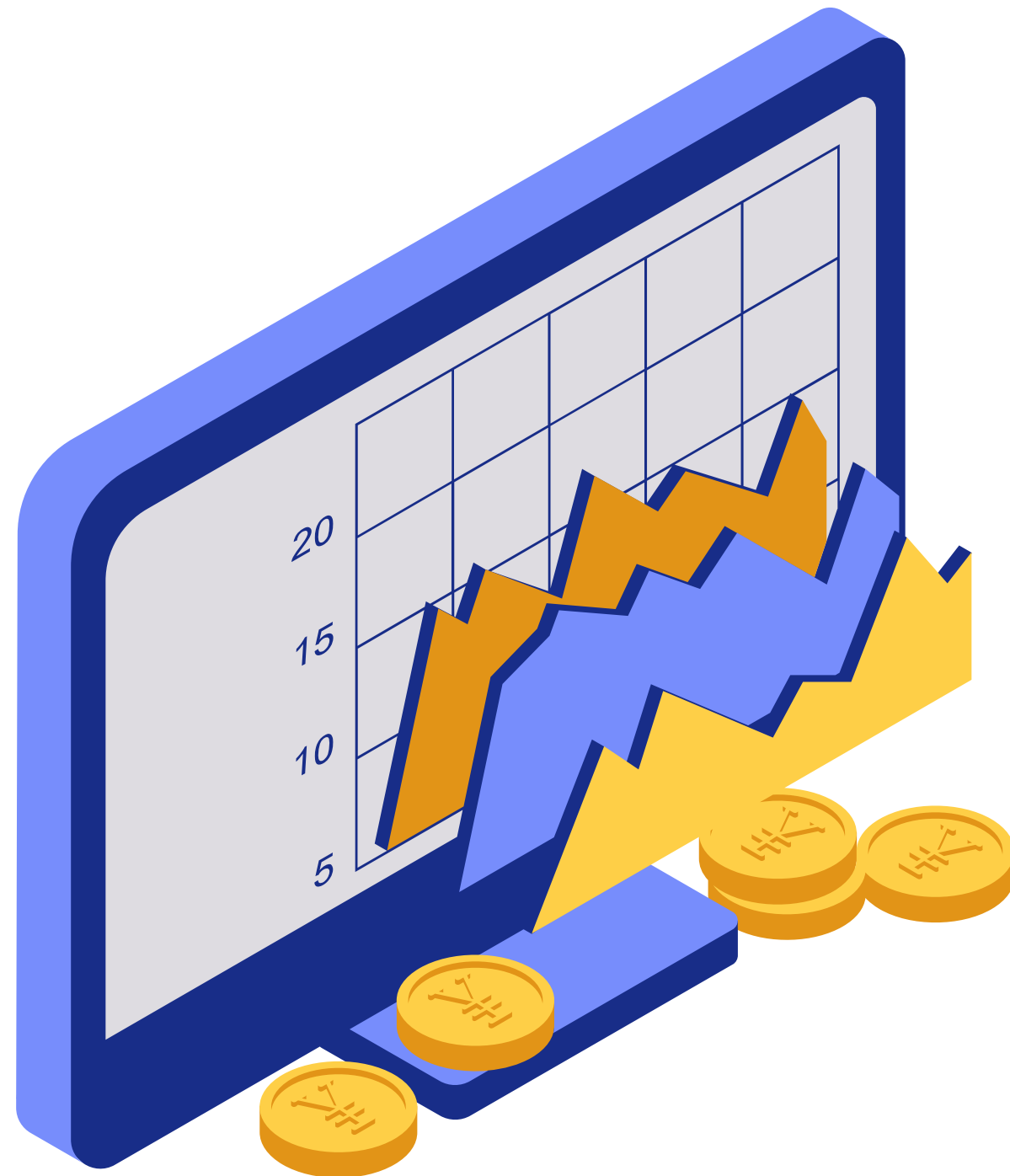


1/04/2026



Investment Portfolio Optimisation

MIS775 — Decision Modelling for Business Analytics
Trimester 1, 2026 | Assessment Task 1

Name: Nikhil Gupta
Student ID: 225006885



Introduction

Ten ASX-listed stocks were selected across five industry sectors, with two stocks per sector. Three stocks were pre-specified by the assignment: Pro Medicus (PME) in Health Care, Stockland (SGP) in Real Estate, and Telstra (TLS) in Communication Services. The remaining seven were chosen based on three criteria: complete 48-month closing price history from January 2022 to January 2026, positive average monthly returns, and mid-range volatility suitable for classification across four risk categories.

Sector	Stock 1	Reason	Stock 2	Reason
Health Care (S1)	PME (pre-specified)	High-growth health tech, strong returns	COH (Cochlear)	chosen as the second health care stock due to its established market presence as a global leader in hearing implant technology, providing a moderate-volatility counterpart to the higher-volatility PME.
Real Estate (S2)	SGP (pre-specified)	Diversified property group	GMG (Goodman Group)	Goodman Group (GMG) was selected as a high-growth real estate investment group with significant exposure to industrial and logistics properties, offering a different risk profile to the more diversified Stockland.
Comm. Services (S3)	TLS (pre-specified)	Defensive telecom utility, lowest volatility	CAR (CAR Group)	CAR Group (CAR) was selected as the second communication services stock. CAR Group operates Australia's leading online automotive classifieds platform and provides a growth-oriented complement to the defensive, utility-like Telstra.
Financials (S4)	CBA (Commonwealth Bank)	Selected as Australia's largest bank by market capitalisation, CBA provides strong and consistent returns at 1.17% per month. As a major pillar of the Australian financial system, it offers stability and reliable dividend income, making it a solid moderate-risk investment for the portfolio.	ANZ (ANZ Group)	Selected for its low volatility profile at 5.20% standard deviation, the second-lowest in the portfolio. ANZ provides essential defensive exposure to the banking sector and complements CBA by falling into the R1 risk category, ensuring the portfolio has sufficient representation in the lowest-risk group as required for the constraints.
Energy (S5)	ORG (Origin Energy)	Selected for its strong average monthly return of 1.87%, the second-highest in the entire portfolio. Origin Energy is one of Australia's largest integrated energy companies with operations spanning electricity generation, natural gas, and renewable energy. Its diversified energy mix provides resilience against market fluctuations in any single energy source.	WDS (Woodside Energy Group)	Selected to provide exposure to Australia's oil and gas export sector. Woodside is Australia's largest independent oil and gas company with significant LNG operations. Its moderate standard deviation of 6.51% places it in the R2 risk category, providing a lower-volatility counterpart to ORG and ensuring the Energy sector has representation across different risk levels.



Risk Classification Methodology



Risk was measured using the standard deviation of each stock's 48 monthly returns (January 2022 to January 2026). Standard deviation captures return volatility — higher values indicate greater uncertainty and higher risk (Markowitz, 1952).

Monthly returns were calculated as:

Monthly rate of return

$$R_t = (P_t - P_{t-1}) / P_{t-1}$$

Where P_t = closing price at month t, and P_{t-1} = closing price at previous month

The observed standard deviation range (3.11% to 11.24%) was divided into four risk groups with boundaries at 5.5%, 7.0%, and 8.5%.

