Workers' Compensation D-Ratios, An Alternative Method of Estimation

by Howard C. Mahler, FCAS, MAAA

WORKERS' COMPENSATION D-RATIOS, AN ALTERNATIVE METHOD OF ESTIMATION

BY HOWARD C. MAHLER, FCAS, MAAA
THE WORKERS' COMPENSATION RATING AND INSPECTION BUREAU OF MASSACHUSETTS

Abstract

This paper presents a new method of estimating D-Ratios by class based on estimated average claim costs by class, that is being used in Massachusetts Workers' Compensation.

WORKERS' COMPENSATION D-RATIOS, AN ALTERNATIVE METHOD OF ESTIMATION

This paper will present a new method of estimating D-Ratios by class that is being used for Massachusetts Workers' Compensation.[1] This method based on average claim cost is compared to the prior method in Table 8.

Background

In Workers' Compensation Experience Rating claims are generally split into a Primary and Excess portion. In Massachusetts and most other states, the portion of each claim below $5,000 is Primary. The portion above $5,000 is Excess, but all the dollars above a certain limit (which is currently $175,000 in Massachusetts) are excluded from Experience Rating.

The D-Ratio (Discount Ratio) is defined as the ratio of the future Expected Primary Losses to the Expected Primary plus Excess Losses.[2] A separate D-Ratio for each classification in each state is needed. For Massachusetts the D-Ratios are generally between 10% and 30%.[3]

The effect on the Experience Modification of a difference in D-Ratios is discussed in the Appendix. All other things being equal the higher the D-Ratio the lower the Experience

[1] This method turns out to be similar to one presented by Arthur Bailey [1].

[2] In Workers' Compensation experience rating Expected Losses are obtained by multiplying payrolls by class times the corresponding Expected Loss Rates by class. Then for each class the Expected Primary Losses are the product of the Expected Losses times the D-Ratio for that class.

[3] In a state with lower average claim costs but using the same $5,000 dividing point, the percentage of primary losses would be higher and thus the D-Ratios would be higher.

Modification.[4] In order to get an accurate Experience Modification one desires the best estimate of D-Ratios.[5]

There are two basic problems in estimating D-Ratios. First, we are interested in the expected future value. Therefore, we need to adjust the past data to reflect future conditions. This is relatively routine and involves the usual severity trend and on-level factors for law amendments used elsewhere in ratemaking.[6] An example is shown in Table 1. Note that the factors in Table 1 adjust the data[7] available at the time of the rate indication to the expected level of the data that will be used to experience rate insureds during the policy effective period.[8]

Overview of Methodology

This paper will focus on the second and more difficult problem. The volume of data by class in a state is insufficient in most cases to allow a good estimate of the D-Ratio directly from the data for that class.

However, one can work with the larger groupings.[9] Currently, there are five Industry Groups generally used for Workers' Compensation for ratemaking: Manufacturing, Contracting,

[4] A .10 higher D-Ratio will result in a .04 to .07 lower Experience Modification, as discussed in the Appendix.

[5] As well as the best estimate of other inputs such as Expected Loss Rates, credibilities, etc.

[6] See for example Kallop [2] or Feldblum [3].

[7] Unit Statistical Plan data is usually compiled into a report called Schedule Z.

[8] Generally one would use three years of data to experience rate insureds. For example, during 1996 one would generally use 1994 at first report, 1993 at second report, and 1992 at third report. At the time one was estimating D-Ratios for 1996, one might have available 1992 at first report, 1991 at second report and 1990 at third report. In that case one would adjust the 1992 data at first report to level expected for the 1994 data at first report, etc.

[9] Hazard Groups were tried, but the use of Industry Groups did a better job of estimating D-Ratios. A major problem is that over 90% of the experience is concentrated in Hazard Groups 2 and 3.

Goods and Services, Office and Clerical, and Miscellaneous. In Massachusetts (and states with a similar or larger volume of data[10]) each Industry Group has a sufficient amount of data to estimate its D-Ratio directly from the data. (See Table 2.)

The Construction Industry Group stands out from the other four as having a very significantly lower D-Ratio.[11] Thus this breakdown splits out many of the classes with the lowest D-Ratios. Also, as will be seen, much of the remaining variation within Industry Group can be captured via relative average claim costs by class.

The methodology consists of estimating the D-Ratio of each class relative to the D-Ratio of its Industry Group. (These estimated relativities will be balanced to unity.) This relative D-Ratio for each class will in turn be estimated from the relative average claim cost for that class. Classes with higher than average severities will be estimated to have lower than average D-Ratios. In other words, if the average claim size is larger, more of the claim is excess and less is primary.

Estimated Relative Average Claim Costs by Class

The estimated Relative Average Claim Costs by class are calculated based on the most recent seven years of Unit Statistical Plan data at second report.[12] Average Claim Costs are calculated based on data excluding fatal, permanent total, and medical-only claims, as was used

[10] In states with very small amounts of data one could calculate a statewide D-Ratio and spread it to Industry Group based on the relativities over a longer period of time or in other states.

[11] More large claims apparently lead to a smaller percent of primary losses.

[12] Second report is the approximate average maturity of data used for experience rating. Unit Statistical Plan Data is submitted on every individual claim of size $2,000 or more. Evaluations are currently on a paid plus case reserve basis at the first five reports. First report is 18 months from policy inception. Subsequent reports are at 12 month intervals.

in the development of the model discussed subsequently. Table 3 is an example for the Office and Clerical Industry Group for Composite Policy Year 91/92.[13]

For each year, for each Industry Group, the Relative Average Claim Cost for a class is the ratio of the Class Average Claim Cost to the Industry Group Average Claim Cost. Figure 1 shows the results for two classes in the Office and Clerical Industry Group. For each class, the seven years of Observed Relative Average Claim Costs are combined by taking a weighted average using claim counts as weights. (See Table 4.)

However, there are only limited data for smaller classes. Therefore, Credibility has been used to combine the Observed Relative Average Claim Cost by class with unity. (Unity corresponds to the Industry Group average.) Credibility is taken equal to:

$$Z = \sqrt{\frac{\text{number of claims}}{2{,}500}}$$

A class with 2,500 or more claims is assigned a credibility of 1. The classical full credibility criterion of 2,500 claims for severity was selected based on adjusting a criterion for frequency of about 1,000 claims by multiplying by the square of the coefficient of variation of about 2.5.[14] The results herein are relatively insensitive to the precise choice of the full credibility criterion.[15] While a more "sophisticated" credibility method might have been employed, in the author's opinion classical credibility is more than adequate for this particular

[13] Composite Policy Year 91/92 includes all experience on policies with effective dates between 7/1/91 and 6/30/92.

[14] See Longley-Cook [4]. 1082 and 683 are common criterion for full credibility for frequency mentioned by Longley-Cook. The Appendix of Longley-Cook's paper recommends multiplying by the square of the coefficient of variation to get a criterion for average claim costs. The observed square of the coefficient of variation for the severity for permanent partial and temporary total claims is about 2.5. The square of the coefficient of variation = variance/mean^2.

