EXECUTIVE REPORT

FOR NEW·WORLD

HKU Actuarial Solutions

MYOPIA PARAMETRIC INSURANCE

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1. EXECUTIVE SUMMARY

This report aims to propose a parametric insurance product to the Executive Committee of NEW·WORLD. On behalf of HKU Actuarial Solutions, we would like to elaborate on product designs, implementation plans, risks and sensitivity analysis in this report. The proposed new product is called *NewVision*, and it will protect the insured in Ambern a and Pal m n a against economic losses related to short-sightedness.

1.1. MARKET CONSIDERATION

Technological advancement makes digital devices an indispensable part of our daily life.[1] Thus, people are more vulnerable to eye-related diseases due to excessive exposure to blue light transmitted from electronic screens, which increases the risk of myopia, also known as short-sightedness, and other visual impairments.[2] Studies have found that the use of technological devices is positively correlated with myopia progression, while severe myopia will lead to more critical visual illnesses.[3] According to the WHO[4], the short-sighted population is estimated to increase from 33% now to 52% in 2050.[5] Myopia is becoming a global health risk with huge prevalence and significant adverse effects on vision.

NewVision pays the insured when his or her visual measure exceeds a certain level regardless of the severity of loss. For individuals with serious short-sightedness, a corrective surgery ranges from USD 4,000 to 8,000. The insured can be compensated for potential economic burden not only related to eye treatments, but also the loss of job opportunities that require a perfect vision.

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[1] "Mobile Fact Sheet," Pew Research Center, accessed February 18, 2021, https://www.pewresearch.org/internet/fact-sheet/mobile/.
[2] "Digital Devices and Your Eyes – Blue Lights and Your Eyes", Prevent Blindness, accessed February 18, 2021, https://preventblindness.org/blue-light-and-your-eyes/#:~:text=Digital%20eyestrain%3A%20Blue%20light%20from,contrast%20leading%20to%20digital%20eyestrain.&text=Symptoms%20of%20eyestrain%20include%20sore,lead%20to%20damaged%20retinal%20cells.
[3] Hongyu Guan et al., "Impact of various types of near work and time spent outdoors at different times of day on visual acuity and refractive error among Chinese school-going children," PLoS ONE 14, no. 4 (April 2019): 1-14.
[4] WHO is an abbreviation of the World Health Organization.
[5] University of New South Wales, *The impact of myopia and high myopia: report of the Joint World Health Organization–Brien Holden Vision Institute Global Scientific Meeting on Myopia, (*Geneva: World Health Organization), 5.

1.2. PRODUCT HIGHLIGHTS

NEW·WORLD will be the pioneer in the insurance market by launching *NewVision* before Q4 2021. Here are some product highlights of *NewVision*:

- *NewVision* is the first and only parametric vision insurance product in the market that can shield the insured (child) against future uncertainties on eye health and associated economic losses;
- *NewVision* provides flexible options on sum assured to cater to different personal preferences and financial abilities;
- *NewVision* can be purchased through brokers, direct agents, online platforms, and NEW·WORLD's maternity insurance packages with a simplified underwriting process.

1.3. EXPECTED FINANCIAL IMPACTS

Several key financial analyses of *NewVision* are listed below:

- New business value of ψ 44 million per year;
- Premium breakdown: 67.8% myopia benefit, 14.1% overhead, 9.0% commission, 4.9% tax, 3.6% expense, and 0.6% ROP[6] benefit;
- Sensitivity analysis suggests the key risks of *NewVision* are myopia and interest rate risks.

[6] ROP is an abbreviation of the Return of Premium.

2. OBJECTIVES

Myopia, also known as short-sightedness, is a global health risk according to the WHO. As of 2020, 33% of the world population are myopes.[7] Uncorrected myopia can easily deteriorate, leading to further serious visual impairments, such as glaucoma, cataract and complete blindness.[8] Studies have found that myopes are 60% more likely than people without visual defects to develop glaucoma and high myopia is defined by scholars as the risk factor in glaucoma and cataract progression.[9] Other than being widespread, the economic impact of myopia is far from trivial. The annual cost of optical correction of myopia is USD 755 million in Singapore and USD 2 billion in the United States. [10][11]

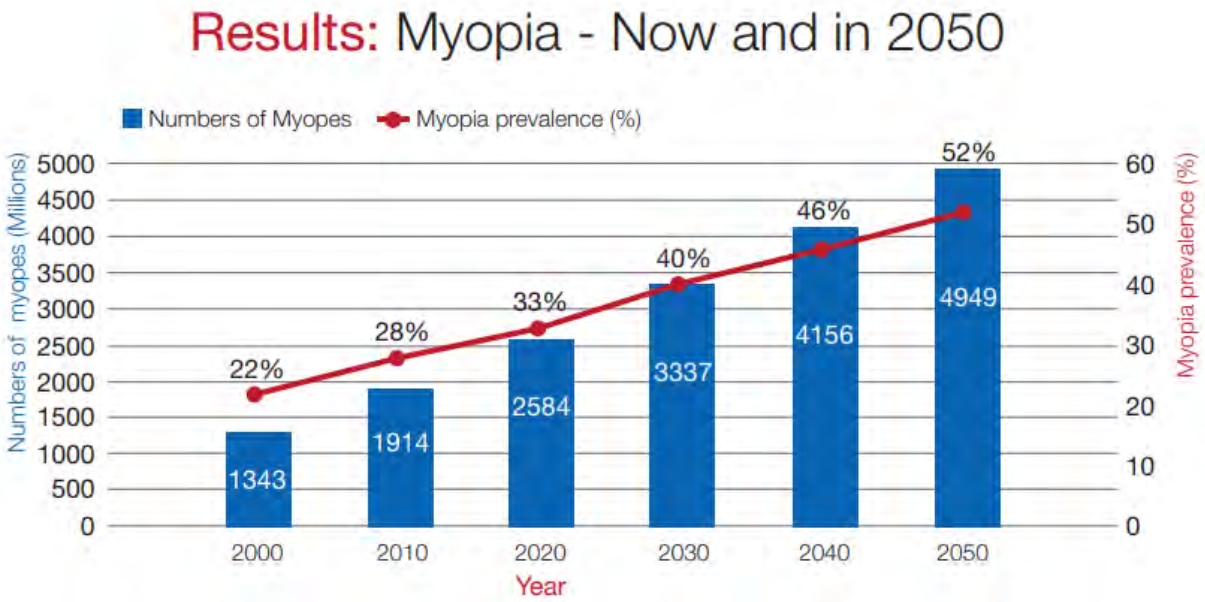

Figure 1: WHO's projection of the number of cases and prevalence of myopia worldwide from 2000 to 2050.[12]

[7] University of New South Wales, *The impact of myopia and high myopia: report of the Joint World Health Organization–Brien Holden Vision Institute Global Scientific Meeting on Myopia*, 5.
[8] Ibid., 1.
[9] Sheng-Ju Cheng et al., "High myopia as a risk factor in primary open angle glaucoma," *International Journal of Ophthalmology 5*, no. 6 (December 2012): 750-753.
[10] Ying-Feng Zheng et al., "The Economic Cost of Myopia in Adults Aged Over 40 Years in Singapore," Investigative Ophthalmology & Visual Science 54, no. 12 (November 2013): 7535.
[11] Rohit Saxena, Praveen Vashist, and Vimla Menon, "Is Myopia a Public Health Problem in India?," Indian Journal of Community Medicine 38, no. 2 (April – June 2013): 83-85.
[12] University of New South Wales, *The impact of myopia and high myopia: report of the Joint World Health Organization–Brien Holden Vision Institute Global Scientific Meeting on Myopia*, 5.

Control of myopia is crucial during childhood, a period when myopia can worsen quickly and irreversibly without appropriate correction. Studies have found a positive correlation between the use of electronic devices and myopia progression.[13] With an increasing usage of smartphones and computers, children are more likely to be short-sighted, and myopic population is expected to rise in the future. The annual corrective cost for a short-sighted child in Singapore is around USD 378, while a radical LASIK surgery ranges from USD 2,000 to 3,000 per eye, which is a significant expense for parents and myopes.[14][15] Meanwhile, short-sighted individuals are not eligible to apply for certain occupations, such as pilots and firemen, which deprives certain job opportunities from them. Currently, there is no insurance product that specifically covers the costs associated with myopia. Therefore, we introduce a parametric insurance product to parents, so they can be covered for the related expenses if their children suffer from myopia.

The severity of myopia is indicated by a negative measure called dioptre (D). The more negative the value, the more severe is one's myopia. In *NewVision*, one's dioptre is the parameter that triggers a lump-sum benefit payment. Myopia is insurable since the value of this index is accidental and estimable, while the loss is significant. Also, the risk of myopia is mainly individual, meaning there is unlikely an event that triggers a lot of benefit payments simultaneously, and no catastrophic loss at community level will occur due to myopia. The design is simple, since the benefit payment only depends on one index that directly reflects the severity of myopia, and the benefit is a one-off payment. However, it cannot directly match loss with a payoff like traditional insurance.

