BAREKENG: Journal of Mathematics and Its Applications
September 2025 Volume 19 Issue 3 Page 1737-1746
P-ISSN: 1978-7227 E-ISSN: 2615-3017
https://doi.org/10.30598/barekengvol19iss3pp1737-1746

ESTIMATION OF BENEFIT RESERVES IN ENDOWMENT INSURANCE USING THE INDONESIAN MORTALITY TABLE IV AND ZILLMER METHOD

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Article History:

Received: 14th October 2024
Revised: 19th January 2025
Accepted: 24th March 2025
Published: 1st July 2025

Keywords:

Benefit Reserve;
Endowment;
Insurance;
Mortality Table;
Premium;
Zillmer Method.

ABSTRACT

This study focuses on determining the benefit reserves for endowment life insurance using the Zillmer method, an extension of the prospective reserve approach. Benefit reserves are crucial as they represent the funds insurance companies must set aside to cover future claims. Traditionally, reserves can be calculated retrospectively or prospectively. Still, the Zillmer method introduces an innovative approach by incorporating a Zillmer rate and time to account for loading costs, particularly at the beginning of the policy period. This research's novelty lies in applying the Zillmer method using the most recent Indonesian Mortality Table (TMI) IV, which provides updated and accurate life expectancy data for calculating reserves. The study reveals that the reserve values calculated using the Zillmer method are initially lower than those derived from the conventional prospective method due to the inclusion of the Zillmer rate. However, as the policy progresses, the reserve values gradually align with the prospective reserves after the Zillmer time period concludes. This study not only applies the Zillmer method in a local context with updated mortality data but also demonstrates how insurance companies can manage reserves more effectively, particularly in the early years of the policy.

How to cite this article:

W. H. Sadli and D. P. Sari., "ESTIMATION OF BENEFIT RESERVES IN ENDOWMENT INSURANCE USING THE INDONESIAN MORTALITY TABLE IV AND ZILLMER METHOD," *BAREKENG: J. Math. & App.,* vol. 19, no. 3, pp. 1737-1746, September, 2025.

Journal homepage: *https://ojs3.unpatti.ac.id/index.php/barekeng/*
Journal e-mail: *barekeng.math@yahoo.com; barekeng.journal@mail.unpatti.ac.id*

Research Article · Open Access

1. INTRODUCTION

In human life, the future is uncertain because no one can predict precisely the risks that will occur. Risk is the possibility of unwanted events that can cause asset losses [1]. Various risks can arise related to health, material assets, and life safety. One common way to reduce the impact of these risks is to participate in an insurance program [2], [3] Life insurance is a form of protection provided by insurance companies to the insured, where the company will provide financial compensation to the insured's heirs in the event of death. This insurance is essential to ensure that when the risk occurs, the family or heirs of the insured still get a stable financial guarantee [4]. Several types of life insurance products are based on the protection period, namely whole life insurance, term life insurance, pure endowment life insurance, and endowment insurance [5]. Endowment insurance is an insurance product that combines life protection with a savings element, thus providing benefits when the insured dies and when he is still alive at the end of the policy period [6]. Premiums are contributions paid by the insured in return for the protection the insurance company provides. The insurance company will use part of this premium to generate interest during the policy period [7]. In life insurance management, the company faces greater losses at the end of the policy period due to the increasing mortality rate of older insureds. However, at the beginning of the policy period, the company usually experiences greater profits because the premium paid is higher than the costs incurred [8]. Insurance companies allocate the premium into a benefit reserve to manage the excess premium at the beginning of the policy and prepare for future benefit payments. The benefit reserve is the accumulation of the difference between premiums paid and benefits expected to be provided. It is essential to ensure that insurance companies fulfill their obligations in the future [9], [10].

An insurance claim is a request from the insured to the insurance company to fulfill the promise of protection provided in the policy [11]. However, in some cases, the number of claims submitted by the insured exceeds the predicted estimate, which causes losses for the insurance company. Insurance companies need adequate reserves to deal with this situation [12]. In life insurance, benefit reserves can be calculated using actuarial methods, where the two primary methods often used are the retrospective method and the prospective method. The prospective method estimates reserves based on the present value of expected future benefits by deducting premiums accrued by the insured [13], [14]. This method allows insurance companies to consider factors that have not yet occurred, such as the risk of death or extension of the policy period, thus providing a more accurate estimate.

