AUTOMOBILE HAZARD IN CITY STREETS

The Basic Cause of its Variation, and Indicated Measures for its Reduction

by

William Junkin Cox, B.A., B.S. in C.E.

An Essay Presented to

The Faculty of the School of Applied Science,

Washington and Lee University,

in Candidacy for the Degree

of Civil Engineer

1928

Note:

This essay is a revision and enlergement of "Automobile Hazard in Cities and its Reduction", by William J. Cox, published in the Proceedings, American Society of Civil Engineers, April, 1927.

Preface

This paper is an attempt to approach the automobile accident problem from a new angle. Efforts at the prevention of these accidents have very generally been directed at what have seemed to be the immediate causes of the accidents - speeding, and other forms of reckless driving, mechanical imperfections in automobiles and roadways, etc.

As between the different cities of the United States, however, there are such great differences in the hazard involved in driving an automobile that it seems impossible to account for them on the basis of any of the surface factors in accident production. The hazard of automobile operation seems to go back to some more fundamental and less obvious thing. To show what this thing is, and to point out some conclusions based on a knowledge of it, is the purpose of this study.

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Part I. The Automobile Accident Problem

From the date when the automobile first made its appearance on the streets of this country, it has been subjected to legal restriction, in the interest of the safety of the public. In the very early days the principal hazard in automobile use lay in its frightening horses, and the first restrictions had this possibility in mind. But as the horse became accustomed to the new invention and lost his fear of it, these early restrictions were gradually allowed to lapse, and others of a different nature replaced them.

For with the rapid increase in automobile use, the number of traffic accidents and fatalities soon rose to a level where it began to attract attention. Restrictions designed to curb this rising hazard were then enacted. During some years, the growth of these regulations was a local and rather haphazard affair. There was little interchange of ideas on the subject between different communities. Each locality felt its own problem, and individually set out to solve it, without other help. This continued to be the case until after the World War and the period of business depression which followed it in 1921.

About 1922 a very decided change began to make itself felt in this situation. The number of automobiles in the United States, which was less than five million in 1917, had increased by 1922 to nine million. With this increase, the number of deaths caused by automobiles had risen from about eight thousand in 1917 to about twelve thousand in 1921. Automobiles were fast becoming the leading factor in causing accidental deaths in this country, and the problem of automobile hazards was coming to be recognized as a national one.

A very energetic response met this recognition. Prior to this time, except for local police departments and state motor vehicle departments already established by Connecticut, Maryland, Massachusetts and New Jersey with fairly wide powers of regulation, there was no agency very actively interested in the prevention of traffic accidents.

By 1928 this situation had changed in many ways. The number of states exercising a supervision over automobile operation by licensing all resident drivers had increased to sixteen. In most of these states, licenses were granted only after examination of applicants as to driving ability and knowledge of motor vehicle laws, and the licenses were made revocable by the state authority for what it might consider fair cause. Police chiefs from all over the country had met in conferences to discuss what they felt to be primarily their problem. Realizing that the problem was too broad, however, to be solved by the police authorities alone, the Secretary of Commerce of the United States had called two National Conferences on Street and Highway Safety. Committees of these conferences had met over periods of months and had drafted exhaustive reports which received wide circulation throughout the country. The National Safety Council, which had been doing effective work in the field of industrial accident prevention for some years prior to 1921 had enlarged its scope to include the field of public safety and was working through local safety councils in almost every large city. The automobile clubs had become interested in the matter, and were making efforts to increase care in driving on the part of their members, and to secure the passage of legislation curbing reckless motorists. The association of automobile manufacturers was devoting considerable effort toward accident prevention. Safety features such as four-wheel brakes had been built into the automobiles themselves. The companies writing automobile accident insurance had flooded their policy-holders with pleas and directions for safe driving. The public schools had considered the new hazard as it affected their pupils, and were making efforts in many cities to counteract it through various programs of "safety education". The railroads of the country had made a determined effort to reduce grade crossing accidents. Cities had installed a wide variety of mechanical devices for regulating and safeguarding traffic. Highway commissions had widened roads, flattened curves, reduced crowns and eliminated grade crossings. Practically every newspaper in the country had repeatedly published editorials about the accident problem. The President of the United States had called solemn attention to the need for a safer highway traffic. Efforts had been made to make "Safety first" a national slogan.

One would naturally expect that this tremendous amount of effort should have had a correspondingly great effect in reducing automobile deaths.

> Since this effort began, the rate of increase in automobile fatalities has been greater than during any other equal period of time since the automobile was invented.

The number of persons killed annually by automobiles in the United States has doubled since 1921. If present trends continue it will not be many years before it will have doubled again, and our automobiles will then be killing as many Americans each year as were killed in all the battles of the World War.

The growths in automobile registrations and in automobile fatalities during recent years are shown in Fig. 1, a and b. Fig. 1, c, correlates these growths and makes clear the most disquieting fact in all this situation: that within the last year we seem to have reached a condition where for the first time in two decades, automobile fatalities are increasing as fast or faster than automobile registrations.

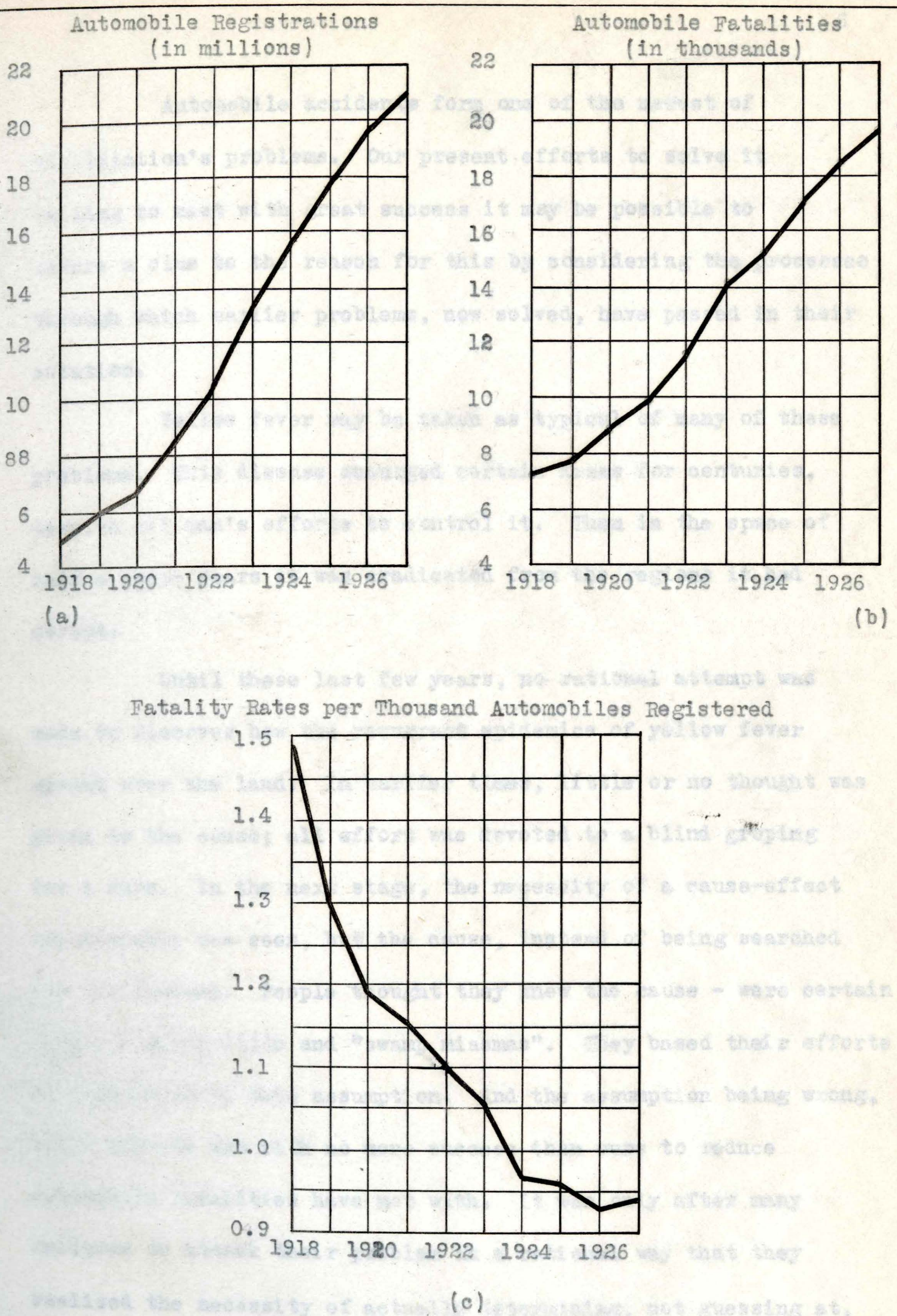

Fig. 1.- Growth in Automobile Registrations and Fatalities and Trend in Fatality Rate per Thousand Cars Registered, 1918-1927, Inclusive, United States Registration Area.

Automobile accidents form one of the newest of civilization's problems. Our present efforts to solve it failing to meet with great success it may be possible to secure a clue to the reason for this by considering the processes through which earlier problems, now solved, have passed in their solution.

Yellow fever may be taken as typical of many of these problems. This disease scourged certain areas for centuries, despite all man's efforts to control it. Then in the space of half a dozen years it was eradicated from the regions it had cursed.

Until these last few years, no rational attempt was made to discover how the recurrent epidemics of yellow fever spread over the land. In earlier times, little or no thought was given to the cause; all effort was devoted to a blind groping for a cure. In the next stage, the necessity of a cause-effect relationship was seen, but the cause, instead of being searched for was assumed. People thought they knew the cause - were certain that it lay in filth and "swamp miasmas". They based their efforts at prevention on this assumption. And the assumption being wrong, their efforts met with no more success than ours to reduce automobile fatalities have met with. It was only after many failures to attack their problem in a rational way that they realized the necessity of actually determining, not guessing at, the cause of epidemics. With activity at last directed into the proper channel the cause was found, corrected, and the epidemics ceased.

Up to the present time, our traffic administrators and accident preventionists are still very largely in the "swamp miasma" stage. Their efforts are all directed towards a "cure" for automobile accidents. Remedies are what they are interested in - not causes. The causes are simple - everyone knows them. The cure is the thing. It hasn't been found yet, but it is being found. Why quibble about the cause?

And so we have the situation where not one of the great traffic conferences which has been held to consider automobile accidents has undertaken to learn what fixes the level of accident hazard where it stands in any city. It is even extremely doubtful if more than a negligible proportion of those attending the conferences have been aware of the fact that it is twice as hazardous to drive an automobile in New York city as in Jersey City, just across the river; and fifty per cent more hazardous in Jersey City than in Newark, in the adjoining county. They probably have not known that the average car goes three times as long without an accident in Chicago as in New York, and twice as long in Indianapolis as in Chicago.

If these facts had been realized, it seems impossible that the reason underlying them should not have been sought. And if the reason were sought, it was clearly not to be found in the things usually thought of as controlling driving hazards.

For the variations which exist, as between our cities, in the hazard of driving an automobile cannot be accounted for on the basis of any of the things usually thought to be important in determining hazard levels. Neither differences in climate nor topography, vehicular congestion nor vehicle speeds, methods of traffic regulation nor attitudes of citizens towards law, foreign elements in population nor activities of safety organizations - none of these things nor any combinations of them, would make possible the variations in driving hazard which are to be found.