[15] For a discussion of this subject see Mahler [5].

application.[16] The range of estimated D-Ratios is so small that minor changes in the estimated relative claim costs have relatively little final impact.[17]

For example, the relative average claim costs by year for class 4361 are shown in Table 4. There is sufficient fluctuation from year to year that any reasonable credibility method would assign significantly less than full weight to this data. For example, suppose instead of 35.9% credibility, 20% credibility were assigned. The relative average claim cost would be .957 rather than .923. The estimated relative D-Ratio would be 1.029 rather than 1.051. The resulting estimated D-Ratio would be .24 rather than .25 as shown in Table 7. This difference is well within the inherent error of the whole estimation procedure.

The relative average claim cost is estimated for each class as seen in Column 11 of Table 4:

Estimated Relative Average Claim Cost = 1 + Z (Observed Relative Average Claim Cost - 1)

These estimated Relative Average Claim Costs[18] are then used in the model, that will be described next, in order to derive estimated Relative D-Ratios.[19]

Model of Average Claim Cost vs. D-Ratio

As seen in Column 12 of Table 4, within industry groups, the overall average D-Ratio is spread to each classification using the following model:

---

[16] For a comparison of the practical impact of using classical credibility versus Bayesian/Bühlmann credibility see Mahler [5]. Mahler [6] discusses the use of different criteria to select optimal credibilities. Mahler [6] and Mahler [7] discuss the possible impact of shifting parameters over time. Taking into account the impact of shifting parameters over time here is a possible area of future research.

[17] See the Appendix.

[18] See Column (11) of Table 4.

[19] See Column (12) of Table 4.

(Relative D-Ratio - 1) = (- 2/3) (Relative Average Claim Cost - 1)

The form of the model is based on the fact that larger claims contribute a smaller percentage to primary losses than do smaller claims. For example, a $3,000 claim has 100% of its losses as primary, while a $100,000 claim has 5/100 = 5% of its losses as primary. Thus classes with higher than average claim sizes will be expected to have a smaller percent of their losses as Primary, and therefore, have lower than average D-Ratios.

The particular coefficient used in the model was selected in Table 5, based on an examination of the historical relationship between average claim costs and D-Ratios.[20] Separately for each Industry Group weighted least squares regressions were performed on Relative Average Claim Costs and Relative D-Ratios by class. Table 6, Page 1 shows the Office and Clerical Industry Group.[21]

The most recent Unit Statistical Plan data (1st, 2nd, and 3rd report combined) by class is used (without adjustment for law amendment or trend). An Observed D-Ratio is calculated in Column 4 of Table 6 for each class as the ratio of Losses Limited to $5,000 to Losses Limited to $175,000. The Relative D-Ratio in Column 5 of Table 6 for each class is the class D-Ratio divided by the average for the Industry Group.

As was done previously, the Average Claim Cost by class is calculated for other than fatal, permanent total, and medical-only claims. The fatal and permanent total claims are rare

[20] In some sense the proportionality constant is a second use of credibility. The proportionality constant measures how much of a deviation from average one would expect in D-Ratio based on a certain deviation from the average severity.

[21] Table 6, Pages 2 and 3 shows the similar calculation for the Construction Industry Group.

and usually very large, and therefore would introduce undesirable random fluctuations.[22] The medical-only claims are very numerous but due to their very small size, account for a very small percent of total losses.[23] Based on the author's attempts to devise a method, apparently the medical only claims mask the important differences between classes which would be expected to lead to different D-Ratios.

Potentially valuable information has been "thrown away" in the calculation of the relative average claim costs by excluding fatal, permanent total and medical-only claims. However, the resulting relative average claim costs by class showed a strong correlation with the relative D-Ratios[24] by class. As in any actuarial computation, it would be possible to devise some way to incorporate this additional information in some manner to some extent. This is an area of potential future research, although given the small range of D-Ratios it is unlikely in the author's opinion to have much practical impact. There is some advantage to simple practical methods that work, without unnecessary technical refinements of no practical importance to the particular application.

The Relative Average Claim Cost by class in Column 9 in Table 6 is the class Average Claim Cost in Column 8 divided by the Industry Group Average Claim Cost. For purposes of the regression, the Relative Average Claim Cost by class is constrained to be between 0.5 and 2.0.

[22] An alternative would have been to include fatal and permanent total claims, but to cap their size as is done for purposes of experience rating. In that case, the standard for full credibility of the observed relative average claim cost would be adjusted upwards.

[23] The medical onlys usually account for a significant proportion of primary losses.

[24] Which include the impact of claims of all injury kinds.

This prevents a small class with an extreme observed average claim cost over these three years, from unduly influencing the regression results.[25]

The weights used in the regression are the number of claims by class in Column 7. Then as stated previously, a weighted least squares regression between Relative Average Claim Costs and Relative D-Ratios by class is performed separately for each Industry Group. Figure 2 shows the regression for the Office and Clerical Industry Group.

These regressions yield five different estimates of an appropriate proportionality constant to be used in the model. As shown in Table 5, a single proportionality constant is selected within the indicated range.[26] The choice of a single proportionality constant is not a necessity for application of the method. That was the author's judgment given the ability to only examine data from one state over a limited period of time. Given data from more states or more years a different choice might have been made. In any case, each user of the method could select appropriate proportionality constants at this stage of the procedure based on the available information and his own judgment.

Then a Relative Average D-Ratio for each class in the Industry Group is calculated in Column 12 of Table 4, using the selected proportionality constant.

Table 7 shows the calculation of the D-Ratios for these classes. The relative D-Ratios are balanced to unity in Column 4 using the Expected Losses by class. In Column 5 the Indicated D-

[25] As seen in Table 5, the results of capping were quite significant for the Miscellaneous Industry Group in this review.

[26] A similar range was indicted in a prior review. However, there is considerable fluctuation in the slopes of the regressions. Performing similar regressions in additional states and over more periods of time might allow one to select different proportionality constants by Industry Group. Again, given the small range of D-Ratios, it is unclear how much impact such a refinement could have on the estimated D-Ratios.

Ratios by class are the product of the balanced relativity D-Ratio for each class times the indicated D-Ratio for the Industry Group, in this case .2355 from Table 2 for the Office and Clerical Group.

For class 8742 (Salespersons) its estimated relative claim cost is 1.143, higher than average for the Office and Clerical Group. This yields an estimated relative D-Ratio of 1 - (2/3) (1.143 - 1) = .905, lower than average for the Office and Clerical Group. After balancing to unity the relative D-Ratio becomes .911. Then the estimated D-Ratio for class 8742 is (.911) (.2355) ≈ .21.

Similarly, for every class its observed relative average claim cost will be used to estimate its claim costs relative to its Industry Group. Then this in turn is used to estimate for each class its relative average D-Ratio. Then the estimated D-Ratio for each class is the product of its relative D-Ratio and the estimated D-Ratio for its Industry Group. Table 7 shows the final estimated D-Ratios for each class in the Office and Clerical Industry Group.[27]

Comparison to a Prior Method

The prior method used in Massachusetts was generally along the lines described in Gillam [8],[28] although some of the details differed. As shown in Table 8 in the prior method one calculated three "partial D-Ratios" as follows.

$$\text{D (Serious)} = \frac{\text{Primary Serious Losses (Indemnity \& Medical)}}{\text{Serious Indemnity Losses}}$$

$$\text{D (Non - Serious)} = \frac{\text{Primary Non - Serious Losses (Indemnity \& Medical)}}{\text{Non - Serious Indemnity Losses}}$$

[27] Similar exhibits would be produced for the other four Industry Groups.

