MAKERERE UNIVERSITY

A MODEL FOR PRICING AND PROFIT EVAULATION OF A UNIT LINKED INSURANCE EDUCATION ASSURED SAVINGS PLAN.

BY

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DECLARATION

I, Nakiryowa Nicholeta, hereby declare that the information contained in this dissertation is my very own and has not been submitted to any college, university or institute for an academic award and all resources that I used have been indicated and acknowledged by references.

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APPROVAL

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DEDICATION

To all the girls who choose math.

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LIST OF ACRONYMS

IRA: Insurance Regulatory Authority.

GWP: Gross Written Premiums.

EPV: Expected Present Value

NPV: Net Present Value

BOU: Bank of Uganda

GDP: Gross Domestic Product

RDR: Risk Discount Rate

ABSTRACT

This dissertation report gives details of an actuarial pricing and profit testing model for a seven year unit linked education assured savings plan designed for the Ugandan market. The proposed product allows parents to choose their desired education benefit based on expected school fees from which a sum assured is calculated. Regular contribution are then invested in a unit-linked fund and in the event of death, disability or maturity, the defined sum assured is payable. The product offers the benefit in the form of an annuity of the parents choosing; a quadrimestrial payment, paid three times a year in case of occurrence of unexpected events.

The model uses key assumptions including a 16.4 risk discount rate, 3% inflation rate, 15.4% unit fund growth rate and 15% non-unit fund growth rate plus mortality and disability rates. It uses a 30 year old female and a quadrimestrial contribution of UGX 1,000,000 which gives a sum assured of UGX 12,113,801 as the base. These give rise to a premium of 910,068 annually.

The results show that premiums vary with age and gender, with the male premiums being initially higher at younger ages but a crossover happening at between age 47 and 48 were female premiums increase more sharply. Profit testing shows that the product achieves profit margins of 5.7 to 5.8% for younger policy holders but falls to about 1% at age 65. Sensitivity analysis also shows that profitability is affected by changes in risk discount rate and expenses.

This report therefore recommends that pricing should consider age related risk and expense loadings into pricing to improve the profitability of the product for older policy holders and maintain its long term viability.

CHAPTER ONE

INTRODUCTION

1.1. Introduction

Education is an important financial responsibility for many families, but the ability to meet education costs can be affected by unexpected events such as death, disability or loss of income. Insurance and savings can help families prepare for these financial risks and ensure that funds are available for future education expenses.

This chapter comprises a background to insurance and the product plus the objectives.

1.2. Background

People and businesses are exposed to different forms of risks throughout their lives and operations. These risks include premature death, disability, illness, loss of income and damage to property. Insurance provides a way of managing some of these risks by transferring the financial consequences of an uncertain event from an individual or business to an insurance company in exchange of a premium. Through pooling of risks from a large number of policyholders so as to manage the losses (Arrow, 2001).

The insurance sector is divided into two types; life and general insurance. Life insurance is important as death or disability of an income earner can significantly affect a household's ability to meet its financial obligations. Without adequate savings or protection from insurance, families may struggle to meet essential expenses, including education costs forcing them to liquidate assets in order to meet different costs which can drive most of these families further into poverty (Hallegatte, 2016). General insurance on the other hand mainly provides protection against risks involving property and other non-life risks like accidents, fires and theft. Both types play an important role in helping individuals and businesses manage financial risks and unexpected losses (Cummins & Weiss, 2014; Swiss Re Institute, 2020).

In Uganda, the insurance sector has continued to develop over the years, with growth in gross written premiums surpassing UGX 2 trillion in 2026 (IRA, 2026) from 1.76 trillion as at the end

of 2024 (IRA, 2025). However despite the growth in GWPs, insurance penetration in Uganda remains relatively at approximately 0.87% of GDP (Wofuma et al., 2024), the lowest in the east African region. The low level of penetration arises from low levels of awareness, mistrust, affordability constraints and products that do not reflect the realities of many households (Businge, 2026), as many households continue to view it as a luxury rather than a necessary financial tool. This suggests that there is still considerable room for the right insurance products to reach more households and address risks that currently being managed without formal insurance.

One of the areas where Ugandan households face financial pressure is education. Primary, secondary and tertiary education require families to meet regular expenses such as tuition, accommodation, transport, meals and other costs. These expenses can be particularly difficult to manage for households whose incomes are irregular or low (Adiele & Ayebatonara, 2022) the problem becomes more serious when the main income earner dies or becomes disabled as the family may lose the income that was being used to finance the child's education. In such situations, savings intended for education may not be sufficient to meet the expected costs.

In Uganda, households contribute a significant proportion of education costs, particularly at the secondary level. The study by Gresham et al(2015) estimates that households contribute about 62% of secondary education funding showing how cost of education can place pressure on household finances. Financial difficulties may thus affect a child's ability to remain in school particularly among lower income households.

Many families therefore need a product that does more than just provide a life cover but a solution that helps them save steadily for education while also protecting those savings against unexpected events such as death or disability of the main income earner. The need for products addressing this are particularly relevant as households contribute a substantial proportion of their income to education costs which then means any risk to the bread winner may then force children out of school (Evans & Popova, 2016; UNESCO, 2020).

The development of an education assured savings product can therefore provide an alternative way for parents to prepare for the future education expenses. The product developed provides death, disability and maturity benefits. The savings element over the policy term while the insurance element offers protection against the specified risks.

1.3. Problem statement.

In Uganda, education is a major financial responsibility for households with the cost of meeting this responsibility continuing to place pressure on families. In addition to school fees, households have to meet other costs such as accommodation, meals and other school related expenses. A single school term can cost up to UGX 2.5 million, making it difficult for some households to consistently meet education costs (Gresham et al., 2015).

The problem is more significant among households with irregular or limited incomes. When the main income earner dies or becomes disabled, the family may lose the income needed to finance children's education. This can force families to use their savings or liquidate assets in order to meet school expenses. The financial pressure associated with education can contribute to school dropout, with more than 30% of students reported to drop out before completing secondary school (UNESCO, 2020). Secondary school enrollment also differs considerably between wealth groups with enrollment reported at 43.1% among the wealthiest households compared to 8.2% among the poorest (Gresham et al., 2015; Kim & Jun, 2022).

Although savings can help families prepare for future education expenses, savings alone may not provide adequate protection when unexpected events occur before the required amount has been accumulated. There is therefore a need for a product that combines education savings with insurance protection while remaining affordable and profitable for the insurer. This product aims to develop a pricing and profit testing model for a seven year unit linked education assured savings plan and assess profitability.

1.4. General objective

To design a pricing and profit testing model that offers death, disability and surrender covers plus a saving plan to parents for a seven year unit linked education assured savings plan.

1.5. Specific objectives

- To determine the appropriate premiums and sum assured for the seven year unit linked education assured savings plan for different ages and genders.
- To examine the effect of age and gender on the premiums and profitability of the proposed product.

- To evaluate the profitability and long term sustainability of the proposed product for the insurer using profit testing.

1.6. Significance of the study.

This dissertation maybe helpful to parents and other policyholders understand how insurance and structured savings can work together to prepare for future education expenses while offering against unexpected events. For many households this product may offer a more disciplined way of savings for school costs.

Academically, the study applies actuarial ideas such as pricing, investment assumptions and profit testing to practical insurance problems in Uganda. It may therefore be useful to other students and researchers interested in product development and actuarial analysis.

1.7. Scope of the study.

The dissertation focuses on the development of seven year unit linked education assured savings plan for the Ugandan market. The product includes a saving component as well as a death, disability and surrender benefit.

The product considers policyholders within the age range 25 to 65 and uses mortality, disability and surrender assumptions in estimating the expected cash flows of the policy. It also includes economic assumptions such as inflation, investments growth, discount rate, expenses, commissions, management charges and bid offer spread.

Pricing and profit testing are carried out using the assumptions and data selected for the study. Mortality and disability data are based on Kenyan tables, since the study assumes that mortality and disability patterns are similar to those of Uganda.

1.8. Limitations of the study.

The limited availability of Uganda specific data was a major limitations. The study relied on available mortality and disability data from Kenya as a proxy for the Uganda population.

The study relied on assumed economic and expense parameters, including the unit fund growth rate, RDR, inflation rate and expense rates. Whereas actual future investments returns and expenses may differ from these assumptions which could then affect product profitability.

CHAPTER TWO

DATA AND ASSUMPTIONS

2.1. Introduction.

This chapter entails the data and assumptions used in the development of the model.

Table 2.1 Assumption used in the policy.

ASSUMPTION	**VALUE USED**
Sum assured	Based on clients need
Risk discount rate	16.4%
Inflation rate	3%
Initial expenses	25% of premium
Renewal expenses	2.5% of premium
Initial commission	25% of premium
Renewal commission	2.5% of premium
Management charge	1%
Bid/offer spread	5%
Allocation in the first year	60%
Allocation in all the other years	85%
Rate of growth in the unit fund	15.4%
Rate of growth in the non-unit fund	15%
Maturity benefit	Stated sum assured
Decrements	**benefit**
Death	Stated sum assured
disability	Stated sum assured
surrender	50% of the premiums paid to date
Tables used	
death	Kenyan mortality tables.
disability	Kenyan disability tables
surrender	As per the current economic situation.

2.2. Explanation of Assumptions.

2.2.1. Tables.

The independent mortality and disability rates were obtained from the Kenyan mortality life tables as the Kenyan mortality and disability pattern is similar to Uganda's.

2.2.2. Inflation rate.

The inflation rate was obtained from Uganda bureau of statistics data from consumer price index reports.

2.2.3. Expenses

Expenses were set at 25% of the annual premium in the initial years and 2.5% in the rest of the years.

2.2.4. Commission

Commission, a payment to agents and brokers for their services as they drive sales, is a crucial part of policy pricing and an initial commission of 25% of the annual premium was used and 2.5% for the proceeding years.

2.2.5. Unit fund growth rate.

This is was derived from an average between the 5 year bond yield and the 10 year bond yield.

2.2.6. Risk discount rate.

This is calculated as the gross government bond yield plus 1% used to discount future cash flows for profitability testing.

