AN ACCIDENT EVALUATION ANALYSIS

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This analysis of accidents is motivated by a need to evaluate and compare the effectiveness of traffic controls at intersections and thereby develop new traffic control warrants. The purpose of this paper is to obtain a quantitative means of comparing accident histories at intersections. An attempt is made to recognize the fact that accident frequency alone is not adequate and can be misleading in making this comparative judgment; hence, the severity and type of accident are incorporated in this analysis. Based on cost figures gathered from several published studies, accident severity weightings are obtained. An accident evaluation index and accident evaluation factors are then computed by using percentage distribution of accidents by type, that is, pedestrian, right-angle, rear-end, left-turn, and all others. The accident evaluation factors are multipliers that, when applied to an accident history profile for an intersection, yield a single figure of merit.

THE NUMERICAL BASIS for accident analysis is the overall costs caused by accidents. Cost evaluation depends not only on the frequency of accidents but also on the severity and type of accidents. For example, upgrading a traffic control, say from a sign to a signal, may in fact result in an increase in the frequency of accidents at the intersection. However, the upgrading may still be warranted if the degree of severity is reduced. This would be reflected in a decreased total cost of accidents, if accident severity is appropriately considered in the cost assignments.

The ultimate objective is to obtain a more valid assessment of the role that accidents should play in the determination of traffic control warrants and to aid in the comparative analysis of various traffic control devices. A consequent purpose is to determine the form and type of accident data that should become part of the signal warrant specifications. For example, in addition to accident frequencies, the need for data on the type and severity of accidents can be specified.

This paper presents cost studies to determine the range of values for fatal, injury, and property-damage-only (PDO) accidents. A discussion of the cost elements and differences in estimation is a necessary part of this summary. These severity cost values differ for rural and urban cases and are further analyzed by type. Then, severity values are summarized and representative values chosen. The analysis by type is based on the following accident categories: right-angle, rear-end, left-turn, and pedestrian. From this analysis, an accident evaluation index is produced that yields a figure of merit for accidents at an intersection based on accident history.

The extreme difficulty of determining the cost of accidents, or of even defining what costs should be included, is well known. Two aspects of the problem, determination of cost elements and assignment of dollar estimates for these cost elements, must each be considered in turn.

COST ELEMENTS

A number of classification schemes and cost breakdown techniques have been proposed (1). For example, there are direct and indirect costs, user and societal costs, on-site and off-site costs, present and future costs, and tangible and intangible costs.

Publication of this paper sponsored by Committee on Traffic Control Devices.

These schemes are further complicated by the fact that the individual categories are not easy to separate. The task of determining reliable cost figures relative to any scheme faces the additional problem of lack of data. For the present purpose, the only practical approach is to tailor accident costs from previous studies to fit our present needs.

Most accident studies have generally emphasized user costs such as property damage, medical expenses, legal and court costs, and wages lost because of lost work time. The justification for these particular cost items is that they are readily available in most cases. Furthermore, for the majority of accidents, these costs usually represent a high percentage of the total costs. However, this is not the case for accidents involving fatalities. Here, a wide disparity of estimates exists because of differences in the cost elements included.

In most studies reported in the literature, cost items are summarized in three categories: PDO, injury, and fatalities. The unit costs that have been given for these three categories will form the basis for the estimates used herein.

An initial and significant problem in the analysis of previous work in this area is that frequently the results are not comparable. There are a number of reasons for this. First, the unit cost values are sometimes given per accident and other times per involvement. The number of involvements in a given accident is the number of individual vehicles involved in an accident. Furthermore, the individual cost elements included vary from one study to another even though both are based on the same classification scheme. For example, nonreported accidents are included in some studies and not in others. The ratio of total cost for all accidents to reported cost varies, in one study from 1.541 for rural accidents to 1.848 for urban accidents (2). For PDO accidents the corresponding ratios are 3.233 and 3.972 for urban and rural accidents respectively. In this paper, data will be given on a per-accident basis inasmuch as this is the more easily used form.