Although many previous studies have discussed the calculation of premium reserves using actuarial methods, including the Fackler [3], [8], New Jersey [15], [16], Canadian [13], [17], and Zillmer [7], [18] methods, the novelty of this study lies in the use of the Indonesian Mortality Table (TMI) IV, the latest and most relevant mortality table to the current condition of the Indonesian population. TMI IV provides more accurate information on mortality rates in Indonesia, essential in estimating benefit reserves on life insurance policies. Mortality tables are an important tool in life insurance because they provide data on life expectancy and mortality risk in various age groups. Most of the previous studies used mortality tables that are older or not specific to the Indonesian population. Therefore, the results of premium reserve calculations based on these tables may not be appropriate when applied to the context of the insurance market in Indonesia. Therefore, the results of premium reserve calculations based on these tables may not be appropriate when applied to the context of the insurance market in Indonesia. By incorporating TMI IV into the calculation of benefit reserves using the Zillmer method, this study aims to provide more accurate estimates that align with the current reality of the Indonesian population. This method is suitable for premium reserve calculation because it balances the company's income from premiums and the costs incurred to acquire new policies. Combining the Zillmer and TMI IV methods provides a new approach to calculating premium reserves that can more accurately reflect the risks and liabilities of insurance companies in Indonesia.

The novelty of this research lies in the use of the TMI IV and the modification of the benefit reserve calculation method relevant to the conditions of the Indonesian insurance market. This research contributes to actuarial development in Indonesia, especially in providing more accurate and appropriate information on Indonesia's demographic conditions. Accurate reserve calculations are essential for insurance companies to ensure they can meet future claim payment obligations while maintaining the company's financial stability. With this research, insurance companies can utilize the results of more relevant benefit reserve calculations, thus assisting in risk management and premium reserve decision-making. In addition, this research also opens up opportunities to update the reserve calculation method used by the insurance industry so that it is more in line with market conditions and the population in Indonesia. Thus, this study has significant novelty in the

use of TMI IV, which is more up-to-date and relevant to Indonesian conditions, as well as the adjusted Zillmer method for calculating endowment insurance benefit reserves.

2. RESEARCH METHODS

There are several concepts needed before formulating a prospective annual premium reserve using the Zillmer method for life insurance, is:

2.1 Life Annuity

An annuity is a payment of a certain amount made at intervals and for a certain length of time on an ongoing basis [19]. Based on the payments, life annuities are divided into annuity due and annuity-immediate [20]. In this study, an initial n-year life annuity will be used, namely:

$$\ddot{a}_{x:\overline{n}|} = \frac{N_x - N_{x+n}}{D_x} \tag{1}$$

To simplify the calculation, a commutation table is used where x is the age of the policyholder, l_x is the number of people living at age x, d_x is the number of people who died at age x years, and ω is the highest age of the policyholder, hence the commutation symbols [10] are:

$$D_x = v^x l_x \tag{2}$$

$$N_x = D_x + D_{x+1} + \cdots + D_\omega \tag{3}$$

$$C_x = v^{x+1} d_x \tag{4}$$

$$M_x = C_x + C_{x+1} + \cdots + C_\omega \tag{5}$$

2.2 Insurance Premiums

The premium is the amount of money paid by the policyholder to the insurance company in a predetermined manner and is a condition for obtaining insurance benefits [21]. Premiums are divided into two types, namely net premiums and gross premiums [6]. A "net premium" is a premium that is calculated without regard to the cost factor [10]. The net premium paid annually is called the annual premium. The annual premium for endowment life insurance with the age of the insured x, the coverage period n, and the premium payment period m years ($_mP_{x:\overline{n}|}$) is paid at the beginning of the year:

$$_mP_{x:\overline{n}|} = \frac{A_{x:\overline{n}|}}{\ddot{a}_{x:\overline{m}|}}$$

where

$$A_{x:\overline{n}|} = \frac{M_x - M_{x+n} + D_{x+n}}{D_x} \tag{6}$$

So that

$$_mP_{x:\overline{n}|} = \frac{M_x - M_{x+n} + D_{x+n}}{N_x - N_{x+m}} \tag{7}$$

If $m = n$ then $P_{x:\overline{n}|}$.