[28] See Pages 238-239, 249-251 of PCAS 1992.

$$\text{D (Medical)} = \frac{\text{Medical Only Losses}}{\text{Total Medical Losses}}$$

The above statewide partial D-Ratios were used to calculate the D-Ratios by using the following formula:

$$\text{D - Ratio} = \frac{(P_s)(D_s) + (P_n)(D_n) + (P_m)(D_m)}{P_s + P_n + P_m} \, LEF, \text{ where } P_s, \; P_n, \text{ and } P_m$$

are the adopted partial pure premiums underlying the rate for a class for the serious, non-serious, and medical losses, respectively; D_s, D_n, and D_m are the statewide partial D-Ratios; and LEF is the appropriate loss elimination factor.[29]

For example, in the filing for 1/1/95 Massachusetts Workers' Compensation rates, the partial D-Ratios were:

$$D_s = .089$$

$$D_n = .521$$

$$D_m = .110$$

For example, for Class 8810 (Clerical Risks) the partial pure premiums from the classification ratemaking process were

$$P_s = .10 \qquad P_n = .07 \qquad P_m = .08.$$

Thus, the estimated ratio of Primary Losses to Total Losses for this class was:

$$\frac{(.10)(.089) + (.07)(.521) + (.08)(.110)}{.10 + .07 + .08} = .217.$$

[29] Loss Elimination Factors (LEF's) varied by hazard group. Multiplication by the LEF was necessary since actual losses used in individual risk experience ratings are limited. The LEF removed that portion of the pure premium which is excluded in the individual risk experience rating.

The Loss Elimination Factor (LEF)[30] for Hazard Group 2[31] was 1.035. So for Class 8810 the estimated ratio of Primary Losses to limited losses entering experience rating was the product (.217) (1.035) = .22. Thus, the proposed D-Ratio for Class 8810 was .22. The D-Ratios for every other class were calculated similarly, with P_s, P_n and P_m differing by class and LEF varying by Hazard Group.

The concept of this prior method is that those classes with more serious losses and fewer non-serious losses would tend to have a corresponding higher proportion of large claims resulting in more excess and less primary losses. In practice, there are a number of potential difficulties.

First, the division between serious and non-serious losses is not always clear cut; it may depend on individual insurers statistical coding practices particularly at early reports.[32] Combined with the limited data available for smaller classes and/or smaller states, this can lead to uncertainty in the relative sizes of the partial pure premiums P_s, P_n and P_m.[33]

Second, the Medical Pure Premium P_m is being multiplied only by a ratio of medical only losses to total medical losses. Since this ratio is generally smaller than the average D-Ratio, the more medical losses a class has compared to similar classes the lower the estimated D-Ratio.

---

[30] This factor takes into account the limit on the dollars of claims that enter into experience rating. While the concept is used in the new alternative method, a separate such factor is not calculated.

[31] Class 8810 is in Hazard Group 2.

[32] A claim reported as Temporary Total is non-serious while one reported as Partial Disability (including the possibility of total benefits prior to partial benefits) is either serious or non-serious. At early reports prior to any partial disability payments, carrier judgments may determine whether a claim is reported as Temporary Total or Partial Disability.

[33] This can occur even if their sum: $P_s + P_n + P_m$ is fine for estimating class relativities.

Yet, a larger proportion of medical losses from both large and small accidents is not obviously a determinant of the proportion of primary dollars of loss.

Third, for the determination of primary and excess losses the medical and indemnity pieces of a claim are summed together rather than divided apart and treated separately.[34] Thus, the prior method employed a split not inherently present in the specific real world phenomena we are trying to measure and/or estimate.

In spite of all these potential problems, this prior method did a reasonable job. To some extent this is due to the relatively small range of D-Ratios compared to the large range of classification rates.[35] One step that could have been added to the prior method was to balance the final estimated D-Ratios by class back to those observed in the (adjusted) data either by Industry Group or overall. This would have removed any bias or off-balance introduced.

Conclusions

The method presented employs a series of relatively simple techniques to estimate D-Ratios by class from D-Ratios by Industry Group. This differs from the prior methodology which for each class weighted together "partial D-Ratios" using formula pure premiums broken down into serious, non-serious, and medical. These two methods are contrasted in Table 8. The method presented has the advantage of taking into account the actual severity data for each class (to the extent it is credible) in estimating the D-Ratio for each class.

[34] In addition, no specific distinction is made in most states based on injury kind for experience rating.

[35] While class rates could easily vary from 20 cents to 100 dollars, D-Ratios might range from about .10 to .30.

REFERENCES

[1] Bailey, Arthur L., "Workmen's Compensation D-Ratio Revision," *PCAS* XXXV, 1948, pp. 26-39.

[2] Kallop, Roy H., "A Current Look at Workers' Compensation Ratemaking," *PCAS* LXII, 1975, pp. 62-133.

[3] Feldblum, Sholom, "Workers' Compensation Ratemaking (selected chapters)," CAS Forum, Special Edition including 1993 Ratemaking Call Papers, February 1993, pp. 241-312.

[4] Longley-Cook, Laurence H., "An Introduction to Credibility Theory," *PCAS* XLIX, 1962, p. 194.

[5] Mahler, Howard C., "An Actuarial Note on Credibility Parameters," *PCAS* LXXIII, 1986, pp. 1-26.

[6] Mahler, Howard C., "An Example of Credibility and Shifting Risk Parameters," *PCAS* LXXVII, 1990, pp. 225-308.

