,401 | 41,816 | 74.5 | 83.3 | 599 | 381 | 21.83 | 8.76 | 64.93 | 33.75 | 38.24 | 22.50 | 554 | 1,707 | 690 | 360 |
| Pedestrians | 1,417 | 3,375 | 6.1 | 6.7 | 791 | 572 | 1.78 | .71 | 5.29 | 2.72 | 3.11 | 1.82 | 45 | 138 | 56 | 29 |
| Fixed objects | 271 | 3,023 | 1.2 | 6.0 | 366 | 414 | .34 | .63 | 1.01 | 2.44 | .60 | 1.63 | 8 | 123 | 11 | 26 |
| Other objects | 1,880 | 673 | 8.0 | 1.3 | 158 | 105 | 2.36 | .14 | 7.01 | .54 | 4.13 | .36 | 60 | 27 | 74 | 6 |
| Non-collision accidents | 2,380 | 1,337 | 10.2 | 2.7 | 583 | 608 | 2.99 | .28 | 8.88 | 1.08 | 5.23 | .72 | 76 | 55 | 94 | 11 |
| All accidents | 23,349 | 50,224 | 100.0 | 100.0 | 491 | 382 | 29.30 | 10.52 | 87.12 | 40.53 | 51.31 | 27.03 | 743 | 2,050 | 925 | 432 |

In comparing the accident rates and costs for the two States, it is quite evident that the results were influenced by such factors as population density, travel speeds, urban characteristics, etc. It is likely that many of the differences could be explained, but to interpret the accident experience of States so widely separated geographically and having such dissimilar characteristics is beyond the scope of this article. Population density alone would be a major factor to consider in any analysis of traffic accidents. In Massachusetts there were 596 persons per square mile, as compared with 10 in Utah.

In spite of the dissimilarities of the two States, however, there is remarkable consistency in the relative distribution of accidents when classified according to severity and type. The most common method of comparison is to express the number of accidents and their costs in terms of 100 million vehicle-miles of travel. This is done in the last two columns of the tables. In general, accidents were costlier in Utah than in Massachusetts, regardless of severity or type of accident or type of collision.

An attempt to draw conclusions on the basis of the data presented here for two strikingly different States would not be justified, but certainly the results add significantly to the knowledge needed to develop national trends of traffic accidents.

**Table 3.—Comparison of the number of collisions between passenger cars or passenger cars and other motor vehicles in Utah during 1955 and Massachusetts during 1953, classified by type of collision**

| Type of collision | Number of collisions | | Percent of total | | Number per 100 million vehicle-miles of travel | |
|---|---|---|---|---|---|---|
| | Utah | Mass. | Utah | Mass. | Utah | Mass. |
| Angle | 9,911 | 53,320 | 34.1 | 48.6 | 393 | 458 |
| Rear-end | 10,580 | 22,501 | 36.4 | 20.5 | 419 | 193 |
| Head-on | 1,117 | 12,789 | 3.9 | 11.6 | 44 | 110 |
| Sideswipe (same direction) | 2,394 | 7,114 | 8.2 | 6.5 | 95 | 61 |
| Sideswipe (opposite direction) | 755 | 1,486 | 2.6 | 1.4 | 30 | 13 |
| Turning movement | 1,876 | 4,752 | 6.5 | 4.3 | 74 | 41 |
| Parking maneuver and backing in traffic lane | 2,411 | 7,768 | 8.3 | 7.1 | 96 | 67 |
| All collisions | 29,044 | 109,730 | 100.0 | 100.0 | 1,151 | 943 |

