SYSTEMS ENGINEERING RESEARCH CENTER

AIRC ACQUISITION INNOVATION RESEARCH CENTER

NDIA

A new framework for characterizing uncertainty in defense megaprojects

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Mega-Projects Overview: DAU's Collaboration with the Acquisition Innovation Research Center (AIRC)

Research Question: How might data visualization, artificial intelligence, and machine learning aid in the management of DoD's largest programs (mega-projects)?

Final Deliverable: Based on the research, AIRC delivers a web event or series of web events to the Acquisition Workforce focused on the practical use of data visualization, artificial intelligence, and machine learning to improve program management.

LINES OF EFFORT

(1) Benchmark non-DoD mega-projects' use of data visualization, artificial intelligence, and machine learning.

(2) Study a DoD mega-project and develop generalized theories on how the use of data visualization, artificial intelligence, and machine learning might improve program management practices.

(3) Hypothesize on the megatrends, trends, and bellweathers that will shape how DAU should train and educate the Defense Acquisition Workforce in 10 to 15 years (considering the use of data visualization, artificial intelligence and machine learning to improve program management).

(4) Prepare a report on the research findings and provide recommendations for future research.

(5) Based on the research-- design, develop, and deliver a web event or series of web events focused on the practical use (a playbook) of data visualization, artificial intelligence, and machine learning to improve program management.

AIRC-DAU Quarterly Research Forums

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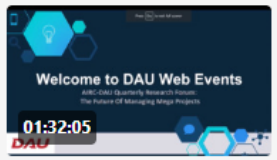


AIRC-DAU Quarterly Research Forum - The Future Of Managing Mega Pr...

AIRC-DAU Quarterly Research Forum: The Future Of Managing Mega ProjectsThe Acquisition Innovation Research Center (AIRC) team is exploring how data visualization, Artificial Intelligence, and Machine Le...

1 Tag 1 Detail Explore

The Future of Managing Mega Projects (Benchmark Results)

The Acquisition Innovation Research Center (AIRC) team is exploring how data visualization, Artificial Intelligence, and Machine Learning can be combined with human knowledge transfer across teams to ...

1 Detail Explore

AIRC-DAU Quarterly Research Forum - Megaproject Lessons Learned 6.1...

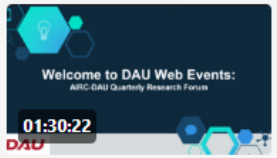
Megaproject success is strongly linked to successful management of project uncertainties. Management of project uncertainties fundamentally differs from the management of project risk. In particular, proje...

1 Tag 1 Detail Explore

AIRC-DAU Quarterly Research Forum 4a

Megaproject success is tied to the effective management of project uncertainties and the cultivation of a shared vision and action plan among team members and stakeholders. In this talk, we delve into the r...

1 Detail Explore



AIRC-DAU Quarterly Research Forum

Megaprojects are large-scale and highly complex, requiring leaders with a specific set of skills to see them successfully to completion. In this final Quarterly Research Forum by the AIRC research team, we...

1 Tag 1 Detail Explore

1. State of the practice in commercial megaprojects
2. Case Studies: benchmarking megaprojects
3. Megaprojects lessons learned and playbook
4. AI and visualization approaches to improve megaproject management
5. Skills and competencies for development of megaproject leaders

What is a Mega-Project?

- **“large-scale, complex ventures that typically cost $1 billion or more, take many years to develop and build, involve multiple public and private stakeholders, are transformational, and impact millions of people.”**
  - Oxford Handbook of Megaproject Management (Flyvbjerg, ed., 2017)
- **“often produce mega-systems that operate with dimensions of behavioral complexity, pluralistic multi-actor decision-making, high criticality, and volatility of the external environment.”**
  - Engineering Mega-Systems (Stevens 2017)
- **“often combine uncertainty with the difficulties of long time horizons and nonstandard technologies.”**
  - S. Lenfle and C. Loch, “Has Megaproject Management Lost its Way: Lessons from History.” in The Oxford Handbook of Megaproject Management

The DoD has long-been a sponsor of megaprojects, and also continues to transition from more standalone platform centric systems to mega-systems.