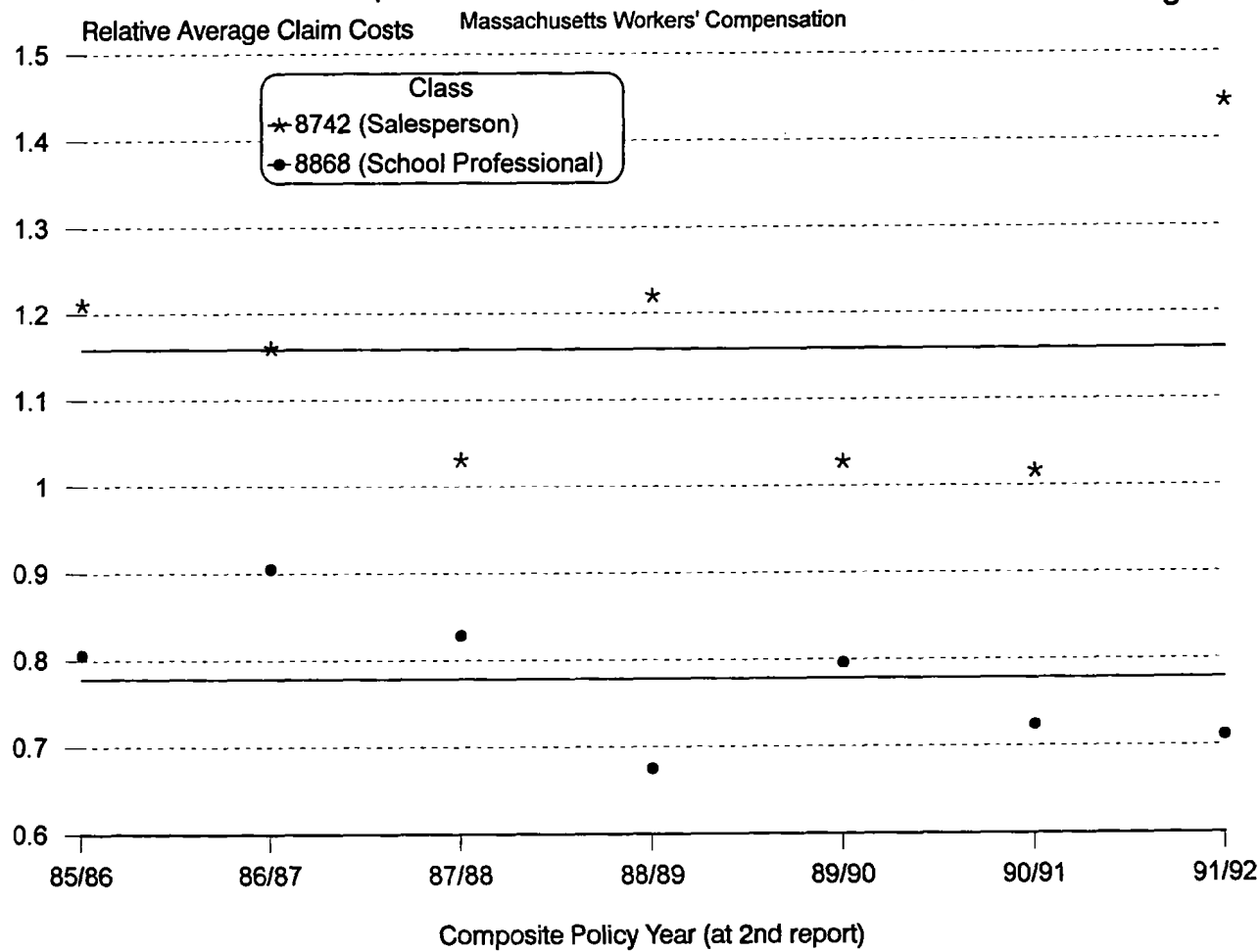
[7] Mahler, Howard C., "A Markov Chain Model of Shifting Risk Parameters," *PCAS* LXXXIV, 1997.

[8] Gillam, William R., "Workers' Compensation Experience Rating: What Every Actuary Should Know," *PCAS* LXXIX, 1992, pp. 215-254.

[9] Mahler, Howard C., Discussion of Gillam: "Parametrizing the Workers' Compensation Experience Rating Plan," *PCAS* LXXX, 1993, pp. 148-183.

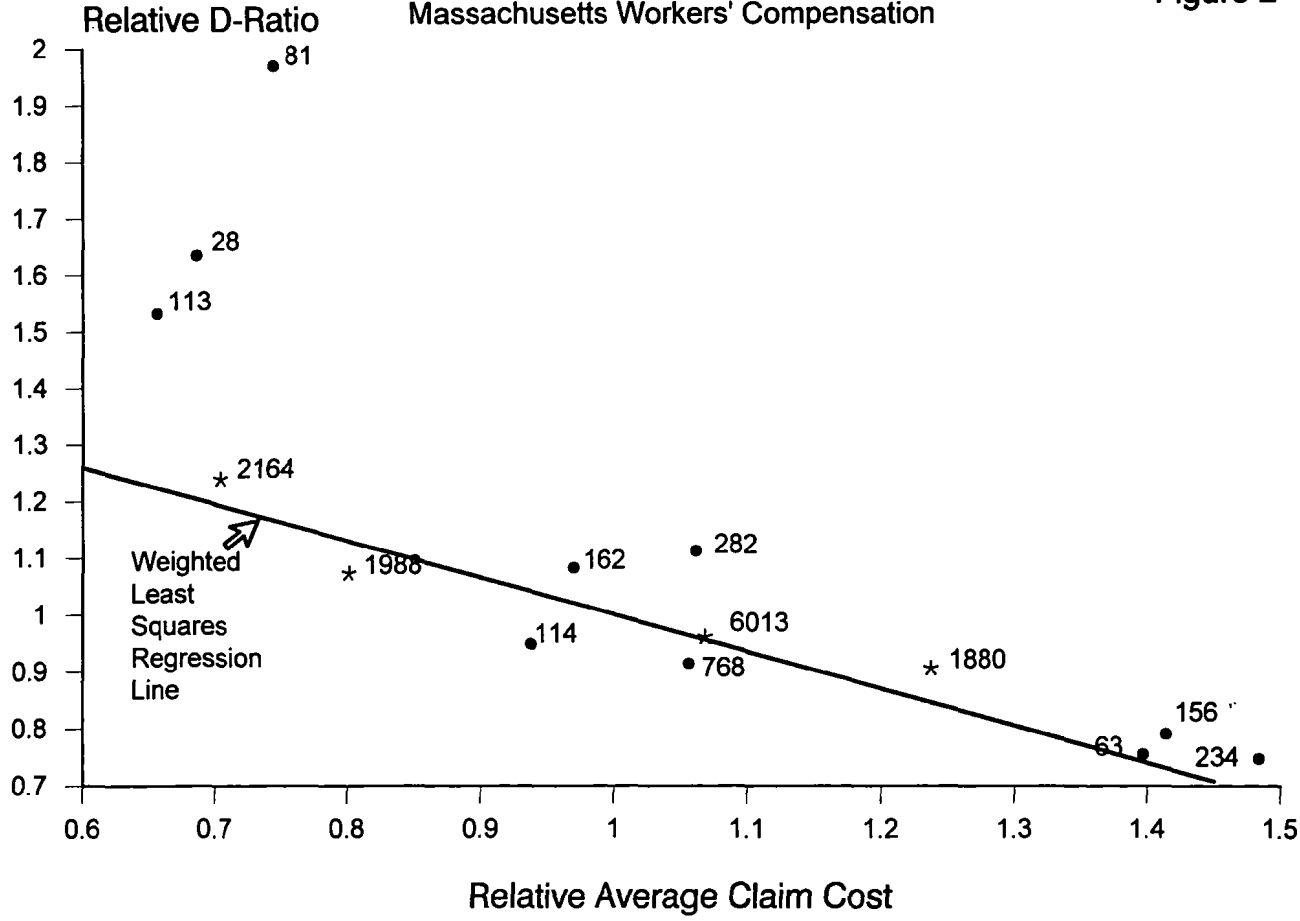
Example Classes from Office & Clerical Industry Group