In the case of fatalities and some injury accidents, cost estimation differences occur for a number of reasons. Estimation of net present worth or probable future income is an involved computation affected by the procedure used and by the subjective assumptions made. For example, future income has been predicted by using an average income rate for the remaining working years and also by using predicted yearly incomes. Discounting of future incomes will yield different results for these two cases. Inclusion or omission of funeral costs is another factor that will alter the final estimates. Finally, for a valid comparison, all cost estimates must be updated to the same time.

In the following section, a number of accident study results will be summarized. These form the basis for the cost estimates used in the accident evaluation index.

ACCIDENT COST STUDIES

Unless otherwise stated, the costs considered in these studies are the value of damages and losses to the motor vehicle owner and to persons injured in an accident, which would not have occurred without the accident.

Illinois Study

In the Illinois study (2), the cost items include property damage, treatment of injuries, loss of use of the vehicle, value of time lost, legal and court expenses, and damages awarded in excess of known cost. The property damage costs account for the damage to the vehicle and the property within as well as for the damage to objects struck by the vehicle. Injury treatment includes ambulance costs, doctor and dentist fees, and hospital and treatment costs, but excludes funeral costs. Damages awarded refers to settlements in or out of court for amounts in excess of known costs and may include some direct costs and, possibly, some amount for past or future loss of income. These excess awards do not duplicate known costs accounted for elsewhere.

A major difference between the results of this study and others lies in the fatal injury class of accidents. The Illinois study did not include the loss of future earnings as an element of direct cost. The value of work time lost only includes gainfully employed persons. This cost item is the single most important component in total costs in fatal accidents.

Table 1 gives the total costs for urban intersection and nonintersection accidents relative to the unit costs that have been itemized for the 1958 Illinois study.

The figures shown for cost per accident are computed from the total costs and number of accidents. For PDO accidents, nonreported accidents are included in the total number of accidents; however, nonreported costs are not. The total PDO figure is approximately $92 million. The information used is from a secondary source (1) and differs somewhat from results given elsewhere for the same data. For example, in NCHRP Report 130 (3) the corresponding figures on cost per accident are $5,242 for fatal, $821 for injury, and $100 for PDO accidents. The values reported are averages for both urban and rural accidents and may differ on other grounds as well.

These values present a rough cost framework for these three types of accidents. More pertinent to our purposes is a breakdown of rural and urban intersection accidents for these three accident categories (Table 2).

Note the consistently and significantly high values in all accident categories as compared with Table 1. This may be accounted for by the fact that a large proportion of intersection accidents involve at least two vehicles. The figures used in Table 2 were computed from figures obtained in 1958 and updated to 1966 by a factor of 1.25 (1).

The figures given in Table 2 include both truck and passenger car accidents. In regard to the differences in urban and rural cost values, it should be noted that Illinois state law requires the reporting of all fatal and nonfatal injury accidents and PDO accidents of $100 or more. In Chicago, however, it is required that PDO accidents of $50 or more be reported.

The rate of accidents based on exposure cannot be determined from these tables because neither the number of intersections nor the traffic volumes are known. It has been determined, however, in the Illinois study that accidents are more costly as the number of traffic lanes increases. The probable explanation is that the number of involvements per accident increases as the number of lanes increases. The Illinois study does show that for all highway types there are more vehicles involved in an accident on the average in urban traffic than in rural traffic. However, the Illinois statistics show that for intersection accidents the involvement rate is about the same (1.696 for urban traffic and 1.719 for rural traffic).

Washington, D.C., Study

The report of the Washington study (1964-65) uses involvements rather than accidents. Vehicle involvement is classified by the severity of the accident rather than the severity applicable to each vehicle involved. Thus, a vehicle may be included in the fatal category because it was in a fatal accident even though no one may have been injured in the vehicle and little or no cost may have been incurred. One cost element in this study not included in the Illinois report is the net present worth of probable future earnings, which amounted to almost 91 percent of the total cost figure in the case of fatal accidents. The future earnings were computed by using an average rate of income for each fatality for all the remaining expected working years. Another method would be to use an income for each year. In either case, this task involves consideration of differences in individual earning power as a function of age, sex, race, employment status, and level of education. In addition, estimation of work-life-spans must be made. Particular problems are encountered when areas such as housewife services and maintenance costs for accident victims are evaluated.