**Table 4.—Comparison of direct costs of collisions between passenger cars or passenger ca[rs] and other motor vehicles in Utah during 1955 and Massachusetts during 1953, classifi[ed] by type of collision**

| Type of collision | Total direct cost | | Percent of total | | Average cost per accident | | Cost per 100 million vehicle-miles of travel | |
|---|---|---|---|---|---|---|---|---|
| | Utah | Mass. | Utah | Mass. | Utah | Mass. | Utah | Mass. |
| | *($1,000)* | *($1,000)* | | | | | *($1,000)* | *($1,000)* |
| Angle | 6,596 | 17,386 | 37.9 | 41.6 | $666 | $327 | 261 | 150 |
| Rear-end | 6,058 | 10,842 | 34.8 | 25.9 | 573 | 482 | 240 | 93 |
| Head-on | 1,834 | 9,078 | 10.5 | 21.7 | 1,642 | 709 | 73 | 78 |
| Sideswipe (same direction) | 1,157 | 1,958 | 6.7 | 4.7 | 483 | 276 | 46 | 17 |
| Sideswipe (opposite direction) | 351 | 706 | 2.0 | 1.7 | 465 | 471 | 14 | 6 |
| Turning movement | 486 | 1,114 | 2.8 | 2.7 | 259 | 232 | 19 | 10 |
| Parking maneuver and backing in traffic lane | 919 | 732 | 5.3 | 1.7 | 381 | 94 | 36 | 6 |
| All collisions | 17,401 | 41,816 | 100.0 | 100.0 | 599 | 381 | 690 | 360 |

# Automatic Time Recorder for Dual-Drum Paver Operation

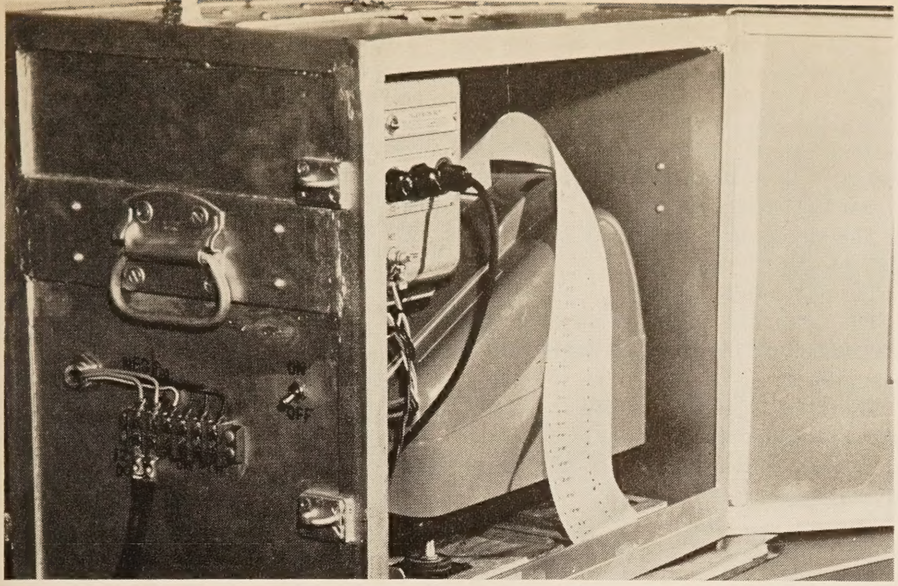

*Figure 1.—Kilrec Timer (with panel door open).*

)NE of the tedious tasks in research studies of portland cement concrete dual-um paver operation is stop-watch timing the paver cycle and mixing time. To do is job automatically, the Bureau of Public oads recently developed a device which easures the elapsed time, in hundredths of minute, of certain elements of the paver cle, and prints the data on paper tape. The vice, named the Kilrec Timer in recognition its co-developers, M. J. Kilpatrick and . N. Records, is assembled from commer-ally available components, including a inting timer, a suitable converter to provide 0-volt alternating current from the paver orage battery, and control circuits of relays, pacitors, and switches. The equipment is oused in a dustproof container with an ternal hookup panel. Intermittent demand r current is about 100 watts.

