Maximising the Success of your Capital Program through Integer Programming Models

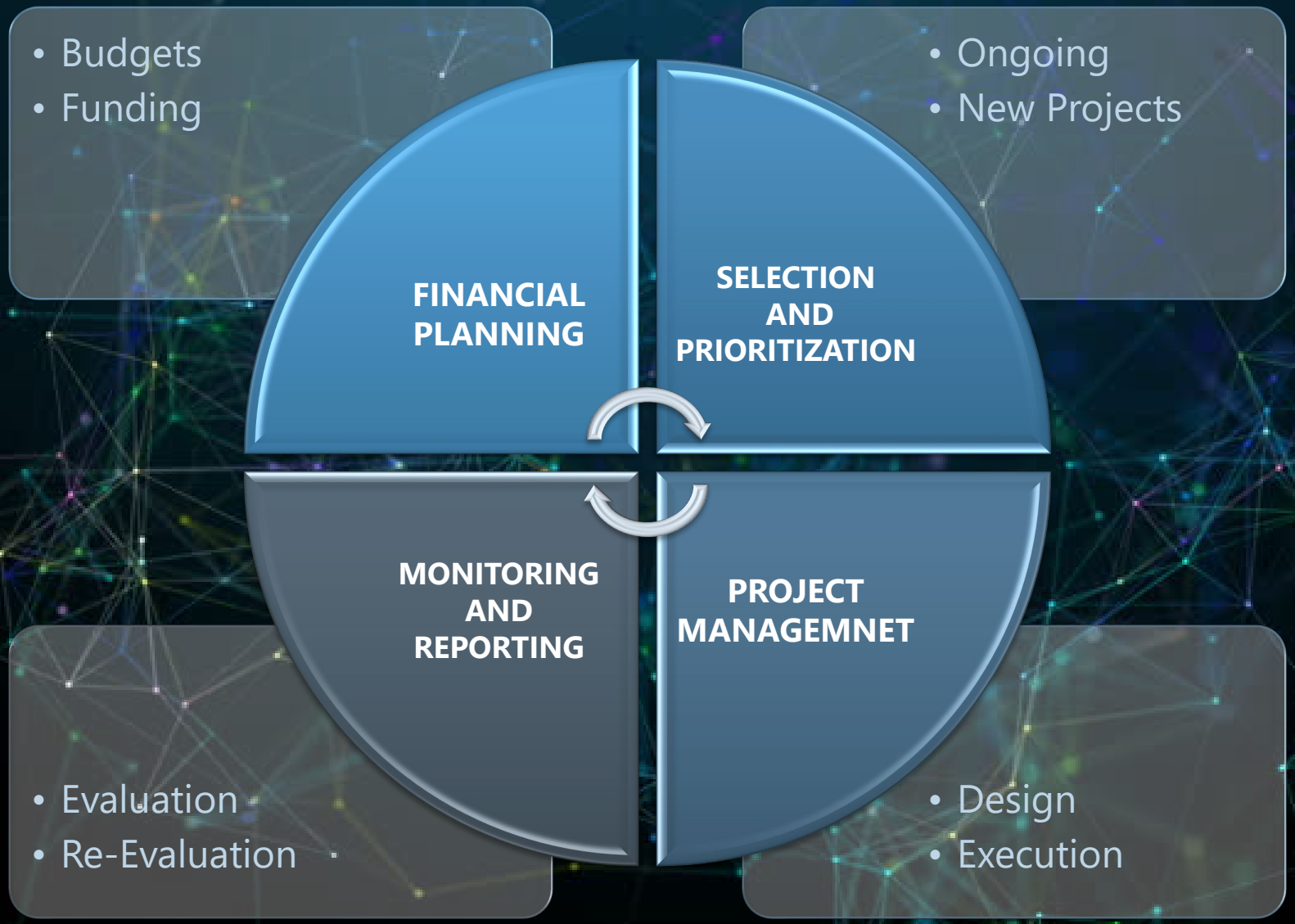
November 14, 2018

Mr. Michael Goggin
Mr. Michael Matosin

ENSTOA

Project Controls EXPO

CAPITAL PLANNING – AN OPPORTUNITY



ENSTOA

Project Controls EXPO

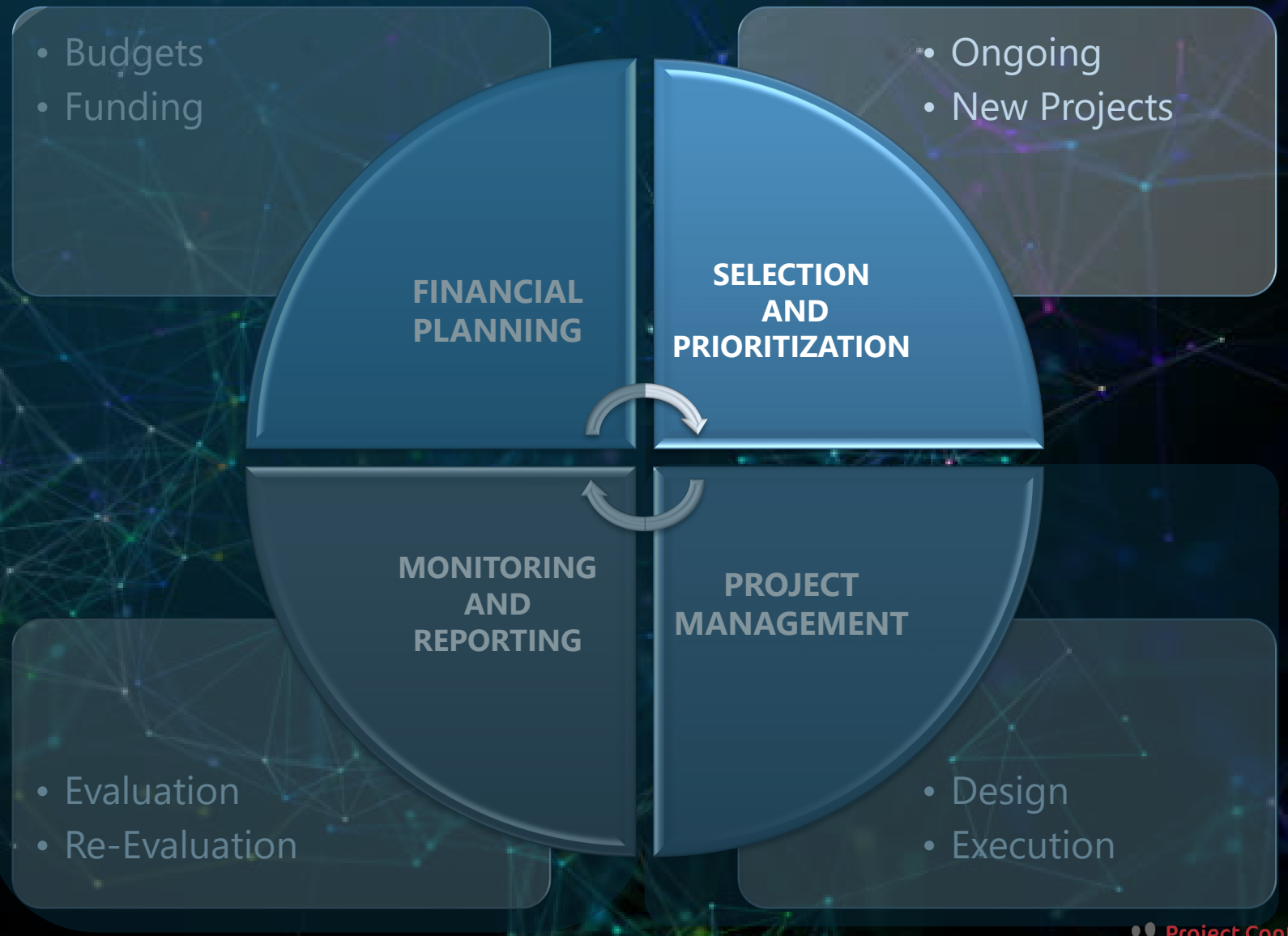
SELECTION AND PRIORITIZATION

It's hard to get right…

- Inputs from wide range of stakeholders
- Changing 'landscape'
- Timing
- Hierarchical planning and revisions
- Reconciliation
- Realistic Scheduling

Heuristics – Critically important

…but are subject to bias



ENSTOA

Project Controls EXPO

Our Argument:

A data-driven decision support system (DSS) can reduce overhead in the planning process by helping planners rapidly consider alternatives.

Our Approach:

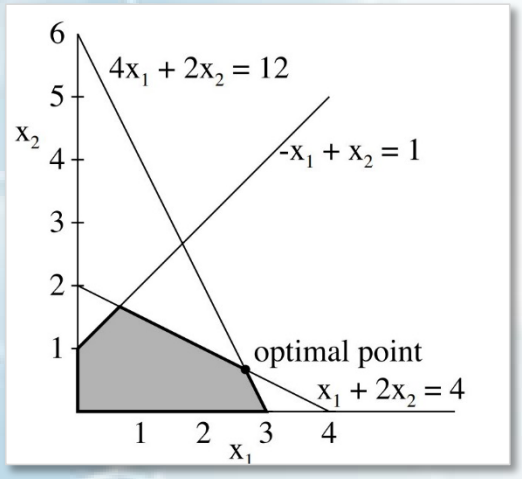
Apply combinatorial optimization and other discrete techniques to Select and Schedule projects so that the 'Value' of the Portfolio is maximized subject to organizational constraints