CHAPTER THREE

METHODOLOGY

3.1. Introduction

This chapter explains how the pricing and profit testing models were developed. It covers the software tools, the mathematical formulas, and the analytical techniques used.

3.2. Conceptual Overview.

The product is an annuity paying insurance product. The annuities start at death disability or maturity. The annuities are set as a quadrimestrial payment which is a payment made three times a year to follow the term structure of Ugandan education. The sum assured is the present value of a seven year annuity and is calculated based on the quadrimestrial payment mentioned.

3.3. Software Used.

Microsoft excel was initially used to price and profit test for a single age 30 at a quadrimestrial payment of 1,000,000. The same procedure is then carried into the python model to calculate premium and profit test for a range of ages 25 to 65. The python model was developed using python 3.14 in visual studio code.

3.4. Formulae.

Table 3.1: Multiple decrement table.

OUTPUT	**FORMULA**
$(aq)_x^d$	$\left(\frac{\mu_x^d}{\mu_x^d + \mu_x^{di}}\right) * \left(1 - e^{-(\mu_x^d + \mu_x^{di})}\right)$
$(aq)_x^{di}$	$\left(\frac{\mu_x^{di}}{\mu_x^d + \mu_x^{di}}\right) * \left(1 - e^{-(\mu_x^d + \mu_x^{di})}\right)$
$(aq)_x^s$	$\left(1 - (aq)_x^d - (aq)_x^{di}\right) * q_x^s$
μ_x^d	$-\ln(1 - q_x^d)$

μ_x^{di}	$-\ln(1-q_x^{di})$
$(ap)_x$	$1-((aq)_x^d+(aq)_x^{di}+(aq)_x^s$
${}_{t-1}(ap)_x$	$(ap)_x * {}_{t-1}(ap)_x$ 1 in the first year.

Table 3.2: Pricing formulae.

OUTPUT	**FORMULA**
Discount factor (assurance)	$(1+risk\ discount\ rate)^{-(year)}$
Death benefit	Sum assured
EPV death benefit	Death benefit * discount factor * $(aq)_x^d$ * ${}_{t-1}(ap)_x$
Disability benefit	Sum assured
EPV disability	Disability benefit * discount factor * $(aq)_x^{di}$ * ${}_{t-1}(ap)_x$
Surrender benefit	50% of premiums paid to date
EPV surrender	Surrender benefit * discount factor * $(aq)_x^s$ * ${}_{t-1}(ap)_x$
Survival benefit	Sum assured
EPV survival	Survival benefit * ${}_{t-1}(ap)_x$ * discount factor
EPV benefits	EPV death + EPV disability + EPV surrender + EPV survival
premium	Assumed premium before goal seek.

Discount factor(annuity)	$(1 + risk\ discount\ rate)^{-(year-1)}$
EPV premium	Premium * discount factor(annuity) * ${}_{t-1}(ap)_x$
Initial expenses and commission (IEC)	50% 0f premium total
Renewal expenses and commission (REC)	5% of premium * $(1 + inflation\ rate)^{(year-1)}$
EPV total expenses	IEC * Discount factor(annuity) * ${}_{t-1}(ap)_x$ REC * Discount factor(annuity) * ${}_{t-1}(ap)_x$
Equation of value	EPV Premium – EPV Benefits – EPV total Expenses

Table 3.3: Profit testing formulae.

OUTPUT	**FORMULA**
Unit fund table	
Allocated premium	60% of premium in the first year 85% of premium in the rest of the years.
Bid/offer spread	5% of the allocated premium.
Cost of allocation	Allocated premium – bid/offer spread
Fund before growth	Fund at the end of previous year + cost of allocation
Fund after growth	Fund before growth * (1 + unit fund growth rate)
Management charge	1% of the fund after growth
Bid value of units	Fund after growth – management charge
Non unit fund table	
Unallocated premium	Premium – allocated premium

Initial expenses and commission (IEC)	50% 0f premium
Renewal expenses and commission (REC)	5% of premium * $(1 + inflation\ rate)^{(year-1)}$
Interest gained in non-unit fund.	(unallocated premium + bid offer spread – expenses) * (non unit fund growth rate)
Extra death cost	((Max(sum assured, bid value of units))- bid value of units) * $(aq)_x^d$
Extra disability cost	((Max(sum assured, bid value of units))- bid value of units) * $(aq)_x^{di}$
Surrender penalty	(bid value of units – surrender benefit) * $(aq)_x^s$
Maturity benefit	(bid value of units – sum assured) * ${}_{t-1}(ap)_x$
Profit vector	(unallocated premium + bid value of units – expenses + interest – extra death cost – extra disability cost + surrender penalty – extra maturity cost)
Discount factor (profits)	$(1 + risk\ discount\ rate)^{-(year)}$
Discount factor (premium)	$(1 + risk\ discount\ rate)^{-(year-1)}$
Profit signature	Profit vector * ${}_{t-1}(ap)_x$
Discounted profits	Profit signature * Discount factor (profits)
Discounted premiums	Discount factor (premium) * premiums * ${}_{t-1}(ap)_x$

NPV profit	Sum of discounted profits
NPV premium	Sum of discounted premiums
Profit margin	$\frac{NPV\ premium}{NPV\ profit} * 100$

3.4.1. Description of symbols

q_x^d : Independent probability of death

q_x^{di} : Independent probability of disability

q_x^s : Independent probability of surrender

μ_x^d : Force of death

μ_x^{di} : Force of disability

$(aq)_x^d$: Dependent probability of death

$(aq)_x^{di}$: Dependent probability of disability

$(aq)_x^s$: Dependent probability of surrender

$(ap)_x$: Dependent probability of survival

${}_{t-1}(ap)_x$: Probability of being in force at the start of the each year

CHAPTER FOUR

PRESNTATION AND DISCUSSION OF RESULTS.

4.1. Introduction

This chapter presents the excel face of the model, analysis of results obtained in terms of premiums and profit margins plus a sensitivity analysis to show how variation of results would affect profitability.

4.2. Results from the model.

This section has been promptly split into two sections males and females. Each section entails the different tables used to derive both the premium and the profit margin.

4.2.1. Females.

Table 4.1: Multiple decrement tables.

n	age	(aq)_x death	(aq)_x disability	q_x withdraw	(aq)_x withdraw	px	t-1 px
1	30	0.001529648	0.000459648	0.1	0.09980107	0.898209633	1
2	31	0.001459664	0.000459664	0.1	0.099808067	0.898272604	0.898209633
3	32	0.001389673	0.000469673	0.1	0.099814065	0.898326588	0.806837107
4	33	0.001329681	0.000479681	0.07	0.069873345	0.928317294	0.724803225
5	34	0.001289678	0.000499677	0.05	0.049910532	0.948300113	0.672847368
6	35	0.001279661	0.000529661	0	0	0.998190678	0.638061235
7	36	0.001299636	0.000559636	0	0	0.998140728	0.636906777
7	36	0.001299636	0.000559636	0	0	0.998140728	0.635722594

Table 4.2: EPV death and disability.

EPV disability and death benefit							
n	**age**	**qx**	**t-1Px**	**k\qx**	**discounting**	**amount**	**EPV**
1	30	0.001989296	1	0.001989296	0.859106529	12,113,800.76	20,702.70
2	31	0.001919328	0.898209633	0.001723959	0.738064029	12,113,800.76	15,413.51
3	32	0.001859347	0.806837107	0.00150019	0.634075626	12,113,800.76	11,523.06
4	33	0.001809362	0.724803225	0.001311431	0.54473851	12,113,800.76	8,653.94
5	34	0.001789355	0.672847368	0.001203963	0.467988411	12,113,800.76	6,825.41
6	35	0.001809322	0.638061235	0.001154458	0.402051899	12,113,800.76	5,622.65
7	36	0.001859272	0.636906777	0.001184183	0.345405412	12,113,800.76	4,954.83
							73,696.08

Table 4.3: EPV surrender.

EPV surrender benefit							
n	**age**	**(aq)_x withdraw**	**t-1Px**	**k\(aq)_x surrender**	**discounting**	**amount**	**EPV**
1	30	0.09980107	1	0.09980107	0.859106529	-	-
2	31	0.099808067	0.898209633	0.089648567	0.738064029	-	-
3	32	0.099814065	0.806837107	0.080533692	0.634075626	-	-
4	33	0.069873345	0.724803225	0.050644426	0.54473851	1,820,135.10	50,213.83
5	34	0.049910532	0.672847368	0.03358217	0.467988411	2,275,168.87	35,756.71
6	35	0	0.638061235	0	0.402051899	2,730,202.65	-
7	36	0	0.636906777	0	0.345405412	3,185,236.42	-
							85,970.54

Table 4.4: EPV premium.

EPV premium					
n	**age**	**npx**	**discounting**	**premium**	**EPV**
1	30	1	1	910,067.55	910067.5497
2	31	0.898209633	0.859106529	910,067.55	702260.6875
3	32	0.806837107	0.738064029	910,067.55	541942.901
4	33	0.724803225	0.634075626	910,067.55	418248.8979
5	34	0.672847368	0.54473851	910,067.55	333563.3032
6	35	0.638061235	0.467988411	910,067.55	271750.9605
7	36	0.636906777	0.402051899	910,067.55	233040.6148
					3,410,874.91

Table 4.5: EPV Survival.

EPV survival					
n	**age**	**npx**	**discounting**	**amount**	**EPV**
7	36	0.635722594	0.345405412	12,113,800.76	**2659972.895**

Table 4.6: EPV expenses.