Figure 1



Office & Clerical Industry Group by Class
Massachusetts Workers' Compensation

Figure 2

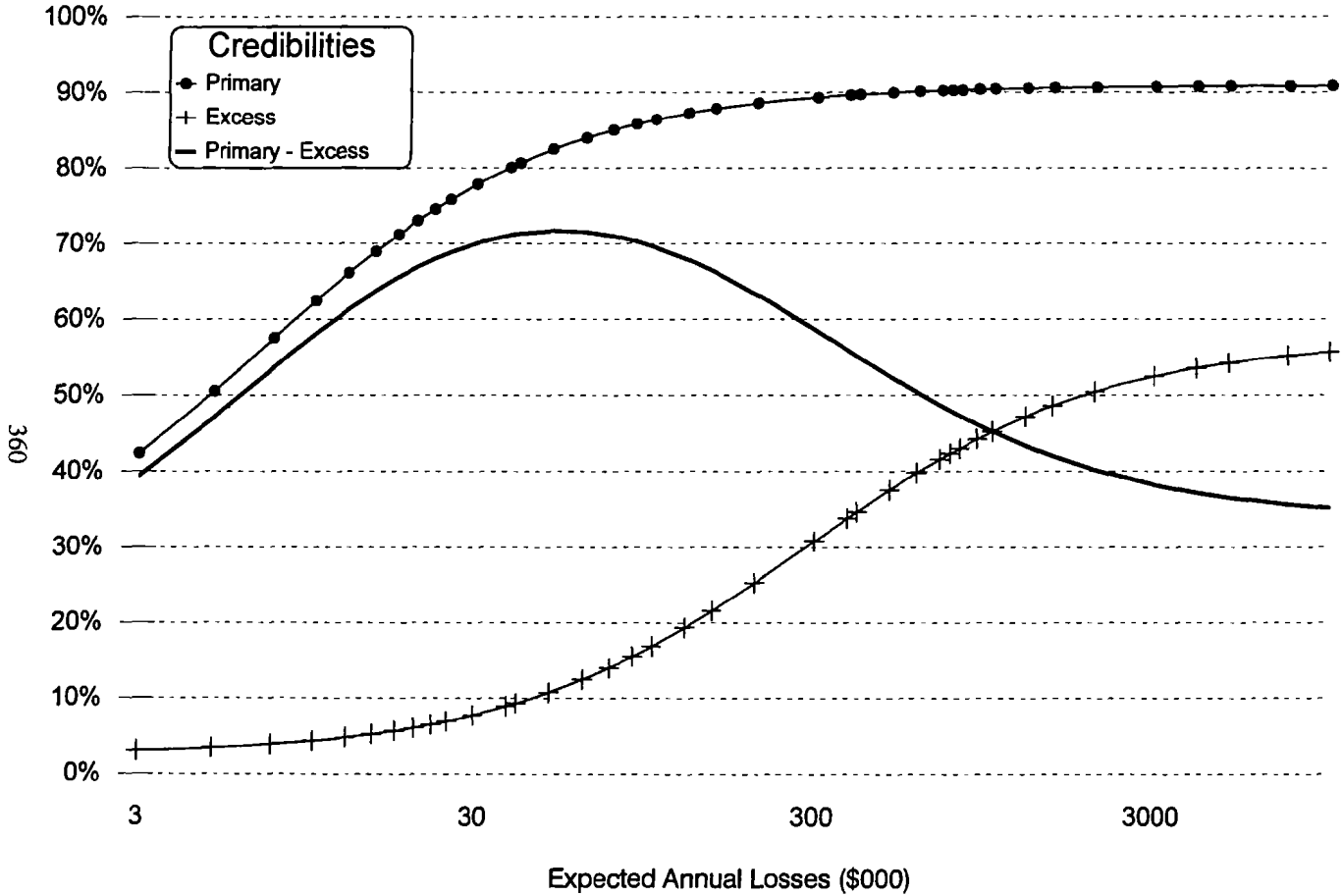


Points for each class labeled by number of claims (3 years). CPY 92/93 @1st, CPY 91/92 @ 2nd, CPY 90/91 @ 3rd, combined. Permanent partial and temporary total claims.

Experience Rating Credibilities, Primary vs Excess

Massachusetts Workers' Compensation

Figure 3



360

Revised Experience Rating Plan, with g = 7

Massachusetts Workers' Compensation

Combined Severity Trend and Law Amendment Factors

A. Severity Trends*

Composite Policy Year	Indemnity Injury Kind 1	2	3	4	5	Medical Injury Kind 1	2	3	4	5	6
90/91	1.0827	1.0827	1.0827	1.0827	1.0827	1.1746	1.1746	1.1746	1.1746	1.1746	1.1746
91/92	1.0699	1.0699	1.0699	1.0699	1.0699	1.1170	1.1170	1.1170	1.1170	1.1170	1.1170
92/93	1.0756	1.0756	1.0756	1.0756	1.0756	1.1077	1.1077	1.1077	1.1077	1.1077	1.1077

B. Law Amendment Factors

90/91	0.771	0.692	0.848	0.961	0.745	1.007	1.007	1.007	1.007	1.007	1.007
91/92	0.979	0.959	0.999	1.038	0.965	1.012	1.012	1.012	1.012	1.012	1.012
92/93	1.026	1.015	1.022	1.040	1.007	1.021	1.021	1.021	1.021	1.021	1.021

C. Combined Severity Trend and Law Amendment Factors (A x B)

90/91	0.8348	0.7492	0.9181	1.0405	0.8066	1.1828	1.1828	1.1828	1.1828	1.1828	1.1828
91/92	1.0474	1.0260	1.0688	1.1106	1.0325	1.1304	1.1304	1.1304	1.1304	1.1304	1.1304
92/93	1.1036	1.0917	1.0993	1.1186	1.0831	1.1310	1.1310	1.1310	1.1310	1.1310	1.1310

* The trend factors are adjusting for the effects of inflation expected during the two year period between the Schedule Z data used in the calculation of D-Ratios and the data that will be used to calculate Experience Modifications during the policy year effective period 7/1/96 to 6/30/97.
(This data corresponds to C.P.Y. 92/93, 93/94, and 94/95.)

Table 2

MASSACHUSETTS WORKERS' COMPENSATION
Observed D-Ratios by Industry Group

(1) Industry Group	(2) Adjusted Schedule Z Losses limited to $5,000	(3) Adjusted Schedule Z Losses limited to $175,000	(4) = (2) / (3) Observed D-Ratio
Manufacturing	107,469,897	431,334,977	0.2492
Construction	52,105,826	351,216,628	0.1484
Office & Clerical	55,821,603	237,007,928	0.2355
Goods & Services	160,437,682	629,524,720	0.2549
Miscellaneous	47,147,170	200,469,410	0.2352

(2), (3): Schedule Z losses (1st, 2nd, and 3rd report combined, includes all injury kind) Losses are adjusted using the Law and Trend Factors shown in Table 1.

MASSACHUSETTS WORKERS' COMPENSATION
Relative Average Claim Costs
Industry Group: Office & Clerical
Composite Policy Year 91/92 @2nd Report

(1)	(2)	(3)	(4) = (2) /(3)	(5) = (4)/TT(4)
Class	Losses (Indemnity+Med)	Number of Claims	Average Claim Cost	Relative Average Claim Cost
4361	512,291	33	15,524	1.002
7610	771,191	58	13,296	0.858
8601	1,290,543	91	14,182	0.915
8742	14,203,155	635	22,367	1.444
8748	847,220	45	18,827	1.215
8800	469,388	42	11,176	0.721
8803	597,359	17	35,139	2.268
8810	31,745,677	2,039	15,569	1.005
8820	2,075,642	87	23,858	1.540
8832	4,516,909	266	16,981	1.096
8833	8,752,453	730	11,990	0.774
8868	7,753,183	704	11,013	0.711
8901	47,799	8	5,975	0.386
9156	416,680	21	19,842	1.281
Total	73,999,490	4,776	15,494	

(2),(3): Losses and Number of Claims are as reported, but excluding any Fatal, Permanent Total, and Medical Only Claims. (Losses are neither limited nor adjusted.)

