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Net Single Premium on Critical Illness Insurance with Multi-State Model

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ABSTRACT

The chances of someone getting a disease or suffering from a critical illness are very large, especially when they get older. The chances of getting a critical illness will be higher. A guarantee of the future is indispensable if a person suffers from a critical illness at any time and requires considerable costs to undergo treatment. Insurance is one of the right choices and is beneficial for people with critical illnesses. In this study, the calculation of Critical Illness insurance premiums was carried out to determine the value of premiums that must be paid by a person when suffering from a critical illness. The critical illnesses used include cancer, heart disease, stroke, kidney failure, diabetes mellitus, and hypertension. Health insurance that protects insureds suffering from critical illnesses is Long Term Care insurance with the Annuity as A Rider Benefit product. The multi-state model is used to determine the probability of a person suffering from a critical illness. The benefits obtained are in the form of death compensation and treatment costs when the insured is diagnosed with a critical illness. The data used are data on the prevalence of critical illnesses and the percentage of deaths due to critical illnesses. In this study, we will compare the amount of premium that must be paid by the insured with different interest rates, gender, coverage period, and age. The higher the age at the beginning of following the insurance, the higher the premium. The higher the interest rate during the payer's period, the lower the premium.

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1. INTRODUCTION

Human activities in everyday life cannot be separated from the name of risk. A risk is an event that is uncertain to occur and may result in an event that causes losses. Such losses can be in the form of physical losses, financial losses, and even death. Humans cannot avoid risks but they can be minimized in many ways. One way is to follow insurance [1]. In Indonesia, many insurance companies offer various types of insurance products, the type of insurance that covers unexpected financial losses due to the death of a person is life insurance [2].

Life insurance is an agreement between an insurance company and a customer to realize an effort to reduce the impact of financial losses due to the occurrence of a death event [3]. Life insurance consists of several products, term life insurance, whole life insurance, and endowment life insurance [4]. In this study, term life insurance was used to protect life insurance within a certain period. Term life insurance provides liability if the insurance participant dies at a period according to the agreed contract [5]. The insured will pay a sum of money at the beginning of the period to the insurance company that has been agreed between the two parties and is usually referred to as a premium. Term life insurance premiums are differentiated into single premiums and annual premiums [6].

Life insurance is very important for families who depend on the income of the breadwinner because when the insured follows life insurance and in the future dies, the transfer of inheritance will get a certain amount of the sum insured from the insurance company. In this study, the calculation of term life insurance premiums with critical illness benefits and death benefits will be discussed. These critical illnesses include cancer, heart disease, stroke, diabetes mellitus, hypertension, and kidney failure. One actuarial calculation application is Long Term Care insurance, one of its products being Annuity as A Rider Benefit [7]. Long Term Care Insurance is insurance with medical care benefits or for people with chronic diseases or body disabilities, this insurance will provide protection to the insured for a long period [8].

The probability of change from one state to another depends only on the current state and does not depend on the previous state is an assumption of the Markov Chain model. The Markov Chain model is used to determine the value of the probability of transition from healthy status to critically ill status, healthy status to death, or critically ill to deceased status with a multi-state model. Based on this description, the net single premium value of term life insurance will be calculated to determine the amount of premium that must be paid for the prospective insured.

2. RESEARCH METHODS

2.1 Stochastic Process

A stochastic process is written with the symbol $\{X(t), t \in T\}$ where t is the subset, so it is necessary to know the law of chance of each random variable that is a member of that set. In other words, $\{X(t), t \in T\}$ can be fully described when for n and each $t_0, t_1, \dots, t_n$. Thus, its odds that can be expressed as:

$$Pr[X(t_n) = X_n | X(t_{n-1}) = X_{n-1}, \dots, X(t_0) = X_0] \quad (1)$$

This suggests that the process will be in a state of X_n in the future. If the state of X_{n-1} at the time $(n + 1)$ at the time of one step earlier, is in the state of X_{n-2} at the time of the previous two steps, then a kind of estimate of what opportunities will occur in the process in the future. In simplifying the stochastic process, it is necessary to add assumptions to the relationship between $X(t_0), X(t_1), \dots, X(t_n)$.

