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Article

Actuarial Reserve for Accumulated Leave Benefits (GCR) with Enhanced Mortality and Interest Rate Modeling

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***Abstract*— The 2023 Malaysian Budget increased the maximum compensable unused leave for public employees from 160 to 180 days, significantly raising future liabilities for public sector employers. Under the Malaysian Private Entities Reporting Standard (MPERS), universities must recognise these benefits, which are payable upon retirement or death, as actuarial liabilities. Existing tools, such as the Jabatan Perkhidmatan Awam (JPA) calculator, offer limited accuracy as they do not account for mortality risk or interest rate fluctuations. This study introduces an enhanced actuarial reserve model that incorporates both uncertainties. The model considers two payment casesw which are upon retirement and upon death, using survival probabilities, interest discounting, and assurance factors to determine the expected present value of future cash awards. To evaluate model performance, a simulation study using a non-parametric bootstrap is conducted on 5,000 simulated employee records. Bootstrap resampling is repeated at increasing levels to measure bias and consistency. Results show that both bias and variance decrease as bootstrap iterations increase, indicating model stability and accuracy. This improved model offers a more realistic and reliable method for estimating future cash awards, ensuring better financial planning, policy compliance, and reserve adequacy for higher education institutions.**

***Keywords*— Actuarial reserve; Accumulated leaves benefit; Mortality risk; Net Present Value (NPV); retirement.**

I. INTRODUCTION

In the 2023 Malaysian Budget, Malaysian government announced an increase in the maximum limit for compensation of unused leave from 160 days to 180 days, equivalent to six months. The unused annual leave is known as “Gantian Cuti Rehat (GCR)”. This revision has significantly elevated the potential future liability for cash awards related to accumulated leave. As the largest employer in the country, the Federal Government bears a substantial responsibility in managing and forecasting future cash reserves to meet the GCR payments.

In 2022, when the maximum allowable accumulated leave stood at 160 days, the allocated budget for Gantian Cuti Rehat (GCR) was RM740 million. By 2025, following the increase to 180 days, the budget allocation rose to RM1.153 billion, which is an increment of 55.85% [1-2]. This sharp increase represents a considerable financial burden, particularly in the context of an ageing workforce, and is expected to continue rising in the future.

It is important to note that the GCR budget referenced above pertains solely to payments made by the Federal Government. This figure does not include GCR payments disbursed by State Governments, Statutory Bodies, or Local Authorities, as the cash award for accumulated leave is the responsibility of the respective employer upon an employee’s retirement. For employees covered under the EPF scheme, any payment in lieu of accumulated leave shall be at the employer’s discretion. Table I outlines the agencies responsible for GCR benefit payments. Therefore, the actual national expenditure on GCR is significantly higher than the amount reported by the Federal Government [2].

TABLE I. AGENCIES RESPONSIBLE FOR GCR BENEFIT PAYMENTS.

Retirement Scheme	Employer	Agency
Pension	Federal government	Jabatan Perkhidmatan Awam (JPA)
	State Governments/ Statutory Bodies/Local Authorities	Respective employer
Employee Provident Fund (EPF)	Federal government	the last department the officer served
	State Governments/ Statutory Bodies/Local Authorities	Payment is limited to EPF Scheme officers who terminate their service upon reaching the retirement age as stipulated in their EPF option.

This GCR can be materialised earlier, before the retirement day, if the government servants meet specific eligibility criteria. The criteria include having at least 15 years of service and being at least 45 years old, with at least 90 days of accumulated annual leave. The application must be submitted through the Head of Department to the Public Service Department (JPA), and the early grant of GCR is allowed only once during the officer's entire service period.

Furthermore, the total payment for cash awards will also increase with the recent salary increment of Malaysian government servants. Malaysian Prime Minister Dato Seri Anwar Ibrahim has announced the introduction of new public employee schemes, “Sistem Saraan Perkhidmatan Awam (SSPA)”, in replacing the old BSM Schemes. Dato Seri Anwar Ibrahim also announced that civil servants will enjoy a salary hike of more than 13% starting this December, marking the highest increase in the nation’s history.

He noted that the adjustment will require an allocation of over RM10 billion. Table II summaries the percentage increment of public employees [3].

TABLE II. PERCENTAGE INCREMENT FOR EACH GROUP UNDER SSPA.

Group	Phase 1: Effective 1 December 2024	Phase 2: Effective 1 January 20
Top (upper) management	4%	3%
Management and professional	8% or minimum RM250, whichever is higher	7%

Last year, civil servants in the management and professional category received an 8% salary increase effective December 1, under the first phase of the government’s 15% pay adjustment initiative. They are scheduled to receive a further 7% increase in the second phase, beginning January 1, 2026.

Meanwhile, civil servants in the top management category received a 4% increase in the first phase, with an additional 3% raise planned for the second phase.

With Malaysia becoming an aging nation, and a small percentage of income tax, this will tremendously add to the existing burden.

