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Report for the Commission of Inquiry Respecting the Muskrat Falls Project

Professor Bent Flyvbjerg

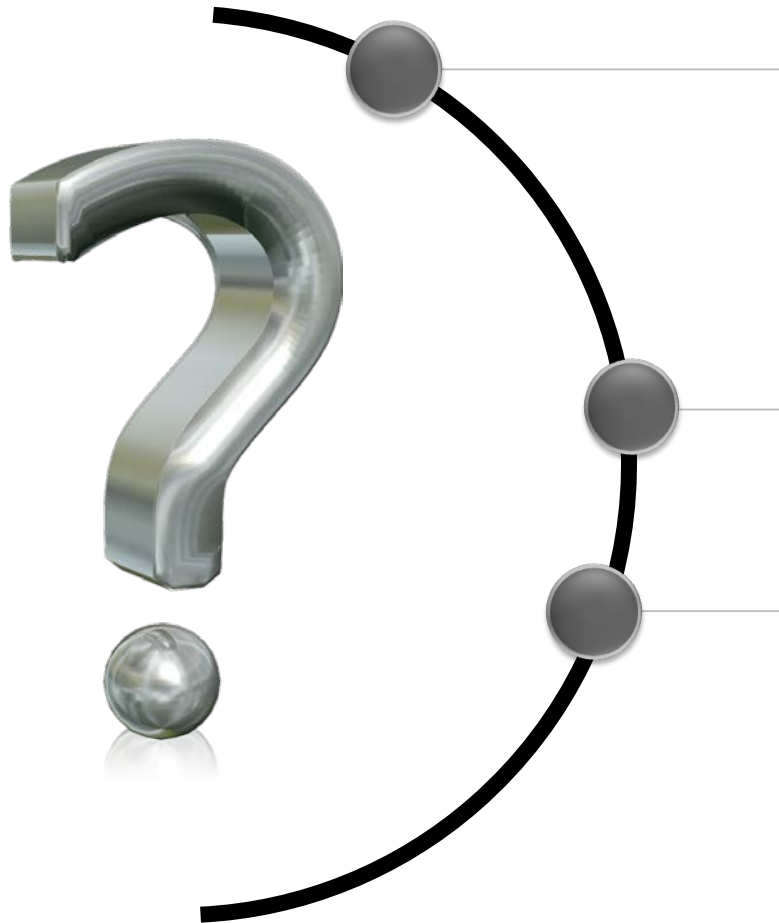
BT Professor and Inaugural Chair in Major Programme Management
Saïd Business School, University of Oxford



The Commission Asked for the Report to Cover 3 Sets of Questions

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What is the **national and international context** of the Muskrat Falls Project with regards to **cost overrun** and **schedule overrun**?

What are the **causes and root causes** of cost and schedule overruns?

What are **recommendations**, based on international experience and research into capital investment projects, to prevent cost and schedule overruns in hydro-electric dam projects and other capital investment projects?

Agenda

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1 National and International Context

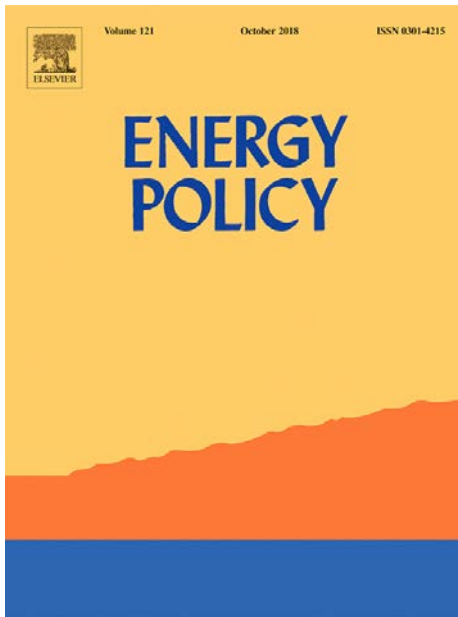
2 Causes and Root Causes

3 Recommendations

The Data

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-
- Our previous research on 245 dams was published in 2014
 - The research included 186 hydro-electric dams
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- For this report we updated the sample to 274 hydro-electric dam projects, in 75 countries on six continents, built from 1936 to 2015
-

How Overrun is Measured

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1. $O = C_a/C_e$ (ratio)
2. $O = (C_a/C_e - 1) \times 100$ (percentage)

Where

O = Overrun in ratio or percent

C_a = Actual costs

C_e = Estimated costs **at date of decision**

All costs measured in **constant prices**

Cost and Schedule Overruns of Hydro-Electric Dam Projects

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	Average	Median	Range	Frequency of overrun	Sample size (n)
Cost overrun	+96%	+32%	-47% to +5142%	77%	269
Schedule overrun	+42%	+27%	-29% to +402%	80%	249