So long as we continue to attempt the prevention of accidents without being able to account for these differences, we are in much the same case as were those who attempted the eradication of yellow fever without knowing the medium through which its infection spread.

The first logical step in the prevention of automobile accidents is the discovery of what governs traffic hazards. When we can say definitely and surely why it is much more dangerous to operate an automobile in Providence than in Chicago, or in Boston than in Baltimore, then and then only can we know whether or not the steps being taken for the prevention of automobile accidents are logical. To find the factors which underlie and control these variations in hazard is the first problem which confronts us in this field.

Before this problem can be attacked with any good prospect of its solution, it must be somewhat narrowed down. Automobile accidents occur in city streets and on country roads, and the circumstances attending accidents of the two classes are so different that it is wise to treat each class separately. Accidents occurring in city streets account for the greater part of automobile injuries and deaths.* This discussion will relate only to them and this fact must be carefully kept in mind.

Furthermore the harm from automobile accidents is of two kinds. It may be damage to property, or it may be injury to person. Some accidents cause one, some another, and some cause both simultaneously. The number of accidents which cause damage to property runs very far in excess of those which cause personal injuries. In New Haven, Connecticut, in 1926, for instance, 1835 accidents caused property damage in excess of ten dollars each and only 855 caused personal injuries.

But investigation has shown that each personal injury was at least six times as serious, in dollars and cents, as was each damage to property, or in other words, three-fourths of the total loss from automobile accidents was in the form of personal injuries.

The problem of hazard variation is much simplified by considering these two types of harm separately, because the variation from city to city in the risk of doing property damage is not the same as the variation in the risk of causing personal injury. Thus, from a personal injury standpoint,

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*For instance, in Massachusetts, where automobile accident statistics are unusually complete, approximately 80 per cent of the fatal automobile accidents and 75 per cent of all those causing personal injuries in 1926 are found to have occurred in cities.

it is three times as dangerous to drive a car in New York as in Chicago, but from a property damage standpoint, it is only twice as dangerous. And whereas the hazard from a personal injury standpoint of driving an automobile in Los Angeles is only one fifth as great as in New York, from a property damage standpoint the hazard is about one third as great. Quite evidently, there is some difference in the factors which determine the property damage hazard from those which determine the personal injury hazard. Since this is so, the two hazards can best be treated separately. This discussion will relate only to the more important of them, the personal injury hazard of driving.

With the field of investigation narrowed down in this way, the next step is to get clearly in mind what will be meant when either of the expressions, "automobile hazard" or "hazard of driving an automobile" is used.

The accidents which result from the use of automobiles may be related to either one of two denominators. One of these is the general public which suffers the accidents. The accident rate may be expressed as so many "per hundred thousand population" for instance. On the other hand, the same accidents may go to make up a rate of so many accidents "per thousand cars in use". These are two quite different aspects of the same accidents.

In discussions of the seriousness of the automobile problem, the automobile death rate in terms of population is generally used. This is correct because this seriousness bears a relationship to the proportion of the population killed rather than to the number of automobiles which did the killing. In discussing why the death rate is what it is, however, the ratio of automobiles to population cannot be neglected. Los Angeles, with one car to each two or three persons, would be expected to have more automobile fatalities in proportion to population than New York with one car to each twelve persons. What is not necessarily expected is that New York, instead of having one-fifth as many fatalities in proportion to population as Los Angeles, has one half as many; in other words, that the death rate per automobile is three times as great in New York as in Los Angeles.

This is the significant fact in the problem, because so far as can now be foreseen, the use of automobiles will increase for many years to come. It is quite possible that no one now living will see the day when there will be fewer automobiles than there now are. Since this is so, a reduction in the annual number of automobile accidents can come about in only one way - by reducing the hazard involved in the operation of the average car.

The hazard with which this discussion will deal, then, is the hazard per car. It will not be the risk of being injured to which the public is subjected by the automobiles in use on the streets of cities. It will be the risk of injuring someone to which the driver of an automobile is subjected by the act of driving. This also should be carefully kept in mind as this discussion proceeds.

The question may well be raised at this point why, if the problem under consideration is to be limited by excluding property damage, it should not be further limited to fatal accidents only. These are the accidents which individually are by far the most serious. Moreover, just as property damage hazard is found to follow a different law of variation from that of personal injury hazard, so also the variation in the fatality hazard of driving an automobile is found to be different from either of the two other hazards.

There are sound reasons for not making this further limitation. It would be interesting to know why automobile fatalities vary as they do. It is much more important, however, that we should find a means of controlling personal injuries, (which include fatalities at their upper limit). It was noted previously that both individually and collectively personal injuries from automobile accidents are more serious than property damage, and therefore more entitled to study. But fatal accidents, while individually they are much the most severe, comprise such a small percentage of the whole number of accidents which cause personal injury, that the total loss due to them is far from being the major part of the personal injury accident toll. In cities, about ninety-seven per cent of the personal injuries caused by automobiles are not fatal. When it is considered that many of these injuries require months for recovery, and that some are permanent, it is easy to realize the possibility that the million non-fatal injuries which may be expected to occur during this year may well give rise to a greater amount of human suffering and loss than will the twenty-five thousand fatalities which may be expected.

A second reason of a practical nature makes it advisable, if not necessary, to discuss primarily the personal injury and not the fatality hazard. The procedure which will be followed in this study will be first to set forth the problem; namely, to find the cause of the great variation in the hazard of driving an automobile in different cities. Secondly, this problem will be attacked from a theoretical standpoint. An expression will be found for the determinants of hazard in a city in which, for purposes of mathematical treatment, certain unreal assumptions are made. Third, it will be shown to what extent the determinants found to control hazard in the hypothetical city also control the hazards which actually exist in cities of the United States. This third step will be carried out by setting up the variation, from one city to another, in driving hazard as called for by the theoretical expression, and likewise the variation in hazard which actually exists, and comparing the two variations.

This procedure makes it necessary that the actual variation in the hazard of driving an automobile in different cities should be known.

At first glance, this requirement would seem automatically to limit the discussion to fatal accidents, since the Census Bureau is the only official agency collecting automobile accident statistics for the entire United States on a comparable basis, and its statistics include fatal accidents only. When, however, it is attempted to use the Census figures for this purpose, it is very quickly found that they do not lend themselves to it. The Census Bureau is interested primarily in the location of each death. Reports come to it from the medical examiners of the various cities, townships and counties, and cover all deaths which occur in those political divisions, irrespective of whether or not the accident which caused the death occurred within that same division, or outside of it. It has been shown that in the case of some cities with good hospital facilities, more than half of the automobile deaths credited to those cities by the Census Bureau were the result of accidents which occurred in adjacent suburban or rural districts. This situation has caused a great deal of dissatisfaction on the part of such cities, and in response to this, the Census Bureau for the last year or two has been making an effort to record also the place of occurrence of the accident, and to tabulate separately the automobile deaths in a city from accidents which also occurred within that same city. But these tabulations all contain a warning that this effort has met with doubtful success.

Moreover, if the Census figures for fatalities were to be used, they would have to be correlated with the registrations of automobiles in the different cities, to express the fatality rate per automobile, or per hundred automobiles in use. Probably in a majority of cases, it is impossible to secure accurate figures for the registration of automobiles in cities, since the registration of automobiles is a state rather than a city function.

Consequently, there is no means of expressing with any degree of certainty the variation from city to city in the fatality hazard of driving an automobile.

There is, however, the means of expressing quite satisfactorily the variation in the personal injury hazard of automobile operation. Besides the Census Bureau, there is one statistical organization interested in automobile accidents the activities of which cover the entire United States. This is the National Bureau of Casualty and Surety Underwriters, an organization created and maintained by the larger automobile insurance companies for the purpose of studying their pooled loss experience and promulgating the insurance rates which they all use. The thirty or more companies supporting this Bureau write the very great majority of all the automobile accident insurance written in this country. Loss reports sent to the Bureau cover all the large cities of the country on an entirely comparable basis. The automobile public liability insurance*

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* Public liability insurance protects the owner of an insured car from legal liability for any personal injuries to others than occupants of his car which operation of that car may cause.

rates based on them afford a very good reflection of the personal injury hazard of driving an automobile in any of those cities. Consequently, the variation in rates affords a very good measure of the variation in hazard, and provides the yardstick which this discussion needs.**

This variation in rates will almost certainly not be a perfect measure of the variation in hazard. It is the result of human effort, which is apt to be in error. But it is also the result of a very carefully worked out procedure, planned to express as truly as it can be done the actual variation in liability hazard, which is much the same as the variation in personal injury hazard. In isolated cases, the rates may be too low or they may be too high, but if it is realized that they are being used in this discussion as an approximate guide, there is no reason why any positive indications they give cannot be accepted. It is altogether probable that the variation in the personal injury hazard of driving an automobile in different cities is very close to the

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** The writer bases the above statement on his personal knowledge as a former employee of the National Bureau of Casualty and Surety Underwriters, familiar with the rate-making process. This process, the fundamental of which is simply the comparison of the actual losses sustained in a given community with the premiums paid in, carries many refinements to eliminate the effects of chance, etc., so that a discussion of it requires considerable space. Such a discussion, together with a discussion of the criticisms which might be made against the use of these rates as a measure of hazard variation, is given in Appendix A.

variation in the rates charged for public liability insurance.

The variation in these rates for the larger cities of the United States is shown in Fig. 2