Hence, Malaysian government has obliged all state governments, statutory bodies and local authorities to recognise employee benefits, including cash awards in lieu of accumulated leave, as liabilities in their annual financial statements. Furthermore, in line with the Government’s commitment to transition from cash-based to accrual accounting, several agencies have begun adopting accrual accounting practices through the Malaysian Public Sector Accounting Standards (MPSAS), Malaysian Financial Reporting Standards (MFRS), or Malaysian Private Entity Reporting Standards (MPERS).

Under accrual accounting, the key principles for post-employment benefits (such as GCR) require a sponsoring entity to:

1) Recognise a liability once an employee has rendered service in exchange for benefits that will be paid in the future; and
2) Recognise an expense when the entity derives economic benefit from the employee’s service in exchange for those benefits.

In this context, the State Government, Statutory Bodies, and Local Authorities are the sponsoring entities for the GCR benefit. Entities that adopt accrual accounting must therefore assess and report the financial impact of GCR obligations in their financial statements.

This raises the question: how should an agency measure and present the GCR liability and expense in its financial statements?

Under the Malaysian Private Entities Reporting Standard (MPERS), universities are required to recognise employee benefits, including cash awards in lieu of accumulated leave, as liabilities in their annual financial statements. These benefits, often payable upon retirement or death, must be assessed using actuarial valuation methods such as the Actuarial Valuation Method (AVM) and Net Present Value (NPV) calculations.

Jabatan Perkhidmatan Awam [4] has built a calculator to calculate the cash award. Yet, the calculator typically allows only a single data input and fails to incorporate key uncertainties, particularly mortality risk and interest rate volatility.

To address this challenge, the Net Present Value (NPV) method and the Gross Premium Value (GPV) method have been proposed to calculate the present value of future cash awards. The NPV and GPV methods assume that cash flows are regular and predictable, but in reality, they can fluctuate due to various factors [5]. Additionally, these methods assume a constant discount rate over time, which is unrealistic given the volatility of interest rates and investment returns over long periods [3, 6, 7]. Moreover, the NPV formula focuses solely on financial aspects, neglecting qualitative or non-financial factors such as social, environmental, and ethical considerations, which may be crucial in investment or project evaluation [8, 9].

Kornish & Kellogg [10] discuss how the long-term nature of projects introduces uncertainties that traditional NPV calculations cannot adequately address, recommending the use of stochastic models for improved forecasting [6,7,10,11].

Traditional methods, including the actuarial method, NPV, and Monte Carlo Simulation, depend on predefined assumptions that may not fully address the complexities and uncertainties surrounding future changes in mortality rates, salary increases, and interest rates [6, 7, 11, 12]. While sensitivity analysis can be helpful, it does not fully encompass the potential risks, especially in highly uncertain environments [13, 14], leading some experts to advocate for real options analysis to more effectively capture uncertainty in financial decision-making.

In light of these concerns, more sophisticated approaches, such as Monte Carlo simulations and stochastic models, have been developed to account for these risks. However, these methods require running numerous simulations and using a wide range of random variables, which can lead to complex mathematical formulations that may be difficult for non-experts to interpret [8, 15]. Additionally, authors of [16] note that these models rely heavily on assumptions about volatility, return rates, and other financial factors, and small changes in these inputs can have a substantial impact on the outcomes. According to Wang & Lin [17], the accuracy of Monte Carlo simulations depends on correctly choosing input distributions for variables such as return rates, inflation, and mortality, with any errors potentially leading to misleading results. On the other hand, Patel & Zhang argue that while Monte Carlo simulations can manage randomness well, they sometimes fail to capture the true probability of rare, high-impact events (tail risks), which can greatly influence future cashflows.

In a nutshell, each of these methods for calculating future retirement funds has its own set of weaknesses that can affect the reliability of its projections. Stochastic models struggle with computational demands and sensitivity to assumptions, while the NPV method oversimplifies uncertainty by assuming a constant discount rate and ignoring risk. The GPV method may overlook changes in policyholder behavior and economic conditions, and Monte Carlo simulations, though flexible, are computationally expensive and may struggle with rare, high-impact events.

This study aims to develop an actuarial formula for calculating the future value of cash awards for accumulated leave that explicitly integrates both mortality risk and fluctuations in interest rates. The proposed model accounts for two payment scenarios: upon retirement and upon death by incorporating probabilistic mortality factors and interest rates. The proposed method is novel and, to the best of our knowledge, has not been applied previously.

II. METHODOLOGY

In this section, we outline the methodological framework employed to develop and evaluate the actuarial model for estimating the financial liability of the Cash Award in Lieu of accumulated leave (GCR) benefit. The approach is structured into three main components: (A) data collection, (B) Assumptions, (C) the actuarial reserve model, (D) simulation study, and (E) error measurement.

First, we describe the data sources and the construction of simulated employee records used for model testing. Second, we specify the demographic and economic assumptions necessary to project future obligations, including mortality and interest rate assumptions. Finally, we present the actuarial reserve model that integrates these assumptions to quantify the liability under both retirement and death scenarios.

