NCCI's 2007 Hazard Group Mapping

Presented by
John Robertson, FCAS, MAAA

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Introduction

- In 2007, NCCI implemented a new 7-hazard-group system, replacing the previous 4-hazard-group system
- The new 7 Hazard Groups have been approved for use in the 35 jurisdictions for which NCCI provides ratemaking services and several independent bureau states; discussion here is for the 35 NCCI jurisdictions
- The new 7-hazard-group system is not a subdivision of the old 4-hazard-group system; it is a completely new assignment of classes to hazard groups

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Background

- In the US, Workers Compensation (WC) insurance pays medical costs and lost wages to workers injured on the job
- NCCI uses about 900 WC classifications, which are groupings of risks in similar occupations
- WC classifications are often used in determining premiums for WC policies, and for other purposes

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Excess Loss Factors

- An excess loss factor (ELF) is the ratio of expected losses excess of some threshold to total expected losses

- Mathematically:

$$ELF(L) = \frac{1}{\mu} E[\max(X - L, 0)] = \frac{1}{\mu} \int_{t=L}^{\infty} (t - L) f(t)\,dt$$

where *L* is the threshold, *X* is the distribution of losses by size with density function *f*(*t*), and

$$\mu = E[X] = \int_{t=0}^{\infty} t\, f(t)\,dt$$

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Hazard Groups

- A hazard group is a collection of WC classifications with similar ELFs over a broad range of thresholds
- NCCI periodically publishes tables of ELFs by hazard group for certain states

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Injury Types

- NCCI often distinguishes claims by the type of benefit paid
  - Fatal—Death claims
  - Permanent Total—Claimant expected to never be able to return work
  - Permanent Partial—Claimant expected to return to work, but with some permanent impairment or disfigurement
  - Temporary Total—Claimant expected to recover fully
  - Medical Only—No benefits for lost wages are expected to be paid

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NCCI Computes ELFs From Injury Type Curves

The ELF for Hazard Group *j* and threshold *L* is

$$ELF_j\left(L\right) = \sum_i w_{i,j} S_i\left(L / \mu_{i,j}\right)$$

where $S_i(r)$ is the normalized ELF for Injury Type *i* at entry ratio *r*

$$S_i(r) = E\left[\max\left(\frac{X_i}{\mu_i} - r, 0\right)\right] = \int_r^\infty (t - r) g_i(t)\, dt$$

$w_{i,j}$ is the proportion of losses for Injury Type *i* in Hazard Group *j*

$\mu_{i,j}$ is the average size of loss for Injury Type *i* in Hazard Group *j*

X_i is the random variable of sizes of loss for Injury Type *i*, with normalized density g_i

μ_i is the average size of loss for Injury Type *i*

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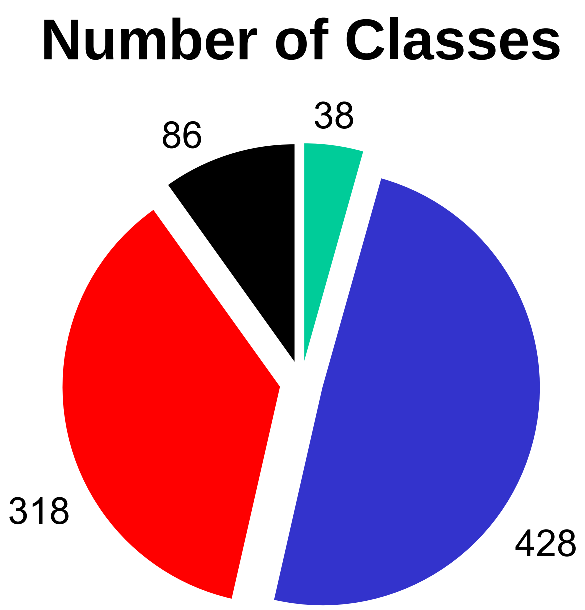
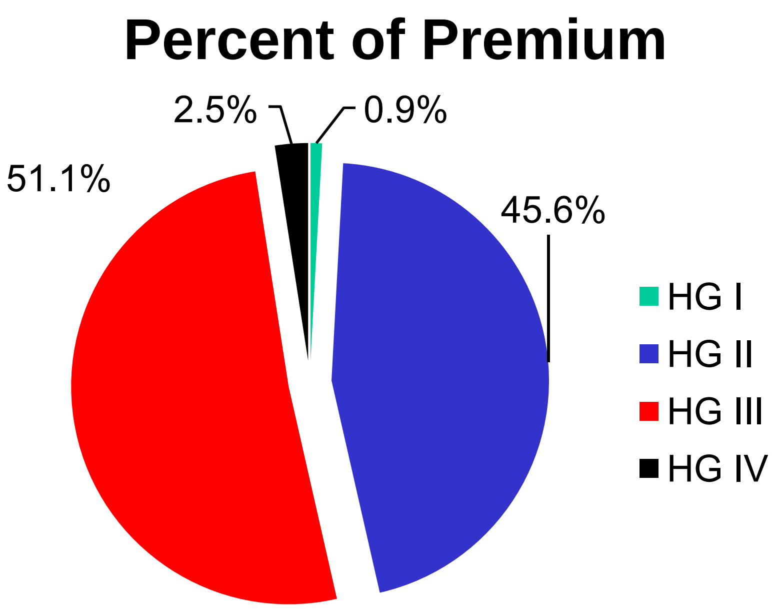
The Previous 4 Hazard Group Mapping





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Outline

- General Considerations
- Credibility
- Cluster Analysis
- Underwriting Review

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General Considerations

- New hazard groups are based only on ELFs
- Previous hazard group mapping used other criteria, such as the serious[1] to total claim frequency ratio
- No crossover
  - Crossover is when at a high threshold the ELF for a high hazard group is lower than the ELF for a low hazard group
  - Based on our a priori expectations regarding size of loss distributions, we had a guiding principle that there would be no crossover

[1] A ***serious claim*** **is one for which at least one of the following benefits for lost wages is paid or is expected to be paid:**
•Fatal (death)
•Permanent Total (injured worker not expected to ever be able to work)
•Permanent Partial (able to work after recovery period, but with a permanent injury, such as loss of a limb) and benefits for lost wages exceed certain thresholds that vary by state and year

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ELFs by Class

- We computed ELFs for each class at several thresholds:

  $100K, $250K, $500K, $1M, $5M

- Similar to computation of ELFs for a hazard group, but used
  - Countrywide curves by injury type
  - Weights and average severities by class