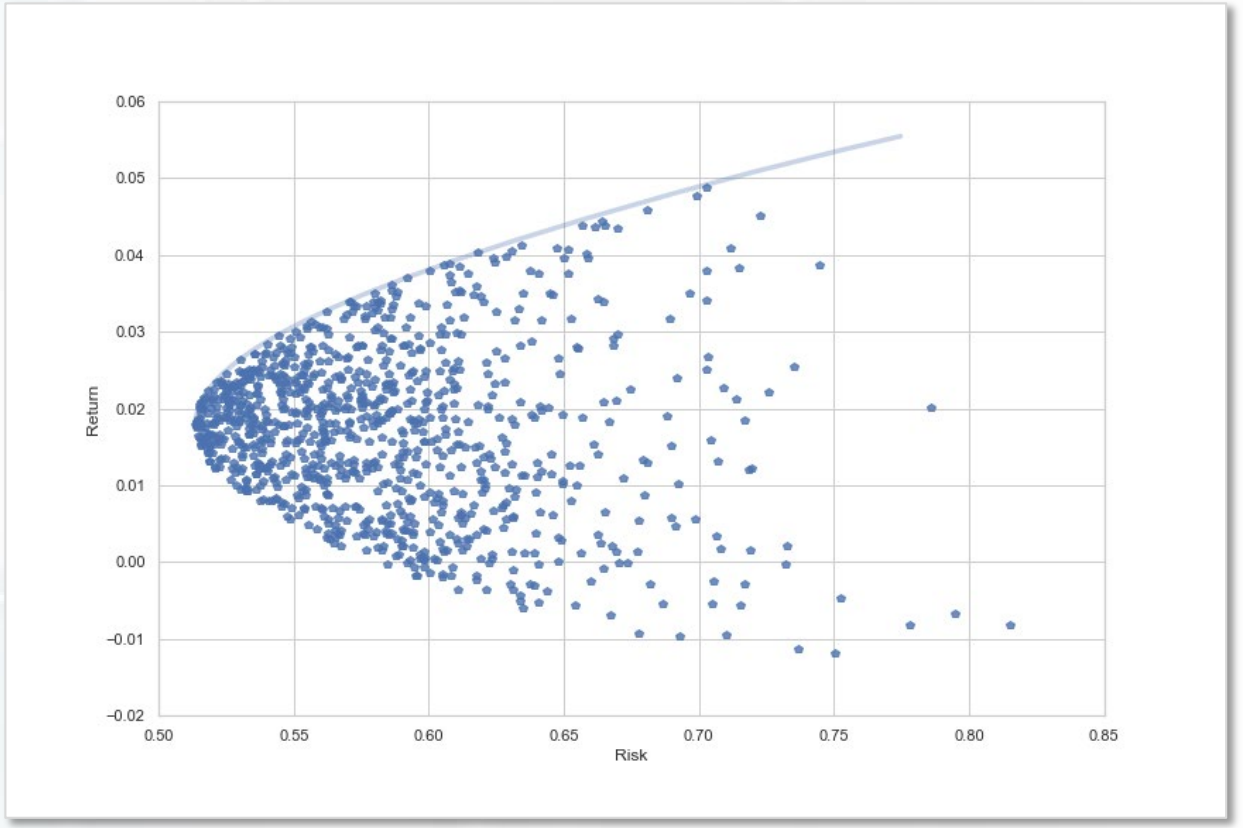
PORTFOLIO OPTIMIZATION – HUMBLE BEGINNINGS

The Goal: Finding an optimal object from a finite set of objects.

- Linear Programs
- Integer Programs
- Traditional portfolio theory

$$\begin{aligned} &\text{minimize} && \mathbf{c}^{\mathrm{T}}\mathbf{x} \\ &\text{subject to} && A\mathbf{x} \leq \mathbf{b} \\ &\text{and} && \mathbf{x} \geq \mathbf{0} \end{aligned}$$





