CONCERNING THE RELATION BETWEEN THE COST OF TRAFFIC ACCIDENTS IN A PARTICULAR COMMUNITY AND THE CONDITIONS THEREIN

BY

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Every event is part of a sequence; it is preceded by causes and followed by consequences. Accidents are no exception: they have causes, they are no longer thought of as just "happenings," and they certainly have consequences. It is their consequences, measured in cost, with which casualty companies are primarily concerned. The usual method of rating is based upon cost, that is upon "experience." Because cause and effect are, however, bound together so closely, it should be possible to make rates in terms of causes as well as in terms of consequences. This is just what has been done in workmen's compensation insurance through schedule-rating and in the field of fire insurance the rates are even more largely based upon an analysis of causes, that is upon the conditions that exist in the particular building and in the particular community. Whether schedule-rating is possible in the field of automobile insurance is wholly a practical question. It will be worthwhile, however, in any case, to see what the problem looks like and an analysis of the hazard may be valuable in various other ways, such as in the grading of cities, even if it may not be feasible when applied to rating.

Rating in terms of consequences, that is in terms of experience, is the more direct and to that extent the more trustworthy method. This, however, is its only advantage. Rating in terms of causes, while more difficult and undoubtedly considerably less accurate, has all the other points in its favor.

First, it is a more effective measure of the hazard. The great disadvantage of rating in terms of experience comes from the fact that time is required for the experience to develop and mature and become incorporated in the rates; as a consequence there is a lag of approximately three years between the time when the accidents happen and the time when the rates that are based upon these accidents come into actual use. On account of this lag the rates will never be exactly right unless conditions are stationary. If conditions are growing worse the rates will be too low and the companies will lose money. If conditions are improving the rates will be too high.

It is important to have a rating system that can meet changes in conditions immediately. Suppose a change of administration in a city has resulted in a twenty-five per cent reduction in the number of traffic police or in any one or more of a dozen other things that would produce adverse traffic accident conditions. Under the present method of rating by experience nothing could be done to modify the rates so as to meet this condition short of about three years. Under a schedule-rating plan, however, an adjustment of the rate could be put into effect immediately. Since rates are affected by conditions, rates, if they are to be responsive to conditions, should be made in terms of conditions.

Second, it has greater preventive effect. Insurance companies are interested in prevention, not merely because the loss-ratio must be kept from going up if the companies are to make money, but also because low-rated business is preferable from every point of view. While rates made on the basis of experience have some preventive effect the lag between a change of conditions and the corresponding change in the rates is so great and the relation between the rate and the cause is so indirect and obscure that the connection is lost sight of and largely disregarded by the insured, and the argument that preventive activities will eventually show in the rates has little effect in producing results. On the other hand, through schedule-rating the effect on the rates of the setting up or abandonment of such activities can be made immediate and peremptory. Schedule-rating is generally acknowledged to have been the most powerful influence in the early development of the industrial safety movement and it has certainly played an enormously important role in the control of the fire hazard.

The third advantage of rating in terms of causes is due to the fact that it is a better basis for understanding and cooperation on the part of the public. People feel instinctively that insurance companies should concern themselves with prevention and the more closely such work is tied in with the business of the individual company the more effective it will be in securing the good will and cooperation of the public. Schedule-rating, furthermore, brings the selling end of the business actively into the field of prevention.

The disadvantages of schedule-rating are as follows:

First, even under the best conditions it is a far less accurate measure of the cost than rating in terms of experience.

Second, it is far more expensive. The services of an engineering corps are needed in order to determine the conditions upon which the rates are to be based. There can be no saving by abandoning the present collection of cost data for these must still be had for checking purposes. Preventive activities have, however, in general, more than paid for themselves and this would undoubtedly be the case here.

