

# **Mortality Assessment Technology: A New Tool for Life Insurance Underwriting**

Guizhou Hu, MD, PhD

BioSignia, Inc, Durham, North Carolina

## **Abstract**

The ability to more accurately predict chronic disease morbidity and mortality endpoints could play a meaningful role in improving life insurance underwriting and actuarial analysis. Currently, most medical risk assessment in life insurance is not only less accurate than probability based prediction, but also unable to incorporate new scientific research findings into its algorithm. In this paper, an evidence-based disease prediction model, mortality assessment technology, that was developed by integrating risk-factor information documented in the medical literature using a patented synthesizing statistical algorithm is introduced. Comparisons were made of risk discrimination in selection of a preferred low risk class between mortality assessment technology and a conventional algorithm, using empirical longitudinal data with mortality outcomes. Age and gender adjusted mortalities were used as the outcomes for comparison. The mortality assessment technology consistently outperformed the conventional criteria on risk discrimination. Therefore, mortality assessment technology can be a very useful tool for life insurance underwriting and actuarial analysis.

## **Introduction**

During the last decade, the life insurance industry has become more and more competitive. To be successful in this market, better risk management and improved life underwriting is critical. It is ironic that while information technology solutions have been widely adopted in most other industries, current life underwriting is still a largely paper driven system; underwriters are still flipping through paper files and turning the pages of thick underwriting manuals. Underwriting rules are still a mixture of subjective judgment and numerical rating systems (debit/credit). Subjective judgment by its nature produces inconsistencies, no matter how experienced the underwriter, and simple debit/credit algorithms cannot optimally reflect the complexity of the associations between risk factors and mortality outcomes. The future of underwriting is in technology that can offer more consistency and accuracy in risk classification and subsequently lead to improved profits.

In this paper a new technology, Mortality Assessment Technology (MAT), is introduced. Embedded in MAT is an algorithm called Synthesis Analysis (SA). SA is a patented statistical algorithm that provides for the construction of multivariate disease/condition prediction equations by combining research findings on each risk factor from disparate studies in the medical literature. SA may be used to build disease/condition-specific morbidity prediction equations. A detailed description of SA was reported elsewhere <sup>1</sup>. MAT is a statistical modeling procedure, which converts multiple synthesized disease-specific morbidity predictions into a simple mortality prediction equation. It predicts the future mortality for subjects who do not show overt clinical impairment.

MAT could help life insurance underwriting in two ways: (1) It could reduce the underwriting cost, and (2) it could improve underwriting accuracy. The cost reduction by MAT is straightforward, so this paper is mainly focused on the accuracy improvement with MAT.

## Mortality Assessment Technology

MAT includes two components: First, there is a process of calculating multiple disease or condition prediction equations, which are developed using SA. The outcomes of the predictions are probabilities of onset for each specific disease or condition within a specified period of time. A common form of the prediction equation appears as follows:

$$P=1/(1+EXP(a+b_1*X_1+b_2*X_2+ \dots+b_i*X_i))$$

- P is the probability of having a specific disease or condition within a specified period of time.
- $X_1 X_2 \dots X_i$  are values of established risk factors for the disease, such as blood pressure, cholesterol, etc.
- $b_1 b_2 \dots b_i$  are regression coefficients (logistic regression).
- a is an intercept of the regression.

The second component of MAT converts condition-specific probabilities into a predicted mortality ratio (PMR) with the following formula:

$$PMR=EXP(M_1*\log(P_1/P_{1m})+M_2*\log(P_2/P_{2m})+M_3*\log(P_3/P_{3m})+\dots+ M_i*\log(P_i/P_{im}) / M_t)$$

- PMR is a ratio of the mortality risk of the individual subject vs. the mean mortality risk in a reference population for the subject's age and gender.
- $P_1 P_2 \dots P_i$  are probabilities for the onset of several diseases and conditions for the individual subject within a specified period of time.
- $P_{1m} P_{2m} \dots P_{im}$  are average probabilities for the onset of the corresponding diseases and conditions in the reference population for the subject's age and gender.
- $M_1 M_2 \dots M_i$  are condition-specific mortalities for the subject's age and gender in the general population.
- $M_t$  is the total mortality for the subject's age and gender in the general population.