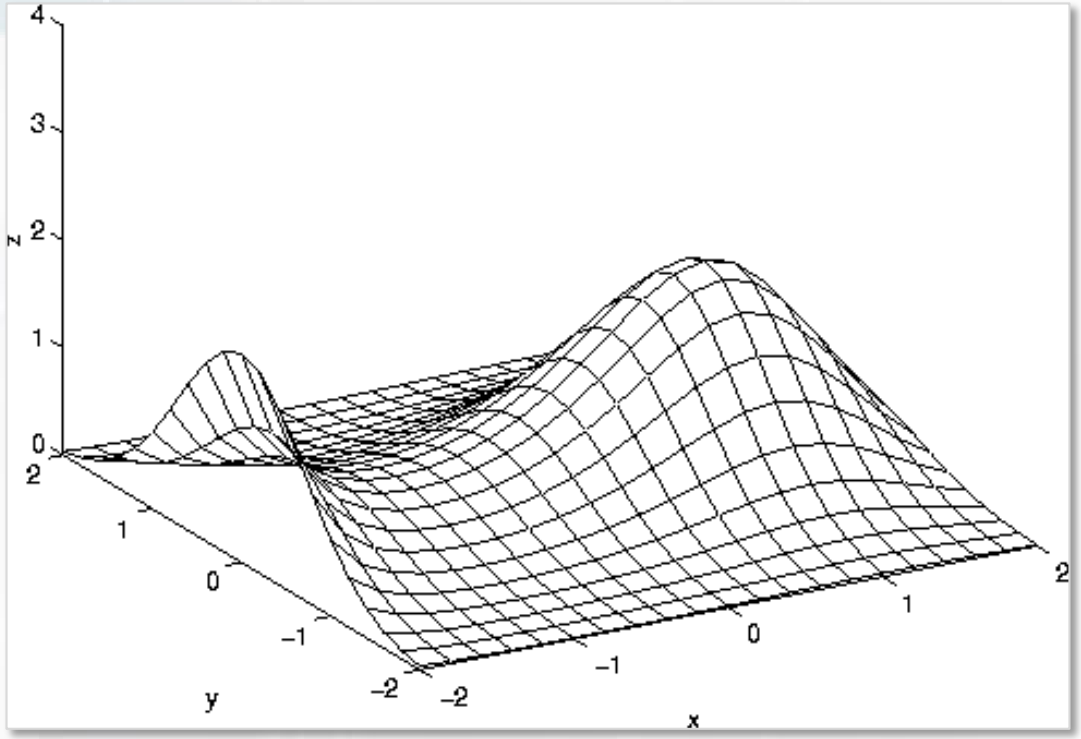
Markowitz' Efficient Frontier

ENSTOA

Project Controls EXPO

THE FUTURE IS BRIGHT

- Global move towards AI and automation
- Increased awareness
- Theoretical developments
- More computing power (Speed, RAM, Parallelization)
  - Ease of Access to scalable resources
  - Problems with *millions* of variables can be handled on a modern laptop



ENSTOA

Project Controls EXPO

A TOUCH OF MATHS

Standard NPV objective function

- Augmented for scheduling feasibility

Alternative objective functions

- Makespan
- Project Count
- Scorecard

Data-driven constraints

- Project details (Schedule, Cost, Type[])
- Resource availability
- Strategic considerations/business rules
- Project relationships and dependencies

$$max \ \ Z = \sum_{i=1}^{K} \beta_i(V_{iw}, d_{iw}, r)$$

$$V_{iw} = \sum_{q=1}^{d_{iw}} CF_{iwq}(1+r)^{q-d_{iw}}$$

$$\beta_i(V_{iw}, d_{iw}, r) = \sum_{w=1}^{W} V_{iw} \left[\sum_{n=E_{ivd_{iw}}}^{L_{ivd_{iw}}} \frac{X_{ivd_{iw}n}}{(1+r)^n} \right]$$

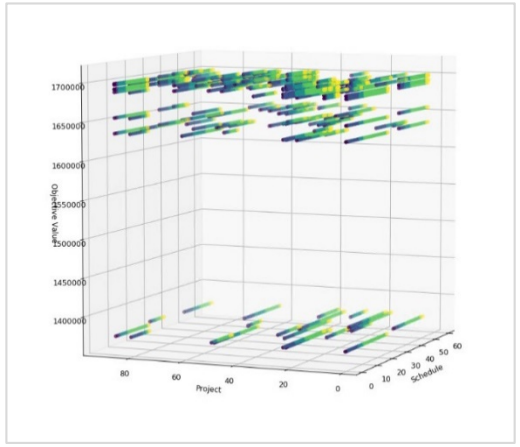
An approximation of a complex real-world problem