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Credibility

- Some classes have only a small number of reported claims
- Several credibility formulas were tested
- We decided to retain the credibility formula used in the previous review,

  $$z = \min\left(\frac{n}{n+k} \times 1.5, 1 \right)$$

  where *z* is the credibility, *n* is the number of claims for the class, *k* is the average number of claims per class
- The complement of the credibility is applied to the vector of ELFs for the mean of the prior Hazard Group

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Classes by Credibility

Credibility Range	Claims per Year	Number of Classes	% of Premiums
$0\% \le z < 10\%$	0–237	355	1.2%
$10\% \le z < 50\%$	238–1662	252	8.1%
$50\% \le z < 100\%$	1663–6649	162	18.8%
$z = 100\%$	6650 +	101	71.8%
Total		870	100.0%

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Cluster Analysis

- Given a vector of five ELFs for each class, the question is how to group them so that classes with similar ELFs are in the same group
- Related questions that we addressed were
  - If you knew you wanted to have *m* groups, how would you determine which classes are assigned to each group?
  - How do you determine that one grouping is better than another?
  - How many groups should there be?

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Cluster Analysis

- We tested divisions of the classes into *m* Hazard Groups where $4 \leq m \leq 9$
- We used weighted *k*-means clustering for each *m*, through the FASTCLUS routine in SAS®*
- We used the Calinski and Harabasz and the Cubic Clustering tests to determine the optimal number of hazard groups

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Weighted *k*-Means Clustering Algorithm

- The number of clusters is specified in advance
- Make an initial assignment of classes to clusters
- Iterate these steps:
  - Compute the weighted centroid of each cluster
  - For each class, find the closest centroid and assign the class to that cluster
  - Continue the iterations until no class changes clusters

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Weighted *k*-Means Clustering Algorithm

Weighted *k*-means clustering minimizes:

$$\sum_{i=1}^{k} \sum_{c \in HG_i} w_c \left\| R_c - \overline{R_i} \right\|_2^2$$

where

$$\overline{R_i} = \frac{\sum_{c \in HG_i} w_c R_c}{\sum_{c \in HG_i} w_c},$$ the weighted centroid for cluster *i*

k is the number of clusters

HG_i for $1 \le i \le k$ is the *i*-th cluster (hazard group) of classes *c*

w_c is the percentage of the total premium in class *c*

R_c is the vector of ELFs for class *c*

$\| * \|_2$ is Euclidean distance

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Tests Applied to Clusterings

- Calinski and Harabasz Statistic
  - Is essentially the ratio of the between-cluster sum of squares to the within-cluster sum of squares, adjusted for the number of classes and number of clusters
  - A higher value indicates better clusters
- Cubic Clustering Criterion
  - Compares amount of variance explained by a set of clusters to that expected when clusters are formed at random
  - A higher value indicates better clusters

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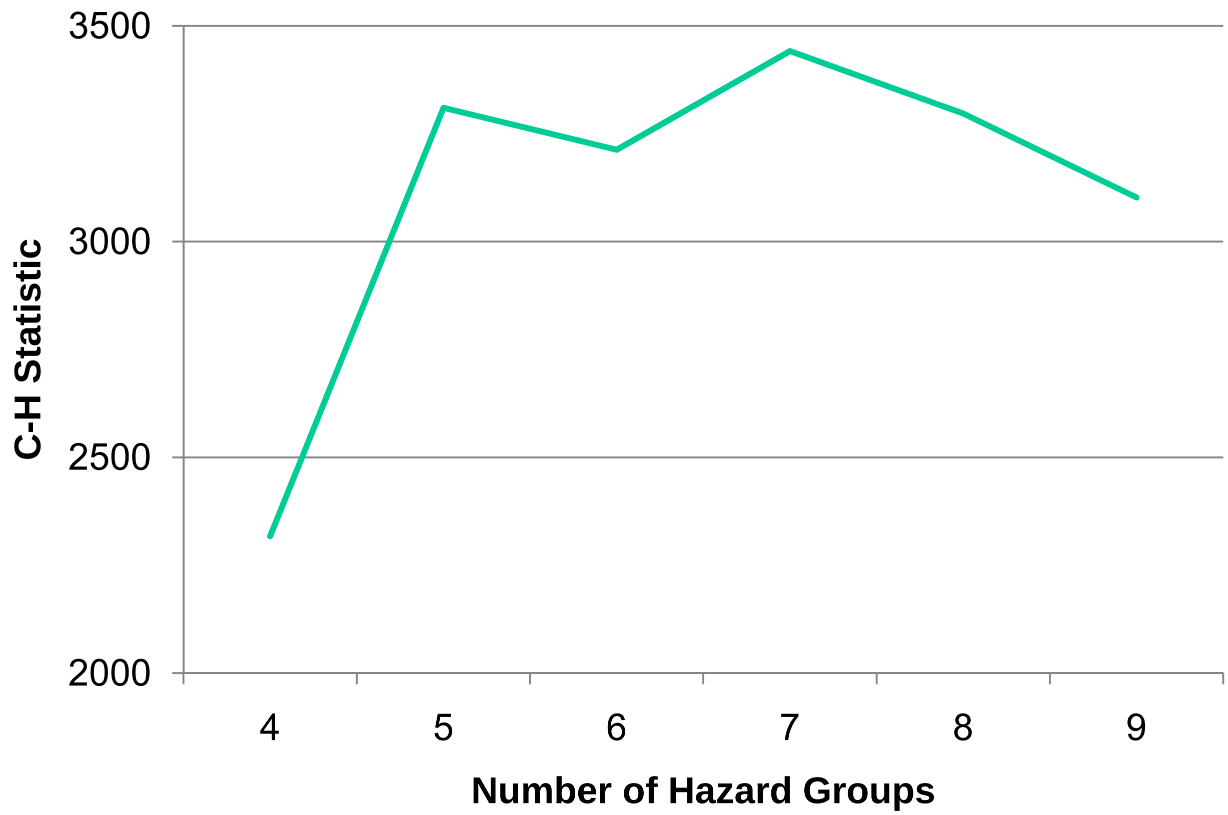
Calinski and Harabasz Statistic