These boundaries were calculated as:

Risk category boundary calculation

Band width = (Max std dev - Min std dev) / Number of categories

Band width = (11.24% - 3.11%) / 4 = 2.03%

Boundary calculation

$$B1 = 3.11\% + 2.03\% = 5.14\% \mid B2 = 5.14\% + 2.03\% = 7.17\% \mid B3 = 7.17\% + 2.03\% = 9.20\%$$

Adjusted boundaries (to ensure min 2 per group)

$$R1: \text{below } 5.5\% \mid R2: 5.5\% \text{ to } 7.0\% \mid R3: 7.0\% \text{ to } 8.5\% \mid R4: \text{above } 8.5\%$$

Risk Group	Range	Stocks	Count
R1 (Lowest)	< 5.5%	TLS (3.11%), ANZ (5.20%)	2
R2 (Low-moderate)	5.5% – 7.0%	CBA (6.34%), WDS (6.51%), SGP (6.76%)	3
R3 (Moderate-high)	7.0% – 8.5%	COH (7.44%), CAR (8.07%), ORG (8.33%)	3
R4 (Highest)	> 8.5%	GMG (8.55%), PME (11.24%)	2

Gap between **ANZ (5.20%)** and **CBA (6.34%)** supports the **R1/R2** boundary. Gap between **SGP (6.76%)** and **COH (7.44%)** supports **R2/R3**. Each group has at least two assets as required.

Table A (Sector vs Risk Cross-Classification)



Each stock belongs to exactly one sector and one risk category. All five sectors and all four risk groups are represented, with no single sector dominating any risk category, ensuring meaningful diversification.

	Health Care S1		Real Estate		Comm. Services S3		Financial. Ser S4		Energy Sector S5		Total
	S11 (PME)	S12 (COH)	S21 (SGP)	S22 (GMG)	S31 (TLS)	S32 (CAR)	S41 (CBA)	S42 (ANZ)	S51 (ORG)	S52 (WDS)	
R1					X			X			2
R2			X				X			X	3
R3		X				X			X		3
R4	X			X							2

LP Model

Objective: Maximise the overall portfolio return

Method: Simplex LP

Decision Variables: $x_1, x_2, \dots, x_{10}$ representing the proportion of investment allocated to each of the ten stocks

Constraints:

- Investment in highest-risk assets (R4) must not exceed 10%
- Lowest-risk assets (R1) must receive the highest allocation compared to all other risk categories
- Each sector must have a minimum of 15% invested, with Energy (S5) requiring a minimum of 20%
- No single stock may exceed 25% of the portfolio
- Risk category R2 must receive at least 20% allocation
- All allocations are non-negative and sum to 100%

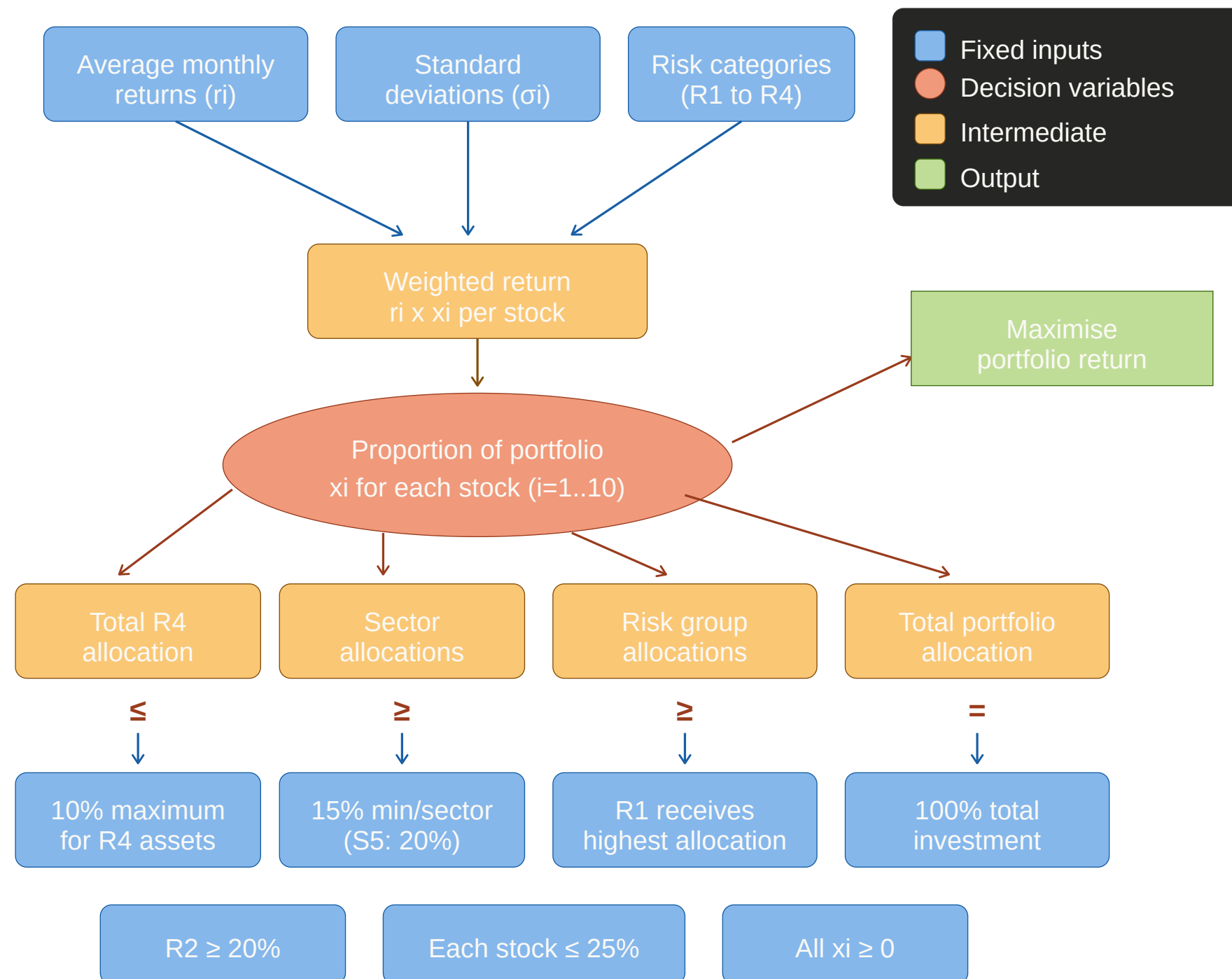
Number of constraints: 13



LP Model



Conceptual Diagram



Algebraic Formulation

Decision variables

x_i = proportion of portfolio allocated to stock i , where $0 \leq x_i \leq 1$ for $i = 1, 2, \dots, 10$

Objective function — maximise expected portfolio return

$$\text{Max } Z = 0.0358x_1 + 0.0097x_2 + 0.0082x_3 + 0.0095x_4 + 0.0050x_5 + 0.0079x_6 + 0.0117x_7 + 0.0081x_8 + 0.0187x_9 + 0.0023x_{10}$$

