# TITLE PAGE

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# 1. Product introduction

## 1.1 Product Description

Asteroid Insurance Co is a major international insurance company. Since our founding in 1996, we have provided a comprehensive range of financial services to clients in over 80 countries and territories throughout the world, including property liability insurance, life insurance, and pension products. We help commercial and personal clients secure their assets, manage risk, and plan for retirement with a wide range of products and services.

Asteroid Pension Insurance provides you with the most appropriate retirement plan adapted to your needs, giving you with the most secure financial safety for your happiness in elder years, based on your various needs. This gives you and your children the assurance that you will be able to live comfortably and respectfully in your later years.

## 1.2 Target Customer

In China, the legal retirement age for male workers is 60 years, and for female workers it is 50 years. This rule was established at the time of New China is founding (1949), based on a variety of factors including per capita life expectancy, labour conditions, and employment policies. However, since the reform and opening up, China's economy and society have undergone significant changes, and the issue of low retirement age in general has become a major concern. Therefore, our target market is people entering retirement at age 65.

## 1.3 Benefits & Premiums

### 1.3.1 Premiums

From 2022 until 2062, the product will be available. We also have three distinct product prices, ranging from 50,000 RMB to 150,000 RMB. Due to inflation and other variables, the price may change over time.

You can choose to pay in a lump sum or in installments. The all payments list below will be accepted, including cash, debt card UnionPay, Visa, MasterCard, Alipay and WeChat.

### 1.3.2 Benefits

As long as the insured is alive, benefits are paid out at the end of each year after the insured turns 65, and the insurer must pay a certain amount of annuity at the end of each year until insured dead or age 105.

### 1.4 Risk Warning

Asteroid Insurance Product Plan's "Asteroid's (2022) Whole Life Insurance" is a universal insurance product, and the settlement interest rate in excess of the minimum guaranteed interest rate is unclear.

# 2. Mortality table development

## 2.1 Past & Future Mortality rate

### 2.1.1 Past mortality rate

We require precise figures to determine the Mortality Rate. The SOA website will provide Mortality and Other Rate Tables, which will be utilised by large corporations to create their products, so its correctness is guaranteed. The website, however, only provides data from 2010 to 2013. And the website just gives us the death rate; we must convert it to the survival rate for each year， as well as the accumulate probability of survival from the initial value to that age. Formula (2.2.1) & (2.2.2)
Therefore, we must design things for 2022. As a result, we must forecast and organise raw data for the future.

### 2.1.2 Future Mortality rate

Depending on medical conditions and way of living, life expectancy differs to some extent from country to country. Although we do not have access to the most recent death figures. The website[1] provides information on life expectancy in China and other nations. On macrotrends, we can find life expectancy and its trends in China and other nations. Because of their genetic similarities, the Japanese area can be used as a primary reference for predicting death rates in China. Because of China's rapid economic development, its life expectancy will progressively catch up with that of other industrialised countries, allowing us to make a life expectancy prediction.
After that, by tweaking the mortality improve factor, the life expectancy matches our projection data perfectly. Therefore, we can use the formula (2.2.3) to get the life expectancy.
The anticipated mortality improvement rate can be used to calculate the projected mortality rate between 2013 and 2022. By adding together all the t_p_x of all ages, which is the probability that a person aged (x) will live through till time of (x+t), life expectancy for 2012, 2013, and 2022 Formula (2.2.4)
As a result, the rate at which life expectancy is increasing may be clearly seen. In comparison to the anticipated life expectancy improvement rate, the relevant mortality improvement rate can be altered until the result equals the value we produced in the previous stage.

[1] https://www.macrotrends.net/countries/CHN/china/life-expectancy

## 2.2 Related formulas

### 2.2.1

$$p_x = 1 - q_x$$

### 2.2.2

$$tPx = \prod_{t=0}^{n} 1Px$$

### 2.2.3

$$E(x) = \sum_{t=0}^{\omega} tpx$$

### 2.2.4

$$q_{x\,(t)} = q_{x(t+n)} \times (1 - past\ mortality\ imp\ rate)^n$$

# 3. Discount curve development

## 3.1 Interpolation Method

We don't have direct access to the original data; the first issue is that, because we need to calculate price for each age, we require the discount rate for each year rather than the initial data, which contains distinct age intervals.
As a result, we must utilise the interpolation method to produce an acceptable estimate for years where we do not know the exact interest rate. Specifically, we should weight the two known data and add them based on the position of the unknown data.
Formula (3.4.1)

## 3.2 Discount & Zero-Coupon Curve

### 3.2.1 Zero Coupon Curve

The first step should be to convert the nominal one-year coupon rate to a half-year effective interest rate. We can get the recursive formula using the bootstrapping method. Formula (3.4.2)

### 3.2.2 Discount Curve

We have all years zero coupons rate. And we can convert all interest rates to discount rates. Formula (3.4.3)

## 3.3 Liquidity premium & Profit Margin

### 3.3.1 Liquidity premium

Any sort of additional compensation required to stimulate investment in assets that cannot be rapidly and efficiently converted into cash at fair market value is known as a liquidity premium. Customers can get a liquidity premium to compensate for the fact that they won't be able to access their money after they acquire the annuity.
The value of the zero rate with liquidity premium can be estimated by adding the original zero rate and a liquidity premium of 0.5 percent, which is a spread that can be earned reliably over the government bond curve without taking credit risk and can represent payment for annuity liquidity. Formula (3.4.4).
Using the same way convert it into discount rate. (3.4.3)

### 3.3.2 Profit Margin

Of course, as a company's product, we also require a portion of the area for the company's profit margin. If profit margin is taken into consideration, the zero rate should be calculated by subtracting the profit margin from the Liquidity Premium.
Formula (3.4.5)
Using the same way convert it into discount rate. (3.4.3)

## 3.4 Related formulas

### 3.4.1

$$R_t = R_a + \frac{(R_b - R_a) \times (t - a)}{b - a}, a \le t \le b$$

### 3.4.2

$$\mathbf{z[k]} = \left(\frac{\mathbf{1} - \frac{\mathbf{i[k]}}{\mathbf{2}} * \sum_{\mathbf{m=0.5}}^{\mathbf{k-0.5}} \mathbf{v[m]}}{\mathbf{1} + \frac{\mathbf{i[k]}}{\mathbf{2}}}\right)^{-\frac{\mathbf{1}}{\mathbf{k}}} - \mathbf{1}$$

### 3.4.3

$$\boldsymbol{v[k] = (1 + z[k])\text{^} - k}$$

### 3.4.4

$$\boldsymbol{z[k](lp) = z[K] + LP}$$

### 3.4.5

$$\boldsymbol{z[k](LP\&PM) = z[K] + LP - spread}$$

# 4. Expense loads

## 4.1 Premium before expense

We already have data on life expectancy with liquidity premium and profit margin in Chapter 3, which is utilised to calculate net and gross reserves. At the issue of an insurance contract, where premiums have been determined using the equivalence principle. And so we write Formula (4.4.1)
The gross premium reserve (at a particular policy duration t) is the actual premium payable by the policyholder. Formula (4.4.2)
The net premium reserve (at a particular policy duration t) is a theoretical net premium. This is found by solving the equation of value for the net premium using the reserve basis. It takes no account of the size of the actual premium payable or of future expenses. Formula (4.4.3)

## 4.2 Expense Classification & calculation

### 4.2.1 Expense Classification

We must examine the numerous costs associated with the creation of a product in order to properly price it and reap the rewards. We previously examined spread and liquidity in step 3, but we may also need to consider the five charges listed below.
1. Expenses associated with product and system development. People must be employed while we design and manufacture items (as we are doing now)
2. Commission. Profits are also required by the salesman.
3. The cost of issuing the policy. Expenses incurred in the underwriting and issuance of debt and equity instruments. Audit fees, investment banking fees, and other costs of issuance are included.
4. The cost of policy maintenance (annual). Any expense made by a person or a company to keep their assets in excellent functioning order.
5. The rate of inflation, as well as the annual increase in its expenses as a result of inflation.

### 4.2.2 Inflation rate

The inflation is the first factor we need to consider before calculating the expense loading. For some fees that need to be paid every year, such as maintenance fee, we need to take into account the impact of inflation rate on it. Analyzing the data of China from 2018-2022, we can find that the inflation rate of China fluctuates from -0.5 to 4.5. We take the middle value of 2%


### 4.2.3 Expense calculation

To begin, we'll need to gather data on current per capita premiums in China as a benchmark and reference for pricing our own company's products. Second, we should use the annual growth rate of major life insurance companies' policies as a benchmark for future price regulations. It should be highlighted that the total sum assured is too enormous to calculate because it is the multiplication of the average yearly policy price and the number of policies sold. As a result, for convenience of calculation, the unit is transformed to a million.
For the Initial Product Development Expenses as well as Policy Issuance Expense. They are all just being charged at the beginning time. The former one is a certain amount of money. We should divide by the gender ratio Formula (4.4.4) The later one is the amount of money being charged per policy. We should accumulate the value. Formula (4.4.5)
In terms of policy maintenance expense, it should be charged annually and the inflation also an important factor should be considering. Formula (4.4.6)
Commission is percentage of the price of total premium rather than certain amount of money. Therefore, we should put it into the final stage when we calculate the expense loads. Formula (4.4.7)

## 4.4 Related formulas

### 4.4.1

$$\boldsymbol{Rerserve} = \boldsymbol{E}[\boldsymbol{L_t}] = \boldsymbol{E}[\boldsymbol{Benefits} - \boldsymbol{premiums}]$$

