Practical Multi-Constraint Portfolio Optimisation

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What we will cover

1. What is Project Portfolio Optimisation (PPO)
2. Benefits of PPO
3. Current Optimisation Practices
4. Why is PPO Difficult?
5. Common Optimisation Techniques
6. Practical Optimisation
7. Conclusion

PPO: Definition

A good working definition:

... “the periodic activity involved in selecting a portfolio, from available project proposals and projects currently under way, that meets the organisation’s stated objectives in a desirable manner without exceeding available resources or violating other constraints” - Archer et al 1999.

What is Project Portfolio Optimisation?

Constraints? Typical aim would be to concurrently:

- Maximise Strategic Alignment
- Maximise return (e.g. NPV)
- Manage cashflow (over time)
- Optimise (not minimise) portfolio Risk (over time)
- Meet Compliance obligations
- Conform to all resourcing and physical constraints (over time)
- Meet delivery date requirements

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Benefits of PPO

It makes excellent financial sense

- Current research ... with even relatively **simplified optimisation techniques**, companies can **save 10% of the overall portfolio budget**.
- Merkhofer (2007): More sophisticated optimisation approaches combined with a good level of project delivery maturity can typically **deliver savings of 20-40%**

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Current practice?

Forrester Research (no relation!)

- Many organisations make no real formal attempt to optimise. e.g
  - Dollars are allocated ‘fairly’ to business units.
  - Volume optimisation (the loudest general manager gets the most money)
- Of those that do optimise, most rank projects against just one constraint and then accept the consequences on other constraints ➔ inherent problems (discussed later).

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Why is PPO difficult?

- A “good” project portfolio optimisation approach will optimise the portfolio of projects <u>across time</u> and against <u>all</u> relevant constraints
- Four main factors contribute to making Portfolio optimisation difficult:
  - Problem space size is daunting
  - Multiple Constraints
  - Cross-correlation of Constraints and of Projects
  - Knowledge is imperfect / incomplete

Why is PPO difficult? Problem size

- Problem space size is daunting. If any project can either be done or not done, then if there are N candidate projects, there are 2^N potential portfolios (including the "do nothing" portfolio). **For 30 projects** there are **more than 1 billion alternative project portfolios**.
- Merkhofer (2002) notes that if there are two ways of doing each of 30 projects, there are $(1+2)^{30}$ ➔ > **200 trillion possible portfolios**.

Why is PPO difficult? Multiple Constraints

- How exactly do you optimise against multiple, often conflicting, sometimes correlated constraints? e.g. To keep it simple, pick the best possible portfolio which maximises NPV while optimising Risk.
- If we maximise NPV, we will tend towards higher Risk projects. Optimising Risk will not maximise NPV.
- If we create a “Risk Adjusted” NPV we hide information about the distribution of Risk across the Portfolio.

Why is PPO difficult? Combined Constraints

- If we create a "Risk Adjusted" NPV we hide information about the distribution of Risk across the Portfolio. e.g. Available Funding = $40M

Project	Cost	NPV	Risk	R.A. NPV
1	$20M	$200M	5	$150M
2	$20M	$160M	2	$150M
3	$20M	$200M	4	$160M

- Portfolios (3,1) and (3,2) are identical in terms of Risk Adjusted NPV ($310M). However, most Management teams would probably not consider them to be identical, and would probably prefer (3,2)

Why is PPO difficult? Imperfect knowledge

- All optimisation approaches rely on accurate estimates of the constraints for each project.
- Need information while the project is still in the Pipeline. Reliability of estimates at this stage is variable at best.
- How sensitive are optimisation results to input assumptions???

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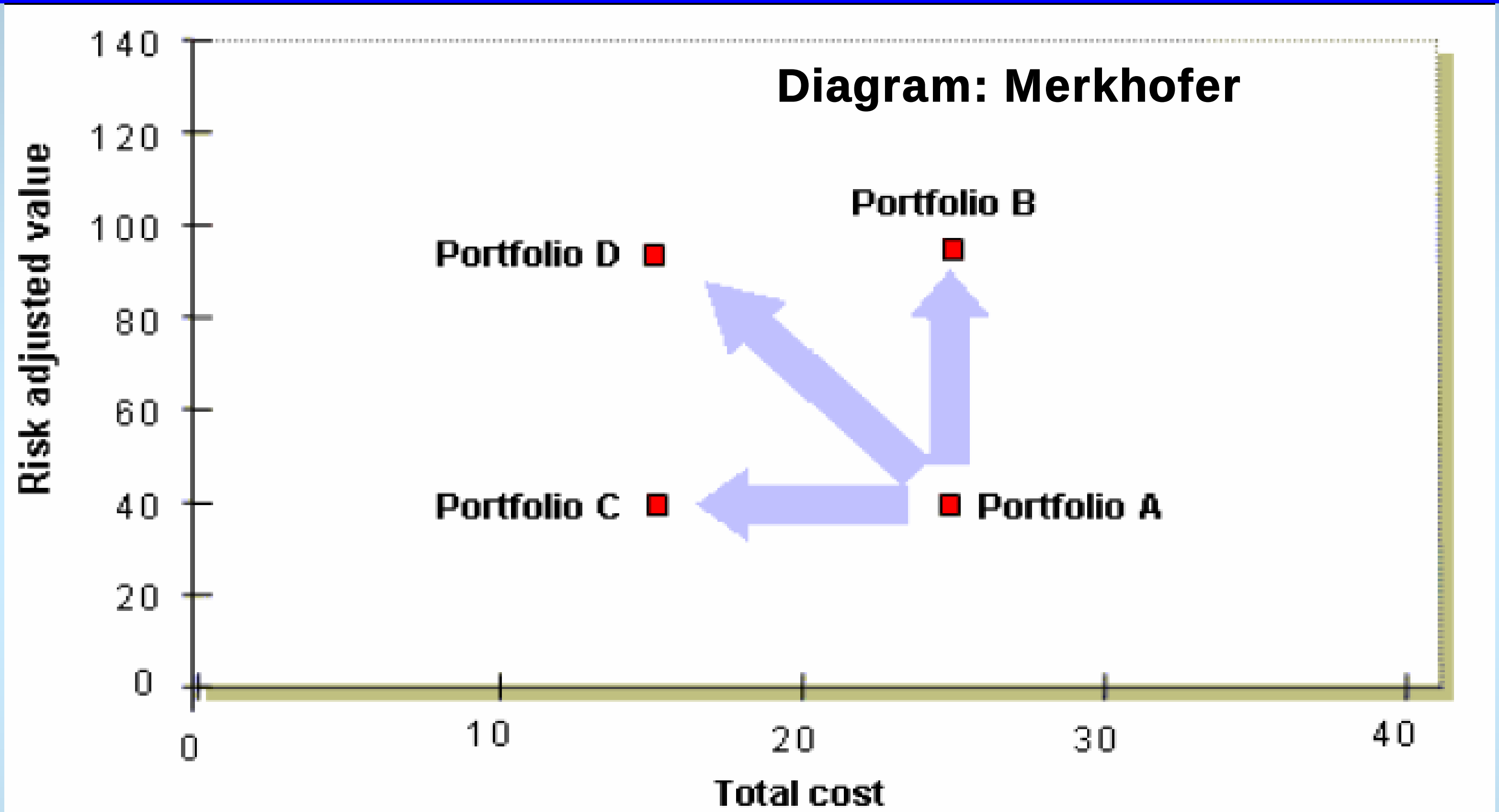
Optimisation Techniques

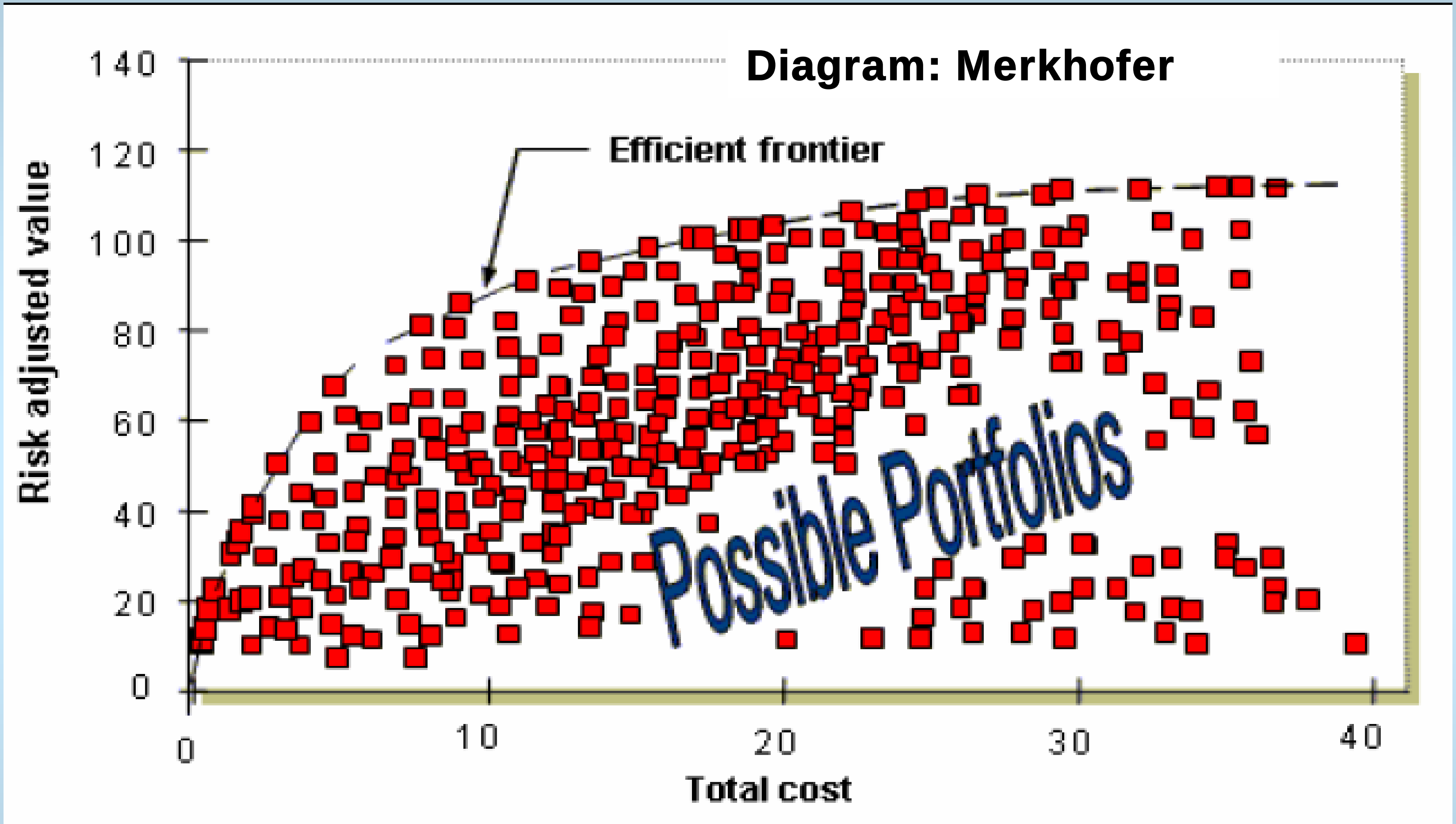
1. Ranking
2. Linear Programming
3. Integer Programming
4. Multi-objective Genetic Algorithms
5. The Efficient Frontier

Optimisation Techniques Efficient Frontier



Portfolio A is inefficient because Portfolio B produces more value for the same cost. Similarly, Portfolio C produces the same value for less cost. Furthermore, there is a Portfolio D with a combination of these two characteristics.

Optimisation Techniques Efficient Frontier



Portfolios along the curve are said to be "efficient" because they allow the organisation to obtain the greatest possible benefit from any specified available budget

Optimisation Techniques Efficient Frontier

- Markowitz quoted in Harder (2002)

  "I would be cautious about applying MPT (Modern Portfolio Theory) to corporate projects as though these are liquid assets. There are different constraints regarding projects, like management expertise, human skill sets, physical production capabilities and other factors that come into play. I'm not sure that the constraint side of the project portfolio problem has been properly modelled."

