



## Comparative Analysis of Four Actuarial Cost Methods on Unfunded Actuarial Liability in a Pekanbaru Pension Scheme

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### ABSTRACT

Unfunded Actuarial Liability (UAL) is an important indicator in assessing the sustainability of a pension fund program, as it reflects the difference between actuarial liabilities and available assets. This study aims to compare the amount of UAL generated by four pension funding methods, namely Accrued Benefit Cost (ABC), Entry Age Normal (EAN), Unit Credit (UC), and Aggregate Cost Method (AGG). A quantitative actuarial valuation is conducted using administrative data from active civil servants of PT. TASPEN (Persero) Pekanbaru Branch Office in 2025 under uniform actuarial assumptions, including the TASPEN mortality table, interest rates, and salary growth rates. A deterministic sensitivity analysis on the discount rate and salary growth rate was conducted to examine the robustness of unfunded actuarial liability estimates. The results show that the ABC, UC, and EAN methods produce identical aggregate UAL values of approximately Rp. 16.841.220.000, - while the Aggregate Cost Method yields a higher UAL of about Rp.22.173.660.000, - due to collective liability recognition. Furthermore, the EAN and AGG methods exhibit relatively more stable contribution patterns over participants' service periods, whereas the ABC and UC methods are more sensitive to variations in participants' age and length of service. These findings indicate that the selection of actuarial cost methods has significant practical implications for pension fund management, particularly in terms of funding stability, contribution planning, and long-term sustainability of pension schemes.

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## 1. INTRODUCTION

The financial sustainability of defined benefit (DB) pension programs has become a critical concern worldwide, as aging populations, longer life expectancies, and economic uncertainties place growing pressure on pension fund solvency and funding adequacy [1]. For pension fund administrators and policymakers, maintaining

long-term solvency requires not only adequate asset accumulation but also careful selection of actuarial methodologies that determine how pension obligations are measured and funded. Defined benefit plans promise retirees predetermined benefit levels typically based on salary and years of service rather than merely returning individual contributions. This creates long-term obligations that must be appropriately valued and funded to ensure that future pension benefits remain secure [2]. A key challenge in managing DB pension schemes lies in properly estimating liabilities and contributions to a task fundamentally shaped by the actuarial cost method employed. An imbalance between pension assets and actuarial liabilities may result in Unfunded Actuarial Liability (UAL), which poses significant financial risks to pension fund administrators. Consequently, the selection of an appropriate actuarial cost method is a crucial aspect of pension fund management and regulatory oversight [3].

In Indonesia, the civil servant pension system is predominantly administered under a defined benefit framework, where benefits are legally guaranteed and financed through a combination of participant contributions and government support. PT TASPEN (Persero) plays a central role in administering pension and old-age benefits for civil servants, making it a representative institutional setting for evaluating actuarial funding practices in the public pension sector.

Actuarial cost methods determine how future pension obligations are allocated across current and future periods, influencing the reported liability levels, annual normal costs contributions, and ultimately the unfunded actuarial liability (UAL) defined as the gap between actuarial liabilities and plan assets. Various actuarial cost methods have been developed and applied in pension valuation, including the Accrued Benefit Cost (ABC), Entry Age Normal (EAN), Unit Credit (UC), and Aggregate Cost Method (AGG). Each method differs in how pension benefits are allocated over participants' working lifetimes, leading to distinct patterns of normal cost, actuarial liability, and ultimately UAL. These differences have direct implications for contribution stability, funding risk, and intergenerational equity, which are central considerations for pension fund managers and policymakers responsible for ensuring sustainable pension financing [4]. Variation in cost methods can lead to materially different liability estimates, with significant implications for funding policy, contribution stability, and intergenerational equity. Indeed, recent research underscores that actuarial assumptions and methodological choices including discount rates, salary growth, and benefit accrual basis shape the reported financial health of pension plans [5].

For instance, the choice of discount rates, often determined by regulatory accounting standards such as IAS 19 [6] or SFAS 158 [7], can substantially affect the present value of pension obligations. Prior studies suggest that underfunded plans may have incentives to adopt assumptions that reduce reported liabilities [8]. Meanwhile, empirical studies have linked underfunded pension obligations to corporate financing risks and valuation consequences in financial markets, particularly in public companies sponsoring large DB plans [9].