Derived Common Analytical Characteristics of Megaprojects

- Large scale, complex interfaces
- Behavioral and structural complexity, high levels of uncertainty
- Often non-standard technology & design
- Transformational outcomes
- Long planning horizons, scope changes significantly over time
- Pluralistic, multi-stakeholder influence and decision-making
- Complex external environment and over-commitment

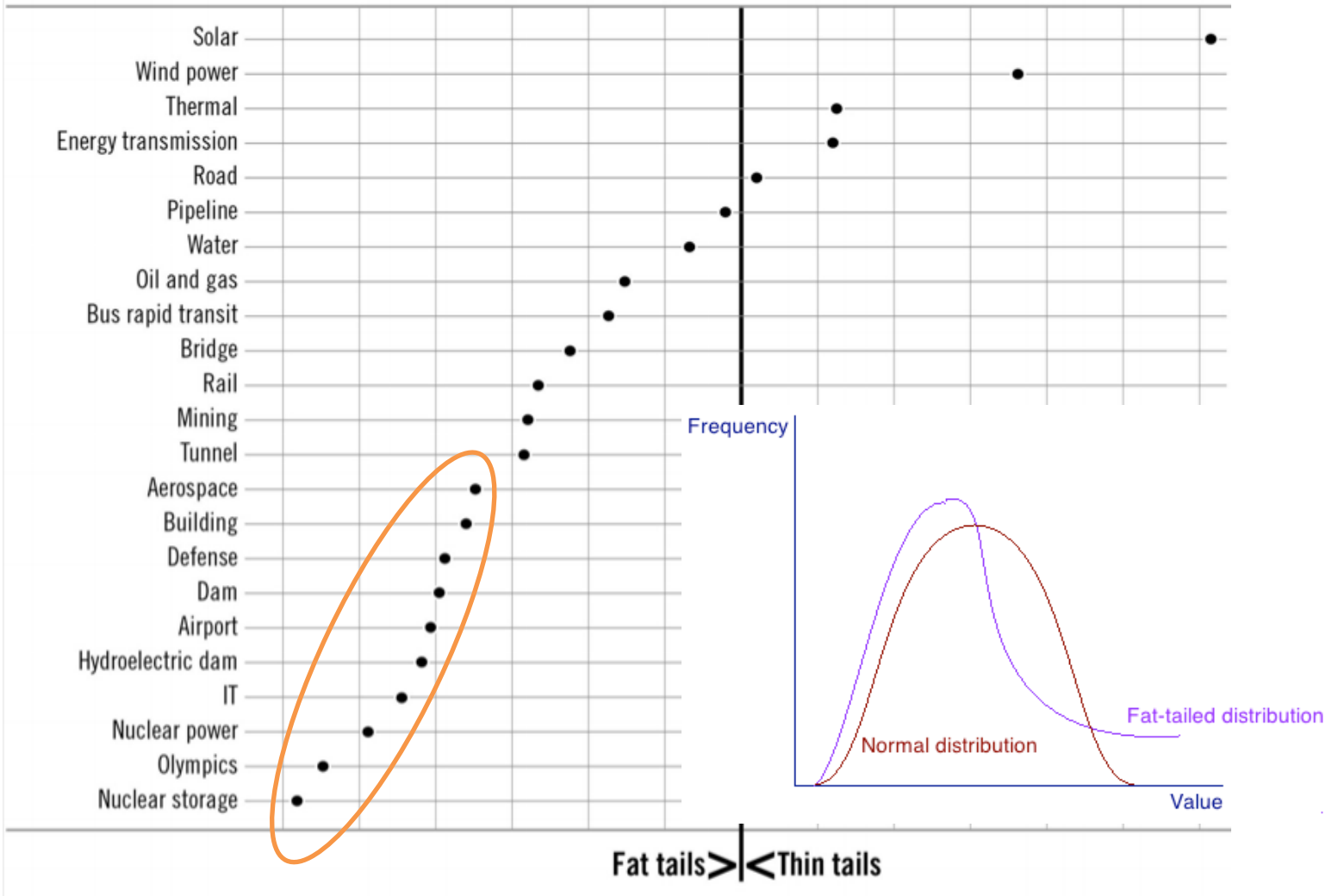
1. Uncertain outcomes: “Fat Tails”
2. Experience major lifecycle shifts
3. Complexity drives uncertainty and management of uncertainty
4. Success/failure difficult to predict, lack of causality
5. Specialized leadership abilities required

The Oxford Handbook of Megaproject Management (Oxford Handbooks) (p. 8). OUP Oxford.

Uncertain outcomes: “Fat Tails”

“all the project types arranged by how “fat-tailed” they are in terms of cost—meaning how much they are in danger of the extreme cost overruns that destroy projects and careers, blow up corporations, and humiliate governments.”

Flyvbjerg, Bent; Gardner, Dan. How Big Things Get Done (pp. 172-173). Crown.