Optimisation Techniques Efficient Frontier

- Practical Issues in using the Efficient Frontier
  - Need to estimate expected rate of return (μ) and the standard deviation of that rate of return (σ) of the individual projects.
    Problem: Std Dev is a consequence of a distribution of independent estimates. To be 95% confident that our mean NPV will be within 10% of the "real" NPV, we need 384 independent NPV estimates for each candidate project ➔ **>23,000 estimates for 60 projects**
  - Also need estimates of correlations (ρ^{ij}) of returns among projects (Gulesian 2006).
    Problem: 60 projects would require nearly 1800 correlation estimates. These correlations are not simple to estimate with any degree of confidence.

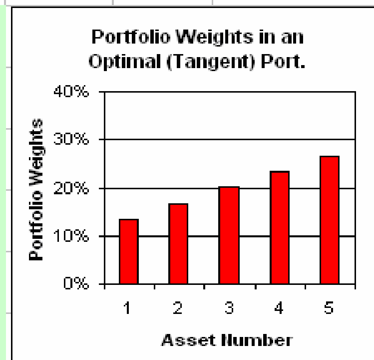
Optimisation Techniques Efficient Frontier

- The Efficient Frontier is quite sensitive to the estimates of standard deviation and correlation.

Portfolio Optimization — Dynamic Chart (Holden)

Inputs

	Expected Return		Standard Deviation	
Riskless Rate	4.0%	20	0.0%	
Risky Asset 1	8.0%	40	20.0%	100
Risky Asset 2	9.0%	45	20.0%	100
Risky Asset 3	10.0%	50	20.0%	100
Risky Asset 4	11.0%	55	20.0%	100
Risky Asset 5	12.0%	60	20.0%	100

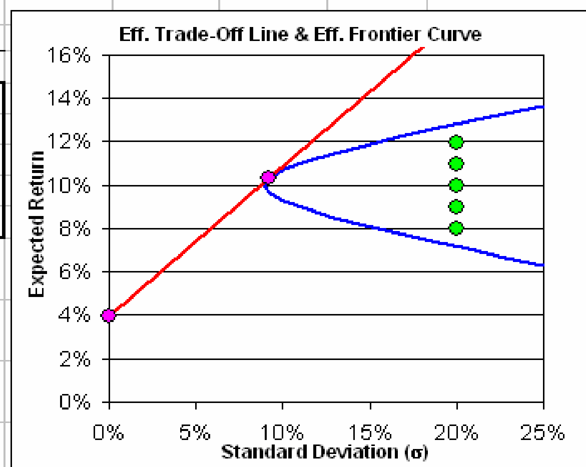


Optimal Combination of Assets		Base Case Allocation and % Diff	
Asset 1	13.33%	13.33%	0.00%
Asset 2	16.67%	16.67%	0.00%
Asset 3	20.00%	20.00%	0.00%
Asset 4	23.33%	23.33%	0.00%
Asset 5	26.67%	26.67%	0.00%

Correlations

	1	2	3	4	5
1	100.0%	0.0%	0.0%	0.0%	0.0%
2	0.0%	100.0%	0.0%	0.0%	0.0%
3	0.0%	0.0%	100.0%	0.0%	0.0%
4	0.0%	0.0%	0.0%	100.0%	0.0%
5	0.0%	0.0%	0.0%	0.0%	100.0%

2	10			
3	10	10		
4	10	10	10	
5	10	10	10	10



E.F. Model: Holden

Optimisation Techniques Efficient Frontier

Base Case: All Std Dev = 20%. No Correlations.

	Expected Return	Standard Deviation	Optimal Combination of Assets		Base Case Allocation and % Diff	
Riskless Rate	4.0%	0.0%				
Risky Asset 1	8.0%	20.0%	Asset 1	13.3%	13.3%	0.0%
Risky Asset 2	9.0%	20.0%	Asset 2	16.7%	16.7%	0.0%
Risky Asset 3	10.0%	20.0%	Asset 3	20.0%	20.0%	0.0%
Risky Asset 4	11.0%	20.0%	Asset 4	23.3%	23.3%	0.0%
Risky Asset 5	12.0%	20.0%	Asset 5	26.7%	26.7%	0.0%

	Correlations				
	1	2	3	4	5
1	100.0%	0.0%	0.0%	0.0%	0.0%
2	0.0%	100.0%	0.0%	0.0%	0.0%
3	0.0%	0.0%	100.0%	0.0%	0.0%
4	0.0%	0.0%	0.0%	100.0%	0.0%
5	0.0%	0.0%	0.0%	0.0%	100.0%

E.F. Model: Holden

Optimisation Techniques Efficient Frontier

Std Devs varied from 20% in range 18% - 22%

	Expected Return	Standard Deviation	Optimal Combination of Assets		Base Case Allocation and % Diff	
Riskless Rate	4.0%	0.0%				
Risky Asset 1	8.0%	18.2%	Asset 1	16.9%	13.3%	26.8%
Risky Asset 2	9.0%	21.6%	Asset 2	15.0%	16.7%	-10.0%
Risky Asset 3	10.0%	19.4%	Asset 3	22.3%	20.0%	11.6%
Risky Asset 4	11.0%	20.8%	Asset 4	22.6%	23.3%	-2.9%
Risky Asset 5	12.0%	22.0%	Asset 5	23.1%	26.7%	-13.2%

Correlations

	1	2	3	4	5
1	100.0%	0.0%	0.0%	0.0%	0.0%
2	0.0%	100.0%	0.0%	0.0%	0.0%
3	0.0%	0.0%	100.0%	0.0%	0.0%
4	0.0%	0.0%	0.0%	100.0%	0.0%
5	0.0%	0.0%	0.0%	0.0%	100.0%

Minor changes in estimates of Std Dev (within 10% range) ➔ asset allocation changes of up to 26.8% above Base Case

E.F. Model: Holden

Optimisation Techniques Efficient Frontier

Changes to Std Dev + minor Correlation changes

	Expected Return	Standard Deviation	Optimal Combination of Assets		Base Case Allocation and % Diff	
Riskless Rate	4.0%	0.0%				
Risky Asset 1	8.0%	18.2%	Asset 1	19.5%	13.3%	46.2%
Risky Asset 2	9.0%	21.6%	Asset 2	15.4%	16.7%	-7.7%
Risky Asset 3	10.0%	19.4%	Asset 3	21.6%	20.0%	8.1%
Risky Asset 4	11.0%	20.8%	Asset 4	21.3%	23.3%	-8.6%
Risky Asset 5	12.0%	22.0%	Asset 5	22.2%	26.7%	-16.9%

	Correlations				
	1	2	3	4	5
1	100.0%	-10.0%	0.0%	0.0%	0.0%
2	-10.0%	100.0%	10.0%	0.0%	0.0%
3	0.0%	10.0%	100.0%	0.0%	0.0%
4	0.0%	0.0%	0.0%	100.0%	10.0%
5	0.0%	0.0%	0.0%	10.0%	100.0%

Adding minor (+/- 10%) changes to correlations ➔ asset allocation changes of up to 46.2% above Base Case

E.F. Model: Holden

Optimisation Techniques Efficient Frontier

- Efficient Frontier limits the optimisation to Portfolio NPV (or some other measure of value) and its Standard Deviation (which is a measure of the risk of the NPV).
- Is not a true multi-constraint optimisation technique and it ignores time-related constraints.
- IF you are confident in your ability to reliably estimate the necessary variables, it can be a useful first filter to winnow the list of potential portfolios, which should then be optimised around ALL of the constraints we have discussed earlier – especially time-related constraints such as “do-ability”

Optimisation Techniques Summary

- Mathematical optimisation techniques are generally oriented to maximise one constraint
- Amalgamating constraints (e.g. Risk Adjusted NPV) results in hiding of information
- None of them adequately addresses time-based constraints (e.g. project resourcing)

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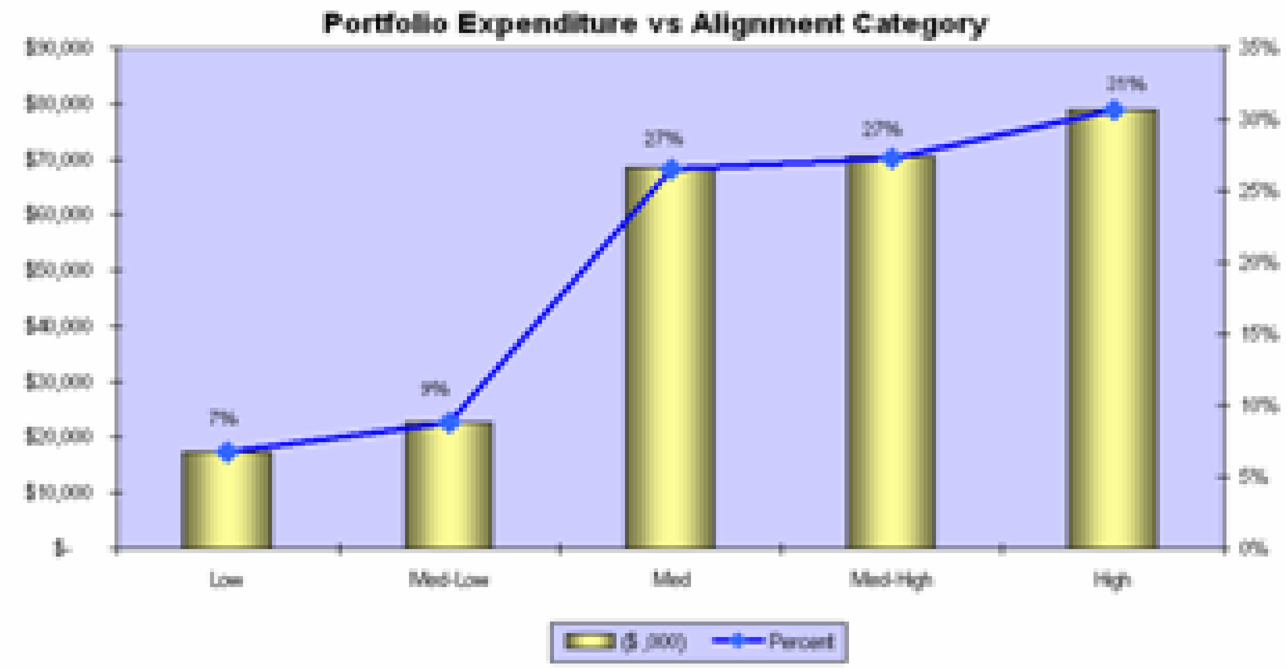
Practical Optimisation

- Purely mathematical techniques do not (yet) offer true multi-constraint optimisation
- ... but spreadsheet models offering
  - Visualisation and
  - What-if capability

can be used to great effect

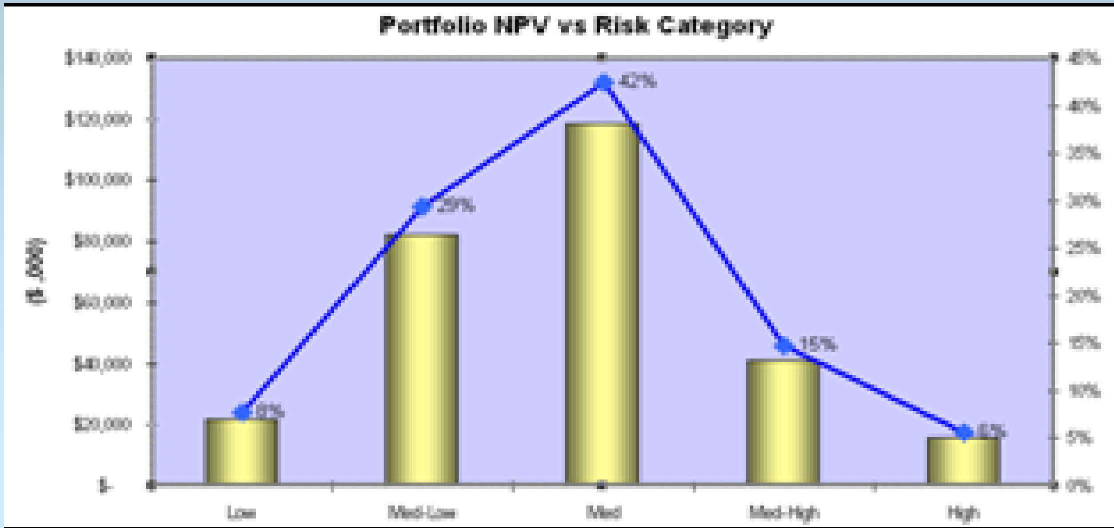
Practical Optimisation: Alignment

Portfolio Expenditure vs Alignment



- Generally we want to see most of our portfolio spend oriented towards higher alignment projects.
- Some Compliance projects will be low alignment.