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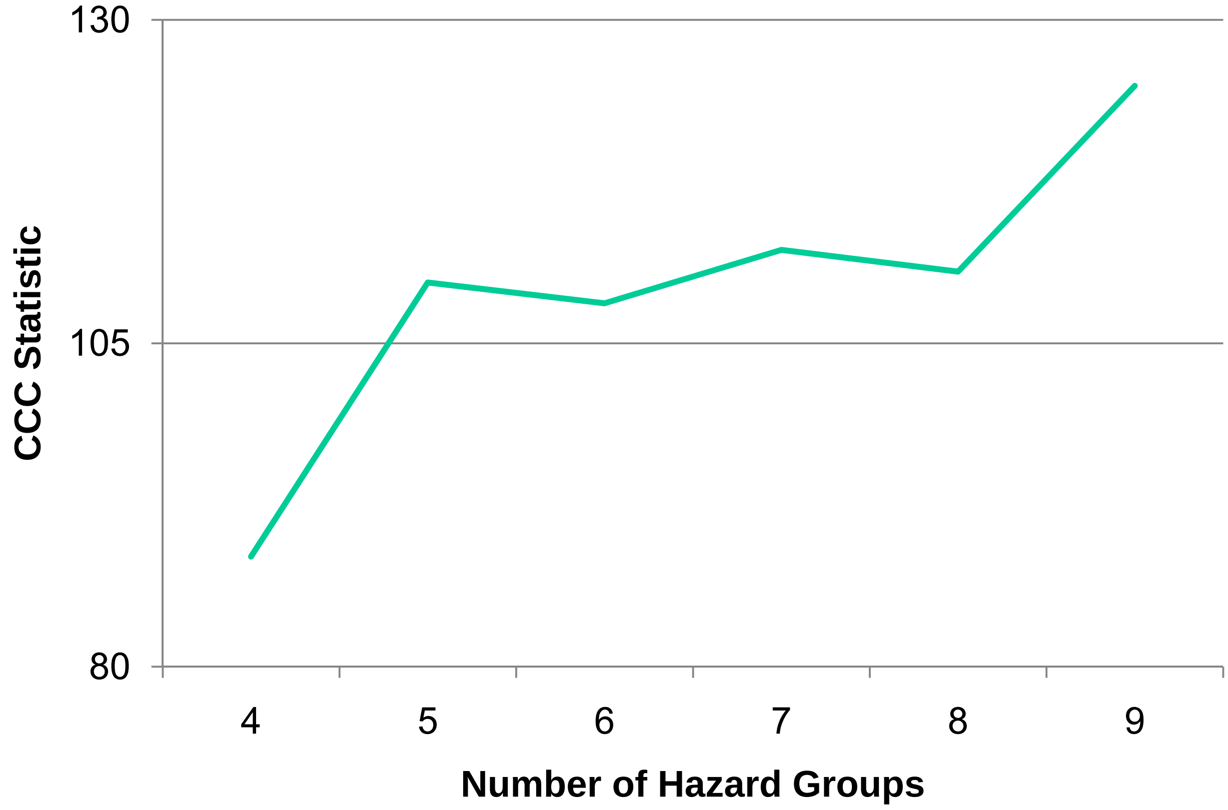
Cubic Clustering Criterion



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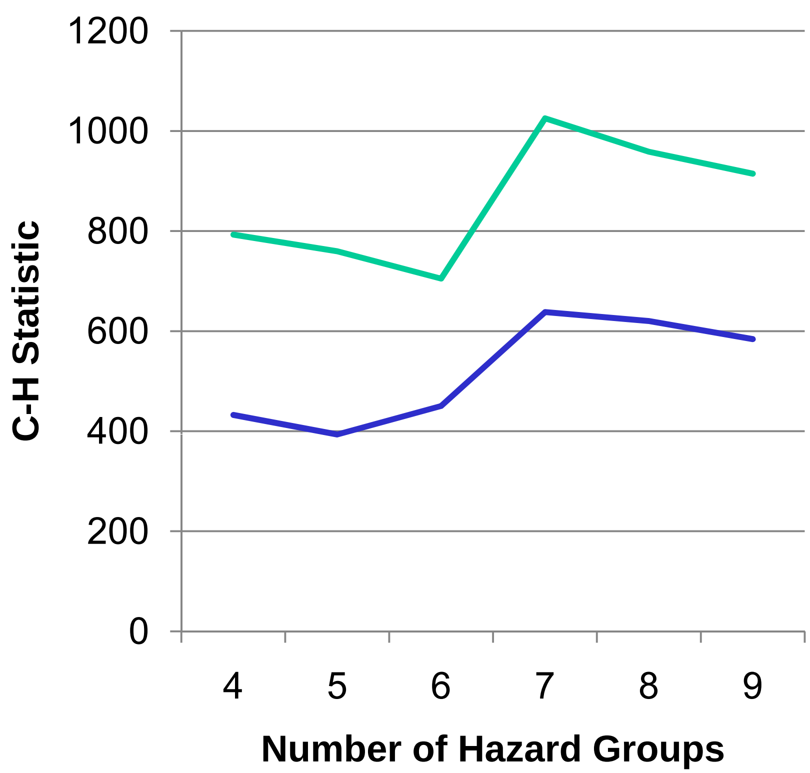
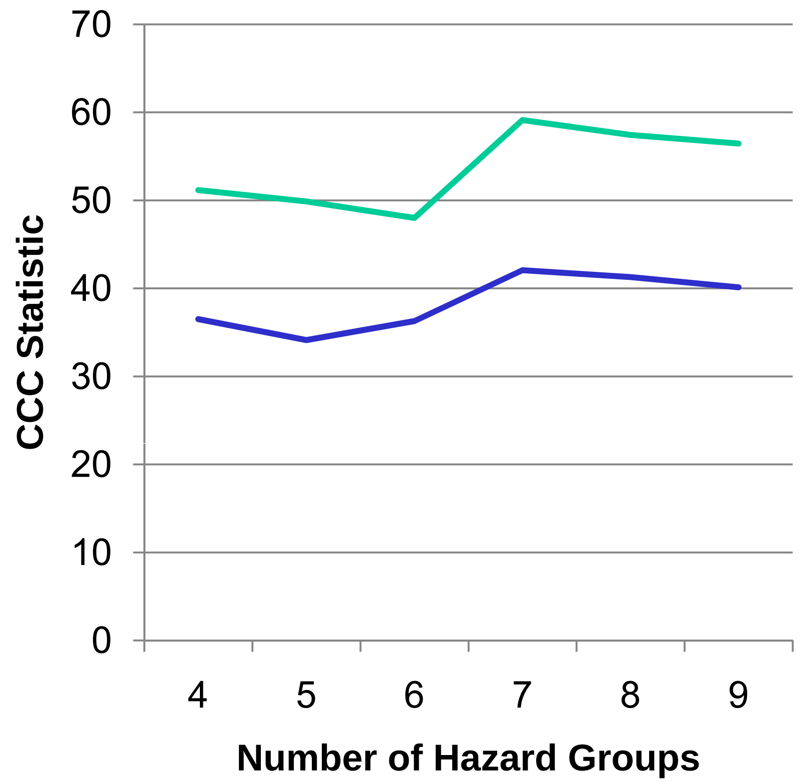
Statistics for Classes with At Least 50% Credibility