- Average actual duration = 100 months (8.3 years)
- Median actual duration = 84 months (7.0 years)

Rate of Outliers in Hydro-Electric Dam Projects

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- Outliers are projects with very high overruns
- Outliers sometimes also called “Black Swans”
- Outliers are defined statistically as observations more than 1.5 inter-quartile ranges away from the top quartile

	Definition	Frequency of outliers	Average overrun of outliers	Sample size (n)
Cost outliers	Overrun \geq +207%	10%	+640%	269
Schedule outliers	Overrun \geq +127%	6%	+195%	249

Hydro-Electric Dam Projects with Overruns $\geq 100\%$

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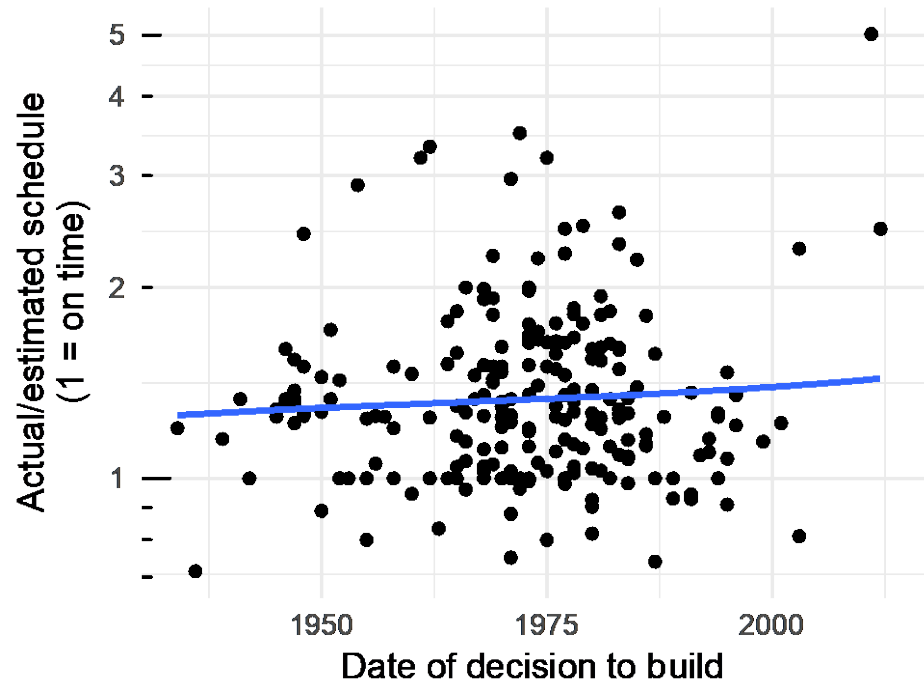
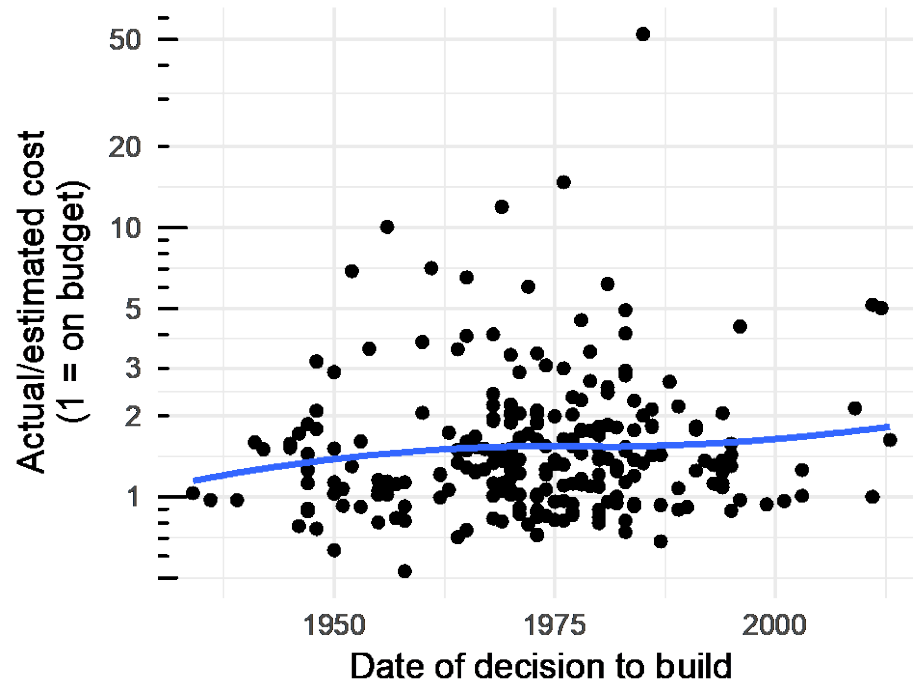
	Frequency of projects with overrun $\geq 100\%$	Average overrun of projects with overrun $\geq 100\%$	Sample size (n)
Cost overrun	22%	+374%	269
Schedule overrun	9%	+171%	249

No Improvement in Overruns Over Time

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— Moving average
— 95% C.I.