The rationale for this approach is twofold. First, the actuarial nature of GCR requires that obligations arising many years in the future be valued at present, which involves discounting, mortality modeling, and probability-weighted valuation. Second, unlike conventional formula-based calculations that may ignore risk factors, our framework seeks to explicitly incorporate demographic uncertainty (mortality risk) and economic uncertainty (interest rate or inflation). This ensures a more realistic quantification of government liability.

A. Data

The data used in this study were originally sourced from two public universities in Malaysia. However, due to privacy and confidentiality concerns, it was not possible to use actual employee records. Instead, we constructed simulated data to test the consistency, bias, and accuracy of the actuarial model. Simulation of data is a common practice in actuarial research when individual-level employment records are unavailable or restricted. We generated 5,000 employee records with:

1. Gender.
2. Date of Birth (DOB): Required to compute age at present and projected age at retirement.
3. Retirement Date: Derived from statutory retirement rules.

4. Current Salary: The base salary drawn at the point of observation.
5. Fixed Allowance (E): A monthly fixed allowance that forms part of pensionable earnings.
6. Accumulated Leave (GCR): The total number of eligible days that may be converted into cash under the GCR benefit.
7. Eligibility for early withdrawal of cash awards.
8. Duration (in days) applicable for early cash awards. Malaysia government allows 80 or 90 days to be encashed.

Key parameters were calibrated to match publicly observable features:

(i) Salaries exhibit right-skew with a lower bound reflecting entry-level scales;
(ii) Allowances are non-negative and clustered by grade;
(iii) GCR accumulation respects eligibility ceilings (180-day policy maximum) and historical usage patterns.
(iv) A lognormal family for base salary (right-skew). Distribution parameters were chosen to reproduce reported aggregates (minima, means/medians, upper quantiles) and to satisfy institutional constraints such as floor salaries and allowable GCR caps of 180 days. We validated the draws by comparing descriptive statistics and histograms to reported summaries, ensuring face validity for Malaysian conditions.

The age range of the simulated employees spans from 22 to 60 years old. Employees above 60 were excluded, as their entitlement to the cash award would already have been realised. This restriction ensures that the liability calculated pertains only to employees who may generate future obligations.

The simulated salaries were bound to reflect realistic Malaysian pay scales. The lowest salary in the dataset is RM1,204, while higher salaries reflect those of senior academic and administrative staff. Leave accumulation was varied across employees to capture heterogeneity in service patterns and entitlements.

Using simulated data enables stress-testing of the model by providing a sufficiently large sample size (5,000 employees) to evaluate the actuarial formulas across a range of plausible employee profiles. The simulation also avoids biases and ethical issues associated with real employee data.

B. Assumptions

Actuarial valuation is inherently assumption-driven, as it attempts to assign a present value to obligations that will only materialise in the future. The reliability of the reserve depends heavily on the validity of the assumptions made regarding economic and demographic variables.

The interest rate represents either the expected investment return on assets backing the liability or, in the absence of a dedicated fund, the rate of inflation to reflect the time value of money.

If the employer maintains an investment fund, the interest rate assumption should align with the long-term expected return on assets (ROA). If there is no such investment, the inflation rate serves as a proxy, discounting future obligations to present value.

In actuarial practice, the selection of an interest rate is a critical step. An excessively high rate would underestimate the liability, while a low rate would overstate it. For robustness, sensitivity tests can be performed at varying interest rates to evaluate the model's stability.

The interest rate is essentially the investment return on the assets (ROA). This should be advised by the employer. However, we were informed by the employers that there is no investment. Hence, the interest rate can be replaced by the Malaysian inflation rate.

The second assumption is the mortality and longevity risks. These demographic risks are usually captured through mortality assumptions, which determine the probability that an employee survives to retirement age or dies earlier. For this study, we employed the Abridged Life Table (ALT) 2024, published by the Department of Statistics Malaysia.

The ALT provides mortality rates by age group, from birth up to age 80. As the table terminates at age 80, we imposed the assumption that all individuals die at this age if not earlier.

To increase precision, the abridged age-group mortality rates were interpolated linearly to derive single-year mortality rates.From these interpolated rates, we calculated:

1. q_x : the probability of dying within a year at age x.
2. p_x : the probability of surviving one year at age x, where px = 1 – qx.
3. ${}_n p_x$: the probability of surviving n years from age x.
4. ${}_{n|} q_x$: the deffered probability of dying, which is calculated as the product of ${}_n p_x$ and q_x .

It is assumed that each employee is statistically independent of others. In other words, the mortality or survival of one employee does not affect another. Furthermore, the model assumes independence from spouses or dependents, focusing solely on the liability associated with the employee's service.

This simplification is common in actuarial studies, as dependencies are complex to model and generally negligible in aggregate government-level calculations.

