# CREDIBILITY AND AUTOMOBILE RATE MAKING

BY

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Recent developments in automobile rate making have again raised the question of credibility, or reliability of experience. Specifically, the question is, how large an exposure is necessary to give a dependable pure premium? How reliable is experience in the present rating territories? How shall this reliability be measured? The subject of reliable experience needs no introduction to the members of this Society. Beginning with the first meeting in 1914, various phases of the problem have been covered almost every year since that time. This paper has no claim to originality of subject matter and theory, but merely proposes certain tests in the application of the credibility formula as it has developed.

There are several reasons why the whole question of credibility should be reconsidered at this time. In the first place greater attention is being given to the fairness and adequacy of rates by territories. Rate supervision by various state departments of insurance has developed to the point where it is necessary to make rates on a more limited territorial basis than formerly. The increase of 200 per cent. in the number of cars in ten years has also been a contributing factor.

The problem of credibility applied to territories is particularly important in Massachusetts. So long as rates were based upon experience of large territories, credibility was a minor question but the application of the present credibility formula to territories with small exposure requires a careful analysis of the theoretical basis upon which such fine territorial distinctions can be drawn.

## Development of Present Theory

One of the first discussions of the reliability of exposure was a paper by Professor Albert H. Mowbray, in 1914, entitled "How Extensive a Payroll Exposure is Necessary to Give a Dependable Pure Premium?" (*Proceedings*, Vol. I, page 24). The theory discussed in this article, which dealt exclusively with workmen's compensation, has been followed by almost every subsequent writer, both with respect to compensation and to other lines.

A dependable pure premium is defined as,

> "—— one for which the probability is high that it does not differ from the absolute (true) pure premium by more than an arbitrary limit which may be selected in view of the other factors referred to."

Following this definition, a method of computing the required volume of exposure is developed from the elementary probabilities. The underlying theory and the method described have been used extensively and a brief statement of both will clarify later discussion.

The empirical probability of an accident in any given territory is the claim frequency obtained by dividing the total number of claims by the number of car years' exposure. This empirical probability is not necessarily the same as the true mathematical probability but with a large exposure the two will be approximately the same. If $p$ equals the probability of an accident and $q$ equals $1 - p$, or the probability of the non-occurrence of an accident, the probability of obtaining exactly $np$ accidents with an exposure of $n$ cars is the maximum term in the expansion of the binomial expression $(p + q)^n$. By allowing a slight variation $K$ above and below the expected claim frequency $p$, the total probability of the number of accidents between $pn - pk$ and $pn + pk$ may be obtained by adding the terms of the above binomial expression between the indicated limits.

By following the demonstration in Bowley's "Elements of Statistics", page 275 *et seq.*, Professor Mowbray shows that this summation approximates very closely to the integral of the normal curve of error. This approximation holds only when the values of $p$ and $q$ are neither very small and when there is a large number of items.

By taking the integral for a portion of the normal curve on either side of the most probable value $p$ we obtain a probability of less than one that the variation from the most probable value will lie within the range of the integral. For instance, if the most probable occurrence of an accident is 5 per 100 cars we may calculate the probability that the accident frequency will not vary more than 5 or 10 per cent. from this rate for any given number of cars. By reversing this procedure and assuming any given probability integral and a fixed allowable departure from the most probable accident rate, the required exposure necessary to conform to this

standard can be computed. Following out this procedure Professor Mowbray demonstrates the calculation of a required exposure for certain probability integrals and certain percentages of allowable variation. From this demonstration it can be shown that the required exposure may be calculated according to the following formula:

$$N = \left(\frac{x}{K}\right)^2 \times \frac{2q}{p} \text{ in which}$$

N is the required exposure
K is the allowable departure from the expected probability of occurrence
q is the probability of non-occurrence of an accident, or 1 — p
p is the probability of occurrence as expressed as a decimal
x is the abscissa in the normal curve corresponding to the adopted probability integral obtained from any ordinary table of functions of the normal curve.

The above method has been followed in most discussions since the publication of Professor Mowbray's paper. The first use of this method in connection with automobile rating territories was described in a paper entitled "Automobile Rate Making" (*Proceedings*, Vol. XI, page 276), by Mr. H. P. Stellwagen before this Society, in 1925. In this paper the method adopted followed Professor Mowbray's formula using an expected accident frequency of 5 per cent. The standard used for a credibility of unity was a departure of not more than 5 per cent. from the expected accident frequency in 99 cases out of 100. The minimum exposure necessary to give the required standard was calculated from this formula to be 50,000 car years. It can be shown from the above formula that the reliability of exposure varies inversely as the root of the exposure. Credibility for an exposure of less than 50,000 car years was determined from the ratio of the square root of the smaller number to the square root of 50,000, or $Z = \sqrt{\frac{n}{50.000}}$. This has been the accepted credibility standard since 1924.

