

Optimization in 401K Portfolio

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Summary

The optimization model presented is for maximizing return on investment on a 401k investment portfolio at Principal Financial Group. As an investor, we are interested in maximizing the return on investment based on risk and as such we would like to identify the funds that would provide the maximum return. The main problem is what mutual funds to select, and what percentage of the total amount should be invested in each of the selected funds in order to maximize our return and minimize risk.

As an investor we would like to allocate a certain percentage of our income to the appropriate funds and therefore knowing the return on investment to choose the fund is very important. We gathered the data for the different funds that Principal had offered and looked at the historical monthly performance of the funds at Principal. The investor could choose to invest in funds based on contribution type but that does not ensure the maximum return on investment and therefore in order to optimize the investment, we studied the performance of different funds offered at Principal and collected the data on 21 investment funds and the Average Annual total return for 1 year, 3 years, 5 years and 10 years. We examined 21 investment funds, taking into account their rate of return and risk category. These 21 funds offered at Principal ranged from Government Bonds, Asset Allocation funds, Real Estate, Growth and Global funds.

Utilizing the collected data, we developed a profit optimization model aiming to achieve the right Average Annual Total Return over 10 years. We considered the risk profile, ranging from a moderate to more risky investor, with the goal of mitigating risks and increasing overall profits. The optimization process was conducted using Microsoft Excel and the Solver add-in, allowing us to determine the allocation of funds. Subsequently, we delved into sensitivity analysis to gain insights into the model's constraints and relationships. Finally, we concluded by

contemplating the practical implementation of this model in a production environment.

Introduction

Asset allocation is the practice of having a mix of different asset classes and investment options within an investment portfolio. The majority of the investment options in the employer's retirement savings plan fall into five asset classes that range from lower risk to higher risk: Short-Term Fixed Income, Fixed Income, Large U.S. Equity, Small/Mid U.S. Equity and Global/International Equity. Generally, asset classes with lower levels of risk usually offer a lower potential for growth. Meanwhile, asset classes with higher levels of risk typically offer more potential for growth.

- For money an investor needs in three to five years, there is more time to weather market volatility, but the investor is still likely sticking to more conservative, fixed income investments like bonds.
- For savings the investor won't need four five or more years, the investor may consider other investments to help spread risk and grow the money, like mutual funds, stocks, exchange traded funds (ETFs), and annuities—depending on their risk tolerance.

Company

Principal Financial Group, commonly referred to as Principal, is a global financial investment management and insurance company headquartered in Des Moines, Iowa, United States. The company offers a wide range of financial products and services to individuals, businesses, and institutional clients. Principal Financial Group helps individuals all around the globe and offer the right solutions and support to reach their financial goals. Principal helps

people create the kinds of lives they dream about, empowered by financial security and stability.

Here are some key aspects of Principal Financial Group:

1. **History:** Principal Financial Group was founded in 1879 as Bankers Life Association, focusing primarily on life insurance. Over the years, it has expanded its offerings and services to include retirement solutions, asset management, insurance, and more.
2. **Products and Service:** Principal offers a diverse range of financial products and services, including retirement planning, investment management, insurance (life, disability, dental, etc.), annuities, and asset management services for institutional investors. They serve both individual clients and businesses of various sizes.
3. **Global Presence:** While Principal's headquarters are in the United States, it has a significant international presence. It operates in several countries worldwide, offering its financial services to clients globally.
4. **Retirement Solutions:** Principal is well-known for its retirement solutions, including 401(k) plans, pension plans, IRAs, and other retirement savings and investment products. They provide tools and resources to help individuals plan and manage their retirement savings effectively.
5. **Asset Management:** Principal Global Investors, the asset management arm of Principal Financial Group, manages assets for institutional investors, including pension funds, sovereign wealth funds, and other large organizations. They offer a variety of investment strategies across asset classes.
6. **Corporate Responsibility:** Principal emphasizes corporate responsibility and sustainability initiatives. They are involved in various community development programs, environmental initiatives, and support diversity and inclusion efforts.

7. **Technology and Innovation:** Like many financial institutions, Principal has invested in technology and innovation to enhance its services. This includes digital platforms for easier access to financial tools and resources, as well as utilizing data analytics to provide personalized solutions to clients.

Overall, Principal Financial Group is a prominent player in the financial services industry, offering a comprehensive suite of products and services to help individuals and businesses achieve their financial goals.

Problem

The problem in this scenario is to select the optimal portfolio of mutual funds that maximizes total return over 10 years while meeting specific return targets and risk constraints.

The key challenges include:

1. **Meeting Return Targets:** The investor aims to achieve at least 3% average annual return in one year, 6% in three years, 8% in five and 10% in ten years from the portfolio. Selecting funds that historically meet these targets while considering future market conditions is crucial.
2. **Managing Risk:** The investor wants to maintain a combined average risk of no higher than average as indicated by the provided risk ratings for each fund. Balancing risk across the portfolio while maximizing return requires careful selection and allocation of funds.
3. **Diversification:** Constructing a diversified portfolio is essential to spread risk across different asset classes and investment objectives. The selection of funds should consider diversification to mitigate the impact of adverse market movements on the overall

portfolio.