Subject to

$$C1: x_1 + x_4 \leq 0.10$$

$$C2: x_5 + x_8 \geq x_3 + x_7 + x_{10}$$

$$C3: x_5 + x_8 \geq x_2 + x_6 + x_9$$

$$C4: x_5 + x_8 \geq x_1 + x_4$$

$$C5: x_1 + x_2 \geq 0.15$$

$$C6: x_3 + x_4 \geq 0.15$$

$$C7: x_5 + x_6 \geq 0.15$$

$$C8: x_7 + x_8 \geq 0.15$$

$$C9: x_9 + x_{10} \geq 0.20$$

$$C10: x_1 + x_2 + \dots + x_{10} = 1$$

$$C11: x_3 + x_7 + x_{10} \geq 0.20$$

$$C12: x_i \leq 0.25 \text{ for all } i$$

$$C13: x_i \geq 0 \text{ for all } i$$

R4 assets $\leq$ 10% of portfolio

R1 allocation $\geq$ R2 allocation

R1 allocation $\geq$ R3 allocation

R1 allocation $\geq$ R4 allocation

S1 (Health Care) $\geq$ 15%

S2 (Real Estate) $\geq$ 15%

S3 (Comm. Services) $\geq$ 15%

S4 (Financials) $\geq$ 15%

S5 (Energy) $\geq$ 20%

Total allocation = 100%

(Custom) R2 allocation $\geq$ 20%

(Custom) No single stock $>$ 25%

Non-negativity (no short selling)

LP Model



Excel Worksheet

LP Model

INPUTS													
Risk category	R4	R3	R2	R4	R1	R3	R2	R1	R3	R2			
Sector	PME	COH	SGP	GMG	TLS	CAR	CBA	ANZ	ORG	WDS			
Average rate of return (ri)	3.5821%	0.9719%	0.8221%	0.9490%	0.5045%	0.7919%	1.1701%	0.8102%	1.8694%	0.2296%			
Std Deviation	11.2382%	7.4357%	6.7590%	8.5505%	3.1114%	8.0667%	6.3428%	5.1967%	8.3256%	6.5076%			
DECISION VARIABLES													
Proportion of investment	0.1	0.05	0.15	0	0.15	0	0.15	0.15	0.25	0	Total allocation		
From 0 to 1											1		
OBJECTIVE FUNCTION													
Maximise the expected rate of return(%)	1.37%												
Average expected rate of return	1.3702%												
CONSTRAINTS													
	PME	COH	SGP	GMG	TLS	CAR	CBA	ANZ	ORG	WDS	LHS	relational operators	RHS
1 Investment in the highest-risk assets (R4) shouldn't exceed 10% of the portfolio.	1			1							0.1	<=	0.1
2 The lowest-risk assets (R1) should receive the highest allocation of investments compared to the low-moderate risk group (R2). Total investment in R1 must be greater than or equal to total investment in R2.					1			1			0.3	>=	0.3
2a Total investment in the low-moderate risk group (R2), used as the comparison value for constraint 2 above.			1				1			1	0.3	>=	0
3 The lowest-risk assets (R1) should receive the highest allocation of investments compared to the moderate-high risk group (R3). Total investment in R1 must be greater than or equal to total investment in R3.					1			1			0.3	>=	0.3
3a Total investment in the moderate-high risk group (R3), used as the comparison value for constraint 3 above.		1				1			1		0.3	>=	0
4a The lowest-risk assets (R1) should receive the highest allocation of investments compared to the highest-risk group (R4). Total investment in R1 must be greater than or equal to total investment in R4.					1			1			0.3	>=	0.1
4b Total investment in the highest-risk group (R4), used as the comparison value for constraint 4 above.	1			1							0.1	>=	0
5 To ensure diversification, the Health Care sector (S1) must have a minimum of 15% of the total portfolio invested.	1	1									0.15	>=	0.15
6 To ensure diversification, the Real Estate sector (S2) must have a minimum of 15% of the total portfolio invested.			1	1							0.15	>=	0.15
7 To ensure diversification, the Communication Services sector (S3) must have a minimum of 15% of the total portfolio invested.					1	1					0.15	>=	0.15
8 To ensure diversification, the Financials sector (S4) must have a minimum of 15% of the total portfolio invested.							1	1			0.3	>=	0.15
9 To ensure diversification, the Energy sector (S5) is chosen to have a higher minimum of 20% of the total portfolio invested, as it contains the second-highest returning asset in the portfolio.									1	1	0.25	>=	0.2
10 The total portfolio allocation must equal 100%. The investor intends to allocate all available funds to the stock market, with no funds left uninvested.	1	1	1	1	1	1	1	1	1	1	1	=	1
11 The total allocation to the low-moderate risk group (R2) must be at least 20%, ensuring the portfolio maintains a solid foundation of stable, moderate-volatility investments.			1				1			1	0.3	>=	0.2
12 No single stock should receive more than 25% of the total portfolio. This prevents over-concentration in any individual asset and ensures genuine diversification across all investments.											0	<=	0.25
13 All investment proportions must be greater than or equal to zero. The portfolio does not allow short selling.											0	>=	0

Solver

Solver Parameters

Set Objective:

\$D\$15

↑

To:

☒ Max

☐ Min

☐ Value Of:

0

By Changing Variable Cells:

\$D\$11:\$M\$11

↑

Subject to the Constraints:

\$D\$11:\$M\$11 <= 0.25

\$D\$11:\$M\$11 >= 0

\$N\$20 <= \$P\$20

\$N\$21:\$N\$31 >= \$P\$21:\$P\$31

\$N\$32 = \$P\$32

\$N\$33 >= \$P\$33

Add

Change

Delete

Reset All

Load/Save

☒ Make Unconstrained Variables Non-Negative

Select a Solving Method:

Simplex LP

Options

Solving Method

Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.

Help

Solve

Close

LP Model — Optimal Solution



Symbol	Company	Sector	Sector code	Sector code for chosen assets	Std. Deviation	Risk Category (R1 .. R4)	Proportion of investment
(ASX:PME)	Pro Medicus Limited	Healthcare	S1	S11	11.24%	R4	0.1
(ASX:COH)	Cochlear			S12	7.44%	R3	0.05
(ASX:SGP)	Stockland Group	Real Estate	S2	S21	6.76%	R2	0.15
(ASX:GMG)	Goodman group			S22	8.55%	R4	0
(ASX:TLS)	Telstra Group Limited	Communication services	S3	S31	3.11%	R1	0.15
(ASX:CAR)	CAR Group			S32	8.07%	R3	0
(ASX:CBA)	Commonwealth Bank	Financial Services	S4	S41	6.34%	R2	0.15
(ASX:ANZ)	ANZ Group Holdings Limited			S42	5.20%	R1	0.15
(ASX:ORG)	Origin Energy limited	Energy Sector	S5	S51	8.33%	R3	0.25
(ASX:WDS)	Woodside Energy Group Private Limited			S52	6.51%	R2	0
	Maxmise the expected rate of return(%)	1.37%					