The principal limitation in the application of this standard of credibility was that it made no allowance for variation in claim frequency. In Professor Mowbray's original article he states that the exposure necessary to give a dependable pure premium varies with three things: accident frequency, the percentage of allowable departure from expected value, and the probability integral

adopted. He also shows that with the same probability integral and constant accident frequency, the volume of exposure varies inversely as the square of the allowable variation. With a fixed value for the allowable departure the required exposure varies inversely with the accident frequency. With a given accident frequency and a fixed value for the allowable departure the exposure varies directly with the probability integral and in a ratio greater than the square.

## Experience Rating Applied to Territories

Credibility in automobile rate making, based upon both exposure and claim frequency, was discussed in a paper read before this Society in 1929, by Mr. Harmon T. Barber, entitled "A Suggested Method for Developing Automobile Rates" (*Proceedings*, Vol. XV, page 191). In this paper it was pointed out that weight should be given to the variation in claim frequency, in measuring the reliability of experience. A method was also proposed of experience rating territories with a credibility of less than one, the credibility to be calculated from the formula $Z = \sqrt{\frac{n}{c}}$ where $n$ is the exposure in a territory to be rated, and $c$ is the exposure necessary to give perfect credibility with the accident frequency of the smaller territory.

This method was also suggested in the determination of territories for Massachusetts last year as shown by the following quotation from a memorandum to the Governing Committee of the Massachusetts Automobile Rating and Accident Prevention Bureau:

> "The Committee of Four on Statistics recommends the adoption of the principle of experience rating whereby the pure premium in a given town or group of towns is determined, through the use of proper credibility criteria, by comparison to the town or group of towns pure premium with the average pure premium for the territory in which the town or group of towns is located."

Following out this recommendation an automobile credibility table was prepared in which the credibility expressed in per cent. was shown for various exposures varying with claim frequency. The credibility standard adopted as unity was that the indicated pure premium should not vary more than 5 per cent. in 99 cases

out of 100. It was further proposed by the Committee that rates be based upon broad territories which would have a credibility of unity according to the above standard, but that rates for individual towns should be a weighted average between the territory rate and the town's own experience, the weight given to the town's experience to be its credibility as determined by the table. This proposal was not adopted but it is still a live issue. At several of the legislative hearings during the past winter similar proposals were made by laymen entirely unfamiliar with the principle of experience rating.

## Theoretical Limitations of the Credibility Formula

In view of the growing use of credibility criteria as previously noted, it seems desirable to analyze the formulae upon which these criteria are based both from a mathematical standpoint and from the standpoint of practical results achieved by their use. In the first place the integral upon which credibility is based is an approximation formula. It applies only where there are large numbers of cases involved and in which the probability of success and the probability of failure are neither very small. If the accident frequency is small then the formula fails to give an accurate measure of the credibility of a given exposure. It is questionable whether the credibility is measured accurately where the accident frequency is less than 5 per cent.

A second limitation on the use of the credibility formula is that in theory it applies only to statistical series similar to the series obtained by expanding the binomial $(p + q)^n$. In other words, the integral is applicable only when the series is a so-called normal series in that it conforms closely to the normal curve of error. This was noted by Mr. Arne Fisher in a paper before this Society entitled "Outline of Method for Determining Basic Pure Premiums" (*Proceedings*, Vol. II, page 394). In this paper he pointed out that most social insurance series are not normal or Bernoulli series. The criticism applies equally to automobile insurance series. The underlying assumption in a normal, or Bernoulli, series is that conditions are absolutely uniform for each trial or, in other words, if we attempt to apply the Bernoulli theory to automobile series we must assume that conditions making for automobile accidents are exactly similar from year to year, from

town to town and from season to season. Obviously, this assumption is incorrect. Accidents are caused by a variety of factors, very few of which are constant from year to year or from town to town. To mention a few of the more variable influences, accidents will vary with the number of cars on the road, street and highway conditions, weather conditions, traffic regulations and mechanical changes in automobile construction. There is also the question of moral hazard which, while often discussed, has never been defined. I refer to the difference in mental viewpoint and moral standards between drivers which will be reflected in part by their accident experience, as well as the difference in "claim consciousness" found in various communities.

All of these factors make for changes in accident frequency and the application of a standard of credibility based upon the assumption of uniform conditions is, at best, an approximation. Such a standard is and has been of immense practical value but it should be recognized that it does not include changes due to factors other than pure chance. Variation in automobile accidents is certainly the product of more than chance, as will be shown later in an analysis of automobile experience in certain Massachusetts cities and towns.

A third and perhaps more serious objection to the strict adherence to the present credibility standard is that it does not necessarily apply to pure premiums. Most writers have assumed that variation in pure premiums and variation in claim frequency are one and the same thing. In the original article of Professor Mowbray, accident frequency is used in the calculation of a credibility standard and the result is applied to pure premiums. The same method was followed in the use of the formula by Mr. Stellwagen in 1925, by Mr. Barber last year, and by the Massachusetts Automobile Rating and Accident Prevention Bureau.