EPV expenses						
n	**age**	**npx**	**discounting**	**expenses**	**commission**	**EPV**
1	30	1	1	227,516.89	227,516.89	455033.7749
2	31	0.89821	0.85911	22,751.69	22,751.69	36166.42541
3	32	0.80684	0.73806	22,751.69	22,751.69	28747.36118
4	33	0.7248	0.63408	22,751.69	22,751.69	22851.59317
5	34	0.67285	0.54474	22,751.69	22,751.69	18771.42182
6	35	0.63806	0.46799	22,751.69	22,751.69	15751.69216
7	36	0.63691	0.40205	22,751.69	22,751.69	13913.13407
						591,235.40

The Profit testing model

Table 4.7: Unit fund.

year	age	allocated	bid/offer spread	cost of allocation	fund before growth	fund after growth	maintenance charge	bid value of units
1	30	546,040.53	(27,302.03)	518,738.50	518,738.50	598,624.23	(5,986.24)	592,637.99
2	31	773,557.42	(38,677.87)	734,879.55	1,327,517.54	1,531,955.24	(15,319.55)	1,516,635.69
3	32	773,557.42	(38,677.87)	734,879.55	2,251,515.23	2,598,248.58	(25,982.49)	2,572,266.09
4	33	773,557.42	(38,677.87)	734,879.55	3,307,145.64	3,816,446.07	(38,164.46)	3,778,281.61
5	34	773,557.42	(38,677.87)	734,879.55	4,513,161.15	5,208,187.97	(52,081.88)	5,156,106.09
6	35	773,557.42	(38,677.87)	734,879.55	5,890,985.64	6,798,197.42	(67,981.97)	6,730,215.45
7	36	773,557.42	(38,677.87)	734,879.55	7,465,095.00	8,614,719.63	(86,147.20)	8,528,572.43

Table 4.8: The non-unit fund.

year	age	unallocated	bid/offer spread	expenses	interest	mc	extra death benefit	extra disability benefit	surrender penalty	extra maturity benefit	profit
1	30	364027	27302	-455034	-9555.7	5986.24	-17623	-5295.7	59145.9		-31047.29
2	31	136510	38677.9	-46868	19247.9	15319.6	-15468	-4871.1	151372		293920.04
3	32	136510	38677.9	-48275	19037	25982.5	-13260	-4481.4	256748		410940.29
4	33	136510	38677.9	-49723	18819.8	38164.5	-11084	-3998.4	136822		304189.76
5	34	136510	38677.9	-51214	18596	52081.9	-8973.2	-3476.6	143789		325990.79
6	35	136510	38677.9	-52751	18365.6	67982	-6889.2	-2851.5	0		199044.02
7	36	136510	38677.9	-54333	18128.2	86147.2	-4659.5	-2006.4	0	-2279210.7	-2060747

year	age	discounting at rdr	t-1Px	present value of profits	premium	discounting	t-1Px	present value of premium
1	30	0.859106529	1	(26,672.93)	910,067.55	1	1	910,067.55
2	31	0.738064029	0.89820963	194,850.24	910,067.55	0.859106529	0.89820963	702,260.69
3	32	0.634075626	0.80683711	210,235.30	910,067.55	0.738064029	0.80683711	541,942.90
4	33	0.54473851	0.72480323	120,102.70	910,067.55	0.634075626	0.72480323	418,248.90
5	34	0.467988411	0.67284737	102,649.53	910,067.55	0.54473851	0.67284737	333,563.30
6	35	0.402051899	0.63806124	51,061.51	910,067.55	0.467988411	0.63806124	271,750.96
7	36	0.345405412	0.63690678	(453,345.80)	910,067.55	0.402051899	0.63690678	233,040.61
0				**198,880.55**				**3,410,874.91**

4.2.2. Males.

Table 4.9: Multiple decrement tables.

n	age	(aq)_x death	(aq)_x disability	q_x withdraw	(aq)_x withdraw	px	t-1 px
1	30	0.001889424	0.000460361	0.1	0.099765022	0.897885194	1
2	31	0.001839421	0.000468521	0.1	0.099769206	0.897922852	0.897885194
3	32	0.001799415	0.000476765	0.1	0.099772382	0.897951438	0.806231634
4	33	0.001779386	0.000496438	0.07	0.069840692	0.927883483	0.723956855
5	34	0.001789347	0.000517684	0.05	0.049884648	0.947808321	0.671747609
6	35	0.00181929	0.000545092	0	0	0.997635617	0.636687973
7	36	0.00187922	0.000574804	0	0	0.997545976	0.635182599
7	36	0.00187922	0.000574804	0	0	0.997545976	0.633623846

Table 4.10: EPV death and disability.

n	age	qx	t-1Px	Probability	Discounting	Amount	EPV
1	30	0.002349785	1	0.002349785	0.859106529	12,113,800.76	24,454.32
2	31	0.002307942	0.897885194	0.002072267	0.738064029	12,113,800.76	18,527.64
3	32	0.00227618	0.806231634	0.001835128	0.634075626	12,113,800.76	14,095.74
4	33	0.002275824	0.723956855	0.001647599	0.54473851	12,113,800.76	10,872.26
5	34	0.002307031	0.671747609	0.001549742	0.467988411	12,113,800.76	8,785.67
6	35	0.002364383	0.636687973	0.001505374	0.402051899	12,113,800.76	7,331.74
7	36	0.002454024	0.635182599	0.001558754	0.345405412	12,113,800.76	6,522.09
							90,589.47

Table 4.11: The EPV surrender.

n	age	(aq)_x withdraw	t-1Px	k\(aq)_x surrender	discounting	amount	EPV
1	30	0.099765022	1	0.099765022	0.859106529	-	-
2	31	0.099769206	0.897885194	0.089581293	0.738064029	-	-
3	32	0.099772382	0.806231634	0.080439651	0.634075626	-	-
4	33	0.069840692	0.723956855	0.050561648	0.54473851	1,827,265.44	50,328.15
5	34	0.049884648	0.671747609	0.033509893	0.467988411	2,284,081.80	35,819.52
6	35	0	0.636687973	0	0.402051899	2,740,898.16	-
7	36	0	0.635182599	0	0.345405412	3,197,714.52	-
							86,147.67

Table 4.12: EPV premium.

EPV premium					
n	**age**	**npx**	**discounting**	**premium**	**EPV**
1	30	1	1	913,632.72	913632.7195
2	31	0.897885194	0.859106529	913,632.72	704757.1231
3	32	0.806231634	0.738064029	913,632.72	543657.6686
4	33	0.723956855	0.634075626	913,632.72	419397.0664
5	34	0.671747609	0.54473851	913,632.72	334322.6898
6	35	0.636687973	0.467988411	913,632.72	272228.3739
7	36	0.635182599	0.402051899	913,632.72	233320.2078
					3,421,315.85

Table 4.13: EPV survival.

EPV survival					
n	**age**	**npx**	**discounting**	**amount**	**EPV**
7	36	0.633623846	0.345405412	12,113,800.76	**2651191.369**

Table 4.14: EPV expenses

EPV expenses						
n	**age**	**npx**	**discounting**	**expenses**	**commission**	**EPV**
1	30	1	1	228,408.18	228408.18	456816.3597
2	31	0.89789	0.85910653	22,840.82	22,840.82	36294.99184
3	32	0.80623	0.73806403	22,840.82	22,840.82	28838.32103
4	33	0.72396	0.63407563	22,840.82	22,840.82	22914.32491
5	34	0.67175	0.54473851	22,840.82	22,840.82	18814.15664
6	35	0.63669	0.46798841	22,840.82	22,840.82	15779.36481
7	36	0.63518	0.4020519	22,840.82	22,840.82	13929.8265
						593,387.35

Table 4.15: Unit fund table.

year	age	allocated	bid/offer spread	cost of allocation	fund before growth	fund after growth	maintenance charge	bid value of units
1	30	548,179.63	(27,408.98)	520,770.65	520,770.65	600,969.33	(6,009.69)	594,959.64
2	31	776,587.81	(38,829.39)	737,758.42	1,332,718.06	1,537,956.64	(15,379.57)	1,522,577.07
3	32	776,587.81	(38,829.39)	737,758.42	2,260,335.49	2,608,427.16	(26,084.27)	2,582,342.89
4	33	776,587.81	(38,829.39)	737,758.42	3,320,101.31	3,831,396.91	(38,313.97)	3,793,082.94
5	34	776,587.81	(38,829.39)	737,758.42	4,530,841.36	5,228,590.93	(52,285.91)	5,176,305.02
6	35	776,587.81	(38,829.39)	737,758.42	5,914,063.44	6,824,829.21	(68,248.29)	6,756,580.92
7	36	776,587.81	(38,829.39)	737,758.42	7,494,339.34	8,648,467.60	(86,484.68)	8,561,982.93

Table 4.16: The non-unit fund table.

year	age	unallocated	bid/offer spread	expenses	interest	mc	extra death benefit	extra disability benefit	surrender penalty	extra maturity benefit	profit
1	30	365453	27409	-456816	-9593.1	6009.69	-21764	-5302.8	59356.2		-35248.4
2	31	137045	38829.4	-47052	19323.3	15379.6	-19482	-4962.2	151906		290987.5
3	32	137045	38829.4	-48464	19111.6	26084.3	-17151	-4544.3	257647		408557.7
4	33	137045	38829.4	-49918	18893.5	38314	-14806	-4130.7	137294		301521.8
5	34	137045	38829.4	-51415	18668.9	52285.9	-12414	-3591.4	144278		323686.5
6	35	137045	38829.4	-52958	18437.5	68248.3	-9746.3	-2920.2	0		196936.1
7	36	137045	38829.4	-54546	18199.2	86484.7	-6674.6	-2041.6	0	-2250516.5	-2033220.8

year	age	discountign at rdr	t-1Px	present value of profits	premium	discounting	t-1Px	present value of premium
1	30	0.859106529	1	(30,282.11)	913,632.72	1	1	913,632.72
2	31	0.738064029	0.897885194	192,836.47	913,632.72	0.859106529	0.897885194	704,757.12
3	32	0.634075626	0.806231634	208,859.53	913,632.72	0.738064029	0.806231634	543,657.67
4	33	0.54473851	0.723956855	118,910.30	913,632.72	0.634075626	0.723956855	419,397.07
5	34	0.467988411	0.671747609	101,757.37	913,632.72	0.54473851	0.671747609	334,322.69
6	35	0.402051899	0.636687973	50,412.01	913,632.72	0.467988411	0.636687973	272,228.37
7	36	0.345405412	0.635182599	(446,079.51)	913,632.72	0.402051899	0.635182599	233,320.21
0				**196,414.05**				**3,421,315.85**

