Journal of Quality Measurement and Analysis *JQMA* 22(SI) 2026, 31-52
e-ISSN: 2600-8602 *http://www.ukm.my/jqma*
https://doi.org/10.17576/jqma.22si.2026.03

ASSESSING THE ADEQUACY OF A DEFINED CONTRIBUTION RETIREMENT PLAN: AN ACTUARIAL ANALYSIS OF INCOME REPLACEMENT RATIOS

(*Menilai Kecukupan Pelan Persaraan Caruman Pencen: Analisis Aktuari Terhadap Nisbah Penggantian Pendapatan*)

AIMI SYAIRAH MD SA'AT, SYAZREEN NIZA SHAIR* & NORAZLIANI MD LAZAM

ABSTRACT

This study proposes a method for estimating optimal contribution rates for a defined contribution (DC) retirement plan by incorporating uncertainties to ensure income adequacy for retirees. The replacement ratio, representing post-retirement income as a proportion of the final salary, serves as the key indicator of adequacy. The study assesses the impacts of interest rates and mortality uncertainties on the replacement ratio, with findings constrained to the specified set of uncertainty indicators under consideration. The Entry Age Normal (EAN) method allocates the present value of future benefits as a level percentage of salary from entry age to retirement, while the actuarial present value framework is used to determine the value of retirement annuity benefits. Using the equivalence principle, the study calculates the annual retirement income and replacement ratio. Results show that while higher interest rates and investment returns increase the replacement ratio, restricting lump-sum withdrawals between 55 and 60 can further enhance income adequacy. The study proposes gender- and age-specific contribution rates to ensure sufficient retirement income. Finally, the study assesses the financial sustainability of retirees using the optimal contribution rates in the context of Malaysia's median annual salary.

Keywords: defined contribution retirement plan; retirement income adequacy; replacement ratio; Entry Age Normal (EAN)

ABSTRAK

Kajian ini mencadangkan satu kaedah untuk menganggarkan kadar caruman optimum bagi pelan persaraan berasaskan sumbangan pasti (defined contribution, DC) dengan mengambil kira ketidaktentuan ekonomi dan demografi bagi menjamin kecukupan pendapatan. Nisbah penggantian, iaitu peratusan pendapatan selepas persaraan berbanding gaji akhir sebelum bersara, digunakan sebagai penunjuk utama kecukupan pendapatan persaraan. Kajian ini menilai kesan ketidaktentuan kadar faedah dan risiko kematian terhadap nisbah penggantian. Kaedah Entry Age Normal (EAN) mengagihkan nilai kini faedah masa hadapan sebagai satu peratusan gaji yang tetap dari umur mula bekerja hingga umur persaraan, manakala pendekatan nilai kini aktuari digunakan untuk menentukan nilai anuiti persaraan. Prinsip kesetaraan digunakan bagi mengira pendapatan tahunan persaraan dan menentukan nisbah penggantian. Dapatan kajian menunjukkan bahawa kadar faedah dan pulangan pelaburan yang lebih tinggi menyumbang meningkatkan nisbah penggantian, manakala sekatan pengeluaran sekaligus antara umur 55 hingga 60 tahun dapat meningkatkan lagi kecukupan pendapatan persaraan. Kajian ini turut mencadangkan kadar caruman yang berbeza mengikut jantina dan umur bagi memastikan pendapatan persaraan yang mencukupi. Kajian ini disimpulkan dengan penilaian kelestarian kewangan pesara berdasarkan kadar caruman optimum dan gaji tahunan median di Malaysia.

Kata kunci: pelan persaraan sumbangan tetap; kecukupan pendapatan persaraan; nisbah penggantian; kaedah Entry Age Normal (EAN)

1. Introduction

Retirement income adequacy is a critical concern for individuals and policymakers, impacting retirees' quality of life and financial security. Defined contribution (DC) pension plans are becoming the global standard for retirement savings due to their flexibility and financial sustainability for employers. However, ensuring income adequacy in retirement requires well-designed contribution rates, effective investment strategies and potential annuitisation to provide lifelong income security. In Malaysia, the mandatory DC plan for formal sector employees has evolved into one of the largest schemes globally (Asher 1999; Caraher 2003; Saidi *et al*. 2017). Under this plan, employees and employers contribute a fixed percentage of their salary into an individual retirement savings account (Agarwal *et al*. 2023). These contributions accrue returns based on an annual dividend rate declared at the end of each calendar year. Nonetheless, the final amount available at retirement is uncertain due to various factors beyond the employee's control, including investment performance and longevity risk.

In Malaysia, the defined contribution (DC) plan is the primary retirement income scheme for private sector employees, managed by the Employees Provident Fund (EPF). Employees contribute 11% of their salary to the fund, while employers contribute either 12% or 13%, depending on whether the salary is below or above RM5,000 per month, up to the age of 60. Employees have the option to withdraw up to 30% from their Account 2 for educational, housing loan and other purposes before the allowable lump sum withdrawal at age 55. As of 2023, the EPF has 16,073,317 members, with 53% active contributors (Employees Provident Fund 2023). Active members are currently contributing to the fund, whereas non-active members have accumulated savings but are no longer part of the workforce or contributing to the fund. The fund recorded RM97.56 billion in annual contributions from employees and employers, along with RM50.57 billion in withdrawals and refunds. Due to the uncertainty surrounding the DC plan at retirement, the adequacy of the retirement benefits provided by the EPF has been a subject of debate. Recently, concerns have been raised about the scheme's ability to deliver sufficient income for a comfortable standard of living in retirement (Caraher 2003). The EPF reported that 70% of Malaysians deplete their retirement savings within ten years of withdrawing at age 55 (The Star 2020). It was also reported that 68% of EPF members aged 54 had savings below RM50,000, which would last only approximately 4.5 years (Jomo 2017; New Straits Times 2026). These statistics highlight the inadequacy of retirement savings and the potential risk of old-age poverty.

Retirement income adequacy, or the standard of living after retirement, can be estimated using the concept of replacement income ratio, which is calculated by dividing the employee's post-retirement income by the pre-retirement income or final salary (Aon 2018). As the ratio is calculated individually, workers in different income groups (B40, M40, T20) are expected to continue in broadly the same relative standard of living after retirement, rather than transitioning across income tiers (Organisation for Economic Co-operation and Development 2023). Some important factors affecting this ratio include salary and salary progress, investment returns and old-age mortality (Heong Lian *et al*. 2000). The replacement ratio is one of the most widely used indicators to determine the adequacy of post-retirement income. Heong Lian *et al*. (2000) analysed the replacement ratio of Singapore's DC plan, the Central Provident Fund (CPF), and found that it depends highly on retirement age and contribution rate. In 2011, Yuh projected that at least 44% of pre-retired US households would be unable to maintain 70% of their permanent income during retirement, indicating that a significant portion may face reduced living standards. The paper identified factors such as retirement age, investment returns and asset allocations significantly impacting the replacement ratio. Yu *et al*. (2019) aimed to align with the Chinese Ministry of Human Resources and Social Security's goal of achieving an 80% total replacement rate, with 60% from the basic pension and 20% from supplementary annuities. The paper used actuarial modelling techniques and concluded that a contribution rate of 14% and a return rate of 9% could achieve the targeted replacement ratio of 20%. Symeonidis *et al*. (2021) explored ways to improve pension adequacy in Greece while simultaneously reducing the fiscal burden and fostering domestic investments and growth. Their paper suggests that implementing a new scheme in Greece could lead to a higher replacement rate at retirement while easing the state's fiscal obligations.

In the Malaysian context, Saidi *et al*. (2017) found that the replacement ratio did not reach the 60% benchmark, indicating that the DC plan was inadequate and suggesting that adjustments to contribution rates are necessary to achieve adequacy. However, the projected replacement ratio remains below the recommended baseline level, and constantly adjusting the contribution rate may prove impractical. Kamal and Ismail (2025) examined the adequacy of a DC plan by proposing Inflation-Indexed Life Annuities (IILAs) as an alternative to lump-sum withdrawals. They used an optimisation method to assess the optimal amount to be set aside at retirement. Analysis of the data from the Household Income and Expenditure Survey revealed that immediate IILAs offer an average replacement ratio of over 50%, while deferred IILAs provide more than 40%. While these average replacement ratios remain below its targeted rate of 70%, no further analysis has been conducted on the uncertainty elements highlighted in other literature, their potential effect on the replacement ratio, or how improved longevity would influence the valuations. Recently, the EPF launched a three-tier retirement savings framework, the Retirement Income Adequacy (RIA), which is scheduled for implementation in 2026 (Employees Provident Fund 2024). This framework defines the three tiers as basic, adequate, and enhanced savings and income, with the basic tier amounting to 60% of the adequate tier and the enhanced tier set at twice that level. Notably, the 60% threshold aligns with the benchmark established by both the Government Pension Scheme and the EPF's RIA framework at the basic level, a ratio explicitly imposed by the government uniformly across all income strata. This threshold is designed to reflect the proportion of salary maintained from employment into retirement (Employees Provident Fund 2025; Hussein 2019). Similarly, the projections do not emphasise the relationship between the replacement ratio and economic and demographic assumptions.