Comparison to Transport Infrastructure Projects

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	Cost overrun (mean)	Frequency of cost overrun	Schedule overrun (mean)	Frequency of schedule overrun	Sample size (n)
Hydro-electric dams	+96%	77%	+42%	80%	274
Roads	+24%***	72%	+20%***	71%	963
Bridges	+32%*	71%	+23%	74%	51
Tunnels	+38%	73%	+22%**	50%	56
Rail	+41%	80%	+48%	80%	308

*** p < 0.001; ** p < 0.01; * p < 0.05 (p-values based on the difference between hydro-electric dam projects and other project types using two-sample Wilcoxon tests)

Comparison to Energy Projects

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	Cost overrun (mean)	Frequency of cost overrun	Schedule overrun (mean)	Frequency of schedule overrun	Sample size (n)
Hydro-electric dams	+96%	77%	+44%	80%	274
Wind power	+13%***	64%	+22%*	64%	53
Solar power	+1%***	41%	-0%***	22%	39
Thermal (oil, gas, diesel, coal)	+31%***	59%	+36%	76%	124
Transmission	+8%***	40%	+8%***	12%	50
Nuclear	+122%***	97%	+65%***	93%	191

*** p < 0.001; ** p < 0.01; * p < 0.05 (p-values based on the difference between hydro-electric dam projects and other project types using two-sample Wilcoxon tests)

Comparison to Mining and Oil & Gas Projects

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	Cost overrun (mean)	Frequency of cost overrun	Sample size (N)
Hydro-electric dams	+96%	77%	274
Mining, oil & gas	+17%***	60%	531

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$ (p-values based on the difference between hydro-electric dam projects and other project types using two-sample Wilcoxon tests)

Comparison of Hydro-Electric Projects in Canada vs. Elsewhere

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	Cost overrun (mean)	Frequency of cost overrun	Schedule overrun (mean)	Frequency of schedule overrun	Sample size (n)
Canada	+41%	50%	+13%*	50%	19
Rest of the world	+99%	78%	+43%*	81%	254

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$ (p-values based on the difference between hydro-electric dam projects and other project types using two-sample Wilcoxon tests)

Comparison of Other Projects in Canada vs. Elsewhere

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Project type	Location	Cost overrun (mean)	Frequency of cost overrun	Schedule overrun (mean)	Frequency of schedule overrun	Sample size (n)
Transport	Canada	+20%	60%	+4%**	42%	21
	Rest of world	+29%	74%	+42%**	77%	1365
Energy (excluding hydro-electric)	Canada	+74%	83%	+46%	57%	24
	Rest of world	+79%	76%	+41%	74%	633
Mining, oil and gas	Canada	+13%***	56%	+16%	81%	458
	Rest of world	+44%***	85%	NA	NA	73

*** p < 0.001; ** p < 0.01; * p < 0.05 (p-values based on the difference between hydro-electric dam projects and other project types using two-sample Wilcoxon tests)

Summary: The National and International Context

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- Average cost overrun of hydro-electric dam projects is 96% (median 32%)
- Average schedule overrun of hydro-electric dam projects is 42% (median 27%)
- Cost and schedule overruns of hydro-electric dam projects have remained constant in the last 60 years
- Comparison of cost overrun of hydro-electric dams
 - Statistically significantly **higher cost overruns** than road and bridge projects in transport; wind, solar and thermal power plant projects in energy; and mining, oil & gas projects.
 - **Similar cost overrun**, i.e. not statistically significantly different, to rail and tunnel projects.
 - Statistically significantly **lower cost overruns** than nuclear power plants.
- Comparison of schedule overrun of hydro-electric dams
 - Statistically significantly **higher schedule overrun** than road and tunnel projects; and wind and solar power projects.
 - **Similar schedule overrun** as bridges and rail; thermal power plants.
 - Statistically significantly **lower schedule overrun** than nuclear power.
- Comparison of Canada vs Rest of the World
 - **Similar cost overrun** in hydro-electric dam, transport, energy projects are similar (i.e. not statistically significantly different).
 - Statistically significantly **lower cost overrun** in mining, oil & gas projects.
 - Statistically significantly **lower schedule overrun** in hydro-electric dam and transport projects.
 - **Similar schedule overruns** are similar in other energy projects (excluding hydro-electric dams).