Despite the importance of methodological choices, much of the existing literature has focused on broad actuarial assumptions (discount rate, mortality, salary growth) and regulatory disclosures, rather than systematically comparing the effects of different actuarial cost methods on liability estimates and funding stability within a DB pension context. Recent empirical and simulation-based studies within Indonesia for example, comparisons between cost methods such as Entry Age Normal (EAN), Attained Age Normal (AAN), or Individual Level Premium (ILP) demonstrate meaningful differences in liability values and funding patterns across methods [10]. However, these studies often remain limited to a narrow set of methods or do not simultaneously consider a comprehensive suite of widely recognized cost methods (e.g. including Accrued Benefit or Unit Credit, Aggregate Cost).

Thus, a clear research gap persists there is limited literature that directly compares multiple actuarial cost methods including both individual-benefit-based and collective funding approaches within a single DB pension scheme simulation, assessing how each method affects the present value of future benefits, normal cost, actuarial liability, and unfunded liability over time under identical demographic and salary assumptions. Addressing this gap is critical because selecting an inappropriate method may lead to misleading liability measures, unpredictable contribution paths, and potential underfunding undermining the long-term viability of pension schemes [11]. Although this study is conducted using administrative data from PT TASPEN (Persero), the analytical framework and findings are broadly applicable to other defined benefit pension schemes, particularly public-sector pension systems facing similar demographic pressures, contribution constraints, and funding sustainability challenges.

The present study seeks to fill this gap by conducting a systematic quantitative comparison of four actuarial cost methods Accrued Benefit Cost (ABC), Entry Age Normal (EAN), Unit Credit (UC), and Aggregate Cost Method (AGG) calculated consistently based on actual participant data and the latest TASPEN mortality table within a defined benefit pension program [12]. By applying identical demographic and salary input data, we examine how each method influences the present value of future pension benefits, normal cost, actuarial liability, and unfunded actuarial liability [13]. This approach provides evidence that is directly relevant for pension fund administrators and policymakers in evaluating funding strategies and actuarial practices [14].

Unlike previous studies that typically compare only one or two actuarial cost methods, this research integrates individual based and aggregate based approaches within a single analytical framework and incorporates sensitivity analysis on discount rate and salary growth assumptions. The objective of this study is to assess the impact of four actuarial cost methods on unfunded actuarial liability in a defined benefit pension program and to compare the relative funding stability characteristics across methods.

## 2. RESEARCH METHOD

This research adopted a quantitative actuarial modelling approach to compare the estimation of actuarial liability and unfunded actuarial liability under four actuarial cost methods, Accrued Benefit Cost (ABC), Entry Age Normal (EAN), Unit Credit (UC), and the Aggregate Cost Method (AGG). The analysis was conducted within a single defined benefit pension scheme using a consistent set of demographic and economic assumptions to isolate the effects of actuarial cost method selection. A deterministic valuation framework was employed, complemented by sensitivity analysis on key actuarial parameters, particularly the discount rate and salary growth assumptions, to examine their influence on unfunded actuarial liability. This approach enables a structured comparison of liability allocation patterns and funding outcomes across methods, while recognizing that stochastic modelling and broader scenario analysis are beyond the scope of this study and remain important directions for future research [2], [8].

### 2.1 Data and Actuarial Assumptions

This study employs a quantitative actuarial valuation using administrative data from active male civil servant participants enrolled in PT TASPEN (Persero), Pekanbaru Branch Office, for the year 2025. The dataset consists of 670 active participants who were included based on the criteria for being actively employed and registered in the defined benefit pension scheme during the valuation year. Retirees, deferred members, and female participants were excluded to maintain a homogeneous participant group and ensure consistency in the actuarial valuation framework.

The exclusion of female participants is primarily motivated by differences in retirement age, benefit eligibility rules, and mortality patterns between male and female civil servants, which would require separate actuarial assumptions and could obscure the comparative effects of actuarial cost methods. By restricting the sample to male participants, this study aims to isolate methodological differences while minimizing demographic heterogeneity.

The variables analyzed include date of birth, date of employment commencement, age at entry into the pension scheme, current basic salary, rank, and length of service. Salary values are recorded in Indonesian Rupiah (IDR), and ages are measured in completed years. Prior to analysis, the administrative records were reviewed for completeness and internal consistency, including checks for missing values, implausible age-service combinations, and logical consistency between dates of birth and employment history.