[13] Guan, "Impact of various types of near work and time spent outdoors at different times of day on visual acuity and refractive error among Chinese school-going children".
[14] M.C.C. Lim et al., "Direct cost of myopia in Singapore," Investigative Ophthalmology & Visual Science 49, no.13 (May 2008): 4998.
[15] "LASIK Eye Surgery Cost," All about Vision, accessed February 18, 2021, https://www.allaboutvision.com/visionsurgery/cost.htm.

Table 1: Definitions

Term	Definition
Global health risk	Factor that has a global spread and raises the probability of other adverse health outcomes (e.g. chronic disease).[16]
Economic loss	Any downside deviation from the expected economic value, which can include unexpected expenses or damage of potential economic gain.
Myopia	A condition in which a person's refractive error in either eye is less than -0.50 D.[17]
High myopia	A condition in which a person's refractive error in either eye is less than -5.00 D.[18]

[16] World Health Organization, *Global Health Risk – Mortality and burden of disease attributable to selected major risks, (*Geneva: World Health Organization), 1.
[17] University of New South Wales, *The impact of myopia and high myopia: report of the Joint World Health Organization–Brien Holden Vision Institute Global Scientific Meeting on Myopia*, 1.
[18]Ibid., 1.

3. DESIGN PROVISIONS

NewVision is a high myopia parametric insurance product. The product involves 2 parties, which are:

1) The insured, a child aged 0-0.5 upon policy entrance, will receive benefits when triggering event occurs;

2) The policyholder, usually one of the parents[19], will pay a single premium.

NewVision pays out a lump-sum benefit based on the diagnosis of high myopia indicated by one's dioptre. The table below summarizes the product features of *NewVision*.

Table 2: Design Provisions of NewVision with Elaboration

	Feature			Elaboration
Plan Type	Parametric insurance on myopia			--
Currency	Silon (Ψ)			--
Sum Assured	Option 1 Ψ 18,000	Option 2 Ψ 60,000	Option 3 Ψ 100,000	3 options (low, medium, and high benefits) are offered to cater different personal preferences and family financial abilities. The annual corrective cost (costs of content lenses, eyeglasses, etc.) for a short-sighted child in Singapore is around USD 378, while a radical LASIK surgery to completely cure myopia ranges from USD 2,000 to 3,000 per eye.[20] [21] The basic amount of sum assured offered (Option 1) covers these fundamental expenses that a myope would incur.

[19] Highest premium rates would be adopted if the policyholder is not the father or mother of the insured.
[20] M.C.C. Lim et al, "Direct cost of myopia in Singapore," 4998.
[21] "LASIK Eye Surgery Cost".

				Uncorrected myopia can further lead to glaucoma, cataract, and other visual impairments. For curing glaucoma, the average direct cost, which includes surgery, meditation and lasers, is around USD 8,769.52.[22] The actual treatment cost of glaucoma varies greatly from USD 623 to 2,511 per year depending on the severity of individual patient.[23] For curing cataract, the cost of a standard surgery is in between USD 3,000 to 5,000 per eye, and the cost of a laser-assisted surgery goes from USD 4,000 to 6,000.[24] Option 2 covers surgery costs of related eye diseases that can stem from myopia deterioration. In addition to treatment costs, the loss of education and job opportunities is not quantifiable. Hence, we have set the sum assured at a higher amount. Option 3 covers all the quantitative costs mentioned above, and qualitative economic loss of job opportunities.
Issue Age	Before age 0	Age 0 – 0.5		Since one's eyesight can be measured starting from 6 months old, the issue age is required to be at around the birth of the child to avoid adverse selection.
Policy Term	21	20.5 - 21		In general, myopia first occurs before adulthood. Since the eye continues to grow during childhood, it progresses until age 21.[25] As visions stabilize after age 21, the product provides protection until 21st birthday of the insured (child).

[22] Kailing Yong et al., "Direct Cost of Glaucoma Treatment For Patients With Primary Angle Closure Glaucoma Over 10 Years," *Investigative Ophthalmology & Visual Science* 54, no. 14 (March, 2012): 6388.
[23] Paul P. Lee et al., "A multicenter, retrospective pilot study of resource use and costs associated with severity of disease in glaucoma," *Arch Ophthamol 124*, no. 1 (January 2006): 12-19.
[24] "How Much Does Cataract Surgery Cost?," University of Central Florida, accessed February 22, 2021, https://ucfhealth.com/our-services/ophthalmology/cataract-surgery-cost/#:~:text=The%20total%20cost%20of%20cataract,procedures%20using%20advanced%20lens%20implants.
[25] "Myopia (nearsightedness)," American Optometric Association, accessed February 18, 2021, https://www.aoa.org/healthy-eyes/eye-and-vision-conditions/myopia?sso=y.

Premium Payment Mode	Single premium	Single premium provides convenience and reduces complexity for parents in purchasing insurance for their children. It also simplifies the policy which can reduce maintenance expense.
Premium Structure	• Premium varies by plan, gender, parental myopia and education level of biological parents • Refer *to Appendix A* for premium rates	It is found that the myopia rate of child can be correlated with parental myopia, which refers to the vision levels of both biological parents and their education levels.[26] Therefore, the product also includes these factors in determining the myopia rate, thus the premium. Highest premium rates will be adopted when there is absence of information (e.g. absence of biological father or mother's eyesight and education level).
Triggering Event	Upon diagnosis of -5.00D in either eye by qualified optometrist	Since myopia is irreversible, once it occurs, related costs (e.g. job opportunity loss and treatment cost) will incur. Occurrence of high myopia (observation of -5.00D in either eye) is chosen to be the triggering event instead of myopia (observation of -0.50D in either eye), because high myopia incurs a higher economic loss and has a higher chance to cause glaucoma, cataract and other severe eye-related disease.[27]
Myopia Benefit	100% of sum assured	Myopia benefit is paid upon the occurrence of the triggering event.
Death Benefit	Return of premium to policyholder	Upon death of the insured (child), premiums paid by the policyholder (one of the parents) will be returned.

[26] Lisa A. Jones et al., "Parental History of Myopia, Sports and Outdoor Activities, and Future Myopia," Investigative Ophthalmology & Visual Science 48, no. 8 (May 2010): 3524-3532.
[27] Sheng-Ju Cheng et al., "High myopia as a risk factor in primary open angle glaucoma," 750-753.

3.1. INSURABILITY

A product is considered as insurable if the related loss is accidental, significant, estimable and the premium is affordable.[28] *NewVision* is insurable as justified as follows.

Table 3: Insurability of NewVision with Elaboration

Element of Insurability	Elaboration
Accidental	The occurrence of myopia is uncertain and unwanted that lies outside the control of the child. The diagnosis of myopia is determined by qualified optometrist and cannot be manipulated.
Significant	The likelihood of mild myopia is high and the expense is relatively insignificant to the child, while the likelihood of high myopia is low and the loss of education and job opportunities is significant along with high expense of vision correction. This motivates parents to seek such protection for their children.
Estimable	With observed myopia rates, the probability of triggering can be estimated.
Affordable	With a relatively low likelihood of high myopia, the resulting premium should be affordable for parents with different financial abilities.

[28] Robert I. Mehr, and Emerson Cammack. *Principles of Insurance* (Homewood, Ill.: R.D. Irwin, 1976), 34-37.

4. ACTUARIAL IMPLEMENTATION PLAN

4.1. ANALYSIS OF PREMIUM AND REVENUE

NewVision is expected to generate a new business value (NBV) of **ψ 44 million** per year. We assume that parents of each new-born baby will have a 50% chance of purchasing *NewVision*. Formulas for calculating exposure, gross premium, and NBV are included in *Appendix E.* The 10-year projected gross premiums and NBV of *NewVision* are listed below.

Table 4: 10-Year Gross Premium and New Business Value Projection

Year	Total Exposure (million)		Total Gross Premium (million)		NBV (million)		
	Palòmïnïa	Ambernïa	Palòmïnïa	Ambernïa	Palòmïnïa	Ambernïa	Total
2022	9,421	1,738	705	175	35	9	44
2023	9,472	1,754	709	177	36	9	44
2024	9,523	1,771	712	178	36	9	45
2025	9,575	1,787	716	180	36	9	45
2026	9,626	1,804	720	182	36	9	45
2027	9,679	1,821	724	183	36	9	46
2028	9,731	1,838	728	185	37	9	46
2029	9,783	1,855	732	187	37	9	46
2030	9,836	1,873	736	188	37	9	46
2031	9,890	1,890	740	190	37	9	47
2032	9,943	1,908	744	192	37	10	47

Stochastic test was performed on the cash flow. Firstly, we analyzed the randomness in emerging experience. The resulting distribution did not have a large tail, because *NewVision* would be sold to a large market. Since a large number of policies are expected to be sold, most variabilities are diversified. The following table summarizes the distribution of gross premium and net present value (NPV). 95% VaR and 99.5% VaR represent the gross premium and NPV at the 5% and 0.5% worst case respectively.