The gross premium is the total amount received by the insurance company from the policyholder which exceeds the net premium. The difference, known as the loading or cost, covers administrative expenses, agent commissions, policy acquisition, and, in some cases, company profits. While some funds may generate interest if invested, reserves are primarily set aside to cover future claims. Additionally, the company allocates part of the loading for operational, marketing, and underwriting expenses. The gross premium (P_k) is the sum of the net premium (P) and costs (S). So that it can be expressed mathematically, is:

$$P_k = P + S \tag{8}$$

2.3 Premium Reserve

The premium reserve is the amount of money the company has in the coverage period. The calculation of the annual premium reserve is based on the net premium amount. Benefit reserves are divided into two categories, namely prospective and retrospective reserves [10]. In this study, prospective reserves are used where these reserves refer to the future [22]. The prospective reserve value is a method of calculating benefit reserves, which is the difference between future compensation values and future cash premium values for each policyholder. If x is a policyholder's age, n is the coverage period, m is the insurance payment period, and t is the prospective reserve year, then the prospective reserve is ${}^{m}_{t}V_{x:\overline{n}|}$ with a benefit of 1 for endowment life insurance.

$${}^{m}_{t}V_{x:\overline{n}|} = A_{x+t:\overline{n-t}|} - {}_{m}P_{x:\overline{n}|}\ddot{a}_{x+t:\overline{m-t}|} \tag{9}$$

2.4 Zillmer Method

August Zillmer, a Berlin actuary, discovered the Zillmer method. This method requires the gross premium as the basis for its calculation, which is the sum of the net premium and costs incurred by the company [10]. August Zillmer believes that the loading in the first year is greater than the standard loading in subsequent years, so the net premium is smaller.

For example, in endowment life insurance, if P_1 is the first year's premium and P_2 is the premium starting from the second year to h, where h is Zillmer time and $h < n$ [23]:

$$\begin{aligned} P_1 &< P_2 \\ P_2 - P_1 &= \alpha \end{aligned} \tag{10}$$

The value of α is defined as the Zillmer level or Zillmer rate. Assume that the premium for an n-year endowment life insurance policy with payment at the beginning and age x is P_i, where $i = 1, 2, 3, \ldots n$. Then the total premium income is [24]:

$$P_{x:\overline{n}|}\ddot{a}_{x:\overline{h}|} = \sum_{i=0}^{n} P_i$$

$$P_{x:\overline{n}|}\ddot{a}_{x:h|} = P_1 + P_2 + P_3 + \cdots + P_n$$

Because the amount of premium earned in the second year and so on is the same, then:

$$P_{x:\overline{n}|}\ddot{a}_{x:h|} = P_1 + P_2\left(\ddot{a}_{x:\overline{h}|} - 1\right)$$

$$P_{x:\overline{n}|}\ddot{a}_{x:\overline{h}|} = P_1 - P_2 + P_2\ddot{a}_{x:\overline{h}|}$$

By using **Equation (10)**, it is obtained:

$$P_{x:\overline{n}|}\ddot{a}_{x:\overline{h}|} = -\alpha + P_2\left(\ddot{a}_{x:\overline{h}|}\right) \tag{11}$$

So that the value of P_2 is obtained:

$$P_2 = P_{x:\overline{n}|} + \frac{\alpha}{\ddot{a}_{x:\overline{h}|}} \tag{12}$$

Because the premium is paid for m years, **Equation (12)** becomes the amount of reserves from the second to the nth year:

$$P_2 = {}_mP_{x:\overline{n}|} + \frac{\alpha}{\ddot{a}_{x:\overline{h}|}} \tag{13}$$

Using the prospective method, the annual premium is denoted as P_2, so that:

$${}_t^mV_{x:\overline{n}|}^{(hZ)} = {}_t^mV_{x:\overline{n}|} - \frac{\alpha}{\ddot{a}_{x:\overline{h}|}} \cdot \ddot{a}_{x+t:\overline{h-t}|} \tag{14}$$

The research begins with analyzing theories relevant to the discussed issues based on a comprehensive literature review. Following this, a commutation table is developed using data from the TMI IV. The next step involves calculating the future benefits of endowment life insurance, which is then followed by determining the annual premium required for this type of insurance. Additionally, the study includes calculating the initial term life annuity value with payment limits. Furthermore, the research examines the prospective reserves in endowment life insurance, ensuring an accurate assessment of financial obligations. Subsequently, the study calculates the initial term life annuity value using the Zillmer time method. Finally, the research determines the prospective benefit reserves using the Zillmer method for endowment life insurance, providing a comprehensive evaluation of financial sustainability within the insurance framework.