#### 4.4.2

$$\begin{aligned} &Gross\ reserve \\ &= EPV(Future\ benefit\ payments) \\ &+ EPV(Future\ expense\ payments) \\ &- EPV(Future\ gross\ premium\ payments) \end{aligned}$$

#### 4.4.3

$$\begin{aligned} Net\ reserve &= EPV(Future\ benefit\ payments) \\ &- EPV(Future\ net\ premium\ payments) \end{aligned}$$

#### 4.4.4

$$Total\ \ Ex = ratio\ of\ Female * Female\ \ Ex + \ ratio\ of\ Male * Male\ Ex$$

#### 4.4.5

$$Ex = fee * number\ of\ policy$$

#### 4.4.6

$$Ex = fee * number\ of\ policy * gross\ premium * inflation\ facor$$

#### 4.4.7

$$Premium\ Expense\ Load = \frac{pv(loading\ premium)}{pv(all\ premium)} + commission$$

# 5. GAAP reserves

GAAP Reserves means the policy and claim and related liabilities established in accordance with generally accepted accounting principles in the United States. To begin, we must set aside funds at a rate based on the mortality rate, which should be neither too low nor too high to cover the benefits due at the end of each year, nor too high to reduce the company's profitability by having too many liquid assets. We employ an 80 percent factor for accounting reserves. The GAAP mortality improvement assumption of 1% per year for all years is outdated.
Second, we apply the government discount curve for GAAP. As a result, there is no additional liquidity premium and no profit margin reduction.
Based on Formula (4.4.2), we should accumulate present value of all future cashflow to get the GAAP reserves that we need.

## 5.1 The Classification of cash flow

Identical tastes Part 4 entails calculating all of the expenditures associated with the new mortality rate. But not all costs are incurred at the same time or in the same cash flow direction. As a result, we must classify the various costs into various categories, with the cash flow timing being the first consideration,

### 5.1.1 Beginning of year

When addressing the cash flow at the start of the year, First and foremost, we must consider the gross premium, which is the amount of money an insurer must pay at the start of the year. Because this cash flow is going into the company, it has a negative worth. The acquisition charge is the same as the commission fee. However, the premium, which is the money that the firm should pay out, is not in the same direction as these two cash flows.

### 5.1.2 End of year

At the end of each year, the firm is compelled to pay a set amount of premium to the survival insurer (annuity benefit). Similarly, maintenance costs are paid at the end of each year to ensure that our product remains in good working order. It is the sum of money that the corporation should pay out.

### 5.1.3The different

When calculating the present value of all the different cash flows, there is a one-year difference between the discount rate that occurs at the beginning of the year and the discount rate that occurs at the end of the year; for example, the discount rate at the end of 2022 is the same as the discount rate at the beginning of 2023.  Formula (5.4.1)

## 5.2 Cashflow for a single average size policy

Following the examination of cash flow timing, the cash flow direction is the next consideration,

### 5.1.1 Inflow

This part is very simple, only the premium is the company's income and that income occurs at the beginning of each year. We provide three different price policies. So we should figure out the average price per policy, Formula (5.4.2) and the expense loading factor should be took into account. Formula (5.4.3)

### 5.1.2 Outflow

By contrast, the outflow cash flow is the money that the company should pay out. For commission, acquisition, they are only charged at the begging of purchase year. Formula (5.4.4)
Commission depends on the price of premium selves. Differently, the acquisition cost is same for policy with different price.
Therefore, the maintenance cost has to be paid annually (inflation should be considered). Formula (5.4.5)
The last part is the benefits that the company should pay out for elderly alive. We can just simply use the Formula (5.4.2)

## 5.3 Negative Reserve & Amortization Factor

### 5.3.1 Negative reserve

When we calculate the average reserve of each insurance policy per year, we discover that the first year's reserve is negative, which is contrary to the law. However, this is reasonable because the premium received from the sale of the product in the first year is potentially the firm's whole income, implying that the corporation will collect a large sum of money in the first year for future reserves and investments, resulting in a negative value.

### 5.3.2 Amortization Factor

Amortization is a method of accounting that involves reducing the carrying value of an asset over a predetermined period of time.

In this instance, we must account for the amortisation of the annuity value before updating the GAAP reserves using the steps below. The sum of successive GAAP mortality rates adjusted by a year-end discount factor, also known as K-factor amortisation, is the annuity value. Formula (5.4.6)
It is clear to see how the annuity value falls over time, which makes sense given the elderly's greater mortality rate.
The initial annuity value, the first year of K-factor amortisation, is divided by the minimum value between the GAAP reserve amount and zero to arrive at the K-value. The reserve balance should vary by an amount equal to the k-value per unit reduced from the annuity value in order to maintain a constant ratio. Furthermore, because the annuity value drops over time, the profit reserve must be decreased from the initial GAAP reserve to reflect this decrease.
As a result, by adding the profit reserve to the initial GAAP reserve, the final GAAP reserve may be computed. There can be no profits reported at the time of product issuance under GAAP standards, hence there can be no positive GAAP reserves. The reserve looks to be positive in the computation table, but it is actually a loss.

## 5.4 Related formulas

### 5.4.1

$$\boldsymbol{BOY\ v[k+1] = EOY\ \ v[k]}$$

### 5.4.2

$$\boldsymbol{Avarage\ price = \frac{\sum_{n=1}^{3} p_1 * number\ of\ policy(n)}{total}}$$

### 5.4.3

$$\boldsymbol{Avarage\ price * Premium * (1 + expense\ loading\ factor)}$$

### 5.4.4

$$\boldsymbol{commission = Premium * commison\ factor}$$

### 5.4.5

$$\boldsymbol{nth\ years' maintenance = maintenance * (1 + inflation)\text{^}n}$$

### 5.4.6

$$\boldsymbol{Annuity\ value_{time\ k}} = \sum_{\boldsymbol{k}}^{\boldsymbol{41}} [\boldsymbol{v(k)_{EOY}} \times \boldsymbol{tpx}]$$

# 6. Solvency requirements

## 6.1 Risk Classification

### 6.1.1 Operational Risk

Due to economic slump or the company's own mismanagement at the start of a product's selling. This frequently results in lower-than-expected sales of their items. This is a consideration when calculating GAAP reserves.

### 6.1.2 Interest Rate Risk

In real life, interest rates on cash flows from assets and liabilities are frequently not the same. At the same time, unforeseen occurrences may cause interest rates to fluctuate.

### 6.1.3 Expenses

The number of claims isn't quite as precise as the estimate. There are times when there are too many claims, much beyond the original mortality chart. As a result, we require a stressed mortality table. Any corporation must consider the insured person's credit risk as well as the profit in-investment risk. All of these considerations must be made by insurance firms. These hazards, however, are not taken into account in the pricing criteria.

### 6.1.4 Credit risk / investment risk (do not need consider)

Any business must consider the insured person's credit risk as well as the profit in-investment risk. All of these considerations must be made by insurance firms. These hazards, however, are not taken into account in the pricing criteria.

## 6.2 Risks Calculation (per policy still alive)

### 6.2.1 Mortality Risk Required Capital

We need to consider the unpredictable mortality improve formula (6.3.1) to our products.
Then, using the stressed mortality table to get another cashflow table. It should be noted that all cash flows at the beginning of the year are irrelevant with mortality rates

so for ease of calculation we can use the raw data (GAAP). Moreover, adjusting from the amount of people alive basically on the CROSS & GAAP basis, how much CROSS reserve is going be holding at a point subtracted by how much GAAP reserve is going be holding at the point is the mortality risk capital required.
In other words, Mortality risk capital required is the difference between those 2 future reserve balances, adjusting from the actual number of lives we expected to be in place as shown in formula
we can use the shortcut to get the cash flow of end of the year. (*ratio of t_p_x) Formula (6.3.2)

### 6.2.2 Interest Rate Risk Required Capital

As 6.1 motioned, there are two risk factors that we should consider, duration mismatch assumption and interest rate shock.
We assuming that the interest rate sensitivity of liability and asset is 1.0 year. For the interest rate shock, we need a high level of assurance of long-term survival. Capital held to cover 99.5% or higher of risk is common. We will use 99.5% tile and 1 year sensitivity to get 2% move of interest rate.
According to the theory that Bond value change = duration x Interest rate change, the interest rate changed throughout the duration mismatched can be generated by duration mismatched we assumed multiplied by interest rate shock of 2%.
The risk capital necessary, as shown in formula (6.3.4), is the interest rate that varies over time depending on the amount of assets the company actually holds. Formula

### 6.2.3 Operational Risk Required Capital

Based on GAAP reserves capital as a percentage of total assets. "Operational risk," as defined by the International Association of Insurance Supervisors (IAIS), is the risk of a negative change in the value of capital resources as a result of operational events such as inadequacy or failure of internal systems, personnel, procedures, or controls, as well as external events.
It is the risk that arises as a result of deficiencies or inadequacies in the management of otherwise quantifiable risk, as well as unplanned external occurrences that can affect an insurer.
The required operational risk capital is also dependent on the assets that the company actually owns, which is the GAAP reserve plus cash inflows at the start of the year. The operational risk rate is considered to be 1% under a 99.5 percent percentage tail.
As a result, the required operational risk capital can be produced as illustrated in formula(6.3.5).

### 6.2.4Adding Up Risk

Risk correlation is calculated in the same way that variance is calculated using the matrix multiplication function.
Those required capitals adjusted by the tax rate charged, taking the worst case tax factor into account, can be generated as CROSS risk capital required based on the Mortality Risk, Interest Rate Risk, and Operational Risk correlation matrix.
The key to maintaining a lower risk capital required to real quantity of assets is to minimise the mortality improvement rate under solvency assumptions.
Because the mortality improvement rate under solvency assumptions is greater than GAAP assumptions, the mortality rate lowers in the solvency case, resulting in lower CROSS cash flow at year's end, CROSS reserve, and Mortality risk capital required, and hence a lower ratio.