Table 5: Distribution of Premium and Net Present Value

	Total Gross Premium	Net Present Value
Mean	ψ 880 million	ψ 49 million
SD	ψ 1.06 million	ψ 1.79 million
Median	ψ 880 million	ψ 49 million
95% VaR	ψ 878 million	ψ 47 million
99.5% VaR	ψ 877 million	ψ 46 million

Furthermore, a stochastic test was performed to capture the randomness in myopia and interest rate assumptions. These assumptions systematically affect all policies in the portfolio. The following table summarizes the distribution of net present value.

Table 6: Distribution of NPV from Systematic Randomness in Key Assumptions

	Net Present Value
Mean	ψ 38 million
SD	ψ 64 million
Median	ψ 38 million
95% VaR	ψ -71 million
99.5% VaR	ψ -134 million

In addition, *NewVision* would bring a positive net present value with a 73% probability. There is a 49% chance for the net present value to be above 90% of the baseline (> ψ 40 million) upon launching *NewVision*.

4.2. ANALYSIS OF EXPENSE

For *NewVision* being sold in the first year, the present value of expense is projected as a proportion of the gross premiums. Commission is paid immediately at policy inception, while expense and tax are equivalent to about **ψ 5 million** per year for 20 years. Formula for calculating expense is included in *Appendix E.* The net present value of each expense components are listed below.

Table 7: Net Present Value of Expense by Components

Expense Component	Net Present Value
Maintenance expense	ψ 32 million
Tax	ψ 43 million
Commission	ψ 79 million
Total	ψ 154 million

4.3. PRODUCT CHARACTERISTICS

A deterministic model is used to analyse the cashflow pattern on a product level. *NewVision* is expected to generate a net business value per premium of **5%**. Formula for calculating profit signature is included in *Appendix E.* The following table shows the profit signature.

Table 8: Profit Signature

Year	Profit per Premium
0	-159%
1	21%
2	10%
3	17%
4	23%
5	24%
6	25%
7	32%
8	36%
9	37%
10	53%

Year	Profit per Premium
11	63%
12	57%
13	52%
14	48%
15	46%
16	26%
17	13%
18	13%
19	12%
20	12%
21	5%

The premium breakdown is summarized as follows.

Table 9: Premium Breakdown

Premium Component	Proportion
Myopia benefit	67.8%
ROP benefit	0.6%
Expense	3.6%
Tax	4.9%
Commission	9.0%
Overhead	14.1%
Total	100.0%

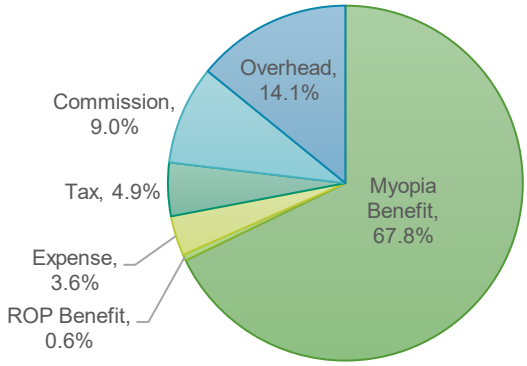

Figure 2: Portfolio Average Premium Breakdown at Earn Rate.

Premium rates are determined by country and 3 individual risk factors (i.e. sex, number of myopic parents, number of parents with undergraduate degree). Premium rates range from ψ 3,967 to ψ 25,901 for sum assured of ψ 100,000.

Table 10: Category of Premium Rates by Country and Individual Risk Factors

Premium Rate Category	Description	Premium Rate (Per 1000 Sum Assured)	
		Palòmïnïa	**Ambernïa**
Highest rate	• Sex: male • Number of myopic parents: 2 • Number of parents with undergraduate degree: 2	198.00	259.01
Average rate	Average of the expected business mix	74.81	100.63
Lowest rate	• Sex: female • Number of myopic parents: 0 • Number of parents with undergraduate degree: 0	39.67	52.86

5. BUSINESS IMPLEMENTATION PLAN

NewVision is expected to be launched before Q4 2021. No similar products are offered in the market. It is expected that *NewVision* will be able to gain and maintain a large market share.

5.1. MARKETING PLAN

NEW·WORLD thrives with myopia eye care and management for kids. As the first in the world to introduce a parametric insurance product regarding short-sightedness, we expect little competition in market share in the coming years.

To promote *NewVision*, we will advertise it through various channels as follows:

- Send marketing promotional emails to NEW·WORLD's existing clients who are parents and parents-to-be;
- Promote on NEW·WORLD official website and through agents;
- Publish product-centric blog posts and articles on parenting magazines and social media;
- Advertise on public transports (e.g. bus stops and underground railroad stations), and in maternity hospital, birth control clinics and childcare centres;
- Purchase advertisement on search engines as well as parenting and healthcare websites.

5.2. PARTNERSHIPS WITH OTHER COMPANIES

Since our target customers are parents seeking myopia eye care for their children, partnering companies in eye care and children education can add advantage for both sides presenting new opportunities to reach new patrons at a reduced advertising cost.

Table 11: Possible Partnerships with Other Stakeholders

Partnership	Elaboration
Partner with optometry clinics	Provide valid and reliable eye examination results
Partner with obstetrics clinics	Promote products to pregnant couples

5.3. DISTRIBUTION CHANNELS

We will distribute *NewVision* mainly through an online platform. Since *NewVision* only requires simple underwriting, all essential information can be obtained through an online questionnaire, which can reduce expense.

Moreover, commissions are provided for business partners, brokers, and direct agents, who would redirect and guide potential customer to make their purchase online. Their strong basis of customer connections will be the major source of business income, as well as a way to extend the reach of this new product.

Besides, we suggest NEW·WORLD to offer *NewVision* as a rider in NEW·WORLD current line of health and maternity insurance products, so to increase protection for the child.

5.4. KEY METRICS TO MEASURE PRODUCT'S SUCCESS AND POSSIBLE LOSSES

We have identified three important metrics for NEW·WORLD to measure this product's success and possible losses.

Table 12: Key Metrics to Measure Product's Success and Possible Losses

Key Metric	Elaboration
Gross premium written	Gross premium written is one of the most basic parameters of success, indicating the popularity and growing potential of a product in the market. An increasing written gross premium suggests a positive sign towards the success of *NewVision*, whereas a decreasing rate advises the market loses interest in the product.
Market penetration	This metric reveals the popularity of a product in the market. A high ratio of active policyholders over the total estimated market suggests a success in the marketing plan and strong insurability of this product.
Embedded Value	Embedded value represents the net present value of the liabilities and the assets held in reserve to support them. This metric can account for changes in liability assumption and reflect underwriting profit and loss.

6. ASSUMPTIONS

6.1. MYOPIA ASSUMPTION

Since the data provided by NEW·WORLD did not include myopia assumptions, research papers were referred to when determining the effect of different factors on myopia rates of children. The table below summarizes the factors and their corresponding sources. Detailed myopia rates are displayed in *Appendix C*.

Table 13: Factors Contributing to Myopia Rates and Their Corresponding References

Factor	Association	Source of Data
Age of child	Myopia develops slowly from age 2 to age 21. About 10% - 11% of lives will suffer from high myopia before age 21.	Table 2 in Refractive error by age group in "Myopia prevalence and risk factors in children".[29]
Education levels of parents	For each parent that has a high education level, their child has 10% higher odds to suffer from myopia.	Table 3 in Association of age, gender, outdoor time, near work and parental education level with myopia with children in "High prevalence of myopia in children and their parents in Hong Kong Chinese Population: the Hong Kong Children Eye Study".[30]
Parental myopia	If 1 parent suffers from myopia, their child has 108% higher odds to suffer from myopia. If both parents suffer from myopia, their child has 407% higher odds to suffer from myopia.	Table 4 in Logistic Model Showing Results of Inclusion of All Significant Variables from the AUC Models Adjusted for Other Variables in "Parental History of Myopia, Sports and Outdoor Activities, and Future Myopia".[31]

[29] Christos Theophanous et al., "Myopia prevalence and risk factors in children," Clinical Ophthalmology 12, (August 2018): 1581-1587.
[30] Jason C. Yam et al., "High prevalence of myopia in children and their parents in Hong Kong Chinese Population: The Hong Kong Children EYE Study," *Acta Ophthalmological 98*, no. 5 (August 2020): 639-649.
[31] Jones et al., "Parental History of Myopia, Sports and Outdoor Activities, and Future Myopia," 3524-3532.