This study aims to enhance the existing literature by proposing periodical retirement withdrawals and incorporating the uncertainty elements into the assessment of retirement adequacy to achieve an optimal replacement ratio by identifying the optimal contribution rates for a DC plan. The purpose of this research is to investigate the adequacy of retirement income from a DC plan. This research uses actuarial analysis to evaluate the replacement income ratio and incorporates economic and demographic factors. It analyses the direct impact of mortality and interest rate risks, mortality improvement factors and investment returns, while incorporating other factors like Malaysia's salary scale, inflation rates, and retirement ages. It also considers years of employment and median salaries by age and gender. Additionally, the accumulated lump sum from the DC plan will be used as the net single premium to purchase a retirement annuity, which provides annual income during retirement. The maximum attainable age is set as 100 years for both genders.

This research paper contributes significantly by providing insights into the current adequacy level of the DC plan in Malaysia. It uses replacement ratios that incorporate longevity and interest rate risks. Additionally, this paper proposes a hybrid retirement model that integrates defined contribution and defined benefit (DB) elements. Under this approach, the lump sum accumulated savings are converted into a retirement annuity, resulting in fixed annual payments throughout retirement. This model aims to estimate the post-retirement income stream and compare it to the pre-retirement income to measure the adequacy of retirement income. One factor explored in this paper is the potential revision of the percentage of total contribution rates to the DC plan according to gender and age of entry into the workforce, by defining an optimal replacement ratio. This provides a foundation for policymakers to evaluate potential reforms to existing policies, strengthening efforts to ensure retirement income adequacy and securing sufficient income for retirees. The analysis concludes with additional calculations to determine the number of financially sustainable years after retirement based on Malaysia's Poverty Line Income (PLI).

The structure of the paper is as follows: Section 2 reviews relevant literature on the risks associated with an ageing population and highlights the importance of ensuring sufficient income after retirement. It also describes the replacement ratio as a measure of adequacy and explores the key factors influencing the likelihood of achieving a target ratio. An overview of the literature on life annuities as a source of retirement income is also briefly explained. Section 3 summarises data and indicators related to the uncertainty elements and outlines the methods used to develop the replacement ratio calculation. This includes sections on calculating the actuarial present values of life annuities and replacement ratio. Section 4 presents the results, focusing initially on the attainable replacement ratio by gender and age of workforce entry using current economic and demographic assumptions. A table of suggested contribution rates is presented based on an optimal replacement ratio derived from these results. Additionally, the estimated number of sustainable years post-retirement is discussed. Finally, Section 5 emphasises the main conclusions from the analysis, highlights important indicators impacting the adequacy of the DC plan and suggests additional points to be considered for future research.

2. Literature Review

2.1. *Malaysia as an ageing population*

Recent trends show a significant decline in the ratio of working-age individuals to older adults, driven by increasing life expectancy and declining fertility rates (Chen *et al*. 2024). The Department of Statistics Malaysia (DOSM) reported in 2021 that life expectancy for those aged 60 has increased by 1% for males and 3% for females from 2014 to 2020, and this trend is expected to continue. An increase in life expectancy may raise the cost of providing post-retirement income. This issue is worsened by the unchanged mandatory retirement age policy despite increasing longevity (Ibrahim & Mohd Nordin 2020). As a result, there will be more pressure to ensure that the funds accumulated during employment are sustainable and sufficient to support a longer retirement.

2.2. *Malaysia's Employees Provident Fund (EPF)*

Malaysia's defined contribution retirement plan is managed by the Employees Provident Fund (EPF), which consists of three main accounts: Retirement (previously Account 1), Wellbeing (previously Account 2), and the recently established and announced Flexible account for addressing short-term financial needs (Employees Provident Fund 2024). The EPF allows for partial or entire withdrawals from all three accounts at the age of 55, even though the minimum retirement age for private sector employees is 60, according to the Minimum Retirement Age Act 2012. Over the past several decades, various changes have been made to the EPF's statutory contribution rates as part of the Malaysian government's effort to provide financial relief to EPF contributors amid changing economic conditions and external factors such as a pandemic. In 2016 and 2020, the contribution rate for employees aged 60 and below was revised to 8% and 7%, respectively, down from the original 11%, whereas the employer contribution rate remained constant at 12%. These adjustments were applied mainly due to the economic conditions and the impact of the COVID-19 pandemic, respectively, and to increase consumer spending and avoid economic recession. From 2021 to 2022, the employees' contribution rate increased slightly to 9%, and currently, it stands at 11%. The mandatory contribution rate by employers is either 12% or 13%, depending on the employee's salary (Employees Provident Fund 2024).

2.3. *The adequacy of a defined contribution pension plan*

Much of the literature has proposed various ways to improve the adequacy of a DC plan. These modifications usually involve adjusting retirement age and contribution rates, along with the actuarial and financial bases of mortality and interest rates. As previously mentioned, these efforts were further explored in various studies from different countries. For example, Yuh (2011) highlighted that modifying factors like retirement age and investment returns can further improve the replacement ratio. Meanwhile, Yu *et al*. (2019) performed simulations to analyse how changes in the DC contribution and interest rates affect the replacement ratio, identifying suitable rates for use. Saidi *et al*. (2017) also suggested adjustments to the contribution rates to achieve a higher replacement ratio. Recently, Kamal and Ismail (2025) proposed using Inflation-Indexed Life Annuities (IILAs) and an optimisation model to improve the adequacy of a DC plan by analysing its replacement ratio. It is evident that these economic and demographic factors significantly impact the outcome of the replacement ratio.

The adequacy of a retirement system refers to its ability to provide sufficient benefits by generating streams of retirement income from retirees' amassed wealth to meet their needs and prevent old-age poverty (Villanueva-García *et al*. 2025). Aon (2018) similarly views retirement income adequacy in the report on the U.S. retirement system, considering both available retirement resources and required retirement needs. Resources encompass the available assets employees are expected to have upon retirement, while the needs cover the required assets to maintain an employee's pre-retirement standard of living after retiring. Simply, if resources exceed needs, there is a surplus, and if needs surpass resources, there is a shortfall or deficit Aon (2018). As the accumulated amount in a DC plan upon retirement depends on the mandated contribution rates and other important factors, it is essential to analyse whether this accumulated amount can adequately support retirement income and identify the limitations of existing policies.

2.4. *Replacement ratio as a measure of retirement income adequacy*

A more formal approach to the measurement of retirement income adequacy involves calculating the replacement ratio, which serves as a straightforward indicator of retirement income adequacy, primarily due to its simplicity in both calculation and understanding. Many studies continue to employ the standard range of replacement ratios suggested in earlier research, indicating that no single fixed rate can be regarded as universally ideal. In the United States, Yuh (2011) projected that the optimal replacement ratio for households was 70%. In China, Yu *et al*. (2019) identified that a replacement ratio of 60% is enough to maintain basic needs during retirement, while an 80% replacement ratio is required for a comfortable retirement life funded by both mandatory and supplementary pension plans. In Singapore, estimates by the Ministry of Manpower indicate that the Central Provident Fund

(CPF), the national defined contribution pension scheme, is projected to provide a median income replacement rate of 70% for new male entrants to the workforce and 64% for new female entrants at age 65 (Chia & Tsui 2012). Furthermore, its mandatory pension schemes as reported by the OECD indicate a gross income replacement ratio of approximately 61.7%, and a net replacement ratio of around 57.6%, excluding housing assets (Organisation for Economic Co-operation and Development 2024). In Malaysia, the work of Alaudin *et al.* (2017), Saidi *et al.* (2017), and Rahim and Yusoff (2024) are based on the suggested range of 65% to 90%. Saidi *et al.* (2017) reported that Malaysia's replacement ratio at the time was approximately 42% and suggested that an annual decrease in the employee's EPF contribution rate could increase the replacement ratio to 49%; however, this remains below the minimum requirement. Kamal *et al.* (2018) suggested using different replacement ratios based on household income classes. They revised the replacement ratios to 45% for high-income earners, 95% for low-income earners, and retained 70% for middle-income earners. According to the Organisation for Economic Co-operation and Development, Malaysia's future gross replacement rate for an average earner with full career is below 40% (Organisation for Economic Co-operation and Development 2024). For Malaysian public sector employees under the defined benefit plan, the replacement ratio is adopted from the standards of the Service Pension (payable monthly), as specified by the Malaysian Public Service Department (JPA). The JPA specifies the monthly service pension as 1/600 of the number of years of service multiplied by the final monthly salary, with a maximum of 30 years of service (360 months) (Jabatan Perkhidmatan Awam Malaysia 2024). This yields a maximum 60% replacement ratio, commonly viewed as the optimal benchmark. This threshold is also adopted in the RIA framework, which defines basic savings and income as 60% of the adequate amount. As most replacement ratios are estimated based on fixed assumptions, this study aims to estimate the optimal replacement ratio for private sector workers while considering changes in future trends in mortality and interest rates.