Proposed Solution

To find the solution to the problem, we analyzed information about past performance of the designated mutual funds. This information collected from the funds' prospectus is present in the **Figure 1** below,

401K Portfolio from Principal									
		Average Annual Total Return, %							
Decisions	(in %)	1 Year	3 Years	5 years	10 years	Risk	Risk Scale	Risk	Category
Liquid Assets Separate Account	X1 = 0.0000	4.04	1.21	0.78	0.18	1	1	Low risk	Short-Term Fixed Income
Core Plus Bond Separate Account	X2 = 0.0000	0.79	-4.14	0.37	0.95	2	2	Low to moderate risk	Fixed Income
Government & High Quality Bond Sep Acct	X3 = 0.0000	-0.58	-4.24	-1.2	0.02	2	3	Moderate risk	Balanced / Asset Allocation
Principal LifeTime Strategic Income Separate Account	X4 = 0.0000	5.56	-0.41	3.04	2.76	3	4	Moderate to high risk	Large U.S. Equity
Principal LifeTime 2020 Separate Account	X5 = 0.0000	6.25	0.99	4.98	4.55	3	5	High risk	Small / Mid U.S. Equity
Principal LifeTime 2030 Separate Account	X6 = 0.0000	7.68	2.03	6.38	5.62	3	6	Extremely high risk	Global/International Equity
Principal LifeTime 2040 Separate Account	X7 = 0.0000	9.8	3.2	7.61	6.52	3			
Principal LifeTime 2050 Separate Account	X8 = 0.0000	11.14	4.03	8.39	7.06	3			
Principal LifeTime 2060 Separate Account	X9 = 0.0000	11.16	4.33	8.66	7.21	3			
LargeCap S&P 500 Index Separate Account	X10 = 0.0000	19.54	9.84	13.12	11.44	4			
LargeCap Growth I Separate Account	X11 = 0.0000	32.02	4.77	13.24	12.63	4			
LargeCap Value III Separate Account	X12 = 0.0000	5.26	8.81	8.83	8.28	4			
MidCap Value I Separate Account	X13 = 0.0000	2.9	10.01	10.09	7.94	5			
MidCap S&P 400 Index Separate Account	X14 = 0.0000	3.7	5.83	8.88	8.17	5			
SmallCap S&P 600 Index Separate Account	X15 = 0.0000	0.75	2.54	6.78	7.5	5			
SmallCap Separate Account	X16 = 0.0000	1.24	0.96	7.27	7.00	5			
Real Estate Securities Sep Acct	X17 = 0.0000	-3.26	3.3	4.15	6.71	5			
MidCap Growth III Separate Account	X18 = 0.0000	8.13	0.17	10.10	8.74	5			
SmallCap Value II Separate Account	X19 = 0.0000	4.5	9.81	8.88	7.06	5			
Diversified International Separate Account	X20 = 0.0000	7.75	0.42	5.45	3.80	6			
International SmallCap Separate Account	X21 = 0.0000	2.33	-2.87	1.80	2.83	6			
Required returns		3	6	8	10	3			

(Figure 1)

Our solution involves:

1. **Analyzing Fund Performance:** We analyzed the funds performance by using the data provided for each fund and considering an average annual total return and risk ratings.
2. **Setting Allocation Targets:** Determine the desired allocation percentages for each fund based on their performance, risk, and investment objectives.
3. **Constructing the Portfolio:** Allocate funds according to the determined targets, ensuring diversification across different objectives and asset classes to manage risk effectively.
4. **Monitoring and Rebalancing:** Regularly monitor the portfolio's performance and make adjustments as needed to align with changing market conditions and investment objectives. Rebalance the portfolio periodically to maintain the desired asset allocation.

By carefully selecting funds that meet return targets, managing risk through diversification, and regularly monitoring the portfolio, the investor can construct an optimal portfolio that maximizes total return over the specified time horizon while staying within the desired risk parameters.

Main Chapter

Data Collection

The data provided below (**Table1**) has been sourced from a retirement account in Principal.