Agenda

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1 National and International Context

2 Causes and Root Causes

3 Recommendations

The Niagara Tunnel Project Explains Cost Overrun and Delay

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Niagara Tunnel Project

- 62% cost overrun
- 42 months delay (+43%)

Ontario Power Generation cited the causes of the overrun and delay as:

- “Slower than planned TBM progress due to **worse than expected [ground] conditions** in the Queenston shale once the tunnel passed the St. David’s Gorge.
- Expectation of continuing challenges as the tunnel ascends to higher rock strata and undertakes more mixed-face mining. [...]
- Restoring the tunnel to a circular profile (“profile restoration”) is an **additional task** that was not included in the original schedule. [...]
- Additional time to allow for removal of tunneling equipment before removal of the cofferdam at the intake structure.”



Right? Wrong!
Because these are causes,
not root causes

Root Cause of Risk

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**Your biggest
risk is you!!**

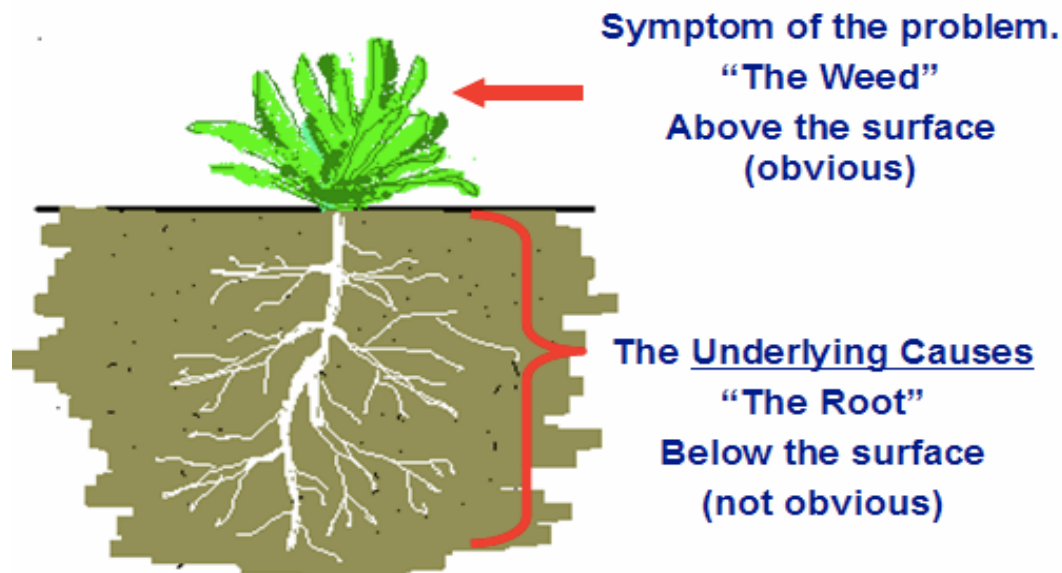


Causes and Root Causes

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1. **Causes:** Scope changes, complexity, delays, inflation, geology, weather, bad data and models, etc.
2. **Root causes:** Optimism bias, strategic misrepresentation



Root Cause is Internal, Not External

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- Conventional wisdom sees causes of risk as mainly **external** to programs
-
- The root cause of risk is **internal**. It consists in the way leaders systematically misconceive of risk

**Complete change
of perspective**



Three Types of Explanation

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1. **Technical:** Errors in data and models (Vanston & Vanston)
2. **Psychological:** Optimism bias (Kahneman, Tversky)
3. **Political-economic:** Strategic misrepresentation (Wachs, Flyvbjerg)

The Technical Explanation

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"The two most common reasons for poor forecasts are the use of unreliable or outdated **data** and the use of inappropriate forecasting **models**."

(Vanston & Vanston 2004:33)

Poor data + poor models → **Error!**

The Problem Is Not Error, It's Bias

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<i>Overrun in hydro-electric dam projects</i>	Mean	Wilcoxon test, whether the error centers on zero	Frequency of overrun	Binomial test, whether overruns are as frequent as underruns
Cost overrun	96%	$p < 0.001$	77%	$p < 0.001$
Schedule overrun	42%	$p < 0.001$	80%	$p < 0.001$

⇒ Technical explanations are **falsified**
(with an unusually high level of statistical significance)

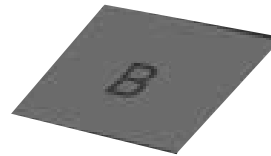
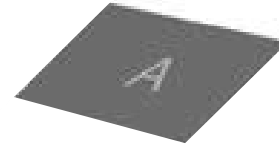
Biases do not cancel out, like error; biases compound!!