To calculate the replacement ratio, one must take the ratio of accumulated savings just before retirement to the final annual salary. Extending the ideas from the work of Villanueva-García *et al.* (2025), this study incorporates uncertainty elements related to longevity risk and interest rate risk in analysing the replacement ratio to assess both the sustainability and adequacy of the DC plan. Longevity risk accounts for changes in mortality rates over the years, whereas interest rate risk serves as a proxy for risk-free rates and the inflation index. The formulation of the replacement ratio, as established by Heong Lian *et al.* (2000), is extended to incorporate both elements of risks. Saidi *et al.* (2017) focused on decreasing the proportion of contribution rates to improve the replacement ratio. While this has shown some improvement to the rate, it remains below all the suggested rates, and revising contribution rates multiple times may not be feasible. Ibrahim *et al.* (2021) adopted the Projected Unit Credit method to estimate the costs of retirement by varying retirement age, mortality rate, and salary growth, but their focus was primarily on the DB plan. Alaudin *et al.* (2017) incorporated economic factors to estimate replacement ratios for both DC and DB plans while addressing some of the effects of demographic factors on the valuation. Kamal and Ismail (2025) estimated the replacement ratio using an optimisation model; however, the results showed that the intended 70% replacement ratio was not achieved. This study intends to examine both economic and demographic impacts on the replacement ratio for a DC plan before and after retirement while identifying the optimal contribution rates according to the age of entry into the workforce.

2.5. *Annuity as retirement income*

Annuity products would be most beneficial for future retirees by providing a continuous stream of income after they are no longer receiving employment income (Wettstein *et al*. 2021). It is in-line with the recently tabled Thirteenth Malaysia Plan, 2026−2030 (RMK13) which highlights the exploration for EPF contribution to be separated into retirement savings and pension, allowing for retirees to receive monthly pension (Economic Planning Unit 2025). However, concerns have been raised about using life annuities as retirement income option within DC plans. Employees often prefer to withdraw their entire savings upon reaching retirement age rather than opting for periodic withdrawals (New Straits Times 2026). The Organisation for Economic Co-operation and Development (2010) explains that only a small proportion of retirees purchase a life annuity at retirement age because many prefer having greater liquidity during the early years of retirement, and the possibility of leaving a bequest should they pass away early. This situation is commonly referred to as the "annuity puzzle", where individuals are reluctant to purchase life annuities despite their potential benefits for long-term income security.

The expected value of the present value of a life annuity benefit is the actuarial present value (APV) of future series of level payments that are paid out for as long as the insured remains alive. Estimating a present value involves discounting future outgo against future income over time and considering the policyholder's random lifetime (Pitacco & Tabakova 2021). The equivalence principle is an approach used to estimate an appropriate premium to be charged based only on the actuarial present value of future benefits (Dickson *et al*. 2019). This value serves as a starting point for setting a reasonable price for insurance and annuity products. The equivalence principle is applied by equating the APV of future benefits outgo with the APV of periodic premiums to be received. The result gives a minimum cost of an annuity plan for the benefits to be disbursed in the future.

3. Methodology

This paper proposes a hybrid retirement model that integrates elements of both defined contribution and defined benefit plans. Several calculations, including the actuarial present values of the proposed retirement annuity and the accumulated contribution amount during employment, are needed to implement this model and determine the replacement ratio and the optimal contribution rate.

Calculating the actuarial present value of the annuity requires assumptions about mortality rates, discount factors, and inflation rates, whereas the actuarial present value of accumulated retirement savings depends on assumptions related to salary scale and investment returns (Ibrahim *et al*. 2021). Once the data is finalised, the analysis is carried out using the methodologies described below, implemented in R Programming and Microsoft Excel.

To ensure consistency between the accumulation and payout phases, the methodology begins by defining the annuity factor, which provides the actuarial present value of both pre-retirement contribution streams and post-retirement income streams. This conceptual foundation supports the subsequent derivations for the actuarial present values of term-life annuity of retirement savings and life annuity of post-retirement income, and is integrated into the valuation of the replacement ratio.

3.1. *Data collection*

All data and indicators used are from 2023 and have been obtained from multiple sources of reference. Additionally, to capture longevity risk, mortality rate data from 1980 to 2023 have been obtained from the Department of Statistics Malaysia (DOSM) and used to identify the expected changes in mortality and their effect on future valuations. The interest rate data for the year 2023 were based on the Kuala Lumpur Interbank Offered Rate (KLIBOR) and were retrieved from Bank Negara Malaysia's Financial Markets Information Portal (FMIP).

3.1.1. *Mortality data*

The Malaysian mortality data is used to identify future mortality trends and to calculate the likelihood of survival in subsequent years. This dataset consists of abridged mortality rates for males and females aged 0 to 75, covering the period from 1980 to 2023. The data were reliable and of high quality, and any missing entries were filled using linear interpolation. Figures 1 present the mortality rates for males and females in 1980 and 2023. The curves display the common trend of increasing mortality rates with age for both genders, with males generally exhibiting higher mortality rates. Both figures demonstrate a significant decline in mortality rates over time, indicating an improvement in longevity risk, particularly among older age groups.

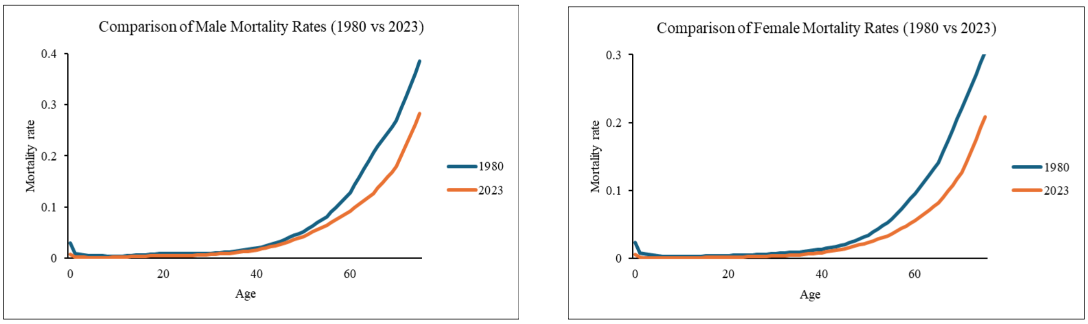


Figure 1: Mortality rates for males and females for the years 1980 and 2023

The mortality improvement factor is calculated by averaging the changes in mortality by age and gender. Table 1 presents a summary of the mortality changes at selected ages. It shows an overall improvement in mortality, with the increase in longevity being more pronounced for males compared to females across all ages. Table 2 displays the changes in life expectancy from 1980 to 2023, showing that longevity risk is improving over time.

Table 1: Mortality trends by age and gender

	Male		Female	
Age	Average change	Improvement factor	Average change	Improvement factor
15	-0.011	0.989	-0.033	0.967
20	-0.014	0.986	-0.035	0.965
25	-0.014	0.986	-0.029	0.971
30	-0.008	0.992	-0.021	0.979
35	-0.005	0.995	-0.020	0.980
40	-0.005	0.995	-0.019	0.981
45	-0.004	0.996	-0.018	0.982
50	-0.005	0.995	-0.018	0.982
55	-0.005	0.995	-0.019	0.981
60	-0.008	0.992	-0.019	0.981
65	-0.011	0.989	-0.021	0.979
70	-0.009	0.991	-0.017	0.983
75	-0.007	0.993	-0.014	0.986

Table 2: Longevity risk trends

Age	Male Life Expectancy			Female Life Expectancy		
	1980	2023	Change	1980	2023	Change
15	53.1	56.0	+ 2.9	55.9	59.2	+ 3.3
20	48.4	51.2	+ 2.8	51.1	54.3	+ 3.2
25	43.8	46.4	+ 2.6	46.4	49.4	+ 3.1
30	39.2	41.7	+ 2.4	41.6	44.5	+ 3
35	34.6	37.0	+ 2.4	36.8	39.7	+ 2.9
40	30.0	32.3	+ 2.3	32.2	34.9	+ 2.7
45	25.5	27.7	+ 2.2	27.7	30.2	+ 2.5
50	21.3	23.2	+ 1.9	23.4	25.6	+ 2.2
55	17.3	19.0	+ 1.6	19.3	21.1	+ 1.9
60	13.6	15.0	+ 1.3	15.4	16.8	+ 1.4
65	10.3	11.3	+ 1	11.7	12.7	+ 1
70	7.3	7.7	+ 0.5	8.1	8.6	+ 0.5
75	4.0	4.2	+ 0.2	4.3	4.5	+ 0.2

3.1.2. *Other economic uncertainties*

The calculation of the actuarial present values of life annuity of post-retirement income and term-life annuity of retirement savings relies on several key assumptions to ensure accuracy and robustness. One of the primary assumptions is the mortality rate of the annuitant, which determines the probability of survival and the expected duration of annuity payments. A second critical assumption is the discount rate, which is used to compute the present value of future annuity payments. The discount rate is typically derived from prevailing market interest rates and reflects the time value of money (Pitacco 2016).