Sports/outdoors hours	If children spend more time outdoors, their odds for suffering myopia decrease by 10%.	Table 4 in Logistic Model Showing Results of Inclusion of All Significant Variables from the AUC Models Adjusted for Other Variables in "Parental History of Myopia, Sports and Outdoor Activities, and Future Myopia".[32]
Sex	No significant correlation is found between sex and rate of myopia. However, this variable is kept for stochastic analysis.	Table 3 in Association of age, gender, outdoor time, near work and parental education level with myopia with children in "High prevalence of myopia in children and their parents in Hong Kong Chinese Population: the Hong Kong Children Eye Study".[33]

[32] Jones et al., "Parental History of Myopia, Sports and Outdoor Activities, and Future Myopia," 3524-3532.
[33] Jason C. Yam et al., "High prevalence of myopia in children and their parents in Hong Kong Chinese Population: The Hong Kong Children EYE Study," 639-649.

6.2. ECONOMIC, MORTALITY, AND EXPENSE ASSUMPTIONS

The table below summarizes other key assumptions besides myopia assumption. Detailed mortality and interest rates, as well as calculation of expense assumptions are displayed in *Appendices D and E*.

Table 14: Economic, Mortality, and Expense Assumptions Used for Pricing NewVision

<table>
<tr><th>Category</th><th>Range</th><th>Justification</th></tr>
<tr><td>Mortality assumption</td><td>Mortality rate:<table><tr><td>Pal m n a</td><td>Developing country</td><td>Mexico Mortality Table 2000[34]</td></tr><tr><td>Ambern a</td><td>Developed country</td><td>United States Life Table 2017[35]</td></tr></table></td><td>Pal m n a is a developing country, thus we used life table from Mexico as a proxy.
Similarly, Ambern a is a developed country. United States life table was used.
Moreover, Mexico and the United States are chosen because they are neighbouring countries with similar proportion of GDP gap as Pal m n a and Ambern a.
Note that no evidence suggests any adjustment is needed on top of the life tables.</td></tr>
<tr><td rowspan="2">Expense assumption</td><td>Commission expense:
9.0% of gross premiums</td><td>Commission is paid to the business partners, brokers, and agents for selling the products. The rate is estimated using NEW·WORLD’s income statement.</td></tr>
<tr><td>Maintenance expense:
4.5% of gross premiums</td><td>50% of the maintenance expense is estimated using NEW·WORLD’s income statement due to simple product and digitized operations.</td></tr>
</table>

[34] “Mortality and Other Rate Tables”, Society of Actuaries, accessed February 18, 2021, https://mort.soa.org/ViewTable.aspx?&TableIdentity=15006.
[35] Elizabeth Arias, and Jiaquan Xu, “United States Life Table, 2017,” National Vital Statistics Reports 68, no. 17 (June 2019): 1-66.

<table>
<tr><td></td><td>Claim expense:
4.3% of gross premiums</td><td>50% of the claims expense is estimated using NEW·WORLD’s income statement due to simple product and digitized operations.</td></tr>
<tr><td></td><td>Expected inflation rate:
<table><tr><td>Pal m n a</td><td>7.44%</td></tr><tr><td>Ambern a</td><td>1.35%</td></tr></table></td><td>The expected inflation rates are average inflation rates that are based on the CPI from 2012 to 2020 for each country.</td></tr>
<tr><td rowspan="3">Economic assumption</td><td>Income tax rate:
25.61%</td><td>Income tax rate expense is estimated using NEW·WORLD’s income statement.</td></tr>
<tr><td>Long-term interest rate and volatility:
<table><tr><th></th><th>Pal m n a</th><th>Ambern a</th></tr><tr><td>Mean</td><td>4.07%</td><td>1.94%</td></tr><tr><td>Volatility</td><td>1.71%</td><td>1.67%</td></tr></table></td><td>The numbers are mean and standard deviation of the long-term interest rates from January 1, 2010 to January 1, 2020 provided by NEW·WORLD.</td></tr>
<tr><td>3-month interest rate and volatility:
<table><tr><th></th><th>Pal m n a</th><th>Ambern a</th></tr><tr><td>Mean</td><td>2.63%</td><td>0.43%</td></tr><tr><td>Volatility</td><td>1.67%</td><td>0.79%</td></tr></table></td><td>The numbers are mean and standard deviation of the 3-month interest rates from January 1, 2010 to January 1, 2020 provided by NEW·WORLD.</td></tr>
</table>

6.3. EFFECTS OF KEY ASSUMPTIONS ON PROFIT

The ranges of the top 3 sensitive assumptions that will result in an outcome within 30% of baseline revenue are listed as follows.

Table 15: Effects of Key Assumptions on Profit

Category	70% Revenue (ψ 31 million)	130% Revenue (ψ 57 million)
Myopia Rates	106% of baseline	94% of baseline
Interest Rates	92% of baseline	108% of baseline
Market Penetration	70% of baseline (i.e. 35% of total available market)	130% of baseline (i.e. 65% of total available market)

7. RISK AND RISK MITIGATION STRATEGIES

7.1. KEY RISKS

Risk categories are quantified and ranked in the following table.

Table 16: List of Key Risks

Risk Category	Risk	Description	Credible Worse Case
Insurance	Adverse selection risk	Direct cause of myopia is currently unknown. Risk factors used in pricing may not be able to fully segregate lives with a higher risk from those with a lower risk. It is possible that lower rates are offered to risky lives.	50% of lives in lower risk classes exhibit similar characteristic as the highest risk classes. Expected decrease in present value would be **Ψ 427 million**.
	Myopia rate risk	Myopia rate is highly demographic dependent. Our pricing model is also highly sensitive to myopia rate.	Myopia rate is triple of the current assumptions. Expected decrease in present value would be **Ψ 212 million.**
Financial	Interest rate risk	*NewVision* may be in force for 20 years and premium is received at time 0. Our pricing model is highly sensitive to interest rate.	Economic recession causes interest rate to drop to zero. Net present value per premium would decreases by -18.3%. Expected decrease in present value would be **Ψ 161 million**.
Operational	Claim fraud	*NewVision* depends on a single medical report for triggering claims. Such report may be easy to be counterfeit.	After actual experience is 1 SD lower than expected, detailed review finds out most large claims are fraudulent. NEW·WORLD would lose **Ψ 64 million**.
Strategic	Sales - performance risk	*NewVision* is a new product, so market acceptance is an important determinant of the product's success.	Customer is totally not interested in the product. No sale is made. No revenue is generated. However, no significant expense is incurred. Net present value would be **Ψ 44 million** lower than baseline.

7.2. RISK MITIGATION

For insurance risk, myopia risk is in fact a novel one to be insured. There are very few options to mitigate this risk. However, we can seek partnership with reinsurers and investigate the possibility of issuing catastrophe bonds or the use of reinsurance special purpose vehicle.

For interest rate risk, sustainable asset liability management technique will be implemented using bonds and interest rate swaps to match the duration of liability.

For sales performance risk, adequate market research before launch can lower the likelihood of missing sales target.

For claim fraud, we will partner with optical clinics. We only accept reports directly submitted by these clinics networks in order to verify the legitimacy and credibility of the reports.

7.3. OTHER RISKS

Although *NewVision* is first-to-market, it is expected that existing market leaders will leverage their advantages and deploy similar or more competitive parametric vision insurance products if *NewVision* is successful. Our market share will be challenged, and profit margin may need to be reduced to increase competitiveness.

If technological improvement can ease the prevalence of myopia, customers may be less interested in *NewVision*, causing sales to decrease. However, actuarial profit will increase as myopia experience for the existing product will improve.

Since the risk exposure is less than 29% of NEW·WORLD's equity, there is no significant risk that will lead to default. NEW·WORLD is fully capable in absorbing all losses.

8. SENSITIVITY ANALYSIS

The following table shows the sensitivity of the assumption used in pricing *NewVision*. The model is highly sensitive to myopia and interest rate assumptions. While mortality and expense assumptions are not material in pricing.

Table 17: Sensitivity Analysis

	NBV per Gross Premium	Variance from Base
Baseline	**5.0%**	--
Mortality * 80%	5.0%	0.0%
Mortality * 120%	5.0%	0.0%
Myopia * 80%	10.1%	5.1%
Myopia * 120%	0.0%	-5.0%
Myopia * 300%	-19.1%	-24.1%
Myopia Trend: Rate + 1% per year (multiplicative)	2.3%	-2.7%
Earn Rate +50bps	7.7%	2.6%
Earn Rate -50bps	2.4%	-2.7%
Earn Rate -100bps	-0.3%	-5.3%
Earn Rate = 0%	-13.2%	-18.3%
Expense * 80%	5.3%	0.3%
Expense * 120%	4.7%	-0.3%
Expense Inflation + 1% additive	4.9%	-0.1%

The following table shows the impact of sale performance on total revenue. NBV is linearly correlated with market penetration.