Pure premium as determined by formula $\frac{L}{n}$ where $L$ equals incurred losses and $n$ equals number of cars, is the joint product of the number of claims and of claim cost. From a theoretical standpoint we have probability of variation in claim frequency and probability of variation in claim cost. Therefore, the probability of variation in pure premium is a compound probability and it is to be expected that variation in pure premium will be noticeably greater than the variation in either claim cost or claim frequency.

In establishing a standard of credibility based entirely upon claim frequency, the variable cost per claim has been omitted from consideration. That this factor is an important one can be demonstrated by comparing variations in claim frequency, in pure premium and in claim cost. The experience of 150 Massachusetts cities and towns for the years 1927 and 1928 has been used for this analysis. Original reportings have been used in each case in order to make the figures as nearly comparable as possible.

## CREDIBILITY IN MASSACHUSETTS CITIES AND TOWNS

The relative stability of claim frequency, claim cost and pure premium is shown by the statewide averages from the first reporting for each year.

| | Claim Frequency | Claim Cost | Pure Premiums |
|---|---|---|---|
| 1927..... | 7.9 | $240 | $18.99 |
| 1928..... | 7.9 | 244 | 19.35 |

The variation in pure premium of 36 cents or nearly 2 per cent. is entirely due to the increase in claim cost. The probability of such a departure in claim frequency 99 times in 100 requires an exposure of 190,000 cars, or forty per cent. of the statewide exposure of 420,000 cars. Using the total exposure, the probability is .99 that the variation would not be more than 1.3 per cent. from the indicated average of 7.9.

The relative variation in claim frequency, claim cost and pure premium is shown in the total columns of Tables I, II and III. These tables are simple frequency tables showing the number of cities and towns that have different percentage variations from the two year average, further grouped according to volume of exposure.

Claim frequency is less variable than either claim cost or pure premium. This is shown by the extreme variation of more than 90 per cent. for both as contrasted with a maximum of less than 60 per cent. for claim frequency. More cities also show low variations in claim frequency than in the other factors. The percentage differences in variation are shown in Table IV and graphically on Chart I. An illustration will suffice to demonstrate the relative stability of each variable. Taking a departure from the two year

average of 20 per cent., the percentage of total cities and towns above or below this departure is as follows:

| | 20% or less | Over 20% |
|---|---|---|
| Claim Frequency | 86 | 14 |
| Claim Cost | 68 | 32 |
| Pure Premium | 64 | 36 |

The chart shows the cumulative percentage of cities and towns with departures equal to or less than the values on the horizontal scale. The curves for claim cost and pure premium follow each other very closely indicating the necessity of giving weight to the cost factor in a credibility formula. The present formula, based entirely upon claim frequency, cannot give the results expected of it in view of the indicated importance of claim cost.

In passing it should be noted that the frequency distributions based upon departures from the two year average are not normal distributions, particularly with respect to individual exposure groups. This was to be expected from the discussion of the theoretical assumptions underlying a normal distribution.

The relationship between variation in claim frequency, claim cost and pure premium can be shown in still another way. Tables VI and VII show the average and median percentage deviations from the two year average for each factor for cities and towns grouped by volume of exposure. These figures show that in general the percentage variation in cities and towns decreased with an increase in exposure. The median figures shown in Table VII are perhaps a better measure than the average deviations in Table VI, in that they are more typical of each group. The relative effect of claim cost, and claim frequency on pure premium is shown by the ratios of the median deviations. For cities and towns with more than 1,000 car years exposure the median deviation of pure premium averages less than the median deviation of claim cost but from 13 per cent. to 83 per cent. more than of claim frequency.

One further measure of this relationship is the relative dispersion in each series, the measure of dispersion being the standard deviation in Tables V and VIII. The significance of this measure is that if the distributions are not too badly skewed, the standard deviation shows the percentage departure from the mean or 0 necessary to include 68 per cent. of the cities and towns. Using the ratios in the two right hand columns of Table VIII, the dispersion in pure premium varies from 40 per cent. to 80 per cent.

more than similar dispersion for claim frequency, while for claim cost it is from 8 per cent. to 24 per cent. higher.

In general the variation on all factors is in inverse ratio to the volume of exposure. However, this does not hold, for individual size groups of cities and towns. For instance, 13 towns with an exposure of from 3,000 to 5,000 car years show relatively less variation than 12 cities and towns with from 5,000 to 10,000 car years exposure. The difference is too marked to be attributable entirely to chance. The present investigation has not revealed causes for such differences but they are sufficient to indicate the importance of factors other than chance which, in turn, has an effect upon the credibility standard used.