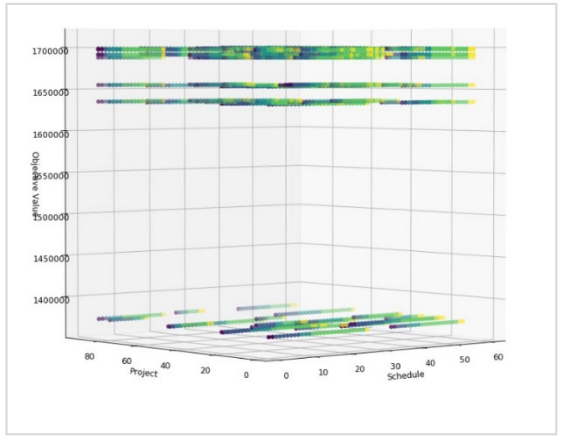
ENSTOA

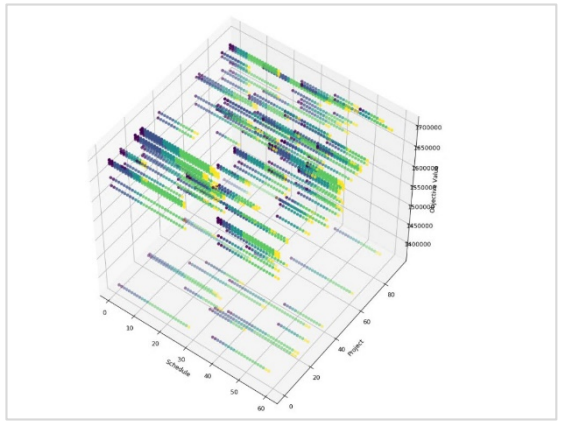
Project Controls EXPO

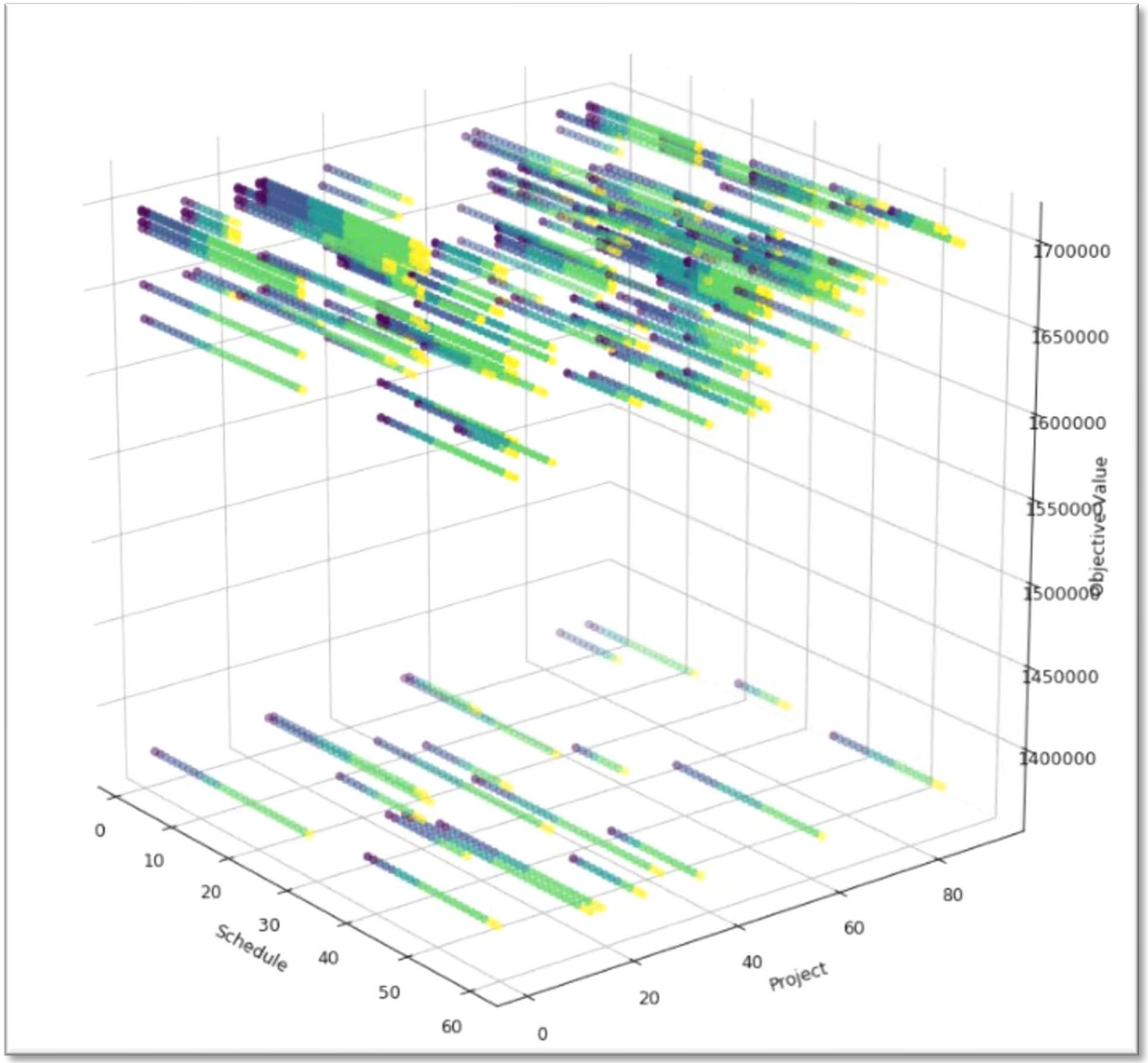
ITERATING THROUGH FEASIBILITY

Which projects should be selected in a 5 year plan and how should they be scheduled?