The study uses a 4 percent discount rate per year to compute these future earnings. Subsequent studies (4) have suggested that this rate is too low and also that damage awards and the full cost of funeral expenses should not be included. Table 3 gives the values obtained from these data under these three viewpoints. When these are compared with the urban area figures from the Illinois study, the results are similar only in the injury case. The major difference in fatality values is the inclusion of lost future earnings, and the primary reason for difference in the PDO category is that the Washington, D.C., study used only reported accidents whereas the Illinois study included all accidents, both reported and unreported. If it is assumed that there are 1.2 fatalities per fatal accident, then the per-accident cost of a fatal accident is given as

$71,400 (4). These differences give some indication that the cost of traffic accidents cannot be assigned specific values. Cost estimates and results often reflect subjective feelings and inadequate statistical data.

Texas Study

A recent study by the Texas Transportation Institute (5) uses cost data developed in other states and studies (Illinois 1958, Massachusetts 1953, New Mexico 1955-56, and Utah 1955-56) to develop a method for estimating Texas accident costs. The cost estimates are per involvement and include property damage, medical costs, legal and court fees, values for loss of work time and loss of vehicle use, damages awarded in excess of costs, and, for fatalities, the present value of expected future earnings. Frequency data for involvements and accidents were obtained for reported Texas accidents in 1969 and used to develop weights to apply to the cost data. Fatal accident costs are obtained by adding direct costs and a value for the loss of future earnings. The results are given in Table 4. Differences between Table 3 and Table 4 are probably attributable to the per-accident as opposed to per-involvement tabulation and the use of highway data.

A cost breakdown of particular interest that is obtainable from this report is in terms of head-on, rear-end, angle, sideswipe, and turning accidents. These values are given in Table 5. A very rough rank ordering, excluding pedestrian accidents, indicates that head-on accidents are most costly, followed by angle accidents. Rear-end and turning accidents are next, and sideswipes are the least costly among these categories.

Societal and Intangible Costs Study

A recent study (6) attempted to define and estimate in economic terms the losses in "societal welfare" or "level of social well-being." The categories included in this analysis are property damage, medical costs, productivity costs, insurance administration, losses to other individuals, employer losses, funeral costs, community service losses, pain and suffering, and miscellaneous accident costs. The breakdown does not separate rural and urban accident experience. It is to be pointed out that current data are inadequate for precise estimation of these costs; thus, $234,960 for a fatality, $11,200 for an injury, and $500 for a PDO accident must be considered as gross estimates.

Other studies have attempted to include the intangible and noneconomic losses due to accidents in the analysis of highway improvement projects (4, 7). A calculation for a particular highway project (4) leads to a value of $550,000 for intangible costs necessary to make the net benefit zero. Widerkehr's approach (7) depends on fractional reductions in accidents attributable to a given safety improvement. He classifies accidents into two categories: fatalities and/or injuries and PDO. Fatalities and injuries are combined because fatality sample sizes are too small for reliable estimation and because fatalities can be regarded as random events among injury accidents. A formula is developed for the total economic gain or the total calculable dollar benefit from a given highway improvement.

Crash Damage Study

A recent study (8) was conducted by Allstate Insurance, Kemper Insurance, Liberty Mutual Insurance, and State Farm Mutual Insurance Companies, in cooperation with the American Mutual Insurance Alliance, in which detailed information was analyzed on 89,060 crash repair estimates on a nationwide basis. A number of significant results have been established for the cost distribution of repairs. The average repair bill was $321. Different patterns of cost are noted for property damage liability claims as opposed to collision claims because car owners generally pay for damage below $50 or $100 collision deductibles. Thus, collision claim averages tend to be higher. For our purposes, the values obtained for liability claims are more appropriate. Interesting is the distribution of repair costs by point of impact on the vehicle. The frequency of claims and the average repair cost are given for various points of impact. Some general findings that can be deduced are that about 70 percent of all crash damage occurs at either the front or rear end and front-end damage is generally more costly. Further analysis indicated that front- and rear-end involvements occur with about equal frequency in low-speed crashes.

Other Sources

Other sources of cost information that have been investigated include the National Safety Council (NSC) statistics, insurance agencies such as the Insurance Information Institute (I.I.I.) and the Insurance Services Office, and legal sources.