A final test may be made on the reliability of the credibility formula by comparing the actual variation with the expected variation computed from the formula giving due weight both to volume of exposure and average claim frequency of the group. This is shown in Table V and graphically in Chart III. The standard deviation, or measure of dispersion, has been computed for variations in pure premium and claim frequency giving due weight to the volume of exposure. A smooth curve has been fitted to the points typical of each class. The results compare with the data of Table VIII which were computed for larger classes. Using the median exposure and claim frequency an expected percentage departure has been computed for each group, using the accepted method of computation with the exception that the probability of .68 was used instead of .99. This probability was used in order to make these data comparable with the standard deviation, or measure of dispersion. From Chart III it will be noted that for the smaller size groups the expected departure and the actual departure are fairly comparable. For the cities and towns which have more than 5,000 car years exposure, the actual variation is noticeably greater than the expected variation. This would indicate that the credibility formula is less reliable where it is most likely to be used, that is for the larger cities and towns.

## Proposed Changes in the Credibility Formula

Our analysis has now proceeded to the point where we may draw preliminary conclusions. It has been shown that the theory underlying the present credibility formula is not strictly applicable to automobile series. The use of the probability integral for a

moderately skewed type of frequency distribution similar to actual automobile series would improve results but would require considerably more data than are now available. Until such curve types can be determined accurately the present standard will have to be used, with due allowance for its limitations.

It has also been shown that the present credibility formula cannot be applied strictly to pure premiums when based upon claim frequency. By a separate analysis of variation in claim frequency and claim cost, it has been shown that changes in pure premium are more likely to be caused by changes in claim cost than in claim frequency. Variations in claim frequency are also more likely to follow the normal curve than variations in claim cost and pure premium. These results demonstrate the need for a standard of credibility which will give weight to claim cost and to claim frequency in order to conform more closely to actual conditions.

One method of developing such a standard is to have separate credibility requirements for claim cost and claim frequency. A credibility formula for claim cost can be developed from a frequency distribution of claims by size on a statewide basis. Until such an analysis can be made it is suggested that the credibility for claim cost be based upon a high standard applied to claim frequency, while the credibility for claim frequency will be based upon lower requirements. Differences in the series, previously noted, indicate the necessity for different standards.

The present standard on a claim frequency basis of only 5 per cent. variation in 99 per cent. of the cases appears unusually high and it is possible that it was adopted with a view toward a more practical standard, when applied to pure premium. A slight change in the probability integral and in the allowable variation makes considerable difference in the required exposure as shown by the following figures, based upon a constant claim frequency of 5 per cent.

| | Allowable Departure Not More Than | |
|---|---|---|
| Probability | 5 per cent. | 10 per cent. |
| .99 | 50,427 | 12,607 |
| .98 | 41,133 | 10,283 |
| .95 | 29,197 | 7,299 |

In view of the greater stability of claim frequency to the extent of nearly twice that of pure premium, it would appear that the

standard of unit credibility now in use for pure premiums could safely be reduced to approximately one-fourth the present requirement. In other words, a 99% probability of a 10% departure. On the other hand, since the claim cost shows about the same degree of stability as pure premiums the present standard of 5% variation in 99% of the cases could, therefore, be retained.

Under this plan the exposure requirement for stability of claim cost would be the basis of determining broad territories, while the requirements for claim frequency would determine the credibility of the individual city or town. The pure premium in any city with a *unit credibility* for claim frequency would be determined from the formula $P = \frac{Cf}{100}$ where

P = pure premium.
C = average claim cost for the territory.
f = claim frequency in the city to be rated.

For towns in which the credibility of claim frequency is *less than one*, the pure premium will be calculated from the weighted average claim frequency between the town and the territory, the credibility factor being the weight given to the town.

### Elimination of Claim Cost

Rate making would be materially improved if territories could be determined more nearly upon the probability of variation in their claim frequency. A study of the distribution of liability claims by size groups suggests another method by which this may be accomplished. The variation in size of claim is one of the most important factors affecting the average claim cost and as a consequence the elimination of a small percentage of the excess claims would materially reduce variations in claim cost.

An analysis of the experience of the Liberty Mutual Insurance Company in Massachusetts for the years 1927 and 1928 shows a wide difference in pure premium for certain classes of cars. Investigation shows that this difference is due almost entirely to the change in number of claims costing $1,000 or more. For instance, the pure premium on Y cars increased from $22.65 in 1927 to $34.08 in 1928. There was a marked increase in claims costing more than $1,000 in this group. At the same time the pure premium on Commercial cars dropped from $27.75 in 1927 to $21.09 in 1928, with a decrease in claims costing more than $1,000. The average

annual exposure was 3,000 car years for the commercial group and 2,400 car years for the Y group. An elimination of the excess claims gives the following pure premiums, illustrated graphically on Chart II:

| | Y Cars | Commercial Cars |
|---|---|---|
| 1927 | $12.26 | $14.47 |
| 1928 | 14.72 | 13.74 |

The variation from year to year is still noticeable and yet the marked increase in stability indicates the desirability of using some such method in establishing rates for territories with relatively small exposure. For the determination of the pure premium arising out of cases costing less than $1,000, a credibility standard for claim frequency would be followed as at the present time with the suggested increase in allowable variation to 10 per cent. The claims costing more than $1,000 would be distributed on a wide territorial basis either uniformly or to each town in proportion to losses on claims under $1,000. The final pure premium of the individual town under this plan would be based upon its own experience on claims of less than $1,000, provided the credibility was unity under the standard adopted for claim frequency and an additional pure premium would be added to cover the average excess loss on whatever basis might be adopted. This plan is comparable to the rating of compensation insurance where pure premiums are determined separately for serious and non-serious losses and is, possibly, the more feasible of the two plans.