All actuarial computations were implemented using Microsoft Excel. To enhance reliability and reproducibility, the valuation worksheets were structured with consistent formula references, internal cross-checks of key actuarial quantities, and reconciliation of aggregate results across actuarial cost methods to reduce the risk of undetected computational errors. While individual-level actuarial liabilities were calculated internally, the study reports aggregate results to emphasize comparative funding patterns across methods; detailed participant-level breakdowns and computational worksheets provided upon request to support reproducibility.

The actuarial assumptions were applied uniformly across all funding methods to isolate the effect of actuarial cost method selection. The assumptions include an annual interest rate of 6%, a salary growth rate of 4%, a normal retirement age of 58 years, and a benefit accrual rate of 2.5% per year of service. Pension benefits are assumed to be paid in the form of a monthly life annuity, and mortality is modelled using the TASPEN Mortality Table for male participants [12]. It is acknowledged that the use of a single institutional dataset, restricted to male participants from one regional branch and a single valuation year, limits the external validity of the findings; therefore, the results should be interpreted as methodological comparisons rather than population-wide estimates.

### 2.2 Pension Benefit Formula

The actuarial valuation followed standard pension funding principles [4]. The annual pension benefit payable at the normal retirement age  $r$  is defined as:

$$B_r = \alpha Y_r S_r \quad (1)$$

where  $Y_r$  denotes total years of service at retirement age  $r$  and  $S_r$  represents the projected final salary at retirement age  $r$ , and  $\alpha$  is the benefit accrual rate [15].

The present value of future benefits (PVFB) at valuation age  $x$  is given by [16]:

$$PVFB_x = B_r v^{(r-x)} {}_{r-x}p_x \ddot{a}_r^{(12)} \quad (2)$$

Where  $v = (1 + i)^{-1}$  is the annual discount factor,  ${}_{r-x}p_x = \frac{l_r}{l_x}$  denotes the probability that a participant aged  $x$  survives to retirement age  $r$ , and  $\ddot{a}_r^{(12)}$  represents the present value of a monthly life annuity-due payable from age  $r$ , calculated using the TASPEN Mortality Table for male participants.

### 2.3 Accrued Benefit Cost (ABC)

Under the Accrued Benefit Cost method, actuarial liability at age  $x$  is calculated proportionally to the service already rendered:

$$AL_x^{ABC} = PVFB \times \frac{Y_x}{Y_r} \quad (3)$$

where  $Y_x$  is years of service at valuation age [17].

### 2.4 Unit Credit (UC) Method

The Unit Credit method recognizes actuarial liability based on benefit units accrued up to age  $x$ . In aggregate form, the actuarial liability is expressed as:

$$AL_x^{UC} = PVFB \times \frac{Y_x}{Y_r} \quad (4)$$

Although the actuarial liability is numerically similar to the ABC method, the normal cost pattern differs across ages [17].

### 2.5 Entry Age Normal (EAN)

The Entry Age Normal method determines a level normal cost payable from entry age  $e$  until retirement age  $r$ . The actuarial liability at valuation age  $x$  is defined as:

$$AL_x^{EAN} = PVFB_x - PVNC_x \quad (5)$$

where  $PVNC_x$  denotes the present value of future normal contributions [18].

### 2.6 Aggregate Cost Method

Under the Aggregate Cost Method, actuarial liability is calculated on a collective basis as:

$$AL^{Agg} = \sum PVFB - \sum A \quad (6)$$

where  $A$  denotes the actuarial value of assets. In the absence of asset data, actuarial liability equals the total unfunded actuarial liability [19]. Under the Aggregate Cost Method, the reported actuarial liability represents the collective allocation of the present value of future benefits under a zero-asset benchmark and is presented solely for comparative analytical purposes rather than as an individual accrued liability measure.

### 2.7 Unfunded Actuarial Liability (UAL)

Unfunded Actuarial Liability (UAL) is defined as the difference between total actuarial liabilities and accumulated funds available at the valuation date [8]. Based on the present value of future benefits (PVFB), the Actuarial Liability (AL) and Normal Cost (NC) are determined according to the allocation rules of each actuarial cost method [20]. The unfunded actuarial liability is calculated as follows:

$$UAL_x = TAL_x - F_x \quad (7)$$

$$TAL_x = \sum_{i=1}^N AL_{x,i} \quad (8)$$

$$UAL_x = TAL_x - F_x \quad (9)$$

where  $UAL_x$  denotes the unfunded actuarial liability at valuation age  $x$ ,  $TAL_x$  represents the total actuarial liability aggregated over all  $N$  participants, and  $F_x$  is the accumulated fund or available asset value at the valuation date.