	<i>Average Annual Total Return, %</i>			
	<i>1 Year</i>	<i>3 Years</i>	<i>5 years</i>	<i>10 years</i>
Short-Term Fixed Income				
<i>Liquid Assets Separate Account</i>	4.04	1.21	0.78	0.18
Fixed Income				
<i>Core Plus Bond Separate Account</i>	0.79	-4.14	0.37	0.95
<i>Government & High Quality Bond Sep Acct</i>	-0.58	-4.24	-1.2	0.02
Balanced/Asset Allocation				
<i>Principal LifeTime Strategic Income Separate Account</i>	5.56	-0.41	3.04	2.76
<i>Principal LifeTime 2020 Separate Account</i>	6.25	0.99	4.98	4.55
<i>Principal LifeTime 2030 Separate Account</i>	7.68	2.03	6.38	5.62
<i>Principal LifeTime 2040 Separate Account</i>	9.8	3.2	7.61	6.52
<i>Principal LifeTime 2050 Separate Account</i>	11.14	4.03	8.39	7.06
<i>Principal LifeTime 2060 Separate Account</i>	11.16	4.33	8.66	7.21
Large U.S. Equity				
<i>LargeCap S&P 500 Index Separate Account</i>	19.54	9.84	13.12	11.44
<i>LargeCap Growth I Separate Account</i>	32.02	4.77	13.24	12.63
<i>LargeCap Value III Separate Account</i>	5.26	8.81	8.83	8.28
Small/Mid U.S. Equity				
<i>MidCap Value I Separate Account</i>	2.9	10.01	10.09	7.94
<i>MidCap S&P 400 Index Separate Account</i>	3.7	5.83	8.88	8.17
<i>SmallCap S&P 600 Index Separate Account</i>	0.75	2.54	6.78	7.5
<i>SmallCap Separate Account</i>	1.24	0.96	7.27	7.00
<i>Real Estate Securities Sep Acct</i>	-3.26	3.3	4.15	6.71
<i>MidCap Growth III Separate Account</i>	8.13	0.17	10.10	8.74
<i>SmallCap Value II Separate Account</i>	4.5	9.81	8.88	7.06

Global/International Equity				
<i>Diversified International Separate Account</i>	7.75	0.42	5.45	3.80
<i>International SmallCap Separate Account</i>	2.33	-2.87	1.80	2.83

(Table 1)

In addition, we added the Risk Scale ranging from 1 to 6 to align with the Risk spectrum provided in Principal.

Risk	Category	Risk Scale
Low risk	Short-Term Fixed Income	1
Low to moderate risk	Fixed Income	2
Moderate risk	Balanced / Asset Allocation	3
Moderate to high risk	Large U.S. Equity	4
High risk	Small / Mid U.S Equity	5
Very high risk	Global/International Equity	6

Optimization Model

After compiling our dataset, we constructed our linear programming model with the following specifications. Our decision variables in our model are the 21 investment options.

401K Portfolio from Principal			Average Annual Total Return, %				
Decisions		<i>(in %)</i>	1 Year	3 Years	5 years	10 years	Risk
Liquid Assets Separate Account	X1 =	0	4.04	1.21	0.78	0.18	1
Core Plus Bond Separate Account	X2 =	0	0.79	-4.14	0.37	0.95	2
Government & High Quality Bond Sep Acct	X3 =	0	-0.58	-4.24	-1.2	0.02	2
Principal LifeTime Strategic Income Separate Account	X4 =	0	5.56	-0.41	3.04	2.76	3
Principal LifeTime 2020 Separate Account	X5 =	0	6.25	0.99	4.98	4.55	3
Principal LifeTime 2030 Separate Account	X6 =	0	7.68	2.03	6.38	5.62	3
Principal LifeTime 2040 Separate Account	X7 =	0	9.8	3.2	7.61	6.52	3
Principal LifeTime 2050 Separate Account	X8 =	0	11.14	4.03	8.39	7.06	3
Principal LifeTime 2060 Separate Account	X9 =	0	11.16	4.33	8.66	7.21	3
LargeCap S&P 500 Index Separate Account	X10 =	0	19.54	9.84	13.12	11.44	4
LargeCap Growth I Separate Account	X11 =	0	32.02	4.77	13.24	12.63	4
LargeCap Value III Separate Account	X12 =	0	5.26	8.81	8.83	8.28	4
MidCap Value I Separate Account	X13 =	0	2.9	10.01	10.09	7.94	5

MidCap S&P 400 Index Separate Account	X14 =	0	3.7	5.83	8.88	8.17	5
SmallCap S&P 600 Index Separate Account	X15 =	0	0.75	2.54	6.78	7.5	5
SmallCap Separate Account	X16 =	0	1.24	0.96	7.27	7.00	5
Real Estate Securities Sep Acct	X17 =	0	-3.26	3.3	4.15	6.71	5
MidCap Growth III Separate Account	X18 =	0	8.13	0.17	10.10	8.74	5
SmallCap Value II Separate Account	X19 =	0	4.5	9.81	8.88	7.06	5
Diversified International Separate Account	X20 =	0	7.75	0.42	5.45	3.80	6
International SmallCap Separate Account	X21 =	0	2.33	-2.87	1.80	2.83	6

Inputs

i = fund number, $i = 1, 2, 3, \dots, 21$

j = number of return years, $j = 1, 3, 5, 10$

a_{ij} = percentage of average annual total return of fund i in year j

r_i = risk of fund i

Decision variables

X_i = proportion of investment in fund i , ($0 \leq X_i \leq 1$, $i = 1, 2, 3, \dots, 21$)