MASSACHUSETTS WORKERS' COMPENSATION
Estimated Relative D-Ratio
Industry Group: Office & Clerical

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11) = 1+(10)x[(9)-1]	(12) = 1-(2/3)x[(11)-1
Class Code	85/86 Relative ACC	86/87 Relative ACC	87/88 Relative ACC	88/89 Relative ACC	89/90 Relative ACC	90/91 Relative ACC	91/92 Relative ACC	Combined Relative ACC	Credibility	Estimated Relative ACC	Estimated Relative D-Ratio
4361	0.680	0.920	0.640	0.708	1.087	0.428	1.002	0.785	0.359	0.923	1.051
7610	1.625	1.351	0.839	0.934	1.127	0.969	0.858	1.059	0.382	1.023	0.985
8601	0.983	1.440	1.169	1.069	1.026	0.919	0.915	1.100	0.613	1.061	0.959
8742	1.211	1.161	1.031	1.221	1.028	1.017	1.444	1.143	1.000	1.143	0.905
8748	2.065	1.747	2.151	1.967	2.130	1.626	1.215	1.895	0.425	1.380	0.747
8800	0.626	0.725	1.025	0.830	0.883	1.365	0.721	0.889	0.361	0.960	1.027
8803	0.416	1.124	0.472	1.893	0.830	1.109	2.268	1.029	0.274	1.008	0.995
8810	0.982	1.021	1.044	1.040	1.068	1.113	1.005	1.040	1.000	1.040	0.973
8820	1.800	1.307	1.630	1.639	1.236	1.216	1.540	1.450	0.413	1.186	0.876
8832	1.031	1.233	1.536	1.176	1.051	1.037	1.096	1.150	0.769	1.115	0.923
8833	0.952	0.773	0.814	0.792	0.863	0.884	0.774	0.837	1.000	0.837	1.109
8868	0.806	0.905	0.828	0.675	0.796	0.724	0.711	0.774	1.000	0.774	1.151
8901	1.019	0.556	1.128	1.068	0.788	0.567	0.386	0.817	0.263	0.952	1.032
9156	0.490	0.668	1.005	1.066	0.701	0.604	1.281	0.803	0.261	0.949	1.034

(8): See Table 3.

(9): Seven Years of relative average claim costs are combined by taking a weighted average using claim counts as weights.

(10): Credibility = square root of (7-yrs-claim-count by class / 2,500) limited to unity.

(11): Relative Average Claim Costs are credibility weighted with unity.

(12): Relative D-Ratio = 1 - (2/3) (Relative ACC - 1), where the proportionality constant is selected based on separate regressions fit to data for each industry group. See Table 5.

MASSACHUSETTS WORKERS' COMPENSATION
Determining the Proportionality Constant for Relative D-Ratio

(1) Industry Group	(2) Computed Proportionality Constant	(3) Computed Proportionality Constant (Capped)
Manufacturing	-0.568	-0.694
Construction	-0.719	-0.737
Office & Clerical	-0.650	-0.650
Goods & Services	-0.523	-0.540
Miscellaneous	-0.374	-0.898
Selected		- 2/3

(2) The proportionality constant is selected based on separate regressions fit to the relative average claim costs (for Permanent Partial and Temporary Total Claims) versus relative D-Ratios by class.
Data is from Schedule Z for first, second, and third report combined. It is not adjusted.
(3) The Relative Average Claim Cost by class is constrained to be between 0.5 and 2.0.

MASSACHUSETTS WORKERS' COMPENSATION
Determining the Proportionality Constant for Relative D-Ratio
Industry Group: Office & Clerical

(1) Class Code	(2) Losses Limited to $5,000	(3) Losses Limited to $175,000	(4) D-Ratio	(5) Relative D-Ratio*	(6) Total Losses (Ind.+Med.)	(7) Number of Claims	(8) ACC	(9) Relative ACC*
4361	417,428	1,169,121	0.357	1.532	1,198,587	113	10,607	0.656
7610	703,047	2,787,015	0.252	1.082	2,538,887	162	15,672	0.969
8601	1,233,601	4,762,304	0.259	1.112	4,836,242	282	17,150	1.061
8742	7,650,471	36,311,049	0.211	0.906	37,593,218	1,880	19,996	1.237
8748	659,224	3,592,017	0.184	0.790	3,566,061	156	22,859	1.414
8800	395,163	1,791,027	0.221	0.948	1,727,521	114	15,154	0.937
8803	258,653	1,468,291	0.176	0.755	1,423,213	63	22,591	1.397
8810	23,295,475	103,767,838	0.224	0.961	103,870,417	6,013	17,274	1.068
8820	1,007,946	5,777,652	0.174	0.747	5,615,590	234	23,998	1.484
8832	2,884,430	13,527,932	0.213	0.914	13,111,606	768	17,072	1.056
8833	6,682,957	26,771,313	0.250	1.073	25,744,078	1,988	12,950	0.801
8868	7,705,442	26,671,767	0.289	1.240	24,622,778	2,164	11,378	0.704
8901	130,497	342,235	0.381	1.635	310,662	28	11,095	0.686
9156	568,573	1,237,821	0.459	1.970	974,157	81	12,027	0.744
Total	53,592,907	229,977,382	0.233		227,133,017	14,046	16,171	

The weighted-least-squares solution for the straight-line regression (i.e., y= b+mx) is given by the formulas*:

$$m = \frac{\sum WXY - (\sum WX)(\sum WY)/\sum W}{\sum WX^2 - (\sum WX)^2/\sum W} \quad \text{and} \quad b = \frac{\sum WY}{\sum W} - m\left(\frac{\sum WX}{\sum W}\right)$$

where X = Relative ACC - 1, Y = Relative D-Ratio - 1, and W = Claim Count

Regression Result:

Uncapped Result	=> Y = 0.020 - 0.650 X	=> *Proportionality Constant*	=	-0.650
Capped Result	=> Y = 0.020 - 0.650 X	=> *Proportionality Constant*	=	-0.650

(2), (3): Latest schedule Z data, 1st Report (PY92/93), 2nd Report (PY91/92), and 3rd Report (PY90/91).
(6), (7): Latest Schedule Z data at 1st, 2nd, and 3rd report and injury kinds 3,4, and 5, (permanent partial and temporary total claims).

* The proportionality constants are calculated based on two separate weighted least squares regressions of Relative Average Claim Costs and Relative D-Ratios by class.
For the capped result, the Relative Average Claim Cost by class is constrained to be between 0.5 and 2.0.
The proportionality constants will be used to determine the slope of the line, Relative D-Ratio = 1 - m (Relative ACC -1).
Weights for the regression are the number of claims for the three years used to compute the relative ACC.