3. RESULTS AND DISCUSSION

This research will present a case study as a simulation of calculating insurance benefit reserves for endowment life insurance with a program that will help form the calculation, namely with Microsoft Excel and using the TMI IV. In the case example, a 40-year-old man wants to buy an insurance product from an insurance company, with death benefits that will be received if the insured dies during the coverage period, which is IDR. 300,000,000. If the insured survives the coverage period, he will get the final benefit of the contract (savings) of IDR. 30,000,000 with a coverage period of 15 years and a premium payment of 12 years. The interest rate is 5%, the Zillmer time is 10 years, and the Zillmer rate is $\alpha = 0.015$. To prevent losses to the company, the premium paid must be allocated as reserves. In this case, the amount of reserves will be calculated using the Zillmer method and compared with calculations using the primary method, namely the prospective method.

3.1 Expected Present Value of Benefit

The expected present value of endowment insurance is an essential part of financial planning for life insurance. The insurance company will pay the amount to the insured or their beneficiaries at the end of the policy period or if the insured dies during the coverage period. Endowment insurance offers a combination of life protection and savings, which means that if the insured dies during the coverage period, the beneficiary will receive an amount of money that matches the value of the benefit at that time. On the other hand, if the insured is still alive until the end of the policy period, they will receive the full benefit promised at the beginning of the contract. We modified **Equation (6)** to $A_{x+t:\overline{n-t}|} = \frac{M_{x+t}-M_{x+n}+D_{x+n}}{D_{x+t}}$ and show the result in **Table 1**.

Table 1. Expected Present Value of Benefit

t	$A_{x+t:\overline{n-t}\rceil}$	t	$A_{x+t:\overline{n-t}\rceil}$
1	25,543,742	9	30,325,500
2	26,292,674	10	30,599,840
3	27,017,666	11	30,762,103
4	27,712,336	12	30,803,476
5	28,364,537	13	30,703,635
6	28,964,236	14	30,440,857
7	29,498,152	15	30,000,000
8	29,954,990		

At the beginning of the policy period, the value of future benefits tends to be lower than at the end of the coverage period. This is because the risk of death of the insured is still relatively low and the premium paid is just starting to accumulate. For example, in the first year of the policy term ($t = 1$), the future benefit value could be around IDR 25,543,742. The beneficiary would pay this amount if the insured dies that year. However, this benefit value continues to increase over time. Two main factors influence this increase. First, the risk of death increases with the age of the insured. The older the insured, the greater the risk of death, so the insurance company must provide greater benefits. Second, the premiums paid by the insured during the policy period are accumulated by the insurance company and kept in reserves, which are used to pay future benefits. In the last year of the policy period, the value of future benefits reaches its peak, which is the amount the insurance company promised from the beginning. For example, at the end of the coverage period ($t = 15$), the value of future benefits may reach IDR 30,000,000. This is the full amount that will be paid to the insured if they are still alive when the policy ends, or to the beneficiary if the insured dies beforehand.

The advantage of endowment insurance is the certainty of the benefit value. The insured is not only protected during the policy period but also has the guarantee of getting the full benefit at the end of the period, either in the form of life protection or long-term savings. This gives the insured a sense of security as they know the promised benefits will remain at the end of the coverage period. Overall, the value of future benefits in endowment insurance is important in ensuring that the insured or their beneficiaries are compensated accordingly. This value continues to increase yearly until it reaches the promised amount, providing stable and measurable financial protection. At the end of the policy term, the full benefit value will be paid out, ensuring that the insurance company fulfills its commitment to the financial protection of the insured. The value of future compensation for endowment life insurance is obtained at $(x + t)$; details of the calculation results can be seen in **Table 1**.

3.2 Temporary Life Annuity Due

The temporary life annuity due value is an important component in calculating of the value of benefits in a life insurance policy. This value describes annuity payments made over a certain period, where payments are made at the beginning and at the end of a predetermined period. Based on the calculation results, this annuity value decreases over time. By modifying **Equation (1)** to $\ddot{a}_{x+t:\overline{m-t}\rceil} = \frac{N_{x+t}-N_{x+n}}{D_{x+t}}$, the results presented in **Table 2** were obtained.

Table 2. Calculation Results for The Initial Futures Life Annuity Value

t	$\ddot{a}_{x+t:\overline{m-t}\rceil}$	T	$\ddot{a}_{x+t:\overline{m-t}\rceil}$
1	8.614484054	9	2.846252081
2	8.010668848	10	1.947542857
3	7.377136906	11	1
4	6.712170081	12	0
5	6.014016429	13	
6	5.280664859	14	
7	4.509941705	15	
8	3.699385473		

In a temporary life annuity paid at the beginning of the period (due), payments are made at the beginning of each period until a predetermined time limit. In this case, the payment limit is set for some time. At the beginning of the period, the annuity value is higher because payments are still being made. However, as the end of the period approaches, the annuity value starts to decrease. This decrease reflects that fewer payments must be made as the coverage period ends.