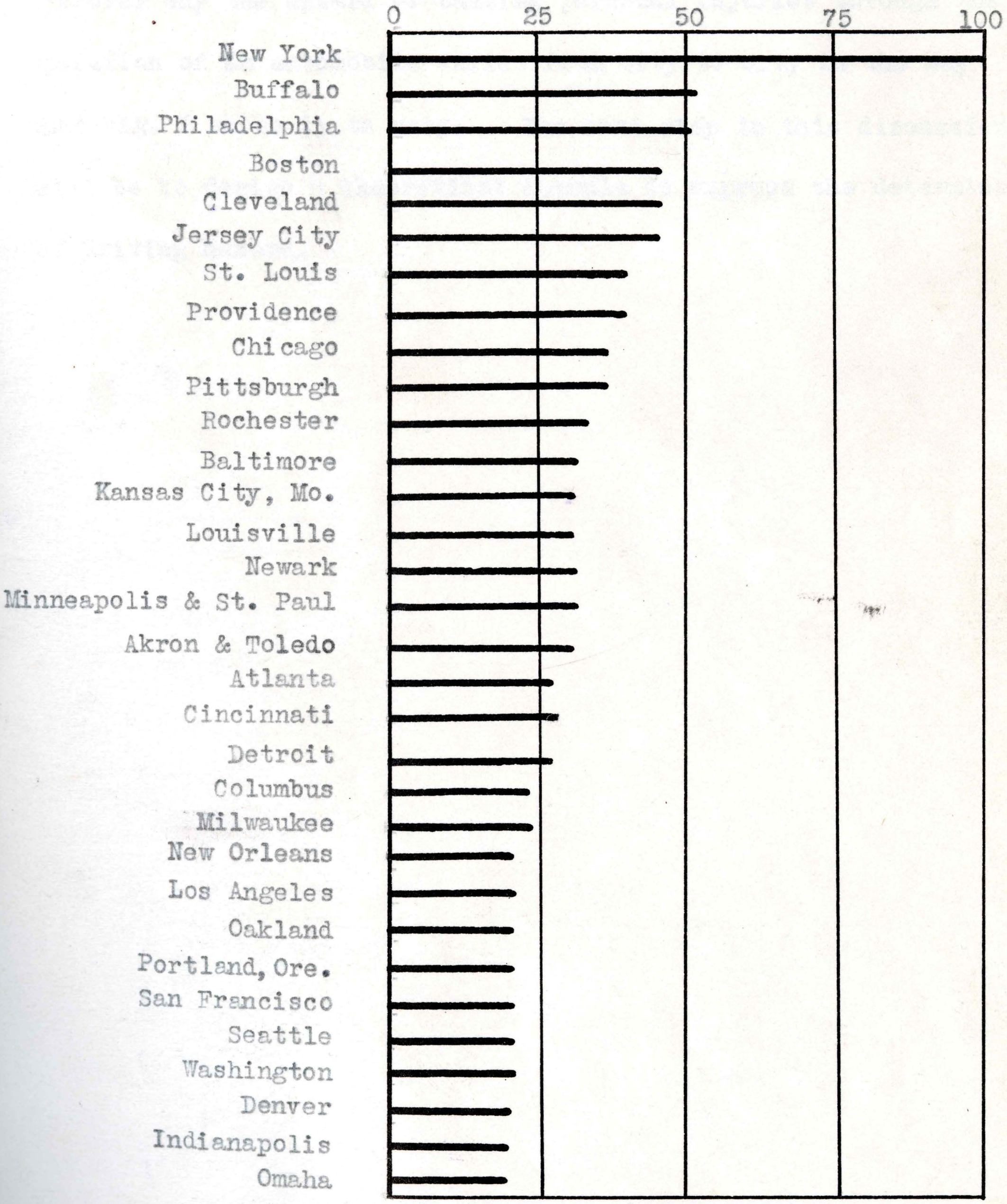

Fig. 2 - Variation in the Personal Injury Hazard of Automobile Operation, as Measured by Variation in Public Liability Insurance Rates.

The preceding pages have summarized the automobile accident problem in the United States and have gone to tiresome but nevertheless necessary lengths in the formulation and definition of the first logical step in attacking it; namely, to discover why the hazard of causing personal injuries through the operation of an automobile varies from city to city in the way that Fig. 2 shows it to vary. The next step in this discussion will be to derive a theoretical formula to express the determinants of driving hazard.

Part II. Theory of the Hazard Involved in Automobile Operation

For purposes of analysis, imagine a city in which traffic, both vehicular and pedestrian, is distributed uniformly over the entire street mileage, all paved; in which no automobile accidents occur except collisions of automobiles with other automobiles and with pedestrians; in which all automobiles are of the same type, and are the only vehicles in use; and in which the percentage of automobiles in use at any given time is the same as the percentage of the population using the streets as pedestrians at that same time.

Let H = the hazard that results from the annual use in this city of the average automobile (average in respect to total annual mileage, maintenance, and driving skill).

h = the hazard that results from operation of this automobile through a unit distance.

h_a and h_p = the components of this hazard that relate to collisions with other automobiles and with pedestrians, respectively.

Then,

$$h = h_a + h_p$$

Let M = the street mileage of the city.

P = the population of the city.

R = the number of automobiles registered in the city.

a = the average number of occupants of each automobile in use.

p and r = the number of pedestrians and of automobiles, respectively, that the average automobile passes from any direction in traveling a unit distance.

As pedestrians and automobiles are uniformly distributed over the streets of the city, $p \propto \frac{P - aR}{M}$ and $r \propto \frac{R}{M}$.

As every time an automobile passes a pedestrian or another automobile, there is danger of a collision, obviously, $h_p \propto p$ and $h_a \propto r$.

Then,

$$h_p \propto \frac{P - aR}{M}, \text{ or } h_p = k_1 \frac{P - aR}{M}$$

and,

$$h_a \propto \frac{R}{M}, \text{ or } h_a = k_2 \frac{R}{M}$$

k_1 and k_2 being constants.

And,

$$h = k_1 \frac{P - aR}{M} + k_2 \frac{R}{M}$$

Let,

$$\frac{k_2}{k_1} = w$$

then,

$$h = k_1 \frac{P - aR}{M} + k_1 \frac{wR}{M}$$

or,

$$h \propto \frac{P - aR + wR}{M}$$

or,

$$h \propto \frac{P + (w - a)R}{M}.$$

Also,

$$H \propto h;$$

then,

$$H \propto \frac{P - (w-a) R}{M}$$

Traffic counts taken in various cities of the United States show that the average number of occupants in each automobile is very close to 2. This value will therefore be assumed for a in the assumed city.

The symbol, w, represents the ratio, $\frac{k_2}{k_1}$, these constants being used in the equation,

$$h = k_1 \frac{P - a R}{M} + k_2 \frac{R}{M}$$

As,

$$h_a = k_2 \frac{R}{M}$$

and,

$$h_p = k_1 \frac{P - a R}{M}$$

$$\frac{h_a}{h_p} = \frac{k_2 R}{k_1 P'}$$

in which, $P' = P - a R$.

Now the relative importance, $\frac{h_a}{h_p}$, of the hazard of collisions between two automobiles as compared with the hazard of collisions of an automobile with a pedestrian depends jointly on the relative severity and the relative frequency of these two types of collision. As regards severity, a somewhat larger proportion of collisions with pedestrians results fatally than is the case with collisions between two automobiles. But when two automobiles collide with enough force to cause any personal injuries to the occupants, almost always more than one person is hurt, the average being nearer three. Investigation of about fifteen hundred accidents has shown about the same indemnity resulting from a collision with a pedestrian as from a collision between two automobiles, and it appears that little error is introduced by considering that on the average a collision of either type does very nearly the same amount of personal injury.

Hence the relative importance of these two classes of collisions may be said to vary as their relative frequencies, or

$$\frac{h_a}{h_p} = \frac{f_a}{f_p}$$

in which, f_a and f_p represent the two frequencies. Equating the two values of $\frac{h_a}{h_p}$,

$$\frac{k_2 R}{k_1 P'} = \frac{f_a}{f_p}$$

or,

$$\frac{k_2}{k_1} = \frac{f_a}{f_p} x \frac{P'}{R} = w$$

The next step is to consider the relative frequency, $\frac{f_a}{f_p}$, of collisions between two automobiles and collisions of an automobile with a pedestrian. For a city in which all travel was by automobile, obviously all accidents would be collisions between two automobiles (assuming only the two types of collisions here dealt with) and the ratio, $\frac{f_a}{f_p}$, would be infinity. In a city with very few automobiles in proportion to the population, practically all accidents would be collisions with pedestrians, and the value of the ratio would approach zero. Hence, if the abscissas of a set of co-ordinates represent values of $\frac{P'}{R}$ and the ordinates represent values of the ratio, $\frac{f_a}{f_p}$, this ratio will be expressed by a graph tangent to the Y-axis at plus infinity, and to the X-axis at plus infinity. Reliable data for the determination of intermediate points are lacking, as such data involve not only complete reports of both fatal and non-fatal personal injury accidents over a considerable period to establish the ratio, $\frac{f_a}{f_p}$, but also accurate figures for automobile registrations to establish the ratio, $\frac{P'}{R}$. It is difficult to obtain trustworthy figures covering all these quantities in any one city. The writer has secured what appear to be fairly reliable figures for $\frac{f_a}{f_p}$, however, for ratios of $\frac{P'}{R}$, which are probably about 3.0, 6.2, and 14.0. These points are plotted on Fig. 2. On Fig. 2 is drawn also a hyperbolic curve such that any ordinate multiplied by its corresponding abscissa (that is, $\frac{f_a}{f_p} \times \frac{P'}{R}$, the product being the quantity, w), gives a value of 2. This curve fits the three plotted points (both co-ordinates to which, it will be recalled, are of somewhat doubtful accuracy) with sufficient exactness to permit the acceptance of 2 as the approximate value of w. This is especially true as the quantity, R, in the expression,

$$H \propto \frac{P + (w - a) R}{M}$$

is so much smaller than P for most cities that a considerable error in the value of the coefficient of R has a comparatively small effect on the value of H. Within the limits of exactness attempted in this paper, then, it may be assumed that $w = 2$, and, hence, that $a = w$. The expression,

$$H \propto \frac{P + (w - a) R}{M}$$

thus reduces to $H \propto \frac{P}{M}$.

This gives the relation of automobile hazard to physical surroundings, on the basis of the assumptions made in its derivation.

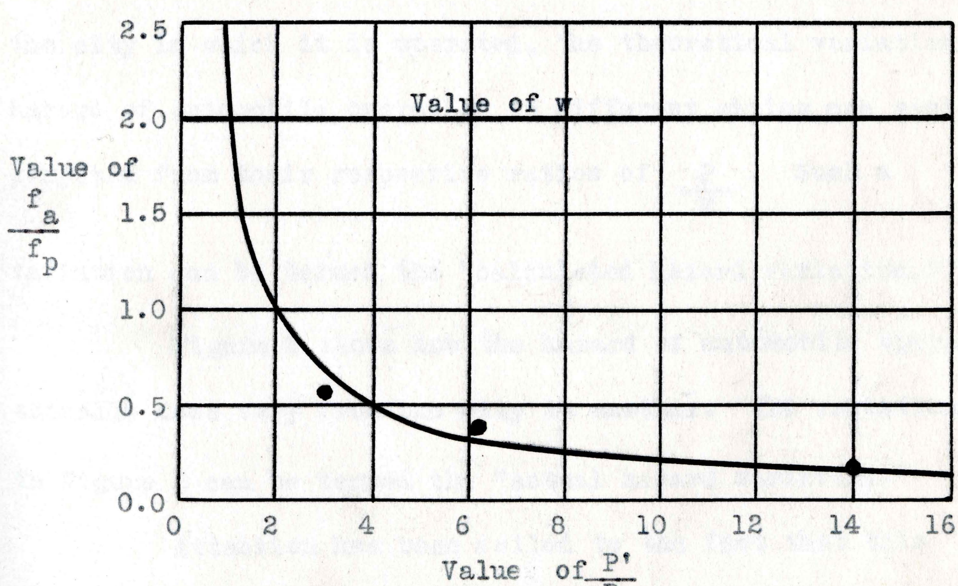

Fig. 2.- Values of $\frac{f_a}{f_p}$ (Relative Frequencies of Collisions between Automobiles and with Pedestrians) and of "w", for various ratios of P'/R

Part III. A Check of Theory Against Known Facts

The expression $H \propto \frac{P}{M}$ is rationally deduced and should express accurately the controlling determinant of hazard of automobile operation in the city for which it was derived. Of course it does not necessarily follow that it applies with equal accuracy or with any accuracy at all to existing cities of the United States. Its derivation rested on many assumptions which do not hold true in those cities.

The effect which one or another false assumption might have on applicability of the formula to existing cities can be argued at length, but that does not give promise of conclusions of any special worth. A better way of determining the practical value of the formula is actually to try it out and see if it fits known conditions. Assuming that the hazard of operating an automobile is proportional simply to the density of population of the city in which it is operated, the theoretical variation in hazard of automobile operation in different cities can easily be computed from their respective ratios of $\frac{P}{M}$. Such a variation can be termed the "calculated hazard variation."

Figure 2 shows how the hazard of automobile operation actually does vary from one city to another. The variation shown in Figure 2 can be termed the "actual hazard variation."