NSC statistics were examined from a number of council publications (9, 10). The latest information obtained (1971) gave the following cost breakdown: fatal, $52,000; injury, $3,100; and PDO, $440.

I.I.I. (11) used NSC figures on traffic deaths, but all other figures such as number of traffic injuries, number of traffic accidents, and economic losses are based on its own projections. The figures are computed by using a sampling of state traffic accident reports and include all injuries and accidents whether on private roads and property or on public streets and highways. The figures for 1971—$48,115 for a fatality, $2,850 for an injury accident, and $570 for a PDO accident—include adjustments for the cost-of-living index and the general price level. It should be noted that these values include wage loss, medical expense, property damage, and insurance administrative costs for insurance companies and self insurers. This latter cost is the difference between premiums paid to insurance companies and the claims paid by them.

I.I.I., which is a public relations and educational organization sponsored by the insurance industry, also publishes a yearbook of insurance facts. In the 1972 edition (10), average paid claim costs for injury and PDO accidents are $1,923 and $345 respectively. These data were obtained from the Insurance Services Office. This office provides rating and statistical services to insurers and other organizations based on a compilation of insurance coverage and claims paid as filed by participating companies.

A legal source of data on accident costs was sought to ascertain unit cost estimates from the viewpoint of the courts. Statistical data have been compiled and categorized in a series of handbooks (13) to indicate the average jury-verdict award for a wide variety of injury and fatality accidents. The "verdict expectancy for injury" values are determined from a data base consisting of more than 75,000 court cases. Most of these cases are automobile accident cases, but industrial accidents are also included. The tabulations are made by state and county. Although the data are not summarized in a form suitable for our needs, they could be. This would represent a significant data bank for future investigations and could provide a more definitive basis for estimating injury and fatality costs, including the "pain and suffering" element, as currently judged by juries throughout the country. This is not to claim that these are the "true" societal values of injuries and fatalities, only that they form a numerical data base that indicates trends and can serve to supply much needed data in this area. Although this source was not pursued further, it was determined that tabulations do exist for automobile court case histories under a number of different categories, including but not limited to the following: intersection collisions, pedestrian hit by car, and rear-end, head-on, change-of-lane, passing-vehicle, and speeding collisions.

ACCIDENT EVALUATION INDEX

The summary of cost studies presents the background and state of the art in this area of investigation. It will be used as a basis for the development of a quantitative figure of merit or index to aid in the evaluation of accidents as it affects the decision-making process inherent in the definition of traffic signal warrants. For this purpose our main interest is the relative numerical weight to apply per accident to each of the accident categories in the traffic signal warrant decision process. The accident cost study results given in economic terms will thus be used to yield pure number "weightings" (which will not be interpreted as dollar values).

Accident Severity Weightings

Table 6 gives the relevant accident severity cost figures as given in the unit cost study, which are generally comparable in that losses due to work time lost are included

Table 1. Urban accident costs for Illinois.

Accident Severity	No. of Accidents	No. of Involvements	Total Cost (dollars)	Cost per Accident (dollars)
Fatal	536	690	2,908,590	5,426
Injury	92,509	144,863	79,569,672	860
PDO	809,855	1,227,952	92,422,214	114

Table 2. Intersection accident costs for Illinois.

Area	Accident Severity	No. of Accidents	Cost per Accident (dollars)
Urban	Fatal	247	7,272
	Injury	53,579	1,633
	PDO	287,641	165
Rural	Fatal	191	9,330
	Injury	6,630	1,490
	PDO	23,420	255

Table 3. Cost (in dollars) per involvement for Washington, D.C.

Accident Severity	Original Study (4 Percent Discount Rate)	Damage Awards and Funeral Costs Deleted	
		4 Percent Discount Rate	10 Percent Discount Rate
Fatal	47,481	47,000	20,300
Injury	863	770	740
PDO	193	193	193

Table 4. Cost (in dollars) per accident for Texas.

Accident Severity	4 Percent Discount Rate	10 Percent Discount Rate
Fatal	50,227	29,927
Injury	1,917	1,917
PDO	334	334

Table 5. Cost (in dollars) per accident at 4 percent discount rate.