LP Model- Interpretation & Suggestions

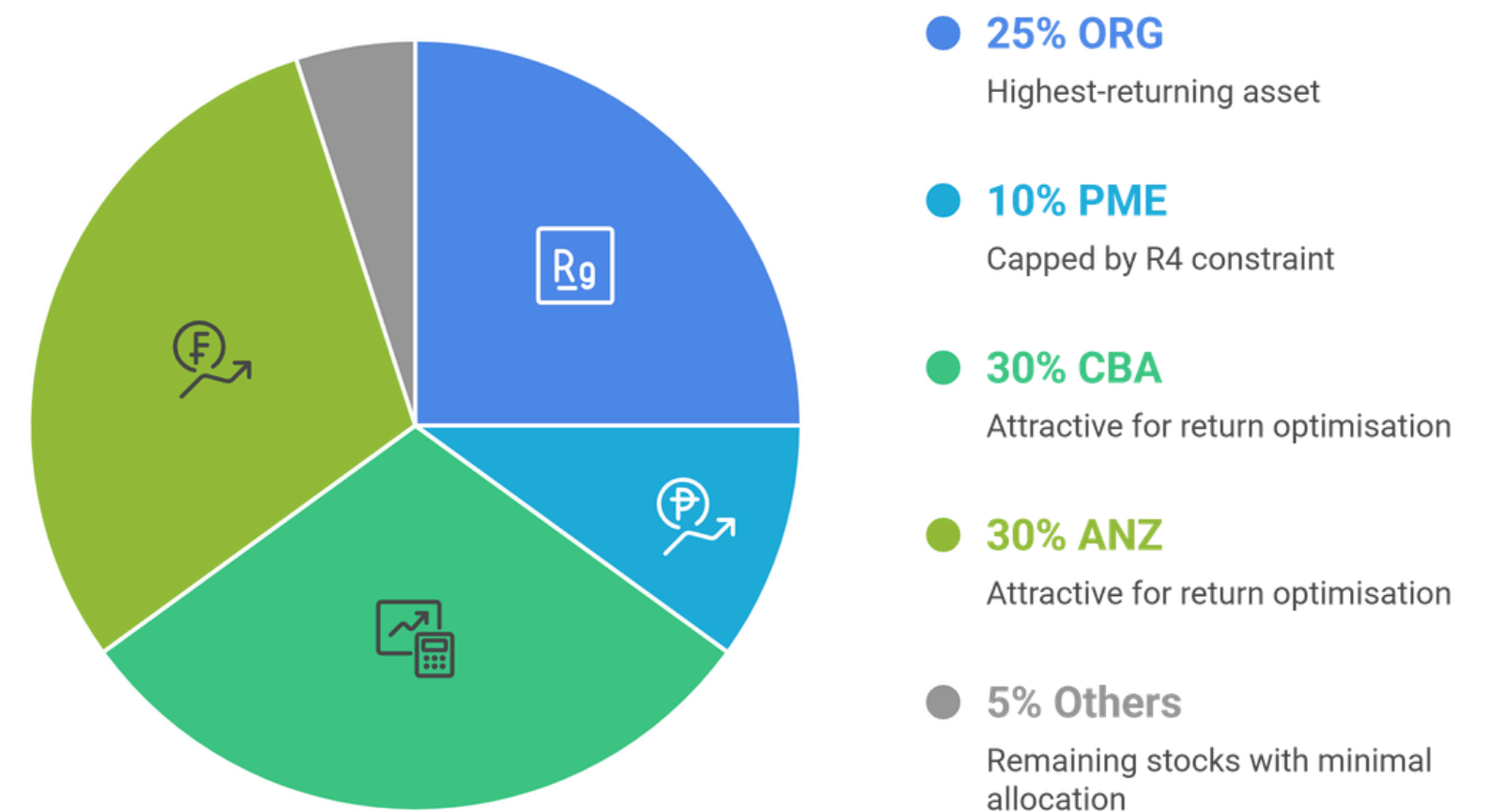
Interpretation:

- The LP model allocated funds to 7 out of 10 stocks. Three stocks received zero allocation — GMG (0.95%), CAR (0.79%), and WDS (0.23%) — as their lower returns were unnecessary once sector minimums were met. Solver concentrated in the highest-returning assets: ORG received the maximum 25% due to its 1.87% return, and PME received exactly 10%, capped by the R4 constraint.
- Several constraints are binding at their exact limits: the R4 cap at 10%, Health Care, Real Estate, and Communication Services at their 15% minimums, and R1 equals both R2 and R3 at 30% each. These actively limit the achievable return. The Financials sector voluntarily received 30% despite only requiring 15%, indicating CBA and ANZ are attractive for return optimisation.

Suggestions:

The R4 risk cap serves as the most stringent limitation. For investors with a higher risk tolerance, adjusting it from 10% to 15% would enable a larger allocation to PME, thus enhancing returns. The sector minimums for Real Estate and Communication Services incur the highest costs; lowering these from 15% to 10% would free up capital for investments with better returns. CAR Group is positioned right on the edge of inclusion and requires close monitoring, as any improvement in performance could integrate it into the optimal portfolio. The current 30% overweight in Financials should be preserved, as this was naturally selected by the optimizer. Additionally, the portfolio should be rebalanced periodically using the most up-to-date data.

Allocation of Funds to Stocks



LP Model — Sensitivity Analysis Report



Interpretation:

- The sensitivity analysis reveals how changes to the risk and sector constraints would affect the optimal portfolio. The R4 risk cap ($\leq 10\%$) has the highest shadow price of 0.0268, meaning that for every 1% increase in the R4 limit, the portfolio return would improve by approximately 0.027%. This cap could be increased by up to 5% (to 15%) before the shadow price changes, allowing more allocation to the high-returning PME stock.
- The $R1 \geq R2$ constraint has a shadow price of -0.0014, indicating that requiring the lowest-risk group to hold the highest allocation slightly reduces returns. Relaxing this requirement would allow Solver to redirect funds from the defensive TLS and ANZ towards higher-returning assets.
- Among sector constraints, Real Estate (S2) and Communication Services (S3) have shadow prices of -0.0035 and -0.0031 respectively. Reducing these sector minimums from 15% to as low as 5% would improve returns by freeing capital from lower-returning stocks like SGP (0.82%) and TLS (0.50%).
- The Financials (S4) and Energy (S5) constraints are non-binding with zero shadow prices, meaning changing their minimums would have no effect on the optimal solution as these sectors already exceed their requirements.