To operate the device, suitable switches, ired to the control mechanism, are attached the transfer and discharge chutes of the ver. Closing of the transfer chute or ening of the discharge chute actuates the propriate switch, which completes an ectrical circuit and thereby causes the timer record the time that has elapsed since the receding switch actuation. The elapsed time id an indication of which switch closed, is itomatically printed on a paper tape.

Figure 2 represents a section of tape, with terpreted data added on each side. On the pe itself, DT represents the closing of ie transfer chute, and the time recorded pposite the symbol is the time interval from ie opening of the discharge chute to the osing of the transfer chute. During this eriod only one batch is in the paver, in ther the first or second compartment of ie drum.

TD on the tape represents the opening of ie discharge chute, and the time recorded pposite this symbol is the time interval from ie closing of the transfer chute to the opening f the discharge chute. This is the period of multaneous mixing, when there is a separate batch in each of the two compartments of the drum. (The printing timer actually prints the digits 1 or 2 on the tape, but DT and TD are used in the illustration, with successively numbered subscripts, for clarity in the explanation that follows.)

Referring to figure 2, it may be seen how actual paver cycle time is derived from the tape. The first simultaneous mixing interval, $TD_1$, was 0.26 minute. The next time interval, $DT_2$, was 0.47 minute, and accounts for discharging time, transfer time, and any delay time in raising the skip. The sum of these, shown at the left of the tape, was 0.73 minute, and this was the time elapsed during that particular paver cycle.

The data in figure 2 were obtained on a paver whose batchmeter was set for a minimum mixing time of 0.90 minute (54 seconds) and a minimum paver cylce of 0.65 minute (39 seconds). From these values, it was calculated that the minimum simultaneous mixing time, TD, should be 0.33 minute and the minimum nonsimultaneous mixing time, DT, should be 0.32 minute. In the two columns at the extreme left of the tape, in figure 2, comparison is made of the actual elapsed time, as recorded, with these minimum values. For example, $TD_1$, recorded on the tape as 0.26 minute, was 0.07 minute less than the minimum value of 0.33 minute. Minus signs indicate that the actual elapsed time was shorter than should be expected with the batchmeter setting; plus signs indicate longer elapsed time—that is, delays.

The total mixing time of each successive batch passing through the paver can also be derived from the data printed on the tape. The first batch recorded in figure 2, for example, entered the first compartment when the transfer chute closed, at the point in time represented by $DT_1$. It had been mixing 0.26 minute when the discharge chute opened ($TD_1$) to discharge the preceding batch from the second compartment. Mixing continued for the batch in the first compartment while discharge was underway. By the time the transfer chute had opened and closed again, shifting the batch from the first to the second compartment, at $DT_2$, another 0.47 minute had elapsed. When the discharge chute again opened, at $TD_2$, beginning discharge of the batch into the bucket, 0.32 minute more had elapsed.

The total elapsed time recorded for this batch was $0.26+0.47+0.32=1.05$ minutes. However, from this total must be deducted the time lag between the moment of the first transfer chute closing and the entry of all solid material from the skip into the first compartment. This averages about 0.08 min-

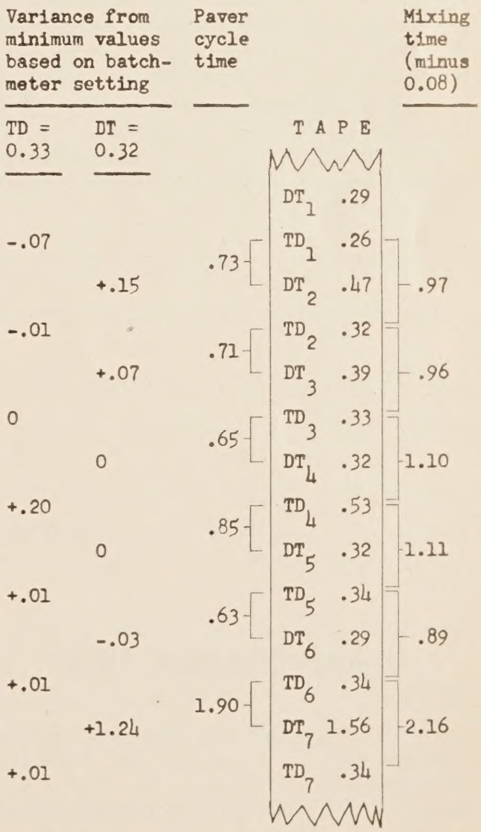


*Figure 2.—A sample tape recorded by the Kilrec Timer, with interpreted data added.*