50%+ Credibility Classes   Fully Credible Classes

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NCCI Selected 7 Hazard Groups

- Almost all of these tests indicated 7 hazard groups
- Milligan and Cooper found that the Calinski and Harabasz test performed better than the Cubic Clustering Criterion
- The CCC procedure does not perform as well when correlation is present, as when correlation is not present. There is significant correlation between ELFs at the five thresholds used

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NCCI Selected 7 Hazard Groups

- We have more confidence in the results for the large classes, where most of the experience is concentrated
- There is crossover in the 9-hazard-group mapping, and we had a guiding principle that there would not be crossover. We ascribed the observed crossover to random fluctuations and took this as a sign that 9 hazard groups is too fine a split

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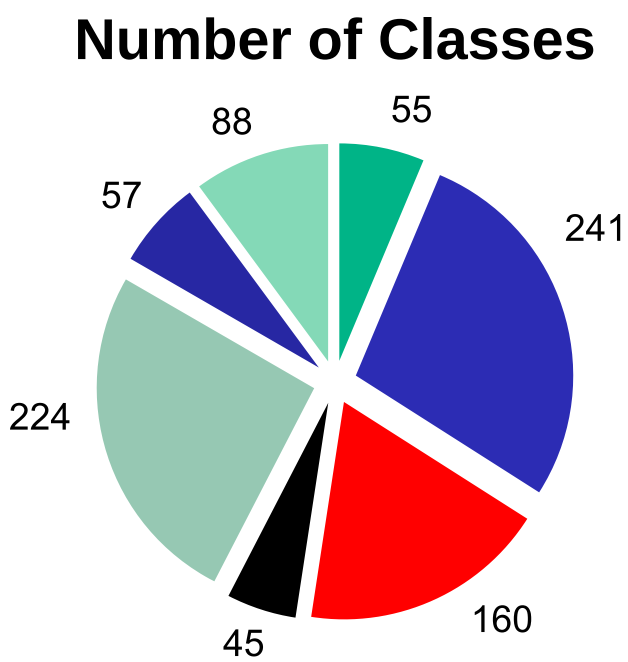
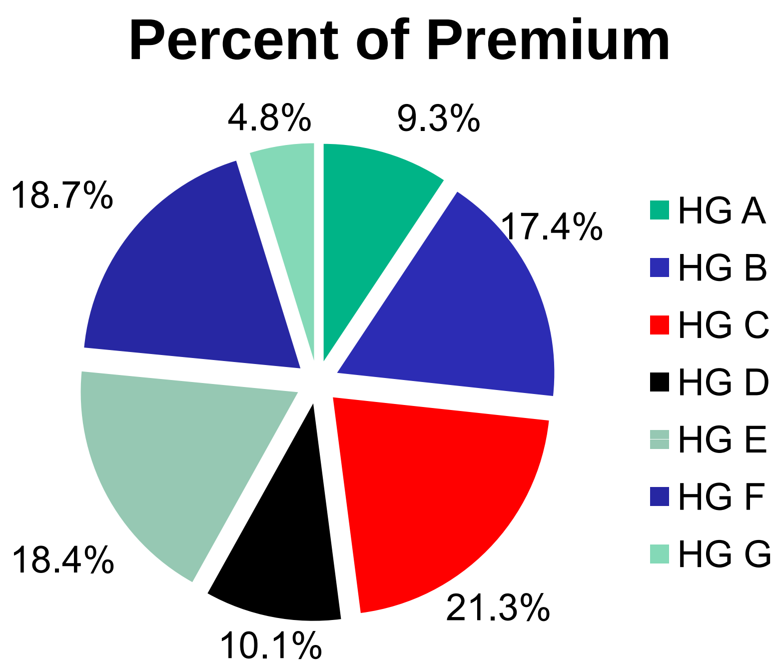
The New 7 Hazard Group Mapping





The new 7 hazard group mapping is prior to underwriting review.

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Hierarchical Mapping From 7 Hazard Groups To New 4 Hazard Groups

7 Hazard Groups	New 4 Hazard Groups
A, B	1
C, D	2
E, F	3
G	4

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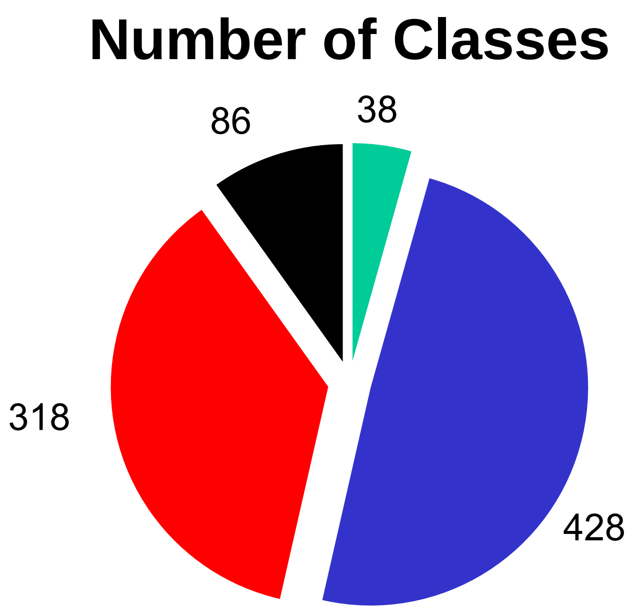
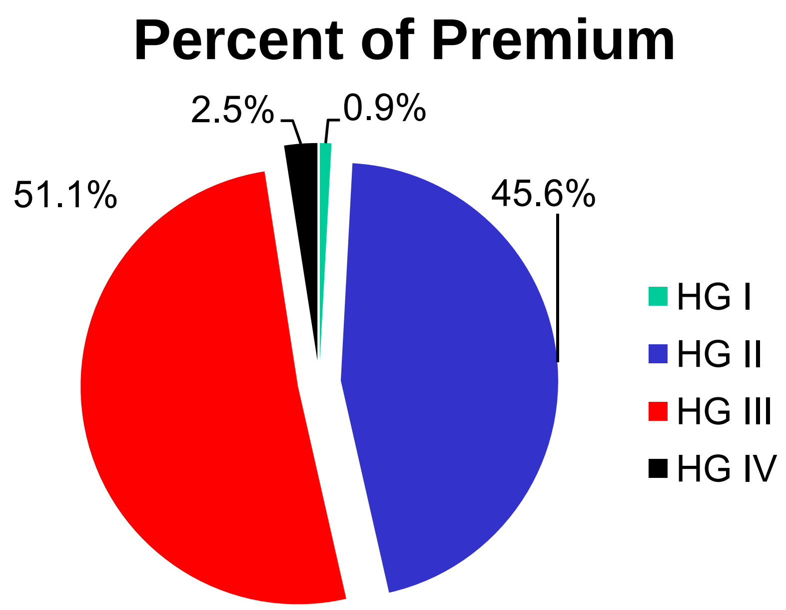
The Previous 4 Hazard Group Mapping