Microsoft Excel 16.0 Sensitivity Report						
Worksheet: [MIS775 Assessment Task 1-Excel Template.xlsx]2.a. LP Modelling						
Report Created: 29/03/2026 8:07:56 PM						
Variable Cells						
	Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase
	SD\$9	Proportion of investment S11	0.1	0	0.035821	1E+30
	SE\$9	Proportion of investment S12	0.05	0	0.009719	0.001258
	SF\$9	Proportion of investment S21	0.15	0	0.008221	0.00348
	SG\$9	Proportion of investment S22	0	-0.024109	0.00949	0.024109
	SH\$9	Proportion of investment S31	0.15	0	0.005045	0.001074
	SI\$9	Proportion of investment S32	0	0	0.007919	0.004324
	SJ\$9	Proportion of investment S41	0.15	0	0.011701	0.002149
	SK\$9	Proportion of investment S42	0.15	0	0.008102	0.002162
	SL\$9	Proportion of investment S51	0.25	0.007717	0.018694	1E+30
	SM\$9	Proportion of investment S52	0	-0.009405	0.002296	0.009405
Constraints						
	Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase
	SN\$18	Investment in the highest-risk assets (R4) shouldn't exceed 10% of the portfolio. LHS	0.1	0.026819	0.1	0.05
	SN\$19	The lowest-risk assets (R1) should receive the highest allocation of investments compared to the low-moderate risk group (R2). Total investment in R1 must be greater than or equal to total investment in R2. LHS	0.3	-0.001441	0	0.15
	SN\$20	Total investment in the low-moderate risk group (R2), used as the comparison value for constraint 2 above. LHS	0.3	0	0	0.3
	SN\$21	The lowest-risk assets (R1) should receive the highest allocation of investments compared to the moderate-high risk group (R3). Total investment in R1 must be greater than or equal to total investment in R3. LHS	0.3	-0.000716	0	0
	SN\$22	Total investment in the moderate-high risk group (R3), used as the comparison value for constraint 3 above. LHS	0.3	0	0	0.3
	SN\$23	The lowest-risk assets (R1) should receive the highest allocation of investments compared to the highest-risk group (R4). Total investment in R1 must be greater than or equal to total investment in R4. LHS	0.3	0	0	0.2
	SN\$24	Total investment in the highest-risk group (R4), used as the comparison value for constraint 4 above. LHS	0.1	0	0	0.1
	SN\$25	To ensure diversification, the Health Care sector (S1) must have a minimum of 15% of the total portfolio invested. LHS	0.15	-0.001258	0	0
	SN\$26	To ensure diversification, the Real Estate sector (S2) must have a minimum of 15% of the total portfolio invested. LHS	0.15	-0.00348	0	0.1
	SN\$27	To ensure diversification, the Communication Services sector (S3) must have a minimum of 15% of the total portfolio invested. LHS	0.15	-0.003057	0	0.1
	SN\$28	To ensure diversification, the Financials sector (S4) must have a minimum of 15% of the total portfolio invested. LHS	0.3	0	0	0.15
	SN\$29	To ensure diversification, the Energy sector (S5) is chosen to have a higher minimum of 20% of the total portfolio invested, as it contains the second-highest returning asset in the portfolio. LHS	0.25	0	0	0.05
	SN\$30	The total portfolio allocation must equal 100%. The investor intends to allocate all available funds to the stock market, with no funds left uninvested. LHS	1	0.01026	1	0.15
	SN\$31	The total allocation to the low-moderate risk group (R2) must be at least 20%, ensuring the portfolio maintains a solid foundation of stable, moderate-volatility investments. LHS	0.3	0	0.2	0.1
	SN\$33	All investment proportions must be greater than or equal to zero. The portfolio does not allow short selling. LHS	0	0	0	0

ILP Model

Objective: Maximise the expected rate of return

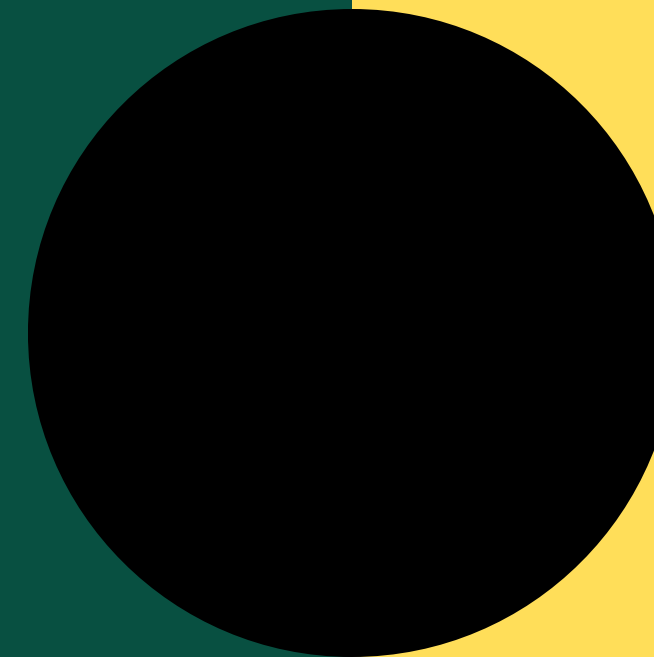
Method: Simplex LP with Binary Variables

Decision Variables: $y_1, y_2, \dots, y_{10}$ representing binary selection (1 = selected, 0 = not selected) for each of the ten stocks

Constraints:

- A balanced portfolio of exactly seven assets to be chosen
- All five investment sectors must be included
- At most one asset can be in the riskiest group (R4)
- At least two assets must be in the least-risky group (R1)
- An asset from R4 can be selected only if at least one asset from R3 is selected
- At least one asset must be selected from R2
- At least one asset must be selected from R3
- All variables are binary (0 or 1)

Number of constraints: 12



ILP Model — Algebraic Formulation



Decision variables

$y_i \in \{0, 1\}$ for $i = 1, 2, \dots, 10$ (binary: 1 = invest, 0 = exclude)

Objective function — maximise total expected return

$$\begin{aligned} \text{Max } Z = & 0.0358y_1 + 0.0097y_2 + 0.0082y_3 + 0.0095y_4 + 0.0050y_5 \\ & + 0.0079y_6 + 0.0117y_7 + 0.0081y_8 + 0.0187y_9 + 0.0023y_{10} \end{aligned}$$