The PMR is essentially a weighted average of mortality ratios. The weights are contributions of disease-specific mortality over total mortality ( $M_i/M_t$ ) for a specific age and gender. For example, for a male at age 50, death from heart disease accounts for 20% of total mortality, and stroke accounts for 5%. The values of those weights ( $M_1 M_2 \dots M_i$  and  $M_t$ ) were derived from US national vital statistics<sup>2</sup>. Although the absolute mortality for the general population is higher than the life insurance population, the death rank order in terms of contributions to overall death for major diseases/conditions that were modeled are believed to be similar between the two populations. The morbidity ratios ( $P_i/P_{im}$ ) are the ratios of disease specific risk predictions of an evaluated subject over a reference population for a given age and gender. The reference population is the reference of PMR. In other words, the interpretation of PMR is in the context of a reference population. Ideally, it is a population representing the overall standard life insurance population, although choosing a different reference should not affect the discrimination power of MAT. For those diseases or conditions for which no prediction models were available, a morbidity ratio of 1 was used, meaning no discrimination.

The purpose of MAT is to predict the future mortality for subjects who do not show overt clinical impairment; therefore MAT is not a direct risk assessment tool to determine a clinical impaired (existing disease) risk. It does not mean MAT is not useful in those situations, because evaluating existing impairment should always be in context with evaluating non-impairments risks. The application of MAT on this matter will be addressed in other publications. In this paper we only focus on the risk discrimination of MAT among non-impaired subjects. One useful application of the evaluation of non-impaired risk is in selection of a preferred low risk class. In other words, since high risk is complicated by existing impairment, we will focus on the simple

issue of selecting low risk individuals. Therefore the mortality experience of the preferred class defined by MAT and by conventional criteria was compared.

## **Research Methods**

In order to demonstrate the validity of MAT, a comparison of risk discrimination between MAT and a conventionally used algorithm was made using empirical longitudinal data with mortality outcomes.

### ***Data***

The First National Health and Nutrition Examination Survey (NHANES-I) and The NHANES-I Epidemiologic Follow-up Study (NHEFS) are national longitudinal studies designed to investigate the relationships between clinical, nutritional, and behavioral factors assessed at baseline and subsequent mortality. It was conducted by the National Center for Health Statistics, which is part of the Centers for Disease Control and Prevention. The baseline survey of NHANES-I was conducted on a nationwide probability sample of approximately 32,000 people, ages 1 to 74, from 1971 to 1975. Follow-ups of the NHANES-I population were conducted in 1982-84, 1986, 1987, and 1992 among 14,407 subjects that were 25-74 years old at the baseline. The details of the study design were published elsewhere <sup>3</sup>.

In this study the subjects were further limited to those who had complete information at baseline regarding smoking history, height, weight, blood pressure, cholesterol, etc. In an effort to exclude impaired (existing disease) cases, all subjects with known incidence of heart disease, stroke, diabetes, COPD, asthma, and any cancers were excluded. It is expected that certain impairments (such as drug user, HIV infection) were not removed due to the lack of information. This may make the mortality of the study population higher than what is expected among the non-impaired general population. The final number of subjects included in the analysis was 5,409. There were 52,086 person-years of observation for the first ten years following the baseline survey. There were 519 deaths during this period of time.

### ***Classification of preferred class by conventional life insurance criteria***

The preferred classification criteria were cited from Dworkin Associates Inc (<http://www.dworkin.com/superpref.htm>) as follows:

- Free of any existing disease
- Non smoker
- No family history of CHD
- Cholesterol <230, total cholesterol/HDL <5.0
- Blood pressure <140/85 (≤ 60 yrs old), <150/90 (>60 yrs old)
- Weight did not exceed chart values (not shown)
- No hazardous hobbies or occupations.
- No cancer history

Applying these criteria to the data resulted in 851 (15.7%) subjects being qualified as preferred class.