Table 18: Market Penetration

Market Penetration	Total Exposure (Ψ million)	Total Gross Premium (Ψ million)	NBV (Ψ million)
70%	15,623	1,232	62
60%	13,391	1,056	53
50% (Baseline)	11,159	880	44
40%	8,927	704	35
30%	6,696	528	26
20%	4,464	352	18
10%	2,232	176	9

9. FUTURE IMPLICATIONS

9.1. DATA LIMITATION

Firstly, we do not have enough information about the trend factor on child high myopia. Various reports have included the projection of myopic population for the next decades, such as the trend produced by the WHO in *Section 2*. However, we do not know the exact increment in child myopic population in Ambern a and Pal m n a. We did not include a trend factor for pricing, but it should be monitored closely in future experience studies.

Furthermore, the causal linkage between parents' education level and children eyesight is relatively indirect, although there is a positive correlation in between.[36] Household income seems to be a better risk classification factor because it directly affects children's access to electronic devices. Hence, household income should be monitored closely in future experience studies as well.

Moreover, although data provided by NEW·WORLD was sufficient to set up various assumptions, we lacked information on the exchange rate of Silon. We assume the exchange rate is Ψ 3 per USD 1 by equating the GDP in Ambern a in Silon with the average GDP of the developed countries in USD.

Last but not least, we did not have sufficient knowledge about the impact of recession on the economic developments of Ambern a and Pal m n a. Since the data provided by NEW·WORLD reflects a relatively stable economic development in the past few years, we conducted the projection by assuming stable economic condition in the next 20 years.

9.2. REPORTING SCHEDULE AND METRICS

Myopia rates, interest rates, and mortality rates should be monitored closely.

For myopia rates, experience studies need to be performed at least every 3 years. We currently rely on data from published reports and academic articles from various countries for pricing. To ensure credibility, we should continue to monitor myopia rates and trends based on reliable and authorized sources. Efforts should be made to work with local census and

[36] Jason C. Yam et al., "High prevalence of myopia in children and their parents in Hong Kong Chinese Population: The Hong Kong Children EYE Study," 639-649.

health authorities in gathering official data, such as child myopia related reports produced by local clinics, to uplift credibility. Since myopia rate is the key risk of *NewVision,* trend factor and risk factors of myopia should be monitored closely for making adjustments on possible deviation.

For interest rate movements, experience studies should be conducted by the investment team on a regular basis. Re-pricing or re-vamp action will take place when deemed necessary.

For mortality rates, experience studies need to be performed at least every 3 years. Since mortality is not the key risk of *NewVision*, we can save time and resources by making a reference on the mortality assumptions of other NEW·WORLD's products.

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APPENDICES

APPENDIX A – PREMIUM RATE TABLE

Key	Sex	Number of Myopic Parents	Number of High Educated Parents	Country	Rate per 1000 Sum Assured	Business Mix
M00A	M	0	0	A	52.86	1.52%
M01A	M	0	1	A	57.86	0.30%
M02A	M	0	2	A	63.26	1.22%
M10A	M	1	0	A	104.35	1.52%
M11A	M	1	1	A	113.83	0.30%
M12A	M	1	2	A	123.96	1.22%
M20A	M	2	0	A	223.60	0.34%
M21A	M	2	1	A	241.01	0.07%
M22A	M	2	2	A	259.62	0.27%
F00A	F	0	0	A	52.70	1.52%
F01A	F	0	1	A	57.70	0.30%
F02A	F	0	2	A	63.08	1.22%
F10A	F	1	0	A	104.04	1.52%
F11A	F	1	1	A	113.51	0.30%
F12A	F	1	2	A	123.62	1.22%
F20A	F	2	0	A	223.06	0.34%
F21A	F	2	1	A	240.44	0.07%
F22A	F	2	2	A	259.01	0.27%
M00P	M	0	0	P	39.67	11.67%
M01P	M	0	1	P	43.44	1.95%
M02P	M	0	2	P	47.54	5.84%
M10P	M	1	0	P	78.75	11.67%
M11P	M	1	1	P	85.89	1.95%
M12P	M	1	2	P	93.59	5.84%
M20P	M	2	0	P	170.46	2.59%
M21P	M	2	1	P	184.07	0.43%
M22P	M	2	2	P	198.00	1.30%
F00P	F	0	0	P	39.61	11.67%
F01P	F	0	1	P	43.38	1.95%
F02P	F	0	2	P	47.47	5.84%
F10P	F	1	0	P	78.64	11.67%
F11P	F	1	1	P	85.78	1.95%
F12P	F	1	2	P	93.47	5.84%
F20P	F	2	0	P	170.26	2.59%
F21P	F	2	1	P	183.86	0.43%
F22P	F	2	2	P	198.00	1.30%

APPENDIX B – BUSINESS MIX FOR PROFITABILITY PROJECTION

COUNTRY

Country	Percentage of Total Sum Assured
Palòmïnïa	86%
Ambernïa	14%

The percentage is the product of market penetration and average sum assured in the next sub-section. We expect more *NewVision* will be sold in Pal m n a because Pal m n a has 4 times the population as that of Ambern a. We assume larger population has a higher annual birth rates.

SUM ASSURED

Option of Sum Assured	Palòmïnïa	Ambernïa
Option 1: ψ 18,000	50%	30%
Option 2: ψ 60,000	30%	50%
Option 3: ψ 100,000	20%	20%
Average Sum Assured	ψ 47,000	ψ 55,400

Since Ambern a is a comparatively more developed than Pal m n a and household saving rates in Ambern a is high than that of Pal m n a, we expect majority of the customers will purchase the basic plan (Option 1) of *NewVision* in Pal m n a and more parents will purchase Option 2 of *NewVision* in Ambern a.

BUSINESS SIZE

Country	Market Penetration
Palòmïnïa	50%
Ambernïa	50%

Market penetration means that 50% of the parents-to-be and parents of new-borns in Pal m n a or Ambern a will purchase *NewVision*. Since myopia becomes more prevalent nowadays alongside the rising ownerships of technological devices among children, most parents will purchase *NewVision* to protect their children against potential economic loss incur due to this global health risk.

SEX

Sex	Palòmïnïa	Ambernïa
Male	50%	50%
Female	50%	50%

Since NEW·WORLD did not provide any information about the sex ratio of the two countries, we assume half-and-half for now.

NUMBER OF MYOPIC PARENTS

Number of Myopic Parents	Palòmïnïa	Ambernïa
0: both father and mother are not myopic	45%	45%
1: either father or mother is myopic	45%	45%
2: both father and mother are myopic	10%	10%

The proportions are calculated based on binominal distribution, with the number of trials being 2 and probability of success on a single trial being the myopia prevalence in 2020 (i.e. Bin(n=2, p=0.33)).[37]

NUMBER OF HIGHLY EDUCATED PARENTS

Number of Highly Educated Parents	Palòmïnïa	Ambernïa
0: both father and mother do not obtain undergraduate degree	60%	50%
1: either father or mother obtains undergraduate degree	10%	10%
2: both father and mother obtain undergraduate degree	30%	40%

The proportions are set by referring to the education attainment data provided by NEW·WORLD.

[37] Rohit Saxena, Praveen Vashist, and Vimla Menon, "Is Myopia a Public Health Problem in India?," Indian Journal of Community Medicine 38, no. 2 (April – June 2013): 83-85.

APPENDIX C – METHODOLOGY OF MYOPIA ASSUMPTION

COUNTRY FACTOR

Country specific factors include income level, exercise frequency, and number of highly educated parents.

Since Ambern a is comparatively more developed than Pal m n a, we assume the former is a high-income country while the latter is a low-income country.

Income	Odds Ratio	Exposure	
		Palòmïnïa	Ambernïa
High	1	0%	100%
Low	0.9	100%	0%

Exposure is based on the percentage of population in age band 15-19 participating in aerobic sports provided by NEW·WORLD.

Exercise	Odds Ratio	Exposure	
		Palòmïnïa	Ambernïa
No	1	66.80%	16.68%
Yes	0.9	33.20%	83.32%

For the number of highly educated parents, adjustment is made to the baseline rate such that individual adjustment can be consolidated with the population value. Exposure is based on the percentage of people aged 30-50 with tertiary education provided by NEW·WORLD. We assume that couples tend to have high correlation in education level.

Number of Highly Educated Parents	Odds Ratio	Exposure	
		Palòmïnïa	Ambernïa
0: both father and mother do not obtain undergraduate degree	1	66.65%	55.22%
1: either father or mother obtains undergraduate degree	$\frac{1}{1.1}$	0.00%	0.00%
2: both father and mother obtain undergraduate degree	$\frac{1}{1.21}$	33.35%	44.78%

Finally, the country adjustment factor is the product of each odds ratio and their corresponding exposure.

Country	Country Adjustment Factor
Palòmïnïa	0.81
Ambernïa	0.84

UNDERWRITING FACTOR

Underwriting adjustment factors include sex, number of myopic parents, and number of highly educated parents.

Note that although the odds ratio for each sex is the same for the deterministic model, this factor is used during stochastic testing.