Cognitive Bias

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1. Even if you know the bias is there, you are subject to the bias
2. Experts and lay people alike are subject to cognitive bias



Definition of Optimism Bias

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- Optimism bias is the demonstrated systematic tendency for people to be overly optimistic about the outcome of planned actions
- This includes overestimating the likelihood of positive events and underestimating the likelihood of negative events

How Optimism Bias Influences Managers' Decisions

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- Managers **underestimate** costs, completion times, and risks of planned decisions
- Managers **overestimate** the benefits of the same decisions
- Underestimation + overestimation = **the planning fallacy**



Planning Fallacy: Cause and Cure

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- Cause: “**Inside view**” focusing on the constituents of the specific planned action, seeing this action as unique
- Cure: “**Outside view**” focusing on the outcomes of similar actions that have already been completed



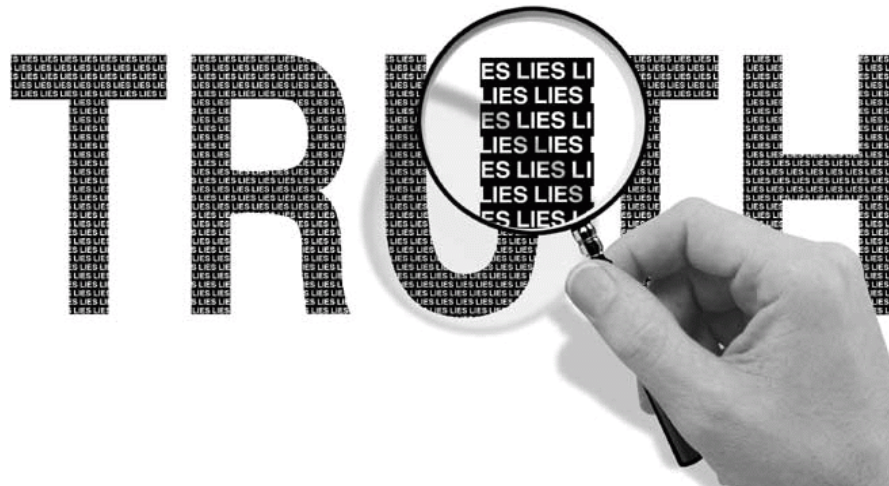
Strategic Misrepresentation

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“Strategic misrepresentation is the planned, systematic distortion or misstatement of fact – lying - in response to incentives in the budget process.”