Subject to

C1: $y_1 + y_2 + y_3 + \dots + y_{10} = 7$

Exactly 7 assets selected

C2: $y_1 + y_2 \geq 1$

S1 (Health Care) included

C3: $y_3 + y_4 \geq 1$

S2 (Real Estate) included

C4: $y_5 + y_6 \geq 1$

S3 (Comm. Services) included

C5: $y_7 + y_8 \geq 1$

S4 (Financials) included

C6: $y_9 + y_{10} \geq 1$

S5 (Energy) included

C7: $y_1 + y_4 \leq 1$

At most 1 R4 asset

C8: $y_5 + y_8 \geq 2$

At least 2 R1 assets

C9: $(y_2 + y_6 + y_9) \geq (y_1 + y_4)$

R3 count $\geq$ R4 count

C10: $y_3 + y_7 + y_{10} \geq 1$

(Custom) At least 1 R2 asset

C11: $y_3 + y_5 + y_7 + y_8 + y_{10} \geq 3$

(Custom) R1+R2 combined ≥ 3

C12: $y_i \in \{0, 1\}$ for all i

Binary constraint

ILP Model



Excel Worksheet

ILP model																								
INPUTS																								
Risk category	R4	R3	R2	R4	R1	R3	R2	R1	R3	R2														
Sector	S11	S12	S21	S22	S31	S32	S41	S42	S51	S52														
Average rate of return (ri)	3.5821%	0.9719%	0.8221%	0.9490%	0.5045%	0.7919%	1.1701%	0.8102%	1.8694%	0.2296%														
Std Deviation	11.2382%	7.4357%	6.7590%	8.5505%	3.1114%	8.0667%	6.3428%	5.1967%	8.3256%	6.5076%														
DECISION VARIABLES																								
Invest? (1=yes, 0=no)	1	1	1	0	1	0	1	1	1	0	Total allocation	7												
OBJECTIVE FUNCTION																								
Maaimise the expected rate of return(%)	9.73%																							
Average expected rate of return	1.3901%																							
CONSTRAINTS											PME	COH	SGP	GMG	TLS	CAR	CBA	ANZ	ORG	VDS	LHS	relational operators	RHS	
1	A balanced portfolio of exactly 7 assets to be chosen out of the 10 available stocks. This ensures sufficient diversification while excluding the 3 least attractive assets.										1	1	1	1	1	1	1	1	1	1	1	7	=	7
2	All five investment sectors must be included. At least one stock from the Health Care sector (S1) must be selected. S1 contains PME and COH.										1	1										2	>=	1
3	All five investment sectors must be included. At least one stock from the Real Estate sector (S2) must be selected. S2 contains SGP and GMG.												1	1								1	>=	1
4	All five investment sectors must be included. At least one stock from the Communication Services sector (S3) must be selected. S3 contains TLS and CAR.														1	1						1	>=	1
5	All five investment sectors must be included. At least one stock from the Financials sector (S4) must be selected. S4 contains CBA and ANZ.																1	1				2	>=	1
6	All five investment sectors must be included. At least one stock from the Energy sector (S5) must be selected. S5 contains ORG and VDS.																		1	1		1	>=	1
7	At most one of the assets can be in the riskiest group (R4). The total number of R4 assets selected must not exceed 1. R4 contains PME (std dev 11.24%) and GMG (std dev 8.55%). This limits exposure to the most volatile stocks.										1			1								1	<=	1
8	At least two assets must be in the least-risky group (R1). R1 contains TLS (std dev 3.11%) and ANZ (std dev 5.20%). Since R1 has exactly two stocks, this constraint requires both to be selected, ensuring a strong defensive foundation.														1			1				2	>=	2
9	An asset from R4 can be selected only if at least one asset from R3 is also selected. The number of R3 assets selected must be greater than or equal to the number of R4 assets selected. This ensures higher-risk investments are only included when moderate-high risk assets are also present. R3 count shown here.												1				1		1			2	>=	1
	Total number of R4 assets selected, used as the comparison value for constraint 9 above. R4 contains PME and GMG.										1			1								1	>=	0
10	At least one asset from the moderate-risk group (R2) must be selected. R2 contains SGP (std dev 6.76%), CBA (std dev 6.34%), and VDS (std dev 6.51%). This ensures the portfolio includes stable, moderate-volatility investments and is not composed entirely of low-risk and high-risk extremes.												1				1			1		2	>=	1
11	At least 3 assets must come from the two lowest risk groups (R1 and R2) combined. R1 contains TLS and ANZ, R2 contains SGP, CBA, and VDS. This ensures the portfolio is tilted towards stability and that the majority of selected assets have moderate or low volatility.												1		1		1	1		1		4	>=	3

Solver

Solver Parameters

Set Objective:

=\$C\$15

↑

To:

☒ Max

☐ Min

☐ Value Of:

0

By Changing Variable Cells:

=\$C\$11:\$L\$11

↑

Subject to the Constraints:

\$C\$11:\$L\$11 = binary

\$M\$20 = \$O\$20

\$M\$21:\$M\$25 >= \$O\$21:\$O\$25

\$M\$26 <= \$O\$26

\$M\$27:\$M\$31 >= \$O\$27:\$O\$31

Add

Change

Delete

Reset All

Load/Save

☒ Make Unconstrained Variables Non-Negative

Select a Solving Method:

Simplex LP

Options

Solving Method

Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.

Help

Solve

Close

ILP Model — Optimal Solution



Symbol	Company	Sector	Sector code	Sector code for chosen assets	Std. Deviation	Risk Category (R1 .. R4)	Proportion of investment
(ASX:PME)	Pro Medicus Limited	Healthcare	S1	S11	11.24%	R4	1
(ASX:COH)	Cochlear			S12	7.44%	R3	1
(ASX:SGP)	Stockland Group	Real Estate	S2	S21	6.76%	R2	1
(ASX:GMG)	Goodman group			S22	8.55%	R4	0
(ASX:TLS)	Telstra Group Limited	Communication services	S3	S31	3.11%	R1	1
(ASX:CAR)	CAR Group			S32	8.07%	R3	0
(ASX:CBA)	Commonwealth Bank	Financial Services	S4	S41	6.34%	R2	1
(ASX:ANZ)	ANZ Group Holdings Limited			S42	5.20%	R1	1
(ASX:ORG)	Origin Energy limited	Energy Sector	S5	S51	8.33%	R3	1
(ASX:WDS)	Woodside Energy Group Private Limited			S52	6.51%	R2	0
	Maxmise the expected rate of return(%)	9.73%					

ILP Model- Interpretation & Suggestions

Interpretation:

The ILP model selected 7 out of 10 stocks and excluded Goodman Group (0.95% return), CAR Group (0.79% return), and Woodside Energy (0.23% return) — the three lowest-returning stocks. Pro Medicus was retained as the only R4 asset, leveraging its highest return of 3.58% while respecting the constraint that at most one R4 asset can be selected. Both R1 assets, Telstra and ANZ, were selected as required, ensuring a strong defensive foundation. All five sectors are represented, with Health Care and Financials having both stocks selected, while Real Estate, Communication Services, and Energy each retain one stock. The average return per selected asset is 1.39%, which is higher than the LP model's optimal return of 1.37%, as the ILP model excludes underperforming stocks entirely rather than allocating small proportions to them.

Recommendations:

The ILP results confirm that Goodman Group, CAR Group, and Woodside Energy are the least attractive investments, consistent with the LP model which also allocated 0% to these three stocks. This consistency across two different optimisation approaches strengthens the recommendation to exclude these assets. The investor should build their portfolio around the seven selected stocks, using the LP model to determine the specific allocation percentages for each. If the investor wishes to reduce the portfolio further, Cochlear (0.97% return) and Telstra (0.50% return) would be the next candidates for review, though removing them would violate the sector coverage and R1 minimum constraints. The investor should also note that the R4 constraint limited selection to only one of PME or GMG — if this constraint were relaxed to allow two R4 assets, GMG would likely be included, increasing the total return but also increasing portfolio risk.

ILP Model's Stock Selection

Sector Representation

All five sectors are represented, with Health Care and Financials having two stocks each.

Defensive Base

Telstra and ANZ were selected to provide a strong defensive foundation.



Excluded Stocks

Goodman Group, CAR Group, and Woodside Energy were excluded due to low returns.

Retained R4 Asset

Pro Medicus was retained for its high return while respecting constraints.

NLP Model

Objective: Minimise the overall portfolio risk (variance)

Method: GRG Nonlinear

Decision Variables: $w_1, w_2, \dots, w_{10}$ representing the proportion of investment allocated to each of the ten stocks

Constraints:

- Portfolio expected return must be at least 1.50% per month
- Total investment proportions must equal 100%
- All allocations are non-negative (no short selling)
- No sector or risk group constraints imposed

Number of constraints: 3

Key Feature: Uses the 10×10 covariance matrix to capture how stock returns move together, applying Markowitz's Modern Portfolio Theory to find the minimum-variance portfolio



NLP Model — Algebraic Formulation



Decision variables

x_i = proportion of portfolio allocated to stock i , where $0 \leq x_i \leq 1$ for $i = 1, 2, \dots, 10$

Objective function — minimise portfolio risk

Min $\sigma_p^2 = \sum_i \sum_j x_i \times x_j \times \text{Cov}(i, j)$ for all $i, j = 1$ to 10

Portfolio standard deviation: $\sigma_p = \sqrt{\sigma_p^2}$

$\text{Cov}(i, j)$ values from the 10×10 covariance matrix of monthly returns

Subject to

C1: $\sum (r_i \times x_i) \geq 0.015$

C2: $x_1 + x_2 + x_3 + \dots + x_{10} = 1$

C3: $x_i \geq 0$ for all i

No sector or risk group constraints imposed

Portfolio return $\geq 1.50\%$ per month

Total allocation = 100%

Non-negativity (no short selling)