Attention has been called to the fact that this actual hazard variation cannot at all be accounted for on the basis of the factors to which hazardous driving conditions are usually attributed. If this variation can be accounted for by variations in population density, as called for by the formula $H \propto \frac{P}{M}$, then very strong evidence of the applicability of this formula to existing conditions will have been offered.

Before this comparison of calculated and actual hazard variations is made, however, consideration must be given to one fact. The city for which the formula was derived was assumed to have no unpaved streets, so that the term "M" represents paved mileage only. In actual cities, however, there is always a certain amount of unpaved mileage, the relative proportion of which varies widely from city to city. In applying the formula to such cities it is not fair wholly to disregard this unpaved mileage, nor should it be included at its face value. For actual cities the mileage used in the formula should be what may be termed "equivalent paved mileage" - that is a figure made up by taking the paved mileage at full value, and adding to it something less than the full mileage of unpaved streets.

In a typical city in which the unpaved mileage makes up 25 or 30% of the total, the unpaved streets are largely on the outskirts of the city, where perhaps the majority of lots are vacant and the streets do not carry the traffic that would warrant their being paved. Hence, in including them with paved mileage, they should be weighted at much less than unity to indicate their much lower mile-for-mile value in distributing traffic and population.

Considering a city, however, in which there are several miles of unpaved streets for each mile of paved streets, a large portion of unpaved streets will be in outlying, partly developed areas, but a part will also be in built-up districts and will carry almost as much local traffic as they would carry if paved. These latter streets should be included with paved streets at not much less than their face value, or if both these classes of unpaved streets be lumped together (as must be done, practically) a higher coefficient should be used to express their average weighted value than was used for the typical city in which paved mileage exceeds the unpaved. This principle can be expressed as follows:

In determining the value of M in the expression, $H \propto \frac{P}{M}$, paved street mileage should be counted at its full face value, whereas unpaved street mileage should be multiplied by a coefficient less than one, this coefficient increasing, at a slowly decreasing rate, with the increase in the ratio of unpaved streets to total street mileage.

The values to be assigned this coefficient are wholly a matter of judgment. It seems impossible to express exactly the relative importance of the two classes of streets in all cities by a single graph, but as an approximation sufficiently close for present purposes, Figure 3 is suggested.

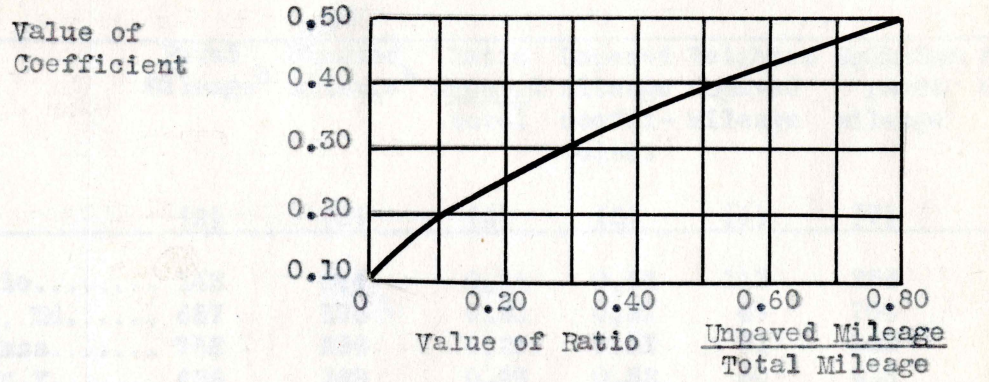

Fig. 3. - Coefficients to be Used in Weighting Mileages of Unpaved Streets.

Table 1 shows mileages weighted in accordance with the foregoing principles for all cities in the United States of 200 000 population and more (except Newark and Jersey City, N.J., which will be discussed later) for which the writer has been able to secure the necessary data. These mileages will be used for the quantity, M, in the formula, $H \propto \frac{P}{M}$.*

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* In applying the principle of weighting unpaved mileage at less than a normal value, gravel and water-bound macadam streets present a problem. In most cities they should be classified as unpaved streets in that the surfacing is temporary, pending sufficient development to warrant improved paving. In a few instances, however, the mileage of water-bound macadam streets is so great as to lead to a belief that it is continued in use on streets which have reached their full(usually residential) development. In this paper, therefore, the term "paved streets" is restricted to include only types of paving better than water-bound macadam, except where the mileage of water-bound macadam exceeds that of the better types. In such cities (Providence, R.I., Denver, Colo., Worcester, Mass., and Hartford, Conn., for example) the excess of water-bound macadam over higher types of paving is considered as "paved".

Table I. Street Mileages of Cities of 200,000 Population and Over

City	Paved mileage[b]	Unpaved mileage[b]	Ratio unpaved/total	Unpaved mileage coefficient	Weighted unpaved mileage	Equivalent paved mileage	Adjusted equivalent paved mileage[a] M
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Akron, Ohio........	143	257	0.64	0.44	113	256	256
Baltimore, Md......	657	173	0.21	0.27	47	704	694
[f]Boston, Mass.......	762	294	0.28	0.31	91	853	853
Buffalo, N.Y.......	456	189	0.29	0.32	60	516	516
Chicago, Ill.......	2756	600	0.18	0.25	150	2906	2834
Cincinnati, Ohio...	306	646	0.68	0.45	291[c]	597[c]	537[c]
Cleveland, Ohio....	657	293	0.31	0.33	97[c]	754[c]	678[c]
Columbus, Ohio.....	340	110	0.24	0.29	32	372	359
Denver, Colo.......	241	659	0.73	0.47	309	550	536
Detroit, Mich......	826	600	0.42	0.37	222	1048	1048
Indianapolis, Ind...	558	135	0.19	0.26	35	593	593
Los Angeles, Calif..	557	1599	0.74	0.47	751[c]	1308[c]	1163[c]
Louisville, Ky.....	245[d]	99	0.29	0.32	32	277	273
Milwaukee, Wis.....	446	58	0.12	0.22	13	459	459
[e]Minneapolis and St. Paul, Minn....	334	1116	0.77	0.48	536	870	870
New Orleans, La....	203	890	0.81	0.50	445	648	618
[g]New York, N. Y.....	1829	1505	0.45	0.38	571	2400	2400
Omaha, Nebr........	290	380	0.56	0.42	159	449	414
Philadelphia, Pa...	1177	...	....	....	...	...	1413
Pittsburgh, Pa.....	518	...	....	....	...	...	622
Portland, Ore......	441	418	0.49	0.39	163	604	604
[h]Providence, R.I....	224	152	0.40	0.36	55	279	279
Rochester, N. Y....	309	191	0.38	0.35	67	376	353
Seattle, Wash.......	510	271	0.35	0.33	89	599	599
St. Louis, Mo.......	467	502	0.52	0.41	206	673	666
Toledo, Ohio.......	255	239	0.48	0.38	91	346	346
Washington, D. C...	257	270	0.51	0.40	108	365	357

(For notes on this table, see next page)

Notes, Table 1.

a - The writer requested mileage figures as of January 1, 1922, but, in some instances, they were, furnished as of later dates. Adjustment to January 1, 1922 is as follows: Make deductions from the weighted mileage at the rate of 6% of the paved or unpaved mileage per annum, whichever figure is the smaller.

b - Mileages as of the following dates: May 7, 1924, New Orleans; January 1, 1924, Chicago, Rochester, Columbus and Omaha; January 1, 1923, Baltimore and Denver; September 1, 1922, Louisville; July 1, 1922, Los Angeles and Washington; April 12, 1922, St. Louis; January 1, 1922, in all other cases.

c - Includes a 10% reduction to allow for alleys.

d - Includes 56 miles of macadam streets; estimate by A.A. Krieger, M. Am. Soc. C.E., indicated that they were entitled to such classification.

e - Includes the Cities of Brookline, Cambridge, Chelsea, Everett, Malden, and Somerville which are included in Boston insurance territory.

f - Minneapolis and St. Paul form one insurance territory.

g - Excludes Staten Island, which is not included in New York City insurance territory.

h - Includes the City of Pawtucket, R.I., which is included in Providence insurance territory.

Table 2 shows in numerical form the actual variation in driving hazard shown graphically in Figure 2 (for all the cities for which mileage data could be secured) and also the variation in hazard as calculated from the expression $H \propto \frac{P}{M}$. In this table both the actual and calculated hazards of all cities are expressed as percentages of their values in Chicago.*

Figure 4 is a graphic representation of the comparison of actual and calculated hazard variations which is given numerically in Table 2.**

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* In Figure 2 New York was taken as the base city, so that the hazards of other cities would all be expressed in percentages less than 100. From a traffic standpoint, however, New York is far from being a typical city. It has seemed better, therefore, to select some other city as the base for Table 2, and Chicago has been selected.

** These tables and figures are all based on conditions in 1922. That year is selected because a later year would introduce greater errors in the value of P (since between censuses, the Census Bureau merely estimates city populations) while for earlier years there would be greater inaccuracies in the actual hazard variation, due to the fact that the insurance rate-making procedure was not fully developed for earlier years.

Table 2. Calculated and Actual Hazard Variations for Cities of 200,000 Population and Over

City (1)	Population, (P), in thousands (2)	Weighted street mileage (M) (3)	$\frac{P}{M}$ (4)	Calculated variation[a] (5)	Actual variation[a] (6)
[b]Akron and Toledo Ohio............	469	602	779	78	78
Baltimore, Md......	762	694	1098	110	80
[c]Boston, Mass.......	1150	853	1350	135	125
Buffalo, N. Y......	528	516	1024	102	142
Chicago, Ill.......	2833	2834	1000	100	100
Cincinnati, Ohio...	405	537	753	75	75
Cleveland, Ohio....	855	678	1262	126	125
Columbus, Ohio.....	255	359	710	71	64[g]
Denver, Colo.......	268	536	500	50	54
Detroit, Mich......	994	1048	948	95	75
Indianapolis, Ind..	335	593	566	57	54[g]
Los Angeles,Calif..	635	1163	547	55	59
Louisville, Ky.....	257	273	942	94	80[g]
Milwaukee, Wis.....	477	459	1039	104	64
[d]Minneapolis and St. Paul, Minn.......	641	870	737	74	80
New Orleans, La....	400	618	647	65	59
[e]New York, N.Y......	5715	2400	2381	238	273
Omaha, Nebr........	201	414	486	49	54[g]
Philadelphia, Pa...	1895	1413	1341	134	137
Pittsburgh, Pa.....	608	622	978	98	100
Portland, Ore......	269	604	446	45	59
[f]Providence, R.I....	309	279	1108	111	109
Rochester, N. Y....	312	353	884	88	92
Seattle, Wash......	316	599	528	53	59[g]
St. Louis..........	795	666	1190	119	109
Washington, D. C...	438	357	1227	123	59

a - As percentages of the value for Chicago.

b - Loss experience for these two cities is combined to get an indicative exposure for determination of their insurance rate (the calculated hazard for Akron alone would be 81 and for Toledo alone would be 75).

c - Includes the Cities of Brookline, Cambridge, Chelsea, Everett, Malden and Somerville.

d - Minneapolis and St. Paul form one insurance territory.

e - Exclusive of Staten Island, which is not included in New York City insurance territory.

f - Includes the City of Pawtucket.

g - Determined from local loss experience combined with similar experience in smaller cities near-by, owing to insufficient volume of local loss experience.