At the beginning of the payment period (e.g., at $t = 1$), the life annuity value is still temporarily high because the insured still has many payment periods. However, the value of the annuity will continue to decrease over time, showing that as the end of the annuity period approaches, the remaining payments decrease; hence, the value decreases. At $t = 11$, the value of the temporary annuity reaches 1, which means that in the 11th period, only one more payment is made at the beginning of the period. This is the last annuity payment made before the annuity period ends. Thus, the annuity value at $t = 11$ reflects the one payment remaining before the end of the contract. At $t = 12$, it can be seen that the annuity value becomes 0. This is due to the fact that annuity payments have already been made at the beginning of each period, including at $t = 11$. Therefore, at $t = 12$, which is the end of the annuity period, no more payments are made. This is because the last payment was made at the beginning of the 11th period, so there is no longer a payment obligation at time $t = 12$.

This decrease in annuity value illustrates the nature of a temporary life annuity paid at the beginning of the period, where payments are made up to a certain time limit and then stopped. In this scenario, when the last payment has been made at the beginning of the period before time $t = 12$, then at the end of the period, there is no longer a payment obligation, so the annuity value reaches zero. Overall, this temporary life annuity impairment reflects the characteristics of an annuity product that is structured over a period of time. Payments are made regularly at the beginning of each period until the predetermined time limit is reached. The declining annuity value indicates the remaining payment obligation decreases as the end of the coverage period approaches. Finally, at the end of the period, no payment obligation remains.

3.3 Prospective Reserve Method

In calculating the prospective reserve value for endowment life insurance, it is important to understand that this reserve is a fund set aside by the insurance company to ensure the payment of promised benefits to the insured at the end of the coverage period. Prospective reserves are calculated based on the value of future benefits to be paid and premiums paid by the insured. **Table 3** shows the results of calculating the prospective reserve value with a coverage period of 15 years obtained from **Equation (9)**.

Table 3. Prospective Reserve Method

t	${}^{m}_{t}V_{x:\overline{n}\rceil}$	t	${}^{m}_{t}V_{x:\overline{n}\rceil}$
1	2,316,164,014	9	22,651,036,245
2	4,693,187,117	10	25,348,602,164
3	7,126,396,540	11	28,065,763,401
4	9,614,043,262	12	30,803,475,948
5	12,148,703,976	13	30,703,634,882
6	14,725,768,045	14	30,440,857,143
7	17,337,815,314	15	30,000,000,000
8	19,980,188,441		

In the first year of the coverage period, the resulting prospective reserve value is IDR 2,316,164,014. This value reflects the amount of funds the insurance company has set aside in the first year to cover the obligation to pay insurance benefits in the future. This prospective reserve is needed because although the insurance company receives premiums from the insured, most of the new benefits will be paid at the end of the coverage period or if a claim occurs during the policy period. Over time, the value of this prospective reserve will continue to increase every year. This is due to several factors. First, the longer the coverage period, the closer the insurance company is to when benefit payments will be due. Therefore, the company must ensure sufficient reserves are prepared to pay the benefits. Second, as the age of the insured increases, the risk of death also increases, so insurance companies need to allocate more funds in anticipation of benefit payments.

An increase in the prospective reserve value from year to year indicates that the insurance company is gradually accumulating sufficient funds to fulfill its financial obligations. For example, in the first year, the reserve value is still relatively low because the premium paid by the insured is just starting to be collected, and the risk of claims is still low. However, as time passes, the premiums collected get bigger, and the insurance company gets closer to when they have to pay the full insurance benefits. At the end of the coverage period, the insurance company has prepared the money promised to the insured. The prospective reserve value at the end of the coverage period must include the entire amount of benefits paid, according to the initial agreement. This means that the insurance company needs to carefully calculate the amount of premium received and the value of the promised benefits and ensure that the funds that have been reserved are sufficient to pay claims that may arise.