4.3. Analysis of Results.

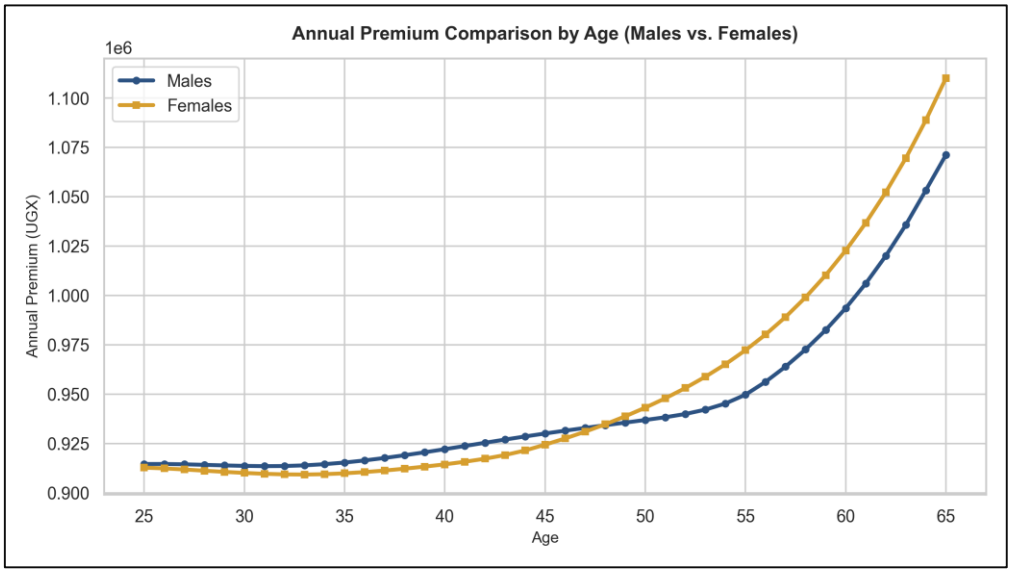
4.3.1. Premiums

Looking at a female aged 30 for a quadrimestrial benefit of 1,000,000 resulting in the sum assured of UGX 12,113,800, the premium is 910,068 for females and 913,633 for males, with male premiums being higher than female premiums as males have higher rates of mortality and disability.

The graph and table below indicate that annual premiums increase with age for both males and females, with a relatively gradual rise at younger ages and a much steeper increase after about age 50. This pattern reflects the increasing probability of adverse events as age advances, which raises the expected cost of providing cover. At younger ages, male premiums are slightly higher than female premiums, but the trend reverses at around age 47, after which female premiums rise more rapidly and exceed male premiums through age 65. By age 65, the female premium reaches approximately UGX 1.11 million compared to about UGX 1.07 million for males, suggesting a stronger late-age risk escalation for females under the assumptions used.

Figure 4.1: A graph showing the comparison in the annual premium between males and females from age 25 to 65.

:



4.3.2. Profit margins

The profit margin trend mirrors this pricing pattern in reverse as shown by the graph below. Margins remain relatively strong at younger ages, averaging about 5.7%, but decline steadily with age and fall more sharply after age 50. By age 65, margins compress to about 1% to 2%, indicating that older ages generate much thinner returns under the current premium structure. The female margin is initially higher than the male margin, but it declines more rapidly after the crossover point, reinforcing the fact that late-age policies are less profitable and more exposed to adverse selection and higher claim costs.

Figure 4.2: A graph showing the comparison in the profit margin between males and females from age 25 to 65.

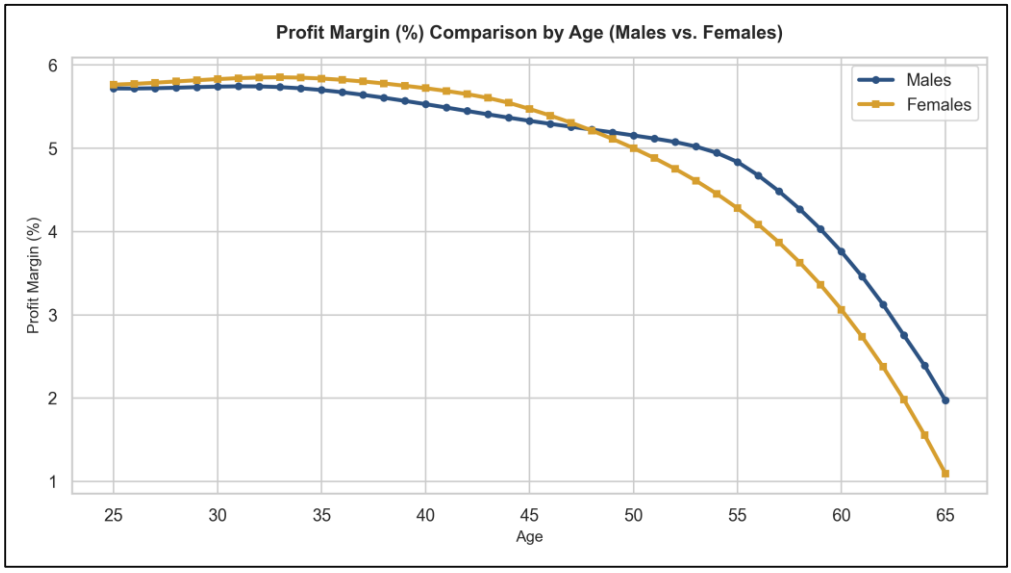


Table 4.17: A table showing results of annual premiums and profit margins form age 25 to 65 for both males and females.

		MALES		FEMALES	
Age	**Sum Assured (UGX)**	**Annual Premium (UGX)**	**Profit Margin (%)**	**Annual Premium (UGX)**	**Profit Margin (%)**
25	12,113,801	914,587	5.72%	912,728	5.76%
26	12,113,801	914,597	5.72%	912,355	5.77%
27	12,113,801	914,429	5.72%	911,804	5.79%
28	12,113,801	914,164	5.73%	911,195	5.80%
29	12,113,801	913,871	5.73%	910,606	5.82%
30	12,113,801	913,633	5.74%	910,068	5.83%
31	12,113,801	913,499	5.74%	909,623	5.84%
32	12,113,801	913,568	5.74%	909,335	5.85%
33	12,113,801	913,905	5.74%	909,252	5.85%
34	12,113,801	914,500	5.72%	909,435	5.85%
35	12,113,801	915,333	5.70%	909,875	5.84%
36	12,113,801	916,399	5.67%	910,506	5.82%
37	12,113,801	917,656	5.64%	911,281	5.80%
38	12,113,801	919,039	5.61%	912,222	5.78%
39	12,113,801	920,533	5.57%	913,271	5.75%
40	12,113,801	922,106	5.53%	914,416	5.72%
41	12,113,801	923,715	5.49%	915,739	5.69%
42	12,113,801	925,347	5.45%	917,263	5.65%
43	12,113,801	926,965	5.41%	919,118	5.60%
44	12,113,801	928,532	5.37%	921,442	5.55%
45	12,113,801	930,036	5.33%	924,371	5.47%
46	12,113,801	931,481	5.29%	927,530	5.39%
47	12,113,801	932,875	5.26%	930,954	5.31%
48	12,113,801	934,236	5.22%	934,699	5.21%
49	12,113,801	935,558	5.19%	938,749	5.11%
50	12,113,801	936,890	5.15%	943,138	5.00%
51	12,113,801	938,275	5.12%	947,877	4.88%
52	12,113,801	939,923	5.08%	953,085	4.75%
53	12,113,801	942,142	5.02%	958,800	4.61%

		MALES		FEMALES	
Age	**Sum Assured (UGX)**	**Annual Premium (UGX)**	**Profit Margin (%)**	**Annual Premium (UGX)**	**Profit Margin (%)**
54	12,113,801	945,232	4.95%	965,137	4.46%
55	12,113,801	949,698	4.84%	972,227	4.28%
56	12,113,801	956,212	4.68%	980,168	4.09%
57	12,113,801	963,933	4.48%	989,067	3.87%
58	12,113,801	972,631	4.27%	999,040	3.63%
59	12,113,801	982,443	4.03%	1,010,217	3.36%
60	12,113,801	993,529	3.76%	1,022,751	3.06%
61	12,113,801	1,006,009	3.46%	1,036,681	2.74%
62	12,113,801	1,020,011	3.13%	1,052,228	2.38%
63	12,113,801	1,035,705	2.76%	1,069,524	1.99%
64	12,113,801	1,053,292	2.39%	1,088,755	1.56%
65	12,113,801	1,071,153	1.97%	1,110,046	1.10%

4.4. Sensitivity analysis.

Table 4.18: Sensitivity analysis.

ASSUMPTIONS		**% CHANGE**	**PROFIT MARGIN**	**COMMENT**
EXPENSES	Increase	10%	4.12%	An increase in expenses has a negative relationship with the profit margin as an increase in expenses results in a decrease in the profit margin.
	Standard	0	5.83%	
	Decrease	10%	7.54%	
RISK DISCOUNT RATE	Increase	10%	-8.24%	an increase in interest results in a decrease in the profit margin and vice versa,
	Standard	0	5.83%	
	Decrease	10%	24.49%	
MORTALITY	Increase	10%	5.80%	With an increase in mortality, there is a decrease in the profit margin with a decrease resulting in an increase in mortality.
	Standard	0	5.83%	
	Decrease	10%	5.86%	
DISABILITY	Increase	10%	5.82%	A decrease in disability results in an increase in the profit margin.
	Standard	0	5.83%	
	Decrease	10%	5.84%	

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS.

5.1. Conclusions.

This product developed an actuarial pricing and profit testing model for a seven year unit linked education assured savings plan incorporating death and disability benefits. The model was developed to provide parents with a structured way of preparing for future education expenses while providing financial protection against the selected risks.

The pricing results showed that the required premiums vary with age and gender. For the 30 year old, the model produced a sum assured of UGX 12113801, with an annual premium of UGX 910,068 for females and UGX 913,633 for males. Premiums generally increased with age, although the pattern varied at younger ages. The female premiums became higher than the male premiums between ages 47 to 48 under the assumptions used for the study.

Profit testing showed that the product was more profitable for younger policy holders with profit margins of approximately 5.7% to 5.8%. However, profitability declined with increasing age and at age 65, the margin was approximately 1.1% for females and approximately 1.97% for males.