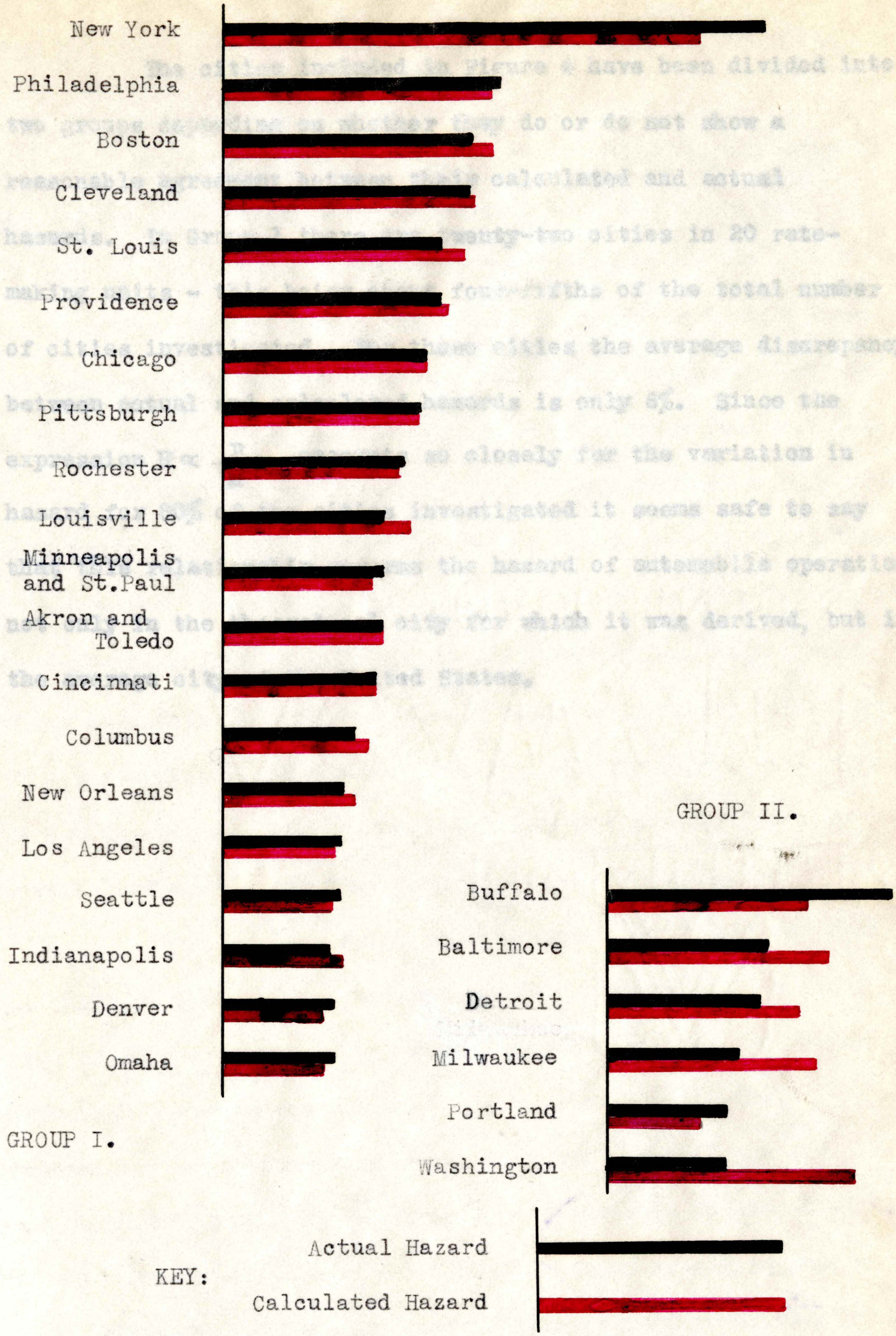

Fig. 4. - Actual and Calculated Hazard Variations (from Table 2.)

The cities included in Figure 4 have been divided into two groups depending on whether they do or do not show a reasonable agreement between their calculated and actual hazards. In Group 1 there are twenty-two cities in 20 rate-making units - this being about four-fifths of the total number of cities investigated. For these cities the average discrepancy between actual and calculated hazards is only 6%. Since the expression $H \propto \frac{P}{M}$ accounts so closely for the variation in hazard for 80% of the cities investigated it seems safe to say that this relationship governs the hazard of automobile operation, not only in the theoretical city for which it was derived, but in the average city of the United States.

Part IV. Applications of the Formula $H \propto \frac{P}{M}$ and of the Principles Underlying its Derivation

The main facts of the automobile accident situation in the United States have been outlined in this paper, as well as some of the efforts at accident prevention which the situation has called forth. It has been pointed out that these efforts do not appear to have met with all the success that could be hoped for. It has been suggested by an analogy that valuable aid in reducing traffic hazards might be secured from a knowledge of what basic factor it is that determines the degree of these hazards. A theoretical formula has been derived to express this factor, and by comparison of hazard levels in different cities it has been shown that this theoretical formula applies to actual conditions to a surprisingly satisfactory extent. The practical point now is how to make use of the knowledge that the density of population governs automobile accident hazards.

At an earlier point in this paper, attention was called to the fact that yellow fever was wholly eradicated in a short time after the medium of its spread was discovered. We cannot hope that the same results will follow discovery of the determinant of automobile hazard. The two problems are not entirely analogous. It was cheaper to eradicate yellow fever than to tolerate it and it was not a problem to be met by compromise. To be successful, eradication of the disease had to be absolute. With the disease eradicated for even a short period of time, the germs which caused it died and the danger of its return became remote.

Automobile accidents present a different situation from this. It is cheaper to tolerate a certain proportion of automobile accidents than to eliminate them all. The complete elimination of them would then mean a complete stoppage of automobile use, since obviously the traffic hazard determinant cannot be reduced to zero. Also even though a complete stoppage of automobile use were enforced for a brief time, there is here no germ to die out. Resumption of automobile traffic would mean an immediate recurrence of accidents.

This is a situation, then, which will have to be met by compromises and partial measures; where a material reduction of the hazard below present levels, rather than its elimination, must be the goal.

The principle that driving hazard is chiefly determined by density of population will be found to be of material assistance to efforts to reach this goal. Such efforts fall into two main divisions: first, kinds now being widely made, and secondly, efforts of types which have not so far been much used. A knowledge of the hazard determinant will promote the success of both of these classes of efforts.

In the surface the fact that in the average city the hazard of automobile operation depends on the density of the city's population is a depressing one. It would seem to follow that the only possible means of reducing the hazard in any city would be by diffusing its population. This is something which cannot be artifically done. A belief has become widely established in recent years that the increase of urban congestion is an undesirable thing for many reasons, and the zoning principle has been widely used to check it. But this merely holds things static. It does not diffuse populations, and so at best it could only prevent a further increase in driving hazard. What is needed is some means whereby this hazard can actually be reduced.

The direct statement of the hazard formula is that the risk in driving an automobile would be decreased by reducing the density of population. This fact cannot be practically utilized. Therefore, if the principle set forth is to have any value in hazard reduction, it must be in other ways than this.

Before entering on a discussion of these ways, attention should be called to the fact that this principle does not express the <u>cause</u> of accidents. No accident is caused by the density of population. Automobile accidents are caused only by some improper act, intentional or unintentional, on the part of one or more street users, at least one of whom is driving an automobile. This improper act may occur anywhere, but usually it does occur where, and at the moment when, the paths of two street users cross. The hazard level is determined by population density not through any direct effect of the latter on the causes of accidents, <u>but through its effect on the frequency of accident opportunities</u>. The fewer people there are per mile of street in a city, the fewer the chances of collision for an automobile travelling that mile.

The prevention of automobile accidents, then, may evidently be based on either

(a) Decreasing the improper acts of street users at points where their paths cross.

(b) Decreasing the number of such crossings.

Up to the present time, only the first of these lines of attack has been extensively recognized and used in cities. Accident prevention efforts comprise three main classes, legal, educational and engineering. Practically all attempts to reduce accidents through legal constraint have dealt with the control of vehicles at path intersections, rather than with the guidance of vehicles into such routes that a minimum number of intersections will occur. Likewise, efforts to educate the motoring and pedestrian public in safe traffic practises have been almost wholly directed towards greater care at path crossings, rather than the avoidance of unnecessary crossings. And finally, such attempts as have been made to reduce street accidents through engineering measures, have almost entirely neglected the safer routing of traffic, and have aimed at enabling it to go through intersections with greater safety.

The formula for hazard variations makes its greatest contribution in calling attention to the importance of reducing to a minimum the number of crossings of travel units.* This contribution will be discussed at some length later on, but before that is done, consideration will be given to the value of the formula in connection with traffic accident prevention work along the lines now generally followed.

In any kind of work, it is an advantage to have some standard against which the results of effort may be checked. This is particularly important in a pioneer field where new methods, some good and some of little value, are continually being developed. In automobile accident prevention work, so far as the writer knows, there is no reliable standard against which to measure success except the hazard formula proposed here.

This formula has several distinct uses as a standard of this sort. Its first use is in selecting cities in which methods of traffic control have met with results better than the average.

As was said at the beginning of this paper, we have reached a time when there is much discussion among traffic administrators concerning the best methods of handling their problems. The more progressive police departments and public safety bureaus are anxious to learn of sound accident prevention methods used in other localities. The question must inevitably come up, then, how to select the localities which will best repay study.

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* Note that this is not the number of crossing points or intersections, but the actual number of times the path of one unit crosses the path of another unit. The tendency to dangerous actions in making crossings may also be somewhat controlled by the regulation of the number of crossing places; e.g., by the elimination of "jay-walking". This is another matter, although the two are related in ways that will be brought out.

The first thought might be that the cities with the best traffic control would be those cities where accident rates, in relation to automobiles in use, were lowest. This conclusion would generally be wrong. Low accident rates are only rarely the result of good traffic control, and the cities where driving hazard is greatest are likely to be the very cities where traffic regulation is most advanced. This is easily seen to be logical. Owing to human inertia, we do not worry about a problem or set to work to remedy it, until it has become pretty bad. Consequently, good traffic regulation is the outgrowth of high hazard rather than the cause of low hazard.

But there are exceptions to all rules, and there are cities where hazard is not only high but where it is much higher than it has any business to be. The simple rule that high-hazard cities should be studied, then, is apt to lead one into error.

While methods of traffic control do not enter into the formula, $H \propto \frac{P}{M}$, this does not mean that traffic control is unimportant. It simply means that, if the efficiency of traffic control is the same in all cities, it does not affect the variation in hazard from one to another. In 1922, the year against which the accuracy of the formula was checked, the indication is that there was not a wide degree of difference in efficiency of control methods, although even at that date, there was some.* Detroit, Milwaukee, Baltimore and Washington had much lower hazards than a study of their population densities would have led one to expect.

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*The probability is that differences are greater at the present time.

Portland and Buffalo had much higher hazards.

This permits formulation of the rule that the cities to be studied are those in which actual hazards, whether high or low, are lower than those which the expression $H \propto \frac{P}{M}$ calls for.