ENSTOA

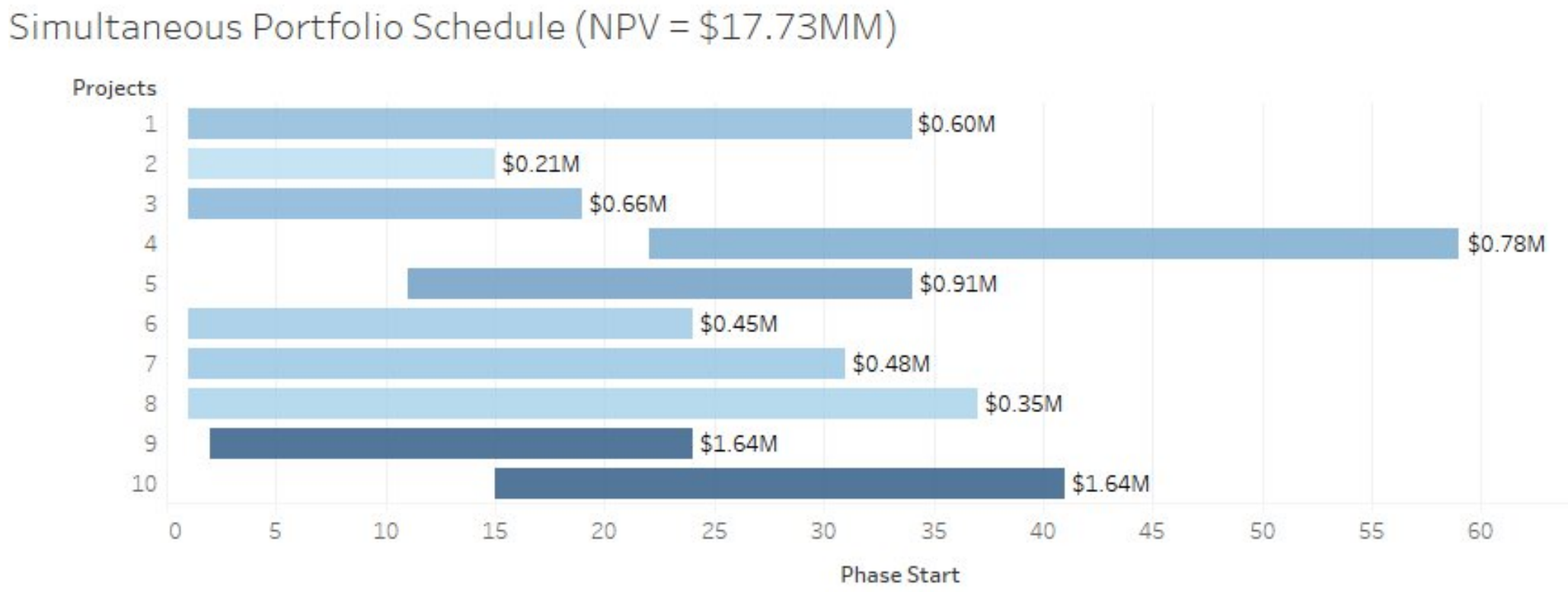
Project Controls EXPO

LIVE DEMONSTRATION

Maximize the value of our portfolio subject to:

- Budget Limitations
- Other Resource Limitations
- Business / Operations Rules

AN OPTIMIZED PLAN



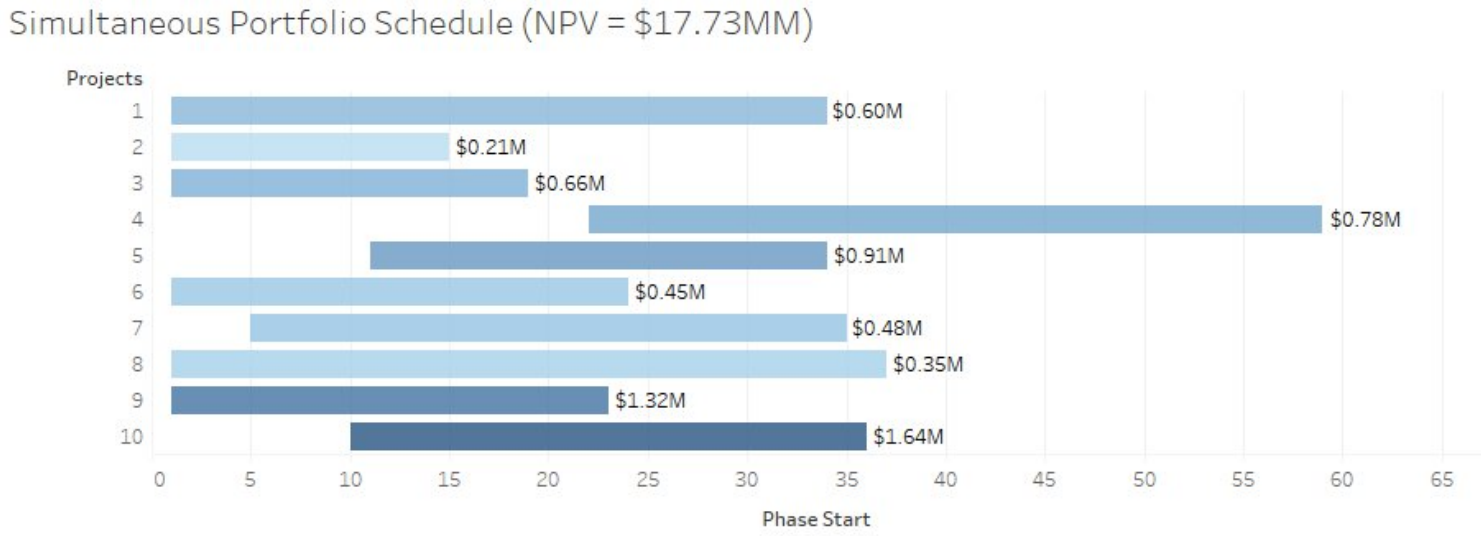
ENSTOA

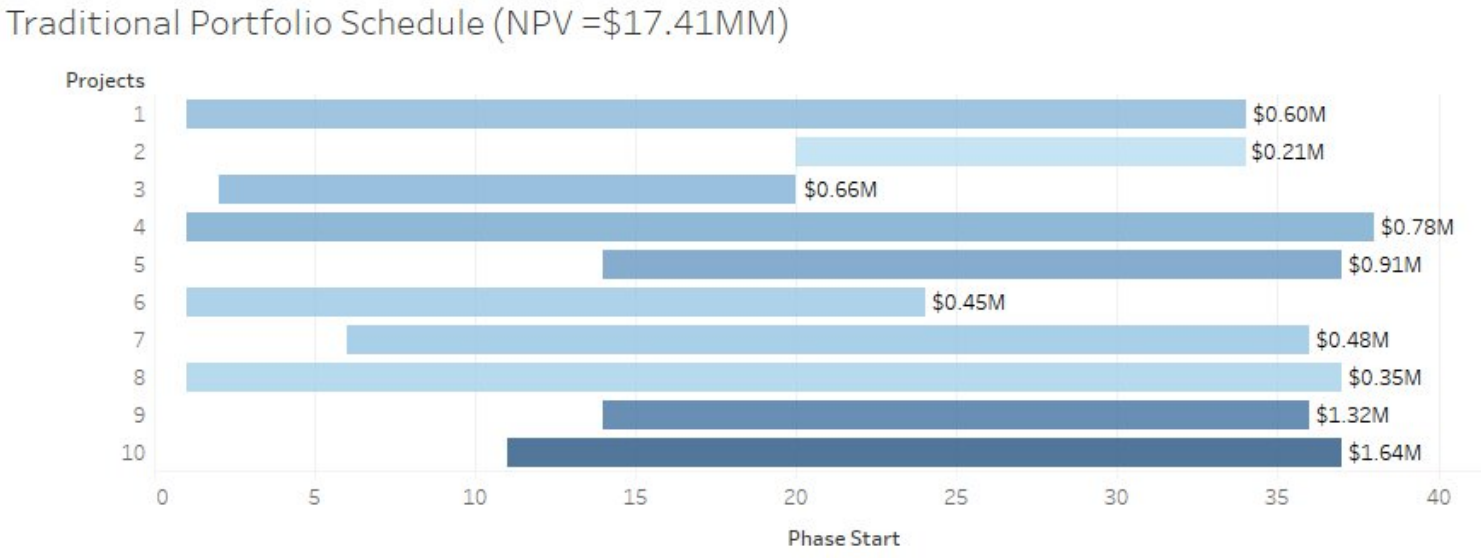
Project Controls EXPO

MAKESPAN VS NPV SCHEDULING

How do the following techniques compare? Which is the more valuable portfolio of projects.

- Minimized Portfolio Schedule Length (i.e., “Makespan”)
- Maximized NPV Schedule





ENSTOA

Project Controls EXPO

BENCHMARKS

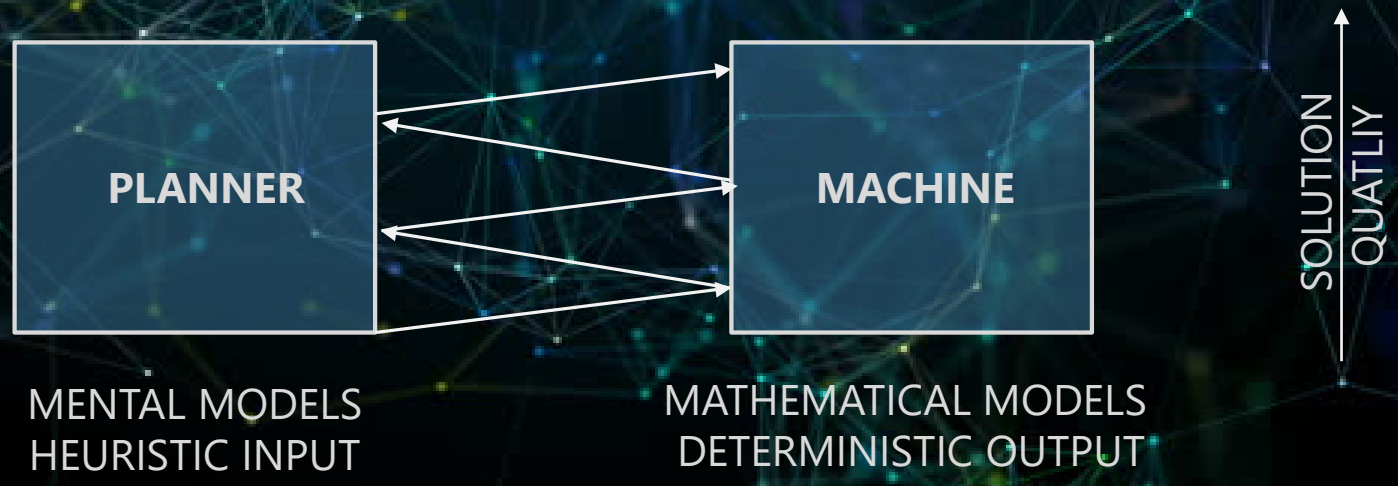
# of Projects	Budget Period	Difficulty	Duration (Months)	delta	Solve Time (Seconds)	Optimality Gap (OG) 10%	5%	2.50%	1%	0.50%	0.10%	0% Final	OG Value ($)
100	Yearly	Easy	60	<1s	<1s	<1s	<1s	<1s	<1s	<1s	<1s	0%	0.00
100	Yearly	Mid	60	46	43.66	<1s	<1s	<1s	1s	1s	5s	43s	0%	0.00
100	Yearly	Hard	60	243	240	<1s	<1s	1s	1s	>240s	>240s	>240s	0.51%	5,497.00
100	Monthly	Easy	60	4	240	<1s	<1s	<1s	<1s	<1s	<1s	1s	0%	0.00
100	Monthly	Mid	60	243	240	1s	1s	2s	25s	165s	>240s	>240s	0.41%	12,647.00