The sensitivity analysis showed that profitability is particularly sensitive to changes in the risk discount rate and expenses. Changes in mortality and disability rates had a smaller effect on profitability within the range tested. This suggests that investment and financial assumptions are important considerations when assessing the long term profitability of the proposed product.

The model provides a basis for pricing and profitability assessment, although the results could be improved as more reliable Uganda specific actuarial and policyholder data become available.

5.2. Recommendations.

First, the insurers should endeavor to use age indexed loadings rather than relying on a flat pricing structure across all ages. Since margins deteriorate sharply after age 50, older entry brackets should attract higher risk and expense loadings to better reflect their true cost of cover. This would help protect profitability while maintaining pricing adequacy.

Second, the sensitivity analysis showed that changes in expenses have a noticeable effect on profitability. The insurers should therefore regularly review acquisition, administration and other policy related expenses to ensure that they remain appropriate and do not unnecessarily reduce profit margins. The sensitivity analysis also showed that profitability is highly sensitive to changes the risk discount rate and therefore the insurer should therefore review it periodically and update it when there are significant changes in economic conditions.

Finally, underwriting for older entrants should be strengthened through stricter risk selection and medical screening**.** Since older cohorts carry higher adverse selection and claim risk, tighter underwriting can help ensure that only insurable risks are admitted at acceptable pricing levels. This will support policy quality and reduce the likelihood of unprofitable policy issuance,

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APPENDIX:

APPENDIX A: PYTHON OUTPUT

Figure 7.1: The front initial display of the

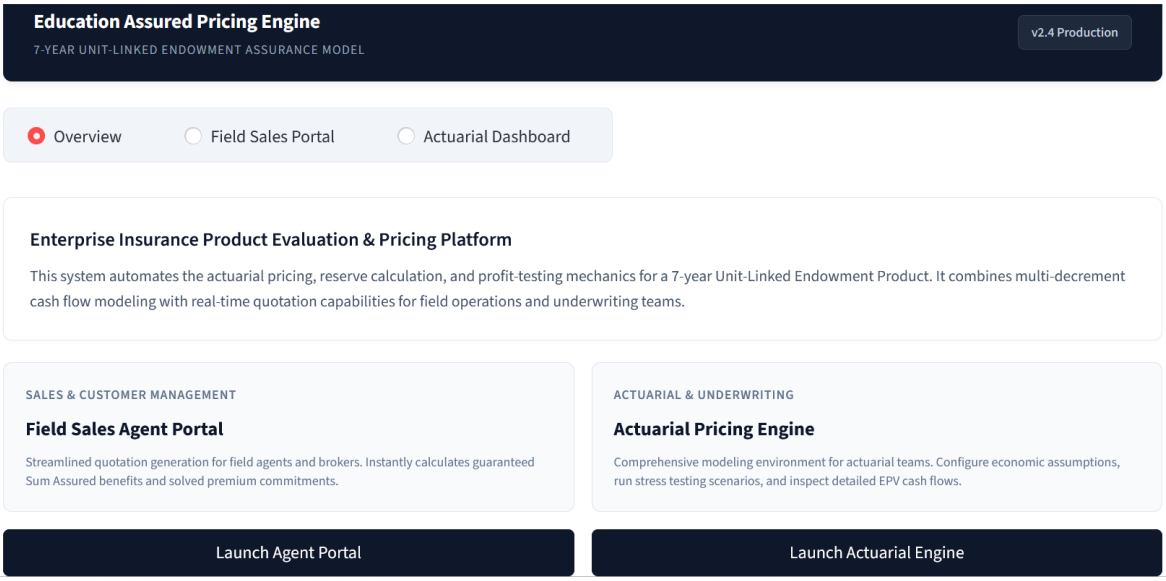


Figure 7.2: The field sales portal of the education assured application.

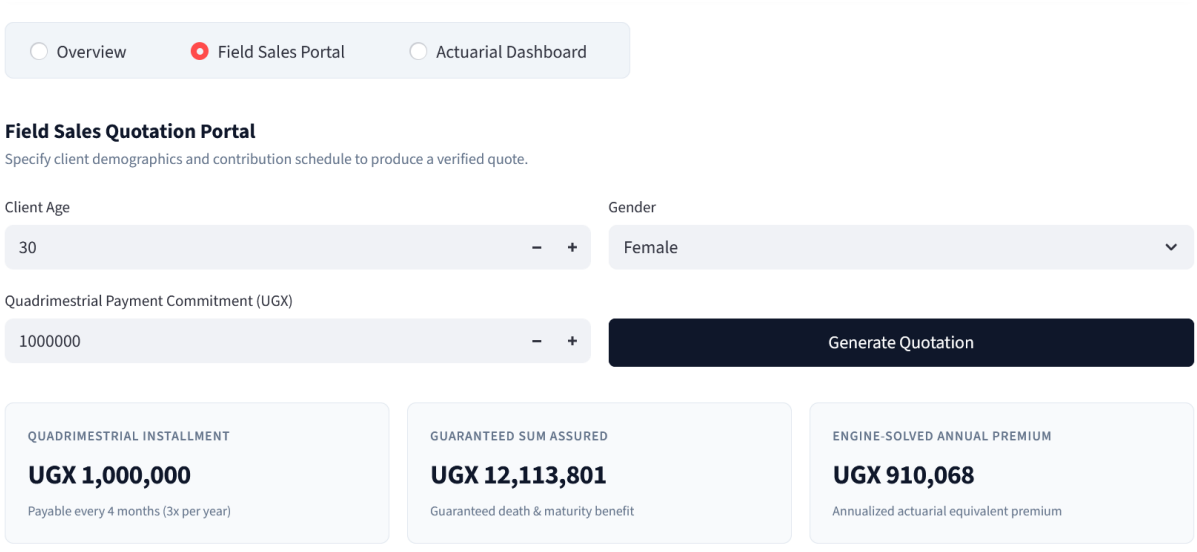


Figure 7.3: The actuarial dashboard of the application.

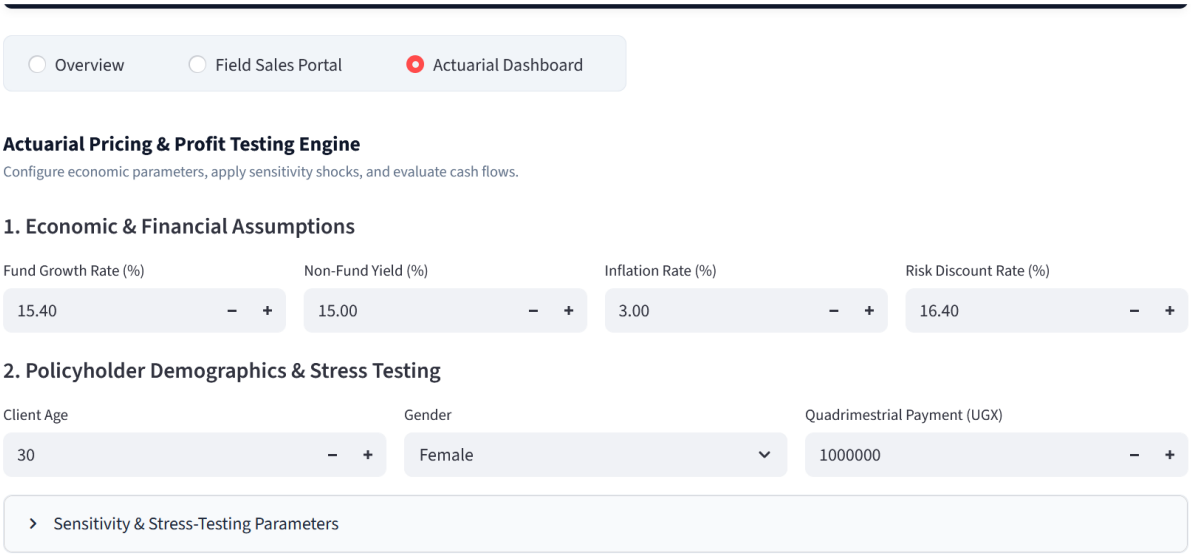


Figure 7.4: The sensitivity analysis section of the application.

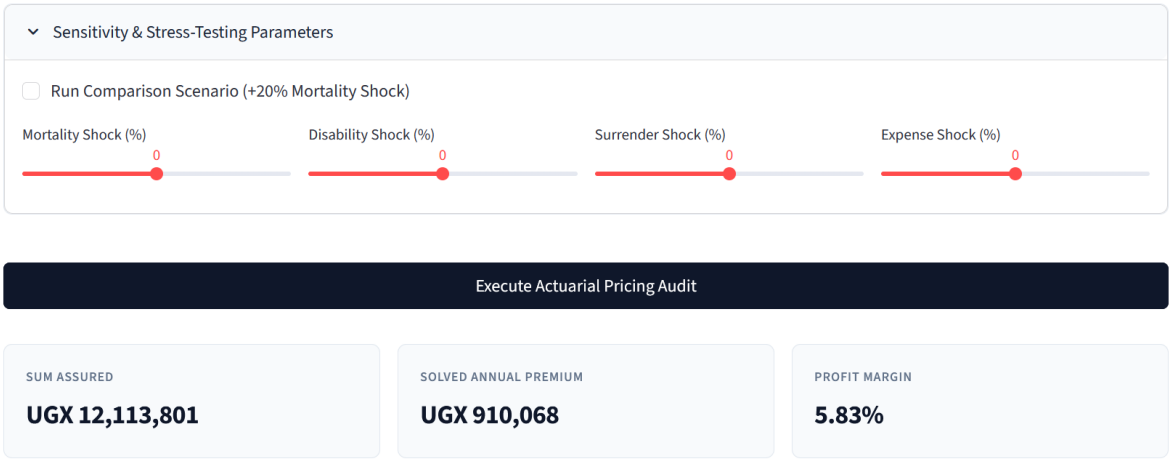


Figure 7.5: The display of the sum assured, annual premium and profit margin.