In this study, the proxy for the risk-free rate (He *et al*. 2022) was the 12-month Kuala Lumpur Interbank Offered Rate (KLIBOR) for 2023, sourced from the Financial Markets Investor Portal (FMIP). To enhance the robustness of the analysis, both the highest and lowest rates observed in 2023 were considered in the simulation. In addition, two macroeconomic indicators obtained from DOSM were incorporated. The 2023 Consumer Price Index (CPI) served as a proxy for inflation to calculate the real rates based on the interest rates defined above. The average salary growth rate in 2023 was used to adjust for salary progression per annum, where the salary scale refers to the annual percentage increase in salary. Furthermore, three additional indicators sourced from the EPF were included. The EPF's statutory contribution rate for 2023 was used for the contribution rate of a DC plan. The mandatory contribution rate for employees is 11%, and the employer's mandatory contribution rate is either 12 % or 13%, depending on the employee's salary. This results in a maximum total contribution rate of 24%. The investment returns on the DC fund are set at 2.5% and 5.5%, which are the lowest and highest EPF conventional dividend rates as of 2023. The retirement age is set at 55 years, which represents the earliest permitted age for a lump sum withdrawal under the EPF regulations. A summary of the indicators related to the economic uncertainties, along with their respective data sources, is presented in Table 3.

This study also incorporates the age of entry into the workforce to determine the total number of working years. According to the Malaysia Ministry of Human Resources (1966), the Children and Young Persons (Employment) Act (1966) defines a child as someone who has not completed the fifteenth year of age. Therefore, the minimum working age is established at 15 years old. Additionally, this study limits the entry age to a maximum of 30 years to align with typical career trajectories. This results in a minimum of 25 years and a maximum of 40 years of working experience. Furthermore, the median annual salary, obtained from DOSM, served as a proxy to estimate the accumulated amount in the DC plan upon retirement.

Table 3: Summary of economic indicators

	Indicator	Minimum	Maximum	Portal
Interest rate	12-month KLIBOR	2.18%	3.79%	FMIP[a]
Investment return	EPF dividend rate	2.50%	5.50%	EPF[b]
		Fixed		
Inflation rate	Consumer Price Index (CPI)	2.49%		DOSM[c]
Salary scale	Average salary growth rate	5%		DOSM[c]
DC contribution rate	EPF total contribution rate	24%		EPF[d]
Retirement age	EPF earliest full withdrawal	55		EPF[e]

[a]https://financialmarkets.bnm.gov.my/
[b]https://www.kwsp.gov.my/en/others/resource-centre/dividend
[c]https://open.dosm.gov.my/
[d]https://www.kwsp.gov.my/en/member/overview/contribution
[e]https://www.kwsp.gov.my/en/member/life-stages/age-55-60-withdrawal

3.2. *The annuity factor*

The annuity factor represents the actuarial present value of a stream of payments and forms the foundation for valuing both the accumulation of contributions before retirement and the income stream paid during retirement. Its theoretical basis is well established in actuarial literature (Bowers *et al*. 1997; Dickson *et al*. 2019)

3.2.1. *Term-life annuity of retirement savings and life annuity of post-retirement income*

During the employment period, contributions are made annually from entry age to retirement age. Since contributions are assumed to continue only while the worker remains alive and employed, this structure corresponds to a term-life annuity, where payments continue for a finite number of years subject to survival. Each annual payment is discounted back to the entry age and adjusted for salary progression and investment returns.

At retirement, the accumulated savings are converted into a stream of lifetime income. This income stream reflects payments contingent upon survival and is valued using a life annuity factor, where each payment is weighted by the probability that the retiree survives to receive it and discounted to the retirement age.

The principles underlying such valuations follow the standard treatment of annuities, and the role of survival probabilities and present value discounting are presented in standard actuarial references mentioned above. Additional discussion on modelling lifetime income and longevity risk can be found in works like Chang and Sherris (2018) and Wettstein *et al*. (2021).

3.2.2. *Linking accumulation and decumulation*

The term-life annuity of retirement savings and the life annuity of post-retirement income factors provide a consistent actuarial bridge between the contribution phase (accumulation) and the payout phase (decumulation). Under the equivalence principle, the actuarial present value of accumulated contributions is equated to the actuarial present value of retirement income, ensuring fairness and internal consistency in retirement income determination.

This principle is central to linking accumulation and decumulation in pension and retirement income systems. Wadsworth *et al*. (2001) further show how the equivalence principle forms the basis for designing coherent retirement income structures that integrate savings accumulation with annuitisation.

3.3. *The actuarial present value of term-life retirement savings annuity*

The present value of future normal costs was calculated using the Entry Age Normal (EAN) Level Cost Individual Cost Method, where pension benefits based on salary are funded through a level percentage of salary (Aitken 1996). To determine the actuarial present value of the term-life annuity, the total contributions from both the employee and employer, accumulated from the entry age *e* until the retirement age *r*, are valued at entry age *e*. The term-life annuity represents the available funds (cash inflow) used to purchase the retirement annuity (cash outflow).

As dividends are declared annually, the actuarial present value is calculated using annual contributions, with 24% of the employee's annual salary contributed each year. The study assumes that salary grows at a fixed salary scale of 5% per annum and that the retirement account earns investment returns based on declared annual dividends. Adopting the level percent of salary model described in Aitken (1996), the actuarial present value of the accumulated contributions at entry age *e*, $\mathrm{APV}_e(C)$, can be defined as Eq. (1).

$$
\begin{aligned}
\mathrm{APV}_e(C) &= cS\ddot{a}_{e:\overline{r-e}|j} \\
&= cS + cS\left(\frac{1+s}{1+\delta}\right){}_1p_e + cS\left(\frac{1+s}{1+\delta}\right)^2{}_2p_e + \ldots + +cS\left(\frac{1+s}{1+\delta}\right)^{r-1-e}{}_{r-1-e}p_e \\
&= cS + cS\left(\frac{1}{1+j}\right){}_1p_e + cS\left(\frac{1}{1+j}\right)^2{}_2p_e + \ldots + cS\left(\frac{1}{1+j}\right)^{r-1-e}{}_{r-1-e}p_e \\
&= cS\sum_{k=0}^{r-1-e} v^k\,{}_kp_e \qquad (1)
\end{aligned}
$$

In this equation, C represents the total contribution amount, and c is the EPF's total contribution rate. The current annual salary is denoted by S. s represents the salary scale, defined as the annual percentage increase in salary, assumed to be independent of age. The EPF's annual dividend rate is denoted by δ where $\delta_{\min} = 2.5\%$ and $\delta_{\max} = 5.5\%$. The value j represents the adjusted scale using the dividend rate and the salary scale where $j = \frac{1+\delta}{1+s} - 1$. This gives $j_{\min} = -2.381\%$ and $j_{\max} = 0.476\%$. v^k is the discount factor for k years, using the rate j and ${}_kp_e$ is the survival probability for a person aged e for k years. Lastly, $\ddot{a}_{e:\overline{r-e}|j}$ is the annuity factor at entry age e for $r-e$ years using rate j.