100	Monthly	Hard	60	243	240	2s	40s	>240s	>240s	>240s	>240s	>240s	3.92%	66,649.00
500	Yearly	Easy	60	26	14	<10s	<10s	<10s	10s	10s	10s	13	0.00%	0.00
500	Yearly	Mid	60	252	240	9s	10s	10s	10s	10s	12s	>240s	0.09%	1,678.00
500	Yearly	Hard	60	252	240	10s	10s	10s	10s	14s	>240s	>240s	0.45%	3,192.00
500	Monthly	Easy	60	30.5	17.5	<11s	<11s	<11s	11s	11s	11s	17s	0.00%	0.00
500	Monthly	Mid	60	251	240	24s	24s	100s	>240s	>240s	>240s	>240s	2.15%	76,044.00
500	Monthly	Hard	60	254	240	20s	20s	>240s	>240s	>240s	>240s	>240s	2.56%	93,442.00
1000	Yearly	Easy	60	56	32	24s	25s	27s	28s	30s	32s	32s	0.00%	0.00
1000	Yearly	Mid	60	261	240	<30s	<30s	<30s	<30s	<30s	35	>240s	0.01%	2,000.00
1000	Yearly	Hard	60	260	240	<20s	21s	21s	53s	>240s	>240s	>240s	0.77%	8,120.00
1000	Monthly	Med	60	265	240	<45s	<45s	<45s	47s	47s	48s	>240s	0.03%	9,000.00
1000	Monthly	Med	60	226	203.6	97s	103s	110s	140s	160s	195	199	0	0.00
1000	Monthly	Hard	60	264	240	60s	60s	78s	>240s	>240s	>240s	>240s	1.23%	117,000.00