Third, the difficulty of setting up and administering a satisfactory system of schedule-rating for automobile insurance would undoubtedly be very great; there would probably be considerably greater difficulties than in the case of either workmen's compensation insurance or fire insurance, where the conditions are in general more tangible and hence more susceptible of analysis. Whether these difficulties are prohibitive is a practical question that can be answered only by a thorough study of the situation. The first step in such a study must be an actuarial analysis of the problem.

The Actuarial Problem: To develop a formula for the pure premium for a given territory in terms of conditions in that territory.

Let $\pi =$ the pure premium.

$N =$ number of car-years.

$n =$ number of accidents during N car-years.

$m =$ number of units of car-use per car-year.

$\Delta t =$ length of unit of car-use, where Δt is sufficiently small so that not more than one accident is physically possible during that time. Just as the tossing of a die represents the unit of exposure in regard to the possible throwing of a six-spot, so the unit of car-use represents the unit of exposure in regard to having an accident.

$T = m \Delta t$ or length of time car is in use per car-year.

$\Delta p =$ probability of accident during a unit of car-use.

$q = 1 - \Delta p$.

$P =$ limiting value of $\frac{\Delta p}{\Delta t}$ as Δt approaches O.

$K =$ cost of accidents during N car-years.

$C =$ average cost per accident.
$s_j =$ proportion of accidents of severity j.
$c_j =$ average cost of an accident of severity j.
$S =$ average severity of all accidents.

$$V = \text{index of claim cost} = \frac{C}{S}.$$

$\pi = \frac{K}{N}$. If the value of π were to be obtained retrospectively then K and N would be gotten directly from the experience. When π is to be obtained prospectively, that is in terms of conditions, then K must be analyzed into elements that can be expressed in terms of the conditions in the territory.

During the mN units of car-use the probabilities of $0, 1, 2, \cdots\cdots (mN - 1), mN$ accidents will be given by the corresponding terms in the expansion of $(q + \Delta p)^{mN}$, and n, the expected number of accidents, will be equal to the sum of the expectations got by multiplying each of these terms by the corresponding number of accidents. This, by the application of a well-known theorem, will be seen to equal $mN\Delta p$.

$$\therefore n = mN\Delta p \text{ and since } K = nC, \therefore K = mN\Delta pC,$$

and $\pi = \frac{K}{N} = \frac{mN\Delta pC}{N} = \Delta pmC$.

$\pi = \Delta pmC$ may be written in the form

$$\pi = m\Delta t \cdot \frac{\Delta p}{\Delta t} \cdot C = T \cdot \frac{\Delta p}{\Delta t} \cdot C.$$

$\Delta p/\Delta t$ is what is called, or what may be called, the average density of probability during the time Δt. Instead of agreeing on some finite value of Δt, it is more practical, since we have made no limitation on the smallness of Δt, to let Δt become infinitesimal, m at the same time becoming infinite, then $\Delta p/\Delta t$ takes the form of a differential quotient and approaches a limit P, which may be called the instantaneous density of probability. Then $\pi = TPC$. While there is no theoretical reason why P in general should be considered constant, we may, from a practical point of view in this case, consider it so to be.

To analyze C, accidents must be classified as to severity. On the basis of a standardized appraisal of the cost of each type of accidents, such cost being the fair, average compensation for each type of injury, all types of accidents can be grouped in classes, so arranged that the average cost so determined of the accidents in class j will be j times the similar cost of accidents in Class 1. This classification of accidents is irrespective of conditions in the given territory.

The average cost of an accident for the given territory, or C, will then be

$$C = s_1 c_1 + s_2 c_2 + \cdots + s_j c_j + \cdots$$

In this expression claim cost and severity are intermingled. It is possible to separate these elements by writing C in the following form:

$$C = \frac{s_1 c_1 + s_2 c_2 + \cdots + s_j c_j + \cdots}{s_1 + 2s_2 + \cdots + js_j + \cdots} \cdot (s_1 + 2s_2 + \cdots + js_j + \cdots)$$

The expression $s_1 + 2s_2 + \cdots + js_j$ is S, the average severity of accidents in the given territory, each accident being evaluated according to the standardized scale.