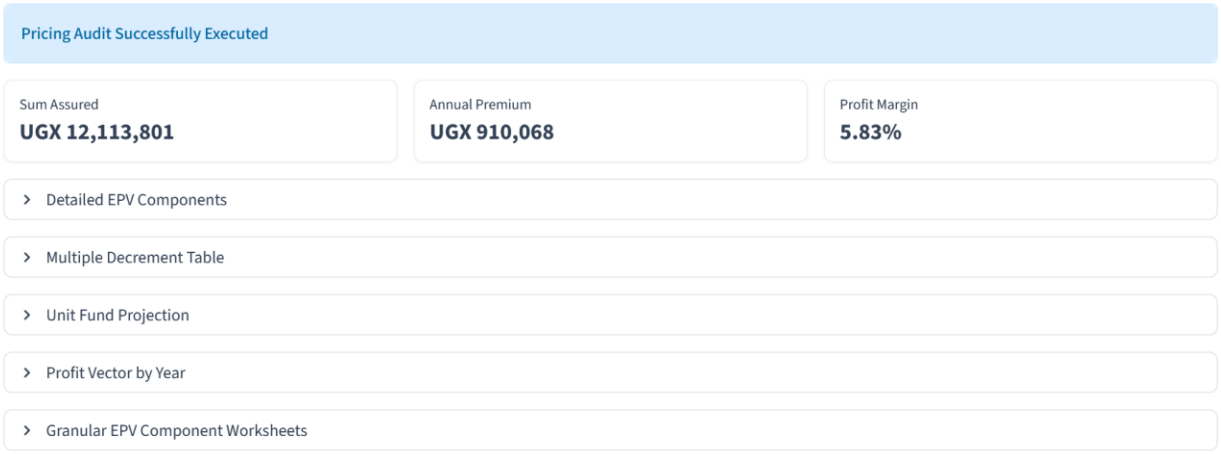


Figure 7.6: The multiple decrement tables.



	Age	aq_death	aq_disability	Year	qx_surr	aq_surr	px	t_minus_1_px
10	30	0.15%	0.05%	1	0.1	9.98%	89.82%	1
11	31	0.15%	0.05%	2	0.1	9.98%	89.83%	0.8982
12	32	0.14%	0.05%	3	0.1	9.98%	89.83%	0.8068
13	33	0.13%	0.05%	4	0.07	6.99%	92.83%	0.7248
14	34	0.13%	0.05%	5	0.05	4.99%	94.83%	0.6728
15	35	0.13%	0.05%	6	0	0.00%	99.82%	0.6381
16	36	0.13%	0.06%	7	0	0.00%	99.81%	0.6369

Figure 7.7: The EPV death and disabilities.

Detailed year-by-year actuarial worksheets breaking down probabilities, discounting, cash flows, and EPV contributions.

1. EPV Disability & Death Benefit

	n	age	qx	t-1Px	k|qx	discounting	amount	epv
0	1	30	0.0019893	1.00000000	0.001989296	0.859106529	12,113,800.76	20,702.70
1	2	31	0.0019193	0.89820963	0.001723959	0.738064029	12,113,800.76	15,413.51
2	3	32	0.0018593	0.80683711	0.001500190	0.634075626	12,113,800.76	11,523.06
3	4	33	0.0018094	0.72480323	0.001311431	0.544738510	12,113,800.76	8,653.94
4	5	34	0.0017894	0.67284737	0.001203963	0.467988411	12,113,800.76	6,825.41
5	6	35	0.0018093	0.63806124	0.001154458	0.402051899	12,113,800.76	5,622.65
6	7	36	0.0018593	0.63690678	0.001184183	0.345405412	12,113,800.76	4,954.83

Total EPV Death/Disability

UGX 73,696.08

Figure 7.8: The EPV premium, expenses and commissions.

2. EPV Premium

	n	age	npx	discounting	premium	epv
0	1	30	1.00000000	1.000000000	910,067.55	910,067.55
1	2	31	0.89820963	0.859106529	910,067.55	702,260.69
2	3	32	0.80683711	0.738064029	910,067.55	541,942.90
3	4	33	0.72480323	0.634075626	910,067.55	418,248.90
4	5	34	0.67284737	0.544738510	910,067.55	333,563.30
5	6	35	0.63806124	0.467988411	910,067.55	271,750.96
6	7	36	0.63690678	0.402051899	910,067.55	233,040.61

Total EPV Premium

UGX 3,410,874.91

3. EPV Expenses & Commissions

	n	age	npx	discounting	expense_pct	expenses	commission
0	1	30	1.00000	1.00000	50.0%	455,033.77	455,033.77
1	2	31	0.89821	0.85911	5.0%	46,868.48	46,868.48
2	3	32	0.80684	0.73806	5.0%	48,274.53	48,274.53
3	4	33	0.72480	0.63408	5.0%	49,722.77	49,722.77
4	5	34	0.67285	0.54474	5.0%	51,214.45	51,214.45
5	6	35	0.63806	0.46799	5.0%	52,750.89	52,750.89
6	7	36	0.63691	0.40205	5.0%	54,333.41	54,333.41

Total EPV Expenses

UGX 591,235.40

Figure 7.9: The EPV survival.

4. EPV Survival (Maturity)

	n	age	npx	discounting	amount	epv
0	7	37	0.63572259	0.345405412	12,113,800.76	2,659,972.90