### ***Classification of preferred class by MAT***

PMRs were calculated for each subject using the formula mentioned above. The disease/condition-specific prediction models used included models for heart disease, stroke, diabetes and lung cancer. The risk factors used for those models included age, gender, smoking status, physical activity level, anti-hypertension medication, height, weight, blood pressure, cholesterol and albumin. The age and gender-specific average morbidities were used

as a reference to calculate PMR. For the sake of comparison, the lowest 15.7 percentile of PMR was used as the cut-off point for preferred classification. The 15.7 percentile of PMR value was 0.838, thus all subjects with PMR values under 0.838 were classified as preferred by MAT.

### **Statistical analysis of mortality**

The average annual mortality for the first 10 years following the classification was used as the end point for comparison. The proportional hazard (Cox) model<sup>4</sup> was used to adjust for age and gender when mortalities between groups were compared. It is believed that the main difference between this study sample and the life insurance population is that the latter has higher socioeconomic status (SES). In order to explore the effect of SES on the comparison results, all analysis were stratified according to two levels of SES, which was defined by average annual income.

### **Results**

Table 1 summarizes the baseline information and mortality of the study population. It shows that SES has significant impact on the overall health status as well as mortality in the study sample.

Table 1. Baseline characteristics of study population (NHANES I Follow-up Study)

	High SES	Low SES	All
Number	2913	2496	5409
Age (yrs)	44.0±12.2	50.6±15.0	47.1±14.0
Male (%)	48.6	42.7	45.9
SBP (mmHg)*	128±20	136±25	132±23
TC (mg/dL)*	218±45	225±48	221±46
BMI (kg/m <sup>2</sup> )*	25.2±4.6	26.3±5.5	25.7±5.1
Smoke (%)	36.5	36.9	36.7
Albumin (mg/dL)	4.4±0.2	4.3±0.3	4.4±0.3
Physical activity (%)			
Light	30.6	32.7	31.5
Moderate	53.7	52.2	53.1
Heavy	15.7	15.1	15.4
Income (per person)	>\$10,000	<\$10,000	
Person-years observation of first 10 years	28,572	23,514	52,086
Annual mortality (per thousand) **	7.5	12.9	10.0

\*SBP – Systolic blood pressure, TC – Total cholesterol. BMI – Body mass index

\*\* The mortality is adjusted based on age and gender distribution of the entire study sample

As is shown in Table 2, the mortalities of the preferred class defined by either conventional criteria or MAT were all lower than the entire group mortalities. The amount of mortality reduction was higher for MAT than conventional criteria across SES levels.

Table 2. Annual age and sex-adjusted mortality (per thousand) of preferred classes defined by conventional criteria and MAT (NHANES I Follow-up Study)

	High SES	Low SES	All
Whole group	7.5	12.9	10.0
Preferred class defined by MAT	4.2	7.9	5.9
Preferred class defined by conventional criteria	6.2	8.1	7.2

Table 3 is a 2 by 2 cross table of the classification of preferred class by MAT and conventional criteria in the study sample. It is shown that while that there is 79% ((276+3983)/5409) consistency between the two classification methods, it is the 21% discrepancy that makes the preferred class defined by MAT have a significantly lower mortality than the preferred class defined by conventional criteria (5.9 vs. 7.2). This comparison is also illustrated in figure 1.

Table 3 Comparison of the classification of preferred class and their annual mortality between conventional criteria and MAT (NHANES I Follow-up Study)

		Convention criteria		
		Preferred	Other	Total
MAT	Preferred	276(4.7)*	575(6.4)	851(5.9)
	Other	575(8.3)	3,983(10.9)	4,558(10.7)
	Total	851(7.2)	4,558(10.5)	5,409(10.0)

\*Number of subjects classified in the group, and its annual mortality (per thousand) in parenthesis for the first 10 years following the baseline.