The adoption of either one of the above methods would make it possible to derive a better gauge of the hazard from the experience of the individual city or town and therefore, reflect more accurately any measures which might be taken or fail to be taken by such city or town to provide adequate traffic regulation, safety education and other safety measures.*

*Acknowledgment is rendered to Mr. Hubert W. Yount of the Actuarial Department of the Liberty Mutual Insurance Company, for his conduct of the investigation, the results of which are contained in this paper.

TABLE I
RELATION BETWEEN EXPOSURE AND STABILITY OF CLAIM FREQUENCY
150 Massachusetts Cities and Towns, 1927-1928

| Percentage Deviation from 2 Year Average Claim Frequency | Number of Car Years Exposure | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 500–1000 | 1001–1500 | 1501–2000 | 2001–3000 | 3001–5000 | 5001–10000 | 10001–15000 | 15001–25000 | 25001–50000 | Total |
| 50.1–60.0 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | 1 |
| 40.1–50.0 | 3 | .. | .. | .. | .. | .. | .. | .. | .. | 3 |
| 30.1–40.0 | 5 | 1 | .. | .. | .. | .. | .. | .. | .. | 6 |
| 25.1–30.0 | 4 | 1 | .. | .. | .. | .. | .. | .. | .. | 5 |
| 20.1–25.0 | 2 | 2 | 1 | 1 | .. | .. | .. | .. | .. | 6 |
| 17.6–20.0 | 7 | 2 | .. | 1 | .. | .. | .. | .. | .. | 10 |
| 15.1–17.5 | 3 | .. | 1 | .. | .. | .. | .. | .. | .. | 4 |
| 12.6–15.0 | 5 | 1 | 3 | .. | .. | .. | .. | .. | .. | 9 |
| 10.1–12.5 | 6 | 3 | .. | 2 | .. | 2 | .. | .. | .. | 13 |
| 7.6–10.0 | 2 | 3 | 2 | 2 | 2 | .. | 1 | .. | .. | 12 |
| 5.1– 7.5 | 7 | 2 | 3 | 2 | 1 | 3 | 1 | 1 | .. | 20 |
| 2.6– 5.0 | 7 | 4 | 6 | 3 | 6 | 3 | 1 | .. | .. | 30 |
| 0– 2.5 | 5 | 8 | 3 | 4 | 4 | 4 | 1 | 1 | 1 | 31 |
| Total | 57 | 27 | 19 | 15 | 13 | 12 | 4 | 2 | 1 | 150 |

TABLE 2
RELATION BETWEEN EXPOSURE AND STABILITY OF CLAIM COST
150 Massachusetts Cities and Towns, 1927-1928

| Percentage Deviation from 2 Year Average Claim Cost | Number of Car Years Exposure | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 500–1000 | 1001–1500 | 1501–2000 | 2001–3000 | 3001–5000 | 5001–10000 | 10001–15000 | 15001–25000 | 25001–50000 | Total |
| 80.1–90.0 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | 1 |
| 70.1–80.0 | 0 | .. | .. | .. | .. | .. | .. | .. | .. | 0 |
| 60.1–70.0 | 4 | .. | .. | .. | .. | .. | .. | .. | .. | 4 |
| 50.1–60.0 | 4 | .. | .. | .. | .. | .. | .. | .. | .. | 4 |
| 40.1–50.0 | 7 | 1 | .. | .. | .. | .. | .. | .. | .. | 8 |
| 30.1–40.0 | 8 | 3 | 1 | 1 | .. | .. | .. | .. | .. | 13 |
| 25.1–30.0 | 2 | 1 | 1 | 3 | .. | .. | .. | .. | .. | 7 |
| 20.1–25.0 | 7 | 1 | 3 | 0 | .. | .. | .. | .. | .. | 11 |
| 17.6–20.0 | 1 | 3 | 0 | 0 | 1 | .. | .. | .. | .. | 5 |
| 15.1–17.5 | 3 | 3 | 1 | 2 | 1 | .. | .. | .. | .. | 10 |
| 12.6–15.0 | 2 | 2 | 0 | 2 | 3 | .. | .. | .. | .. | 9 |
| 10.1–12.5 | 1 | 1 | 3 | 0 | 1 | 1 | .. | .. | .. | 7 |
| 7.6–10.0 | 4 | 6 | 3 | 0 | 3 | 3 | 1 | .. | .. | 20 |
| 5.1– 7.5 | 5 | 1 | 3 | 3 | 0 | 3 | 2 | 1 | .. | 18 |
| 2.6– 5.0 | 5 | 2 | 2 | 3 | 2 | 4 | 1 | 1 | .. | 20 |
| 0– 2.5 | 3 | 3 | 2 | 1 | 2 | 1 | 0 | 0 | 1 | 13 |
| Total | 57 | 27 | 19 | 15 | 13 | 12 | 4 | 2 | 1 | 150 |