C. Actuarial Reserve Model

The GCR benefit is payable under two mutually exclusive conditions:

1. Retirement: If the employee survives to retirement age, the benefit is paid at that time.
2. Death before retirement: If the employee dies before reaching retirement, the benefit is paid immediately to the legal heir.

Jabatan Perkhidmatan Awam (JPA) [4] calculated this cash award using formula (1)

$$\frac{1}{30} \times (S + E) \times GCR \tag{1}$$

Where *S* stands for the last drawn salary, *E* is the fixed allowance, and *GCR* is the accumulated leaves. This formula, however, ignores the effects of mortality and economic uncertainty, potentially underestimating long-term government liabilities.

Hence, we formulate a new formula to account for these uncertainties. To address these limitations, we propose an actuarial reserve model that integrates both interest rate and mortality assumptions. The model decomposes the reserve into two components, which are the actuarial reserve for retirement and the actuarial reserve for death before the retirement age.

The first component is that the cash award will be materialised if the employee retires successfully. Hence, the actuarial reserve consists of two uncertainties, which are the interest rate and survival rate $V^n \, {}_n p_x$. The formula is as equation (2).

$$\frac{1}{30} \times (S+E) \times GCR \times V^n \times {}_n p_x \quad (2)$$

For the interest rate component $V^n = (1+i)^{-n}$, it is the present value factor, which simply means we are discounting a value back *n* years using compound interest. It consists of *i* as the annual interest rate and *n* as the difference between the retirement age and the present age. Whereas for the survival rate ${}_n p_x$, it is the probability that an employee aged *x* today survives *n* years until retirement age.

If the employee dies before retirement, the liability arises earlier. In this case, the heir of the employee will receive the cash award and its actuarial reserve is calculated as equation (3).

$$\frac{1}{30} \times (S+E) \times GCR \times A_{x:n} \quad (3)$$

In the equation 3, we introduce a new factor which is called the assurance factor, $A_{x:n}$. The assurance factor is the present value of the cash award payable at the moment of death, but only if death occurs within *n* years from age *x*. The present value of that expected cash award considers the interest rate for discounting V^n, the defered probability of dying ${}_{n|} q_x$. Thus,

$$A_{x:n} = \sum_{m=0}^{m-1} V^{m+1} \, {}_m p_x \, q_{x+m} \quad (4)$$

Finally, the total actuarial reserve is the sum of both components, representing the probability-weighted present value of GCR under both retirement and death scenarios, which is finalised as equation (5).

$$\frac{1}{30} \times (S+E) \times GCR \times V^n \times {}_n p_x + \frac{1}{30} \times (S+E) \times GCR \times A_{x:n}$$
$$= \frac{1}{30} \times (S+E) \times GCR \times (V^n \, {}_n p_x + A_{x:n}) \quad (5)$$

This actuarial reserve formula ensures that the liability recorded in financial statements reflects the true expected cost of cash award benefits rather than a simplistic cash-out formula. The incorporation of mortality and interest rate assumptions aligns with Malaysian Private Entity Reporting Standards (MPERS) that govern post-employment benefits for the public universities.

D. *Simulation Study*

In order to evaluate the statistical properties of the proposed actuarial reserve model, particularly its bias and consistency, a non-parametric bootstrap procedure was employed. Bootstrapping is a powerful resampling technique widely used in statistical inference when the theoretical distribution of an estimator is unknown or analytically complex. This study allows us to empirically approximate the distribution of the estimated actuarial reserves by repeatedly generating samples from the original employee dataset and recalculating the reserves for each sample. This approach provides a practical framework for quantifying the extent of estimation error and for assessing the reliability of the proposed model in predicting the financial liability associated with accumulated leave benefits.

Bias is defined as the difference between the expected value of the estimator and the true value of the parameter being estimated. In the context of this study, bias measures the systematic deviation of the actuarial model's predicted cash award from the actual or "true" amount. A low bias indicates that, on average, the model produces predictions that are close to reality. Consistency, on the other hand, refers to the property of an estimator to converge to the true value as the sample size or the number of replications increases. A consistent estimator will produce estimates that become increasingly precise as more data are included in the analysis or as the number of bootstrap resamples grows.

$$Bias = \frac{1}{B} \sum_{b-1}^{B} (\theta_b^* - \theta)$$
$$Variance = \frac{1}{B-1} \sum_{b-1}^{B} (\theta_b^* - \overline{\theta}^*)^2 \quad (6)$$

The bootstrap analysis was conducted across four different levels of iterations: R = 100, 1,000, 10,000, and 100,000. These increasing levels of resampling provide a means to evaluate the convergence behavior of the estimator. At lower iterations, bootstrap estimates may fluctuate substantially due to random sampling variation. However, as the number of resamples increases, the empirical distribution of the estimator stabilises, yielding more reliable estimates of bias and variance.