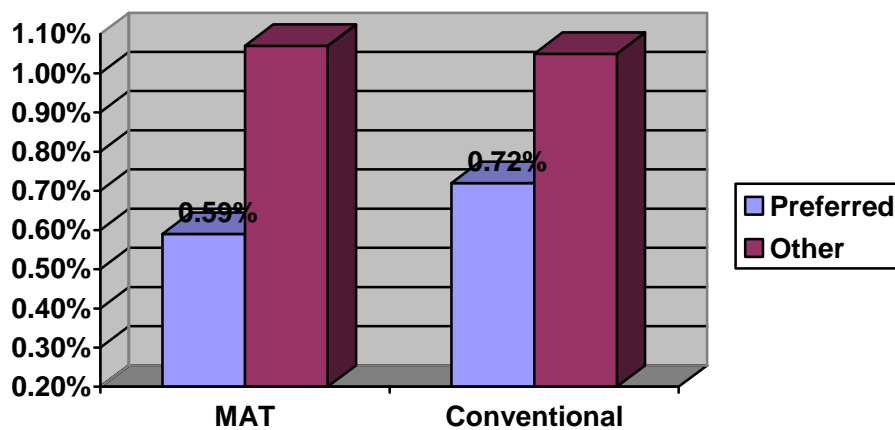
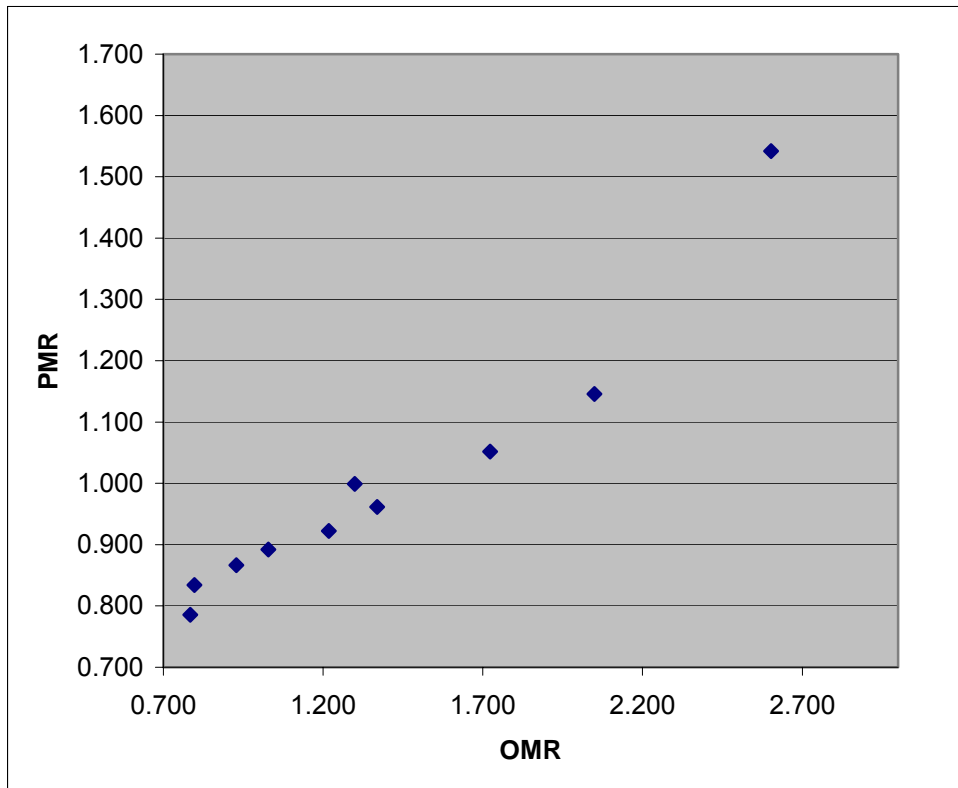