MASSACHUSETTS WORKERS' COMPENSATION
Determining the Proportionality Constant for Relative D-Ratio
Industry Group: Construction

(1) Class Code	(2) Losses Limited to $5,000	(3) Losses Limited to $175,000	(4) D-Ratio	(5) Relative D-Ratio*	(6) Total Losses (Ind.+Med.)	(7) Number of Claims	(8) ACC	(9) Relative ACC*
0050	0	0	0.000	0.000	0	0	0	0.000
3365	290,960	1,356,389	0.215	1.463	1,338,905	73	18,341	0.645
3724	2,021,485	10,603,943	0.191	1.299	9,381,940	519	18,077	0.636
3726	473,608	3,361,013	0.141	0.959	3,539,978	99	35,757	1.258
5020	184,446	710,580	0.260	1.769	688,540	44	15,649	0.550
5022	1,890,905	18,396,114	0.103	0.701	18,147,377	473	38,367	1.350
5037	59,546	878,054	0.068	0.463	872,591	12	72,716	2.558
5040	282,117	2,423,818	0.116	0.789	2,464,765	61	40,406	1.421
5057	179,242	1,832,777	0.098	0.667	2,065,949	45	45,910	1.615
5059	197,854	2,806,431	0.071	0.483	2,766,448	47	58,861	2.071
5069	0	0	0.000	0.000	0	0	0	0.000
5102	348,074	2,560,599	0.136	0.925	2,546,968	80	31,837	1.120
5146	418,689	2,866,815	0.146	0.993	4,275,866	100	42,759	1.504
5160	523,541	3,121,718	0.168	1.143	2,547,110	114	22,343	0.786
5183	5,468,919	30,309,688	0.180	1.224	30,120,877	1,364	22,083	0.777
5188	514,284	2,657,775	0.194	1.320	2,711,444	130	20,857	0.734
5190	4,846,811	26,036,511	0.186	1.265	28,324,142	1,231	23,009	0.809
5213	2,298,598	20,666,128	0.111	0.755	22,559,557	498	45,300	1.593
5215	540,583	2,818,636	0.192	1.306	3,650,903	151	24,178	0.850
5221	2,041,603	14,044,385	0.145	0.986	14,136,217	478	29,574	1.040
5222	323,049	2,458,801	0.131	0.891	2,445,396	72	33,964	1.195
5223	135,945	721,686	0.188	1.279	706,148	43	16,422	0.578
5348	313,358	3,019,976	0.104	0.707	3,302,631	78	42,341	1.489
5402	12,711	130,765	0.097	0.660	128,604	3	42,868	1.508
5403	1,007,087	6,336,159	0.159	1.082	6,510,484	250	26,042	0.916
5437	2,844,361	18,628,306	0.153	1.041	19,259,851	712	27,050	0.952
5443	4,503	4,503	1.000	6.803	4,503	1	4,503	0.158
5445	1,582,566	12,917,375	0.123	0.837	12,756,711	383	33,307	1.172
5462	428,823	2,839,970	0.151	1.027	2,872,793	102	28,165	0.991
5472	10,044	51,123	0.196	1.333	51,079	2	25,540	0.898
5473	56,427	243,086	0.232	1.578	237,221	13	18,248	0.642
5474	1,919,025	13,372,654	0.144	0.980	14,356,636	504	28,485	1.002
5479	1,404,906	8,703,239	0.161	1.095	8,862,747	363	24,415	0.859
5480	240,153	1,758,259	0.137	0.932	1,811,186	56	32,343	1.138
5491	0	0	0.000	0.000	0	0	0	0.000
5506	473,963	3,770,454	0.126	0.857	3,539,603	113	31,324	1.102
5507	606,373	5,260,851	0.115	0.782	5,017,185	131	38,299	1.347
5508	15,586	170,900	0.091	0.619	170,314	3	56,771	1.997
5509	399,010	1,498,814	0.266	1.810	1,527,072	129	11,838	0.416
5538	1,820,815	11,952,588	0.152	1.034	11,691,223	451	25,923	0.912
5545	92,886	931,065	0.100	0.680	933,751	24	38,906	1.369
5547	1,053,311	8,262,439	0.127	0.864	8,101,468	264	30,687	1.079
5606	1,675,797	12,448,637	0.135	0.918	13,197,169	384	34,368	1.209
5610	293,814	2,738,318	0.107	0.728	2,704,521	67	40,366	1.420
5645	4,247,167	25,132,765	0.169	1.150	27,353,628	1,125	24,314	0.855
5651	733,647	5,371,526	0.137	0.932	4,861,738	180	27,010	0.950
5701	0	0	0.000	0.000	0	0	0	0.000
5703	28,082	67,179	0.418	2.844	54,059	4	13,515	0.475
5705	7,784	74,872	0.104	0.707	74,872	2	37,436	1.317
6003	120,541	1,013,355	0.119	0.810	1,009,488	27	37,388	1.315

MASSACHUSETTS WORKERS' COMPENSATION
Determining the Proportionality Constant for Relative D-Ratio
Industry Group: Construction

(1) Class Code	(2) Losses Limited to $5,000	(3) Losses Limited to $175,000	(4) D-Ratio	(5) Relative D-Ratio*	(6) Total Losses (Ind.+Med.)	(7) Number of Claims	(8) ACC	(9) Relative ACC*
6005	0	0	0.000	0.000	0	0	0	0.000
6204	428,238	3,353,397	0.128	0.871	3,334,883	103	32,378	1.139
6217	2,835,335	22,451,780	0.126	0.857	23,588,377	628	37,561	1.321
6229	123,324	513,513	0.240	1.633	486,348	33	14,738	0.518
6233	147,313	1,319,626	0.112	0.762	1,394,680	29	48,092	1.692
6251	301,721	1,808,839	0.167	1.136	1,558,398	46	33,878	1.192
6252	46,410	178,983	0.259	1.762	162,315	7	23,188	0.816
6306	346,744	3,057,488	0.113	0.769	3,324,338	80	41,554	1.462
6319	459,265	3,943,188	0.116	0.789	4,298,717	108	39,803	1.400
6325	68,290	404,803	0.169	1.150	219,621	14	15,687	0.552
6400	190,150	1,031,940	0.184	1.252	993,606	53	18,747	0.659
7538	78,217	524,010	0.149	1.014	515,923	19	27,154	0.955
7601	133,924	1,114,583	0.120	0.816	1,100,339	37	29,739	1.046
7855	33,647	569,450	0.059	0.401	565,803	6	94,301	3.317
8227	720,884	4,705,343	0.153	1.041	4,511,813	193	23,377	0.822
9530	0	0	0.000	0.000	0	0	0	0.000
9534	55,093	611,613	0.090	0.612	610,404	10	61,040	2.147
9545	24,015	32,868	0.731	4.973	26,532	7	3,790	0.133
9549	41,916	100,213	0.418	2.844	97,394	11	8,854	0.311
9552	227,315	1,298,740	0.175	1.190	1,284,387	57	22,533	0.793
9553	15,104	145,338	0.104	0.707	145,234	3	48,411	1.703
Total	50,709,904	344,496,754	0.147		353,900,770	12,449	28,428	

The weighted-least-squares solution for the straight-line regression (i.e., y= b+mx) is given by the formulas*:

$$m = \frac{\sum WXY - (\sum WX)(\sum WY)/\sum W}{\sum WX^2 - (\sum WX)^2/\sum W} \quad \text{and} \quad b = \frac{\sum WY}{\sum W} - m\left(\frac{\sum WX}{\sum W}\right)$$

where X = Relative ACC - 1, Y = Relative D-Ratio - 1, and W = Claim Count

Regression Result:

Uncapped Result	=>	Y = 0.057 - 0.719 X	=> *Proportionality Constant*	=	-0.719
Capped Result	=>	Y = 0.057 - 0.737 X	=> *Proportionality Constant*	=	-0.737

(2), (3): Latest schedule Z data, 1st Report (PY92/93), 2nd Report (PY91/92), and 3rd Report (PY90/91).