APPENDIX B: PYTHON CODE

The pricing engine:

```
import numpy as np
import pandas as pd
from scipy.optimize import fsolve

DEFAULT_ASSUMPTIONS = {
    "duration": 7,
    "fund_growth_rate": 0.154,
    "non_fund_rate": 0.15,
    "fmc_rate": 0.01,
    "bid_offer_spread": 0.05,
    "rdr": 0.164,
    "inflation_rate": 0.03,
}


def calculate_sum_assured_from_annuity(
    quadrimestrial_payment, annual_rate=0.164
):
  """Calculates the total Sum Assured based on a series of quadrimestrial

  annuity payments discounted at the RDR annual rate over 18 periods (6 years).
  """
  total_periods = 18
  period_rate = (1 + annual_rate) ** (1 / 3) - 1
  return sum(
      quadrimestrial_payment / (1 + period_rate) ** t
      for t in range(total_periods)
  )


def load_probability_table(excel_file, gender):
  """Loads raw mortality and disability probabilities from an Excel workbook

  based on the specified gender sheet ('MALES' or 'FEMALES').
  """
  sheet_name = "FEMALES" if gender.upper() == "FEMALE" else "MALES"
  df = pd.read_excel(excel_file, sheet_name=sheet_name, header=1)
  df = df.iloc[:, [0, 9, 10]].copy()
  df.columns = ["Age", "aq_death", "aq_disability"]
  return df
```

```
def prepare_decrements(start_age, df_probs, duration, stress):
  """Builds the Multiple Decrement Table (MDT) incorporating mortality,

  disability, and surrender rates, along with active survival probabilities
  (px).
  """
  df = df_probs[
     (df_probs["Age"] >= start_age) & (df_probs["Age"] < start_age + duration)
  ].copy()
  df["Year"] = range(1, duration + 1)
  df["aq_death"] *= 1 + stress.get("mortality", 0) / 100
  df["aq_disability"] *= 1 + stress.get("disability", 0) / 100
  base_surr = np.array([0.10, 0.10, 0.10, 0.07, 0.05, 0.00, 0.00])
  df["qx_surr"] = base_surr * (1 + stress.get("surrender", 0) / 100)
  df["aq_surr"] = df["qx_surr"] * (1 - df["aq_death"] - df["aq_disability"])
  df["px"] = 1 - df["aq_death"] - df["aq_disability"] - df["aq_surr"]
  t_minus_1_px = [1.0]
  for i in range(duration - 1):
    t_minus_1_px.append(t_minus_1_px[-1] * df["px"].iloc[i])
  df["t_minus_1_px"] = t_minus_1_px
  prob_survive_to_end = df["t_minus_1_px"].iloc[-1] * df["px"].iloc[-1]
  return df, t_minus_1_px, prob_survive_to_end


def solve_premium(sum_assured, df, prob_survive_to_end, assumptions):
  """Solves for the exact premium using the Equivalence Principle via root-finding

  (fsolve), ensuring Expected Present Value (EPV) of inflows equals outflows
  using the RDR.
  """
  rdr = assumptions["rdr"]
  surrender_factors = np.array([0, 0, 0, 0.5, 0.5, 0.5, 0.5])

  def equation(P):
    v = (1 / (1 + rdr)) ** df["Year"]
    pv_death = (sum_assured * df["aq_death"] * v * df["t_minus_1_px"]).sum()
    pv_disability = (
       sum_assured * df["aq_disability"] * v * df["t_minus_1_px"]
    ).sum()
    pv_surrender = (
       (P * df["Year"] * surrender_factors)
       * df["aq_surr"]
       * v
       * df["t_minus_1_px"]
    ).sum()
    pv_maturity = sum_assured * prob_survive_to_end * (1 / (1 + rdr)) ** 7
    expense_rates = np.array([0.5] + [0.05] * 6)
```

```
    pv_expenses = (
        P
        * expense_rates
        * ((1 + assumptions["inflation_rate"]) ** (df["Year"] - 1))
        * (1 / (1 + rdr)) ** (df["Year"] - 1)
        * df["t_minus_1_px"]
    ).sum()
    pv_premium = (P * (1 / (1 + rdr)) ** (df["Year"] - 1) * df["t_minus_1_px"]).sum()


    return (
        pv_premium
        - pv_death
        - pv_disability
        - pv_surrender
        - pv_maturity
        - pv_expenses
    )

  result = fsolve(equation, 2_000_000)
  return result[0]


def project_unit_fund(premium, assumptions):
  """Projects the unit-linked fund account balance year-by-year, accounting for

  allocation rates, bid-offer spreads, fund growth, and Fund Management Charges
  (FMC).
  """
  allocation_rates = [0.60] + [0.85] * 6
  closing_funds, fmc_stream, bid_offer_stream = [], [], []
  balance = 0
  for i in range(7):
    allocated = premium * allocation_rates[i]
    bid_offer = allocated * assumptions["bid_offer_spread"]
    bid_offer_stream.append(bid_offer)
    invested = allocated - bid_offer
    opening = balance + invested
    growth = opening * assumptions["fund_growth_rate"]
    before_fmc = opening + growth
    fmc = before_fmc * assumptions["fmc_rate"]
    fmc_stream.append(fmc)
    balance = before_fmc - fmc
    closing_funds.append(balance)
  return closing_funds, fmc_stream, bid_offer_stream
```

```
def profit_test(
    premium,
    sum_assured,
    df,
    closing_funds,
    fmc_stream,
    bid_offer_stream,
    t_minus_1_px,
    prob_survive_to_end,
    assumptions,
    stress,
):
    """Performs a cash flow profit test to generate the profit signature,

    calculating the Net Present Value of profit (PV Profit) and Profit Margin (%).
    """
    allocation_rates = [0.60] + [0.85] * 6
    surrender_factors = np.array([0, 0, 0, 0.5, 0.5, 0.5, 0.5])
    profits = []
    for i in range(7):
        unallocated = premium * (1 - allocation_rates[i])
        expenses = (
            premium
            * ([0.5] + [0.05] * 6)[i]
            * ((1 + assumptions["inflation_rate"]) ** i)
        ) * (1 + stress.get("expenses", 0) / 100)
        cash_start = unallocated + bid_offer_stream[i] - expenses
        interest = cash_start * assumptions["non_fund_rate"]
        fund = closing_funds[i]
        expected_claims = (max(sum_assured, fund) - fund) * (
            df["aq_death"].iloc[i] + df["aq_disability"].iloc[i]
        )
        surrender_paid = premium * df["Year"].iloc[i] * surrender_factors[i]
        penalty = max(0, fund - surrender_paid)
        surrender_income = penalty * df["aq_surr"].iloc[i]
        maturity_cost = (
            (max(0, sum_assured - fund) * prob_survive_to_end) if i == 6 else 0
        )
        profits.append(
            cash_start
            + interest
            + fmc_stream[i]
            + surrender_income
            - expected_claims
            - maturity_cost
        )
```

```
  pv_profit = sum(
      p * ((1 / (1 + assumptions["rdr"])) ** (i + 1)) * t_minus_1_px[i]
      for i, p in enumerate(profits)
  )
  pv_premium = sum(
      premium * ((1 / (1 + assumptions["rdr"])) ** i) * t_minus_1_px[i]
      for i in range(7)
  )
  margin = (pv_profit / pv_premium) * 100
  return margin, pv_profit, profits


def get_epv_components(sum_assured, P, df, assumptions, prob_survive_to_end):
  """Calculates the disaggregated Expected Present Value (EPV) components

  (Death, Disability, Surrender, Expenses, Maturity) for premium composition
  analysis.
  """
  v = (1 / (1 + assumptions["rdr"])) ** df["Year"]
  return {
      "Death": (sum_assured * df["aq_death"] * v * df["t_minus_1_px"]).sum(),
      "Disability": (
          sum_assured * df["aq_disability"] * v * df["t_minus_1_px"]
      ).sum(),
      "Surrender": (
          (P * df["Year"] * np.array([0, 0, 0, 0.5, 0.5, 0.5, 0.5]))
          * df["aq_surr"]
          * v
          * df["t_minus_1_px"]
      ).sum(),
      "Expenses": (
          P
          * np.array([0.5] + [0.05] * 6)
          * ((1 + assumptions["inflation_rate"]) ** (df["Year"] - 1))
          * (1 / (1 + assumptions["rdr"])) ** (df["Year"] - 1)
          * df["t_minus_1_px"]
      ).sum(),
      "Maturity": sum_assured
      * prob_survive_to_end
      * (1 / (1 + assumptions["rdr"])) ** 7,
  }


def calculate_quote(
      age,
      gender,
      quadrimestrial_payment,
```

```
    excel_file="the_pricing.xlsx",
    assumptions=None,
    stress=None,
):
    """Master pricing orchestration function. Executes decrement calculations,

    premium solving, fund projections, and profit testing to return a comprehensive
    dictionary.
    """
    if stress is None:
        stress = {"mortality": 0, "disability": 0, "surrender": 0, "expenses": 0}
    if assumptions is None:
        assumptions = DEFAULT_ASSUMPTIONS

    df_probs = load_probability_table(excel_file, gender)
    sum_assured = calculate_sum_assured_from_annuity(
        quadrimestrial_payment, annual_rate=assumptions["rdr"]
    )
    df, t_minus_1_px, prob_survive_to_end = prepare_decrements(
        age, df_probs, assumptions["duration"], stress
    )
    premium = solve_premium(sum_assured, df, prob_survive_to_end, assumptions)
    closing_funds, fmc_stream, bid_offer_stream = project_unit_fund(
        premium, assumptions
    )
    margin, pv_profit, profit_signature = profit_test(
        premium,
        sum_assured,
        df,
        closing_funds,
        fmc_stream,
        bid_offer_stream,
        t_minus_1_px,
        prob_survive_to_end,
        assumptions,
        stress,
    )
    return {
        "age": age,
        "gender": gender,
        "sum_assured": sum_assured,
        "premium": premium,
        "margin": margin,
        "pv_profit": pv_profit,
        "fund_projection": closing_funds,
        "profit_signature": profit_signature,
```

```
    "decrement_table": df,
    "prob_survive_to_end": prob_survive_to_end,
    "fund_projection_df": pd.DataFrame({
        "Year": range(1, 8),
        "Closing Fund": closing_funds,
        "FMC": fmc_stream,
        "Bid-Offer": bid_offer_stream,
    }),
    "profit_projection_df": pd.DataFrame(
        {"Year": range(1, 8), "Profit": profit_signature}
    ),
  }
```