## 6.3Related formulas

### 6.3.1

$$\boldsymbol{t_{px} *= t_{px} * (1 + imp\ factor)\text{^}years}$$

### 6.3.2

$$\boldsymbol{cash\ flow(GPPA) * \frac{t_{px}}{t_{pxGAAP}} - cash\ flow(CROSS)\frac{t_{px}}{t_{pxCROSS}}}$$

### 6.3.3

$$\textbf{Interest rate risk captial required} = \textbf{In\_rate shock} \times \textbf{duration mismatched} \times (\textbf{Reserve}_{\textbf{GAAP}} - \textbf{E}[\textbf{Cashflow}_{\textbf{BOY}})$$

### 6.3.4

$$\textbf{Operational risk} = \textbf{Operational risk rate of } 1\% \times (\textbf{Reserve}_{\textbf{GAAP}} - \textbf{ExpectedCF}_{\textbf{GAAP}})$$

# 7. Pricing metrics

## 7.1 Duration

The traditional measure of duration (D) for a bond is the Macaulay duration formula (7.5.1)
The cash flows previously obtained cannot be directly derived present value, due to the different risk rate. For example, government bonds generally hold lower yield rate than others, which means we should use different discount rate to calculated present value. Alternatively, we can also use same discount rate by changing the cash flow separately instead.
If the expected cash flows will fluctuate, the implied duration can easily measure the price change of the bonds. For example, there were to be a change in yield of 1%, then the bonds' price would be change by the implied duration (7.5.2)

## 7.2Balance sheet strain

For our product, GAAP reserves as well as CROSS requirements are also part of money we should hold, but they are holding totally different risk. The CROSS is the real risk the company should take. To be conservative we need to keep a higher ratio rate than the policy requires (150%)

### 7.2.1 Redundant reserve

The GAAP reserves exceeding cash flow is not a real loss or a risk but instead an accounting timing issue. The cumulative profit over all methods always equates in the end (The default risk free rate is 4%. Because from the discount curve table the zero-coupon rate with liquid is around 4%. Therefore, the GAAP reserves company borrow from shareholder is 1% higher than risk free rate.). So, we should be able to borrow this at a lower cost.
There is a shortcut (t_p_x ratio to GAAP) to simplify the calculation. We can use the ratio rate to get all cash we need from the GAAP & CROSS table. Formula (7.5.3)

### 7.2.2 Solvency requirement

The amount of CROSS requirement, also called as solvency requirement, is the amount of the assets exceeding liabilities, that can be developed by multiplying target capital ratio of 150% by CROSS risk capital required calculated in previous step. That requires company to hold 150% of minimum solvency requirement as capital requirement,

which can be borrowed from stock investors at cost of capital excess over risk-free rate, since this is capital that is put at risk and expected to ear a return.

### 7.2.3 Cost of Capital

The cost of capital can be developed by the cost rate and amount of capital at certain assumption. Formula (7.5.4)

## 7.3 Market consistent value (MCVNB)

A metric for appraising insurance companies is market consistent value. Specifically, we should consider the entire asset and obligation. The present value of an asset or liability can be calculated in two ways. The first method, which is difficult to calculate, is to use a larger return rate for the higher risk segment. Another option is to remove the excess return from the forecasted cash flows and discount them at the risk-free rate. We went with the latter option.
The market normally compensates for risk by requiring a greater necessary rate of return than the risk-free rate when it comes to assets. To arrive at a market value, this greater interest rate is utilised to discount larger predicted cash flows. The rate of insurance liabilities would be affected by changes in mortality. The ultimate rate will be lower than the risk-free rate (we can afford to pay less). As a result, to obtain the MCVNB, we should adjust the cash flow somewhat higher than the original.
The risk-free curve is used for discounting, and the cash flows are adjusted to cover the risk we assume. We can use the solvency system (CROSS) as a proxy for the risk we assume and charge our customers the cost of capital we must carry to bear the risk because it is a risk-based system.

## 7.4Cash flow pay-back period

As a company, we must invest money for the product. And we certainly need know how many years for our capital to be returned. Another word, the time when the cumulative profit exceeds the balance sheet strain (GAAP+CROSS). It is the time that company can start to share our profit with shareholders in the form of dividends.

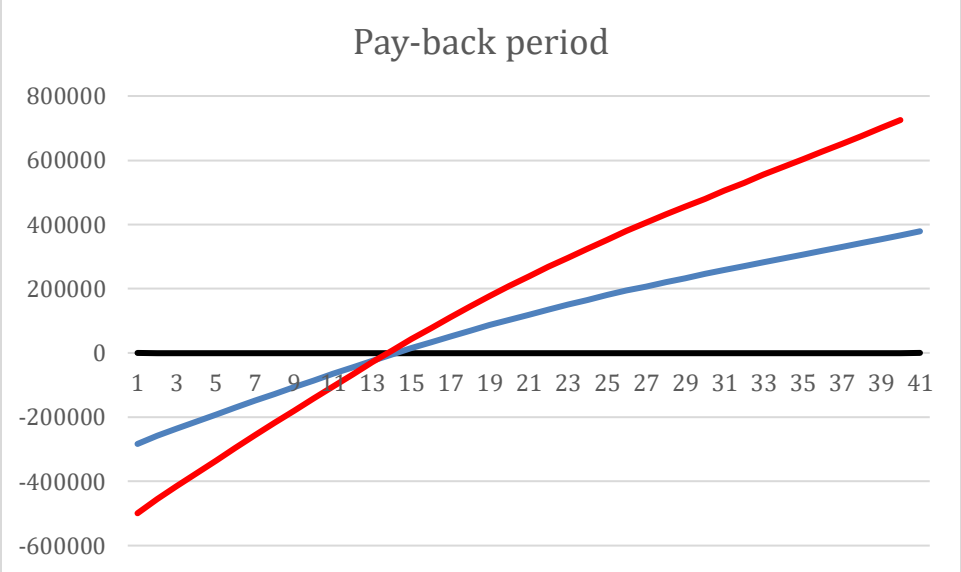
### 7.4.1 Cumulative profit

The first thing we should aware is the tax rate should be considering. We only need the cumulative profit after tax. The cumulative profit is the sum of each years' net cash flow. The asset is the source for selling the product (EOY CF) minus the best estimate reserve, which can use risk free rate. For the redundant reserve we can use the cost of

financing balance sheet strain due to the higher risk, same for the solvency requirement. Formula (7.5.5)

### 7.4.2pay-back period

When the interest that we earn exceed the cost of capital, the company begin to make profit. We can easily use the cumulative profit minus GAAP-Best Est Res and Target CROSS Cap. When the outcome from negative to positive, it is the pay-back year. We can notice that the payback period is 15years both for male and female.




## 7.5Related formulas

### 7.5.1

$$\boldsymbol{duration} = \frac{\sum \boldsymbol{t} * \boldsymbol{CF(t)/(1+r)\hat{}t}}{\boldsymbol{P}}$$

### 7.5.2

$$\boldsymbol{implied\ duration} = \frac{\boldsymbol{PV(CFlp) - PV(CFlp\&1bp)}}{\boldsymbol{PV(CFlp) * 0.0001}}$$

### 7.5.3

$$\boldsymbol{new\ CF = GAAP\ CF * (\frac{Expected\ tpx}{GAAP\ tpx})}$$

### 7.5.4

$$\boldsymbol{Capital = Capital\ exxcess\ over\ rf * T_{CROSS} + balance\ sheet\ strain * Redundant}$$

### 7.5.5

$$\mathbf{profit} = \sum_{0}^{n} \mathbf{assets} * \mathbf{spread} - \mathbf{GAAP} * \mathbf{balance\ sheet\ strain} + \boldsymbol{cross} * \boldsymbol{return}\ (\boldsymbol{assets\ acking\ surplus})$$

# 8.Sensitivity analysis

## 8.1 Methodology Overview

First, we need to consider whether a change in value has a positive or negative impact on the MCVNB, which is an extremely macro concept, and also to consider to what extent the data changes to the point where the MCVNB becomes zero, i.e., the product has no benefit. If the impact is significant, we need to also focus on it as an important aspect of risk.

Secondly, in the actual excel calculation, we need to make sure that the other values do not change while changing a certain value, thus ensuring a single variable. To achieve this, the following method is used.

Our MCVNB calculations are differentiated by gender, however, in the final sensitivity analysis we need the complete profit, so first, we need a weighted average of the MCVNB for both genders. Formula (8.3.1)

For the convenience of the narrative we choose a sample. A change in any of the data in the Control table will have a greater or lesser impact on the final MCVNB, so we start our analysis from top to bottom. In GAAP & CROSS we have calculated the change in mortality rate as part of the risk. Therefore, we need to consider the three cases of increasing and decreasing data and how much the MCVNB will change to zero, so we need to replicate the data four times (the first time for the original value as a comparison item), and we need to pay attention to the first excel format all in the form of formulas (planning solutions must use formulas rather than values). Note that at this

point, the formula of MCVNB needs to be changed to value to prevent it from continuing to change with subsequent changes in data.
In the end, we can find no solution by planning. This is because the impact of interest rate on MCVNB is too small. At the same time, the risk-free interest rate will not produce large changes.

| Rate of change | 6-month interest rate | MCVNB% |
|---|---|---|
| 0.00% | 1.99% | 1.47% |
| 10.05% | 2.19% | 1.47% |
| 10.05% | 1.79% | 1.47% |
| / | no solution | 0.00% |

## 8.2 Sensitivities

According to the order from top to bottom, I have chosen the following data sets as the reference objects.