3.4. *The actuarial present value of post-retirement income life annuity*

To represent the post-retirement income stream, the actuarial present value of a life annuity was calculated. This calculation involves determining the actuarial present value of the annuity at the age of retirement for as long as the retiree lives, with a maximum attainable age of 100. This value represents the retirement annuity. The actuarial present value of the retirement annuity is the net single premium or the actuarial cost of providing a series of fixed payments upon retirement for the entire duration of the retiree's life. The net single premium at entry age e of the retirement annuity due payable annually from the retirement age r, $\mathrm{APV}_e(B_r)$, can be defined as follows:

$$\mathrm{APV}_e(B_r) = v^{r-e}\ {}_{r-e}p_e B_r \ddot{a}_r \tag{2}$$

where;
B_r is the level annual retirement annuity benefit.
v^{r-e} is the discount factor using the real rates; $i_{\min} = -0.303\%$ and $i_{\max} = 1.268\%$
${}_{r-e}p_e$ is the survival probability for a person aged e over $r-e$ years
$\ddot{a}_r$ is the annuity factor at age r using the real rates

The annual retirement benefit payment can be calculated using the equivalence principle, which states that the actuarial present value of cash inflows, $\mathrm{APV}_e(C)$ in Eq. (1), is equal to the actuarial present value of cash outflows, $\mathrm{APV}_e(B_r)$ in Eq. (2). Hence,

$$B_r = \frac{cS\ddot{a}_{e:\overline{r-e}|j}}{v^{r-e}\ {}_{r-e}p_e \ddot{a}_r} \tag{3}$$

3.5. *The replacement ratio calculation*

The replacement ratio is defined as the employee's post-retirement income divided by their pre-retirement income or the final salary (Aon Consulting 2008). The post-retirement income after retirement is denoted as B_r, and salary is assumed to grow according to the annual salary scale, and the replacement ratio at retirement age r, RR_r is calculated as:

$$\mathrm{RR}_r = \frac{B_r}{S_{r-1}} = \frac{B_r}{S_e(1+s)^{r-1-e}} \tag{3}$$

The B_r formulation in Eq. (3) is integrated into Eq. (4); thus:

$$\begin{aligned}\mathrm{RR}_r &= \frac{cS\ddot{a}_{e:\overline{r-e}|j}}{S(1+s)^{r-1-e}v^{r-e}\ {}_{r-e}p_e \ddot{a}_r} \\ &= \frac{c\ddot{a}_{e:\overline{r-e}|j}}{(1+s)^{r-1-e}v^{r-e}\ {}_{r-e}p_e \ddot{a}_r}\end{aligned} \tag{4}$$

The same equation is also used to identify the optimal contribution rates by age and gender. A 60% replacement ratio is chosen to benchmark adequacy, consistent with the maximum rate prescribed by Malaysia's Government Pension Scheme after 30 years of service.

4. Results and analysis

This section covers key findings from the actuarial analysis of the income replacement ratio after retirement, considering the uncertainty elements of longevity risk and interest rate risk and their impact on retirement adequacy. It provides an overview of the projected annuity factors and presents the results of the attainable replacement ratio and optimal contribution rates. A short analysis of the level of expected shortfall concludes this section.

4.1. *Analysis of the annuity factors*

This analysis calculates two annuity factors: the term-life annuity $\ddot{a}_{e:\overline{r-e}|j}$ from Eq. (1) and the retirement annuity $\ddot{a}_r$ from Eq. (2). Table 4 shows the annuity factors for the term-life annuity at retirement ages 55 and 60. The annuity factors are higher for retirement age 60 due to a longer survival time being considered. It is observed that the factors are considerably higher when calculated using $j_{\min}$, as a lower discount factor leads to a higher present value. It is also observed that females have a higher survival probability compared to males, resulting in higher annuity factors for females of all ages.

Table 4: The $\ddot{a}_{e:\overline{r-e}|j}$ factors using retirement ages 55 and 60

retirement age 55					retirement age 60				
	$j_{\min}$		$j_{\max}$			$j_{\min}$		$j_{\max}$	
Age	Male	Female	Male	Female	Age	Male	Female	Male	Female
15	54.104	59.541	31.286	33.642	15	59.976	68.197	33.041	36.224
16	52.034	57.228	30.545	32.844	16	57.788	65.689	32.314	35.442
17	50.016	54.971	29.803	32.043	17	55.655	63.244	31.588	34.658
18	48.047	52.770	29.060	31.241	18	53.575	60.858	30.861	33.871
19	46.126	50.621	28.316	30.435	19	51.546	58.531	30.133	33.083
20	44.252	48.525	27.570	29.628	20	49.566	56.260	29.405	32.293
21	42.422	46.479	26.823	28.817	21	47.634	54.043	28.675	31.500
22	40.629	44.485	26.070	28.005	22	45.742	51.884	27.940	30.706
23	38.873	42.541	25.312	27.192	23	43.888	49.779	27.200	29.912
24	37.153	40.645	24.547	26.378	24	42.072	47.728	26.453	29.116
25	35.467	38.797	23.777	25.561	25	40.293	45.727	25.701	28.320
26	33.815	36.993	23.000	24.743	26	38.550	43.777	24.943	27.522
27	32.206	35.236	22.224	23.924	27	36.853	41.877	24.187	26.724
28	30.637	33.524	21.447	23.103	28	35.200	40.026	23.431	25.926
29	29.108	31.854	20.669	22.282	29	33.589	38.222	22.675	25.127
30	27.615	30.225	19.890	21.458	30	32.018	36.464	21.918	24.327

The retirement annuity factors are calculated using minimum and maximum real rates, with consideration of the mortality improvement factors at older ages. This approach helps identify the effect of longevity risk in the actuarial valuations of post-retirement income benefits. Table 5 summarises the retirement annuity factors. Similar observations are found whereby the annuity factors for males are lower than those for females and using a higher discount rate results in a lower actuarial present value. All annuity factors increase with mortality improvement, as both genders are expected to have higher survival rates, leading to a higher cost of annuity. The annuity factors decrease as the retirement age increases to 60, indicating a lower cost of annuity over a shorter period.

Table 5: The $\ddot{a}_r$ factors estimated at retirement ages 55 and 60

Retirement age	Real rates	No mortality improvement Male	No mortality improvement Female	With mortality improvement Male	With mortality improvement Female
55	-0.303%	9.554	12.761	9.607	12.904
	1.268%	8.692	11.315	8.735	11.428
60	-0.303%	7.532	10.011	7.584	10.135
	1.268%	6.984	9.079	7.028	9.181

4.2. *Analysis of the replacement ratio*

The analysis of the replacement ratio incorporates the result of Eq. (5). It comprises of two parts: the first part analyses the replacement ratio using fixed mortality rates for all ages, while the second part incorporates mortality improvement factors, reflecting longevity risk. These sections further analyse the impact of interest rate risk by pairing the minimum real rate with the minimum dividend rate (min. rates), and the maximum real rate with the maximum dividend rate (max. rates). The justification for choosing this combination is that the mixture of minimum and maximum real rates and dividend rates may not adequately reflect the actual scenarios, where low interest rates tend to result in a low investment return. Investments are less likely to generate higher returns and dividends during periods of economic slowdown or low interest rates, as businesses face lower profits and reduced growth prospects (Fama & French 1992; 1993). Conversely, stronger economic conditions and higher interest rates tend to support higher returns, although this can vary based on asset types and market dynamics (Campbell & Shiller 1988; 2005). Therefore, this analysis focuses exclusively on the combinations of maximum and minimum rates.

Table 6 shows the attainable replacement ratio by age and gender using retirement age 55. The results indicate that the attainable replacement ratio increases with growing interest and dividend rates, consistent with findings that investment returns are a primary driver of retirement income and significantly influence replacement ratios (Castro 2024). The replacement ratio is also observed to increase as the entry age increases, a pattern that is also observed in Social Security Administration analyses where later workforce entry can lead to higher replacement ratios when benefits are calculated over shorter, wage-indexed earning periods (Burkhalter & Rose 2024). This indication is a result of the complex relationship with the age of entry, which is also influenced by the survival probabilities, discounting, and the time value of money. Although entering the workforce earlier allows for more years of contribution, an extended accumulation period can also result in a lower replacement ratio. This occurs because the accumulated savings may represent a smaller percentage of the final salary compared to someone who started working later. Additionally, the effect of discounting and the time value of money over an extended time horizon is more apparent at younger ages. When employees enter the workforce at a significantly younger age, they have a longer time horizon until retirement. Thus, the discounting effect over this longer period may offset the benefits of future salary growth and contributions. This causes the actuarial present value to decrease. At older ages, however, it is observed that the offsetting effect of discounting reduces, leading to a decrease in the replacement ratio as age increases. The replacement ratios for both genders tend to decrease when mortality improvement factors are incorporated. As mortality declines, survival probabilities increase, which raises the cost of providing annuity (Di Palo 2025). However, the impact of longevity risk on the replacement ratio is relatively small compared to the effect of interest rate.

The findings suggest that the Malaysian government needs to reform the statutory contribution rates and ensure that the replacement ratio can be maintained while accommodating improvements in mortality rates. Finally, none of the replacement ratios can achieve 60%, with the highest attainable ratio of only 42.6%. Although this figure meets the International Labour Organisation's (ILO) baseline standard of 40% (International Labour Organization 2022), they also indicate that a replacement ratio below 55% may cause employees to struggle with maintaining their standard of living and face challenges in covering daily expenses and medical costs. Additionally, this result aligns with the preliminary findings of Saidi *et al*. (2017), suggesting that the attainable replacement ratio has not increased.