Sex	Odds Ratio
Male	1
Female	1

Number of Myopic Parents	Odds Ratio
0: both father and mother are not myopic	1
1: either father or mother is myopic	2.08
2: both father and mother are myopic	5.07

Number of High Educated Parents	Odds Ratio
0: both father and mother do not obtain undergraduate degree	1
1: either father or mother obtains undergraduate degree	1.1
2: both father and mother obtain undergraduate degree	1.21

The underwriting adjustment factor is the product of the corresponding odds ratio.

BASELINE RATE

Baseline odds is derived from myopia prevalence in the United States, adjusted for exposure and risk factors. It represents the odds for a male life developing high myopia, who does not have myopic parents, does not exercise, and lives in a high-income country.

Age	Baseline Odds	Age	Baseline Odds	Age	Baseline Odds
0	-	**7**	0.0075	**14**	0.0415
1	-	**8**	0.0100	**15**	0.0469
2	-	**9**	0.0126	**16**	0.0483
3	0.0012	**10**	0.0186	**17**	0.0496
4	0.0025	**11**	0.0247	**18**	0.0510
5	0.0037	**12**	0.0308	**19**	0.0523
6	0.0050	**13**	0.0361	**20**	0.0537

INDIVIDUAL RATE

Baseline odds are adjusted for both country factors and underwriting factors to derive the odds for each risk category.

$$Adjusted\ Odds = Baseline\ Odds \times Country\ Factor \times Underwriting\ Factor$$

Then, odds are converted into the cumulative probability that a live develops myopia at a certain age.

$$Cumulative\ Probability = \frac{Adjusted\ Odds}{1 + Adjusted\ Odds}$$

Finally, the rate that a life develops myopia in each age can be found.

$$Rate\ for\ age\ x = \frac{(Cumulative\ Prob\ for\ age\ x) - (Cumulative\ Prob\ for\ age\ x - 1)}{1 - (Cumulative\ Prob\ for\ age\ x - 1)}$$

APPENDIX D – MORTALITY ASSUMPTION TABLE (FOR AGE 0 - 22)

As elaborated in *Section 6.2*, we used the life tables from Mexico and the United States for our mortality assumptions. The details of the mortality assumption are as follows.

Age	Palòmïnïa (Mexico Mortality Table 2000)[38]		Ambernïa (United States Life Table 2017)[39]	
	Male	Female	Male	Female
0	0.6000	0.3300	0.4227	0.3391
1	0.6000	0.3300	0.4227	0.3391
2	0.5400	0.3320	0.2874	0.2075
3	0.4900	0.3340	0.2249	0.1592
4	0.4600	0.3360	0.1582	0.1389
5	0.4300	0.3380	0.1555	0.1256
6	0.4100	0.3410	0.1385	0.1130
7	0.4000	0.3440	0.1244	0.1036
8	0.3900	0.3480	0.1104	0.0967
9	0.3800	0.3510	0.0982	0.0924
10	0.3700	0.3550	0.0940	0.0920
11	0.3700	0.3600	0.1079	0.0979
12	0.3500	0.3650	0.1516	0.1127
13	0.4260	0.3710	0.2319	0.1379
14	0.5180	0.3770	0.3414	0.1717
15	0.5980	0.3850	0.4613	0.2100
16	0.6680	0.3920	0.5842	0.2502
17	0.7300	0.4010	0.7176	0.2926
18	0.7540	0.4110	0.8586	0.3357
19	0.7570	0.4220	1.0015	0.3790
20	0.7570	0.4340	1.1471	0.4245
21	0.7720	0.4480	1.2859	0.4706
22	0.8200	0.4630	1.4028	0.5131

[38] "Mortality and Other Rate Tables", Society of Actuaries, accessed February 18, 2021. https://mort.soa.org/ViewTable.aspx?&TableIdentity=15006.

[39] Elizabeth Arias, and Jiaquan Xu, "United States Life Table, 2017," 1-66.

APPENDIX E – FORMULA

FORMULA FOR ANALYSIS OF PREMIUM AND REVENUE

The following formulas are used to calculate premium and revenue related analysis in *Section 4*.

Category	Formula
Gross premium and NBV projection	$(Total\ exposure)_t = Population_t \times Birth\ Rate \times Average\ SA \times Market\ Penetration$
	$(Gross\ premium)_t = (Total\ exposure)_t \times Average\ Rates$
	$NBV_t = (Gross\ premium)_t \times NBV\ per\ gross\ premium$
Expense	$Expense\ per\ year = \frac{(Total\ expense + Tax)}{a_{\overline{20}\rceil}}$
Profit signature	$Profit = Premium - Benefit\ Outgo - Expense\ Outgo - Change\ in\ Reserve - Tax + Interest$

FORMULA FOR EXPENSE AND ECONOMIC ASSUMPTIONS

The following assumptions are set with reference to NEW·WORLD's income statement.

Category	Formula
Expense	$Commission\ expense\ rate = \frac{Commissions}{Gross\ premium\ written} \times 100\%$
	$Maintenance\ expense\ rate = \frac{Salaries\ and\ fees}{Gross\ premium\ written} \times 50\%$
	$Claim\ expense\ rate = \frac{Net\ adjusting\ expense}{Gross\ premium\ written} \times 50\%$
Economic	$Income\ tax\ rate = \frac{Income\ tax\ expense}{Income\ before\ income\ tax\ expense} \times 100\%$

APPENDIX F – R CODE

````
---
title: "Stochastic_Test"
author: "ActuarialCat"
date: "February 20, 2021"
output: html_document
---
````

````
```{r setup, include=FALSE}
knitr::opts_chunk$set(echo = TRUE)
```
````

````
```{r library}
library(data.table)
library(ggplot2)

library(parallel)
```
````

````
```{r load table}
tables_file = "tables/"

tbl_mortality = fread(paste0(tables_file, "mortality.csv"))
tbl_myopia = fread(paste0(tables_file, "myopia.csv"))
tbl_myopia_odds = fread(paste0(tables_file, "myopia_odds.csv"))

tbl_economic = fread(paste0(tables_file, "economic.csv"))
tbl_expense = fread(paste0(tables_file, "expense.csv"))

tbl_PAD = fread(paste0(tables_file, "PAD.csv"))
tbl_param = fread(paste0(tables_file, "param.csv"))

tbl_business_mix = fread(paste0(tables_file, "business_mix.csv"))
tbl_rates = fread(paste0(tables_file, "rates.csv"))

tbl_SA = fread(paste0(tables_file, "SA.csv"))
```
````

````
``` {r parameters}

param = data.table(
    entry_age = 0.5,
    SA = 1000000,

    sex = "M",
    num_of_myopic_parents = 2,
    num_of_educated_parents = 2,
    country = "P",