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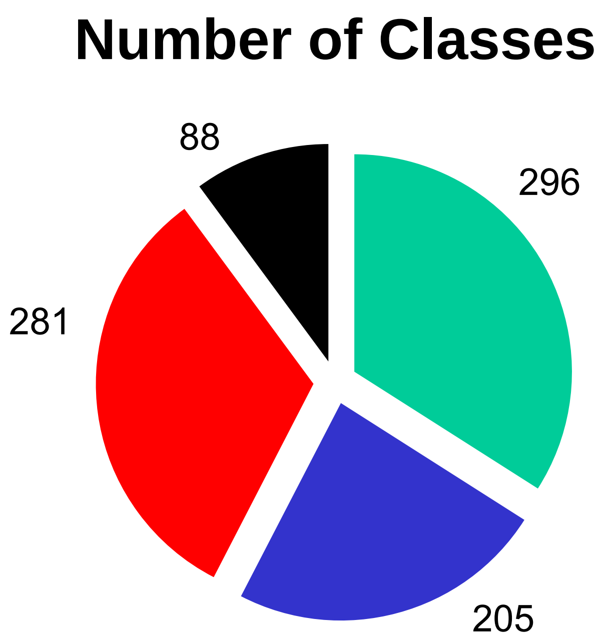
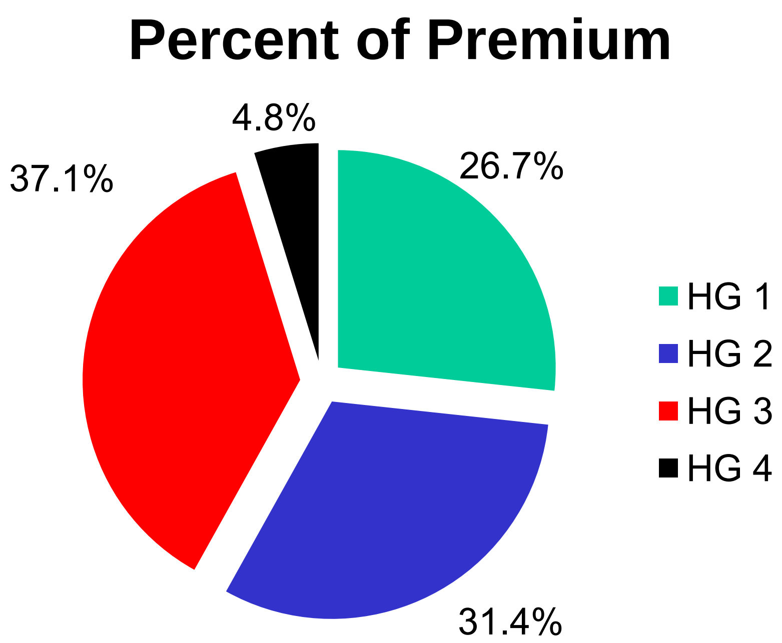
The New 4 Hazard Group Mapping





The new 4 hazard group mapping is prior to underwriting review

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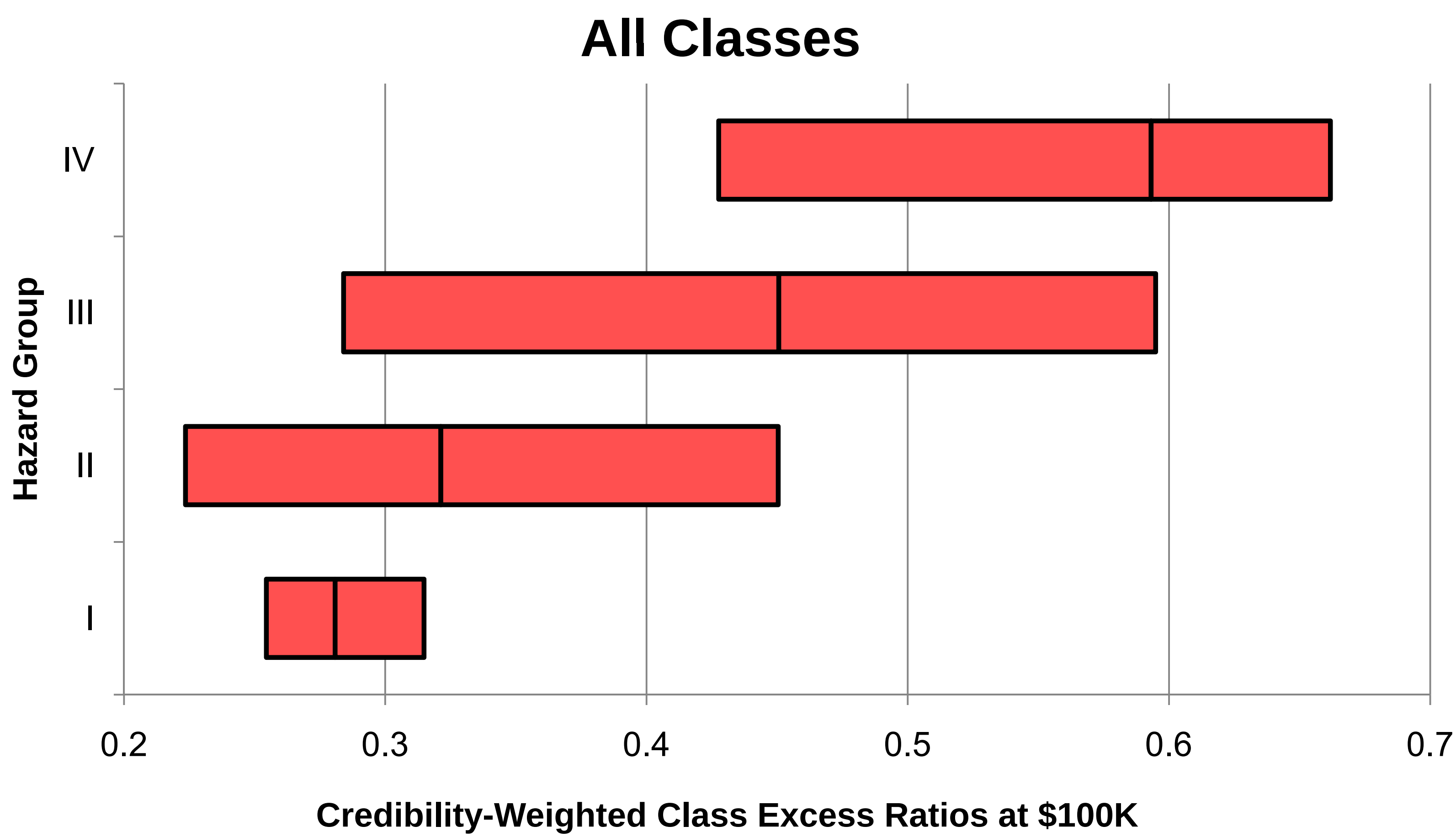
Old 4 Hazard Groups
Excess Ratios at $100K