Our objective function is maximize the total return in 10 years

Max $0.18X_1 + 0.95X_2 + 0.02X_3 + 2.76X_4 + 4.55X_5 + 5.62X_6 + 6.52X_7 + 7.06X_8 + 7.21X_9 + 11.44X_{10}$
 $+ 12.63X_{11} + 8.28X_{12} + 7.94X_{13} + 8.17X_{14} + 7.5X_{15} + 7X_{16} + 6.71X_{17} + 8.74X_{18} + 7.06X_{19} +$
 $3.8X_{20} + 2.83X_{21}$

Constraints

Considering this is designed for a moderate investor, we constructed the following constraints,

Constraints	LHS		RHS
Return in 1 year $\geq 3\%$	$\sum a_{ij} * X_i$, where $i=1,2,3,\dots, 21$ and $j = 1$	\geq	3

Return in 3 years $\geq 6\%$	$\sum a_{ij} * X_i$, where $i=1,2,3,\dots, 21$ and $j = 3$	\geq	6
Return in 5 years $\geq 8\%$	$\sum a_{ij} * X_i$, where $i=1,2,3,\dots, 21$ and $j = 5$	\geq	8
Return in 10 years $\geq 10\%$	$\sum a_{ij} * X_i$, where $i=1,2,3,\dots, 21$ and $j = 10$	\geq	10
Average risk ≤ 3	$\sum r_i * X_i$, where $i=1,2,3,\dots, 21$	\leq	3
Total investor distribution = 1	$\sum X_i$, where $i=1,2,3,\dots, 21$	$=$	1

Optimization Results

Considering the investment options available for the 401K portfolio from the Principal, our primary objective was to construct an optimization model geared towards maximizing returns over 10 years, catering to the risk profile of a moderate investor. To achieve this, we initiated the development of Model1, incorporating the above constraints aligned with the criteria typical of a moderate investor. Additionally, we set the condition for an average risk level to be maintained below 3. However, upon running the Solver, we encountered no feasible solution. This outcome leads us to a critical inference: emphasizing a low-risk strategy, the initial approach might not be the most advantageous path considering the specific investment options and their associated annual total return rates.

In response, we strategically decided to revise our model, adjusting the risk threshold to 4 in Model 2. The revised model suggests allocating 24.26% of the portfolio to the LargeCap S&P 500 Index Separate Account (Fund 10) and 75.74% to the LargeCap Growth I Separate Account (Fund 11). This strategic allocation, under the increased risk threshold, maximizes the return over 10 years, yielding an impressive 12.34%.

Constraints	LHS		RHS
Return in 1 year $\geq 3\%$	$\sum a_{ij} * X_i$, where $i=1,2,3,\dots, 21$ and $j = 1$	\geq	3
Return in 3 years $\geq 6\%$	$\sum a_{ij} * X_i$, where $i=1,2,3,\dots, 21$ and $j = 3$	\geq	6
Return in 5 years $\geq 8\%$	$\sum a_{ij} * X_i$, where $i=1,2,3,\dots, 21$ and $j = 5$	\geq	8
Return in 10 years $\geq 10\%$	$\sum a_{ij} * X_i$, where $i=1,2,3,\dots, 21$ and $j = 10$	\geq	10
Average risk ≤ 4	$\sum r_i * X_i$, where $i=1,2,3,\dots, 21$	\leq	4

Total investor distribution = 1	$\sum X_i$, where $i=1,2,3,\dots, 21$	=	1
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Remarkably, the highest achievable return rate is 28.99% in one year, followed by 6% and 13.21% returns in three and five years, respectively, with the same optimal investment allocation. Upon closer examination of the data, it becomes evident that Fund 10 and Fund 11 are the only options with a risk level of 4, distinguishing themselves by having an average annual return rate exceeding 10% over 10 years. In contrast, other funds fall short of the 10% benchmark. Therefore, these two funds emerge as the most favorable choices if our objective is to achieve a 10% return over 10 years. See **Figure 2**.