Table 6: The attainable replacement ratio using retirement age 55 (%)

Age	No mortality improvement				With mortality improvement			
	Min. rates		Max. rates		Min. rates		Max. rates	
	Male	Female	Male	Female	Male	Female	Male	Female
15	34.3	21.0	40.8	25.0	34.1	20.7	40.6	24.7
16	34.6	21.2	41.1	25.2	34.4	21.0	40.9	25.0
17	34.9	21.4	41.4	25.5	34.7	21.2	41.2	25.2
18	35.2	21.6	41.7	25.7	35.0	21.4	41.5	25.5
19	35.4	21.8	42.0	25.9	35.2	21.5	41.8	25.7
20	35.6	22.0	42.2	26.1	35.4	21.7	42.0	25.9
21	35.8	22.1	42.3	26.3	35.6	21.9	42.1	26.0
22	35.9	22.2	42.5	26.5	35.8	22.0	42.3	26.2
23	36.0	22.4	42.6	26.6	35.9	22.1	42.3	26.3
24	36.1	22.4	42.6	26.7	35.9	22.2	42.4	26.4
25	36.1	22.5	42.5	26.7	35.9	22.3	42.3	26.5
26	36.1	22.5	42.5	26.8	35.9	22.3	42.3	26.5
27	36.0	22.6	42.3	26.7	35.8	22.3	42.1	26.5
28	35.9	22.5	42.1	26.7	35.7	22.3	41.9	26.4
29	35.7	22.5	41.8	26.6	35.5	22.2	41.6	26.4
30	35.4	22.4	41.5	26.5	35.2	22.1	41.2	26.2

Table 7 presents the analysis with the minimum retirement age raised to 60. Attainable replacement ratios increase notably, with gains ranging from 37% to 64%. The optimal 60% ratio is reached only for males under maximum real rates, suggesting that extending the retirement age alone is insufficient to ensure retirement adequacy.

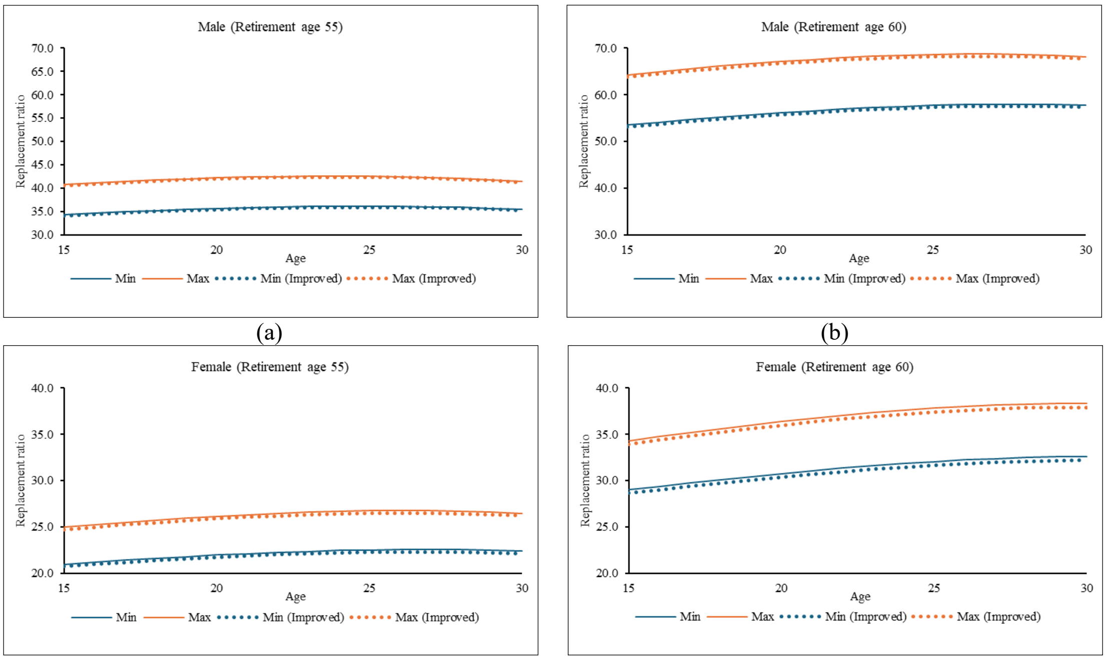
Table 7: The attainable replacement ratio using retirement age 60 (%)

Age	No mortality improvement				With mortality improvement			
	Min. rates		Max. rates		Min. rates		Max. rates	
	Male	Female	Male	Female	Male	Female	Male	Female
15	53.5	29.0	64.2	34.3	53.1	28.6	63.8	33.9
16	54.1	29.4	64.9	34.8	53.7	29.0	64.5	34.4
17	54.6	29.7	65.5	35.2	54.3	29.4	65.1	34.8
18	55.2	30.1	66.1	35.6	54.8	29.7	65.7	35.2
19	55.7	30.4	66.6	36.0	55.3	30.1	66.2	35.6
20	56.1	30.8	67.1	36.4	55.7	30.4	66.7	36.0
21	56.5	31.1	67.5	36.7	56.1	30.7	67.1	36.3
22	56.9	31.3	67.9	37.0	56.5	31.0	67.5	36.6

Table 7 (Continued)

23	57.2	31.6	68.2	37.3	56.8	31.2	67.8	36.9
24	57.5	31.8	68.4	37.6	57.1	31.4	68.0	37.2
25	57.7	32.0	68.6	37.8	57.3	31.7	68.2	37.4
26	57.8	32.2	68.7	38.0	57.5	31.8	68.3	37.6
27	57.9	32.4	68.7	38.2	57.5	32.0	68.3	37.7
28	57.9	32.5	68.6	38.3	57.5	32.1	68.2	37.8
29	57.9	32.6	68.4	38.3	57.5	32.2	68.0	37.9
30	57.7	32.6	68.1	38.3	57.3	32.2	67.7	37.9

Figures 2 present the attainable replacement ratios by age and gender at retirement ages 55 and 60, under alternative scenarios of mortality improvement and varying assumptions for minimum and maximum real rates and investment returns. Overall, the results indicate that replacement ratios are higher under assumptions of maximum real rates and dividend returns. Conversely, the inclusion of mortality improvement reduces the replacement ratios, reflecting the impact of higher survival probabilities across all ages. Extending the retirement age to 60 produces a marked improvement in replacement ratios for males, attributable to both the longer contribution accumulation period and their generally lower survival probabilities relative to females. For females, the increase in replacement ratios at retirement age 60 is more modest, suggesting that the effect of lower mortality plays a more dominant role.



(a) (b)

(c) (d)

Figures 2: Attainable replacement ratios by age and gender at retirement ages 55 and 60, under alternative scenarios of mortality improvement, real rates, and investment returns

4.3. *Analysis of the optimal contribution rates*

This analysis uses the actuarial present value of annuity formulas, using Eq. (1) through Eq. (3), to determine optimal contribution rates, based on a 60% replacement ratio target. The optimal contribution rates represent the total percentage of an individual's annual salary that should be transferred to their retirement account, by both the employees and employers. Table 8 presents the optimal total contribution rates by entry age and gender, assuming a retirement age of 60, to achieve the optimal replacement ratio. It is observed that some rates tend to be higher for younger individuals of both genders and scenarios, which reflects the trends observed in Tables 6 and 7.

The observed contribution rates for males are notably lower than those for females, reflecting the effect of incorporating survival probabilities in the valuation. For males, contribution rates derived under higher real interest and dividend rate assumptions fall slightly below the statutory rate of 24%, suggesting the need to reassess current mandatory contribution levels. Nevertheless, these estimates remain highly sensitive to the economic outlook, particularly assumptions regarding the discount rate and investment returns. In contrast, all calculated rates for females exceed the statutory threshold, with the minimum reaching as high as 38%. The higher contribution requirements for females are attributable to their longer life expectancy, which necessitates a larger accumulation of resources to sustain consumption after retirement.

A comparison with Singapore highlights the policy implications of these findings. The CPF mandates total contribution rates of 37% for employees under age 55 and 32.5% for those aged 55 to 60, with the latter scheduled to increase to 34% in January 2026 (Central Provident Fund Board 2025). This framework already exceeds Malaysia's EPF contribution rates, with further adjustments planned. Another comparison is with Denmark's Occupational Pension that is mandated through collective bargaining agreements which covers nearly 90% of the existing workforce in the country. Employees contribute 9% to 17% of their salary, which represents one-third of the total combined contribution, and employers contribute the remaining two-thirds of the total (Denmark Expat 2025). This brings a total contribution rate of up to 51%. Such differences underscore the importance of considering higher contribution levels in Malaysia to strengthen retirement adequacy and address longevity risk.