E. *Error Measurement*

To evaluate the accuracy of the proposed actuarial reserve formula relative to the JPA formula, the Root Mean Square Error (RMSE) was employed. RMSE is a widely used statistical measure that quantifies the average magnitude of error between predicted and actual values. It indicates, on average, the extent to which model predictions deviate from the true observations. Equation (7) presents the formula for RMSE.

$$RMSE = \sqrt{\frac{1}{5000}\sum_{i=1}^{5000}(y_i - y_i)^2} \quad (7)$$

In equation (6), y_i denotes the predicted amount of cash award and y_i represents the actual cash award.

III. RESULTS AND DISCUSSION

A. Data Description

This study used simulated data of two public universities in Malaysia from 2024. The dataset consisted of a total of 8,692 records, including gender, date of birth (DOB), retirement date, current salary, fixed allowance, accumulated annual leave (GCR), eligibility for early withdrawal of cash awards arightnd duration (in days) applicable for early cash awards.

In terms of gender composition, 4,593 participants (52.9%) were male, while 4,099 participants (47.1%) were female, indicating a relatively balanced distribution.

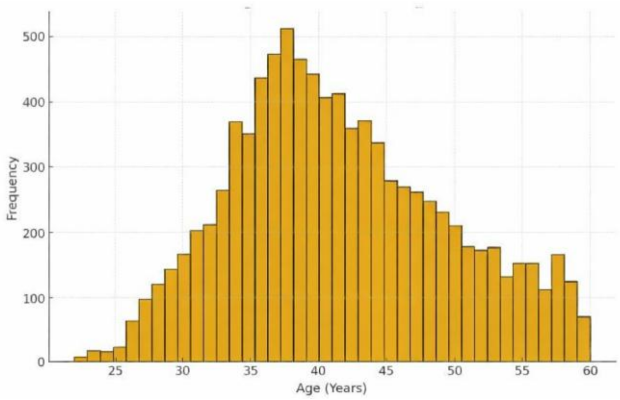

Figure 1. Distribution of age

With respect to age, the respondents ranged between 22 and 60 years. Figure 1 above illustrates the distribution of age. The age distribution approximated a normal curve, with the majority of individuals concentrated around the mean age of 41.6 years, and fewer cases observed at the extreme younger and older ends. This suggests that the majority of individuals in the dataset were in their mid-career stages.

The analysis of basic salary as of 31 December 2024 showed considerable variation, with the minimum salary recorded at RM1,204.00 and the maximum at RM30,583.38. The average basic salary was RM5,402.44, reflecting moderate income levels across the sample. Figure 2 presents the distribution of basic salary. From this graph, we can see that the graph is positive skew (right-skewed), which is very common in salary distributions. This means that most salaries are clustered at the lower-to-middle range, while a smaller number of individuals earn much higher salaries.

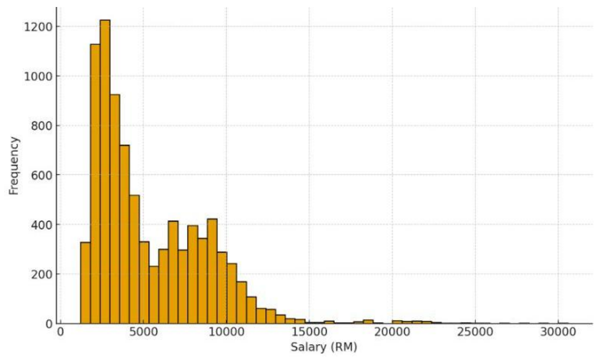

Figure 2. Distribution of basic salary

The fixed allowance also displayed substantial variation, ranging from RM325.00 to RM10,500.00, with an average of RM853.65. Furthermore, the accumulated GCR as of 31 December 2024 ranged from 0 to 293 days, with an average of 63.8 days. Around 7.36% of the total servants had been granted the early cash withdrawal.

B. Assumptions

In calculating the actuarial reserve, we assign a present value to liabilities that may materialise many years in the future. Hence, it is essential to formulate assumptions on anticipated future experiences, including the interest rate and projected death rate. The interest rate is essentially the investment return on the assets. This should be advised by the employer. However, as we were informed by the employers, there is no investment so far, and thus, the interest rate can be replaced by the Malaysian inflation rate of 1.8% [18].

As for the mortality assumption, we utilised the probability of death extracted from the Abridged Life Table (ALT) 2024 published by the Department of Statistics, Malaysia. As the table closes off at age 80, we assume that everyone dies at this age. These abridged rates were then interpolated linearly to estimate the single age mortality rates. We also assume that each employee is not only independent from other employees but also from their spouses. From these rates, we also calculate the survival rates p_x, the deferred mortality rates ${}_{n|}q_x$ and the Assurance factor $A_{x:n}$.