ute. Hence the mixing time of this batch was 1.05−0.08=0.97 minute, as shown at the right of the tape in figure 2.

From the illustration it can be seen that three batch mixing times, 0.97, 0.96, and 0.89 minute, were only a few seconds off the batchmeter set time. It will be noted, however, that there was considerable compensating fluctuation in the individual elapsed times of the three stages composing the total mixing time. The long mixing times of the third and fourth batches, 1.10 and 1.11 minutes, were due to the 0.20-minute delay in $TD_4$. In this step of the paver operation, the delay must have occurred in opening the discharge chute. The last batch illustrated had a mixing time of 2.16 minutes, due to the 1.24-minute delay in $DT_7$. This delay, which must have occurred in raising the skip, resulted in a mixing time almost 2½ times the batchmeter setting.

It is evident from this explanation of the data that can be derived from the Kilrec Timer tape, that the device readily produces the following information:

1. The mixing time for individual batches of concrete.

2. The paver cycle time.

3. The frequency and duration of delays, and whether they occur at the skip or at the discharge chute.

4. The location of the individual batches, insofar as mixing time is concerned, in relation to other batches produced during the period that the timer is attached to the pave

While the Kilrec Timer was developed f use in research, it could also readily be en ployed, either by the contractor or the co tracting authority's inspector, and either c the job while the paver is operating or late for purposes of checking the operation of t paver and comparisons of actual with specifie mixing time.

Details as to the components and circuitr used in building the Kilrec Timer may l obtained by writing to the Highway Nee and Economy Division, Bureau of Publ Roads, Washington 25, D.C. The cost the components and materials used in t recorder built by Public Roads was approx mately $900, of which $750 was for t printing timer.

## The Economic Cost of Traffic Accidents in Relation to the Highway Systems

(*Continued from page 43*)

traffic, there was some variation from the 1955 curves. Values on the uncontrolled-access highways were somewhat lower than the curve in this volume range. One explanation for this may be that the over-crowding of the uncontrolled-access roads actually tends to prevent certain types of collisions.

Data for only one section of the controlled-access highways in this high volume range were available—Route 128, a section of the northern circumferential highway near Boston. This section of highway, although opened in 1952, has been reaching capacity and it is now being improved to higher standards. The accident rate on this highway section was 161.7 accidents per 100 million vehicle-miles in 1957. This was double the rate in 1953—accident costs per mile had increased from $19,100 in 1955 to $30,100 in 1957. When improvement of this section is complete there should be, without doubt, a reversal o the upward trend.

In summation, it may be stated that th low accident rates and costs on the controlled access highways are consistent with previou findings. These highways most certainl contribute their part in maintaining a com paratively low accident rate on the Stat highways in the Federal-aid primary system

## Highway Statistics, 1958

The Bureau's *Highway Statistics, 1958* is now available. The bulletin, the fourteenth of an annual series, presents the 1958 statistical and analytical tables of general interest on motor fuel, motor vehicles, highway-user taxation, State and local highway finance, highway mileage, and Federal aid for highways.

Included in the 1958 bulletin are motor-vehicle travel data for 1957 and 1958, data on contract bid prices for rural Federal-aid highway construction, and mileage data and status of the National System of Interstate Highways. In addition, there is included the status of the Highway Trust Fund, which gives the contributions and expenditures o a current basis.

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