For comparison purposes, the asset value is assumed to be zero to construct a controlled analytical setting that isolates differences arising solely from actuarial cost method allocation rules [21]. This zero-asset assumption is explicitly adopted as a methodological benchmark and does not aim to represent real-world funding conditions; rather, it allows a transparent comparison of how different actuarial cost methods allocate the present value of future benefits into actuarial liability and normal cost under identical assumptions. Consequently, the resulting unfunded actuarial liability values should be interpreted as relative indicators of liability recognition patterns across methods, not as measures of actual funding adequacy or solvency.

Under this analytical framework, the present value of future benefits is allocated according to the characteristics of each method under the Accrued Benefit Cost (ABC) method, liabilities increase proportionally with completed service; under the Unit Credit (UC) method, liabilities accrue uniformly per year of service; under the Entry Age Normal (EAN) method, costs are levelled from entry age to retirement, generating relatively

stable contribution patterns; and under the Aggregate Cost method (AGG), total PVFB is allocated collectively across participants without computing individual liabilities [22]. All actuarial computations are implemented using Microsoft Excel.

### 3. RESULT AND ANALYSIS

This section presents the findings of the actuarial valuation conducted under four different pension cost methods: Accrued Benefit Cost (ABC), Unit Credit (UC), Entry Age Normal (EAN), and Aggregate Cost (AGG). The results include the present value of future pension benefits (PVFB), actuarial liability (AL), normal cost (NC), and unfunded actuarial liability (UAL). Quantitative outcomes are summarized to evaluate funding characteristics and liability progression produced by each method. It should be emphasized that the zero-asset assumption is adopted as an analytical benchmark to isolate differences in actuarial liability allocation across methods. Consequently, the reported UAL values reflect methodological contrasts in liability recognition rather than funding dynamics under realistic asset accumulation paths. From a practical perspective, these comparative results provide insight into how different actuarial cost methods may influence contribution stability, funding volatility, and long-term planning decisions faced by pension fund administrators. The analysis also interprets the implications of the valuation patterns in relation to pension funding management.

#### 3.1 Computation Table

The commutation table is used to calculate the present value of annuities and insurance benefits that will be paid in the future. To construct a commutation table, a mortality table can be used, which contains  $x$  (age),  $S_x$  (the present value of a life insurance payment of 1 unit to be paid upon the death of a person aged  $x$ ),  $l_x$  (the number of individuals alive at age  $x$ ),  $d_x$  (the number of individuals who die at age  $x$ ),  $V^x$  (the discount factor at age  $x$ ),  $D_x$  (the present value at age zero of the number of people alive at that age ( $l_0$ ) who will survive to age  $x$  and pay 1 rupiah exactly on their birthday),  $N_x$  (the present value at age zero of the number of people alive at that age ( $l_0$ ) who will survive to age  $x$  and continuously pay 1 rupiah on each birthday until they die). The commutation functions derived in Table 1 are used to compute the annuity due in Equation (2) for the valuation of future pension benefits. The assumptions used to construct the mortality table are an initial number of participants of 100,000 and an interest rate of 6%.

**Table 1.** Commutation Table

Age(x)	$S_x$	$l_x$	$d_x$	$V^x$	$D_x$	$N_x$
0	1,00000	100000	421	1	100000	1500598
1	0,99579	99579	43	0,93457	93064	1400598
2	0,99536	99536	33	0,87344	86939	1307534
3	0,99503	99503	27	0,81629	81224	1220595
4	0,99476	99476	24	0,76289	75224	1139371
⋮	⋮	⋮	⋮	⋮	⋮	⋮
109	0,00012	12	5	0,00063	0	0
110	0,00007	7	3	0,00058	0	0
111	0,00004	4	4	0,00055	0	0

#### 3.2 Actuarial Liability and Unfunded Actuarial Liability

The results of actuarial valuation for the four pension funding methods are summarized in Table 2. This table presents the total actuarial liability and the corresponding unfunded actuarial liability calculated using consistent actuarial assumptions and identical participant data. Since information on pension fund assets is not available in this study, the unfunded actuarial liability is defined as equal to the total actuarial liability for each method. The comparison in Table 2 highlights the differences in liability recognition patterns across the Accrued Benefit Cost (ABC), Unit Credit (UC), Entry Age Normal (EAN), and Aggregate Cost methods (AGG).