<i>401K Portfolio from Principal</i>							
Decisions		(in %)	Average Annual Total Return, %				Risk
			1 Year	3 Years	5 years	10 years	
Liquid Assets Separate Account	X1 =	0.00	4.04	1.21	0.78	0.18	1
Core Plus Bond Separate Account	X2 =	0.00	0.79	-4.14	0.37	0.95	2
Government & High Quality Bond Sep Acct	X3 =	0.00	-0.58	-4.24	-1.2	0.02	2
Principal LifeTime Strategic Income Separate Account	X4 =	0.00	5.56	-0.41	3.04	2.76	3
Principal LifeTime 2020 Separate Account	X5 =	0.00	6.25	0.99	4.98	4.55	3
Principal LifeTime 2030 Separate Account	X6 =	0.00	7.68	2.03	6.38	5.62	3
Principal LifeTime 2040 Separate Account	X7 =	0.00	9.8	3.2	7.61	6.52	3
Principal LifeTime 2050 Separate Account	X8 =	0.00	11.14	4.03	8.39	7.06	3
Principal LifeTime 2060 Separate Account	X9 =	0.00	11.16	4.33	8.66	7.21	3
LargeCap S&P 500 Index Separate Account	X10 =	0.24	19.54	9.84	13.12	11.44	4
LargeCap Growth I Separate Account	X11 =	0.76	32.02	4.77	13.24	12.63	4
LargeCap Value III Separate Account	X12 =	0.00	5.26	8.81	8.83	8.28	4
MidCap Value I Separate Account	X13 =	0.00	2.9	10.01	10.09	7.94	5
MidCap S&P 400 Index Separate Account	X14 =	0.00	3.7	5.83	8.88	8.17	5
SmallCap S&P 600 Index Separate Account	X15 =	0.00	0.75	2.54	6.78	7.5	5
SmallCap Separate Account	X16 =	0.00	1.24	0.96	7.27	7.00	5
Real Estate Securities Sep Acct	X17 =	0.00	-3.26	3.3	4.15	6.71	5
MidCap Growth III Separate Account	X18 =	0.00	8.13	0.17	10.10	8.74	5
SmallCap Value II Separate Account	X19 =	0.00	4.5	9.81	8.88	7.06	5
Diversified International Separate Account	X20 =	0.00	7.75	0.42	5.45	3.80	6
International SmallCap Separate Account	X21 =	0.00	2.33	-2.87	1.80	2.83	6
Required returns			3	6	8	10	4
Objective (in %)							
Maximize return in 10 years		12.34					
Constraints							
Return in 1 year >= 3%	28.99	>=	3				
Return in 3 years >= 6%	6.00	>=	6				
Return in 5 years >= 8%	13.21	>=	8				
Return in 10 years >= 10%	12.34	>=	10				
Average risk <= 4	4	<=	4				
Total investor distribution = 1	1	=	1				

(Figure 2 Revised Model)

Data Analysis on Sensitivity Report

Microsoft Excel 16.0 Sensitivity Report

Worksheet: [Draft - Group Project - 401K Portfolio Optimization Model.xlsx]Model2

Report Created: 3/10/2024 3:03:38 AM

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease	Upper Limit	Lower Limit
\$C\$4	X1 = (in %)	0	-13.28558185	0.18	13.28558185	1E+30	13.46558185	-1E+30
\$C\$5	X2 = (in %)	0	-13.77130178	0.95	13.77130178	1E+30	14.72130178	-1E+30
\$C\$6	X3 = (in %)	0	-14.72477318	0.02	14.72477318	1E+30	14.74477318	-1E+30
\$C\$7	X4 = (in %)	0	-11.08581854	2.76	11.08581854	1E+30	13.84581854	-1E+30
\$C\$8	X5 = (in %)	0	-8.967218935	4.55	8.967218935	1E+30	13.51721893	-1E+30
\$C\$9	X6 = (in %)	0	-7.653116371	5.62	7.653116371	1E+30	13.27311637	-1E+30
\$C\$10	X7 = (in %)	0	-6.478500986	6.52	6.478500986	1E+30	12.99850099	-1E+30
\$C\$11	X8 = (in %)	0	-5.743688363	7.06	5.743688363	1E+30	12.80368836	-1E+30
\$C\$12	X9 = (in %)	0	-5.523274162	7.21	5.523274162	1E+30	12.73327416	-1E+30
\$C\$13	X10 = (in %)	0.24260355	0	11.44	1.19	3.347843511	12.63	8.09215649
\$C\$14	X11 = (in %)	0.75739645	0	12.63	103.1923529	1.19	115.8223529	11.44
\$C\$15	X12 = (in %)	0	-3.401755424	8.28	3.401755424	1E+30	11.68175542	-1E+30
\$C\$16	X13 = (in %)	0	-3.460098619	7.94	3.460098619	1E+30	11.40009862	-1E+30
\$C\$17	X14 = (in %)	0	-4.211203156	8.17	4.211203156	1E+30	12.38120316	-1E+30
\$C\$18	X15 = (in %)	0	-5.653412229	7.5	5.653412229	1E+30	13.15341223	-1E+30
\$C\$19	X16 = (in %)	0	-6.524260355	7	6.524260355	1E+30	13.52426036	-1E+30
\$C\$20	X17 = (in %)	0	-6.265029586	6.71	6.265029586	1E+30	12.97502959	-1E+30
\$C\$21	X18 = (in %)	0	-4.969684418	8.74	4.969684418	1E+30	13.70968442	-1E+30
\$C\$22	X19 = (in %)	0	-4.38704142	7.06	4.38704142	1E+30	11.44704142	-1E+30
\$C\$23	X20 = (in %)	0	-9.851005917	3.8	9.851005917	1E+30	13.65100592	-1E+30
\$C\$24	X21 = (in %)	0	-11.59321499	2.83	11.59321499	1E+30	14.42321499	-1E+30