The vertical line within each bar represents the overall excess ratio for the hazard group

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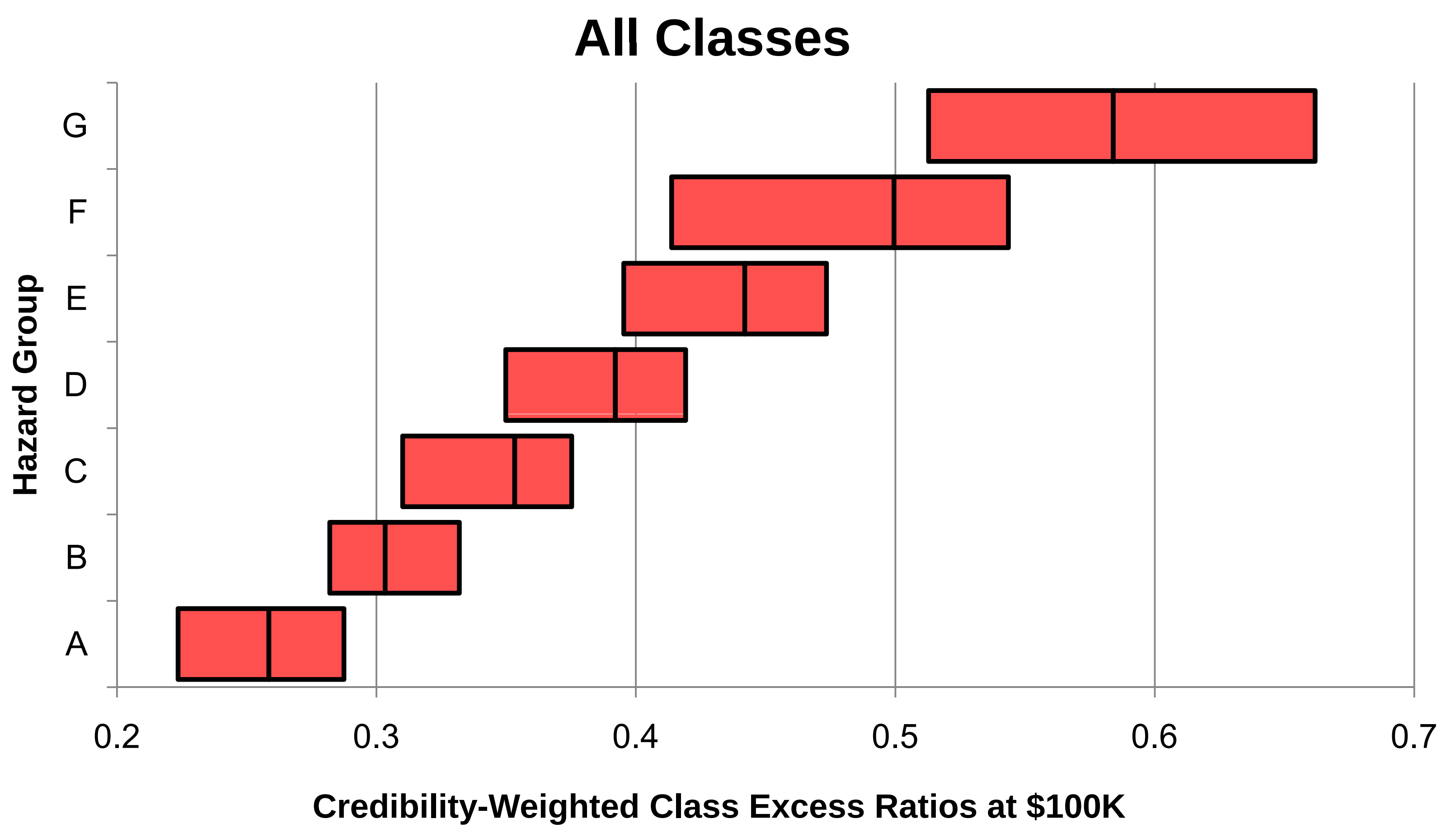
New 7 Hazard Groups
Excess Ratios at $100K



The vertical line within each bar represents the overall excess ratio for the hazard group.
The new 7 hazard group mapping is prior to underwriting review.