The first factor, $\frac{C}{S}$, is V, the index of claim cost for the territory in question; it is namely the ratio of the actual average cost of all accidents in the given territory, the cost of each accident being the amount actually paid, to the average cost of the same accidents when evaluated in terms of the standardized scale.

$$C \text{ then} = VS \text{ and } \pi = TPC = TPSV.$$

Now let us consider each of these four factors separately.

(1) T, the length of time a car is in use per car-year, serves in effect as an index of car-use in the given territory. It depends upon various conditions in the territory, for instance the climate and the temperament and economic status of the people. The fact that T is in the formula has no importance from a preventive point of view and it is important only as an element in the correct measurement of the hazard. There would seem, therefore, to be no point in trying to evaluate it in terms of conditions in the state and community other than by means of the statistical facts regarding actual use of cars.

(2) P, the density of probability of an accident, is the element

in the formula which is most significant from a preventive point of view and we are therefore particularly concerned with those elements in P that will have to do with controllable conditions. However, all conditions must be brought in and these may be classified as follows:

(a) Causes characteristic of or under control of the state.
(b) Causes characteristic of or under control of the community.
(c) Causes characteristic of or under control of the individual.
(d) Causes having to do with the car.
(e) All other causes.

We have assumed that during the unit of exposure not more than one accident is physically possible. The probability of an accident during the time Δt will then be the sum of the probabilities for each of these five causes, and therefore the density of probability will be the sum of the five densities.

For the particular purpose in view, which is a schedule-rating on the basis of state and community conditions, we may consolidate the last three of these five densities of probability into one, namely the density of probability of accident from all causes other than those having to do with the state and the community. It is probably not feasible and it is certainly not desirable in this particular inquiry to deal with the condition of the individual car or with the hazard of the individual driver. The condition of cars in general will come up in considering the probabilities for state and community in the form of whether or not there are state or municipal inspection stations and similarly for the hazard of drivers in general in the given territory. The three elements of the probability of an accident that should be considered in this kind of a study are therefore (1) the probability due to conditions in the state, (2) the probability due to conditions in the community and (3) the probability due to all other conditions.

Now each of these three probabilities will be in turn the sum of a number of different probabilities, each of these secondary elements being the measure of the effect of a particular contributory cause. The recognition of these various causes and the determination of their relative importance forms one of the two major steps in the practical problem of setting up a schedule-rating plan. Some of the causes that can be readily seen to be operative in the case of state conditions are general underlying conditions involving topography, climate, character of population, etc., conditions regarding the licensing of drivers and conditions regarding enforcement such as existence of highway patrols.

Some of the causes that will be operative in the case of the community involve degree of traffic congestion, traffic engineering conditions, law enforcement conditions and conditions in regard to safety education.

It will be evident that this reasoning is based on the assumption that an accident has only one cause. That of course is contrary to fact; every accident is undoubtedly due to the coexistence of many causal conditions. If the subject were to be analyzed from this point of view it would, however, become an extremely difficult problem in multiple correlation and probably beyond the possibility of practical analysis. It would furthermore almost certainly be beyond the point of practical application in the formulation of a schedule-rating plan. We are therefore, by the practicalities of the situation from both an analytical as well as an administrative point of view, forced to assume, at least in general, that the causes will be uniquely operative as well as disjunctive. It must be remembered that we shall possess only the most primitive means of measuring the effect of causes and a schedule-rating plan must of necessity therefore be only a rough affair at best.

(3) S, the average severity of accidents in the given territory, depends upon various local conditions, notably whether the territory is rural or in the city, severity in general being larger in rural areas on account of higher speeds. To some extent S may depend on claim conditions, for bad claim conditions may result in the faking of accidents or in exaggerating their severity. S is a function of a number of variables but the nature of the function is problematical and is a matter for further study.