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease	Upper Limit	Lower Limit
\$B\$32	Return in 1 year >= 3% X21 =	28.99230769	0	3	25.99230769	1E+30	28.99230769	-1E+30
\$B\$33	Return in 3 years >= 6% X21 =	6	-0.234714004	6	3.84	1.23	9.84	4.77
\$B\$34	Return in 5 years >= 8% X21 =	13.21088757	0	8	5.210887574	1E+30	13.21088757	-1E+30
\$B\$35	Return in 10 years >= 10% X21 =	12.34130178	0	10	2.341301775	1E+30	12.34130178	-1E+30
\$B\$36	Average risk <= 4 X21 =	4	0	4	1E+30	8.16244E-16	1E+30	4
\$B\$37	Total investor distribution = 1 X21 =	1	13.7495858	1	2.04061E-16	0.170281622	1	0.82971838

(Figure 3 Sensitivity Report)

The Sensitivity Report shown in **Figure 3** includes information on shadow prices and reduced costs, which are crucial to understanding the solution's implications and how sensitive it is to changes.

A reduced cost value is associated with each variable of the model. It is the amount by which an objective function parameter would have to improve before it would be possible for a corresponding variable to assume a positive value in the optimal solution. The Reduced Cost parameter in the Sensitivity Report of a linear programming (LP) model provides significant insights into how the objective function could be improved, or what the effects would be of

changing certain decision variables.

Analyzing the report, we noted that the reduced costs for both Fund 10 and Fund 11 are zero. This signifies that the optimal solution, with an allocation of 24.26% to Fund 10 and 75.73% to Fund 11, will remain unchanged unless the average annual return rate of Fund 10 in 10 years exceeds the upper limit of 12.63% ($11.44 + 1.19 = 12.63$) and 115.82% ($12.63 + 103.19 = 115.82$) for Fund 11, or falls below the lower limit of 8.09% ($11.44 - 335 = 8.09$) for Fund 10 and 11.44% ($12.63 - 1.19 = 11.44$) for Fund 11. We could experiment by changing the reduced cost and see how the optimal solution is changing.

Investment Option	Return Rate = Obj. Coeff - Reduced Cost, %
Fund 1	13.47
Fund 2	14.72
Fund 3	14.74
Fund 4	13.85
Fund 5	13.52
Fund 6	13.27
Fund 7	13
Fund 8	12.8
Fund 9	12.73
Fund 12	11.44
Fund 13	12.63
Fund 14	11.68
Fund 15	11.4
Fund 16	12.38
Fund 17	13.15
Fund 18	13.52
Fund 19	12.98
Fund 20	13.71
Fund 21	11.45

(Table 2)

Additionally, to achieve a more diversified portfolio and invest in the other funds, their

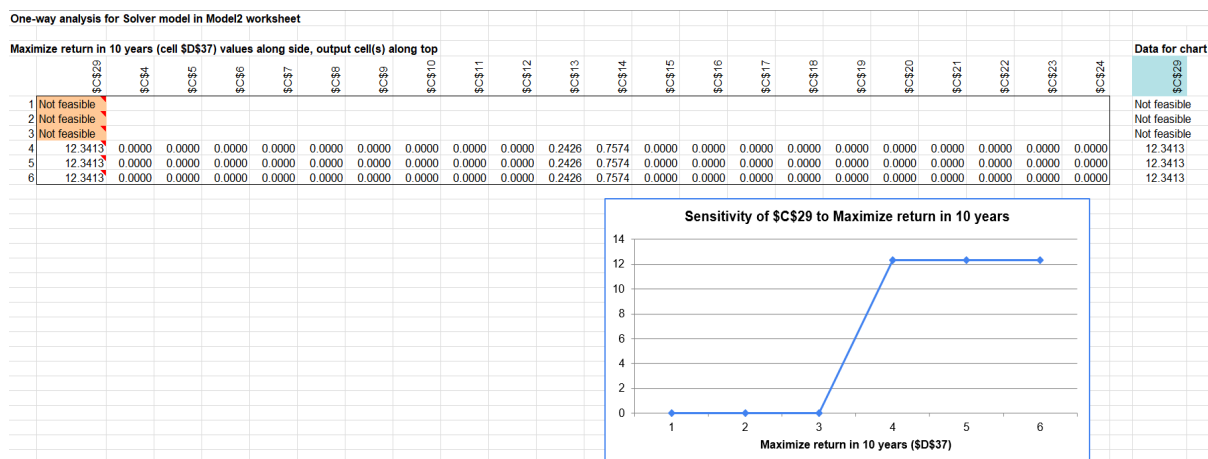
average annual return rates over the 10 years need to be above the return rate (Objective Coefficient - Reduced Cost) indicated in **Table 2**. For instance, considering Fund 1, with the reduced cost of -13.28 and the objective coefficient of 0.18, the return rate for an investor to consider investing in Fund 1 should be increased to 13.47% ($0.18 + 13.28 = 13.47$).