TABLE 3
RELATION BETWEEN EXPOSURE AND STABILITY OF PURE PREMIUM
150 Massachusetts Cities and Towns, 1927-1928

| Percentage Deviation from 2 Year Average Pure Premium | Number of Car Years Exposure | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 500-1000 | 1001-1500 | 1501-2000 | 2001-3000 | 3001-5000 | 5001-10000 | 10001-15000 | 15001-25000 | 25001-50000 | Total |
| 90.1–100.0 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | 1 |
| 80.1– 90.0 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | 1 |
| 70.1– 80.0 | 2 | .. | .. | .. | .. | .. | .. | .. | .. | 2 |
| 60.1– 70.0 | 1 | .. | .. | .. | .. | .. | .. | .. | .. | 1 |
| 50.1– 60.0 | 5 | .. | .. | .. | .. | .. | .. | .. | .. | 5 |
| 40.1– 50.0 | 5 | 3 | .. | .. | .. | .. | .. | .. | .. | 8 |
| 30.1– 40.0 | 7 | 3 | 3 | 1 | .. | .. | .. | .. | .. | 14 |
| 25.1– 30.0 | 5 | 2 | 1 | 2 | .. | .. | .. | .. | .. | 10 |
| 20.1– 25.0 | 6 | 4 | 0 | 0 | 1 | 1 | .. | .. | .. | 12 |
| 17.6– 20.0 | 2 | 0 | 1 | 3 | 0 | .. | .. | .. | .. | 6 |
| 15.1– 17.5 | 4 | 1 | 2 | 0 | 2 | .. | .. | .. | .. | 9 |
| 12.6– 15.0 | 3 | 2 | 1 | 1 | 1 | .. | 1 | .. | .. | 9 |
| 10.1– 12.5 | 4 | 1 | 2 | 1 | 2 | .. | .. | .. | .. | 10 |
| 7.6– 10.0 | 3 | 3 | 4 | 0 | 0 | 2 | .. | .. | .. | 12 |
| 5.1– 7.5 | 1 | 2 | 2 | 0 | 0 | 4 | .. | 1 | .. | 10 |
| 2.6– 5.0 | 3 | 5 | 2 | 3 | 4 | 4 | 2 | 1 | 1 | 25 |
| 0– 2.5 | 4 | 1 | 1 | 4 | 3 | 1 | 1 | .. | 0 | 15 |
| Total | 57 | 27 | 19 | 15 | 13 | 12 | 4 | 2 | 1 | 150 |

TABLE 4
COMPARISON OF VARIATION IN CLAIM FREQUENCY, CLAIM COST AND PURE PREMIUM
Percentage of Total Cities and Towns Having a Departure Equal to or Below Values Shown

| % Deviation from 2 Year Average | Claim Frequency | | Claim Cost | | Pure Premium | |
|---|---|---|---|---|---|---|
| | % of Total | % Cumulative | % of Total | % Cumulative | % of Total | % Cumulative |
| 0– 5 | 40.7 | 40.7 | 22.0 | 22.0 | 26.6 | 26.6 |
| 6– 10 | 21.3 | 62.0 | 25.3 | 47.3 | 14.7 | 41.3 |
| 11– 15 | 14.7 | 76.7 | 10.7 | 58.0 | 12.7 | 54.0 |
| 16– 20 | 9.3 | 86.0 | 10.0 | 68.0 | 10.0 | 64.0 |
| 21– 25 | 4.0 | 90.0 | 7.3 | 75.3 | 7.9 | 71.9 |
| 26– 30 | 3.3 | 93.3 | 4.7 | 80.0 | 6.7 | 78.6 |
| 31– 35 | 2.0 | 95.3 | 4.7 | 84.7 | 4.6 | 83.2 |
| 36– 40 | 2.0 | 97.3 | 4.0 | 88.7 | 4.7 | 87.9 |
| 41– 45 | 1.3 | 98.6 | 2.7 | 91.4 | 2.7 | 90.6 |
| 46– 50 | .7 | 99.3 | 2.7 | 94.1 | 2.7 | 93.3 |
| 51– 55 | .7 | 100.0 | 1.3 | 95.4 | 2.0 | 95.3 |
| 56– 60 | .... | .... | 1.3 | 96.7 | 1.2 | 96.5 |
| 61– 65 | .... | .... | 1.3 | 98.0 | .7 | 97.2 |
| 66– 70 | .... | .... | 1.3 | 99.3 | 0 | 97.2 |
| 71– 75 | .... | .... | 0 | 99.3 | .7 | 97.9 |
| 76– 80 | .... | .... | 0 | 99.3 | .7 | 98.6 |
| 81– 85 | .... | .... | 0 | 99.3 | .7 | 99.3 |
| 86– 90 | .... | .... | .7 | 100.0 | 0 | 99.3 |
| 96–100 | .... | .... | .... | .... | .7 | 100.0 |