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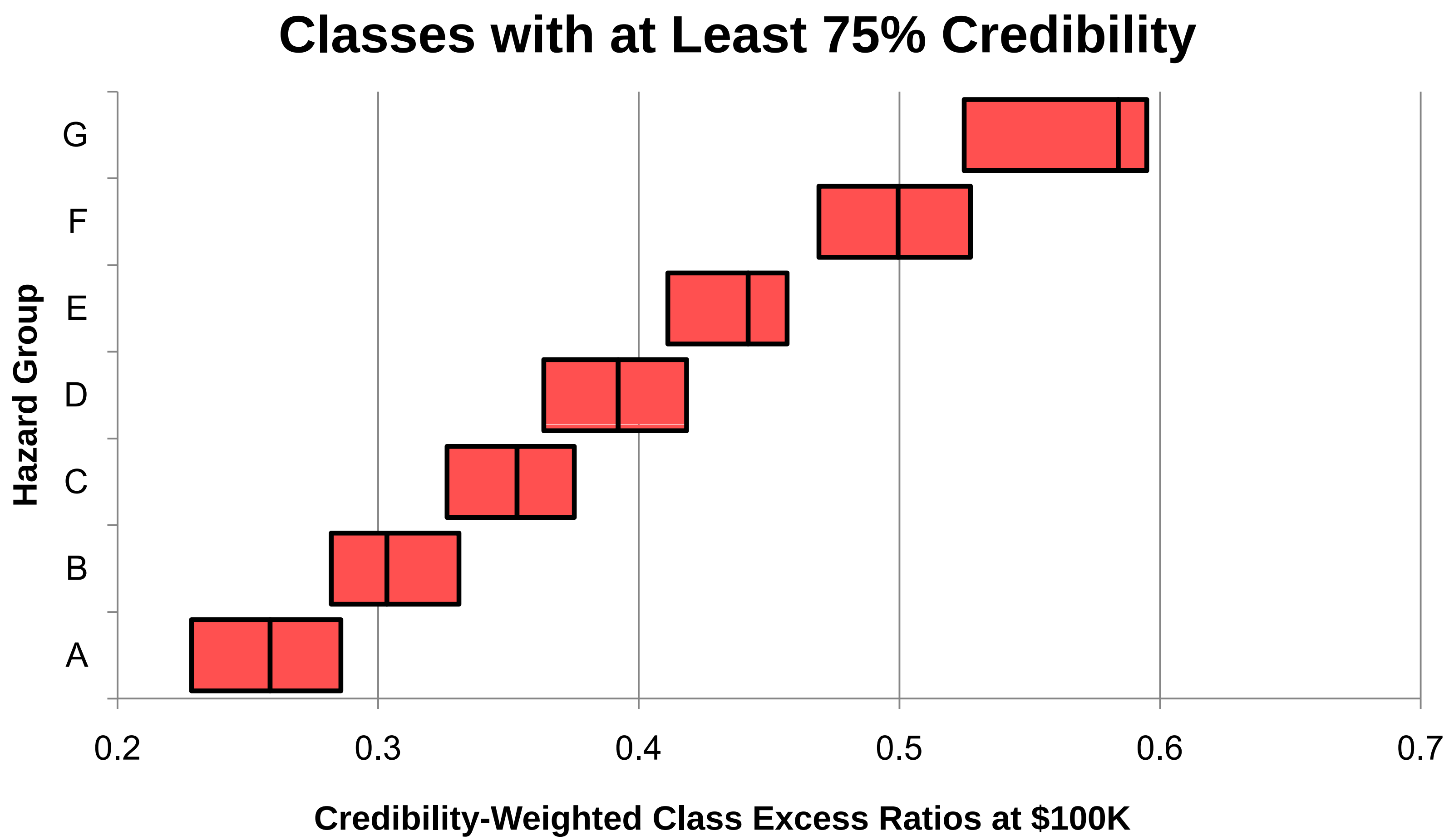
New 7 Hazard Groups
Excess Ratios at $100K



The vertical line within each bar represents the overall excess ratio for the hazard group.
The new 7 hazard group mapping is prior to underwriting review.

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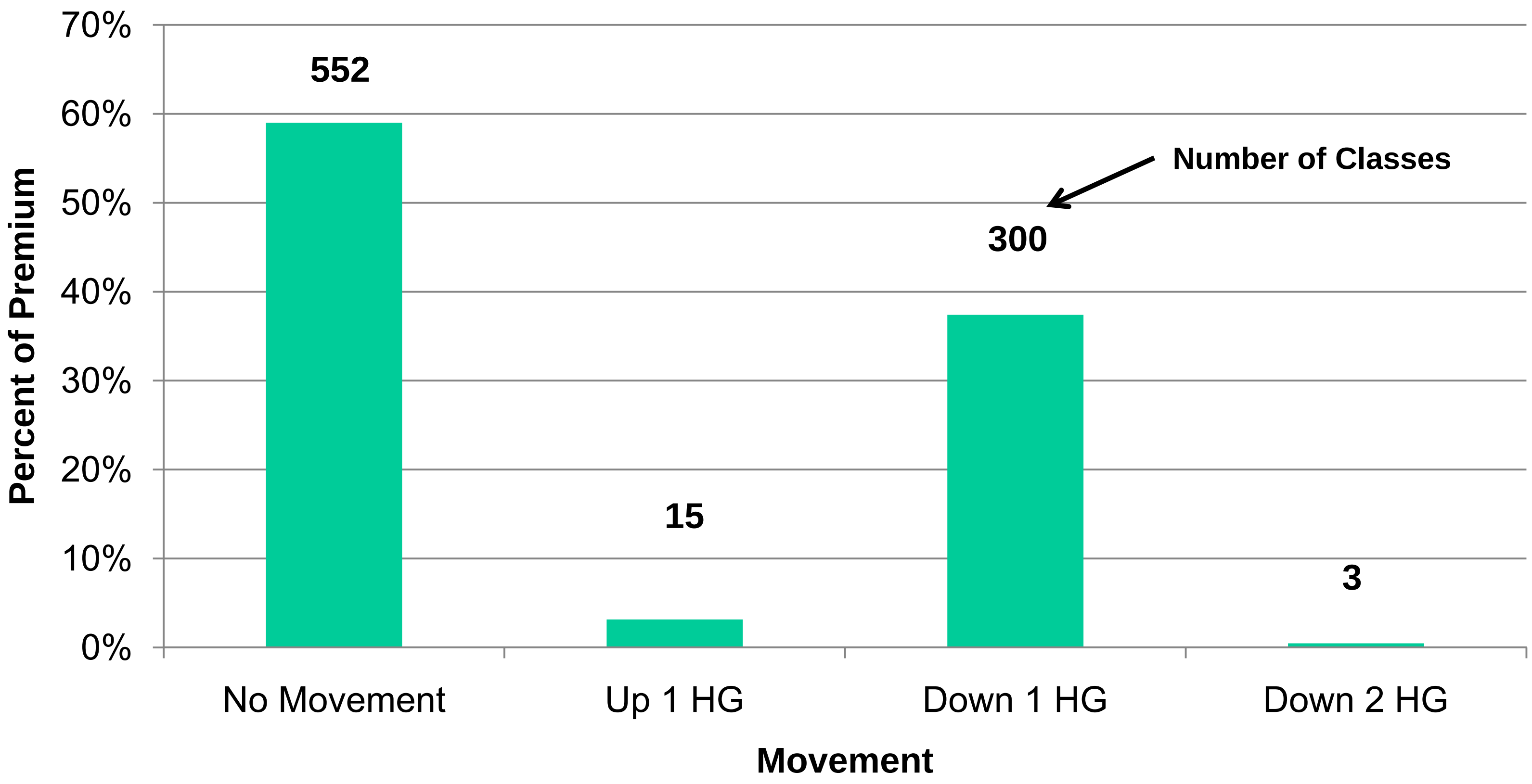
Percent of Premium Moved