Similarly, in the case of Fund 2, considering its reduced cost of -13.771 and the objective coefficient of 0.95, the return rate for an investor to consider investment should be increased to 14.72% ($0.95 + 13.771 = 14.72$). This concept can be extended to the remaining funds, encompassing Fund 3 through Fund 9 and Fund 12 through Fund 21.

On the other hand, by the definition, the shadow price of a constraint of a linear program is the increase in the optimal objective value per unit increase in the RHS of the constraint. In our Sensitivity Report (**Figure 3**), it's worth noting that the constraint for a 6% return in 3 years is binding, while the constraint for a 3% return in one year, an 8% return in 5 year and a 10% return in 10 years are non-binding based on their values of Shadow Price. These non-binding constraints indicate that the optimal solution is not dependent on the exact values of these constraints, as they have shadow prices of zero. Conversely, the binding constraint for a 6% return in 3 years implies that the optimal solution is found at the limit of this constraint. In other words, any changes in this constraint would likely affect the optimal solution. Consequently, for every 1% increase from 6% in the RHS, the total return rate will decrease by 0.23. This decrease will be relevant in the range of 5.07% ($6 - 1.23 = 5.07$) to 9.84% ($6 + 3.84 = 9.84$).

Sensitivity Analysis

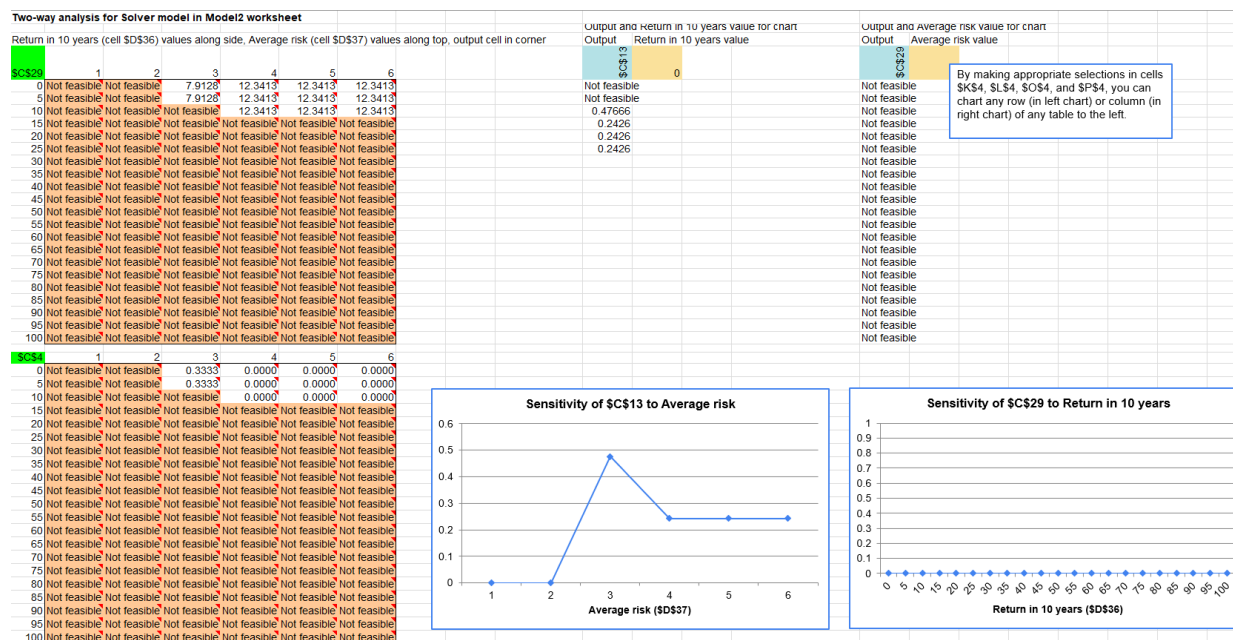
1. One Way Analysis



(Figure 4 One-Way Analysis)

Our interest extended to understanding the sensitivity of the maximum return over 10 years to variations in the average risk in this model by using SovlerTable one-way analysis (**Figure 4**). Our findings indicated that the maximum return is sensitive to variations in the average risk when the risk level is 3 and 4. Moreover, the maximum return remains insensitive and constant to variations in risk levels higher than 4, and no feasible solution exists when the risk level is below 3.

2. Two Way Analysis



(Figure 5 Two-Way Analysis)

Next, we conducted a two-way analysis using SolverTable to examine how the ten-year return rate and the average risk will impact both the maximum return rate and the allocations in those investment options over the years.

The results in **Figure 5** revealed that the maximum return rate is sensitive to the variations in the average risk levels of 3 and 4, as the maximum return rate increases to 12.34% from 7.91%. Additionally, no feasible solution can be found in risk levels of 1 and 2, regardless of how the ten-year return rate changes. Remarkably, there is no feasible solution when the ten-year return rate exceeds 15% across all risk levels from 1 through 6. This implies that given the investment options we have, it's unlikely we will achieve more than a 10% return in the 10 years.