### 8.2.1Margin for non-matchable cash flows

The growth of Margin cash flows decreases MCVNB, indicating that all spot(zero) rates beyond 30 years are reduced by this amount of growth will reduce product profit, vice verse.

| Rate of change | Margin of CFs | MCVNB% |
|---|---|---|
| 0.00% | 0.50% | 1.47% |
| 40.00% | 0.70% | 1.38% |
| 40.00% | 0.30% | 1.55% |
| 442.00% | 2.71% | 0.00% |

### 8.2.2 Liquidity premium assumption

The increase in liquidity premium assumption decreases MCVNB, indicating that the greater the impact of liquidity is detrimental to our product, vice verse.

| Rate of change | Liquidity premium rate | MCVNB% |
|---|---|---|
| 0.00% | 0.50% | 1.47% |
| 40.00% | 0.70% | 1.30% |
| 40.00% | 0.30% | 1.64% |
| 228.00% | 1.64% | 0.00% |

### 8.2.3. Investment spread profit charge (most notable)

Of all the data tested, profit margin is the most sensitivity data.
This is the profit charge to the product which takes the form of a reduction in the interest rate that we can credit to policyholders.

| Rate of change | Investment charge | MCVNB% |
|---|---|---|
| 0.00% | 0.70% | 1.47% |
| 28.57% | 0.90% | 3.19% |
| 28.57% | 0.50% | -0.28% |
| 24.29% | 0.53% | 0.00% |

### 8.2.4 Commission

The growth of Commission makes MCVNB decrease, which is understandable because commission is a part of expense, and the larger its percentage, the less profit.

| Rate of change | Commission rate | MCVNB% |
|---|---|---|
| 0.00% | 3.00% | 1.47% |
| 33.33% | 4.00% | 1.41% |
| 33.33% | 2.00% | 1.51% |

| | | |
|---|---|---|
| 384.47% | 14.53% | 0.00% |

### 8.2.5. Annual inflation rate (not reflected since average policy size also ignores inflation)

The increase of annual inflation rate will make MCVNB decrease, the more powerful the inflation the smaller the benefit of the product.

| Rate of change | Annual inflation rate | MCVNB% |
|---|---|---|
| 0.00% | 2.00% | 1.47% |
| 50.00% | 3.00% | 1.46% |
| 50.00% | 1.00% | 1.47% |
| 960.50% | 21.21% | 0.00% |

## 8.3Related formulas

### 8.3.1

$$\boldsymbol{Female\ percent} * \boldsymbol{Ratio\ MCVNB(Female)} + \boldsymbol{Male\ percent} * \boldsymbol{Ratio\ MCVNB(Male)}$$

## Appendix A – Summary of assumptions

### 1.Mortality assumptions:

Factor on male annuity table：100%
Factor on female annuity table：100%
Past mortality improvement – male：2.9%
Past mortality improvement – Female 3.3%
Future improvement p/a for male: 2.75%
Future improvement p/a for female: 3%

First and foremost, assume that gender is the only factor that influences the death rate; in this scenario, both male and female elements are taken into account equally. And male and female members have different mortality rates.

Secondly, there is a disparity in average life expectancy between men and women, and we require a slightly lower improvement in mortality for males than for women. The previous data can be simply obtained from the website. Based on data from Japan and Taiwan, we may estimate that China will need at least ten years to catch up to their life expectancy. We can readily quantify the previous ten years of mortality improvement this way.

Finally, we need the future mortality rate to assess the pricing of our items because they will be used in the future. We can use around 90% of the recent mortality improvement as a reference for the future, according to historical data from China and other nations. When life expectancy gets close to the limit, the growth rate of life expectancy slows down.

### 2.Discount rate assumptions

Chinese 6-month interest rate in per annum basis2: 1.99%(6month)

Bond curve in semi-annual effective form

| | |
|---|---|
| 2.090% | 1 years |
| 2.519% | 2 years |
| 2.644% | 3 years |
| 2.783% | 5 years |

[2] (https://www.ceicdata.com/en/china/pbc--ccdc-treasury-bond-and-other-bond-yield-daily/bond-yield-treasury-bond-3-month)

2.961% 7 years
2.973% 10 years
3.298% 15 years
3.584% 20 years
3.569% 30 years

We can easily find the 6-month risk free rate for China from the upper website. However, because accurate data for each year is unavailable, we must rely on known data to make educated guesses about unknown data. The interpolated approach is a decent option.

### 3.Assumptions of making premium

Margin for non-matchable cash flows :0.5%
For thirty years, we only have a six-month zero-coupon rate. However, because our goods cover a range of 65 to 105 years old, which is more than thirty years, we can only make educated guesses about data after thirty years. We just add 0.5 percent to the original data to make insurance products less liquid and more stable.
Liquidity premium assumption: 0.5%
Treasury bonds are one of the most stable and lowest interest rate products, while the rest of the products have higher interest rates depending on liquidity. Insurance products should be less liquid and more stable we only add 0.5% to the national bonds' rate.
Investment spread profit charge: 0.7%
The investment spread profit charge is actually similar with the Liquidity premium assumption. It is a method of ensuring the profitability of an insurance policy by lowering the profit charge rates. Therefore, we take 0.5% more just exactly like the liquidity premium assumption.
Expense load profit charge: Male: 2% Female: 0.15%
This profit charge is applied to the premium expense load. Increasing the profit charge on the expense load would result in a greater expected expense load, lowering the fund's taxable portion. As a result, a higher profit charge of expense load could effectively enhance the profitability of the insurance product by subtracting the taxable amount of the product profit.
Annual inflation rate: 2%
In 2020, the average inflation rate in China ranged at around 2.4 percent compared to the previous year. This is actually much higher than the previous data. Therefore, we take the average of ten years, 2%.

### 4. Sales assumption

| | 50,000 | 100,000 | 150,000 | Avg size |
|---|---|---|---|---|
| Male | 25% | 35% | 40% | 107,500 |
| Female | 40% | 35% | 25% | 92,500 |

First of all, people of different genders and different incomes definitely have different investment tendencies for insurance, so we can not just use one data as assumption We can divide them into three categories each according to men and women and different income groups for a total of six categories. Furthermore, we can easily find the data of price of each policy per person online and we can make that assumption table.
Increasing rate of Policies sold by year:

| 2023 | 2024 | 2025 | 2026 | 2027 | 2028 |
|---|---|---|---|---|---|
| 200% | 150% | 133% | 125% | 115% | 110% |

The amount of products sold per year will increase with promotion and the growth rate will gradually slow down due to marginal effects.

## 5. GAAP reserve assumptions

Factor applied to industry mortality table: 80%
Improvement applied to industry table:1%
Following the application of GAAP, there are various assumptions that need to be made. Instead of 100%, the factor used in the industrial mortality table is considered to be 80%.
The industry table improvement rate, which is used to calculate the GAAP mortality rate and GAAP reserve, is assumed to be 1%.

## 6.CROSS assumption

Factor of mortality risk on GAAP mortality table: 90%.

The annual improvement rate of mortality risk: 1.5%.

The operation risk of GAAP reserve capital:1%.

The mismatch duration:1.

The interest rate shock: 2%

worst-case tax :2/3.

Target Capital Ratio: 150%.

CROSS Correlation matrix:

Tabel CROSS correlation matrix

| | Mort Risk | Int Rate Risk | Oper Risk |
|---|---|---|---|
| Mort Risk | 1 | 0 | 0.5 |
| Int Rate Risk | 0 | 1 | 0.25 |
| Op Risk | 0.5 | 0.25 | 1 |

Following the application of GAAP, most of these data are specified according to standards.