Table 8: Optimal total contribution rates for a 60% optimal replacement ratio at retirement age 60 (%)

Age	No mortality improvement				With mortality improvement			
	Min. rates		Max. rates		Min. rates		Max. rates	
	Male	Female	Male	Female	Male	Female	Male	Female
15	27	50	22	42	27	50	23	42
16	27	49	22	41	27	50	22	42
17	26	48	22	41	27	49	22	41
18	26	48	22	40	26	48	22	41
19	26	47	22	40	26	48	22	40
20	26	47	21	40	26	47	22	40
21	25	46	21	39	26	47	21	40
22	25	46	21	39	25	47	21	39
23	25	46	21	39	25	46	21	39
24	25	45	21	38	25	46	21	39
25	25	45	21	38	25	45	21	39
26	25	45	21	38	25	45	21	38
27	25	44	21	38	25	45	21	38
28	25	44	21	38	25	45	21	38
29	25	44	21	38	25	45	21	38
30	25	44	21	38	25	45	21	38

Setting statutory contribution rates at high levels may impose financial strain on employers and substantially reduce employees' disposable income. Implementing staggered regulatory adjustments for both employers and employees could mitigate disruptions to corporate financial planning and budgeting, while allowing employees to better prepare for reductions in net income. In addition, enhancing tax incentives for both parties should be considered to encourage compliance and to promote the broader benefits of higher contribution rates.

4.4. *Analysis of the number of financially sustainable years*

The median income was retrieved from the Department of Statistics Malaysia's *Salaries and Wages Survey Report 2023*, which provides the median salary by age group (15−19 up to 60−64) and gender (Department of Statistics Malaysia 2024b, Table A2). The data was interpolated for entry ages 15 to 30. Table 9 summarises the annualised median salary for males and females, respectively. These annualised median salaries are then used to estimate the number of years retirees can sustain themselves using their retirement income. By applying the optimal contribution rates based on gender and entry age into the workforce, the savings accumulated by retirees at the time of retirement were calculated. This total was compared to Malaysia's average Poverty Line Income (PLI), which was determined by a household income of RM2,589 per month in 2022 (Department of Statistics Malaysia 2023), to estimate the number of years that retirees can financially sustain after retirement. Table 10 shows the number of years retirees can sustain annual withdrawals from their accumulated DC plan savings. The results show significant improvement, especially for females, from the previously reported figure which indicated that retirees could only sustain for less than five years (Jomo 2017, New Straits Time 2026).

Table 9: The annualised median salary by age and gender[a]

Age	Annualised Median Salary (RM)	
	Male	Female
15	17,560.80	12,859.20
16	17,954.40	13,665.60
17	18,348.00	14,472.00
18	18,741.60	15,278.40
19	19,135.20	16,084.80
20	19,528.80	16,891.20
21	19,922.40	17,697.60
22	20,316.00	18,504.00
23	21,237.60	19,401.60
24	22,159.20	20,299.20
25	23,080.80	21,196.80
26	24,002.40	22,094.40
27	24,924.00	22,992.00
28	26,424.00	24,775.20
29	27,924.00	26,558.40
30	29,424.00	28,341.60

[a]Source: Department of Statistics Malaysia 2024b

Table 10: Sustainable years at retirement age 60 using optimal contribution rates

Age	Min. rates		Max. rates	
	Male	Female	Male	Female
15	8.0	12.2	7.4	11.1
16	7.8	12.4	7.2	11.2
17	7.6	12.5	7.1	11.4
18	7.4	12.6	6.9	11.4
19	7.3	12.7	6.7	11.5
20	7.1	12.7	6.6	11.5
21	6.9	12.7	6.4	11.5
22	6.7	12.7	6.3	11.5

Table 10 (Continued)

23	6.7	12.7	6.3	11.5
24	6.7	12.6	6.2	11.5
25	6.7	12.6	6.2	11.4
26	6.7	12.6	6.2	11.4
27	6.6	12.5	6.2	11.3
28	6.8	12.8	6.3	11.6
29	6.8	13.2	6.3	11.9
30	6.9	13.4	6.4	12.2

5. Conclusion

This study analyses the adequacy of a DC plan as a source of retirement income. It serves as a guide for policymakers to review the suitability of statutory rates and regulations, as well as identify potential areas for reform. Additionally, it raises awareness among future retirees regarding possible outcomes and preparation strategies for life after retirement. Retirement adequacy is measured by the attainable replacement ratio using Malaysia's key economic indicators and adapting the Entry Age Normal (EAN) method together with the equivalence principle. The results show that incorporating mortality and interest rate risks, along with other economic indicators, reveals that the optimal replacement ratio of 60% cannot be achieved. This represents the significant impact of these uncertainty elements on retirement adequacy. Increasing the retirement age to 60 years allows only males to attain the optimal replacement ratio; however, this outcome relies heavily on the real and dividend rates used. The study concludes that merely adjusting the age of retirement is not sufficient to ensure retirement income adequacy. The study also identifies the optimal total contribution rates payable by both employees and employers, according to employees' entry age and gender, revealing that most of the calculated rates are significantly higher than the statutory rate, especially for females. This highlights that the contribution rate of the DC plan is also an important factor in achieving retirement income adequacy. The study further recommends the implementation of gradual adjustments to statutory requirements, complemented by tax incentives for both employees and employers. Such measures would encourage constructive preparation, facilitate smoother acceptance of policy reforms, and reward compliance with the changes. Historical evidence indicates that EPF's overseas investments have generated comparatively higher returns, thereby enhancing the overall performance of the fund (The Edge 2024). Accordingly, allocating a greater proportion of assets toward investments with higher return potential may contribute to achieving larger accumulated balances over time.

Estimating the number of years that retirees can sustain using their retirement income indicates a significant improvement in terms of retirement adequacy that is achieved using the optimal contribution rates and a revised retirement age. Again, this highlights the inherent inadequacy of the current system and provides insight into possible regulatory changes. It also calls for a review of the EPF's regulations that allow for entire withdrawal at age 55, even though the minimum retirement age is 60. Adjusting or removing this policy may increase the likelihood of securing a comfortable retirement. In conclusion, the challenge of retirement income insufficiency in Malaysia has persisted for some time and addressing it necessitates the rigorous involvement of multiple stakeholders. The growing impact of longevity risk intensifies the pressure on adequacy levels, compounded by uncertainty elements such as fluctuating investment returns and inflation. Policy responses must therefore align with the government's long-term objectives and global frameworks, including the Sustainable

Development Goals (SDGs), to ensure equitable outcomes for all citizens. Lessons can also be drawn from neighboring countries, such as Singapore, where ongoing revisions to defined contribution (DC) pension schemes highlight the importance of proactive policy adjustments to strengthen retirement security.

One limitation of the study is that the optimal replacement ratio is defined as a single rate. Future research should extend the study by exploring a range of replacement ratios as suggested in earlier studies to identify the best- and worst-case scenarios to balance out the complexity of incorporating uncertainty elements from various aspects to achieve retirement income adequacy. Further analysis on the other uncertainty elements may also be considered to provide a better understanding of their impacts on adequacy.

Acknowledgments

We would like to thank the Ministry of Higher Education (MOHE) for the grant FRGS/1/2023/STG06/UITM/02/6.

References

Agarwal A., Ewald C.O. & Wang Y. 2023. Hedging longevity risk in defined contribution pension schemes. *Computational Management Science* **20**(1): 11.

Aitken W.H. 1996. A Problem-Solving Approach to Pension Funding and Valuation. Winsted, CT: ACTEX Publications.

Alaudin R.I., Ismail N. & Isa Z. 2017. Determinants of retirement wealth adequacy: A case study in Malaysia. *Institutions and Economies* **9**(1): 81–98.

Aon Consulting. 2008. 2008 replacement ratio study™: A measurement tool for retirement planning. https://www.aon.com/about-aon/intellectual-capital/attachments/human-capital-consulting/rrstudy070308.pdf (3 December 2024).

Aon. 2018. The real deal: 2018 retirement income adequacy at U.S. plan sponsors. https://www.aon.com /getmedia/59c14111-6414-46a4-adbb-0dba9e0e8676/Aon-Retirement-Solutions-The-Real-Deal-Full-Report-US-2018.aspx (3 December 2024).

Asher M.G. 1999. The Pension System in Singapore. Washington, DC: World Bank.

Bank Negara Malaysia. 2025. Financial markets information portal. https://financialmarkets.bnm.gov.my/ (10 December 2025).

Bowers N.L., Gerber H.U., Hickman J.C., Jones D.A. & Nesbitt C.J. 1997. *Actuarial Mathematics.* 2nd Ed. Schaumburg, IL: Society of Actuaries.

Burkhalter K. & Rose K. 2024. Replacement rates for hypothetical retired workers (Actuarial Note No. 2024.9). U.S. Social Security Administration, Office of the Chief Actuary.

Campbell J.Y. & Shiller R.J. 1988. Stock prices, earnings, and expected dividends. *The Journal of Finance* **43**(3): 661–676.

Campbell J.Y. & Shiller R.J. 2005. Valuation ratios and the long-run stock market outlook: An update. In Thaler R.H. (ed.). *Advances in Behavioral Finance* **2**: 173–201. Princeton, NJ: Princeton University Press.

Caraher K. 2003. Malaysia: Approaches to income security in old age. *Social Policy and Society* **2**(4): 295-304.

Castro R. 2024. Country-level, mandatory, self-financeable pension replacement rates in OECD countries. *Journal of Pension Economics & Finance* **23**(2): 321–334.