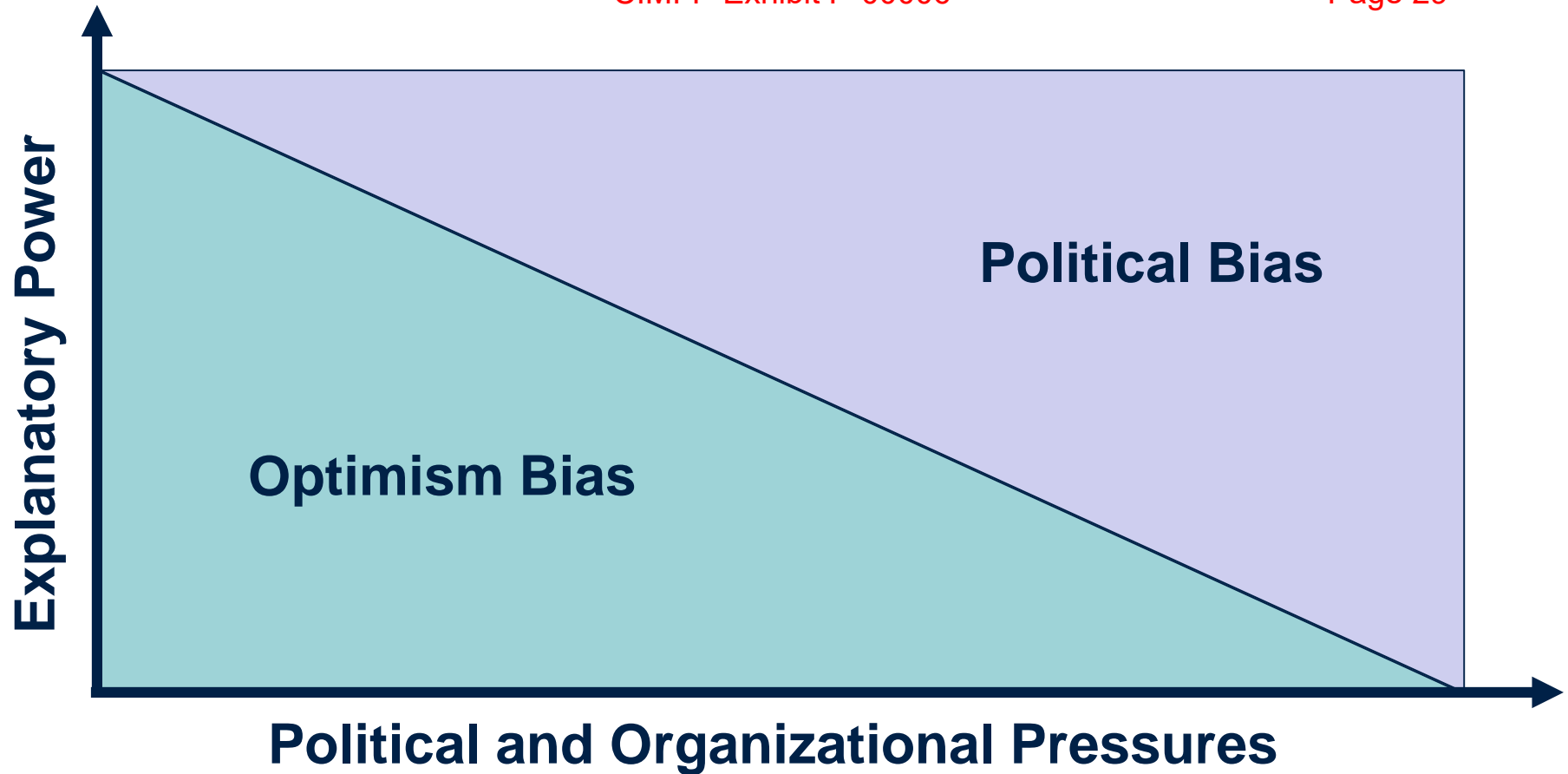
– Jones and Euske, 1991



Root Causes in Sum

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1 National and International Context

2 Causes and Root Causes

3 Recommendations

Viability and risk assessments (1/3)

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Root Cause

The “inside view”
leads to optimistic
estimates and plans

Recommendation

- Take the “outside view”
- Pool and apply lessons from other projects
- Avoid uniqueness bias

Viability and risk assessments (2/3)

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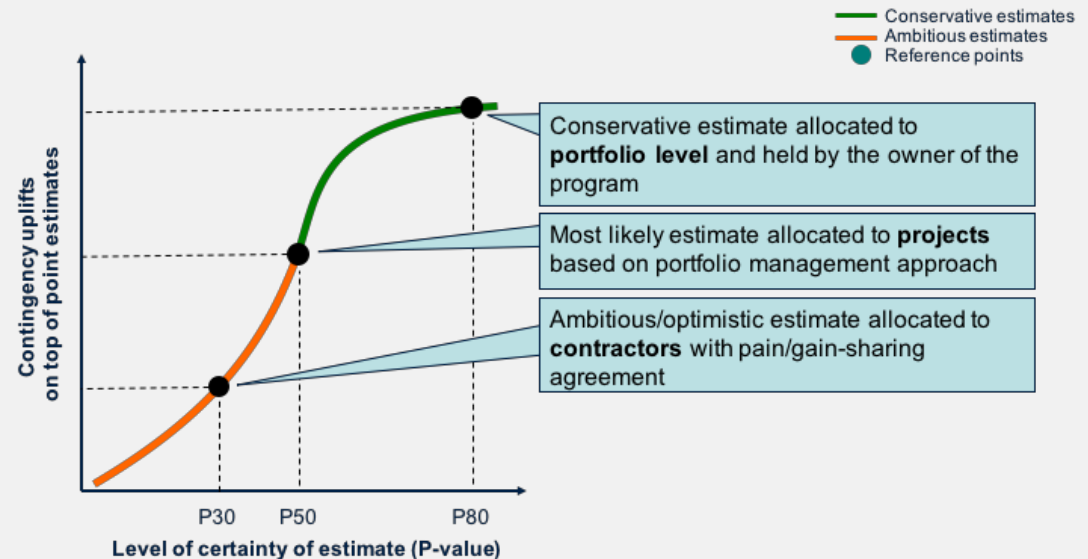
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Recommendation

Consider different risk appetites for different questions when appraising a project proposal:

- Is the project economically viable? Best measure is the mean or median of estimates
- Is the project affordable? Best measure is an extreme downside scenario, e.g. P80 – P90
- What project budget and timeline should be set?