## Appendix B – Mortality table

| Male | original table 2012 | | | final table 2022 | | |
|---|---|---|---|---|---|---|
| Age | q_x | p_x | t_p_x | q_x | p_x | t_p_x |
| 0 | 0.00057 | 0.99943 | 0.99943 | 0.00042 | 0.99958 | 0.99958 |
| 1 | 0.00039 | 0.99961 | 0.99905 | 0.00029 | 0.99971 | 0.99929 |
| 2 | 0.00027 | 0.99973 | 0.99878 | 0.00020 | 0.99980 | 0.99909 |
| 3 | 0.00020 | 0.99980 | 0.99858 | 0.00015 | 0.99985 | 0.99895 |
| 4 | 0.00016 | 0.99984 | 0.99843 | 0.00012 | 0.99988 | 0.99883 |
| 5 | 0.00014 | 0.99986 | 0.99829 | 0.00011 | 0.99989 | 0.99872 |
| 6 | 0.00013 | 0.99987 | 0.99815 | 0.00010 | 0.99990 | 0.99862 |
| 7 | 0.00013 | 0.99987 | 0.99803 | 0.00010 | 0.99990 | 0.99853 |
| 8 | 0.00013 | 0.99987 | 0.99789 | 0.00010 | 0.99990 | 0.99843 |
| 9 | 0.00014 | 0.99986 | 0.99776 | 0.00010 | 0.99990 | 0.99833 |
| 10 | 0.00015 | 0.99985 | 0.99761 | 0.00011 | 0.99989 | 0.99822 |
| 11 | 0.00016 | 0.99984 | 0.99746 | 0.00012 | 0.99988 | 0.99810 |
| 12 | 0.00017 | 0.99983 | 0.99729 | 0.00013 | 0.99987 | 0.99798 |
| 13 | 0.00018 | 0.99982 | 0.99710 | 0.00014 | 0.99986 | 0.99784 |
| 14 | 0.00020 | 0.99980 | 0.99691 | 0.00015 | 0.99985 | 0.99769 |
| 15 | 0.00021 | 0.99979 | 0.99670 | 0.00015 | 0.99985 | 0.99754 |
| 16 | 0.00022 | 0.99978 | 0.99648 | 0.00016 | 0.99984 | 0.99738 |
| 17 | 0.00023 | 0.99977 | 0.99625 | 0.00017 | 0.99983 | 0.99721 |
| 18 | 0.00024 | 0.99977 | 0.99602 | 0.00018 | 0.99982 | 0.99703 |
| 19 | 0.00024 | 0.99976 | 0.99578 | 0.00018 | 0.99982 | 0.99685 |
| 20 | 0.00025 | 0.99975 | 0.99553 | 0.00018 | 0.99982 | 0.99667 |
| 21 | 0.00026 | 0.99974 | 0.99528 | 0.00019 | 0.99981 | 0.99648 |
| 22 | 0.00026 | 0.99974 | 0.99502 | 0.00020 | 0.99980 | 0.99628 |
| 23 | 0.00027 | 0.99973 | 0.99474 | 0.00020 | 0.99980 | 0.99608 |
| 24 | 0.00028 | 0.99972 | 0.99446 | 0.00021 | 0.99979 | 0.99587 |
| 25 | 0.00030 | 0.99970 | 0.99417 | 0.00022 | 0.99978 | 0.99565 |
| 26 | 0.00031 | 0.99969 | 0.99385 | 0.00023 | 0.99977 | 0.99542 |
| 27 | 0.00033 | 0.99967 | 0.99352 | 0.00025 | 0.99975 | 0.99517 |
| 28 | 0.00035 | 0.99965 | 0.99317 | 0.00026 | 0.99974 | 0.99491 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 29 | 0.00038 | 0.99962 | 0.99280 | 0.00028 | 0.99972 | 0.99463 |
| 30 | 0.00041 | 0.99959 | 0.99239 | 0.00030 | 0.99970 | 0.99433 |
| 31 | 0.00044 | 0.99956 | 0.99196 | 0.00033 | 0.99967 | 0.99400 |
| 32 | 0.00047 | 0.99953 | 0.99149 | 0.00035 | 0.99965 | 0.99365 |
| 33 | 0.00051 | 0.99949 | 0.99098 | 0.00038 | 0.99962 | 0.99327 |
| 34 | 0.00055 | 0.99945 | 0.99044 | 0.00041 | 0.99959 | 0.99287 |
| 35 | 0.00059 | 0.99941 | 0.98985 | 0.00044 | 0.99956 | 0.99243 |
| 36 | 0.00064 | 0.99936 | 0.98922 | 0.00048 | 0.99952 | 0.99196 |
| 37 | 0.00069 | 0.99931 | 0.98854 | 0.00051 | 0.99949 | 0.99145 |
| 38 | 0.00075 | 0.99925 | 0.98780 | 0.00056 | 0.99944 | 0.99090 |
| 39 | 0.00081 | 0.99919 | 0.98700 | 0.00060 | 0.99940 | 0.99030 |
| 40 | 0.00088 | 0.99912 | 0.98614 | 0.00065 | 0.99935 | 0.98965 |
| 41 | 0.00096 | 0.99905 | 0.98519 | 0.00071 | 0.99929 | 0.98895 |
| 42 | 0.00104 | 0.99896 | 0.98417 | 0.00078 | 0.99922 | 0.98818 |
| 43 | 0.00114 | 0.99886 | 0.98305 | 0.00085 | 0.99915 | 0.98734 |
| 44 | 0.00125 | 0.99876 | 0.98182 | 0.00093 | 0.99907 | 0.98643 |
| 45 | 0.00136 | 0.99864 | 0.98049 | 0.00102 | 0.99898 | 0.98543 |
| 46 | 0.00150 | 0.99850 | 0.97902 | 0.00111 | 0.99889 | 0.98433 |
| 47 | 0.00164 | 0.99836 | 0.97741 | 0.00122 | 0.99878 | 0.98312 |
| 48 | 0.00180 | 0.99820 | 0.97565 | 0.00134 | 0.99866 | 0.98181 |
| 49 | 0.00197 | 0.99803 | 0.97374 | 0.00147 | 0.99853 | 0.98037 |
| 50 | 0.00215 | 0.99785 | 0.97164 | 0.00160 | 0.99840 | 0.97880 |
| 51 | 0.00234 | 0.99766 | 0.96937 | 0.00174 | 0.99826 | 0.97709 |
| 52 | 0.00254 | 0.99746 | 0.96690 | 0.00190 | 0.99810 | 0.97524 |
| 53 | 0.00276 | 0.99724 | 0.96424 | 0.00206 | 0.99794 | 0.97324 |
| 54 | 0.00299 | 0.99702 | 0.96136 | 0.00222 | 0.99778 | 0.97107 |
| 55 | 0.00322 | 0.99678 | 0.95826 | 0.00240 | 0.99760 | 0.96874 |
| 56 | 0.00347 | 0.99653 | 0.95494 | 0.00258 | 0.99742 | 0.96624 |
| 57 | 0.00373 | 0.99627 | 0.95137 | 0.00278 | 0.99722 | 0.96355 |
| 58 | 0.00401 | 0.99599 | 0.94756 | 0.00299 | 0.99701 | 0.96067 |
| 59 | 0.00432 | 0.99568 | 0.94346 | 0.00322 | 0.99678 | 0.95757 |
| 60 | 0.00466 | 0.99534 | 0.93906 | 0.00347 | 0.99653 | 0.95425 |
| 61 | 0.00503 | 0.99497 | 0.93434 | 0.00375 | 0.99625 | 0.95067 |
| 62 | 0.00545 | 0.99455 | 0.92925 | 0.00406 | 0.99594 | 0.94681 |
| 63 | 0.00591 | 0.99409 | 0.92375 | 0.00440 | 0.99560 | 0.94264 |
| 64 | 0.00642 | 0.99358 | 0.91782 | 0.00478 | 0.99522 | 0.93813 |
| 65 | 0.00699 | 0.99301 | 0.91141 | 0.00521 | 0.99479 | 0.93325 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 66 | 0.00761 | 0.99239 | 0.90447 | 0.00567 | 0.99433 | 0.92796 |
| 67 | 0.00829 | 0.99171 | 0.89697 | 0.00618 | 0.99382 | 0.92222 |
| 68 | 0.00905 | 0.99095 | 0.88886 | 0.00674 | 0.99326 | 0.91601 |
| 69 | 0.00990 | 0.99010 | 0.88006 | 0.00737 | 0.99263 | 0.90925 |
| 70 | 0.01089 | 0.98911 | 0.87048 | 0.00811 | 0.99189 | 0.90188 |
| 71 | 0.01208 | 0.98792 | 0.85996 | 0.00900 | 0.99100 | 0.89376 |
| 72 | 0.01355 | 0.98645 | 0.84831 | 0.01010 | 0.98990 | 0.88474 |
| 73 | 0.01539 | 0.98461 | 0.83526 | 0.01146 | 0.98854 | 0.87460 |
| 74 | 0.01769 | 0.98231 | 0.82049 | 0.01318 | 0.98682 | 0.86307 |
| 75 | 0.02054 | 0.97946 | 0.80363 | 0.01530 | 0.98470 | 0.84986 |
| 76 | 0.02402 | 0.97598 | 0.78433 | 0.01789 | 0.98211 | 0.83466 |
| 77 | 0.02816 | 0.97184 | 0.76225 | 0.02098 | 0.97902 | 0.81714 |
| 78 | 0.03298 | 0.96702 | 0.73711 | 0.02457 | 0.97543 | 0.79706 |
| 79 | 0.03844 | 0.96156 | 0.70878 | 0.02864 | 0.97136 | 0.77424 |
| 80 | 0.04449 | 0.95551 | 0.67724 | 0.03315 | 0.96685 | 0.74857 |
| 81 | 0.05109 | 0.94891 | 0.64264 | 0.03806 | 0.96194 | 0.72008 |
| 82 | 0.05817 | 0.94183 | 0.60526 | 0.04334 | 0.95666 | 0.68887 |
| 83 | 0.06572 | 0.93428 | 0.56548 | 0.04897 | 0.95103 | 0.65514 |
| 84 | 0.07373 | 0.92627 | 0.52379 | 0.05493 | 0.94507 | 0.61915 |
| 85 | 0.08222 | 0.91778 | 0.48072 | 0.06126 | 0.93874 | 0.58122 |
| 86 | 0.09124 | 0.90876 | 0.43686 | 0.06798 | 0.93202 | 0.54171 |
| 87 | 0.10090 | 0.89910 | 0.39278 | 0.07518 | 0.92482 | 0.50099 |
| 88 | 0.11132 | 0.88868 | 0.34906 | 0.08294 | 0.91706 | 0.45943 |
| 89 | 0.12261 | 0.87739 | 0.30626 | 0.09135 | 0.90865 | 0.41746 |
| 90 | 0.13487 | 0.86513 | 0.26495 | 0.10049 | 0.89951 | 0.37551 |
| 91 | 0.14821 | 0.85179 | 0.22568 | 0.11043 | 0.88957 | 0.33405 |
| 92 | 0.16274 | 0.83726 | 0.18896 | 0.12125 | 0.87875 | 0.29354 |
| 93 | 0.17857 | 0.82143 | 0.15521 | 0.13304 | 0.86696 | 0.25449 |
| 94 | 0.19579 | 0.80421 | 0.12482 | 0.14588 | 0.85412 | 0.21737 |
| 95 | 0.21450 | 0.78550 | 0.09805 | 0.15982 | 0.84018 | 0.18263 |
| 96 | 0.23465 | 0.76535 | 0.07504 | 0.17483 | 0.82517 | 0.15070 |
| 97 | 0.25618 | 0.74382 | 0.05582 | 0.19087 | 0.80913 | 0.12193 |
| 98 | 0.27903 | 0.72098 | 0.04024 | 0.20789 | 0.79211 | 0.09659 |
| 99 | 0.30312 | 0.69688 | 0.02804 | 0.22584 | 0.77416 | 0.07477 |
| 100 | 0.32840 | 0.67160 | 0.01883 | 0.24468 | 0.75532 | 0.05648 |
| 101 | 0.35480 | 0.64520 | 0.01215 | 0.26435 | 0.73565 | 0.04155 |
| 102 | 0.38226 | 0.61774 | 0.00751 | 0.28481 | 0.71519 | 0.02971 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 103 | 0.41071 | 0.58929 | 0.00442 | 0.30600 | 0.69400 | 0.02062 |
| 104 | 0.44009 | 0.55991 | 0.00248 | 0.32789 | 0.67211 | 0.01386 |
| 105 | 1 | 0 | 0 | 1 | 0 | 0 |