Central Provident Fund Board. 2025. CPF contribution changes from 1 January 2026. https://www.cpf.gov.sg/employer/infohub/news/cpf-related-announcements/new-contribution-rates (2 January 2026).

Chang Y. & Sherris M. 2018. Longevity risk management and the development of a value-based longevity index. *Risks* **6**(1): 10.

Chen S., Shang H.L. & Yang Y. 2024. Is the age pension in Australia sustainable and fair? Evidence from forecasting the old-age dependency ratio using the Hamilton-Perry model. *arXiv preprint arXiv:* 2401.13943.

Chia N.C. & Tsui A. 2012. Adequacy of Singapore's central provident fund payouts: Income replacement rates of entrant workers (Occasional Paper). https://www.mom.gov.sg/~/media/mom/documents/statistics-publications/occasional-paper-cpf-irr.pdf (3 January 2025).

Dickson D.C.M., Hardy, M.R. & Waters H.R. 2019. *Actuarial Mathematics for Life Contingent Risks*. Cambridge, UK: Cambridge University Press.

Di Palo C. 2025. Decomposing changes in life annuities. *European Actuarial Journal* **15**(2): 557–579.

Denmark Expat. 2025. Pension in Denmark: Everything you need to know. https://denmarkexpat.com/pension-in-denmark/ (12 January 2026).

Department of Statistics Malaysia. 2023. Poverty in Malaysia 2022. https://www.dosm.gov.my/portal-main/release-content/poverty-in-malaysia- (3 January 2025).

Department of Statistics Malaysia. 2024. Salaries and wages survey report 2023. https://open.dosm.gov.my/publications/salaries_wages_2023 (3 January 2025).

Economic Planning Unit. 2025. *Thirteenth Malaysia Plan 2026–2030*. Prime Minister's Department, Malaysia.

Employees Provident Fund. n.d. Age 55-60 withdrawal. https://www.kwsp.gov.my/en/member/life-stages/age-55-60-withdrawal.

Employees Provident Fund. n.d. Member overview: Contribution. https://www.kwsp.gov.my/en/member/overview/contribution.

Employees Provident Fund. 2023. EPF annual report 2023: Facts at a glance. https://www.kwsp.gov.my/documents/d/guest/2-epf_iar23-facts-at-a-glance (2 April 2025).

Employees Provident Fund. 2024. EPF Dividend 2024. https://www.kwsp.gov.my/en/others/resource-centre/dividend (2 April 2025).

Employees Provident Fund. 2024. EPF releases Belanjawanku 2024/2025 and Retirement Income Adequacy Framework. https://www.kwsp.gov.my/en/w/epf-releases-belanjawanku-2024/2025-and-retirement-income-adequacy-framework (2 April 2025).

Fama E.F. & French K.R. 1992. The cross-section of expected stock returns. *The Journal of Finance* **47**(2): 427–465.

Fama E.F. & French K.R. 1993. Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics* **33**(1): 3–56.

He Z., O'Connor F. & Thijssen J. 2022. Identifying proxies for risk-free assets: Evidence from the zero-beta capital asset pricing model. *Research in International Business and Finance* **63**: 101775.

Heong Lian R.K., Valdez E.A. & Chan K.L. 2000. Actuarial analysis of retirement income replacement ratios. *Journal of Actuarial Practice* **8**: 147–176.

Hussein N. 2019. The Malaysian pension system. *Nomura Journal of Asian Capital Markets* **3**(2): 15–20.

Ibrahim R.I. & Mohd Nordin N. 2020. Analysis of mortality improvement on the pension cost due to aging population. *MATEMATIKA* **36**(3): 209–216.

Ibrahim R.I., Nordin N.M. & Chek M.Z.A. 2021. Investigating the sensitivity effect of actuarial assumptions on pension liabilities in Malaysia. *Baghdad Science Journal* **18**(1): 44.

International Labour Organization. 2022. Relevance of ILO Social Security (Minimum Standards) Convention, 1952 (No. 102) to strengthen the social security system in China (ILO Brief). https://www.ilo.org/resource/brief/relevance-ilo-social-security-minimum-standards-convention-1952-no-102 (3 January 2025).

Jabatan Perkhidmatan Awam Malaysia. 2024. Skim pencen. https://pencen.jpa.gov.my/skim-pencen.html (2 February 2025).

Jomo K.S. 2017. Most Malaysians cannot afford to retire. https://www.thestar.com.my/business/business-news/2017/10/25/most-malaysians-cannot-afford-to-retire (10 January 2025).

Kamal Z.K., Isa S.M., Alaudin R.I. & Ismail N. 2018. Adequacy of retirement wealth in Malaysia: Spending behaviour analysis. *The Journal of Social Sciences Research* **2018**(Special Issue 6): 429–435.

Kamal Z.K. & Ismail N. 2025. Adequacy of inflation-indexed life annuity: A case of defined contribution pension plan in Malaysia. *Journal of Computational Innovation and Analytics* **4**(1): 22–38.

Malaysia Ministry of Human Resources. 1966. Children and Young Persons (Employment) Act 1966 (Act 350). https://eakta.mohr.gov.my/assets/pdf/akta_perburuhan/Act%20350%20-%20Children%20and%20Young%20Persons%20(Employment)%20Act%201966.pdf (3 April 2025).

New Straits Times. 2026. Why Malaysians are draining EPF savings and global lessons to watch. https://www.nst.com.my/business/corporate/2026/01/1366106/why-malaysians-are-draining-epf-savings-and-global-lessons-watch (2 February 2026).

Organisation for Economic Co-operation and Development. 2010. *OECD Journal: Financial Market Trends, Volume 2009(2)*. OECD Publishing.

Organisation for Economic Co-operation and Development. 2023. *Pensions at a glance 2023: OECD and G20 indicators*. OECD Publishing.

Organisation for Economic Co-operation and Development. 2024. *Pensions at a glance: Asia/Pacific 2024*. OECD Publishing.

Pitacco E., Denuit M., Haberman S. & Olivieri A. 2009. *Modelling Longevity Dynamics for Pensions and Annuity Business*. Oxford, UK: Oxford University Press.

Pitacco E. 2016. Life annuities: Products, guarantees, basic actuarial models. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2887359.

Pitacco E. & Tabakova D. 2021. Actuarial mathematics: Time-continuous models for life insurance. *SSRN Electronic Journal*.

Rahim N.A. & Yusoff Y.S. 2024. Examining the sufficiency of private pension funds in Malaysia using Monte Carlo simulation. *Semarak International Journal of Fundamental and Applied Mathematics* **1**(1): 38–48.

Saidi N.A.N., Yusuf M.M. & Basah M.Y.A. 2017. Assessing the adequacy of contribution rates towards employees' provident fund in Malaysia. *AIP Conference Proceedings* **1830**(1): 040006.

Symeonidis G., Tinios P. & Xenos P. 2021. Enhancing pension adequacy while reducing the fiscal budget and creating essential capital for domestic investments and growth: Analysing the risks and outcomes in the case of Greece. *Risks* **9**(1): 8.

The Star. 2020. A smarter way to invest for your future. https://www.thestar.com.my/business/business-news/2020/04/22/a-smarter-way-to-invest-for-your-future (12 February 2025).

The Edge. 2024. EPF able to increase domestic investments, says CEO Ahmad Zulqarnain. https://theedgemalaysia.com/node/715348 (12 February 2025).

Villanueva-García J., Moral-Arce I. & García Villalba L.J. 2025. A microsimulation model for sustainability and detailed adequacy analysis of the retirement pension system. *Mathematics* **13**(3): 443.

Wadsworth M., Findlater A. & Boardman T. 2001. Reinventing annuities. https://sias.org.uk/media/1173/reinventing-annuities.pdf (12 February 2025).

Wettstein G., Munnell A.H., Hou W. & Gok N. 2021. The value of annuities. *SSRN Electronic Journal*.

Yu Y., Sun L. & Zhang Y. 2019. Research on estimation of replacement rate of occupational annuity. *Proceedings of the 5th Annual International Conference on Management, Economics and Social Development,* pp. 465-470.

Yuh Y. 2011. Assessing adequacy of retirement income for U.S. households: A replacement ratio approach. *The Geneva Papers on Risk and Insurance–Issues and Practice* **36**(2): 304–323.

Faculty of Computer and Mathematical Sciences
Universiti Teknologi MARA (UiTM)
40450 Shah Alam
Selangor, MALAYSIA
E-mail: syairahsaat@gmail.com

Research Interest Group of Actuarial Risk and Takaful
Faculty of Computer and Mathematical Sciences
Universiti Teknologi MARA (UiTM)
40450 Shah Alam
Selangor, MALAYSIA
E-mail: syazreen@uitm.edu.my, norazliani@uitm.edu.my*

Received: 4 July 2025
Accepted: 14 March 2026

*Corresponding author