    PAD_mort = 1,
    PAD_myopia = 1,
    PAD_lapse = 1,
    PAD_exp = 1,
````
````

```
    PAD_inflation = 0,
    PAD_interest = 0
)

param_res = data.table(
    entry_age = 0.5,
    SA = 1000000,

    sex = "M",
    num_of_myopic_parents = 2,
    num_of_educated_parents = 2,
    country = "P",

    PAD_mort = 1 + tbl_PAD[item == "mortaliy", PAD],
    PAD_myopia = 1 + tbl_PAD[item == "myopia", PAD],
    PAD_lapse = 1 + tbl_PAD[item == "lapse", PAD],
    PAD_exp = 1 + tbl_PAD[item == "expense", PAD],
    PAD_interest = tbl_PAD[item == "interest", PAD],
    PAD_inflation = 0.01
)
```

```{r table generators}

generate_interest_rates = function(short_rate, long_rate, mix_year, PAD = 0){
    # Generatre interest rate table

    t = 1:50

    spot = fifelse(t > mix_year, long_rate,
                   short_rate * (1 - (t-1)/mix_year) + long_rate * (t-1)/mix_year)
    fwd = fifelse(t == 1, spot,
                  (1 + spot) ^ t / (1 + shift(spot, 1)) ^ (t - 1) - 1)
    fwd_PAD = fwd * (1 + PAD)

    fwd_mth = (1 + fwd) ^ (1/12) - 1
    fwd_PAD_mth = (1 + fwd_PAD) ^ (1/12) - 1

    return(data.table(t, spot, fwd, fwd_PAD, fwd_mth, fwd_PAD_mth))
}

generate_decrement_table = function(n, mort, myopia, lapse){
    # Generate a decrement table

    t = seq(0, n - 1/12, 1/12)

    dep_mort_pp = mort * (1 - myopia/2)
    dep_myopia_pp = myopia * (1 - mort/2)
    dep_lapse_pp = lapse * (1 - mort) * (1 - myopia)

    EOP_IF = rep(NA, n * 12)
    EOP_IF[1] = 1

    for (i in 2:(n*12)) {
```

```
        EOP_IF[i]   =   EOP_IF[i-1]   -   (dep_mort_pp[i]   +   dep_myopia_pp[i]   +
dep_lapse_pp[i]) * EOP_IF[i-1]
    }

    BOP_IF = shift(EOP_IF, 1)
    mort_IF = dep_mort_pp * BOP_IF
    myopia_IF = dep_myopia_pp * BOP_IF
    lapse_IF = dep_lapse_pp * BOP_IF

    return(data.table(t, BOP_IF, mort_IF, myopia_IF, lapse_IF, EOP_IF))
}

myopia_cum_to_rate = function(cum_odds){
    # change cummulative rate to condition prob

    cum_prob = cum_odds/(1+cum_odds)
    rate = (cum_prob - shift(cum_prob)) / (1 - shift(cum_prob))
    rate[1] = 0

    return(rate)
}
```

```{r functions}

lookup_misc_rate = function(param){

    #unwarp
    entry_age = param[1, entry_age]
    SA = param[, SA]

    sex = param[, sex]
    num_of_myopic_parents = param[, num_of_myopic_parents]
    num_of_educated_parents = param[, num_of_educated_parents]
    country = param[, country]

    PAD_exp = param[, PAD_exp]
    PAD_inflation = param[, PAD_inflation]
    PAD_interest = param[, PAD_interest]


    #income
    index_code   =   paste0(sex,   num_of_myopic_parents,   num_of_educated_parents,
country)
    premium = tbl_rates[Key == index_code, Rate] * SA / 1000


    #expense
    comm_init = tbl_expense[item == "comm_init", fixed] +
                    tbl_expense[item == "comm_init", per_SA] * SA / 1000 +
                    tbl_expense[item == "comm_init", per_prem] * premium
    comm_renew = tbl_expense[item == "comm_renew", fixed]  +
                    tbl_expense[item == "comm_renew", per_SA] * SA / 1000 +
```

```
                    tbl_expense[item == "comm_renew", per_prem] * premium / 20
    main_exp = tbl_expense[item == "main_exp", fixed] +
                    tbl_expense[item == "main_exp", per_SA] * SA / 1000 +
                    tbl_expense[item == "main_exp", per_prem] * premium / 20
    claim_exp = tbl_expense[item == "claim_exp", fixed] +
                    tbl_expense[item == "claim_exp", per_SA] * SA / 1000 +
                    tbl_expense[item == "claim_exp", per_prem] * premium / 20

    inflation = 1 + tbl_param[item == "inflation", baseline] + PAD_inflation


    #interest
    short_rate = tbl_economic[item == paste0(country, "_short"), mean]
    long_rate = tbl_economic[item == paste0(country, "_long"), mean]


    #ouput
    return(list(premium, comm_init, comm_renew, main_exp, claim_exp, inflation,
short_rate, long_rate))
}



lookup_decrement_rate = function(param){

    #unwarp
    entry_age = param[1, entry_age]

    sex = param[, sex]
    num_of_myopic_parents = param[, num_of_myopic_parents]
    num_of_educated_parents = param[, num_of_educated_parents]
    country = param[, country]

    PAD_mort = param[, PAD_mort]
    PAD_myopia = param[, PAD_myopia]
    PAD_lapse = param[, PAD_lapse]

    #time
    n = 21 - entry_age
    t = seq(0, n - 1/12, 1/12)

    age = entry_age + t
    age_round = floor(age)

    #Myopia Factors
    country_factor = ifelse(country == "P" , 0.813167554186143, 0.837886885292246)

    underwrite_factor = ifelse(sex == "M", 1, tbl_myopia_odds[item == "sex_F",
baseline] ) *
        ifelse(num_of_myopic_parents == 0, 1,
            ifelse(num_of_myopic_parents == 1, tbl_myopia_odds[item == "myopic_1",
baseline],
                    tbl_myopia_odds[item == "myopic_2", baseline])) *
        ifelse(num_of_educated_parents == 0, 1,
            ifelse(num_of_myopic_parents == 1, tbl_myopia_odds[item == "educate_1",
baseline],
                    tbl_myopia_odds[item == "educate_2", baseline]))
```

```
    #Decrement
    mort_raw = merge(data.table(age_round), tbl_mortality, by.x = "age_round", by.y
= "age")
    mort_index = paste0(country, sex)
    mort_PP = mort_raw[, get(mort_index)] / 1000 / 12 * PAD_mort

    tbl_myopia[, cum_odds_adj := cum_odds * country_factor * underwrite_factor]
    tbl_myopia[, rates_adj := myopia_cum_to_rate(cum_odds_adj)]
    myopia_raw = merge(data.table(age_round), tbl_myopia, by.x = "age_round", by.y
= "age")
    myopia_PP = myopia_raw[, rates_adj] / 12 * PAD_myopia

    lapse_PP = rep(0, n*12) * PAD_lapse

    #output
    return(list(mort_PP, myopia_PP, lapse_PP))
}

```

```{r deterministic}

deterministic_model = function(param){

    #unwarp
    entry_age = param[1, entry_age]
    SA = param[, SA]

    sex = param[, sex]
    num_of_myopic_parents = param[, num_of_myopic_parents]
    num_of_educated_parents = param[, num_of_educated_parents]
    country = param[, country]

    PAD_mort = param[, PAD_mort]
    PAD_myopia = param[, PAD_myopia]
    PAD_lapse = param[, PAD_lapse]
    PAD_exp = param[, PAD_exp]
    PAD_inflation = param[, PAD_inflation]
    PAD_interest = param[, PAD_interest]

    #time
    n = 21 - entry_age
    t = seq(0, n - 1/12, 1/12)


    #Param
    exp_list = lookup_misc_rate(param)
    premium = exp_list[[1]]
    comm_init = exp_list[[2]]
    comm_renew = exp_list[[3]]
    main_exp = exp_list[[4]]
    claim_exp = exp_list[[5]]
    inflation = exp_list[[6]]
    short_rate = exp_list[[7]]
```

```
    long_rate = exp_list[[8]]


    interest_raw = generate_interest_rates(short_rate, long_rate, 10, PAD_interest)
    interest = merge(data.table(t, year = ceiling(t)), interest_raw, by.x = "year",
by.y = "t", all.x = TRUE)


    #Decrement
    PP_list = lookup_decrement_rate(param)

    mort_PP = PP_list[[1]]
    myopia_PP = PP_list[[2]]
    lapse_PP = PP_list[[3]]

    decrement = generate_decrement_table(n, mort_PP, myopia_PP, lapse_PP)


    #Cash Flow
    premium_IF = c(0, premium, rep(0, n*12-2)) * decrement[,BOP_IF]

    death_outgo = -premium * decrement[,mort_IF]
    myopia_outgo = -SA * decrement[,myopia_IF]
    benefit_IF = death_outgo + myopia_outgo

    commission_IF = -rep(comm_renew /12, n*12) * decrement[,BOP_IF]
    commission_IF[1] = -comm_init
    claims_exp_IF = -claim_exp * (inflation ^ (t - 1/12)) * (decrement[,mort_IF] +
decrement[,myopia_IF]) * PAD_exp
    main_exp_IF = -main_exp /12 * (inflation ^ (t - 1/12)) * decrement[,BOP_IF] *
PAD_exp

    pre_contract_CF = c(commission_IF[1], rep(0, n*12-1))
    BOP_CF = premium_IF + commission_IF + main_exp_IF
    EOP_CF = benefit_IF + claims_exp_IF

    CF = data.table(t, premium_IF,
                    death_outgo, myopia_outgo, benefit_IF,
                    commission_IF, claims_exp_IF, main_exp_IF,
                    pre_contract_CF, BOP_CF, EOP_CF)

    # Reserve
    EOP_reserve_IF = c(rep(NA, n*12-1), 0)

    for (i in (n*12):2){
        EOP_reserve_IF[i-1] = max(0,
            (EOP_reserve_IF[i] - EOP_CF[i]) / (1 + interest[i, fwd_PAD_mth]) -
BOP_CF[i])
    }

    EOP_reserve_PP = EOP_reserve_IF / decrement[, EOP_IF]


    return( list(decrement, CF, interest, EOP_reserve_PP))
}
```

```
generate_reserve_table = function(){

    reserve = list()

    # loop through all combinations
    for (sex in c("M", "F")){
    for (num_of_myopic_parents in c(0, 1, 2)){
    for (num_of_educated_parents in c(0, 1, 2)){
    for (country in c("A", "P")){

        # param
        index_code = paste0(sex, num_of_myopic_parents, num_of_educated_parents,
country)

        param_inp = data.table(
            entry_age = 0.5,
            SA = 1000,

            sex = sex,
            num_of_myopic_parents = num_of_myopic_parents,
            num_of_educated_parents = num_of_educated_parents,
            country = country,

            PAD_mort = 1 + tbl_PAD[item == "mortaliy", PAD],
            PAD_myopia = 1 + tbl_PAD[item == "myopia", PAD],
            PAD_lapse = 1 + tbl_PAD[item == "lapse", PAD],
            PAD_exp = 1 + tbl_PAD[item == "expense", PAD],
            PAD_interest = tbl_PAD[item == "interest", PAD],
            PAD_inflation = 0.01
        )

        ouput = deterministic_model(param_inp)

        reserve[index_code] = list(ouput[[4]])


    # end big loop
    }
    }
    }
    }

    return (reserve)
}