Practical Optimisation: Risk



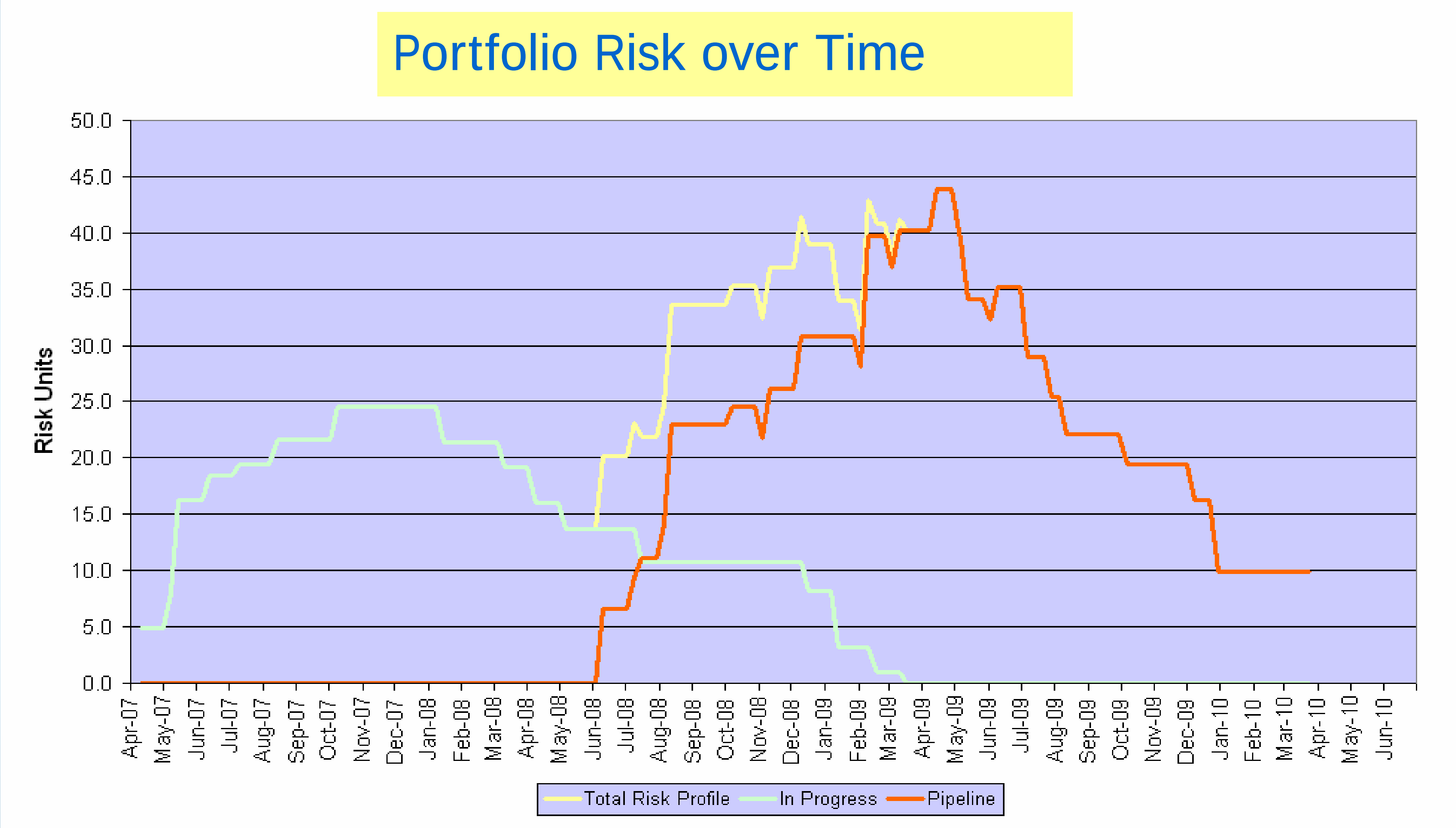
- Generally we would not want to see too much of our NPV associated with high risk projects.

NPV vs Risk

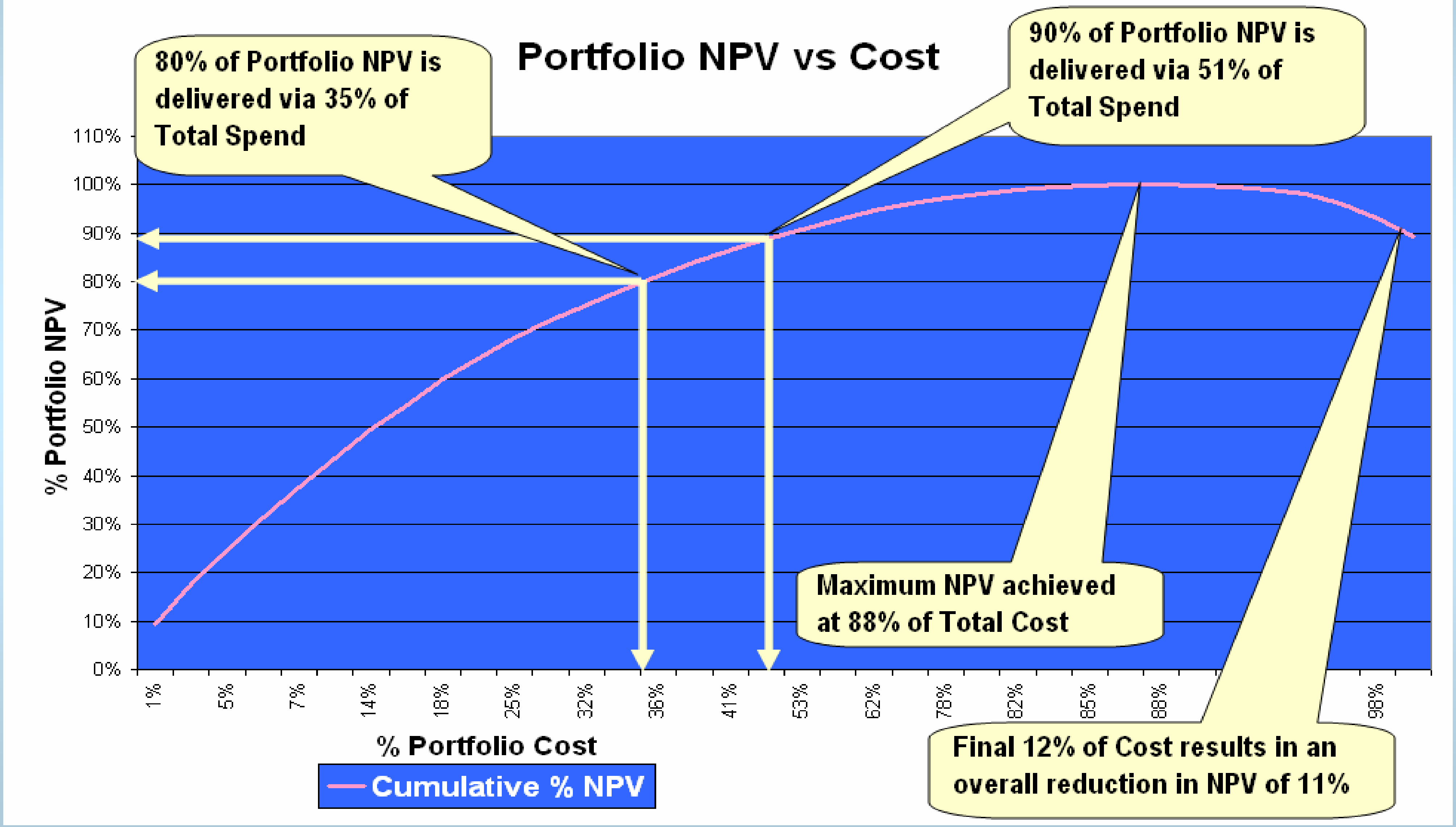
- We would want to see a distribution of our portfolio spend across projects with a range of risk levels.
- The risk profile should be acceptable to the organization