Figure 1. The annual mortality for the first 10 years after the baseline among classification groups defined by MAT and conventional criteria (NHANES I Follow-up Study)

Figure 2. Correlation between the observed mortality ratio (OMR) and predicted mortality ratio (PMR) among deciles defined by PMR (NHANES I Follow-up Study)



Since PMR is a continuous measurement, it allows a comparison between PMR prediction and the observed mortality across the entire spectrum of risk in the data. The data were first rank ordered by PMR and divided into deciles. The average PMR value and observed mortality ratio (equal to the observed mortality of each decile over total mortality) of each decile were calculated. The correlation of PMR and the observed mortality ratio was found to be highly significant (Figure 2), with a correlation coefficient of 0.965 indicating a high accuracy of MAT prediction of mortality. Comparing the absolute value of PMR with OMR indicates that the PMR values are more attenuated toward 1, meaning less discriminating. This is because the calculated PMR in this sample data only includes information on four causes of death (heart disease, stroke, diabetes and lung cancer), which is about 40% of total causes of death. As stated in the method section, for those diseases or conditions for which no prediction models were available, a morbidity ratio of 1 was used, meaning no discrimination. The conventional risk assessment is dichotomous; therefore no comparison could be made between PMR and the conventional method in the whole spectrum of risk.

Comparing the age distribution of the preferred group defined by MAT and conventional criteria indicates that older subjects are more likely to be selected as preferred class by MAT, but younger subjects are more likely to be classified as preferred class by conventional criteria. As is shown in Figure 3, the proportion of preferred class defined by conventional criteria decreased as age increased. However the proportion of preferred class defined by MAT increased as the age increased. Because of the wider distribution of health status among old people than young people, including more older people into the preferred class would make lower age-adjusted mortality. See the discussion section for details.

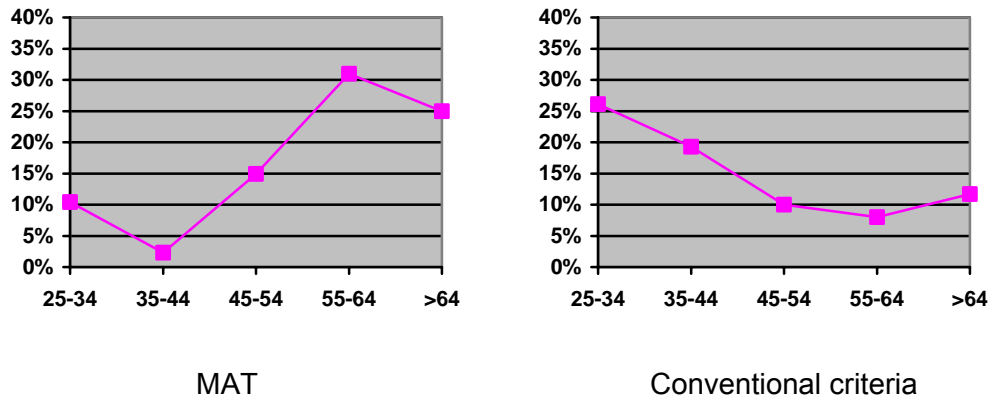


Figure 3. The proportion of preferred class defined by MAT (left graph) and conventional criteria (right graph) across age groups (NHANES I Follow-up Study)

## Discussion

The increased competition in the life insurance industry has put an increasing demand on fast and accurate underwriting tools. The concept of Jet Issue of life insurance policies through the Internet has attracted significant interest in the industry because of the obvious advantage of low processing cost. However, there are concerns whether the trade off in increased mortality by giving up the traditional underwriting process will be worth the processing cost reduction assuming a reduced discrimination power of mortality risk. In this paper we presented a new underwriting tool, MAT, which not only can be easily implemented on any IT platform, but also, and more importantly, has higher validity to discriminate mortality risk over conventional underwriting criteria, at least in selecting preferred classes. This may completely change the conventional way of thinking on this matter, because by using MAT, Jet Issue life insurance not only could have lower cost but also better mortality experience.