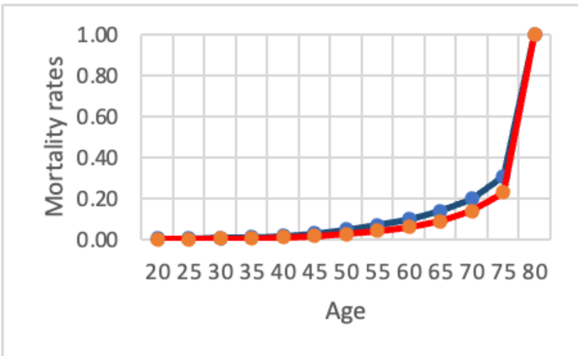

Figure 3. Probability of death q_x from age 20 until 80

Figure 3 illustrates the age-specific probability of death q_x across a lifespan from 20 to 80 years. We plotted the graph starting from the age of 20, as the youngest employee is 21 years old. The red curve represents the female mortality rate, whereas the blue curve represents the male mortality rate. Both male and female curves exhibit a relatively stable and low mortality rate from age 20 to approximately age 50. After age 50, a gradual increase in mortality is observed, with a pronounced escalation beginning around age 70. By age 80, the female curve approaches a mortality rate of 1.00, indicating near certainty of death, while the male curve remains slightly below this threshold. As has been stated before, the abridged life table ended at age 80, and that is why the probability of death spikes at age 80.

This pattern is highly relevant to the current structures of payment of GCR cash awards. Since mortality risk increases significantly after age 60, especially after age 70, it is financially prudent for the government to encourage earlier leave encashment at a fixed age threshold to avoid large lump-sum payments in cases of life death. This policy has already been implemented by the Malaysian government, which permits early cash withdrawal in lieu of accumulated leave (GCR).

Secondly, the mortality curve in Figure 3 helps in actuarial forecasting of expected payouts. For example, if a significant portion of public servants retire between the ages of 55 and age 60, and mortality risk rises considerably thereafter, the government can estimate the likelihood and timing of death-related encashment of GCR cash award. As previously noted, the cash award in lieu of accumulated leave (GCR) becomes payable in the event of an employee's death. Hence, the mortality rate is a crucial factor in estimating the GCR cash award.

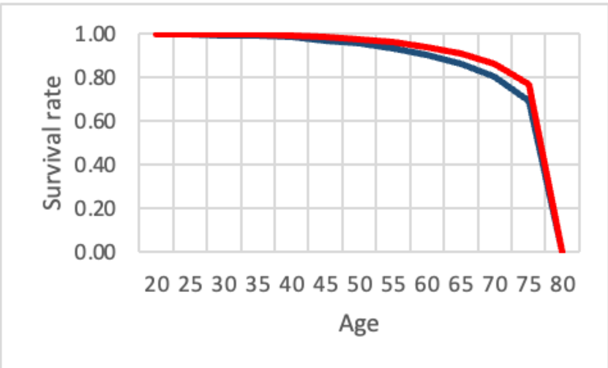

Figure 4. Probability of survival p_x from age 20 until 80

Figure 4 illustrates the probability of survival, or survival rate. Similar to Figure 4, the red line represents the female rate, whereas the blue line represents the male rate. Conceptually, it is the complement of the mortality rate, which measures the likelihood of death over the same period. In contrast to the exponential increase observed in Figure 3, Figure 4 displays a logarithmic decline. The survival curve indicates that a significant proportion of individuals survive well into their retirement age, with a sharp decline only after age 75. This implies that the reserve for cash payments in lieu of accumulated leave must be sufficient to support retirees, especially since most public servants opted to retire at around age 60.

C. Simulation study

A non-parametric bootstrap was applied to evaluate bias and consistency in the proposed model. Simulated samples were repeatedly drawn, and the model was applied to each to compute new cash awards. Resampling was performed for various iterations (R = 100, 1,000, 10,000, 100,000). If the bootstrap estimates, θ_b^* vary between the model estimates θ, this indicates that the proposed model does not appropriately reflect the correct amount of cash awards. Hence, as the number of *R* increases, bootstrap estimates of bias should decrease, which means that the bootstrap estimates are getting closer to the actual value.

TABLE III. BIAS AND VARIANCE FOR EACH BOOTSTRAP ITERATIONS

Bootstrap Iterations (R)	Bias	Variance
100	0.043	0.012
1,000	0.016	0.011
10,000	0.014	0.011
100,000	0.014	0.009

Table III clearly illustrates a downward trend in both bias and variance as the number of iterations increases. At R= 100, the bias is relatively large (0.043), and the variance is 0.012, reflecting the instability of the estimator when the bootstrap distribution is based on limited replications. However, once the number of iterations is increased to R = 1,000, the bias drops considerably to 0.016 while the variance remains relatively stable at 0.011. With further increments to R = 10,000 and R = 100,000, bias is further reduced to 0.014, and variance decreases slightly to 0.009.

These results indicate several important findings. First, the reduction in bias as the number of bootstrap iterations increases demonstrates that the estimator converges toward the true value, highlighting the consistency of the actuarial model. Second, the stability of variance across higher iterations reflects the robustness of the model, as variability in the estimates diminishes when sufficient resampling is performed. Third, the convergence of both bias and variance to small, stable values suggests that the proposed actuarial reserve model provides a reliable and accurate measure of the financial liability for accumulated leave benefits when applied to large datasets or sufficiently resampled bootstrap replications.