It is important not only that we should know where to turn for cities whose example may be followed in street traffic matters, but it is important also that each city should have some means of checking up on the success of its own efforts at accident prevention. If a city is in a stage of rapid growth, an increase in driving hazard may mean that the control of traffic is becoming worse, or it may mean that the population density of the city is becoming greater. Increase in insurance rates will show any increase in hazard; a study of population density will show where the responsibility for the increase should lie. Such increases in hazard are a very important matter. In the past two years automobile insurance rates in New Haven, Conn., for example, have been increased by an amount which without any return takes out of the city a sum of money almost equal to the city's annual appropriation for street paving. By means of the hazard variation formula, it can be shown that the hazard is not due to any normal increase in the danger of driving - there has been no increase in the density of the city's population. With this definite indication that some less defensible thing is to blame, investigation has been shaped along lines which show conclusively that laxity of police control in the past few years has led, not to a growth in the number of accidents, but to an increase in the number of very serious accidents. A few wilfully reckless drivers, realizing a lessening of legal restraint, and fully covered, perhaps, by liability and collision insurance, have driven in a way that has penalized many of the law-abiding drivers of the community.

It is evidently of considerable importance that a city should have some means of checking up on such a situation as this. So far as the writer knows, the expression for hazard variation affords the only reliable means of doing this. Herein lies its second value.

The hazard formula used as a standard serves a third purpose in making possible a determination of the effects of some one type of traffic control which is in use in several localities.

Study of the cities of Figure 4 which had actual traffic hazards much below the calculated level, in some cases led without much difficulty to an understanding of the reasons for the deviation. Thus Detroit was found to owe its favorable traffic hazard condition to an efficient and energetic police department which had shown great progressiveness in its methods, to a traffic court judge who established a wide reputation for severity in dealing with wilful traffic offenders, and to a system of safety education in its schools which had kept traffic accidents among children down to a relatively low level. Washington, the only one of our large cities which has grown in accordance with a definite plan, appeared quite clearly to be paying dividends on that plan in the form of reduced traffic hazards.

Baltimore, however, seemed to show no good reason for an actual hazard 30% below its calculated normal level. Neither police regulation nor city planning gave it any marked traffic advantages. Its low hazard was quite baffling until consideration was given to the fact that in Baltimore, control of traffic by the police was supplemented by a state license law, under which no Maryland citizen could legally operate a motor vehicle in that state without having been licensed to do so; the license, moreover, being given only after examination of his driving ability and knowledge of law, and being revocable for cause.

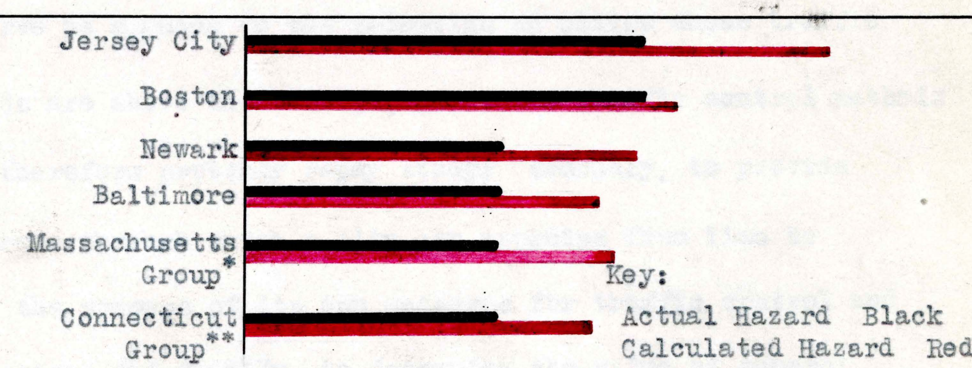
This system of state licenses, which has spread considerably since 1922, was at that time so little used that of the cities in Figure 4, only Baltimore and Boston were affected by it. Both these cities show actual hazards well below the calculated, though Boston does not deviate nearly so far as Baltimore, apparently because Boston, with its old, narrow and crooked streets, is rather the antithesis of Washington in respect to the factor which makes Washington so comparatively safe, and because Boston, rather than being a separate city to itself, is more the center of a cluster of cities.

The four states which in 1922 had the above described licensing laws are Connecticut, Maryland, Mannachusetts and New Jersey. In these states, in 1922, there were only two cities besides Baltimore and Boston which had populations as large as 200,000. These were Jersey City and Newark, N.J.

Both of these latter cities lie so near New York city that they should be thought of, from a traffic standpoint, as parts of the New York metropolitan area, rather than as individual urban centers. For this reason they were omitted from Table 2 and Figure 4.

Besides these four large cities, there were eight smaller cities in Massachusetts and three in Connecticut which were grouped respectively into two insurance territories. That is, the average actual hazard was established collectively for these smaller cities of each state. The calculated hazards for these grouped cities can be set up by dividing the total population of each group by the total equivalent paved mileage for the group.*

Figure 5 shows for these cities the same comparison of actual and calculated hazard variations as Figure 4 showed for its cities.



* Fall River, Haverhill, Lawrence, Lowell, Lynn, New Bedford, Springfield, Worcester.

** Bridgeport, Hartford, New Haven.

Fig. 5, - Actual and Calculated Hazard Variations for Cities in Connecticut, Maryland, Massachusetts and New Jersey.

*Complete data on these cities is given in Appendix B.

From inspection of Figure 5, it is apparent that as between themselves, the actual hazard variation is similar to the calculated hazard variation but that the actual hazards of these cities (except Boston) run uniformly about 30% lower than their population density would lead one to expect. In other words, the factor common to these cities is the state licensing of their motorists, and this appears to be responsible for a reduction in their hazards to a point much below what consideration of other cities in the United States would have indicated to be the "natural" level.

In connection with existing efforts to prevent accidents, the hazard formula has, then, three functions as outlined: first, to serve as a guide to the selection of cities whose traffic records are above the average, and whose traffic control methods will therefore probably repay study; secondly, to provide the means through which a city can appraise from time to time, the success of its own measures for traffic control and regulation; and finally, to determine the value of general methods of traffic control employed in more than one city - as an illustration of which use, an investigation of the effect of state licensing laws on automobile accidents has just been outlined.

Consideration may next be given to the principle shown by the hazard variation formula in connection with the second line of attack on accidents: that accident prevention may take the form of reduction of the number of path crossings of travel units.

The injuries which will be prevented by this latter means are primarily those resulting from the collision of an automobile with a pedestrian. The improper actions which give rise to automobile accidents all go back to a few basic factors: wilful recklessness, intoxication, carelessness, confusion, inexperience, and in a few rare cases to sudden breakages, blowouts and such unforeseeable things as bee-stings. These factors all cause accidents. In cities, however, personal injury from collisions between two automobiles very, very generally goes straight back to wilful recklessness in the form of speed. If speeds are such as are reasonable and proper in almost all sections of the average city, a collision between two automobiles (except in the minority of cases where heavy trucks are involved) will not result in personal injuries of great moment. Persons may be cut by flying glass - this hazard will have disappeared in a few years, with the substitution, now underway, of non-shattering glass - and in rare cases when two automobiles collide even at slow speeds, one of them may be overturned, or one may be thrown out of control, and as a result strike and injure a pedestrian. But ninety per cent of the serious injuries which result from the collision of two vehicles in cities would not be suffered but for the use of speeds which are excessive for conditions at the time and place of the accident. Prevention of personal injuries from collisions between automobiles is primarily a function, then, of traffic control. Cities which are not yet aroused by their accident situations to the point of enforcing ordinances which will curb recklessness on the part of automobile users need hardly consider steps to reduce extensively the number of crossings, since these steps are in general more difficult to carry out than is traffic control. If they have fallen down on the control of traffic, they will be fairly certain not to make a success of attempts at its regulation.

Pedestrian accidents, however, cannot be effectively handled by traffic control alone. Such accidents are not by any means the product of high speeds. A car running over an elderly person or a little child at a speed of fifteen miles an hour will do much the same damage as a car moving twice that fast. These accidents are caused not only by wilful recklessness, but by unintentional carelessness, by inexperience of drivers, by the uncontrollable acts of irresponsible little children, by the sudden confusion of pedestrians. These causes are much less subject to legal control than is recklessness. In fact even recklessness is almost impossible to control when it comes to pedestrians except perhaps by a slow process of education. Consequently the prevention of personal injury accidents resulting from collisions with pedestrians must rest on other means than does the prevention of the personal injuries which result from collisions between two automobiles.

Moreover, while the usual visualization of an automobile accident is a crash between two cars, from a personal injury standpoint collisions with pedestrians are anywhere from two up to four or five times as important as collisions between automobiles. The great bulk of the personal injury accident problem, then, is to prevent conflict between cars and pedestrians.

The two facts, taken simultaneously, that injuries from collisions with pedestrians are the most difficult to control, and that they form the bulk of the traffic accident problem, show clearly why efforts at accident prevention must be widened out. They must include the elimination of the unnecessary path-crossings of pedestrians and automobiles, if they are to achieve very much more success than they have achieved so far.

The expression $H \propto \frac{P}{M}$ was derived on the assumption that both vehicular and pedestrian traffic was uniformly distributed over the streets of a city. This is never the case. The formula apparently holds good despite this because in most cities the deviation from this assumed condition is to about the same extent.

Evidently, if pedestrian travel could be restricted to certain streets of a city, and automobile travel to other parallel streets, no collisions with pedestrians would take place, and personal injuries from automobile accidents would drop to a comparatively small percentage of their present numbers. This condition is obviously one that can never be realized in any city.

Unfortunately, however, the usual deviation from a uniform distribution of traffic is in the opposite direction from this. When a street begins to carry a heavy volume of traffic, it is usually doomed so far as its use for high grade residential purposes is concerned. People do not like to live on such a street. Property values gradually decline, and as they do large single family houses become occupied by several families, or are torn down and replaced with apartments or tenements. The population density of that street is gradually greatly increased. Consequently the normal tandency is for greatest traffic flows to be found in streets of greatest population density, and hence of greatest pedestrian use and greatest personal injury hazard. Instead of there being a safer distribution of traffic than a uniform distribution over all the streets of the city would be, there is a much less safe distribution.

In the central business districts of cities this is not so apt to be the case. There a more or less uniform distribution of traffic necessarily exists.

As these districts are approached the converging traffic often fills every street to its full capacity, or not very far short of it. Such streets have their character pretty well established. Businesses have already sprung up on them, street car tracks are laid. Population density and traffic use of the streets are both well fixed. Aside from seeing that traffic control on such streets is as good as can be provided, there is little that can be done, except in one way. Usually the number of vehicles entering the central district of the city can be reduced.

In every large city, and to an even greater extent in some smaller ones, there is a large amount of traffic from other localities on the streets at all times. Some of this traffic is intentionally in the city because it wants to be there. Probably in most cases, however, a larger proportion of it is there simply because the city or town lies on the road connecting its starting point with the place it wants to reach. It goes through the city, not because it wants to, but because it cannot conveniently avoid doing so.

In cities located on important through routes, the number of accidents caused by this tourist traffic is often very high. In New Haven, which lies on the Post Road connecting Boston with New York City, and which has a heavy through traffic in consequence of this, more than one third of the accidents during the late summer and early fall involve cars from points outside of the city and its adjacent townships. In the winter months about one fifth of the accidents involve such cars. During the entire year, the proportion is about one fourth.

There is no gain whatever in having the bulk of this traffic pass through New Haven. A part of it, probably a rather small part, is in the city on business or pleasure. Most of it is there simply because New Haven has no by-pass routes.