| Female | original table 2012 | | | final table 2022 | | |
|---|---|---|---|---|---|---|
| Age | q_x | p_x | t_p_x | q_x | p_x | t_p_x |
| 0 | 0.00045 | 0.99955 | 0.99955 | 0.00032 | 0.99968 | 0.99968 |
| 1 | 0.00029 | 0.99971 | 0.99926 | 0.00021 | 0.99979 | 0.99947 |
| 2 | 0.00018 | 0.99982 | 0.99907 | 0.00013 | 0.99987 | 0.99934 |
| 3 | 0.00012 | 0.99988 | 0.99895 | 0.00009 | 0.99991 | 0.99925 |
| 4 | 0.00010 | 0.99991 | 0.99886 | 0.00007 | 0.99993 | 0.99918 |
| 5 | 0.00008 | 0.99992 | 0.99877 | 0.00006 | 0.99994 | 0.99912 |
| 6 | 0.00008 | 0.99992 | 0.99869 | 0.00006 | 0.99994 | 0.99907 |
| 7 | 0.00007 | 0.99993 | 0.99862 | 0.00005 | 0.99995 | 0.99901 |
| 8 | 0.00007 | 0.99993 | 0.99855 | 0.00005 | 0.99995 | 0.99896 |
| 9 | 0.00007 | 0.99993 | 0.99848 | 0.00005 | 0.99995 | 0.99891 |
| 10 | 0.00007 | 0.99993 | 0.99840 | 0.00005 | 0.99995 | 0.99886 |
| 11 | 0.00008 | 0.99992 | 0.99833 | 0.00006 | 0.99994 | 0.99880 |
| 12 | 0.00008 | 0.99992 | 0.99825 | 0.00006 | 0.99994 | 0.99875 |
| 13 | 0.00009 | 0.99992 | 0.99816 | 0.00006 | 0.99994 | 0.99868 |
| 14 | 0.00009 | 0.99991 | 0.99807 | 0.00006 | 0.99994 | 0.99862 |
| 15 | 0.00010 | 0.99991 | 0.99798 | 0.00007 | 0.99993 | 0.99855 |
| 16 | 0.00010 | 0.99990 | 0.99788 | 0.00007 | 0.99993 | 0.99848 |
| 17 | 0.00011 | 0.99990 | 0.99777 | 0.00008 | 0.99992 | 0.99841 |
| 18 | 0.00011 | 0.99989 | 0.99766 | 0.00008 | 0.99992 | 0.99833 |
| 19 | 0.00012 | 0.99989 | 0.99755 | 0.00008 | 0.99992 | 0.99825 |
| 20 | 0.00012 | 0.99988 | 0.99743 | 0.00009 | 0.99991 | 0.99816 |
| 21 | 0.00013 | 0.99988 | 0.99730 | 0.00009 | 0.99991 | 0.99807 |
| 22 | 0.00013 | 0.99987 | 0.99717 | 0.00009 | 0.99991 | 0.99798 |
| 23 | 0.00013 | 0.99987 | 0.99704 | 0.00010 | 0.99990 | 0.99788 |
| 24 | 0.00014 | 0.99986 | 0.99690 | 0.00010 | 0.99990 | 0.99778 |
| 25 | 0.00014 | 0.99986 | 0.99676 | 0.00010 | 0.99990 | 0.99768 |
| 26 | 0.00015 | 0.99985 | 0.99661 | 0.00011 | 0.99989 | 0.99757 |
| 27 | 0.00015 | 0.99985 | 0.99646 | 0.00011 | 0.99989 | 0.99747 |
| 28 | 0.00016 | 0.99984 | 0.99630 | 0.00011 | 0.99989 | 0.99735 |
| 29 | 0.00017 | 0.99983 | 0.99613 | 0.00012 | 0.99988 | 0.99723 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 30 | 0.00018 | 0.99983 | 0.99596 | 0.00013 | 0.99987 | 0.99711 |
| 31 | 0.00019 | 0.99981 | 0.99577 | 0.00013 | 0.99987 | 0.99697 |
| 32 | 0.00020 | 0.99980 | 0.99557 | 0.00014 | 0.99986 | 0.99683 |
| 33 | 0.00021 | 0.99979 | 0.99536 | 0.00015 | 0.99985 | 0.99668 |
| 34 | 0.00023 | 0.99977 | 0.99513 | 0.00017 | 0.99983 | 0.99652 |
| 35 | 0.00025 | 0.99975 | 0.99488 | 0.00018 | 0.99982 | 0.99634 |
| 36 | 0.00028 | 0.99972 | 0.99460 | 0.00020 | 0.99980 | 0.99614 |
| 37 | 0.00031 | 0.99970 | 0.99430 | 0.00022 | 0.99978 | 0.99592 |
| 38 | 0.00034 | 0.99966 | 0.99397 | 0.00024 | 0.99976 | 0.99568 |
| 39 | 0.00037 | 0.99963 | 0.99360 | 0.00027 | 0.99973 | 0.99542 |
| 40 | 0.00041 | 0.99959 | 0.99319 | 0.00029 | 0.99971 | 0.99513 |
| 41 | 0.00045 | 0.99955 | 0.99274 | 0.00032 | 0.99968 | 0.99481 |
| 42 | 0.00049 | 0.99951 | 0.99225 | 0.00035 | 0.99965 | 0.99445 |
| 43 | 0.00054 | 0.99946 | 0.99172 | 0.00039 | 0.99961 | 0.99407 |
| 44 | 0.00059 | 0.99941 | 0.99113 | 0.00042 | 0.99958 | 0.99365 |
| 45 | 0.00064 | 0.99936 | 0.99050 | 0.00046 | 0.99954 | 0.99320 |
| 46 | 0.00069 | 0.99931 | 0.98981 | 0.00050 | 0.99950 | 0.99270 |
| 47 | 0.00075 | 0.99925 | 0.98907 | 0.00054 | 0.99946 | 0.99217 |
| 48 | 0.00081 | 0.99919 | 0.98827 | 0.00058 | 0.99942 | 0.99160 |
| 49 | 0.00088 | 0.99912 | 0.98740 | 0.00063 | 0.99937 | 0.99098 |
| 50 | 0.00095 | 0.99905 | 0.98646 | 0.00068 | 0.99932 | 0.99030 |
| 51 | 0.00103 | 0.99897 | 0.98544 | 0.00074 | 0.99926 | 0.98957 |
| 52 | 0.00112 | 0.99888 | 0.98434 | 0.00080 | 0.99920 | 0.98878 |
| 53 | 0.00122 | 0.99878 | 0.98314 | 0.00087 | 0.99913 | 0.98792 |
| 54 | 0.00133 | 0.99867 | 0.98183 | 0.00095 | 0.99905 | 0.98698 |
| 55 | 0.00145 | 0.99855 | 0.98041 | 0.00104 | 0.99896 | 0.98596 |
| 56 | 0.00159 | 0.99842 | 0.97886 | 0.00113 | 0.99887 | 0.98484 |
| 57 | 0.00174 | 0.99826 | 0.97716 | 0.00124 | 0.99876 | 0.98362 |
| 58 | 0.00191 | 0.99810 | 0.97530 | 0.00136 | 0.99864 | 0.98228 |
| 59 | 0.00210 | 0.99790 | 0.97325 | 0.00150 | 0.99850 | 0.98080 |
| 60 | 0.00232 | 0.99769 | 0.97100 | 0.00166 | 0.99834 | 0.97918 |
| 61 | 0.00256 | 0.99744 | 0.96851 | 0.00183 | 0.99817 | 0.97739 |
| 62 | 0.00284 | 0.99716 | 0.96576 | 0.00203 | 0.99797 | 0.97541 |
| 63 | 0.00314 | 0.99686 | 0.96273 | 0.00224 | 0.99776 | 0.97322 |
| 64 | 0.00347 | 0.99653 | 0.95940 | 0.00248 | 0.99752 | 0.97081 |
| 65 | 0.00384 | 0.99617 | 0.95572 | 0.00274 | 0.99726 | 0.96814 |
| 66 | 0.00425 | 0.99575 | 0.95165 | 0.00304 | 0.99696 | 0.96520 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 67 | 0.00474 | 0.99526 | 0.94714 | 0.00339 | 0.99661 | 0.96193 |
| 68 | 0.00530 | 0.99470 | 0.94212 | 0.00379 | 0.99621 | 0.95828 |
| 69 | 0.00594 | 0.99406 | 0.93652 | 0.00425 | 0.99575 | 0.95421 |
| 70 | 0.00666 | 0.99334 | 0.93028 | 0.00476 | 0.99524 | 0.94967 |
| 71 | 0.00746 | 0.99254 | 0.92334 | 0.00533 | 0.99467 | 0.94460 |
| 72 | 0.00837 | 0.99163 | 0.91561 | 0.00598 | 0.99402 | 0.93895 |
| 73 | 0.00944 | 0.99056 | 0.90697 | 0.00675 | 0.99325 | 0.93262 |
| 74 | 0.01073 | 0.98927 | 0.89724 | 0.00767 | 0.99233 | 0.92546 |
| 75 | 0.01233 | 0.98767 | 0.88618 | 0.00882 | 0.99118 | 0.91730 |
| 76 | 0.01432 | 0.98569 | 0.87349 | 0.01023 | 0.98977 | 0.90792 |
| 77 | 0.01673 | 0.98327 | 0.85888 | 0.01196 | 0.98804 | 0.89705 |
| 78 | 0.01962 | 0.98038 | 0.84203 | 0.01403 | 0.98597 | 0.88447 |
| 79 | 0.02297 | 0.97703 | 0.82268 | 0.01642 | 0.98358 | 0.86995 |
| 80 | 0.02677 | 0.97323 | 0.80066 | 0.01914 | 0.98086 | 0.85330 |
| 81 | 0.03099 | 0.96901 | 0.77585 | 0.02216 | 0.97784 | 0.83439 |
| 82 | 0.03560 | 0.96440 | 0.74823 | 0.02545 | 0.97455 | 0.81316 |
| 83 | 0.04058 | 0.95942 | 0.71787 | 0.02901 | 0.97099 | 0.78957 |
| 84 | 0.04592 | 0.95409 | 0.68491 | 0.03283 | 0.96717 | 0.76365 |
| 85 | 0.05162 | 0.94838 | 0.64956 | 0.03690 | 0.96310 | 0.73547 |
| 86 | 0.05765 | 0.94235 | 0.61211 | 0.04121 | 0.95879 | 0.70516 |
| 87 | 0.06408 | 0.93592 | 0.57289 | 0.04582 | 0.95418 | 0.67285 |
| 88 | 0.07094 | 0.92906 | 0.53224 | 0.05072 | 0.94928 | 0.63872 |
| 89 | 0.07824 | 0.92176 | 0.49060 | 0.05594 | 0.94406 | 0.60300 |
| 90 | 0.08600 | 0.91400 | 0.44841 | 0.06149 | 0.93851 | 0.56592 |
| 91 | 0.09425 | 0.90575 | 0.40615 | 0.06738 | 0.93262 | 0.52779 |
| 92 | 0.10300 | 0.89700 | 0.36431 | 0.07364 | 0.92636 | 0.48892 |
| 93 | 0.11228 | 0.88772 | 0.32341 | 0.08027 | 0.91973 | 0.44967 |
| 94 | 0.12211 | 0.87789 | 0.28392 | 0.08730 | 0.91270 | 0.41042 |
| 95 | 0.13254 | 0.86746 | 0.24629 | 0.09476 | 0.90524 | 0.37153 |
| 96 | 0.14376 | 0.85624 | 0.21088 | 0.10278 | 0.89722 | 0.33334 |
| 97 | 0.15598 | 0.84402 | 0.17799 | 0.11151 | 0.88849 | 0.29617 |
| 98 | 0.16942 | 0.83058 | 0.14783 | 0.12112 | 0.87888 | 0.26030 |
| 99 | 0.18430 | 0.81570 | 0.12059 | 0.13176 | 0.86824 | 0.22600 |
| 100 | 0.20084 | 0.79916 | 0.09637 | 0.14358 | 0.85642 | 0.19355 |
| 101 | 0.21924 | 0.78076 | 0.07524 | 0.15674 | 0.84326 | 0.16321 |
| 102 | 0.23974 | 0.76026 | 0.05720 | 0.17140 | 0.82860 | 0.13524 |
| 103 | 0.26254 | 0.73746 | 0.04218 | 0.18770 | 0.81230 | 0.10985 |