(6), (7): Latest Schedule Z data at 1st, 2nd, and 3rd report and injury kinds 3,4, and 5, (permanent partial and temporary total claims).

* The proportionality constants are calculated based on two separate weighted least squares regressions of Relative Average Claim Costs and Relative D-Ratios by class.
For the capped result, the Relative Average Claim Cost by class is constrained to be between 0.5 and 2.0.
The proportionality constants will be used to determine the slope of the line, Relative D-Ratio = 1 - m (Relative ACC -1).
Weights for the regression are the number of claims for the three years used to compute the relative ACC.

MASSACHUSETTS WORKERS' COMPENSATION
D-Ratios, Adjusted for Trend and Law Factors
Industry Group: Office & Clerical
D-Ratios Balanced to: 0.2355

Phraseology	(1) Class Code	(2) Expected Losses ($ million)	(3) Estimated Relative D-Ratio	(4) Balanced Relative D-Ratio	(5) Indicated D-Ratio
Photographer-All Emp-Clerical,Sales-& Dr	4361	1.1	1.051	1.058	0.25
Radio or TV Broadcast-All Emp,Cler-& Dr	7610	2.0	0.985	0.992	0.23
Engineer or Architect-Consulting	8601	3.7	0.959	0.966	0.23
Salesperson,Collector,Messenger-Outside	8742	24.5	0.905	0.911	0.21
Auto Sales or Service Agcy-Salesperson	8748	2.8	0.747	0.752	0.18
Mailing or Addressing Co-& Clerical	8800	1.2	1.027	1.034	0.24
Auditor,Accountant,Etc-Traveling	8803	2.1	0.995	1.002	0.24
Clerical Office Employees NOC	8810	72.8	0.973	0.980	0.23
Attorney-All Emp-Clerical,Messenger & Dr	8820	3.9	0.876	0.882	0.21
Physician-& Clerical	8832	10.5	0.923	0.930	0.22
Hospital-Professional Employees	8833	19.3	1.109	1.117	0.26
School-Professional Emp & Clerical	8868	20.2	1.151	1.159	0.27
Telephone/Telegraph Co-Office Emp & Cl	8901	0.2	1.032	1.039	0.24
Theatre-Players,Entertainers,Musicians	9156	0.9	1.034	1.041	0.25
	Weighted Average	=	0.993	1.000	0.23

(2): Expected Losses are the three years of payrolls times the Indicated Expected Loss Rates.
(3): From Table 4.
(4): Relative D-Ratios are balanced to unity using the expected losses as weights, where
Balanced Relative D-Ratio = (Estimated Relative D-Ratio) / (Estimated Relative D-Ratio Weighted Average)
(5): Proposed D-Ratio = (Balanced Relative D-Ratio) x (Industry Group Observed D-Ratio)
Industry Group Observed D-Ratio is from Table 2.

TABLE 8

OVERVIEW OF TWO METHODS OF ESTIMATING D-RATIOS

Prior Massachusetts Method and/or Gillam [8], PCAS 1992[1]	Current Massachusetts Method (Alternative Method)
1. Adjust the reported data for changes expected between the data available now and that to be used for experience rating in the future.	1. Adjust the reported data for changes expected between the data available now and that to be used for experience rating in the future.
2. Calculate 3 Partial D-Ratios. $\text{Serious Partial D – Ratio} = \frac{\text{Serious Primary Losses}}{\text{Serious Indemnity Losses}}$ $\text{Non - Serious Partial D – Ratio} = \frac{\text{Non - Serious Primary Losses}}{\text{Non - Serious Indemnity Losses}}$ $\text{Medical Partial D – Ratio} = \frac{\text{Medical Only Losses}}{\text{Medical Losses}}$	2. Calculate D-Ratios by Industry Group.[2]
3. For each class take the estimated Serious, Non-Serious and Medical Partial Pure Premiums used to determine classification rate relativities.	3. Estimate Average Relative Claim Cost by Class within Industry Group.
4. Weight the Partial D-Ratios from Step 2 using the Partial Pure Premiums from Step 3.	4. Spread to each class the Average D-Ratio for each Industry Group from Step 2 using Relative Average Claim Costs in Step 3.
5. Adjust for the impact on the D-Ratio of those losses excluded from Experience Rating.[3]	

[1] The National Council on Compensation Insurance has been updating their methodologies every few years. Details have changed and continue to change, but the over-all approach has remained the same.

[2] The denominator of the D-Ratios is total losses minus those excluded from experience rating. The numerator is Primary Losses.

[3] The denominator of the D-Ratios should be expected total losses minus those expected to be excluded from experience rating.

APPENDIX

Let the experience modification be given by:

$$M = \frac{\left(1 - Z_p\right) E_p + Z_p\, A_p + \left(1 - Z_x\right) E_x + Z_x\, A_x}{E}$$

$$= (1 - Z_p)\, D + Z_p\, (A_p/E) + (1 - Z_x)\, (1 - D) + Z_x\, (A_x/E)$$

where:

A_p = Actual Primary Losses

A_x = Actual Excess Losses

E_p = Expected Primary Losses

E_x = Expected Excess Losses

E = $E_p + E_x$

Z_p = Primary Credibility

Z_x = Excess Credibility

D = $E_p/(E_p + E_x) = E_p/E$

then for all the other inputs fixed, for a change in the D-Ratio the change in the experience modification is

$$\frac{\partial M}{\partial D} = \left(1 - Z_p\right) - \left(1 - Z_x\right) = -\left(Z_p - Z_x\right)$$

Thus, the sensitivity of the modification to the D-Ratio depends on the difference between Z_p and Z_x. Since $Z_p > Z_x$, the larger D, the smaller the experience modification. Primary

credibilities are usually 40% to 70% higher than excess credibilities with the result varying by size of risk. For example, for Massachusetts[1] the differences in credibility are shown in Figure 3.

Therefore, a .10 difference in D-Ratio (holding everything else equal) will produce between a .04 and .07 difference in the Experience Modification depending on the size of the insured. A very large difference in D-Ratios[2] produces only a relatively modest difference in the Experience Modification. This is why D-Ratios are rounded to two decimal places. This is also why detailed technical refinements to a methodology to estimate D-Ratios are unlikely to have much practical impact.

[1] Revised Experience Rating Plan with g = 7. See, for example, Mahler [9].

[2] For example, in Massachusetts the D-Ratios range from about .10 to about .30.