ENSTOA

Project Controls EXPO

DECISION SUPPORT

- Planning scenarios can be developed with ‘real time’ feedback to Planners
  - Identify constraints
  - Validate and update assumption
- Quickly Evaluate Alternate and What-if Scenarios
- Support for collaboration during plan drafts
- Real time scenario development and evaluation can better enable the Planning team,

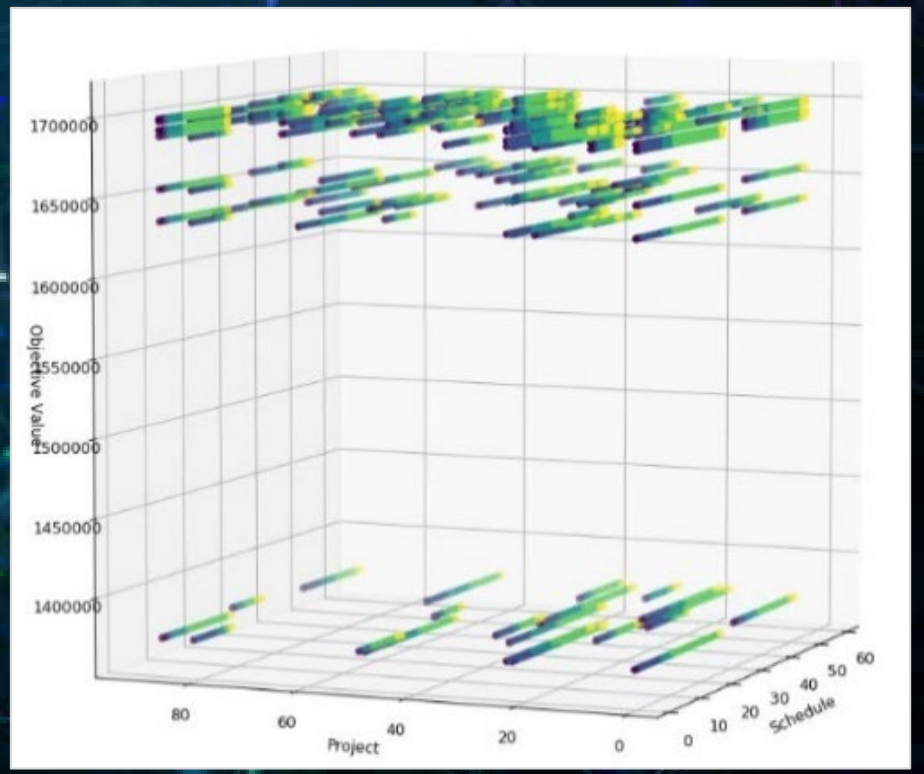


ENSTOA

Project Controls EXPO

KEY TAKEAWAYS

- Competitive advantage
  - Faster decision making, better decisions, and more timely decision cycles.
- Decision Support
  - Human input and intuition is vital/critical to successful planning.
- Value
  - Reduces opportunity cost of the capital planning process
  - Promotes selection of higher valued portfolio



ENSTOA

Project Controls EXPO