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|---|---|---|---|---|---|---|
| 104 | 0.28786 | 0.71214 | 0.03004 | 0.20580 | 0.79420 | 0.08725 |
| 105 | 1 | 0 | 0 | 1 | 0 | 0 |

## Appendix C – Interest rates and discount curves

| Duration[k] | z[k] | v[k] | z[k] LP | v[k] LP | z[k] LP&PM | v[k] LP&PM |
|---|---|---|---|---|---|---|
| 0.5 | 0.01990 | 0.99020 | 0.02490 | 0.98778 | 0.01790 | 0.99117 |
| 1.0 | 0.02102 | 0.97942 | 0.02602 | 0.97464 | 0.01902 | 0.98134 |
| 1.5 | 0.02321 | 0.96617 | 0.02821 | 0.95913 | 0.02121 | 0.96901 |
| 2.0 | 0.02541 | 0.95105 | 0.03041 | 0.94184 | 0.02341 | 0.95477 |
| 2.5 | 0.02605 | 0.93773 | 0.03105 | 0.92640 | 0.02405 | 0.94231 |
| 3.0 | 0.02670 | 0.92400 | 0.03170 | 0.91063 | 0.02470 | 0.92942 |
| 3.5 | 0.02705 | 0.91081 | 0.03205 | 0.89546 | 0.02505 | 0.91704 |
| 4.0 | 0.02741 | 0.89747 | 0.03241 | 0.88021 | 0.02541 | 0.90449 |
| 4.5 | 0.02778 | 0.88401 | 0.03278 | 0.86492 | 0.02578 | 0.89179 |
| 5.0 | 0.02814 | 0.87043 | 0.03314 | 0.84957 | 0.02614 | 0.87895 |
| 5.5 | 0.02862 | 0.85626 | 0.03362 | 0.83372 | 0.02662 | 0.86547 |
| 6.0 | 0.02910 | 0.84190 | 0.03410 | 0.81777 | 0.02710 | 0.85179 |
| 6.5 | 0.02958 | 0.82739 | 0.03458 | 0.80174 | 0.02758 | 0.83791 |
| 7.0 | 0.03007 | 0.81272 | 0.03507 | 0.78564 | 0.02807 | 0.82386 |
| 7.5 | 0.03007 | 0.80073 | 0.03507 | 0.77218 | 0.02807 | 0.81249 |
| 8.0 | 0.03008 | 0.78890 | 0.03508 | 0.75893 | 0.02808 | 0.80127 |
| 8.5 | 0.03009 | 0.77723 | 0.03509 | 0.74589 | 0.02809 | 0.79018 |
| 9.0 | 0.03010 | 0.76571 | 0.03510 | 0.73306 | 0.02810 | 0.77922 |
| 9.5 | 0.03012 | 0.75435 | 0.03512 | 0.72044 | 0.02812 | 0.76841 |
| 10.0 | 0.03013 | 0.74314 | 0.03513 | 0.70801 | 0.02813 | 0.75772 |
| 10.5 | 0.03051 | 0.72937 | 0.03551 | 0.69323 | 0.02851 | 0.74440 |
| 11.0 | 0.03089 | 0.71557 | 0.03589 | 0.67848 | 0.02889 | 0.73102 |
| 11.5 | 0.03128 | 0.70176 | 0.03628 | 0.66379 | 0.02928 | 0.71760 |
| 12.0 | 0.03166 | 0.68793 | 0.03666 | 0.64915 | 0.02966 | 0.70413 |
| 12.5 | 0.03205 | 0.67409 | 0.03705 | 0.63457 | 0.03005 | 0.69064 |
| 13.0 | 0.03245 | 0.66025 | 0.03745 | 0.62006 | 0.03045 | 0.67711 |
| 13.5 | 0.03285 | 0.64642 | 0.03785 | 0.60562 | 0.03085 | 0.66356 |
| 14.0 | 0.03325 | 0.63261 | 0.03825 | 0.59127 | 0.03125 | 0.65000 |
| 14.5 | 0.03365 | 0.61881 | 0.03865 | 0.57699 | 0.03165 | 0.63644 |
| 15.0 | 0.03406 | 0.60504 | 0.03906 | 0.56281 | 0.03206 | 0.62287 |
| 15.5 | 0.03443 | 0.59177 | 0.03943 | 0.54916 | 0.03243 | 0.60979 |