**Table 2.** Summary of Total Actuarial Liability and UAL for Valuation Year 2025

No	Funding Method	Total Actuarial Liability (Rp)	Unfunded Actuarial Liability (Rp)
1	Accrued Benefit Cost (ABC)	16.841.220.000	16.841.220.000
2	Unit Credit (UC)	16.841.220.000	16.841.220.000
3	Entry Age Normal (EAN)	16.841.220.000	16.841.220.000
4	Aggregate Cost Method	22.173.660.000	22.173.660.000

The calculation results show that the amount of Actuarial Liability and Unfunded Actuarial Liability is significantly influenced by the funding method used. The Accrued Benefit Cost and Unit Credit methods yielded a UAL value of Rp.16.841.220.000, - This is due to the approach of both methods, which recognize liabilities proportionally to the participant's length of service up to the valuation year.

The Entry Age Normal (EAN) method yields the same aggregate UAL value, but with different liability allocation characteristics. This method spreads the liability burden more evenly throughout the participant's service period through relatively constant normal contributions from the start of employment. This makes the Entry Age Normal (EAN) method more stable in long-term funding planning. Conversely, the Aggregate Cost Method (AGG) yielded the highest UAL value, at Rp.22.173.660.000,-. This is due to the collective recognition of liabilities for all future pension benefits without distinguishing between individual participant liabilities. Consequently, this method tends to produce a larger liability estimate than the individual method. These findings suggest that while accrued-based methods may better reflect service-related obligations, level-cost and aggregate approaches may be preferred by pension fund managers seeking smoother contribution paths and reduced short-term funding volatility.

The Unfunded Actuarial Liability (UAL) values are obtained directly from the actuarial liability estimates summarized in Table 2. Due to the unavailability of pension fund asset data in this study, UAL is defined as equal to the total actuarial liability for each actuarial cost method. The results indicate that all methods produce positive UAL values, implying the presence of funding shortfalls. However, the magnitude of UAL differs across methods. The Accrued Benefit Cost and Unit Credit methods yield UAL values that are more sensitive to the age distribution and service length of participants, as liabilities are primarily driven by accrued benefits. In contrast, the Entry Age Normal (EAN) and Aggregate Cost methods (AGG) produce relatively more stable UAL estimates due to the spreading of costs over the entire service period and collective recognition of benefits. Although individual-level actuarial liabilities by age are not explicitly tabulated, the aggregate actuarial liability results reported in Table 2 reflect the cumulative effect of individual liability calculations across participants.

To further elucidate the differences among the four actuarial cost methods, Table 3 presents a comparative summary of their key characteristics, including the basis of liability recognition, contribution stability, and sensitivity to participants' age and service profiles. This comparison facilitates a clearer interpretation of the numerical results reported in Table 2 and provides practical insights into the implications of method selection for pension fund funding strategies.

**Table 3.** Comparative Characteristics of Four UAL Methods

No	Funding Method	Basis for Recognition of Liabilities	Contribution Stability	Age Sensitivity
1	Accrued Benefit Cost (ABC)	Accrued benefits	Low	High
2	Unit Credit (UC)	Annual benefit unit	Low	High
3	Entry Age Normal (EAN)	Level contributions from entry age	High	Low
4	Aggregate Cost Method	Collective of all participants	Very high	Very low

The differences in UAL results indicate that no single funding method is superior across the board. The ABC and UC methods better reflect actual liabilities based on years of service but result in sharply increased contributions as retirement approaches. The Entry Age Normal (EAN) and Aggregate Cost method (AGG) exhibit relatively greater contribution stability compared to accrued based methods within the analytical setting of this study. From an academic standpoint, these results reinforce existing actuarial literature that highlights the trade-off between accuracy in accrued liability recognition and contribution smoothing objectives in defined benefit pension valuation.

### 3.3 Analysis Sensitivity

To assess the robustness of unfunded actuarial liability estimates under alternative actuarial assumptions, a deterministic sensitivity analysis was conducted to changes in the discount interest rate ( $i$ ) and salary increase rate ( $s$ ) assumptions. This analysis is important because these two assumptions are the main factors influencing the present value of pension liabilities.