Old Mapping to New 4 Hazard Groups
Before Underwriting Review



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We Sought Input from Underwriters

- Following the initial analytic assignment of classes to hazard groups, the draft hazard group assignments were sent individually to NCCI's Underwriting Advisory List (27 affiliates) and were also reviewed by NCCI staff underwriters
- Underwriters were asked to consider:
  - Given that a claim occurs, the likelihood of it being serious,
  - Similarity of operations between classes
- Underwriters provided written reasons for suggestions for changes to assignments that NCCI considered in its final selections

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Underwriting Review

- Underwriters also commented on
  - Exposure to motor vehicle accidents
  - Extent of use of heavy machinery
  - Exposure to dangerous substances
- Considerations for NCCI's final assignment of classes to hazard groups included
  - Consistency of the underwriting input
  - Credibility of the class
  - Position of the class relative to the two nearest cluster centroids

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Example of Reassignment of Classes Based on Underwriter Input

- Class 0030 is for employees in the sugar cane plantation industry
  - Has 12% credibility; applies in only a few states
  - Was in Hazard Group III
  - Was assigned to Hazard Group E by the cluster analysis
- Class 2021 is for employees who work at sugar cane refining
  - Has 31% credibility; applies nationally
  - Was in Hazard Group II
  - Was assigned to Hazard Group C by the cluster analysis

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Example of Reassignment of Classes Based on Underwriter Input (Cont'd)

- Considerations included:
  - Insureds in either class can have both farming and refining operations
  - Farming and refining both involve use of heavy machinery
  - Prior to credibility weighting, Class 2021 had ELFs close to those for the centroid of Hazard Group D
  - After credibility weighting Class 2021 had ELFs between the centroids for Hazard Groups C and D
- NCCI assigned Class 2021 to Hazard Group D based on its ELFs prior to credibility weighting and its mix of operations
- NCCI assigned Class 0030 to Hazard Group D to put it in the same Hazard Group as Class 2021

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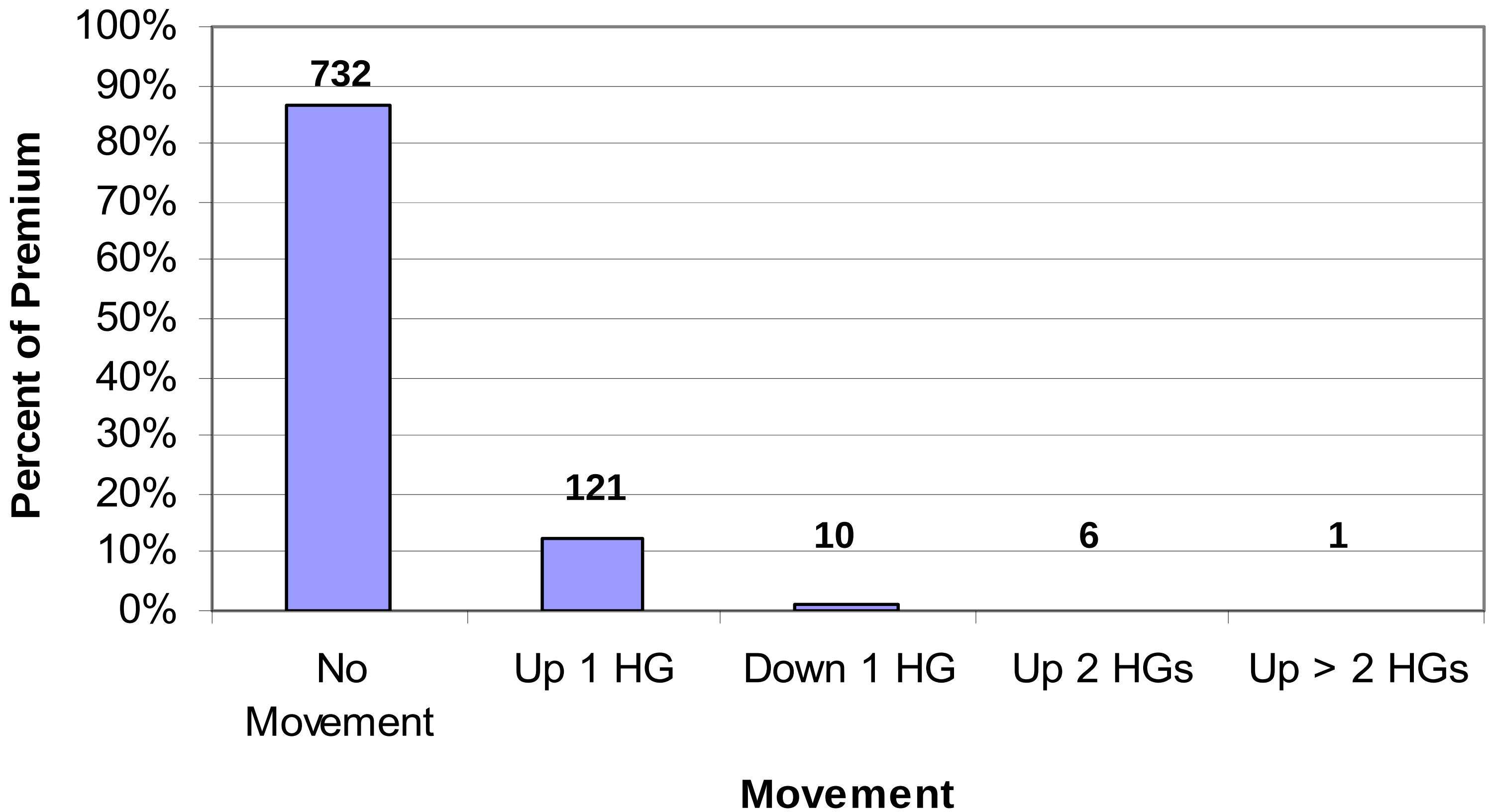
Movement of Classes as a Result of Underwriting Review



Number above bar represents the number of classes in each category. Movement is number of classes that NCCI moved relative to the new 4 hazard groups after considering input from the underwriting review.

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Conclusion

- In 2007 NCCI implemented a new 7 Hazard Group System
- Cluster analysis was used to make initial assignments of classes to hazard groups based on similarity of excess loss factors
- Underwriting review provided input that helped NCCI refine the assignments
- The new 7-Hazard-Group system has been approved for use in all 35 NCCI jurisdictions and several independent bureau states
- The full paper is available at **ncci.com** under Research & Outlook

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QUESTIONS?

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