Expenditure vs Risk

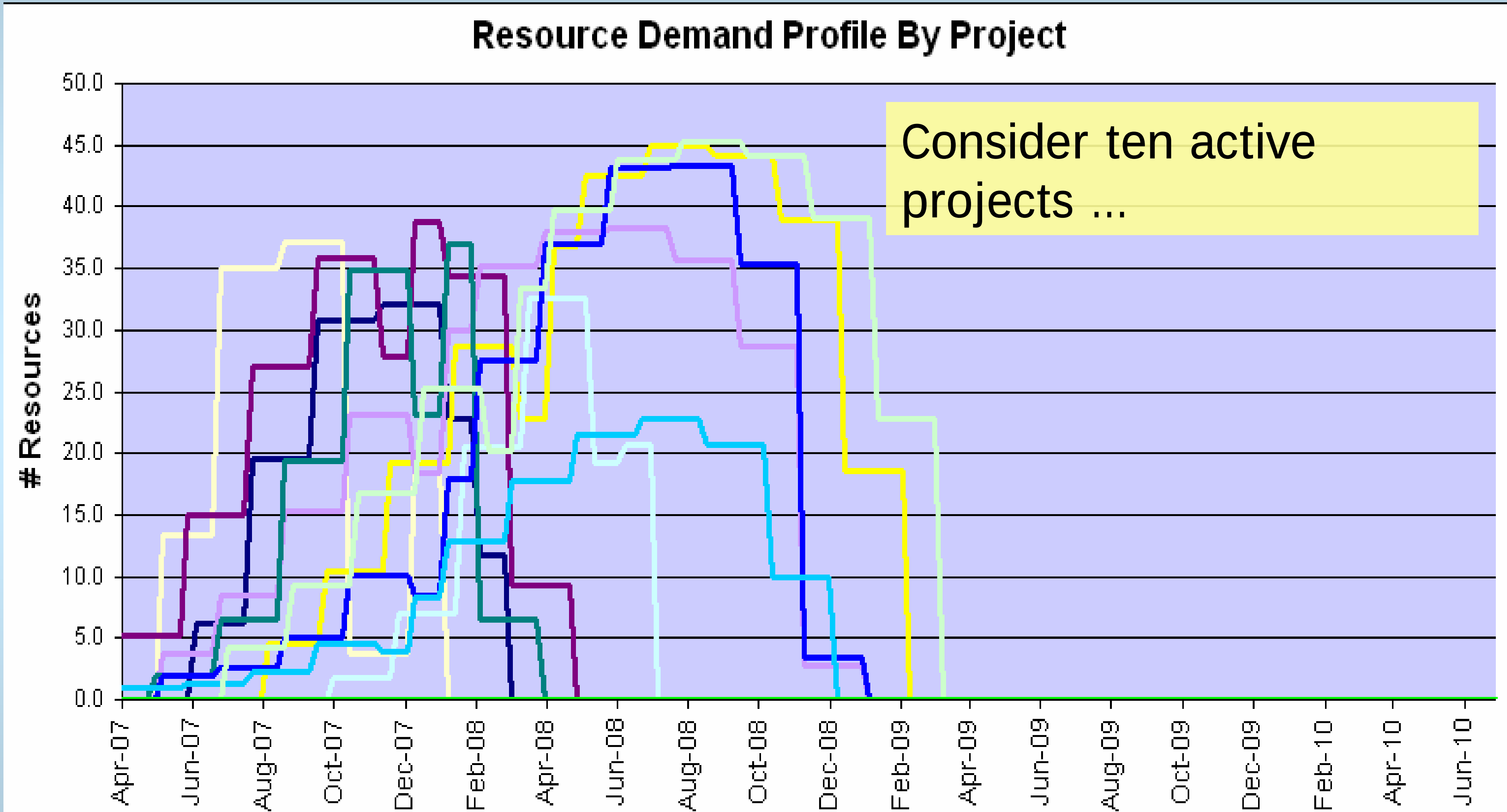
Practical Optimisation: Risk



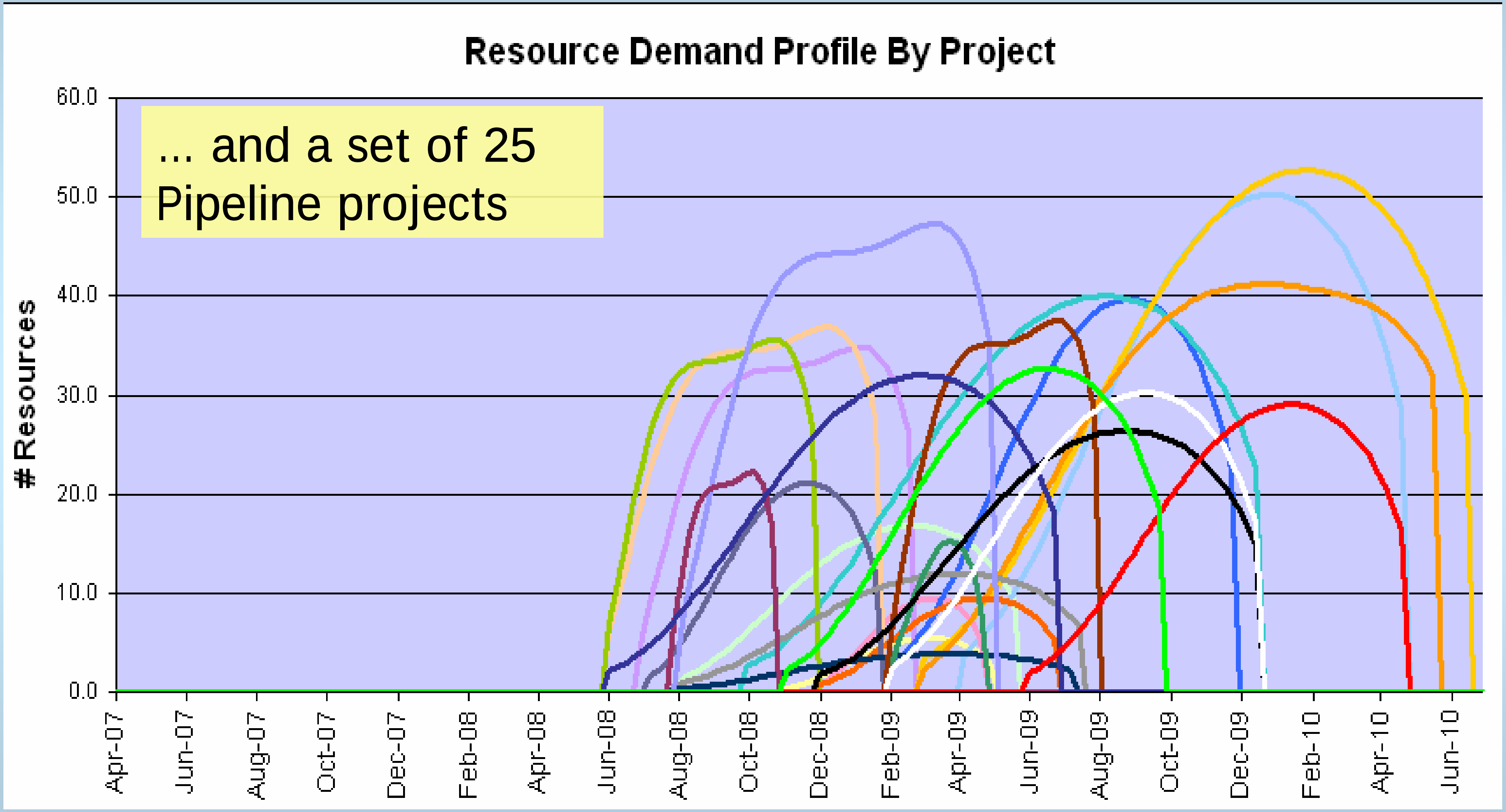
Practical Optimisation: Spend vs Return



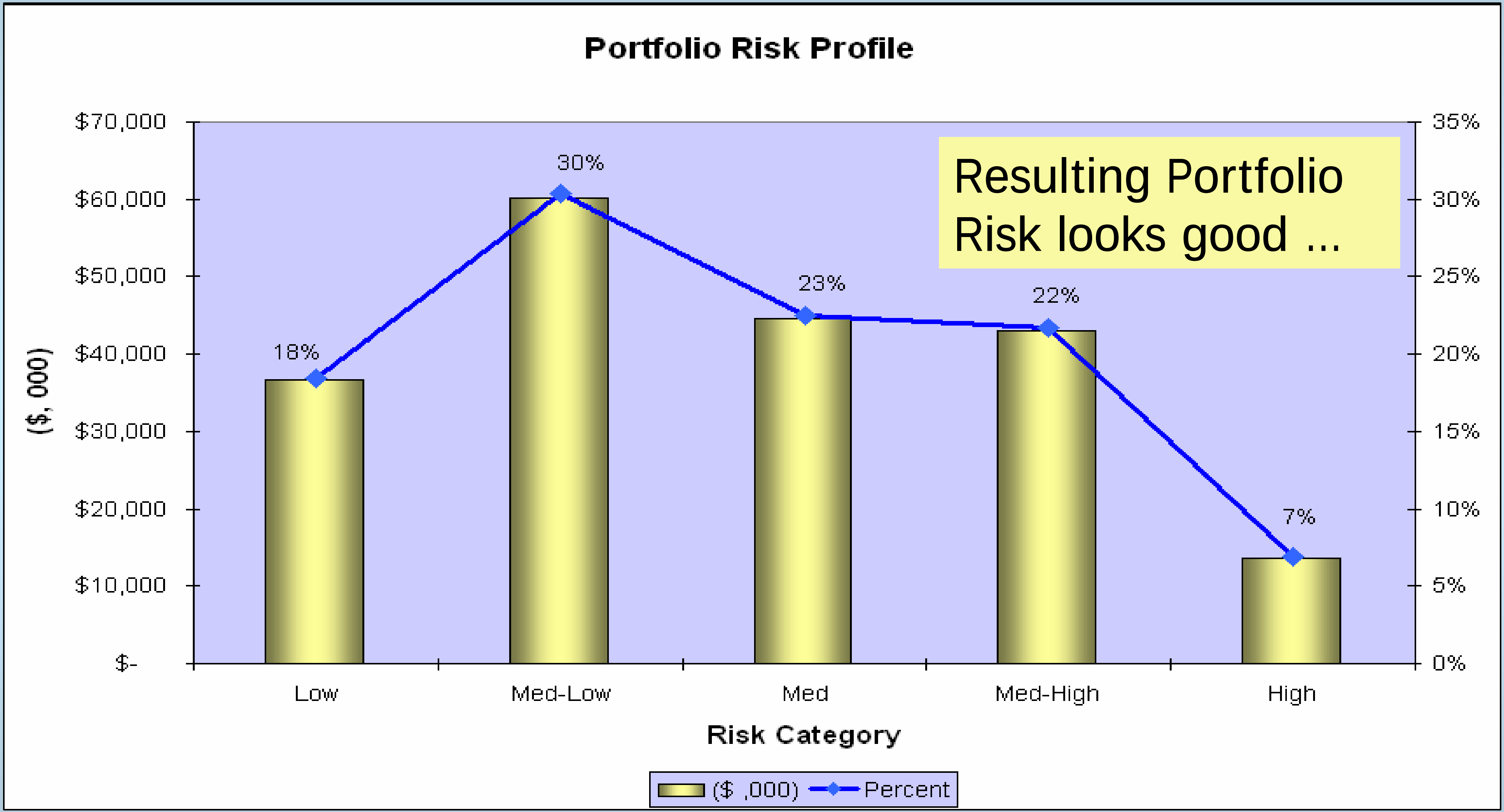
Practical Optimisation: Resourcing



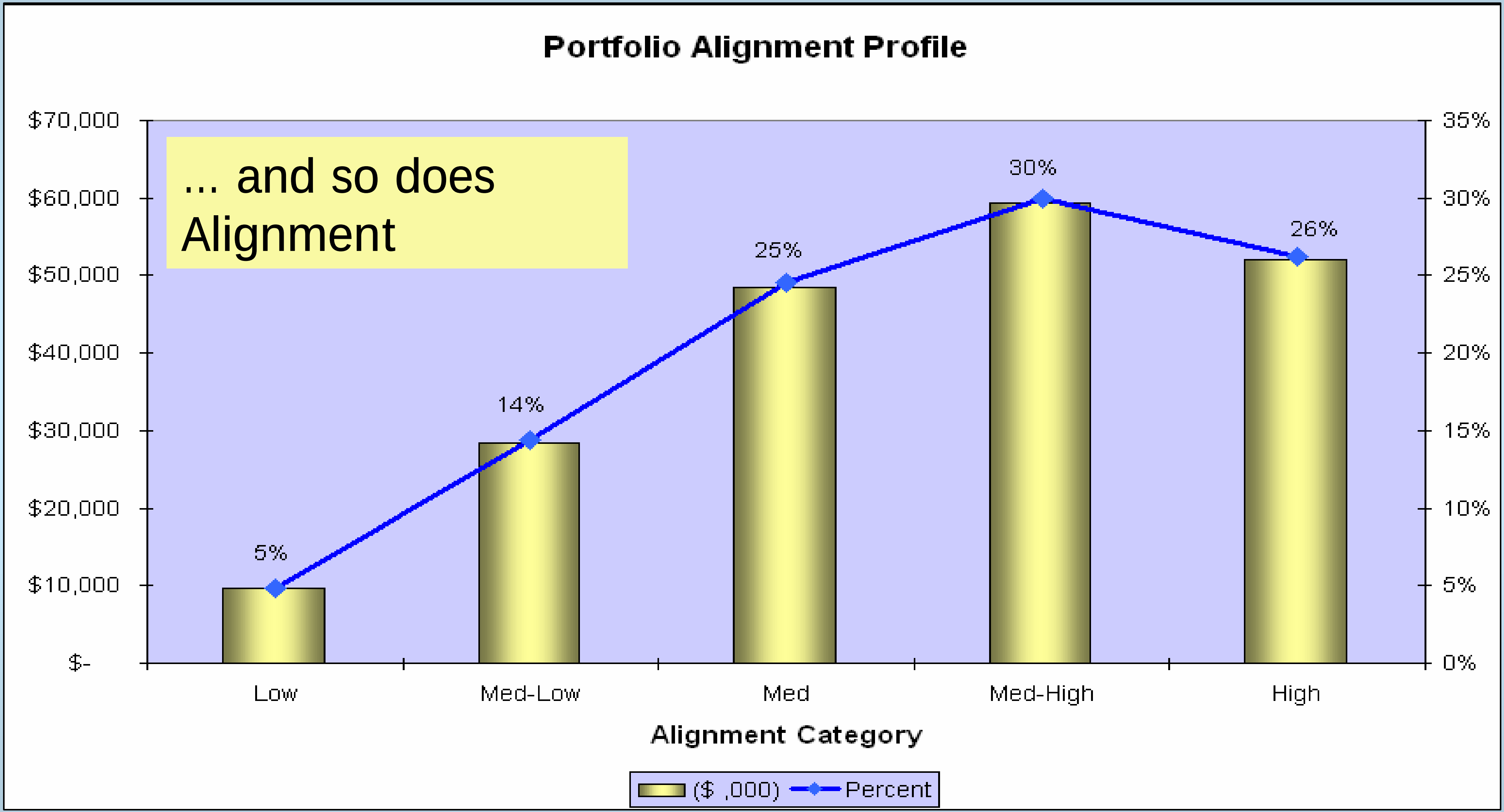
Practical Optimisation: Resourcing