Study	Cost Unit	Accident Severity		
		Fatal	Injury	PDO
Washington, D.C.	Involvement	47,481	863	193
Texas	Accident	50,227	1,917	334
Societal (6)	Accident	234,960	11,200	500
NSC	Case	52,000	3,100	440
I.I.I.	Case	48,115	2,850	570

Table 6. Accident severity cost summary (in dollars).

Accident Severity	Accident Type					
	Head-On	Rear-End	Angle	Sideswipe	Turning	Pedestrian
Fatal	58,116	53,693	55,013	54,399	51,842	46,879
Injury	3,341	1,932	1,873	1,302	1,875	1,433
PDO	595	310	405	246	321	–
All	3,500	700	900	400	700	5,100

Table 7. Percentage of accidents by vehicle movement.

Accident Type	Vehicle Movement	Fatal Accidents		All Accidents	
		Urban	Rural	Urban	Rural
Right-angle	Entering at angle	12.4	9.5	17.4	9.3
Rear-end	Both going straight	0.4	0.4	3.0	0.8
	One turn, one straight	0.4	0.5	3.5	3.3
	One stopped	0.3	0.5	5.1	2.4
	All others	–[a]	0.1	0.9	0.7
Left-turn	One left, one straight	3.3	1.5	5.1	2.5
All others	Both going straight	1.2	0.6	1.1	0.4
	All others	0.1	0.1	0.4	0.4

[a] Less than 0.05 percent.

Table 8. Severity rates and accident evaluation indexes by urban and rural accident types.

Accident Type	Urban				Rural			
	Fatal	Injury	PDO	Accident Evaluation Index	Fatal	Injury	PDO	Accident Evaluation Index
Pedestrian	0.0188	0.9812	–	3,390.0	0.0727	0.9273	–	5,950.0
Right-angle	0.0010	0.0700	0.9290	690.0	0.0069	0.1380	0.8551	1,120.0
Rear-end	0.0001	0.0070	0.9930	520.0	0.0014	0.0280	0.9706	630.0
Left-turn	0.0009	0.0630	0.9360	670.0	0.0041	0.0820	0.9139	870.0
All others	0.0012	0.0840	0.9150	730.0	0.0059	0.1180	0.8761	1,030.0

and the same discounting rate (4 percent) appears to have been used. Note, however, that the values quoted are not all updated to the present. Because we seek only general estimates, reflecting relative magnitudes, this disparity is not significant. For a fatality the weight assignment W_F will be 50,000/accident. A value of 200,000/accident can be considered an upper bound value if a range of values is desired. These values for W_F are convenient and generally conservative if the costs are updated to present values. For injury accidents, 10,000/accident delimits the upper end of the range. To arrive at a weighting value for injuries, W_I, requires that the figures all be in terms of per-accident values because the involvement rate per accident for injuries is approximately 1.8. (For fatalities, this rate is usually taken to be 1.2.) With this value, the Washington, D.C., figure becomes $1,553. Using this result, together with the other values given in Table 6, gives a weighting value of 2,500/accident for an injury accident.

For PDO accidents all five values in Table 6 can be used to yield a single value, W_P, if the Washington, D.C., value of $193 is converted to a per-accident value of $328 by using an involvement-per-accident rate of 1.7. Although the average property damage value obtained after this adjustment is $434, we will use a weight of W_P = 500/accident, which reflects the more recent estimates that tend to be higher. Thus, W_F = 50,000, W_I = 2,500, and W_P = 500. These values will now be transformed into cost-per-accident values for accidents categorized by type. This will permit, for example, distinguishing accident characteristics of different traffic signal control types, in particular, between stop sign control and traffic signal control.

Analysis of Intersection Accidents

From past experience it appears that the most significant change in accident history at an intersection after a change in control type is the relative increase in the frequency of rear-end accidents and relative decrease in angle and head-on accidents. This basic assumption requires that costs be stratified for these two accident types.

In this analysis intersection accidents will be classified into the following categories: right-angle, rear-end (including sideswipes), left-turn, pedestrian, and all others. These categories have been selected because it is felt that, if differences in signal control type affect accidents, distinct differences in the distribution of these types of accidents will be observed. This will constitute a more detailed evaluation of the relation of accidents to traffic control changes than merely differences in the total number of accidents.