As was shown in Table 2 and Table 3 the mortality rate of the preferred group defined by MAT was significantly lower than that defined by conventional criteria. In order to extrapolate this finding to a life insurance population, the mortality of the present study population was compared with basic life table values. The comparison suggested that the high SES group of the study population was close to real life insurance applicants. According to the life table (75-80) of American Society of Actuarial, the annual mortality rate during the first 10 years of policy and ultimate annual mortality rate of the life insurance cohort was 5.2 and 9.8 per thousand after adjusting for age and gender<sup>5</sup>. In the present study, the 10 years annual mortality rate for the high SES group was 7.5 per thousand (Table 1), which was between the life insurance ultimate and first 10 policy years mortality table rates. This indicates the similarity of the two cohorts. That the mortality rate of the high SES group from the study sample was lower than the life insurance ultimate mortality table rate reflects the effect of excluding existing cases and the higher than life insurance first 10 years mortality table rate indicates the existence of residual impaired cases in the data.

In general, the preferred class is designed to have a mortality rate of 75-100% of the standard mortality table rate. In the study sample, the mortality rate of the preferred class in the low SES subgroup (7.9 by MAT, 8.1 by conventional criteria) and the preferred class defined by conventional criteria in the high SES subgroup (6.2) were all higher than the standard mortality table rate (5.2). The high rates reflect the higher initial mortality rate (low SES) and some impairment (such as HIV infection or drug use) still existing in the data. However, in the high SES group, which is similar to the real life insurance population, even with some possibility of residual impaired cases, the preferred class defined by MAT has a mortality rate 4.1 per thousand, which is still 81% (4.2/5.2) of the life table rate.

We assumed that if a proper screening was implemented the residual impaired cases could be removed; the mortality of the preferred class defined by conventional criteria could be reduced to 90% of standard mortality tables ( $0.9 \times 5.2 = 4.7$ ). To be conservative we then assumed the mortality of the preferred class defined by MAT would still be the same (4.2), even though the residual impaired cases were assumed to be removed. This still leads to a  $4.7 - 4.2 = 0.5$  per thousand mortality reduction of the preferred class by MAT over conventional criteria. The following economic analysis demonstrates the significance of this most conservative mortality reduction estimation.

To make a practical example, we took a term life insurance scenario assuming a five-year term and a discount rate of 8%. For every \$1000 of face value, the annual mortality reduction of 0.5 per thousand will generate claims savings of \$2.10 of present value over the five years. If we extrapolate this to 1 million preferred policies with an average face value of \$100,000, then the total savings of MAT over the conventional criteria would be \$210 million.

What are the biological mechanisms that could explain the better mortality discrimination of MAT over conventional criteria? There are at least two: (1) MAT, which includes multiple disease prediction models, is based on a review of the most recent medical literature. Therefore it has better specification on how each risk factor relates to mortality risk, especially when there are multiple risk factors and there are interactions among them. (2) PMR, the basic parameter of MAT, is fully adjusted for age and gender, while the conventional criteria has much less age or gender adjustment. This is important because the preferred class is desired to have a lower age and gender-adjusted mortality, not just lower crude mortality. Lower crude mortality, which can be easily achieved by selecting younger subjects, does not necessarily produce lower age-adjusted mortality, and in fact, it tends to increase the age-adjusted mortality. It is not difficult to conclude by simple examination of the conventional criteria for preferred classification, that younger people are more likely to be qualified. The effect of age and gender on mortality has been fully adjusted in the premium setting. Any factors to define preferred class should no longer be associated with age or gender. To explore this concept further, it makes more biological sense if more older people are included in the preferred class. It is believed that older people tend to have a much wider distribution of their health status, while the distribution range for younger people is much narrower. When the lower relative mortality is desired, more older people should be qualified (Figure 4). An examination of the proportion of preferred classification by the two methods across age groups confirmed the above considerations. As is shown in Figure 3, the proportion of preferred class defined by conventional criteria decreased as age increased, however the proportion of preferred class defined by MAT increased as the age increased.