D. Error Measurement

This study employed the Root Mean Square Error (RMSE) as a measure of model error and predictive accuracy for cash awards in lieu of accumulated leave (GCR). A smaller RMSE value indicates superior model performance. As shown in Table IV, the actuarial reserve formula achieved a lower RMSE (0.029) compared to the JPA formula (0.084). This finding demonstrates that the actuarial reserve approach yields more accurate estimates of future GCR cash awards.

TABLE IV. ROOT MEAN SQUARE ERROR (RMSE)

RMSE	
JPA	0.084
Actuarial Reserve	0.029

III. CONCLUSION

This study introduced and validated an enhanced actuarial reserve model for valuing the Cash Award in Lieu of Accumulated Leave (GCR) benefit in Malaysia. Traditional approaches, such as those employed by the Jabatan Perkhidmatan Awam (JPA), typically calculate cash awards based only on the last drawn salary, fixed allowance, and accumulated leaves without incorporating mortality or economic risks. By contrast, the proposed model accounts for two mutually exclusive contingencies, retirement and death, using present value factors and assurance factors, thereby providing a more realistic and comprehensive valuation framework.

Through the application of non-parametric bootstrap resampling, the model's statistical properties were carefully examined. The findings revealed that as the number of bootstrap resamples increased, both bias and variance of the estimates decreased, confirming the consistency and reliability of the model. In particular, results at higher iterations demonstrated that the proposed actuarial reserve model produces estimates of accumulated leave benefits that closely approximate true values, reducing systematic error and improving predictive accuracy.

Furthermore, the accuracy test using the Root Mean Square Error (RMSE) proved that the actuarial reserve significantly improved the calculation of future cash award in lieu of accumulated leaves.

The implications of these findings are significant for financial management in higher education institutions and other public-sector organisations. By providing more accurate estimates of future liabilities, the model supports more prudent budgeting and resource allocation, reducing the likelihood of unforeseen financial shortfalls.

Additionally, the incorporation of mortality and interest rate assumptions aligns the model more closely with actuarial best practices and international reporting standards such as MPERS (Malaysian Private Entities Reporting Standard).

Nonetheless, this study also highlights several avenues for future research. First, while the model incorporates mortality and interest rate assumptions, it does not explicitly account for salary progression, inflation beyond a fixed rate, or employee turnover, all of which could influence the magnitude of future liabilities. Incorporating dynamic salary growth models, stochastic interest rate processes, or employee attrition probabilities would enhance the model's realism.

Secondly, the use of machine learning algorithms could provide a data-driven means of capturing complex interactions among demographic and economic factors, thereby improving predictive performance.

Lastly, the model was tested on simulated datasets; future work could extend the analysis to real-world administrative data from multiple institutions to further validate generalisability.

In conclusion, this study demonstrates that the proposed actuarial reserve model offers a significant improvement over existing methods by incorporating uncertainty into the valuation of employee benefits. The bootstrap analysis confirms the model's robustness, with decreasing bias and variance across larger resampling iterations. By supporting more informed fiscal planning, this approach not only enhances financial sustainability but also contributes to the broader goal of ensuring fair and timely compensation for employees in the Malaysian public sector.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

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REFERENCES

[1] Ministry of Finance (MOF). "Anggaran PerbelanjaanPersekutuan 2022". 2021. [Online]. Available: https://belanjawan.mof.gov.my/pdf/2022/perbelanjaan/Anggaran_Perbelanjaan_Persekutuan_2022.pdf. Accessed 2026.

[2] A. Gabrielli, R. Richman, and M. V. Wüthrich, "Neural network embedding of the over-dispersed Poisson reserving model," *Scandinavian Actuarial Journal*, vol. 2020, no. 1, pp. 1–29, 2020.

[3] Jabatan Perkhidmatan Awam (JPA). "Pekeliling Perkhidmatan Bilangan 1 Tahun 2024: Pelaksanaan Sistem Saraan Perkhidmatan Awam Bagi Pegawai Perkhidmatan Awam Persekutuan". 2024. [Online]. Available: https://docs.jpa.gov.my/docs/sspa/PP_SSPA_INDUK_COMBINED.pdf. Accessed: 2026.

[4] Jabatan Perkhidmatan Awam. "Kiraan Anggaran Award GCR". [Online]. Available: https://award-gcr.jpa.gov.my/calculator. Accessed: 2026.

[5] Z. Chen and Y. Huang, "Adapting NPV for complex and irregular cash flow streams," *Journal of Financial Modeling*, vol. 24, no. 2, pp. 345–366, 2019.

[6] F. Adams and M. Lee, "The challenges of selecting the right discount rate for NPV analysis," *Financial Economics Journal*, vol. 41, no. 3, pp. 1098–1114, 2022.