2.2 Markov Chain

A stochastic process $\{Xn, n \geq 0\}$ with state space $S = \{0,1,2, \dots\}$ is called Discrete Markov Chain if for all i and j in S.

$$P(Xn + 1 = j | Xn = i, Xn - 1, \dots, X0) = P(Xn + 1 = j | Xn = i) \quad (2)$$

Discrete Markov chains are said to be homogeneous against time if all $n = 0,1,2, \dots$

$$P(Xn + 1 = j | Xn = i) = P(X1 = j | X0 = i) \quad (3)$$

Equation (2) represents the probability of an event in the step to $(n + 1)$ depends only on the nth event or the previous step and does not depend on the previous steps. **Equation (3)** states that the odds of one step depend on the states i and j, and do not depend on the time at which the process occurs (homogeneous time) **[9]**.

2.3 Multi-State Model

Critical illness insurance is modeled in the multi-state form **[10]**. The condition of a person in a healthy status will move to the status of illness or death. A multi-state model requires an opportunity that can estimate the possibility of moving from one state to another within a certain time. If a person is in a state of suffering from a critical illness, then it will transition from a critically ill status to a deceased status, then the chances of that transfer depend on the current status and do not depend on the previous status. A multi-state model is used for stochastic processes where one can move around on a limited number of states **[11]**. The simple model form of the multi-status model with three statuses, namely healthy, sick, and dead statuses which can be seen in **Figure 1**:

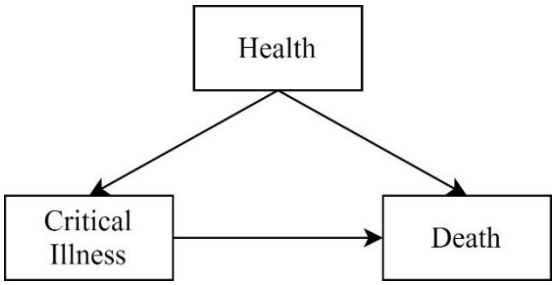

Figure 1. Multi-state model for critical illness insurance

2.4 Premiums Annuity as A Rider Benefit

Annuity as A Rider Benefit is one of the products of long-term care insurance that provides compensation for medical care costs for a period of time and death benefits if the insured dies either dies of an illness he suffers from or dies without experiencing illness first **[12]**. In the Annuity as a Rider Benefit product, there is no transition from sick status to healthy status (no assumption of recovery).

In assessing the parameters of intensity and transition opportunities, data is needed that presents the number of people transitioning from one status to another per unit of time. This study considered 6 types of critical illnesses, namely cancer, heart, stroke, kidney failure, diabetes mellitus, and hypertension. So, there are 14 statuses, namely healthy (H), cancer (C), heart disease (J), stroke (S), kidney failure pain (K), diabetes mellitus pain (M), hypertension pain (Y), died of other (D), died of cancer (CD), died of heart disease (JD), died of a stroke (SD), died of kidney failure (KD), died of diabetes mellitus (MD), died of hypertension (YD).

The value of LTC insurance's net single premium based on Annuity as A Rider Benefit is as follows **[13]**:

$$P\left(A_{x:n\rceil}^{LTC}\right) = c\sum_{e=1}^{n-1} v^{e}\ {}_{e-1}p_x^{11}q_{x+e-1}^{1} + \left(\sum_{e=1}^{n-1} v^{e}\ {}_{e-1}p_x^{11}p_{x+e-1}^{12}\ddot{a}_{x+e-1\rceil}^{22} + CD\right) + \left(\sum_{e=1}^{n-1} v^{e}\ {}_{e-1}p_x^{11}p_{x+e-1}^{13}\ddot{a}_{x+e-1\rceil}^{33} + JD\right) + \left(\sum_{e=1}^{n-1} v^{e}\ {}_{e-1}p_x^{11}p_{x+e-1}^{14}\ddot{a}_{x+e-1\rceil}^{44} + SD\right) + \left(\sum_{e=1}^{n-1} v^{e}\ {}_{e-1}p_x^{11}p_{x+e-1}^{15}\ddot{a}_{x+e-1\rceil}^{55} + KD\right) + \left(\sum_{e=1}^{n-1} v^{e}\ {}_{e-1}p_x^{11}p_{x+e-1}^{16}\ddot{a}_{x+e-1\rceil}^{66} + MD\right) + \left(\sum_{e=1}^{n-1} v^{e}\ {}_{e-1}p_x^{11}p_{x+e-1}^{17}\ddot{a}_{x+e-1\rceil}^{77} + YD\right) \quad (4)$$

3. RESULTS AND DISCUSSION

3.1. Critical Illness Prevalence

In health sciences, prevalence and mortality are the most frequently used measures to describe events that occur in a population. This study used data from 6 types of critical illnesses, namely cancer, heart, stroke, kidney failure, diabetes mellitus, and hypertension which are shown in Table 1 as follows [14]:

Table 1. Prevalence of Critical Illness

Types of Diseases	Prevalence (%)
Kidney Failure	0.38
Diabetes Mellitus	1.50
Heart	1.50
Cancer	1.79
Hypertension	8.36
Stroke	10.90

***Data source**: RISKESDAS 2018*

3.2 Chance of Death from Critical Illness

This study used the Indonesian Mortality Table (TMI) 2019 as a chance of death for each critical illness. According to the Ministry of Health and the World Health Organization (WHO) [15], the number of deaths from each critical illness which are shown in **Table 2** as follows:

Table 2. Death Percentage of Each Disease

Types of Diseases	Prevalence (%)
Kidney Failure	2.93
Diabetes Mellitus	6.70
Heart Disease	12.40
Cancer	13.50
Hypertension	14.40
Stroke	21.00

***Data source**: Ministry of Health and WHO*

In calculating critical illness insurance premiums, data on the mortality prevalence of each disease at each age is needed. This study used residents aged 18-75 years to calculate mortality prevalence data. Then calculated, the chances of death from critical illness at each age, which are shown in **Table 3** and **Table 4** as follows:

Table 3. Chances of Death Critical Illness for Male

Age	Cancer	Heart Disease	Stroke	Kidney Failure	Diabetes Mellitus	Hypertension
18	0.000058	0.000050	0.000090	0.000013	0.000029	0,000062
19	0.000063	0.000055	0.000099	0.000014	0.000031	0,000068
20	0.000066	0.000057	0.000103	0.000014	0.000033	0,000071
⋮	⋮	⋮	⋮	⋮	⋮	⋮
75	0.002735	0.002356	0.004255	0.000594	0.001357	0.002917

Table 4. Chances of Death Critical Illness for Female

Age	Cancer	Heart Disease	Stroke	Kidney Failure	Diabetes Mellitus	Hypertension
18	0.000034	0.000029	0.000053	0.000007	0.000017	0.000036
19	0.000035	0.000030	0.000055	0.000008	0.000017	0.000037
20	0.000036	0.000031	0.000057	0.000008	0.000018	0.000039
⋮	⋮	⋮	⋮	⋮	⋮	⋮
75	0.002353	0.002027	0.003660	0.000511	0.001168	0.002510

3.3 Premium Value with Interest, Age, Gender, and Coverage Period Varies

The calculation of premiums is carried out based on interest rates, age, gender, and varying coverage periods in order to estimate the appropriate amount of premiums with the benefits and circumstances of a policyholder. The calculation is done using Excel software. The following is presented in **Table 5** with variations in the coverage period of 5 years and 10 years:

Table 5. Net Single Premium Comparison

Age (year)	Interest (%)	Net Single Premium (IDR)			
		Male		Female	
		Coverage Period			
		5 year	10 year	5 year	10 year
25	3.75	2,034,482	11,626,313	1,528,326	8,621,134
	5.00	1,982,697	11,093,335	1,489,481	8,227,894
	6.00	1,942.859	10,694,610	1,459,596	7,933,632
35	3.75	4,178,893	29,077,438	3,014,289	19,013,264
	5.00	4,073,388	27,689,845	2,938,865	18,123,755
	6.00	3,992,222	26,653,402	2,880,829	17,458,869
40	3.75	7,123,886	49,421,153	4,604,498	30,421,014
	5.00	6,942,829	47,083,128	4,488,445	28,991,644
	6.00	6,803,560	45,336,042	4,399,161	27,923,336
50	3.75	33,305,339	112,507,138	20,246,609	72,052,675
	5.00	32,218,951	107,500,562	19,583,673	68,778,250
	6.00	31,390,267	103,750,105	19,078,048	66,327,531

4. CONCLUSIONS

Based on the results and discussion of the calculation of a single net premium using a multi-state model, it can be concluded that:

1. The calculation of a single net premium on Long Term Care insurance is based on a multi-status model to determine the transfer of a person's status over time. A person from healthy status can move to the status of being exposed to a critical illness, from a healthy status to a status of death and from a status of being exposed to a critical illness to a status of death.
2. Premium calculation shows that the older a person is at the beginning of participating in insurance, the more expensive the premium value will be. This is due to the chances of death of a person or developing a critical illness at an increasing age.
3. The premium value for men is more expensive than the premium value for women. This is because the chances of getting a critical illness and the chance of death of a man are greater than the woman.
4. An increase in the interest rate will result in a cheaper premium value because the interest rate is a discounted variable.
5. The longer the insurance protection period, the more expensive the premium value will be.

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