Practical Optimisation: Resourcing

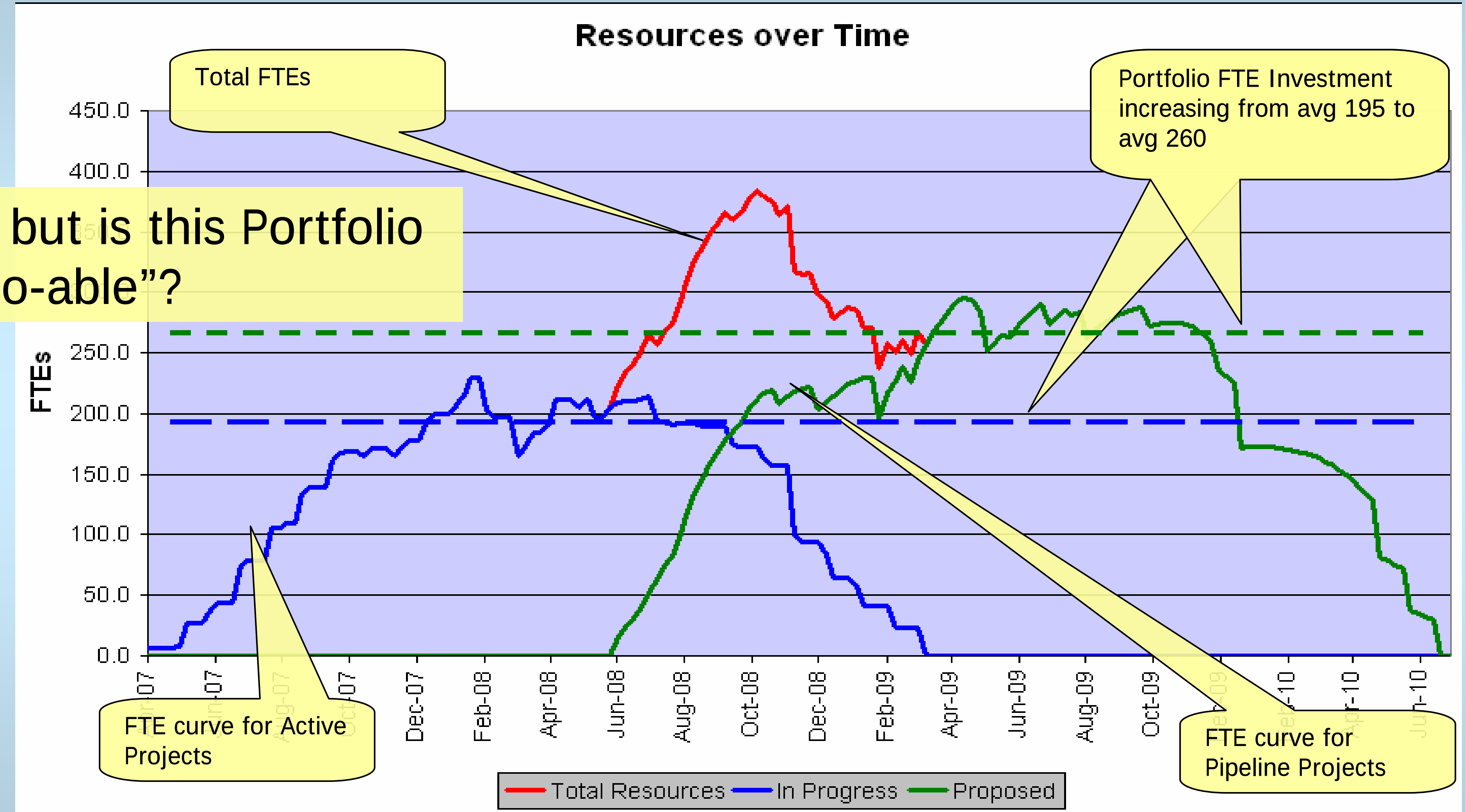


Practical Optimisation: Resourcing



Practical Optimisation: Resourcing

... but is this Portfolio “do-able”?

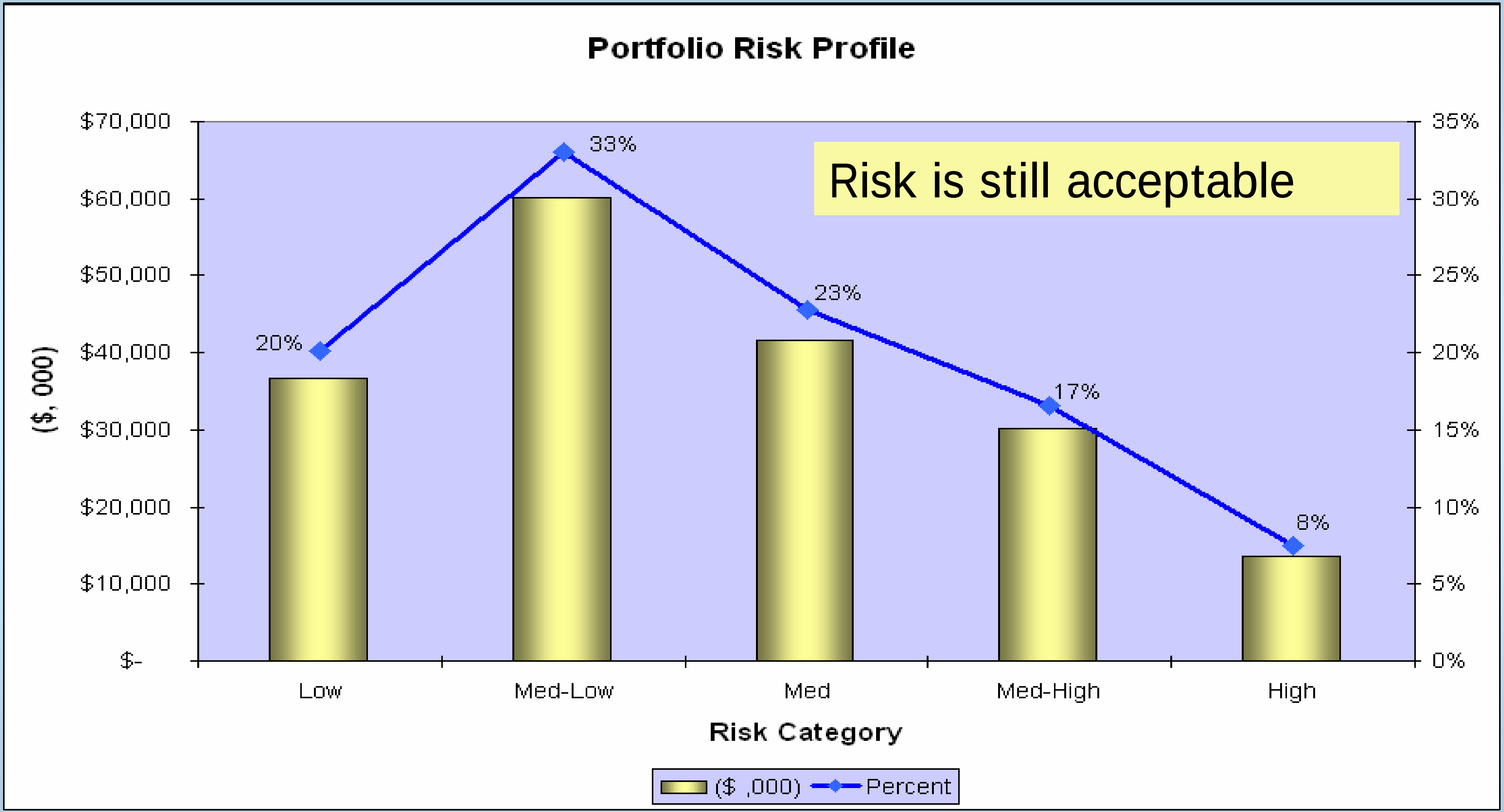


This ramp-up is not feasible …

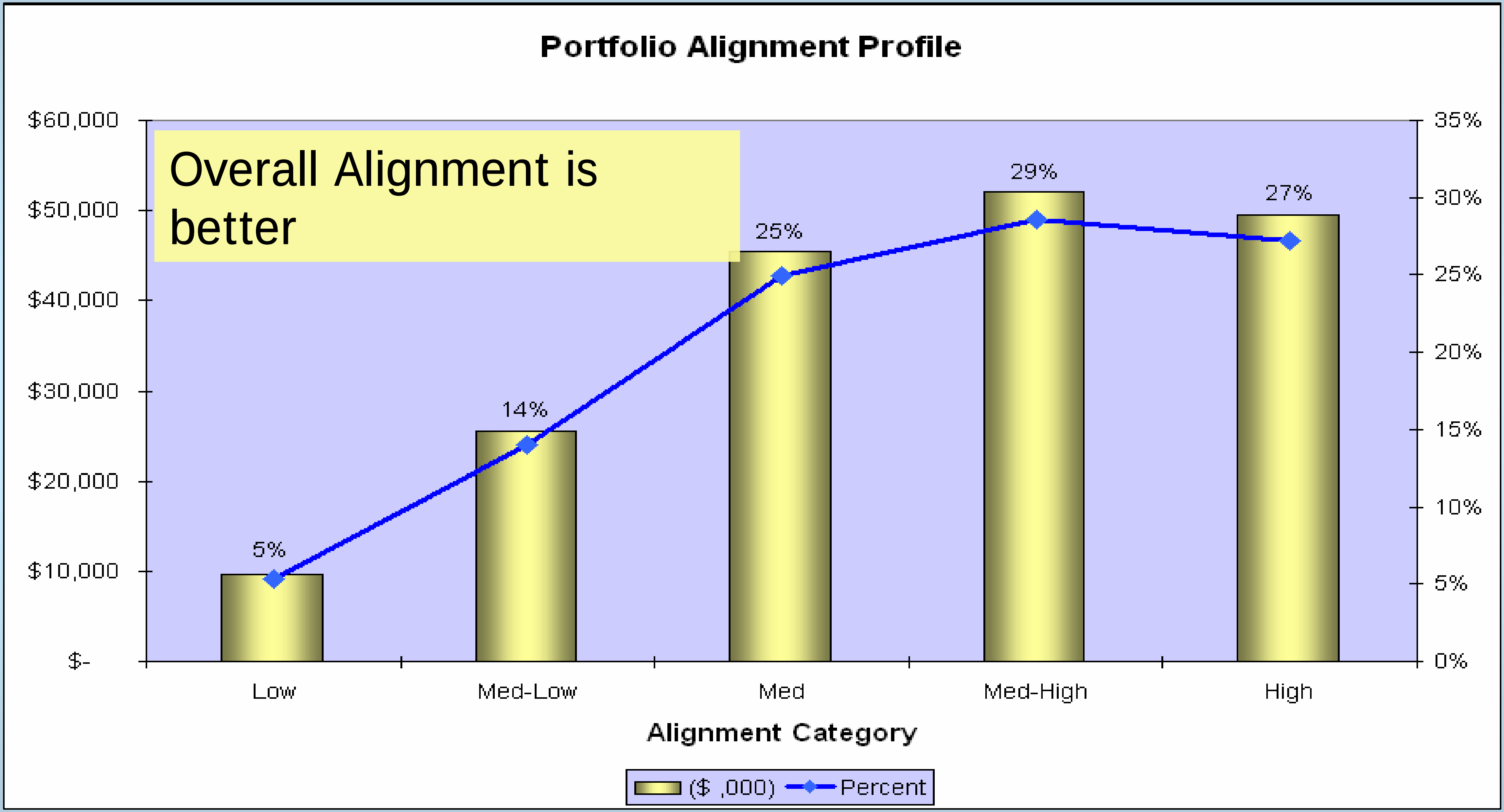
Practical Optimisation: What if we ...