Ignoring the full distributional information of outcomes leads to optimism



Viability and risk assessments (3/3)

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Recommendation

Use **Reference Class Forecasting**, which is a 3-step process:

- 1) **Identify a sample of past, similar projects** – typically a minimum of 20-30 projects is enough to get started, but the more projects the better
- 2) **Establish the risk of the variable in question based on these projects** – e.g. identify the cost overruns of these projects
- 3) **Adjust the current estimate** – through an uplift or by asking whether the project at hand is more or less risky than projects in the reference class, resulting in an adjusted uplift

Root Cause

Projects planned with the "inside view" and without the full distributional information leads to optimism

Viability and risk assessments – Reference Class Forecast Example

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Identify a sample of past, similar projects

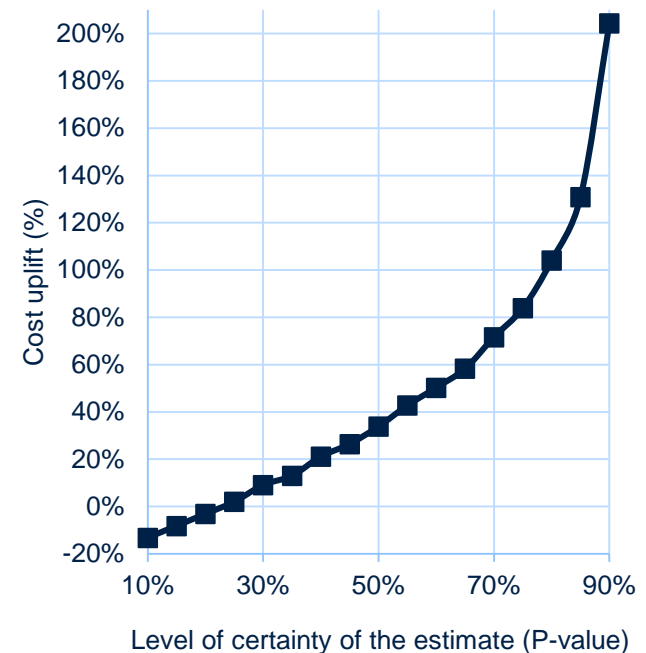
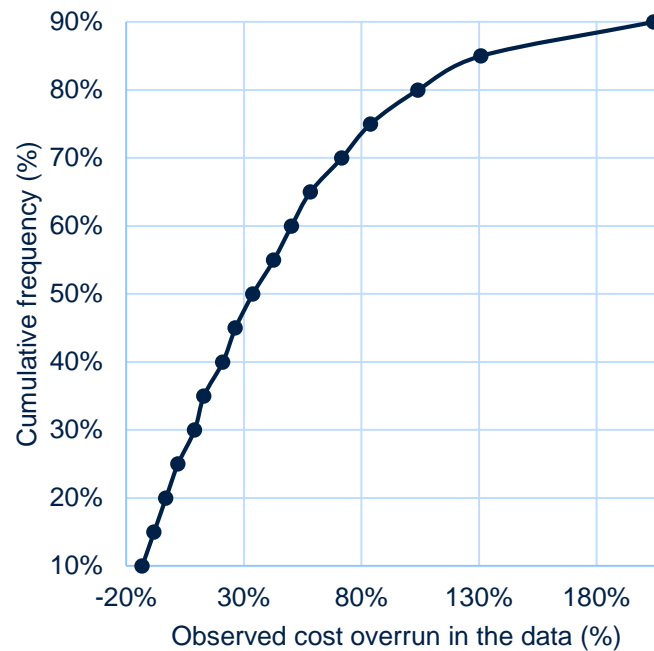


Establish the risk of the variable in question



Adjust the current estimate

- Past hydro-electric dams from this analysis
- N = 274
- No statistically significant difference for Canadian projects



Oversight (1/2)

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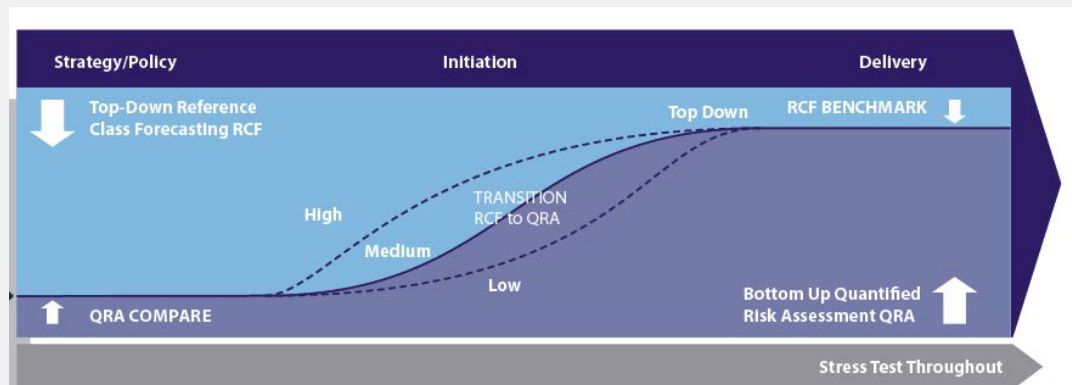
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Recommendation