Solver: GRG Nonlinear

Minimize (variance):

$$\sigma_p^2 = w_1^2 \sigma_1^2 + w_2^2 \sigma_2^2 + w_3^2 \sigma_3^2 + w_4^2 \sigma_4^2 + w_5^2 \sigma_5^2 + w_6^2 \sigma_6^2 + w_7^2 \sigma_7^2 + w_8^2 \sigma_8^2 + w_9^2 \sigma_9^2 + 2(w_1 w_2 \text{Cov}_{12} + w_1 w_3 \text{Cov}_{13} + w_1 w_4 \text{Cov}_{14} + \dots + w_8 w_9 \text{Cov}_{89})$$

Subject to:

$$\sum_{i=1}^9 w_i = 1$$

$$\sum_{i=1}^9 \mu_i w_i \geq R_{\text{target}}$$

$$\bullet w_i \geq 0, \forall i = 1, \dots, 9$$

$$\bullet \sum_{i \in R_4} w_i \leq 0.10$$

$$\bullet \sum_{i \in R_1} w_i \geq \sum_{i \in R_2} w_i, \quad \sum_{i \in R_3} w_i \geq \sum_{i \in R_4} w_i$$

NLP Model



Excel Worksheet

NLP model										
INPUTS										
Stock	PME	COH	SGP	GMG	TLS	CAR	CBA	ANZ	ORG	WDS
Mean	3.58%	0.97%	0.82%	0.95%	0.50%	0.79%	1.17%	0.81%	1.87%	0.23%
std deviation	11.24%	7.44%	6.76%	8.55%	3.11%	8.07%	6.34%	5.20%	8.33%	6.51%
Cov	PME	COH	SGP	GMG	TLS	CAR	CBA	ANZ	ORG	WDS
PME	0.0124	0.0025	0.0024	0.0046	0.0005	0.0052	0.0035	0.0008	0.0014	0.0009
COH	0.0025	0.0054	0.0020	0.0037	0.0002	0.0031	0.0017	0.0009	0.0015	0.0010
SGP	0.0024	0.0020	0.0045	0.0030	0.0007	0.0029	0.0024	0.0020	0.0008	0.0003
GMG	0.0046	0.0037	0.0030	0.0072	0.0003	0.0047	0.0031	0.0020	0.0027	0.0006
TLS	0.0005	0.0002	0.0007	0.0003	0.0009	0.0002	0.0006	0.0002	0.0003	0.0005
CAR	0.0052	0.0031	0.0029	0.0047	0.0002	0.0064	0.0025	0.0019	0.0029	0.0012
CBA	0.0035	0.0017	0.0024	0.0031	0.0006	0.0025	0.0039	0.0018	0.0011	0.0008
ANZ	0.0008	0.0009	0.0020	0.0020	0.0002	0.0019	0.0018	0.0026	0.0004	0.0010
ORG	0.0014	0.0015	0.0008	0.0027	0.0003	0.0029	0.0011	0.0004	0.0068	0.0013
WDS	0.0009	0.0010	0.0003	0.0006	0.0005	0.0012	0.0008	0.0010	0.0013	0.0041
DECISION VARIABLES /Sector										
Investment weights	PME	COH	SGP	GMG	TLS	CAR	CBA	ANZ	ORG	WDS
	21.91%	0.00%	0.00%	0.00%	39.01%	0.00%	0.00%	20.04%	19.05%	0.00%
CALCULATED VARIABLES										
	21.91%	0.00%	0.00%	0.00%	39.01%	0.00%	0.00%	20.04%	19.05%	0.00%
Covariance	PME	COH	SGP	GMG	TLS	CAR	CBA	ANZ	ORG	WDS
21.91%	PME	0.0124	0.0025	0.0024	0.0046	0.0005	0.0052	0.0035	0.0008	0.0014
0.00%	COH	0.0025	0.0054	0.0020	0.0037	0.0002	0.0031	0.0017	0.0009	0.0015
0.00%	SGP	0.0024	0.0020	0.0045	0.0030	0.0007	0.0029	0.0024	0.0020	0.0008
0.00%	GMG	0.0046	0.0037	0.0030	0.0072	0.0003	0.0047	0.0031	0.0020	0.0027
39.01%	TLS	0.0005	0.0002	0.0007	0.0003	0.0009	0.0002	0.0006	0.0002	0.0003
0.00%	CAR	0.0052	0.0031	0.0029	0.0047	0.0002	0.0064	0.0025	0.0019	0.0029
0.00%	CBA	0.0035	0.0017	0.0024	0.0031	0.0006	0.0025	0.0039	0.0018	0.0011
20.04%	ANZ	0.0008	0.0009	0.0020	0.0020	0.0002	0.0019	0.0018	0.0026	0.0004
19.05%	ORG	0.0014	0.0015	0.0008	0.0027	0.0003	0.0029	0.0011	0.0004	0.0068
0.00%	WDS	0.0009	0.0010	0.0003	0.0006	0.0005	0.0012	0.0008	0.0010	0.0041
Portfolio variance	PME	COH	SGP	GMG	TLS	CAR	CBA	ANZ	ORG	WDS
PME	0.00059	0.00000	0.00000	0.00000	0.00004	0.00000	0.00000	0.00004	0.00006	0.00000
COH	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
SGP	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
GMG	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
TLS	0.00004	0.00000	0.00000	0.00000	0.00014	0.00000	0.00000	0.00001	0.00002	0.00000
CAR	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
CBA	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
ANZ	0.00004	0.00000	0.00000	0.00000	0.00001	0.00000	0.00000	0.00011	0.00002	0.00000
ORG	0.00006	0.00000	0.00000	0.00000	0.00002	0.00000	0.00000	0.00002	0.00025	0.00000
WDS	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Average portfolio return 1.50%										
OBJECTIVE FUNCTION										
Standard deviation of portfolio 3.83%										
CONSTRAINTS										
LHS									RHS	
1.50%		≥							1.5%	
100%		=							100%	

Solver

Solver Parameters

Set Objective:

SD\$61

↑

To:

☐ Max

☒ Min

☐ Value Of:

0

By Changing Variable Cells:

SD\$25:SM\$25

↑

Subject to the Constraints:

SB\$65 >= SD\$65
SB\$67 = SD\$67

Add

Change

Delete

Reset All

Load/Save

☒ Make Unconstrained Variables Non-Negative

Select a Solving Method:

GRG Nonlinear

Options

Solving Method

Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.

Help

Solve

Close

NLP Model — Optimal Solution



Symbol	Company	Sector	Sector code	Sector code for chosen assets	Std. Deviation	Risk Category (R1 .. R4)	Proportion of investment
(ASX:PME)	Pro Medicus Limited	Healthcare	S1	S11	11.24%	R4	21.91%
(ASX:COH)	Cochlear			S12	7.44%	R3	0.00%
(ASX:SGP)	Stockland Group	Real Estate	S2	S21	6.76%	R2	0.00%
(ASX:GMG)	Goodman group			S22	8.55%	R4	0.00%
(ASX:TLS)	Telstra Group Limited	Communication services	S3	S31	3.11%	R1	39.01%
(ASX:CAR)	CAR Group			S32	8.07%	R3	0.00%
(ASX:CBA)	Commonwealth Bank	Financial Services	S4	S41	6.34%	R2	0.00%
(ASX:ANZ)	ANZ Group Holdings Limited			S42	5.20%	R1	20.04%
(ASX:ORG)	Origin Energy limited	Energy Sector	S5	S51	8.33%	R3	19.05%
(ASX:WDS)	Woodside Energy Group Private Limited			S52	6.51%	R2	0.00%
	Standard deviation of portfolio	3.83%					