The remedy for a situation like this is a highway turning aside at the outskirts of a city and forming a belt line around it. Such a by-pass should be so marked that it is clear what it is, in order that the occasional tourist wanting to enter the town for business reasons, will do so and will not take the by-pass. By the provision of such a belt line, the situation is made much better for everyone concerned. The tourist goes a little further, but is able to make sufficiently better time to compensate him. The merchant has a chance at all the through traffic that actually wants to do any purchasing, and in addition, his local customers are less interfered with in reaching his store. Finally in this list, but perhaps most important of all, the streets of the city, and often its most congested streets, are relieved of what often amounts to a very considerable traffic and the accident hazard is reduced accordingly.

Large cities should have both an outer and an inner by-pass. The outer should completely avoid the built up districts of the city. The inner should by-pass merely the central congested area, so that tourists wishing to enter the city to make purchases, usually of groceries, drugs, automobile accessories, and the like, can make their purchases at outlying stores and still avoid the center of the city. Smaller cities need only one by-pass, skirting the built up section. As the city grows, it will flow out beyond this by-pass, so that eventually this one will become the inner by-pass and another farther out will be provided.

As has been said, this is about the only thing that can be done (in addition to providing the best possible traffic control), to reduce driving hazard in the central areas of cities. It is an important thing to do, and even though the cost may be great, it will almost always be much less than the cost of allowing accidents to continue. New Haven, for instance, could probably by-pass enough traffic to save around $50,000 a year in accident costs, and this would capitalize at a sufficiently great amount to more than pay the cost of the by-pass.

Away from the central districts of cities, however, the principle expressed by $H \propto \frac{P}{M}$ can be applied very effectively to reduce traffic hazards. In all but the central business district and a few main traffic arteries radiating from it, most cities have an excess of street space, in the sense that the roadway of most streets is rarely filled to its full capacity. Frequently not more than five or ten per cent of the vehicular traffic that could use a street, actually does use it.

Such districts as these, and they comprise large parts of the area of most cities, do often have a traffic distribution that is more or less uniform - thin streams of traffic trickling through many parallel streets, with a very large number of intersection points. Suppose that these thin streams of parallel traffic were all gathered into one dense stream freeing the adjoining streets of all but absolutely local traffic having its origin or destination on or near them. Then so far as those streets were concerned, there would almost be the complete segregation of vehicular from pedestrian traffic which has been spoken of earlier in this paper as the ideal condition from a safety standpoint.

More than this, on the street in which the dense stream of traffic was concentrated, hazard would be decreased, rather than increased. A word of explanation will make this clear.

The most dangerous traffic is an intermittent high speed traffic through a residential area. A dense traffic advertises its presence. Pedestrians are aware of it, and are not so apt to step heedlessly into a street through which it is flowing. Children will naturally not play ball in such a street, if just around the corner there is a street empty of traffic in which they can play. Vehicles approaching on cross streets see the stream of traffic as they approach and slow down accordingly. A dense traffic, finally, because of its density, cannot move at very high speeds.

A thin vehicular traffic, on the other hand, can, and usually does move at high speeds even through areas of dense population and high hazard. It does not advertise its presence. It constitutes something more or less unexpected.

If, then, the traffic which tends to spread out through residential areas is led in some way to collect into dense streams as it passes through those areas, a safer condition for all street users results. This is segregation of traffic, reserving some streets for pedestrian use as much as possible, restricting other streets to vehicle use as much as possible. Carrying out this procedure will have the same effect on driving hazard that reducing the population density of the city would have: it automatically reduces the number of crossings of the paths of vehicles and pedestrians.

The city of New Haven offers an interesting illustration of the carrying out of this principle, and an interesting illustration of disregard of it.

Three times each fall there are football games in the Yale Bowl, on the outskirts of the city, which bring into New Haven from outside points a number of out-of-town cars larger than the number of cars to be found on the streets of the city at any normal time. These cars, plus local cars, plus many thousands of pedestrians all converge in the afternoon towards one small area of the city, so that the density of population is very great there, temporarily, and also the density of vehicles. Take into consideration the excitement attendant on the game in addition to this, and the natural conclusion would be that those days would see a great accident increase.

They would, but for one thing. Moved not so much by a desire to add to the safety of the crowd as to reduce the time required for it to collect and disperse, the police department has worked out a system whereby separate streets are assigned to each type of traffic unit. The street on which street cars run to the Bowl is reserved especially for them; the next parallel street, which offers the shortest route to the Bowl, is restricted absolutely to pedestrians*, and police are stationed at all intersections throughout the area to see that no automobiles attempt to enter or cross that street. Automobiles are routed from the center of town to the Bowl by roundabout streets which take them to the far side of the Bowl, where the parking areas are located. In this way, the crossing of paths of traffic units on the way to the Bowl is reduced to a very small amount. By this segregation of traffic, the same effect from a safety standpoint is achieved as if the value of $\frac{P}{M}$ were much reduced. Accidents are reduced accordingly. Despite the hundred per cent increase in cars on the streets, and the congestion of population in one quarter of

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* Except for persons living on that street, who must secure special permits to pass the cordon of police thrown around the area before they are allowed to drive within it.

the city accidents on game days run only twenty or twenty-five per cent higher than on other days during the fall, and these accidents occur at other places and other times than in the vicinity of the Bowl just before and after the game.

The illustration of failure to observe this principle of reducing the number of path-crossings in the interest of traffic safety occurs on the opposite side of the city from the Yale Bowl, and exists throughout the year, so that it does a good deal more harm than the segregation of traffic on game days does good.

A large part of the traffic entering New Haven from Hartford, comes in by way of a street which as the center of town is approached, becomes a very busy and congested business street. Consequently, out-of-town traffic is routed from this street to a parallel one five blocks distant, when it is about a mile from the center of the city. This is a very wise move. But suffering from the delusion which many traffic administrators seem to have, that vehicular traffic must at all costs be kept diffused, this traffic is not crossed from one to another of the parallel streets in one dense stream. A proper arrangement of conspicuous direction markers, pointing down the entering street until the selected cross-over street was reached, and then directing it to cross, would accomplish this end without any difficulty. Instead of such a system, however, there are small, drab, inconspicuous markers at each one of three successive streets, directing traffic to cross at each one. A more effective system for the diffusion of traffic over the three streets could hardly be better worked out. A number of drivers miss seeing the first marker entirely; a proportion of these miss the second also; a few may even miss the third. The effect is that instead of one dense stream crossing over, there are three thin streams. That this does not cause large numbers of pedestrian accidents, is due only to the fact that the district is one of fairly low population density. It does cause many collisions between automobiles.

For the unfortunate part of this situation is that midway between the street on which traffic enters the city, and the parallel street to which it is crossed over, there is a broad, smooth street, that does not go anywhere in particular, but that carries a high speed, intermittent traffic from the center of town to this residential quarter of the city. The out-of-town traffic, in approaching this street in its three thin streams, passes through a very quiet residential district. It crosses a couple of short streets on which there is no traffic to be seen. It approaches a street which, as it is approached, looks just like another quiet street, empty of traffic. By this time the out-of-town traffic is convinced that there are no traffic dangers to be encountered, and has reached a high rate of speed. And this third street it crosses, is the broad smooth street, with its high speed intermittent traffic. At the points where these two streams meet, there are some of the worst accident corners in the entire city, although there are many other corners which are passed by ten times as much traffic in the course of a year. And almost without exception, each of these accidents involves a car from out of the city - driven by someone unfamiliar with his surroundings and deceived by the quiet appearance of the neighborhood.

The mere collection of this traffic into one street, and crossing it to the other street with a control of some sort at the intervening dangerous intersection, would mean a saving of some thousands of dollars of accident losses each year, but it is not done. And the amusing thing about the situation, if there is one, is that there is already a traffic light protecting the intersection on one cross street, and that no special effort is made to route the traffic over this street. It is a safe statement that the average police chief is entirely ignorant of the fact that safety of traffic is increased by collecting it into dense streams as it traverses residential districts, and proceeds on exactly the opposite theory. He knows that in the very congested district traffic flows better if vehicles are as evenly diffused as possible, and he simply applies the same rule to the outlying districts, where hazard conditions are entirely different.

The specific applications of this principle that has been discussed are more or less individual to each city. A multiplication of illustrations here will not be of value. The discussion of the principle, together with the two illustrations which have been given, should make clear what the principle is. If that is clearly grasped, applications suitable to each locality can be found. In most cities today, such applications form the basis of most of what hope there is for reducing the number of collisions of automobiles with pedestrians. Their use should often bring about important changes; disregard of them will leave little prospect that efforts at accident reduction will have much more success in the future than they have generally had during the past few years.

It is always easier and more satisfactory to do a job right the first time, however, than to try to improve it after it has been done wrong.

The whole layout of our cities is fundamentally wrong for modern conditions. Streets are so laid out that if traffic is to be collected into certain paths, it has to be artifically influenced to do so. There is too much traffic capacity on some streets and in some areas, and not enough in others. This is not the fault of anyone. The cities now in existence were built largely in an age which could not foresee the automobile, or its great growth. If they are not suited to our needs, that is simply our misfortune.

If, however, the cities and parts of cities which will develop in the years ahead are allowed to develop along the present antiquated and unsatisfactory lines, that will be our fault and very much our fault. Up to the present time, with few exceptions, that is exactly the type of development they are still undergoing and if this continues to be the case they will have traffic problems a few years hence much more aggravated than those of the present.

There is no reason why the present type of development, with its excess of roadway space on residential streets, and its inadequacy of arterial routes for traffic which wishes to go from one neighborhood to another, should continue.

Residential streets should neither have wide paved roadways nor be continuous over great lengths. These two characteristics simply tend to attract traffic to them, decreasing the desirability of the streets for residential purposes. A wide street, with a relatively narrow paved roadway of say twenty-four feet, and wide grass plots or plantations, is both much more attractive and more economical than a street with a wide roadway, and is equally suited to the needs of the local traffic it should carry. Moreover, if such streets instead of being made open to through traffic, are made discontinuous, they have the advantage that they can never be well adapted to business uses, and they are given that degree of stability which city planners are so anxious to see neighborhoods have, and which is so uneconomically lacking in most of our cities. Such residential streets have the further advantage that while traffic which has actual business on them can easily enter to transact its business, they will never encourage through traffic and so will never be subject to the hazards which that causes. Some of the most attractive and noted residential districts in the United States, such as Roland Park in Baltimore, have been laid out very much on this plan of having the area intersected by a few main thoroughfares, with most of the streets adapted to nothing but the local traffic which has definite business in them. The areas which have had this treatment have been for the most part areas of high class homes, but every reason for laying out such areas in this way applies with equal or greater force to the layout of more modest neighborhoods. Instead of trying to provide as many streets as possible all alike in their traffic capacities, and none so designed as to carry traffic very efficiently, it is much more desirable that a net work of arteries, designed to carry traffic with the minimum of cross interference, and hence to carry it both efficiently and safely, should be laid down, and that the interstices of this network should be filled in with streets designed for their proper use - to serve the local needs of those localities. From a traffic safety standpoint, the natural segregation of traffic which would follow such street layout is entirely equivalent to a great reduction in population density.

Note that the first step in this process is provision of the proper network of traffic arteries. If these are laid out - and in a proper manner, so that connection of cross streets with them cannot be made at too frequent intervals - the proper filling in of the residential streets will follow to a considerable extent as a natural process.