```

```{r run deterministic}
tbl_EOP_reserve_pp = generate_reserve_table()

```

```{r stochasitc ready data}


```

```
generate_statis_sim_data = function(){
    all_exp_list = list()
    all_decrement_tbl = list()
    all_SA_list = list()

    for (index_code in tbl_business_mix[, Key]){

        # SA
        SA = tbl_SA[country == substr(index_code, 4, 4), SA]
        all_SA_list[[index_code]] = SA

        # Expense List
        param = data.table(
            entry_age = 0.5,
            SA = SA,

            sex = substr(index_code, 1, 1),
            num_of_myopic_parents = as.numeric(substr(index_code, 2, 2)),
            num_of_educated_parents = as.numeric(substr(index_code, 3, 3)),
            country = substr(index_code, 4, 4),

            PAD_mort = 1,
            PAD_myopia = 1,
            PAD_lapse = 1,
            PAD_exp = 1,
            PAD_inflation = 0,
            PAD_interest = 0
        )

        all_exp_list[[index_code]] = lookup_misc_rate(param)

        #Decrement
        PP_list = lookup_decrement_rate(param)
        mort_PP = PP_list[[1]]
        myopia_PP = PP_list[[2]]
        lapse_PP = PP_list[[3]]

        dep_mort_pp = mort_PP * (1 - myopia_PP/2)
        dep_myopia_pp = myopia_PP * (1 - mort_PP/2)

        EOP_reserve = tbl_EOP_reserve_pp[[index_code]] * param[, SA] / 1000

        all_decrement_tbl[[index_code]]    =    list(dep_mort_pp,    dep_myopia_pp,
EOP_reserve)
    }

    return(list(all_exp_list, all_decrement_tbl, all_SA_list))
}

generate_statis_interest = function(){
    #time
    entry_age = 0.5
    n = 21 - entry_age
    t = seq(0, n - 1/12, 1/12)

    P_short = tbl_economic[item == paste0("P", "_short"), mean]
    P_long = tbl_economic[item == paste0("P", "_long"), mean]
    A_short = tbl_economic[item == paste0("A", "_short"), mean]
```

```
    A_long = tbl_economic[item == paste0("A", "_long"), mean]

    P_interest_raw = generate_interest_rates(P_short, P_long, 10, 0)
    A_interest_raw = generate_interest_rates(A_short, A_long, 10, 0)

    P_interest_mth = merge(data.table(t, year = ceiling(t)), P_interest_raw, by.x
= "year", by.y = "t", all.x = TRUE)[, fwd_mth]
    P_interest_mth[1] = 0
    A_interest_mth = merge(data.table(t, year = ceiling(t)), A_interest_raw, by.x
= "year", by.y = "t", all.x = TRUE)[, fwd_mth]
    A_interest_mth[1] = 0

    #output
    return(list(P = P_interest_mth, A = A_interest_mth))
}

temp_out = generate_statis_sim_data()
all_exp_list = temp_out[[1]]
all_decrement_tbl = temp_out[[2]]
all_SA_list = temp_out[[3]]

all_interest_tbl = generate_statis_interest()

# hurdle discount
entry_age = 0.5
n = 21 - entry_age
t = seq(0, n - 1/12, 1/12)

hurdle_rate = 0.1
hurdle_vt = (1 + hurdle_rate) ^ -t

```
```
```{r stochastic}

simulate_business_mix = function(n){
    rnd = runif(n)

    setkey(tbl_business_mix, start, end)
    DT1 = data.table(start = rnd, end = rnd)

    return   (tbl_business_mix$Key[foverlaps(DT1,   tbl_business_mix,   which   =
TRUE)$yid])
}


simulate_cert = function(exp_list, decrement_tbl, interest_mth, SA){

    #load
    premium = exp_list[[1]]
    comm_init = exp_list[[2]]
    comm_renew = exp_list[[3]]
    main_exp = exp_list[[4]]
    claim_exp = exp_list[[5]]
    inflation = exp_list[[6]]
    short_rate = exp_list[[7]]
    long_rate = exp_list[[8]]
```
```

```
    dep_mort_pp = decrement_tbl[[1]]
    dep_myopia_pp = decrement_tbl[[2]]
    EOP_reserve = decrement_tbl[[3]]

    #Simulate
    BOP_CF = rep(0, n*12)
    EOP_CF = rep(0, n*12)

    rnd_dec = c(1, runif(n*12 - 1))

    death_ind = fifelse(rnd_dec < dep_mort_pp, 1, 0)
    myopia_ind = fifelse(rnd_dec >= dep_mort_pp & rnd_dec < dep_mort_pp +
dep_myopia_pp, 1, 0)

    decrement_time_arr = which((death_ind + myopia_ind) > 0)
    if (length(decrement_time_arr) > 0){
        BOP_IF_ind = c(rep(1, decrement_time_arr[1]), rep(0, n*12 -
decrement_time_arr[1]))
        EOP_IF_ind = shift(BOP_IF_ind, -1, 0)
    } else {
        BOP_IF_ind = rep(1, n*12)
        EOP_IF_ind = rep(1, n*12)
    }

    BOP_reserve_change_IF = shift(EOP_reserve) * BOP_IF_ind
    EOP_reserve_change_IF = -EOP_reserve * EOP_IF_ind


    #Cash Flow
    premium_IF = c(0, premium, rep(0, n*12-2)) * BOP_IF_ind

    death_outgo = -premium * death_ind * BOP_IF_ind
    myopia_outgo = -SA * myopia_ind * (1 - death_ind) * BOP_IF_ind
    benefit_IF = death_outgo + myopia_outgo

    commission_IF = c(-comm_init, rep(0, n*12-1))
    claims_exp_IF = -claim_exp * (inflation ^ (t - 1/12)) * (1 - EOP_IF_ind) *
BOP_IF_ind
    main_exp_IF = -main_exp / 12 * (inflation ^ (t - 1/12)) * BOP_IF_ind

    pre_contract_CF = c(commission_IF[1] - EOP_reserve[1], rep(0, n*12-1))
    BOP_CF = premium_IF + commission_IF + main_exp_IF + BOP_reserve_change_IF
    BOP_CF[1] = 0
    EOP_CF = benefit_IF + claims_exp_IF + EOP_reserve_change_IF
    EOP_CF[1] = 0

    CF = pre_contract_CF + EOP_CF + BOP_CF * (1 + interest_mth)
    CF = CF * (1 - 0.256)
    NPV = sum(CF * hurdle_vt)

    #output
    D_rate = ifelse(any(death_outgo != 0), 1, 0)
    M_rate = ifelse(any(myopia_outgo != 0), 1, 0)
    return(list(premium, NPV, D_rate, M_rate, CF))

}
```

```

```{r parallel run}

# init cluster
cl <- makeCluster(detectCores())
clusterEvalQ(cl, {require(data.table, quietly = TRUE)})
clusterExport(cl, ls())

test_func = function(x){
    #param
    N_cert = 231823

    #time
    entry_age = 0.5
    n = 21 - entry_age

    sim_business = simulate_business_mix(N_cert)

    total_prem = 0
    total_NPV = 0

    for(i in 1:N_cert){
        index_code = sim_business[i]
        country = substr(index_code, 4, 4)

        temp = simulate_cert(
            all_exp_list[[index_code]],
            all_decrement_tbl[[index_code]],
            all_interest_tbl[[country]],
            all_SA_list[[index_code]])

        total_prem = total_prem + temp[[1]]
        total_NPV = total_NPV + temp[[2]]
    }

    return(list(total_prem = total_prem, total_NPV = total_NPV))
}

for (k in 1:17){
    out_list = parSapply(cl, 1:6, test_func)

    sim_total_prem = unlist(out_list[1,])
    sim_total_NPV = unlist(out_list[2,])

    load("sim_result_3.Rdata")
    save_1 = c(save_1, sim_total_prem)
    save_2 = c(save_2, sim_total_NPV)
    save(save_1, save_2,  file = "sim_result_3.Rdata")

    print(k)
}

stopCluster(cl)

```
```

```{r stochatic result}

load("sim_result_3.Rdata")
sim_total_prem = save_1
sim_total_NPV = save_2

stoc_summary = function(x){
    mean = mean(x)
    sd = sd(x)
    median = median(x)
    VaR_95 = quantile(x, 0.05)
    VaR_995 = quantile(x, 0.005)

    return(data.table(mean, sd, median, VaR_95, VaR_995))
}

a = stoc_summary(sim_total_prem)
b = stoc_summary(sim_total_NPV)

print(a)
print(b)

ggplot(data.table(prem = sim_total_prem), aes(x = prem)) + geom_histogram()
ggplot(data.table(NPV = sim_total_NPV), aes(x = NPV)) + geom_histogram()



```