This prospective reserve serves as a mechanism to maintain the insurance company's financial stability and protect the insured's interests. By carefully managing these reserves, insurance companies can ensure they can fulfill their benefit payment obligations when the time comes, both at the end of the coverage period and in the event of a prior claim. Overall, the prospective reserve values shown in **Table 3** provide an overview of how insurance companies prepare funds to pay endowment insurance benefits. The increase in the value of reserves every year indicates the continuous accumulation of funds to fulfill the obligation to pay benefits promised to the insured so that insurance companies can maintain financial stability and meet their commitments to the insured.

3.4 Zillmer Time Limit

Based on the Zillmer time limit, the value of the temporary life annuity due is calculated using Microsoft Excel. This annuity value shows the payments made at the beginning of each period but will decrease over time. The data in **Table 4** resulted from an adjustment of **Equation (1)**, setting $x = x + t$ dan $n = h - t$.

Table 4. Annuities with Zillmer Time Limits

t	$\ddot{a}_{x+t:\overline{h-t}\rceil}$	t	$\ddot{a}_{x+t:\overline{h-t}\rceil}$
1	7.393997703	9	1
2	6.726680081	10	0
3	6.02603031	11	
4	5.290080921	12	
5	4.516780274	13	
6	3.703804778	14	
7	2.848623364	15	
8	1.9484		

In **Table 4**, it can be seen that the temporary annuity value from the first year to the 10th year continues to decrease. This decrease is due to the Zillmer time limit set for 10 years, so annuity payments are made within that period. In the early years, the annuity value was higher because many payment periods were still left. However, as the end of the payment period approaches, the annuity value lowers, reflecting the fewer payments remaining.

At the end of the 10th year, the annuity value reaches 0, according to the Zillmer time limit; no more annuity payments are made after the 10th year. All annuity payment obligations have been met at this point, so no further payments need to be made. Overall, the decrease in annuity value over this period illustrates how the Zillmer method of calculating a temporary life annuity works. This method ensures that all payments are made within the set period, with the annuity value gradually decreasing until it reaches zero.

3.5 Prospective Reserves Using the Zillmer Method

Reserves for endowment life insurance premiums can be calculated using the Zillmer method in Microsoft Excel with **Equation (14)**, as shown in **Table 5**. This premium reserve is a fund set aside by the insurance company to guarantee the payment of benefits to the insured at the end of the coverage period. In **Table 5**, it can be seen that the life insurance premium reserve calculated using the Zillmer method in the first year is IDR 2,316,164.001. This value reflects the amount of funds the insurance company prepares to

cover the obligation to pay insurance benefits in the future. The value of this reserve will continue to increase over time during the coverage period.

Table 5. Calculation of Benefit Reserves with the Zillmer Method

t	${}_t^m V_{x:\overline{n}\rceil}^{(hZ)}$	t	${}_t^m V_{x:\overline{n}\rceil}^{(hZ)}$
1	2,316,164,001	9	22,651,036,243
2	4,693,187,104	10	25,348,602,164
3	7,126,396,529	11	28,065,763,401
4	9,614,043,252	12	30,803,475,948
5	12,148,703,968	13	30,703,634,882
6	14,725,768,038	14	30,440,857,143
7	17,337,815,309	15	30,000,000,000
8	19,980,188,437		

The increase in premium reserves reflects the insurance company's strategy to ensure that they have sufficient funds to fulfill their benefit payment obligations at the end of the coverage period. The Zillmer method allows insurance companies to include an initial cost component in the premium calculation, so in the early years, premium reserves may be lower but will gradually increase. When the coverage period ends, the premium reserves that have been accumulated will be sufficient to pay the promised compensation to the insured. Thus, the Zillmer method helps insurance companies prepare themselves financially to fulfill their obligations efficiently and on time.

4. CONCLUSIONS

The Zillmer method in calculating life insurance reserves assumes that the cost burden in the first year of the policy is greater than the standard burden. Based on the case described, this method takes 10 years to reach equilibrium, seen at the end of the 10th year when the annuity value reaches 0. As a result, in the early years, the benefit reserve value calculated using the Zillmer method was smaller than the conventional reserve due to the use of most of the premium in the first year to cover the initial costs of the policy, such as administration fees and agent commissions. However, over time, the value of this reserve will continue to increase and stabilize after 10 years. When the reserve reaches stability, the Zillmer method calculation result will be the same as the conventional prospective reserve. The Zillmer method lowers initial premiums by spreading acquisition costs, while the traditional method fully accumulates reserves. This makes the Zillmer method more flexible for insurance companies and affordable for policyholders, although the total cost may be higher in the long run.

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