Furthermore, the % of investment allocation in these funds either has no feasible solution or is zero except for Fund 10 and Fund 11. We can conclude that given these investment options, considering long-term investment over ten years, allocating in Fund 10 and Fund 11 is the optimal solution.

Conclusion

In conclusion, our report outlines a comprehensive approach to optimizing return on investment in a 401k portfolio offered by Principal. We addressed the challenge of selecting the optimal mix of mutual funds to maximize returns over a 10-year period while managing risk within specified constraints. Our analysis included evaluating performance of 21 investment funds across various asset classes and risk categories.

Our recommendation to the company based on the model results, to have a more diversified portfolio for an investor is that Principal could replace some of its under performing

funds by selecting funds with the potential for high returns within an acceptable risk level in other caps as well. As the market conditions, economic factors, and investor circumstances can evolve unpredictably, our risk minimization model serves as a perfect option for investors to look for funds that may provide an appropriate return with manageable risk.

Overall, our approach provides valuable insights for investors seeking to optimize their 401k portfolios, emphasizing the importance of balancing risk and return to achieve financial goals effectively. By implementing the proposed model, investors can make informed decisions to enhance their investment outcomes and achieve greater financial security and stability in the long run.

Our exploration into optimizing a 401K portfolio using data analysis and decision modeling underscores the potential to achieve improved returns through informed, strategic fund allocation. However, the dynamic nature of financial markets requires that such models be used as part of a broader, adaptive investment strategy that considers both quantitative insights and qualitative factors. Investors should remain vigilant, ready to adjust their strategies in response to new information and market developments to safeguard and grow their retirement savings effectively.

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APPENDIX

A. Risk Minimization Model

<i>401K Portfolio from Principal</i>							
			<i>Average Annual Total Return, %</i>				
<i>Decisions</i>		<i>(in %)</i>	<i>1 Year</i>	<i>3 Years</i>	<i>5 years</i>	<i>10 years</i>	<i>Risk</i>
Liquid Assets Separate Account	X1 =	0.61	4.04	1.21	0.78	0.18	1
Core Plus Bond Separate Account	X2 =	0.00	0.79	-4.14	0.37	0.95	2
Government & High Quality Bond Sep Acct	X3 =	0.00	-0.58	-4.24	-1.2	0.02	2
Principal LifeTime Strategic Income Separate Account	X4 =	0.00	5.56	-0.41	3.04	2.76	3
Principal LifeTime 2020 Separate Account	X5 =	0.00	6.25	0.99	4.98	4.55	3
Principal LifeTime 2030 Separate Account	X6 =	0.00	7.68	2.03	6.38	5.62	3
Principal LifeTime 2040 Separate Account	X7 =	0.00	9.8	3.2	7.61	6.52	3
Principal LifeTime 2050 Separate Account	X8 =	0.00	11.14	4.03	8.39	7.06	3
Principal LifeTime 2060 Separate Account	X9 =	0.00	11.16	4.33	8.66	7.21	3
LargeCap S&P 500 Index Separate Account	X10 =	0.00	19.54	9.84	13.12	11.44	4
LargeCap Growth I Separate Account	X11 =	0.39	32.02	4.77	13.24	12.63	4
LargeCap Value III Separate Account	X12 =	0.00	5.26	8.81	8.83	8.28	4
MidCap Value I Separate Account	X13 =	0.00	2.9	10.01	10.09	7.94	5
MidCap S&P 400 Index Separate Account	X14 =	0.00	3.7	5.83	8.88	8.17	5
SmallCap S&P 600 Index Separate Account	X15 =	0.00	0.75	2.54	6.78	7.5	5
SmallCap Separate Account	X16 =	0.00	1.24	0.96	7.27	7.00	5
Real Estate Securities Sep Acct	X17 =	0.00	-3.26	3.3	4.15	6.71	5
MidCap Growth III Separate Account	X18 =	0.00	8.13	0.17	10.10	8.74	5
SmallCap Value II Separate Account	X19 =	0.00	4.5	9.81	8.88	7.06	5
Diversified International Separate Account	X20 =	0.00	7.75	0.42	5.45	3.80	6
International SmallCap Separate Account	X21 =	0.00	2.33	-2.87	1.80	2.83	6
<i>Objective</i>							
Minimize the risk		2					
<i>Constraints</i>							
Return in 10 years >= 10%	5.00	>=	5				
Total investor distribution = 1	1	=	1				

Since we want our investor to have options, in an event they wanted to be more conservative and invest only in funds that had a minimum risk, we ran a model with an objective to minimize the risk and after running it through the solver, we got a recommendation by the model to invest in Liquid Assets Separate Account and LargeCap Growth I Separate Account with a minimum risk of 2. Although this might not be the optimal solution with the highest rate of return on our investment yet it provides an option for our investors who want to be investing in more conservative funds.