TABLE 5

COMPARATIVE DISPERSION OF VARIATION IN CLAIM FREQUENCY, CLAIM COST & PURE PREMIUM*

150 Massachusetts Cities and Towns

| Exposure Groups No. of Car Years | Group Exposure in 1927 Car Years | No. of Cities and Towns in Group | Group Median Exposure | Group Median Claim Frequency | Dispersion as Percentage Departure from 2-Year Average | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Claim Cost | Claim Frequency | | Pure Premium | | **Computed Dispersion Theoretical |
| | | | | | Unweighted | Weighted | Unweighted | Weighted | Unweighted | |
| 500- 1,000 | 38,634 | 57 | 700 | 4.0 | 34.4 | 20.5 | 22.0 | 34.7 | 36.4 | 18.6 |
| 1,000- 2,000 | 59,536 | 46 | 1,400 | 5.0 | 17.7 | 12.2 | 11.3 | 22.1 | 21.2 | 11.7 |
| 2,000- 3,000 | 42,095 | 15 | 2,300 | 6.0 | 17.4 | 9.3 | 9.4 | 15.8 | 16.7 | 8.3 |
| 3,000- 5,000 | 53,005 | 13 | 3,600 | 6.5 | 11.0 | 4.9 | 4.5 | 10.3 | 10.9 | 6.3 |
| 5,000-10,000 | 87,006 | 12 | 7,000 | 8.0 | 6.6 | 5.6 | 5.7 | 7.6 | 8.5 | 4.1 |
| 10,000-20,000 (1) | 82,261 | 6 | 11,000 | 7.0 | 6.1 | 5.3 | 4.6 | 6.4 | 6.7 | 3.5 |

* Dispersion is measured by standard deviation from zero as the mean.

**Theoretical Dispersion is computed by formula from the median exposure and claim frequency in each group and indicates the approximate theoretical variation in claim frequency necessary to include 68% of the cities and towns in each group.

(1) Boston omitted.

TABLE 6

AVERAGE PERCENTAGE DEVIATION FOR PURE PREMIUM, CLAIM COST AND CLAIM FREQUENCY*

Massachusetts Automobile Experience, 1927 and 1928

| Number of Car Years | Number of Cities and Towns | a. Pure Premium % | b. Claim Cost % | c. Claim Frequency % | Ratios | |
|---|---|---|---|---|---|---|
| | | | | | a/b | a/c |
| Over 500 | 150 | 18.9 | 15.9 | 10.7 | 1.18 | 1.77 |
| Over 1000 | 93 | 12.8 | 11.6 | 6.9 | 1.10 | 1.86 |
| Over 3000 | 32 | 7.1 | 7.3 | 4.3 | .98 | 1.65 |
| Over 5000 | 19 | 6.2 | 5.7 | 4.5 | 1.09 | 1.38 |
| Over 10000 | 7 | 5.2 | 5.2 | 4.1 | 1.00 | 1.27 |

*Percentages are unweighted for variation in exposure.
See Tables 1, 2 and 3.

TABLE 7

MEDIAN PERCENTAGE DEVIATION FOR PURE PREMIUM, CLAIM COST AND CLAIM FREQUENCY*

Massachusetts Automobile Experience, 1927 and 1928

| Number of Car Years | Number of Cities and Towns | a. Pure Premium % | b. Claim Cost % | c. Claim Frequency % | Ratios | |
|---|---|---|---|---|---|---|
| | | | | | a/b | a/c |
| Over 500 | 150 | 13.4 | 11.1 | 6.9 | 1.21 | 1.94 |
| Over 1000 | 93 | 8.8 | 8.9 | 4.8 | .99 | 1.83 |
| Over 3000 | 32 | 4.9 | 6.9 | 3.9 | .71 | 1.25 |
| Over 5000 | 19 | 5.0 | 5.4 | 4.4 | .92 | 1.13 |
| Over 10000 | 7 | 4.4 | 5.8 | 3.8 | .76 | 1.16 |

*The median as used here is the middle sized deviation without regard to exposure.

TABLE 8

DISPERSION OF PERCENTAGE VARIATION IN PURE PREMIUM, CLAIM COST AND CLAIM FREQUENCY

Massachusetts Automobile Experience, 1927 and 1928

| Number of Car Years | Number of Cities and Towns | Dispersion *D | | | Ratios | |
|---|---|---|---|---|---|---|
| | | a. Pure Premium % | b. Claim Cost % | c. Claim Frequency % | a/b | a/c |
| Over 500 | 150 | 26.4 | 24.3 | 14.7 | 1.09 | 1.79 |
| Over 1000 | 93 | 17.2 | 15.0 | 9.6 | 1.15 | 1.80 |
| Over 3000 | 32 | 9.2 | 8.5 | 5.2 | 1.08 | 1.77 |
| Over 5000 | 19 | 7.8 | 6.3 | 5.6 | 1.24 | 1.39 |

*Dispersion as used here measures the percentage variation from the two year average necessary to include 68 per cent. of the cities and towns if the distribution of variation from the average follows the normal curve of error. Each city or town has been considered as a unit without regard to exposure. See Tables 1, 2 and 3.