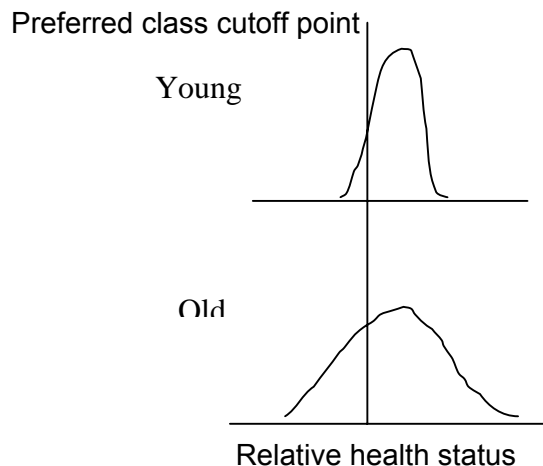


Figure 4. Distribution of health status for young (top) and old (bottom). If the same relative health value is used as cut off point (vertical line) to select a preferred class, then more older people are expected to be included.

The present study estimates the amount of mortality reduction in the preferred class defined by MAT over conventional criteria. However, it is very likely an underestimate of the true mortality reduction effect. In addition to the conservativeness in the calculation, MAT was not used in its full capacity due to the limited information available in the data. First, the data cannot provide enough information to effectively exclude all major impaired cases. Second, the number of disease/condition models that could be used was reduced due to the lack of risk factor information. Even the four models (heart disease, stroke, diabetes and lung cancer) that were used were truncated to fit the information available. Additional information that could improve the prediction models include fasting glucose, serum triglycerides, HDL cholesterol, family history of diseases and, for women, the pregnancy history. That information is typically available in the underwriting process.

The main limitation of this study is that the data are from a national observational sample instead of life insurance real experience. This limitation may be of less concern since the stratification analysis by SES indicates that the benefit of MAT is higher among the subgroup similar to the life insurance population (high SES group). However, this result still needs to be interpreted with caution.

## **Conclusion**

The evolution of the life insurance industry is requiring a robust risk assessment tool that not only could streamline the underwriting process and reduce the processing cost, but also improve the risk assessment quality. The Mortality Assessment Technology (MAT) introduced in this paper was developed for that purpose. MAT is based on multiple evidence-based disease prediction models and a conversion to predicated mortality ratio (PMR). By applying MAT into a national longitudinal cohort dataset, it was shown that MAT accurately predicted mortality and yielded better mortality risk discrimination power than the conventional method. More specifically, the preferred class defined by MAT had significantly lower mortality outcomes than the preferred class defined by conventionally used criteria. It is believed that MAT could play significant roles in the evolution of underwriting from a paper driven process into an automatic, computerized, intelligent decision process.

---

## **Reference**

<sup>1</sup> Hu, G. and Root, M. "Developing disease specific and morbidity-based health risk assessments" The Society of Prospective Medicine 36<sup>th</sup> Annual Meeting, pp53-64, 2000

<sup>2</sup> National Vital Statistics Report Vol 48, No 11, July 24,2000 p 16-25

<sup>3</sup> Plan and Operation of the Health and Nutrition Examination Survey. United States 1971-1973 National Center for Health Statistics. 1973

<sup>4</sup> Cox, DR. Regression Models and Life Tables. Journal of the Royal Statistical Society, B34, 187-220 1972

<sup>5</sup> 1975-1980 Basic Select and Ultimate Mortality Tables for Individual Life Insurance. Society of Actuaries