[7] J. B. Harrison and J. Knight, "Sensitivity analysis and its application in project valuation," *Financial Management Review*, vol. 34, no. 2, pp. 212–230, 2020.

[8] I. Sahin and O. Altay, "Challenges of stochastic models in financial forecasting: Assessing the limitations in cash flow projections," *Journal of Financial Modeling and Analysis*, vol. 18, no. 4, pp. 233–249, 2021.

[9] L. Mendes and R. Santos, "Challenges in using historical data for stochastic modeling in cash flow forecasting," *Financial Risk Management Review*, vol. 29, no. 2, pp. 101–115, 2021.

[10] L. Kornish and R. Kellogg, "The impact of changing discount rates on project evaluation: A case for dynamic discounting," *Journal of Financial and Quantitative Analysis*, vol. 56, no. 4, pp. 1265–1289, 2021.

[11] D. Giles and A. Turner, "Forecasting cash flows: The cumulative effect of small errors in NPV," *Financial Analysis Review*, vol. 52, no. 1, pp. 89–104, 2019.
[12] J. E. Michaels and K. Shaw, "Modernizing actuarial models: Addressing the weaknesses of traditional pension valuations," *International Journal of Actuarial Science*, vol. 19, no. 1, pp. 45–61, 2022.
[13] B. Blaylock and R. Spence, "Flexible project life: A more dynamic approach to discounted cash flow valuation," *Journal of Project Finance*, vol. 29, no. 1, pp. 72–90, 2023.
[14] L. Gomes and J. Silva, "Incorporating uncertainty into the NPV model: An application to real options," *International Journal of Financial Economics*, vol. 27, no. 1, pp. 101–119, 2020.
[15] F. Gomez and M. Pereira, "Computational challenges in stochastic modeling: Implications for forecasting future cash flows," *International Journal of Computational Finance*, vol. 22, no. 1, pp. 34–48, 2023.
[16] J. Chung and S. Lee, "Modeling financial risk: Sensitivity of stochastic models to assumptions and parameters," *Journal of Financial Engineering*, vol. 14, no. 3, pp. 75–89, 2020.
[17] H. Wang and S. Lin, "Overfitting and calibration challenges in stochastic financial models," *Journal of Quantitative Finance*, vol. 18, no. 2, pp. 89–104, 2021.
[18] J. Martinez and S. Rivera, "Long-term forecasting and the limitations of NPV in uncertain environments," *Journal of Financial Risk Management*, vol. 18, no. 4, pp. 301–321, 2021.
[19] R. Patel and Y. Zhang, "Addressing tail risks in stochastic models for future cash flow forecasting," *Journal of Financial Forecasting*, vol. 20, no. 3, pp. 124–139, 2022.
[20] S. Vitali and A. Garcés, "Integrating non-financial factors into investment decisions: A multi-criteria decision analysis approach," *International Journal of Financial Studies*, vol. 10, no. 3, pp. 45–61, 2022.
[21] Jabatan Perkhidmatan Awam (JPA). "Penambahbaikan Pemberian Award Wang Tunai Gantian Cuti Rehat (GCR) Dan Penambahbaikan Pemberian Awal Award Wang Tunai GCR".2023, [Online]. Available: https://docs.jpa.gov.my/docs/se/2023/se12052023.pdf. Accessed 2026.
[22] Ministry of Finance (MOF). "Anggaran Perbelanjaan Persekutuan 2025". 2024. [Online]. Available: https://belanjawan.mof.gov.my/pdf/belanjawan2025/perbelanjaan/Anggaran_Perbelanjaan_Persekutuan_2025.pdf. Accessed 2026.
[23] M. Lindholm, "A collective reserving model with claim openness," *ASTIN Bulletin: The Journal of the IAA*, vol. 52, no. 1, pp. 177–203, 2022.
[24] R. Josa-Fombellida, M. Lahiani, and J. Navarro, "A defined benefit pension plan model with stochastic salary and heterogeneous discounting," *ASTIN Bulletin: The Journal of the IAA*, vol. 53, no. 1, pp. 1–33, 2023.
[25] G. Gao, P. Shi, and M. V. Wüthrich, "Dispersion modelling of outstanding claims with double chain ladder," *Insurance: Mathematics and Economics*, vol. 99, pp. 160–176, 2021.
[26] R. Salato, P. Gomes, and C. Ferreira, "Accrual accounting in the public sector of emerging economies: Bibliometric analysis and future research," *Public Money & Management*, vol. 44, no. 5, pp. 376–388, 2024.
[27] Y. Huang, Z. Qian, and H. Yang, "Valuing guaranteed minimum accumulation benefits by a tree-based method," *Insurance: Mathematics and Economics*, vol. 104, pp. 40–56, 2022.
[28] A. Chen, Y. Chen, and M. Rach, "Dynamic tonuity: Adapting retirement benefits to a changing environment," *ASTIN Bulletin: The Journal of the IAA*, vol. 55, no. 2, pp. 352–373, 2025.