The sensitivity analysis was conducted by varying the discount interest rate by  $\pm 1\%$  from the baseline assumption,  $i = 6\%$  (baseline), using scenarios  $i = 5\%$  and  $s = 7\%$ . The analysis showed that a decrease in the interest rate led to an increase in the UAL for all funding methods, while an increase in the interest rate decreased the UAL. This occurs because a lower interest rate increases the present value of pension benefits to be paid in the future. The Accrued Benefit Cost and Unit Credit methods showed higher sensitivity to interest rate changes than the Entry Age Normal and Aggregate Cost methods, due to the more concentrated recognition of liabilities on accrued benefits. This differential sensitivity highlights an important trade-off between the accuracy of accrued liability measurement and contribution stability, as methods that closely track accrued benefits tend to be more exposed to valuation volatility arising from interest rate fluctuations.

Furthermore, sensitivity to salary increase rates was analyzed by varying the assumption  $s$  by  $\pm 1\%$  from the baseline assumption of  $s = 4\%$  (baseline), using scenarios  $i = 3\%$  and  $s = 5\%$ . The results show that increasing the salary increase rate significantly increases the UAL across all methods, particularly the Entry Age Normal and Aggregate Cost methods. This is due to the increase in the projected final salary, which forms the basis for calculating pension benefits. In contrast, the ABC and UC methods respond relatively more moderately to changes in  $s$  because the recognized benefits are more focused on the length of service. From an intergenerational perspective, methods that allocate costs more evenly over participants' working lifetimes, such as EAN and AGG, implicitly promote contribution smoothing across cohorts, whereas accrued-based methods may shift funding burdens toward later service periods or future generations when assumptions change.

Despite providing a consistent comparison across four actuarial cost methods, this study is subject to several limitations that should be acknowledged. First, the analysis adopts a zero-asset assumption as an analytical benchmark, which isolates the effects of actuarial cost allocation but does not reflect realistic funding dynamics involving asset accumulation and investment returns. Second, the dataset is restricted to active male civil servant participants from a single regional branch, which limits the external validity and generalizability of the results to broader pension populations with heterogeneous demographic characteristics. In addition, the valuation framework is deterministic and does not capture uncertainty in key actuarial assumptions such as interest rates, salary growth, or longevity improvements.

Future research may extend this framework by formally quantifying intergenerational equity and incorporating stochastic modeling, such as cohort-specific present value of contributions relative to benefits, broader participant datasets across regions and genders, asset-liability interactions, and the implications of international accounting standards such as SFAS 158 on actuarial liability recognition and funding assessment.

#### 4. CONCLUSION

The objective of this study is to assess the impact of four actuarial cost methods on unfunded actuarial liability and to evaluate their relative stability under a consistent set of actuarial assumptions. This objective has been addressed through a comparative actuarial valuation framework applied to Accrued Benefit Cost (ABC), Unit Credit (UC), Entry Age Normal (EAN), and the Aggregate Cost Method (AGG) using identical participant data.

The findings demonstrate that actuarial cost methods differ substantially in how pension obligations are recognized and distributed over participants' working lifetimes. Methods based on accrued benefits, such as Accrued Benefit Cost (ABC) and Unit Credit (UC), tend to concentrate liability recognition on past service, making the resulting unfunded actuarial liability more sensitive to participants' age and service profiles. In contrast, methods that allocate costs over the entire service period, such as Entry Age Normal (EAN) and the Aggregate Cost Method (AGG), produce a more even distribution of actuarial obligations, leading to relatively greater stability in unfunded actuarial liability estimates. These differences confirm that the choice of actuarial cost method plays a critical role in shaping the financial profile and funding risk of pension programs.

From a practical perspective, these results provide insights for pension fund managers and policymakers by illustrating the trade-off between accurate recognition of accrued obligations and the desire for contribution stability. While accrued based methods emphasize individual service-related liabilities, level cost, and aggregate approaches support smoother funding patterns. Rather than identifying a universally superior method, the findings suggest that actuarial cost method selection should be aligned with institutional funding objectives, regulatory constraints, and tolerance for contribution volatility.

This study is subject to several limitations. The analysis relies on administrative participant data from a single pension scheme and applies a zero-asset assumption as an analytical benchmark, which restricts the external validity of the findings and does not capture funding dynamics under realistic asset accumulation paths. Accordingly, the conclusions should be interpreted as evidence of relative stability across actuarial cost methods rather than identification of a universally optimal method. Future research may test the robustness of these findings by applying the same comparative framework to multiple regional branches, different pension schemes, or broader demographic compositions, as well as by incorporating asset valuation and stochastic actuarial assumptions. Despite these limitations, the study contributes to the actuarial literature by providing a consistent and transparent comparison of four actuarial cost methods and their implications for unfunded actuarial liability assessment.

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