The streamlit application.

```
# ------------------------------------------------------------------------------
# 1. OVERVIEW / LANDING PAGE
# ------------------------------------------------------------------------------
if st.session_state.portal == "Overview":
    st.markdown("""
    <div class="content-card">
        <div style="font-size: 1.1rem; font-weight: 600; color: #0f172a; margin-bottom:
0.5rem;">
            Enterprise Insurance Product Evaluation & Pricing Platform
        </div>
        <div style="font-size: 0.9rem; color: #475569; line-height: 1.6;">
            This system automates the actuarial pricing, reserve calculation, and profit-
testing mechanics
            for a 7-year Unit-Linked Endowment Product. It combines multi-decrement cash flow
modeling
            with real-time quotation capabilities for field operations and underwriting teams.
        </div>
    </div>
    """, unsafe_allow_html=True)

    col1, col2 = st.columns(2)

    with col1:
        st.markdown("""
        <div class="kpi-tile" style="margin-bottom: 1rem;">
            <div class="kpi-title">Sales & Customer Management</div>
            <div style="font-size: 1.1rem; font-weight: 700; color: #0f172a; margin: 0.5rem
0;">
                Field Sales Agent Portal
            </div>
            <div class="kpi-caption">
                Streamlined quotation generation for field agents and brokers. Instantly
calculates
                guaranteed Sum Assured benefits and solved premium commitments.
            </div>
        </div>
        """, unsafe_allow_html=True)
        if st.button("Launch Agent Portal", type="primary", use_container_width=True):
            st.session_state.portal = "Field Sales Portal"
            st.rerun()

    with col2:
```

```
        st.markdown("""
        <div class="kpi-tile" style="margin-bottom: 1rem;">
            <div class="kpi-title">Actuarial & Underwriting</div>
            <div style="font-size: 1.1rem; font-weight: 700; color: #0f172a; margin: 0.5rem
0;">
                Actuarial Pricing Engine
            </div>
            <div class="kpi-caption">
                Comprehensive modeling environment for actuarial teams. Configure economic
assumptions,
                run stress testing scenarios, and inspect detailed EPV cash flows.
            </div>
        </div>
        """, unsafe_allow_html=True)
        if st.button("Launch Actuarial Engine", type="primary", use_container_width=True):
            st.session_state.portal = "Actuarial Dashboard"
            st.rerun()

    st.markdown("<div style='height: 1rem;'></div>", unsafe_allow_html=True)
    st.markdown("##### Core Actuarial Framework")

    c_a, c_b, c_c = st.columns(3)
    with c_a:
        st.markdown("""
        <div class="kpi-tile">
            <div class="kpi-title">1. Competing Risks</div>
            <div class="kpi-caption" style="margin-top: 0.5rem;">
                Models mortality, disability, and surrender decrements concurrently using a
Multiple Decrement Table (MDT).
            </div>
        </div>
        """, unsafe_allow_html=True)
    with c_b:
        st.markdown("""
        <div class="kpi-tile">
            <div class="kpi-title">2. Equivalence Principle</div>
            <div class="kpi-caption" style="margin-top: 0.5rem;">
                Numerically solves for net/gross premiums balancing expected present values of
inflows and benefit obligations.
            </div>
        </div>
        """, unsafe_allow_html=True)
    with c_c:
        st.markdown("""
        <div class="kpi-tile">
            <div class="kpi-title">3. Profit Testing</div>
            <div class="kpi-caption" style="margin-top: 0.5rem;">
                Projects unit fund progression, bid-offer charges, and FMC to evaluate profit
margins against RDR targets.
            </div>
        </div>
        """, unsafe_allow_html=True)

# ------------------------------------------------------------------------
# 2. FIELD SALES AGENT PORTAL
# ------------------------------------------------------------------------
elif st.session_state.portal == "Field Sales Portal":
    st.markdown("""
    <div style="margin-bottom: 1.25rem;">
        <div style="font-size: 1.15rem; font-weight: 700; color: #0f172a;">Field Sales
Quotation Portal</div>
```

```
        <div style="font-size: 0.85rem; color: #64748b;">Specify client demographics and
contribution schedule to produce a verified quote.</div>
    </div>
    """, unsafe_allow_html=True)

    col_in1, col_in2 = st.columns(2)
    with col_in1:
        agent_age = st.number_input("Client Age", min_value=25, max_value=65, value=30,
key="agent_age")
        agent_payment = st.number_input(
            "Quadrimestrial Payment Commitment (UGX)",
            min_value=100000, max_value=10000000, value=1000000, step=100000,
            key="agent_payment"
        )
    with col_in2:
        agent_gender = st.selectbox("Gender", ["Female", "Male"], key="agent_gender")
        st.markdown("<div style='height: 28px;'></div>", unsafe_allow_html=True)
        gen_quote = st.button("Generate Quotation", type="primary", use_container_width=True)

    if gen_quote or "agent_quote" in st.session_state:
        if gen_quote:
            quote = calculate_quote(age=agent_age, gender=agent_gender,
quadrimestrial_payment=agent_payment)
            st.session_state.agent_quote = (quote, agent_age, agent_gender, agent_payment)
        else:
            quote, agent_age, agent_gender, agent_payment = st.session_state.agent_quote

        st.markdown("<div style='height: 1rem;'></div>", unsafe_allow_html=True)

        m1, m2, m3 = st.columns(3)
        with m1:
            st.markdown(f"""
            <div class="kpi-tile">
                <div class="kpi-title">Quadrimestrial Installment</div>
                <div class="kpi-value">UGX {agent_payment:,.0f}</div>
                <div class="kpi-caption">Payable every 4 months (3x per year)</div>
            </div>
            """, unsafe_allow_html=True)
        with m2:
            st.markdown(f"""
            <div class="kpi-tile">
                <div class="kpi-title">Guaranteed Sum Assured</div>
                <div class="kpi-value">UGX {quote['sum_assured']:,.0f}</div>
                <div class="kpi-caption">Guaranteed death & maturity benefit</div>
            </div>
            """, unsafe_allow_html=True)
        with m3:
            st.markdown(f"""
            <div class="kpi-tile">
                <div class="kpi-title">Engine-Solved Annual Premium</div>
                <div class="kpi-value">UGX {quote['premium']:,.0f}</div>
                <div class="kpi-caption">Annualized actuarial equivalent premium</div>
            </div>
            """, unsafe_allow_html=True)

        st.markdown(f"""
        <div class="summary-block">
            <div style="font-size: 0.9rem; font-weight: 700; color: #0f172a; margin-bottom:
0.75rem; text-transform: uppercase; letter-spacing: 0.05em;">
                Official Policy Quotation Summary
            </div>
```

```
            <div class="summary-row">
                <span class="summary-label">Product Plan</span>
                <span class="summary-val">7-Year Education Assured Endowment</span>
            </div>
            <div class="summary-row">
                <span class="summary-label">Insured Life</span>
                <span class="summary-val">{agent_age} years old ({agent_gender})</span>
            </div>
            <div class="summary-row">
                <span class="summary-label">Payment Frequency</span>
                <span class="summary-val">Quadrimestrial (3 payments / year)</span>
            </div>
            <div class="summary-row">
                <span class="summary-label">Periodic Contribution</span>
                <span class="summary-val">UGX {agent_payment:,.0f}</span>
            </div>
            <div class="summary-row">
                <span class="summary-label">Guaranteed Sum Assured Benefit</span>
                <span class="summary-val">UGX {quote['sum_assured']:,.0f}</span>
            </div>
            <div class="summary-row">
                <span class="summary-label">Actuarial Annual Premium Equivalent</span>
                <span class="summary-val">UGX {quote['premium']:,.0f}</span>
            </div>
        </div>
        """, unsafe_allow_html=True)

# ------------------------------------------------------------------------
# 3. ACTUARIAL PRICING DASHBOARD
# ------------------------------------------------------------------------
elif st.session_state.portal == "Actuarial Dashboard":
    st.markdown("""
    <div style="margin-bottom: 1.25rem;">
        <div style="font-size: 1.15rem; font-weight: 700; color: #0f172a;">Actuarial Pricing &
Profit Testing Engine</div>
        <div style="font-size: 0.85rem; color: #64748b;">Configure economic parameters, apply
sensitivity shocks, and evaluate cash flows.</div>
    </div>
    """, unsafe_allow_html=True)

    st.markdown("##### 1. Economic & Financial Assumptions")
    col_a, col_b, col_c, col_d = st.columns(4)
    with col_a:
        fund_growth = st.number_input("Fund Growth Rate (%)", value=15.4, step=0.1) / 100
    with col_b:
        non_fund = st.number_input("Non-Fund Yield (%)", value=15.0, step=0.1) / 100
    with col_c:
        inflation = st.number_input("Inflation Rate (%)", value=3.0, step=0.1) / 100
    with col_d:
        rdr = st.number_input("Risk Discount Rate (%)", value=16.4, step=0.1) / 100

    st.markdown("##### 2. Policyholder Demographics & Stress Testing")
    col_e, col_f, col_g = st.columns(3)
    with col_e:
        age = st.number_input("Client Age", 25, 65, 30, key="act_age")
    with col_f:
        gender = st.selectbox("Gender", ["Female", "Male"], key="act_gender")
    with col_g:
        payment = st.number_input("Quadrimestrial Payment (UGX)", 100000, 10000000, 1000000,
100000, key="act_payment")
```

```
    with st.expander("Sensitivity & Stress-Testing Parameters"):
        run_stress = st.checkbox("Run Comparison Scenario (+20% Mortality Shock)")
        c_s1, c_s2, c_s3, c_s4 = st.columns(4)
        with c_s1: mortality_stress = st.slider("Mortality Shock (%)", -50, 50, 0)
        with c_s2: disability_stress = st.slider("Disability Shock (%)", -50, 50, 0)
        with c_s3: surrender_stress = st.slider("Surrender Shock (%)", -50, 50, 0)
        with c_s4: expense_stress = st.slider("Expense Shock (%)", -50, 50, 0)

    assumptions = {
        "duration": 7, "fund_growth_rate": fund_growth, "non_fund_rate": non_fund,
        "fmc_rate": 0.01, "bid_offer_spread": 0.05, "rdr": rdr, "inflation_rate": inflation
    }

    st.markdown("<div style='height: 0.5rem;'></div>", unsafe_allow_html=True)
    run_audit = st.button("Execute Actuarial Pricing Audit", type="primary",
use_container_width=True)

    if run_audit or "audit_run" in st.session_state:
        st.session_state.audit_run = True
        stress = {"mortality": mortality_stress, "disability": disability_stress, "surrender":
surrender_stress, "expenses": expense_stress}
        quote = calculate_quote(age, gender, payment, assumptions=assumptions, stress=stress)

        st.markdown("<div style='height: 1rem;'></div>", unsafe_allow_html=True)

        c1, c2, c3 = st.columns(3)
        with c1:
            st.markdown(f"""
            <div class="kpi-tile">
                <div class="kpi-title">Sum Assured</div>
                <div class="kpi-value">UGX {quote['sum_assured']:,.0f}</div>
            </div>
            """, unsafe_allow_html=True)
        with c2:
            st.markdown(f"""
            <div class="kpi-tile">
                <div class="kpi-title">Solved Annual Premium</div>
                <div class="kpi-value">UGX {quote['premium']:,.0f}</div>
            </div>
            """, unsafe_allow_html=True)
        with c3:
            st.markdown(f"""
            <div class="kpi-tile">
                <div class="kpi-title">Profit Margin</div>
                <div class="kpi-value">{quote['margin']:.2f}%</div>
            </div>
            """, unsafe_allow_html=True)

        st.markdown("<div style='height: 1rem;'></div>", unsafe_allow_html=True)

        # 1. Comparison Analysis Expander
        if run_stress:
            stress_comp = {"mortality": 20, "disability": 0, "surrender": 0, "expenses": 0}
            sq = calculate_quote(age, gender, payment, assumptions=assumptions,
stress=stress_comp)
            with st.expander("Scenario Comparison Analysis"):
                comp_df = pd.DataFrame({
                    "Scenario": ["Base Case", "Stressed (+20% Mortality)"],
                    "Profit Margin (%)": [quote['margin'], sq['margin']]
                })
                fig_comp = px.bar(
```

```
                    comp_df, x="Scenario", y="Profit Margin (%)",
                    text_auto=".2f",
                    color="Scenario",
                    color_discrete_map={"Base Case": "#0f172a", "Stressed (+20% Mortality)":
"#64748b"}
                )
                fig_comp.update_layout(
                    template="plotly_white",
                    showlegend=False,
                    margin=dict(l=20, r=20, t=30, b=20),
                    height=280
                )
                st.plotly_chart(fig_comp, use_container_width=True)

        # 2. EPV Components
        with st.expander("Expected Present Value (EPV) Component Breakdown"):
            epv = get_epv_components(quote['sum_assured'], quote['premium'],
quote['decrement_table'], assumptions, quote['prob_survive_to_end'])
            epv_df = pd.DataFrame(list(epv.items()), columns=['Component', 'Value'])

            col_tbl, col_pie = st.columns([1, 1])
            with col_tbl:
                st.dataframe(epv_df.style.format({'Value': 'UGX {:,.0f}'}),
use_container_width=True)
            with col_pie:
                fig_pie = px.pie(
                    epv_df, values='Value', names='Component',
                    hole=0.4,
                    color_discrete_sequence=['#0f172a', '#2563eb', '#0d9488', '#64748b',
'#94a3b8']
                )
                fig_pie.update_layout(
                    template="plotly_white",
                    margin=dict(l=10, r=10, t=20, b=20),
                    height=260
                )
                st.plotly_chart(fig_pie, use_container_width=True)

        # 3. Multiple Decrement Table Expander
        with st.expander("Multiple Decrement Table (MDT) Projections"):
            df_disp = quote['decrement_table'].copy()
            for col in ["aq_death", "aq_disability", "aq_surr", "px"]:
                if col in df_disp.columns:
                    df_disp[col] = df_disp[col].map('{:.2%}'.format)
            st.dataframe(df_disp, use_container_width=True)

        # 4. Unit Fund Projection Expander
        with st.expander("Unit Fund Growth & Charge Projections"):
            st.dataframe(quote['fund_projection_df'].style.format("{:,.0f}"),
use_container_width=True)

        # 5. Profit Vector Expander
        with st.expander("Profit Vector & Cash Flow Projections"):
            st.dataframe(quote['profit_projection_df'].style.format("{:,.0f}"),
use_container_width=True)

            fig_line = px.line(
                quote['profit_projection_df'], x="Year",
y=quote['profit_projection_df'].columns[1],
                markers=True,
                title="Profit Vector Progression Over Policy Duration"
```

```
)
fig_line.update_traces(line_color="#0f172a", line_width=2.5)
fig_line.update_layout(
    template="plotly_white",
    margin=dict(l=20, r=20, t=40, b=20),
    height=300
)
st.plotly_chart(fig_line, use_container_width=True)
```