(4) V is an index number expressing claim conditions in the territory. It evidently will involve such conditions as methods of choosing juries, activities of Bar Associations and other similar matters. If conditions in the territory are normal V reduces to C_1. V will depend upon a number of variables but the nature of the function is problematical, and this also is a matter for further study.

A mathematical formula serves two purposes. First, it gives the form in which the variables go together and second, where the values of the parameters are known, it leads to a numerical result. In the present case and in all similar analyses, as for instance in the field of experience rating and schedule rating for workmen's compensation insurance, the values of the parameters are not known and the sole value of the analysis lies in the determination of the form of the function. There still remains then the problem of determining the values of the parameters and also the form in which they are to be expressed in terms of conditions in the given territory. T can be obtained statistically but P, S and V, each separated into its various elements, must be obtained through trial and error.

If rate-making in terms of conditions in the given territory can be made to work it should entirely supersede the system of making rates in terms of experience, in other words the two systems are alternative, not supplementary, but all the basic experience that is used in the old system must now be used for checking purposes in the determination of the proper weights to be given to the various elements in the new system and for a continuing check-up throughout. The process of obtaining the values in detail for P, S and V is far the largest part of the job, and whether this can be carried out successfully is exactly the crux of the problem.

It is to be noted that the expression for π is not given in the form of a deviation from a norm but is built up from the ground. Most schedule-rating, however, takes the form of a departure from a base rate. The formula, $\pi = TPSV$, or any similar formula for any other schedule-rating problem, may be made to take such a form by application of Taylor's theorem,

$$f(x+\Delta x, y+\Delta y, \cdots) = f(x, y, \cdots) + \frac{df}{dx}\Delta x + \frac{df}{dy}\Delta y + \cdots + \text{higher powers.}$$

In the present case the development is as follows:

$$\pi = \pi_0 + P_0 S_0 V_0 \Delta T + T_0 S_0 V_0 \Delta P + T_0 P_0 V_0 \Delta S + T_0 P_0 S_0 \Delta V + \cdots$$

$$\text{or } \pi = \pi_0 \left(1 + \frac{\Delta T}{T_0} + \frac{\Delta P}{P_0} + \frac{\Delta S}{S_0} + \frac{\Delta V}{V_0}\right) + \text{higher powers,}$$

where π_0 is the base rate and T_0, P_0, S_0 and V_0 are the values of the corresponding parameters.

This formula shows that the rate corresponding to a given departure from the base rate is had by increasing the base rate by a percentage that is got by adding together the percentage changes in the parameters. It may be noted in passing that the same thing holds true in the case of schedule-rating in fire insurance, since here also the pure premium is the product of factors, in this case expressing (1) the probability of ignition, (2) the probability of combustion and (3) susceptibility to damage.

It may be worthwhile to illustrate the application of this formula by an example. Suppose the basic pure premium is taken to be twenty-five dollars and suppose in the given territory that the index of use of the car is ten per cent less than normal, that is ten per cent less than the condition to which the base rate corresponds, suppose, however, that the probability of accident is fifteen per cent greater, the severity five per cent greater and the index of claim conditions ten per cent greater, then the corresponding value of the pure premium will be $(-10+15+5+10)$ per cent, that is twenty per cent, greater than the basic pure premium and the pure premium will therefore be thirty dollars. The neglect of higher powers in this case has affected the result by less than half of one per cent.

The simplicity of this final formula is encouraging, although the critical question, which involves a world of study and trial, is the determination of the structure and values of P, S and V. It may be remarked again that all that the formula $\pi = TPSV$ indicates is that these four quantities, T, P, S and V, stand in a multiplicative relationship to each other; it gives no clue to their make-up in terms of the causal conditions in the territory. This, therefore, marks only the beginning; it does, however, show the fundamental relationships and it shows what still needs to be done.