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|---|---|---|---|---|---|---|
| 16.0 | 0.03479 | 0.57856 | 0.03979 | 0.53561 | 0.03279 | 0.59675 |
| 16.5 | 0.03516 | 0.56540 | 0.04016 | 0.52219 | 0.03316 | 0.58373 |
| 17.0 | 0.03554 | 0.55230 | 0.04054 | 0.50888 | 0.03354 | 0.57075 |
| 17.5 | 0.03592 | 0.53927 | 0.04092 | 0.49569 | 0.03392 | 0.55782 |
| 18.0 | 0.03630 | 0.52631 | 0.04130 | 0.48263 | 0.03430 | 0.54493 |
| 18.5 | 0.03669 | 0.51343 | 0.04169 | 0.46970 | 0.03469 | 0.53210 |
| 19.0 | 0.03709 | 0.50062 | 0.04209 | 0.45690 | 0.03509 | 0.51932 |
| 19.5 | 0.03749 | 0.48790 | 0.04249 | 0.44423 | 0.03549 | 0.50661 |
| 20.0 | 0.03789 | 0.47526 | 0.04289 | 0.43171 | 0.03589 | 0.49395 |
| 20.5 | 0.03784 | 0.46700 | 0.04284 | 0.42319 | 0.03584 | 0.48584 |
| 21.0 | 0.03779 | 0.45890 | 0.04279 | 0.41484 | 0.03579 | 0.47787 |
| 21.5 | 0.03774 | 0.45093 | 0.04274 | 0.40666 | 0.03574 | 0.47003 |
| 22.0 | 0.03769 | 0.44311 | 0.04269 | 0.39865 | 0.03569 | 0.46233 |
| 22.5 | 0.03764 | 0.43544 | 0.04264 | 0.39080 | 0.03564 | 0.45475 |
| 23.0 | 0.03760 | 0.42790 | 0.04260 | 0.38311 | 0.03560 | 0.44731 |
| 23.5 | 0.03755 | 0.42049 | 0.04255 | 0.37557 | 0.03555 | 0.44000 |
| 24.0 | 0.03751 | 0.41322 | 0.04251 | 0.36819 | 0.03551 | 0.43281 |
| 24.5 | 0.03747 | 0.40608 | 0.04247 | 0.36096 | 0.03547 | 0.42574 |
| 25.0 | 0.03743 | 0.39907 | 0.04243 | 0.35387 | 0.03543 | 0.41879 |
| 25.5 | 0.03739 | 0.39218 | 0.04239 | 0.34693 | 0.03539 | 0.41196 |
| 26.0 | 0.03735 | 0.38542 | 0.04235 | 0.34013 | 0.03535 | 0.40525 |
| 26.5 | 0.03731 | 0.37878 | 0.04231 | 0.33346 | 0.03531 | 0.39866 |
| 27.0 | 0.03728 | 0.37226 | 0.04228 | 0.32693 | 0.03528 | 0.39217 |
| 27.5 | 0.03724 | 0.36586 | 0.04224 | 0.32054 | 0.03524 | 0.38580 |
| 28.0 | 0.03721 | 0.35957 | 0.04221 | 0.31427 | 0.03521 | 0.37953 |
| 28.5 | 0.03717 | 0.35339 | 0.04217 | 0.30813 | 0.03517 | 0.37338 |
| 29.0 | 0.03714 | 0.34733 | 0.04214 | 0.30211 | 0.03514 | 0.36732 |
| 29.5 | 0.03711 | 0.34137 | 0.04211 | 0.29622 | 0.03511 | 0.36137 |
| 30.0 | 0.03707 | 0.33552 | 0.04207 | 0.29044 | 0.03507 | 0.35553 |
| 30.5 | 0.03207 | 0.38180 | 0.03707 | 0.32947 | 0.03007 | 0.40507 |
| 31.0 | 0.03207 | 0.37582 | 0.03707 | 0.32353 | 0.03007 | 0.39911 |
| 31.5 | 0.03207 | 0.36993 | 0.03707 | 0.31769 | 0.03007 | 0.39324 |
| 32.0 | 0.03207 | 0.36414 | 0.03707 | 0.31196 | 0.03007 | 0.38746 |
| 32.5 | 0.03207 | 0.35844 | 0.03707 | 0.30634 | 0.03007 | 0.38176 |
| 33.0 | 0.03207 | 0.35282 | 0.03707 | 0.30081 | 0.03007 | 0.37615 |
| 33.5 | 0.03207 | 0.34730 | 0.03707 | 0.29538 | 0.03007 | 0.37061 |
| 34.0 | 0.03207 | 0.34186 | 0.03707 | 0.29006 | 0.03007 | 0.36516 |

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| 34.5 | 0.03207 | 0.33650 | 0.03707 | 0.28483 | 0.03007 | 0.35979 |
| 35.0 | 0.03207 | 0.33123 | 0.03707 | 0.27969 | 0.03007 | 0.35450 |
| 35.5 | 0.03207 | 0.32605 | 0.03707 | 0.27464 | 0.03007 | 0.34929 |
| 36.0 | 0.03207 | 0.32094 | 0.03707 | 0.26969 | 0.03007 | 0.34415 |
| 36.5 | 0.03207 | 0.31591 | 0.03707 | 0.26483 | 0.03007 | 0.33909 |
| 37.0 | 0.03207 | 0.31097 | 0.03707 | 0.26005 | 0.03007 | 0.33411 |
| 37.5 | 0.03207 | 0.30610 | 0.03707 | 0.25536 | 0.03007 | 0.32919 |
| 38.0 | 0.03207 | 0.30130 | 0.03707 | 0.25075 | 0.03007 | 0.32435 |
| 38.5 | 0.03207 | 0.29658 | 0.03707 | 0.24623 | 0.03007 | 0.31958 |
| 39.0 | 0.03207 | 0.29194 | 0.03707 | 0.24179 | 0.03007 | 0.31488 |
| 39.5 | 0.03207 | 0.28737 | 0.03707 | 0.23743 | 0.03007 | 0.31025 |
| 40.0 | 0.03207 | 0.28287 | 0.03707 | 0.23315 | 0.03007 | 0.30569 |
| 40.5 | 0.03207 | 0.27844 | 0.03707 | 0.22894 | 0.03007 | 0.30119 |
| 41.0 | 0.03207 | 0.27408 | 0.03707 | 0.22481 | 0.03007 | 0.29676 |
| 41.5 | 0.03207 | 0.26979 | 0.03707 | 0.22076 | 0.03007 | 0.29240 |
| 42.0 | 0.03207 | 0.26556 | 0.03707 | 0.21677 | 0.03007 | 0.28810 |
| 42.5 | 0.03207 | 0.26140 | 0.03707 | 0.21286 | 0.03007 | 0.28386 |
| 43.0 | 0.03207 | 0.25731 | 0.03707 | 0.20903 | 0.03007 | 0.27969 |
| 43.5 | 0.03207 | 0.25328 | 0.03707 | 0.20526 | 0.03007 | 0.27558 |
| 44.0 | 0.03207 | 0.24931 | 0.03707 | 0.20155 | 0.03007 | 0.27152 |
| 44.5 | 0.03207 | 0.24541 | 0.03707 | 0.19792 | 0.03007 | 0.26753 |
| 45.0 | 0.03207 | 0.24156 | 0.03707 | 0.19435 | 0.03007 | 0.26360 |
| 45.5 | 0.03207 | 0.23778 | 0.03707 | 0.19084 | 0.03007 | 0.25972 |
| 46.0 | 0.03207 | 0.23406 | 0.03707 | 0.18740 | 0.03007 | 0.25590 |
| 46.5 | 0.03207 | 0.23039 | 0.03707 | 0.18402 | 0.03007 | 0.25214 |
| 47.0 | 0.03207 | 0.22678 | 0.03707 | 0.18070 | 0.03007 | 0.24843 |
| 47.5 | 0.03207 | 0.22323 | 0.03707 | 0.17744 | 0.03007 | 0.24478 |
| 48.0 | 0.03207 | 0.21974 | 0.03707 | 0.17424 | 0.03007 | 0.24118 |
| 48.5 | 0.03207 | 0.21629 | 0.03707 | 0.17110 | 0.03007 | 0.23763 |
| 49.0 | 0.03207 | 0.21291 | 0.03707 | 0.16801 | 0.03007 | 0.23414 |
| 49.5 | 0.03207 | 0.20957 | 0.03707 | 0.16498 | 0.03007 | 0.23069 |
| 50.0 | 0.03207 | 0.20629 | 0.03707 | 0.16201 | 0.03007 | 0.22730 |
| 50.5 | 0.03207 | 0.20306 | 0.03707 | 0.15908 | 0.03007 | 0.22396 |
| 51.0 | 0.03207 | 0.19988 | 0.03707 | 0.15622 | 0.03007 | 0.22066 |
| 51.5 | 0.03207 | 0.19675 | 0.03707 | 0.15340 | 0.03007 | 0.21742 |
| 52.0 | 0.03207 | 0.19367 | 0.03707 | 0.15063 | 0.03007 | 0.21422 |
| 52.5 | 0.03207 | 0.19064 | 0.03707 | 0.14791 | 0.03007 | 0.21107 |

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| 53.0 | 0.03207 | 0.18765 | 0.03707 | 0.14525 | 0.03007 | 0.20797 |
| 53.5 | 0.03207 | 0.18471 | 0.03707 | 0.14263 | 0.03007 | 0.20491 |
| 54.0 | 0.03207 | 0.18182 | 0.03707 | 0.14005 | 0.03007 | 0.20190 |
| 54.5 | 0.03207 | 0.17897 | 0.03707 | 0.13753 | 0.03007 | 0.19893 |
| 55.0 | 0.03207 | 0.17617 | 0.03707 | 0.13505 | 0.03007 | 0.19600 |
| 55.5 | 0.03207 | 0.17341 | 0.03707 | 0.13261 | 0.03007 | 0.19312 |
| 56.0 | 0.03207 | 0.17069 | 0.03707 | 0.13022 | 0.03007 | 0.19028 |
| 56.5 | 0.03207 | 0.16802 | 0.03707 | 0.12787 | 0.03007 | 0.18748 |
| 57.0 | 0.03207 | 0.16539 | 0.03707 | 0.12556 | 0.03007 | 0.18472 |
| 57.5 | 0.03207 | 0.16280 | 0.03707 | 0.12330 | 0.03007 | 0.18201 |
| 58.0 | 0.03207 | 0.16025 | 0.03707 | 0.12108 | 0.03007 | 0.17933 |
| 58.5 | 0.03207 | 0.15774 | 0.03707 | 0.11889 | 0.03007 | 0.17669 |
| 59.0 | 0.03207 | 0.15527 | 0.03707 | 0.11675 | 0.03007 | 0.17410 |
| 59.5 | 0.03207 | 0.15284 | 0.03707 | 0.11464 | 0.03007 | 0.17154 |
| 60.0 | 0.03207 | 0.15044 | 0.03707 | 0.11257 | 0.03007 | 0.16901 |