Detroit - where traffic hazards have been so much more successfully restrained than in the average city - has had the vision to see this, and to plan accordingly. Anticipating the day when the city will have spread over a much larger area than it now occupies, and thoughtful of the traffic needs of such a city, a program is now being carried out there in accordance with which great express boulevards are being laid out and constructed to connect the center of the city with its suburbs. These boulevards pass through considerable areas of what is now comparatively undeveloped land, which can be acquired by the city at a small fraction of what its value will be a few years hence. Through these areas the roads are laid out with widths which will accommodate an express electric car service in the center, and automobile traffic on the outer edges. The interesting thing about the routes is that they cannot at any point be crossed by traffic either pedestrian or vehicular. They are through routes. Pedestrians pass under the automobile ways to reach the loading platforms between them. Automobiles can get on or off the roadways at fairly frequent intervals, but cannot cross them anywhere. At intervals of a mile or more, under-passes are provided for cross traffic. Traffic wishing to turn left across the highway, leaves it as one of the underpasses is approached, gets into the system of local streets which connects with the underpass, and so crosses beneath the traffic stream.

When the foreseen time arrives, and the city has extended out along these routes, filling the areas between them, there will be already provided the means of segregating all through vehicular traffic from the pedestrian traffic of each locality, and safety will have been greatly fostered, as will also the efficiency of travel.

Cities which have not had this foresight in the past are paying such heavy penalties in traffic accidents and delays, that some of them are making enormous expenditures to bring about conditions which will be no better than those which could have been brought about a few years ago at a fraction of the cost. A good illustration of this is the raised highway which is being constructed to lead south from the Holland Vehicular Tunnel which connects New York City with northern New Jersey. This tunnel produces a great increase in traffic through an area of dense population, where street systems have already developed and land uses have become more or less fixed. Not only does this create a serious accident problem, but it leads to a degree of congestion which cuts down the usefullness of the tunnel. To meet this situation the very expensive overhead highway is being constructed at a cost of $30,000,000 extending through the Jersey City and Newark , with occasional access to the street level, and with no crossings at grade. It will be a safe means of carrying a tremendous traffic, but few localities can afford such expenditures as this. The only alternative is a very far-sighted view of future traffic needs.

A change in our habits of city-building to more satisfactory types, is not a legislative but is more an educational matter. It starts with the city plan commission. As a result of the mistakes of the past, most plan commissions have their hands pretty full with pressing problems in the existing parts of cities. Consequently they are apt to devote little thought to the provision of outlying facilities designed to be adequate at a period ten or twenty years away. It is often more important that they should do that, however, than that they should devote all their effort to patching up what can never be made a very satisfactory situation in the older parts of the city. Over a period of twenty years, the city will have benefitted more from superior planning of the part of it which has come into existence during that period, than it would have benefitted from anything that could have been done to minimize the mistakes already made.

The average real estate subdivider and builder of suburban homes can hardly be expected to be an authority on city planning, or to depart very radically from precedent set him by his predecessors, unless he has encouragement to do so, and unless he is shown that it is to his advantage to do so. Since quite evidently the present type of subdivision is not suited to our conditions, a well informed and intelligent city plan commission ought to be able to exert a great influence in guiding suburban development along better lines. There is no greater contribution to the welfare of its city that such a commission could make.

As the most comprehensive step in this direction yet taken in this country, great importance and interest attach to the building of Radburn, a suburban city in the New York metropolitan area of northern New Jersey. The City Housing Corporation, a limited dividend company in which a number of able and public-spirited persons are stockholders and directors, has announced within the past few months the purchase of a square mile and a half of country land on which there is to be built a largely self-contained little city (as contrasted with a commuting center) for about twenty-five thousand inhabitants. The proposed street layout of the city is so simple and so intelligent, and at the same time such a radical departure from prevailing practices that it may be worth while to discuss it in a little detail.

Essentially, it will be an application of the principles which have been discussed in this paper. In all its planning, the aim kept in view has been to collect traffic as much as possible in some streets and to free others of it as completely as can be done. A sufficiency of traffic thoroughfares will be provided to care for the city's through traffic needs. Other through traffic will be passed around the city. The main traffic arteries through the city will not be the streets on which the city's homes will front. These will be located on side streets, which will not afford through communication, but will be used only for access to homes fronting on them.

The most radical departure this city will make from those now in existence, however, will be that in addition to a street system for vehicles, there will be a complete separate system of pedestrian parkways, which will make possible to a very large extent the segregation of pedestrian from vehicular travel. The vehicle street is to adjoin one side of each lot, and the parkway the other. Schools, community centers, churches, etc., are to be so located that they can be reached by way of the parkways as well as the streets, with a minimum of roadway crossings.

It is questionable if this particular plan, in all its details, could be carried out in any other way than by some such organization as the one responsible for it. But many parts of the plan are widely applicable, and the venture may have an important bearing on the methods used by subdividers in the adjoining areas, and thence on the traffic hazards in those areas a few years from now.

It is greatly to be hoped that this will be the case, that the city will be so intelligently planned, and the plan so well adhered to in its fulfillment, that it will set a new standard for this country, and will meet with much imitation. The present efforts to prevent traffic accidents are for the most part worth while, and must be continued. But it will be little short of criminal - because it will lead to the deaths of tens of thousands - if we continue to ignore the principles which make for safety in city planning, as we are ignoring them at the present time. Twenty years hence both the mileage of city streets in the United States and the number of automobiles and pedestrians using them, will probably have doubled. With far-sighted, intelligent thought in city planning, the number of automobile deaths each year may be kept from doubling, may even conceivably be held not very far above the present level. But there is no hope of this unless it comes through cooperation of those who control the stream of traffic, and those who plan and create the facilities for its flow, - unless our cities in their growth, shake off their inherited, archaic forms and are fitted to modern uses and needs. Traffic control measures, unless supported by more advanced city planning, will be found to be tragically inadequate.

Appendix A - The Making of Automobile Public Liability Insurance Rates

Automobile public liability insurance rates are established annually in accordance with the following procedure.

The United States is first divided into about two hundred and fifty territories, (each consisting of a large city and its closest suburbs) or territorial groups (each consisting of several small cities or several counties in a state). For each of these territories of groups, separate loss experience is secured and tabulated. In some cases the volume of exposure of a territory or group is not sufficiently large to be fairly indicative, and further combination is necessitated. However, for each community that develops a sufficient exposure (and this includes most of the cities of 200,000 population or more) rates are calculated from that community's individual data, and are in consequence a reflection of that community's traffic hazard.

The tabulated data for these communities shows the number of automobiles insured during each of the three preceding years, and also the losses incurred in each of these years as indemnities for accidents attributable to the insured cars. Dividing the losses for each year by the number of cars insured, and averaging the three resulting quotients, gives the average loss per car or "pure premium". This average "pure premium" is weighted by a fixed percentage to cover the administrative cost of the business and the average rate is thus determined for each community or group. For purposes of business administration these groups are then combined into a much smaller number of "rate territories", in each of which the rate is the average of the rates of the groups included in that "rate territory". The units comprising any given territory may be widely scattered over the country, but the average rate assessed against all localities which are placed in any one rate territory is within a very few per cent of the rate determined individually for each group placed in that territory. About twenty average public liability rates for private passenger cars are thus established, some one of which will apply to any locality in the United.States. Finally, by another set of calculations differentials are obtained which are applied to the average rate to give the actual listed rate for different makes of cars.

The procedure just outlined is that for private passenger cars, which make up the largest number of automobiles insured. There are a few differences in detail in making the rates for commercial and public passenger vehicles, but no difference in principle. The variation in rates from city to city for these latter types of vehicle is much the same as for private passenger cars.

Hence this private passenger car rate may be taken as an accurate reflection of the public liability hazard of operation of insured cars, and variation in rates may be taken as the variation from one city to another in the hazard of their operation.

Use of this rate variation for the wider purpose of measuring the personal injury hazard variation of all automobile operation in those cities is open to three objections. In the first place, it is not necessarily true that the hazard of operating the average uninsured car varies from city to city in just the same way as the hazard of operating the average insured car does. Secondly, it is conceivable that two accidents of exactly the same severity and involving exactly the same liability might result in different indemnities in different localities. Third, it is to be observed that these rates are based on the legal liability for causing injuries, and not directly on the injuries themselves.

These are weaknesses which it seems impossible to escape and the exact effect of which it is impossible to demonstrate. Careful thought about all of them, however, has led to the conclusion that no one of them exerts a materially disturbing influence.

A complete discussion of the making of automobile liability rates is given in "Automobile Rate-Making" by H. P. Stellwagen, Proceedings, Casualty Actuarial Society, Vol. XI, Part 2.

Appendix B - Actual and Calculated Hazard Variations for Cities in Connecticut, Maryland, Massachusetts and New Jersey

The hazards in these cities are based on 1922 conditions, as in the case of the cities included in Table 2 and Figure 4, and for the same reason. In the table following, the street mileages shown are paved and unpaved mileages weighted and combined into an "equivalent total mileage" in accordance with principles set forth previously. The figures for the larger cities are from local sources, usually engineer departments; those for the smaller cities are usually from local sources, but are supplemented in some instances by data from The Asphalt Association, with estimates of the mileage of unsurfaced streets. The error in the mileage figures should in all cases be less than 10 per cent. Hoboken, in Jersey City territory, and Irvington and Bloomfield, in Newark territory, are omitted from Table 4 because of the lack of mileage data. The population figures are from 1922 Census estimates.

Cities	Population, (P) in thousands	Weighted street mileage (M)	$\frac{P}{M}$	Calculated variation[a]	Actual variation
Connecticut :					
Bridgeport					
Hartford	452	420	1 075	108	78
New Haven					
Massachusetts:					
[b]Boston	1 150	853	1 350	135	125
Fall River					
Haverhill.					
Lawrence					
Lowell	945	818	1 154	115	78
Lynn					
New Bedford.					
Springfield.					
Worcester.					
Maryland:					
Baltimore.	762	694	1 098	110	80
New Jersey:					
[c]Jersey City	463	255	1 818	182	125
[d]Newark.	580	476	1 220	122	80

[a] As percentages of the value for Chicago.

[b] Includes Cities of Brookline, Cambridge, Chelsea, Everett, Malden, and Somerville.

[c] Includes Bayonne, West Hoboken, and West York, which are included in Jersey City Insurance territory.

[d] Includes Montclair, East Orange, Orange, West Orange, and Summit, which are included in Newark Insurance territory.

From the table it is seen that all of these cities have calculated hazards considerably higher than the actual hazards are. In Boston, the discrepancy amounts to only 7% of the calculated hazard, but in the other cities, the calculated hazard is about one-third higher than the actual.

The fact has been mentioned that Newark and Jersey City form a part of the New York metropolitan area. The effect of this on their driving hazards is hard to determine. There doubtless is such an effect. In the average city, there is a larger day-time than night-time population, due to the influx of people from the suburbs and the surrounding country in the morning, and its outflow at night. In the two cities just mentioned, this condition is modified by the fact that a considerable portion of their inhabitants commute to New York city, and add to its day-time population, while subtracting from the day-time population of their own cities. As the great bulk of traffic accidents occur in the day-time, this must cause some lessening of the hazard.

On the other hand, an increase in hazard in these two cities, results from the fact that a part of the vehicular traffic converging on New York, passes through them.

There seems to be no way of appraising the net effect of these untypical conditions. It can hardly be nearly great enough, however, to account for the thirty-four and thirty-one per cent differences in calculated and actual hazards which the cities show. It is probable that the greater part of these differences is due to the motor vehicle law of the state.