- Stop selected in-flight projects (cost benefit no longer convincing)
- Exclude selected Pipeline Projects (optimise Risk, maximise Alignment)
- Delay or advance selected Pipeline Projects (smooth resource demand)
- Extend duration of some Pipeline Projects (smooth resource demand)

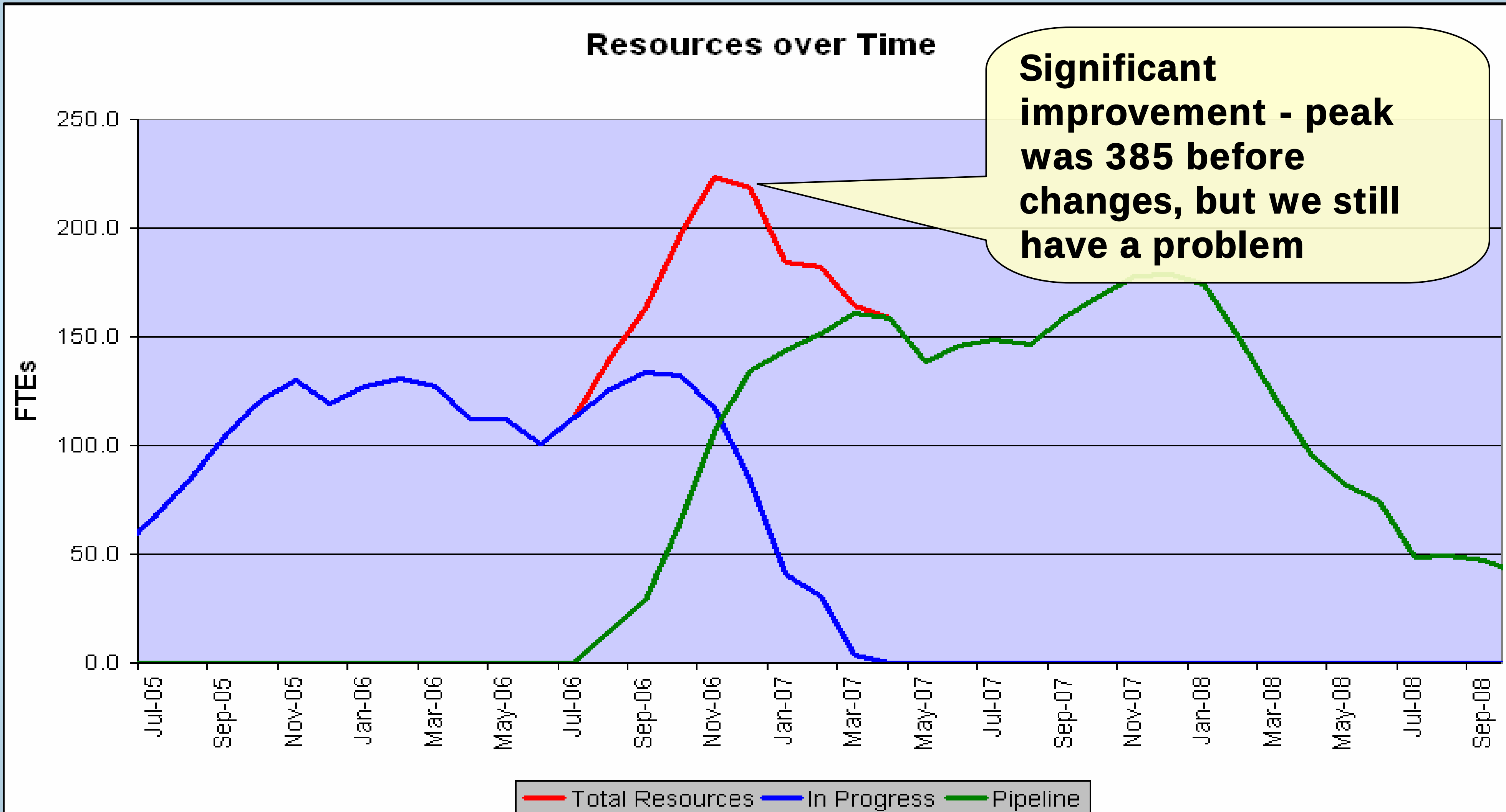
Practical Optimisation: Resourcing



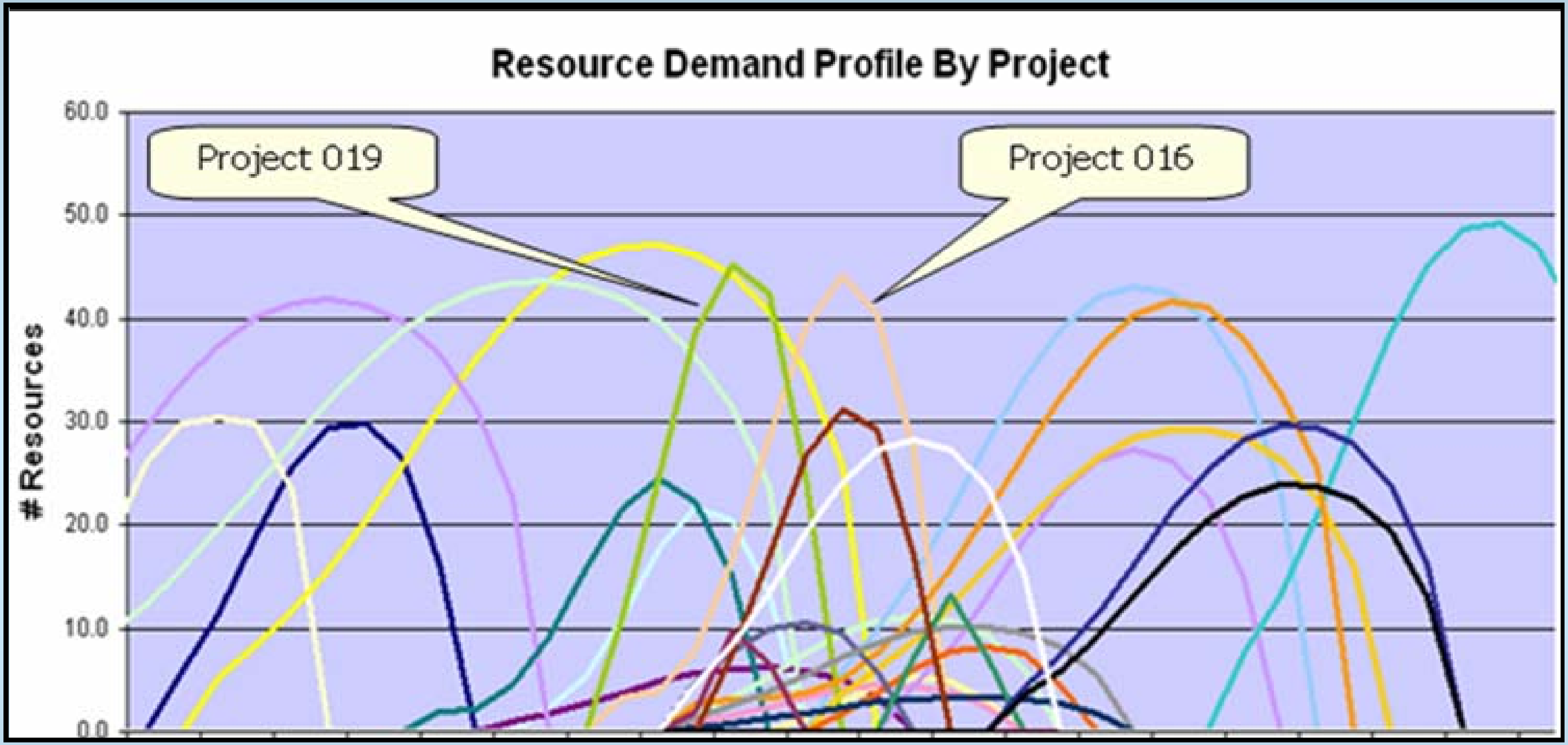
Practical Optimisation: Resourcing



Overall Resourcing after changes ...



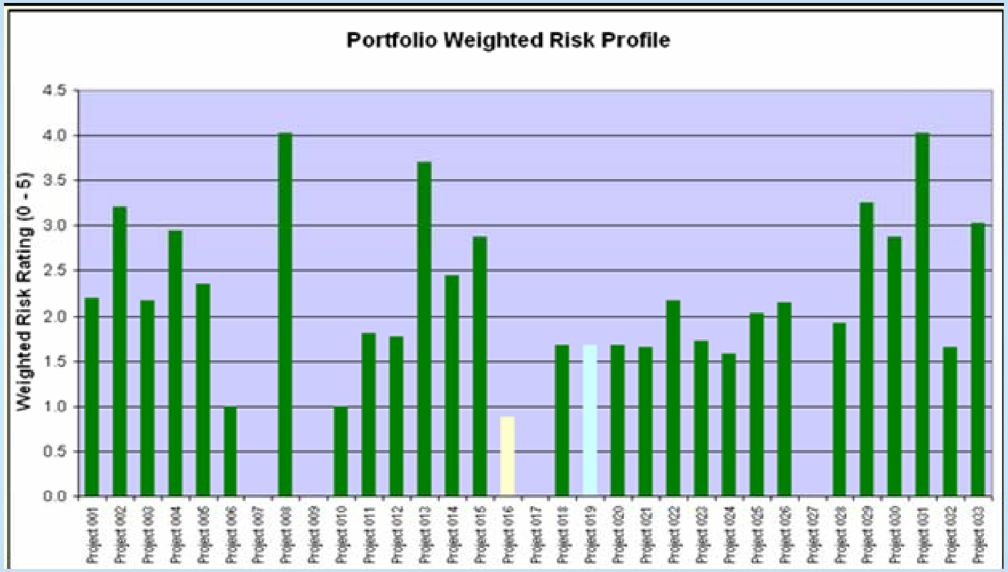
Practical Optimisation



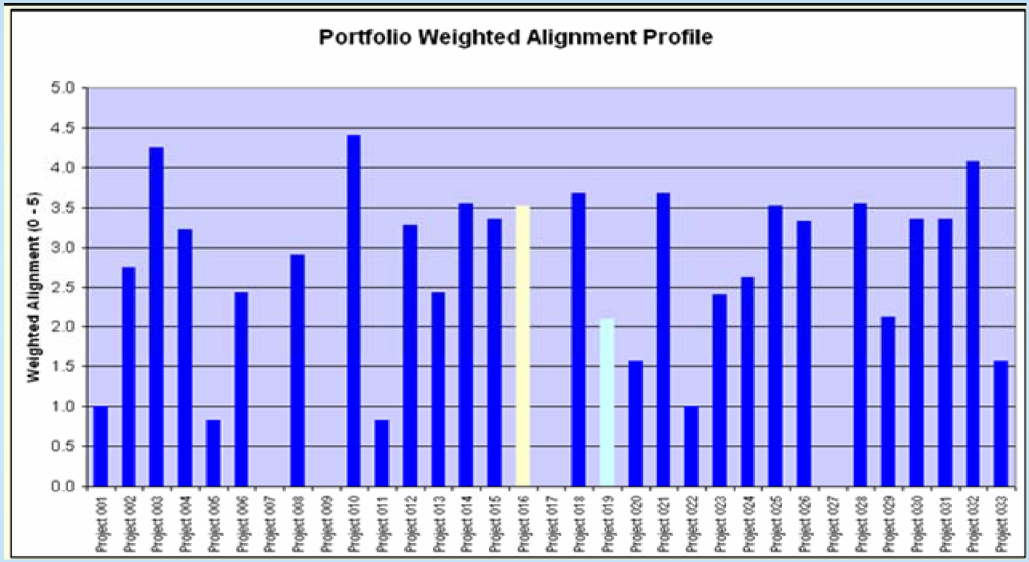
Which projects are contributing to this resource peak?