- Incorporate the outside view (e.g. through Reference Class Forecasting) in the stage gate approval process
 - UK Government requires “Optimism Bias Uplifts” for business case approvals
 - Hong Kong Government has similar procedures
- Provide clear guidance on how to combine inside and outside view risk estimates

Root Cause

Project proposals are typically approved without considering their optimism and/or strategic misrepresentation



Oversight (2/2)

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Recommendation

- Independent reviews – project reviews and audits can surface potential bias; however, reviews need to be independent (free of any political bias)
- Peer reviews – critical friend reviews are a second best alternative. They are successfully used in the UK, where a concern is to balance cost of reviews with independent challenge

Root Cause

Self-interest and thus hidden agendas, hidden action and hidden information leads to strategic misrepresentation

Accountability

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Recommendation

- Review processes use to select project for funding and to award contracts, with regards to avoiding low balling of cost and inflating of benefits
- Hold forecasters accountable for the accuracy of their forecasts, e.g. after the project through the courts
- Introduce positive and negative incentives for forecasters to produce accurate estimates upfront
- Ensure that a direct line of accountability of decision makers and project managers is in place, especially in public sector projects where accountability is often diffuse

Root Cause

Misaligned incentives of forecasters, decision makers and project managers lead to political bias

Transparency (1/2)

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Recommendation

- Effective governance relies on multiple channels of information, which provide different challenging perspectives
- Special emphasis should be posted on early warning signs of potential problems
- Project performance should be compared not only to the latest baseline (which makes the performance of project managers transparent and holds them accountable) but also against original baselines (which makes the performance of decision makers and planners transparent)
- Transparent project information is also needed for better planning methods, e.g. Reference Class Forecasting

Root Cause

Lack of transparent, unbiased and up-to-date information limits the ability of decision-makers to solve problems and bring projects back on track

Transparency (2/2)

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Recommendation

- Establish reasonable levels of contingencies, which tend to be larger than commonly assumed – e.g. through the use of Reference Class Forecasting
- Benchmark the unit cost and productivity of projects to identify unreasonably low or high project proposals
- Set unit cost and productivity (i.e. schedule) targets based on the full distributional information of benchmarks
- Collect and provide unit cost and productivity data to improve project planning in other projects

Root Cause

Fear that realistic forecasts reduce the chances of funding and contract wins leads to political bias

Further Recommendations

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Recommendation

Root Causes

- Projects are too big to succeed
- Capabilities to manage megaprojects are lacking
- Perception that cost overruns get always funded

- Smart scaling – long planning horizons and large size is linked to underestimate cost. Projects need to consider how to scale smartly designing modularity, speed and learning into the project upfront
- Master builder development – invest in the learning and development of project managers; align career paths to reduce frequent turn over; equip project sponsors with the needed capabilities to provide project oversight
- Consider the inclusion of private finance, which adds due diligence and oversight to projects; carefully consider projects that require 100% sovereign guarantees or financing

Summary of the Recommendations

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In all type of projects and in all geographies, project costs and schedules are frequently and systematically underestimated. The root causes of these underestimations can be found in optimism and political biases.

Improve **viability and risk assessments** to de-bias projects upfront and during project delivery

- Plan projects with an **outside view**.
- Use **full distributional information** in planning cost and schedule; set targets according to risk appetites based on distributional information.
- Use **Reference Class Forecasting** to systematically take an outside view and bypass optimism and political biases.

Additional steps are needed to correct political bias.

- Improve **oversight** of projects : Challenge projects at all stage gates of approval for optimism and political biases. Use independent, unbiased reviews to surface signs of bias.
- Create clear lines of **accountability** for planning and delivery of projects. Hold project planners and decision makers accountable for their forecasts.
- **Enhance project reporting** and make performance more transparent, including early warning signals to enable quick problem solving to get projects back on track.
- **Benchmark unit cost** and productivity estimates to eliminate overinflated or low balled project proposals; set targets that balance realism and ambition.
- Build speed and modularity into every project to **scale smarter**.
- Invest in the **learning and development** of leaders of megaprojects and major programs.
- Consider every project as if it is a **private investment**; the added due diligence de-risks proposals.