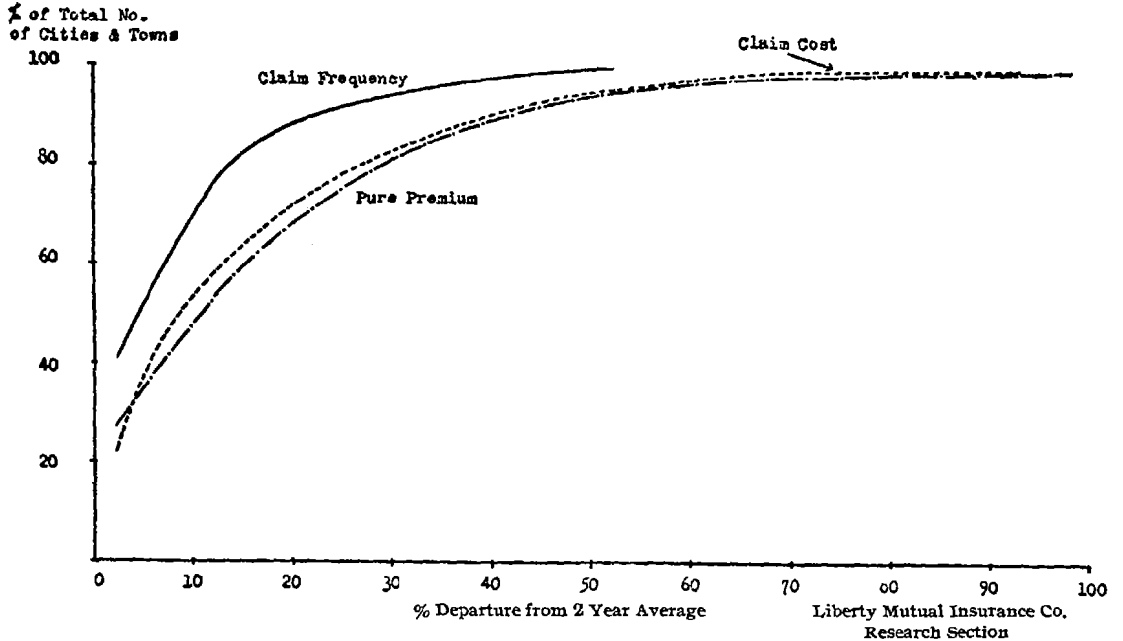
$$D = \sqrt{\frac{\Sigma f d^2}{N}}$$ where $d$ is the percentage deviation.

$f$ is the number of cities and towns within each group.

$N$ is the total number of cities and towns.

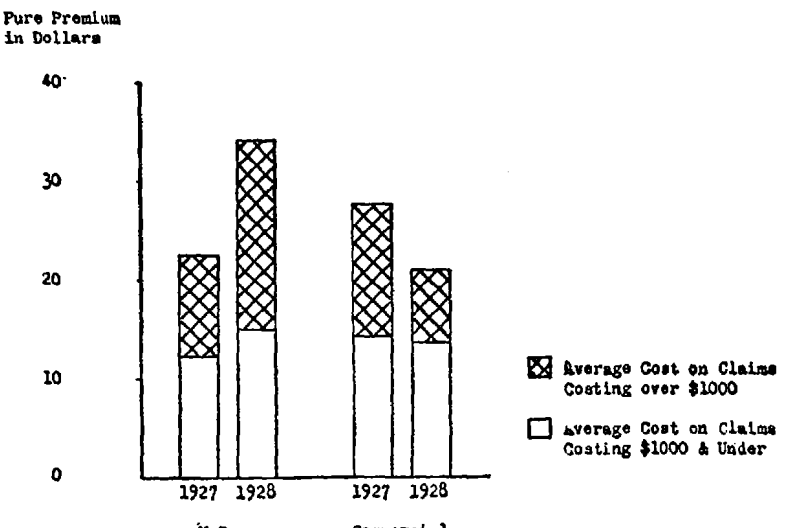
# CHART I

COMPARISON OF VARIATION IN CLAIM FREQUENCY, CLAIM COST AND PURE PREMIUM
Cumulative Frequency Curves showing % of Total Cities and Towns having a Departure Equal to or Below Values Shown



# CHART II

RELATIVE STABILITY OF AUTOMOBILE PURE PREMIUMS
Liberty Mutual Experience in Massachusetts 1927-1928




Liberty Mutual Insurance Co.
Research Section

# CHART III

## RELATION BETWEEN VARIATION IN CLAIM FREQUENCY AND PURE PREMIUM