Practical Optimisation

Project 16 has lower Risk rating and Higher Alignment than Project 19



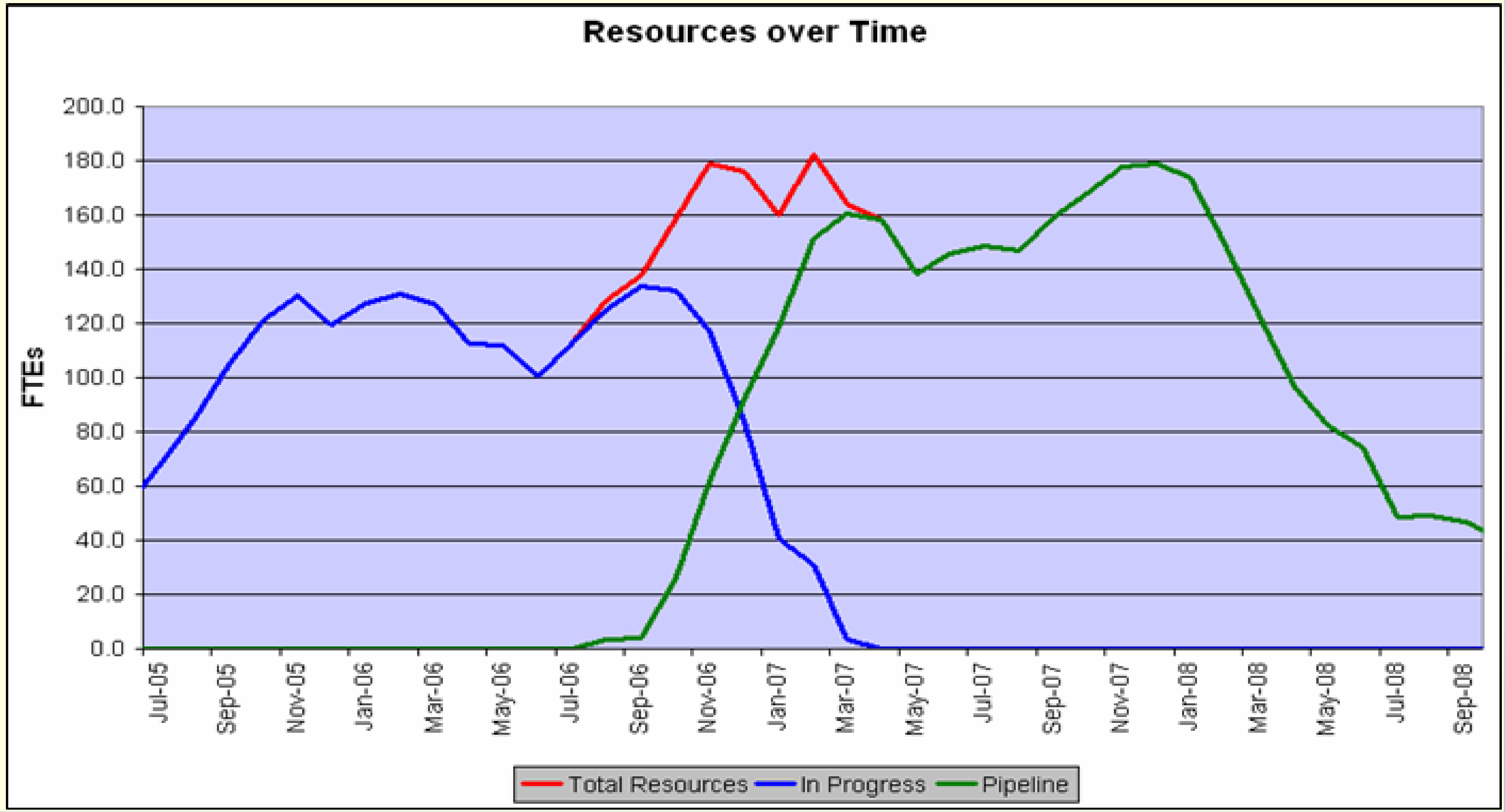
Risk rating



Alignment

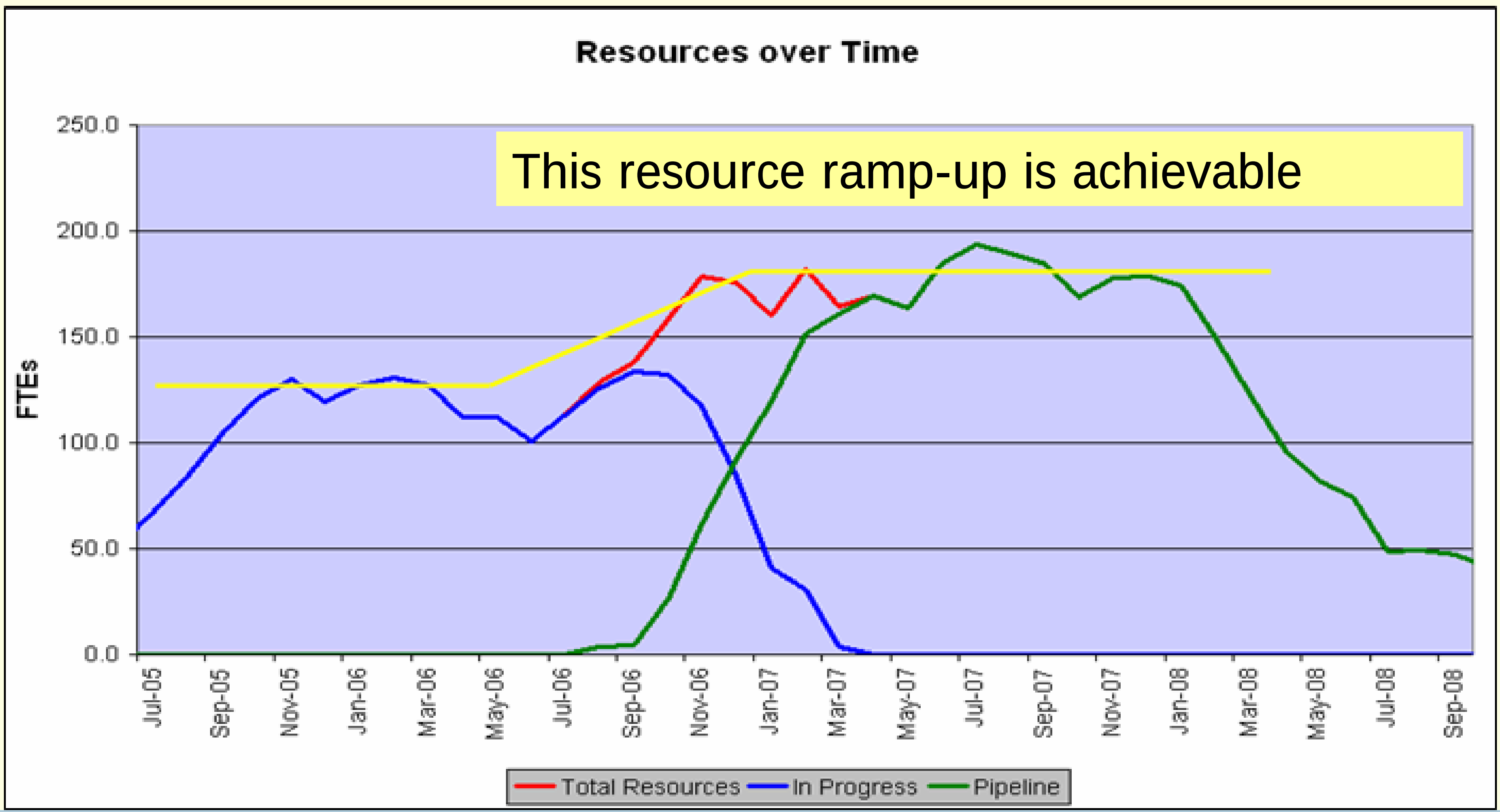
Practical Optimisation

What if ... exclude Project 19

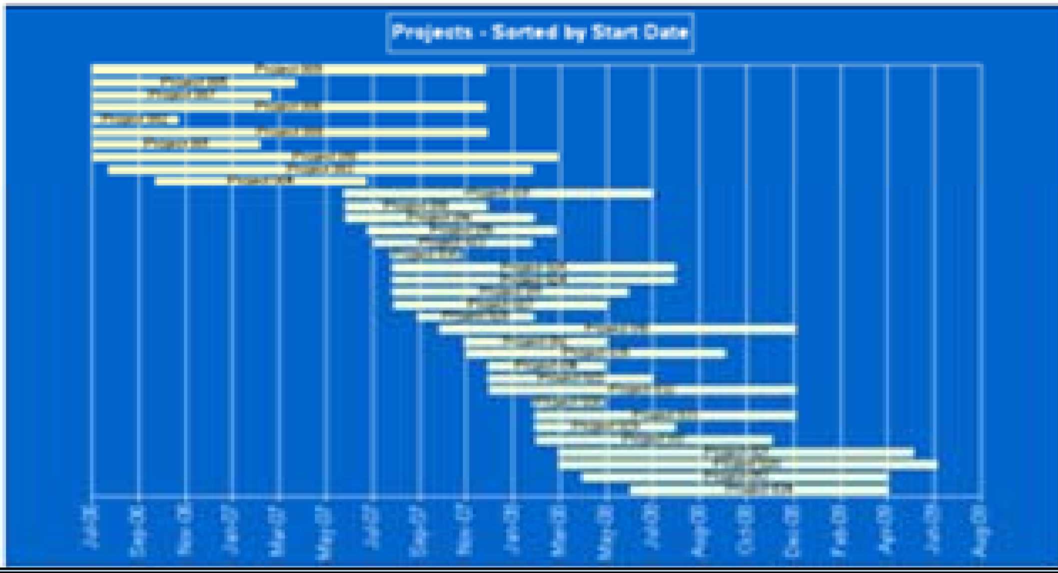


Practical Optimisation

... or delay Project 19 by 8 months

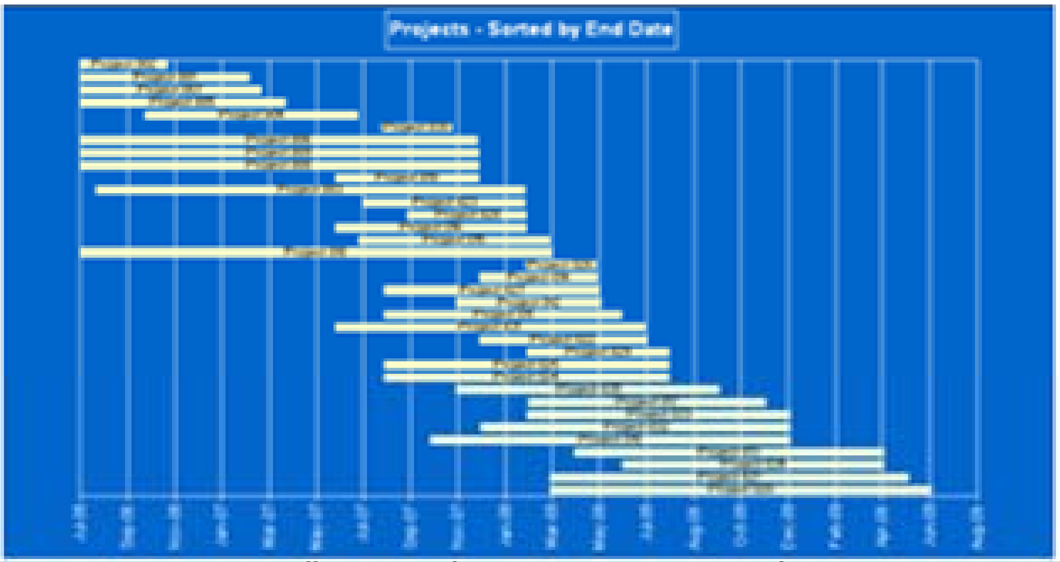


Practical Optimisation



- Are we starting too many projects concurrently?
- Can the shaping teams deal with this concurrent demand?

Project Start Dates



- Are too many projects ending concurrently?
- Do we have sufficient test environments to cope?
- Can the business sustain the concurrent training and change programs?