NLP Model- Interpretation & Suggestions



Interpretation:

- The NLP model takes a fundamentally different approach from the LP and ILP models. Instead of maximising return, it minimises portfolio risk while achieving a target monthly return of at least 1.50%. The model uses the 10×10 covariance matrix to calculate how stocks move together, and finds the combination of weights that produces the lowest possible portfolio variance. Unlike the LP and ILP models, no sector or risk group constraints are imposed — the optimiser is free to allocate purely based on the risk-return profile.
- Initially, a minimum return constraint of 1.00% was tested, which resulted in Telstra dominating the portfolio at 57.32% due to its lowest individual volatility of 3.11%. By raising the target return to 1.50%, the solver was forced to redistribute weight away from the defensive Telstra towards higher-returning stocks. Telstra's allocation decreased from 57.32% to 39.01%, while Origin Energy increased significantly to 19.05% as its strong monthly return of 1.87% helps the portfolio reach the higher target. Pro Medicus received the second-highest allocation at 21.91% because its exceptional return of 3.58% is essential to pull the portfolio return up to the 1.50% minimum. ANZ received 20.04% as a low-volatility stabiliser with very low covariance with the other selected stocks. This demonstrates the fundamental risk-return tradeoff at the heart of Markowitz's Modern Portfolio Theory — demanding higher returns requires accepting greater portfolio risk, as the solver must include more volatile assets to meet the return constraint.
- The optimal portfolio achieves a standard deviation of 3.83%, which is higher than the 2.89% achieved with the 1.00% target but still lower than every individual stock except Telstra (3.11%). Six stocks received zero allocation as they either added too much risk without sufficient return contribution or did not help reduce overall portfolio variance through favourable covariance properties.

Recommendations:

The NLP model with a 1.50% minimum return target provides a more balanced allocation than the conservative 1.00% target, while still benefiting from diversification. The portfolio is concentrated in four stocks — Telstra (39.01%), PME (21.91%), ANZ (20.04%), and Origin Energy (19.05%) — which together account for 100% of the allocation. Although TLS still carries the largest share, it is significantly reduced from 57.32% under the 1.00% target, resulting in a more evenly spread portfolio. The investor should use this NLP solution as a risk benchmark — the portfolio risk of 3.83% represents the minimum achievable through diversification for a 1.50% monthly return target, and any practical portfolio with sector and risk group constraints will carry higher risk than this theoretical minimum. It is recommended to combine insights from all three models: use the LP for sector-diversified returns, the ILP for stock selection decisions, and the NLP as the floor for portfolio risk assessment.

Summary table of results



	LP Model	ILP Model	NLP Model
Objective	Maximise return	Maximise return	Minimise risk
Solver method	Simplex LP	Simplex LP (Binary)	GRG Nonlinear
Optimal value	1.37% monthly return	9.73% total return	3.83% portfolio std dev
PME (S11, R4)	10.00%	Selected	21.91%
COH (S12, R3)	5.00%	Selected	0.00%
SGP (S21, R2)	15.00%	Selected	0.00%
GMG (S22, R4)	0.00%	Not selected	0.00%
TLS (S31, R1)	15.00%	Selected	39.01%
CAR (S32, R3)	0.00%	Not selected	0.00%
CBA (S41, R2)	15.00%	Selected	0.00%
ANZ (S42, R1)	15.00%	Selected	20.04%
ORG (S51, R3)	25.00%	Selected	19.05%
WDS (S52, R2)	0.00%	Not selected	0.00%
Stocks used	7 of 10	7 of 10	4 of 10
Sectors covered	5 of 5	5 of 5	4 of 5 (no Real Estate)
Risk groups covered	R1, R2, R3, R4	R1, R2, R3, R4	R1, R3, R4
Constraints	Sector & risk limits	Binary stock selection	Return $\geq$ 1.50% only



Comparison of approaches

- The three optimisation models offer complementary perspectives on portfolio construction, each suited to a different investment priority.
- The LP model maximises monthly return at 1.37% while enforcing strict sector diversification and risk group constraints. It ensures every sector receives at least 15% allocation and limits the highest-risk assets to 10%, producing a well-diversified portfolio across all five sectors and all four risk categories. Origin Energy receives the largest allocation at 25% due to its strong return of 1.87%, while three stocks — GMG, CAR, and WDS — receive zero allocation as their lower returns make them suboptimal under the linear objective. The LP model is best suited for an investor who values broad diversification with controlled risk exposure.
- The ILP model also maximises return but approaches the problem differently by selecting exactly 7 of the 10 stocks using binary decision variables. It excludes the same three lowest-returning stocks as the LP model — GMG (0.95%), CAR (0.79%), and WDS (0.23%) — confirming that these stocks are consistently the weakest performers across modelling approaches. The ILP ensures all five sectors and all four risk groups are represented, making it useful as a stock screening tool to identify which assets should be included in the portfolio.
- The NLP model takes the opposite approach by minimising portfolio risk rather than maximising return. Using the 10×10 covariance matrix and Markowitz's Modern Portfolio Theory, it finds the minimum-variance portfolio that achieves at least 1.50% monthly return. The result is a concentrated four-stock portfolio dominated by Telstra at 39.01%, with PME (21.91%), ANZ (20.04%), and ORG (19.05%) providing the return needed to meet the target. The portfolio achieves a standard deviation of 3.83%, which is lower than all but one individual stock. However, it covers only four of five sectors and three of four risk groups, sacrificing diversification for mathematical risk minimisation.
- A key insight across all three models is consistency — GMG, CAR, and WDS are excluded or receive zero allocation in every model, indicating these stocks do not contribute effectively to either return maximisation or risk minimisation within this portfolio.



Preferred strategy & rationale

- Based on the comparative analysis across all three models, it is recommended that the investor adopt a strategy informed primarily by the LP model, supplemented by insights from the ILP and NLP models.
- The LP model is the preferred strategy for implementation because it achieves a strong monthly return of 1.37% while maintaining full diversification across all five sectors and all four risk categories. This balanced approach protects the investor against sector-specific downturns — if one industry underperforms, the portfolio's exposure to four other sectors limits the overall impact. The LP constraints also ensure that no single stock exceeds 25% allocation, preventing the concentration risk observed in the NLP model where Telstra alone holds 39.01%.
- The ILP model supports this recommendation by independently confirming that the same seven stocks identified by the LP model are the optimal selection from the pool of ten. The three excluded stocks — Goodman Group, CAR Group, and Woodside Energy — have the lowest average returns in the portfolio at 0.95%, 0.79%, and 0.23% respectively. This consistency across two different modelling approaches strengthens confidence in the stock selection.
- The NLP model provides a valuable risk benchmark. The minimum achievable portfolio risk for a 1.50% monthly return is 3.83%, meaning any constrained portfolio will carry risk above this floor. The investor can use this figure to assess whether the additional risk incurred by the LP model's diversification constraints is acceptable relative to the broader sector protection it provides.
- In summary, the investor should implement the LP allocation with Origin Energy at 25%, Telstra, SGP, CBA, and ANZ each at 15%, PME at 10%, and COH at 5%. This delivers strong returns, full sector coverage, controlled risk exposure, and protection against concentration risk, making it the most practical and defensible strategy for a real-world investment portfolio.

Thank You

- +61466887948
- s225006885@deakin.edu.au
- Nikhil Gupta