If we use NSC figures for 1970, the percentage of fatal pedestrian accidents relative to all pedestrian accidents is approximately 1.9 for urban accidents and 7.3 for rural cases. It will be assumed that all other pedestrian accidents involve negligible property damage; therefore, 98.1 and 92.7 percent are injury producing for the urban and rural cases respectively. Therefore, the accident evaluation index for urban and pedestrian accidents is (0.019)(50,000) + (0.981)(2,500) = 3,403, and for rural accidents it is (0.073)(50,000) + (0.927)(2,500) = 5,968.

For right-angle, rear-end, left-turn, and all other accidents, values from the directional analysis and accident by selected movement table for fatal and all accidents, published by NSC (9), were combined. The directional analysis breakdown for intersection accidents used in this publication closely matches our categories. However, for rear-end accidents we have combined all the accidents described as "entering intersection same direction." The "all other" category includes accidents involving two vehicles entering from opposite directions and both going straight. Intersection accidents involving non-motor vehicles such as trains or bikes and collisions with fixed objects in the road have been omitted.

The portion of the directional analysis table used is given in Table 7. (The percentages in each column add to 100 in the full table, which includes nonintersection accidents as well.) Thus, for example, the values in the column designated fatal urban accidents represent the percentage of all fatal urban accidents that occurred at the given location and for the given vehicle movement. If f represents the percentage of fatal accidents for a given set of conditions as shown in Table 7, t represents the percentage of all accidents under the same conditions, and n_f, n_t represent the number of fatal and all accidents for the given conditions, then the percentage of fatal intersection accidents for each type of vehicle movement is $(f \times n_f)/(t \times n_t)$ where $n_f = 16,300$ and $n_t = 11,500,000$ for the urban case and $n_f = 30,500$ and $n_t = 4,500,000$ for the rural case.

To obtain the relative percentages of injury accidents for each type of vehicle movement, we used NSC figures for the number of nonfatal injuries per death (10), i.e., 70 and 20 nonfatal injuries per death for urban and rural accidents respectively. It is recognized that these figures are for all accidents, including nonintersection accidents; however, they are adequate for our purposes of obtaining approximate weighting factors. (Because an average injury weight has been approximated, an average ratio is appropriate to approximate the offsetting effects of higher ratios and lower average costs.) All other accidents (neither fatal nor injury producing) are then assumed to be PDO accidents.

The resulting severity rates and accident evaluation indexes for the five types of accidents are given in Table 8. The indexes are obtained by multiplying the rates by the appropriate accident severity weights—W_F, W_I, and W_P.

More simply, the following factors can be used to convert an accident history profile of an intersection to a figure of merit. For an urban intersection the factors are 6.5, 1.3, 1.0, 1.3, and 1.4 for pedestrian, right-angle, rear-end, left-turn, and other accidents respectively; for rural intersections, the factors are 9.4, 1.8, 1.0, 1.4, and 1.6 for pedestrian, right-angle, rear-end, left-turn, and other accidents respectively. The values of the accident evaluation index are intended to serve as a means for combining accident history distributions into a single figure of merit. Subsequent analysis will relate this figure to different traffic control types by using accident profiles obtained in an accident survey.

As an illustration, suppose the accident profiles for a common time period at two given urban intersections are 0, 3, 5, 2, and 2 and 2, 1, 3, 2, and 1 for pedestrian, right-angle, rear-end, left-turn, and all other accidents respectively. The two figures of merit are then

$$0(6.5) + 3(1.3) + 5(1.0) + 2(1.3) + 2(1.4) = 14.3$$

and

$$2(6.5) + 1(1.3) + 3(1.0) + 2(1.3) + 1(1.4) = 21.3$$

Thus, the accident impact appears more severe at the second intersection even though it has had fewer accidents.

Initial application of these factors to accident records has indicated that although signalization may show an increase in accident rates, this is usually offset by a reduction in the figure of merit or "disutility" value per accident leading to no significant change in total accident-related disutility.

ACKNOWLEDGMENT

This work was sponsored by the American Association of State Highway Officials, in cooperation with the Federal Highway Administration, and was conducted under the National Cooperative Highway Research Program. The opinions and conclusions expressed or implied in the report are those of the research agency and not necessarily those of the sponsoring agencies.

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