Project End Dates

Practical Optimisation

Resource heat map by team

Tech Breakdown by Team														
Tech Team	Avg Avail.	Peak Avail.	Aug-08	Sep-08	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09
Tech Team 1	20.0	25.0	3	3	2	2	4	5	5	6	5	3	4	4
Tech Team 2	20.0	25.0	20	23	26	26	24	18	19	15	15	16	16	16
Tech Team 3	5.0	8.0	3	3	2	3	5	6	7	7	7	6	4	
Tech Team 4	14.0	18.0	12	11	13	13	17	17	17	18	18	18	15	15
Tech Team 5	12.0	15.0	6	7	7	8	11	13	14	14	12	11	9	10
Tech Team 6	18.0	22.0	16	16	15	20	20	20	19	17	17	19	19	18
Tech Team 7	20.0	23.0	21	22	38	38	38	22	22	15	15	18	17	17
Tech Team 8	13.1	23.9	3	3	4	6	7	7	6	4	4	4	3	2
Tech Team 9	4.0	6.0	2	2	2	4	4	4	2	3	3	3	5	4
Tech Team 10	5.0	7.0	4	4	3	5	5	4	4	4	4	5	5	4
Tech Team 11	18.0	22.0	13	16	19	22	22	22	22	19	17	17	17	17
Tech Team 12	20.0	25.0	14	19	23	23	24	24	24	25	25	19	18	17
Tech Team 13	19.0	23.0	15	16	16	20	22	22	22	16	17	17	17	17
Tech Team 14	15.0	22.0	16	16	16	18	18	14	14	14	13	17	19	21
Tech Team 15	16.0	20.0	11	15	19	20	20	19	18	15	13	13	13	13

- Can specialist teams meet the predicted demand?
- Can we ramp up using contract staff?
- Do we need to consider reshaping the sequencing of projects?

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Conclusion: Why use this approach?

- Purely mathematical optimisation is problematic
- Spreadsheet modelling is an excellent tool to use with the Exec Committee responsible for Portfolio Project Selection.
  - Allows a view of the whole Portfolio
  - Allows exec committee to make trade off decisions
  - Simple and intuitive
  - Visible – no Black Box
  - Addresses time-related optimisation constraints (e.g. resourcing, portfolio risk over time)
  - Supports immediate “what-if analysis”
  - Addresses key constraint of “do-ability”

Questions?

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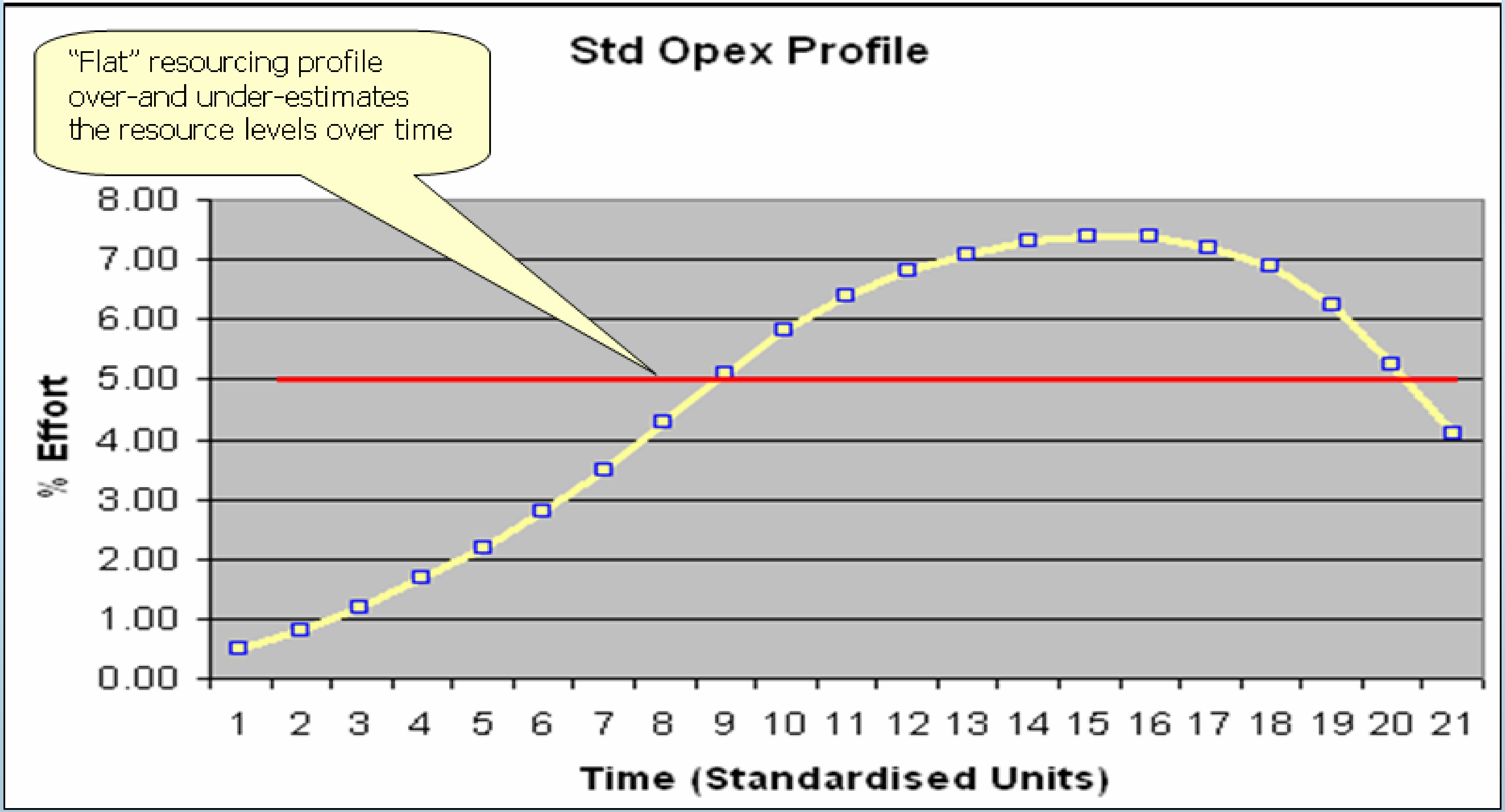
Resource Estimation Technique (1)

- If you have Resource Cost and Duration estimates, you can “distribute” the resource cost across the expected duration.
- For example:
  - $5M project
  - 20% non-FTE (HW, SW, Travel, Accommodation)
  - $4M in FTE-related costs.
- Now distribute the $4M across the expected duration using an appropriate resource profile.

Resource Estimation Technique (2)

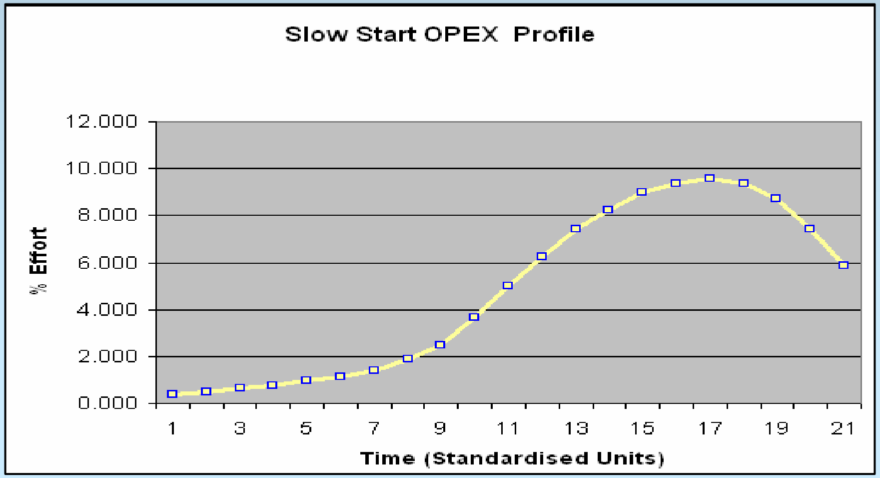
I.T. Project Resource Profiles have a characteristic shape

"Standard" FTE Profile

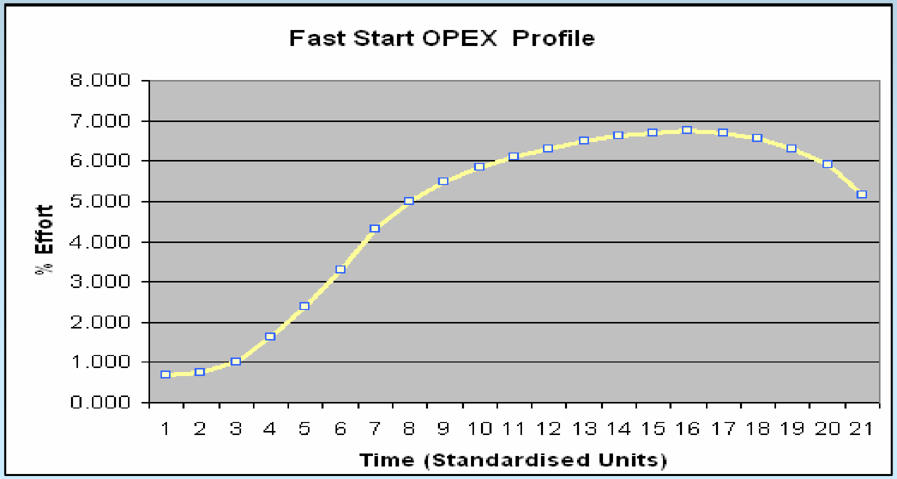


Resource Estimation Technique (3)

Slow Start

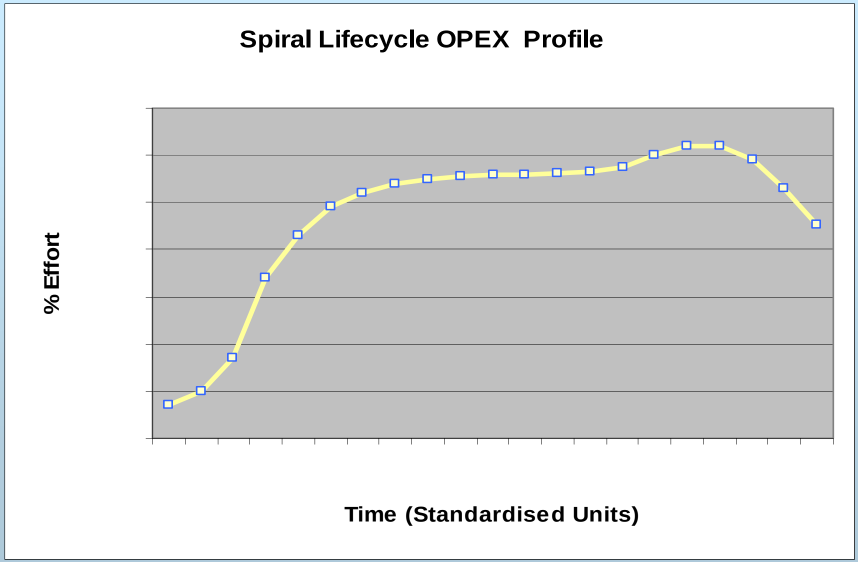


Fast Start



"Spiral" Lifecycle

(ie Design-Build-Test, Design-Build-Test, ...)



Resource Estimation Technique (4)

Use Curve Fitting[1] software to define required curve.

6th Order Polynomials

$(Y = a + bx + cx^2 + dx^3 + ex^4 + fx^5 + gx^6)$

provide a good fit for these types of curves

(i.e. they have relatively low standard errors and high correlation coefficients).

(1) CurveExpert v1.38 © Daniel Hyams

Resource Estimation Technique (5)

The **Standard Error** of the estimate quantifies the spread of the data points around the regression curve. *As the quality of the data model increases, the standard error approaches zero (0).*

The **Correlation Coefficient** describes the strength of the linear relationship between two variables. *As the regression model better describes the data, the correlation coefficient will approach one (1).*

Across this family of curves:

Average Std Err:	0.192
Average Correlation Coeff:	0.998

End of presentation

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