Uncertain outcomes: “Fat Tails”

The table shows cost overruns for twenty-five project types covering sixteen thousand–plus projects. Overrun is measured as (a) mean cost overrun, (b) percentage of projects in the upper tail (defined as ≥ 50 percent), and (c) mean overrun in the tail. Overrun is measured in real terms.

Flyvbjerg, Bent; Gardner, Dan. How Big Things Get Done (p. 191). Crown.

Many defense related projects are in areas that tend to have large mean cost overruns and a fat-tailed cost overrun distribution.

PROJECT TYPE	(A) MEAN COST OVERRUN (%)*	(B) % OF PROJECTS IN TAIL (≥ 50% OVERRUN)	(C) MEAN OVERRUN OF PROJECTS IN TAIL (%)
Nuclear storage	238	48	427
Olympic Games	157	76	200
Nuclear power	120	55	204
Hydroelectric dams	75	37	186
IT	73	18	447
Nonhydroelectric dams	71	33	202
Buildings	62	39	206
Aerospace	60	42	119
Defense	53	21	253
Bus rapid transit	40	43	69
Rail	39	28	116
Airports	39	43	88
Tunnels	37	28	
Oil and gas	34		

1. Why do we see these uncertain outcomes?

2. What data/indicators should have told us we would experience large overruns?

Most Common Causes of Fat Tail Behaviors

1. **Underestimation of, or refusal to acknowledge uncertainty:**
   - Assumption: the design and project plan can be fully defined at the beginning
   - Impossible to plan for all uncertainties, leading to control conflicts on decisions around uncertainty

Complexity
How we learn

2. **Stakeholder neglect or mismanagement:**
   - Megaprojects/systems are coalitions of active partners and other non-active stakeholders
   - Stakeholder conflicts are a major source of project problems. Ignoring stakeholders or creating forced agreements are common conflict areas. These conflicts are often unpredictable.

Stakeholder Alignment
How we lead

3. **Inflexible contractor management:**
   - Many organizations have to cooperate; transparency, honesty and incentives are needed
   - Many megaprojects fail because they are bid incorrectly or dishonestly, or just "priced to win"; win-win strategies must be developed.

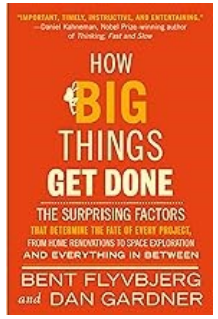
Misrepresentation & Bias
How we plan

Interactions across these causes enhance project failure models

S. Lenfle and C. Loch, "Has Megaproject Management Lost its Way: Lessons from History." in The Oxford Handbook of Megaproject Management.

Megaprojects experience major lifecycle shifts

“Think slow ….. Execute fast”		“The Hiding Hand”
Project Planning Phase	Project Execution Phase	Project Benefits Phase



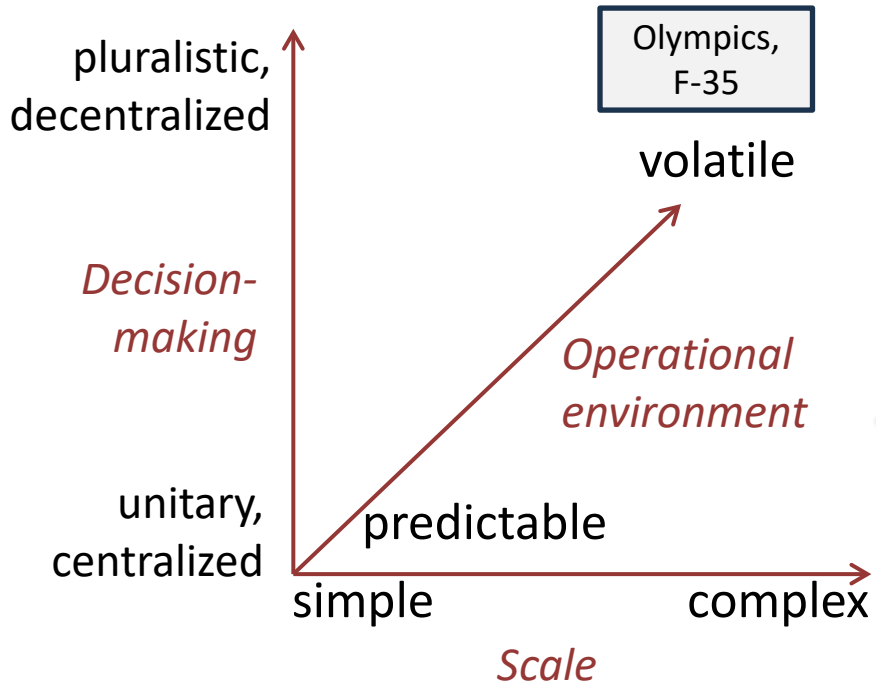
Concepts from literature:

- **“Think slow”** – it’s a serious mistake to treat planning as an exercise in abstract bureaucratic thought and calculation. What sets good planning apart from the rest is something completely different. It is experimentation and experience (learning).
- **“Execute fast”** – Time kills megaprojects, not size. Act fast to reduce changing externalities.
- **“The Hiding Hand”** – ignorance can provoke creative success (Hirshman), but only given a benevolent hand (Flyvbjerg).

- **Equifinality (complexity theory)** – in a complex system there are multiple routes to a specific set of outcomes; more complexity needs more planning cases.

Two views of mega-systems from literature

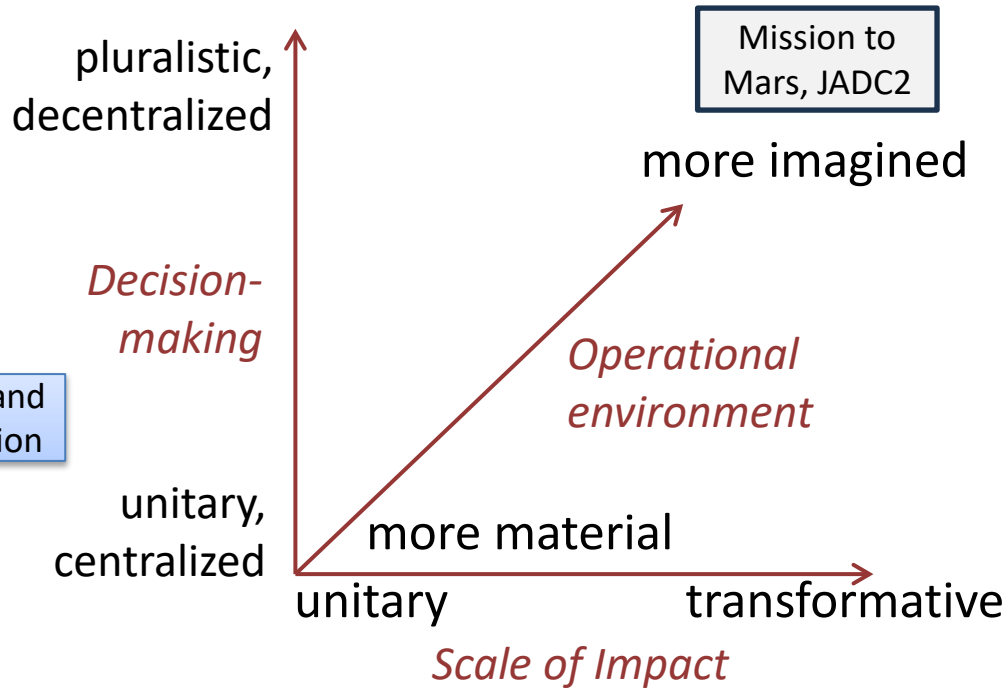
"their sheer scale, the nature and pace of change of their underlying technologies, the potential complexity of their interactions, and the fact that a single organization rarely owns and therefore completely controls the mega-system"



Stevens, R. (2011). Engineering Mega-Systems: The Challenge of Systems Engineering in the Information Age. Auerbach Publications.

time and iteration

"In contrast to their mid-20th century counterparts, contemporary megaprojects are often decentralized and pursued by a range of stakeholders who leverage cutting-edge technology to 'see' complex systems as legible and singular phenomena"



Schindler, S. (2019). Contemporary Megaprojects: Organization, Vision, and Resistance in the 21st Century. Auerbach Publications.

Complexity drives uncertainty/management of uncertainty

- While projects focus on progress to plans, megaprojects should focus on discovery of and burndown of **uncertainties**.
- Based on extensive literature review, we created a **Megaproject Uncertainty Framework** as a decision aid in characterizing megaproject uncertainty dimensions and identifying strategies to combat “fat tails.”

This framework has four uses:

1. It is a qualitative rubric used to organize learning from case studies.
2. It is an assessment framework that can be used to model and actively track megaproject uncertainties over time to design/redesign the project.
3. It created an analytical framework (visualization dashboard) for guiding data visualization and analysis in megaproject execution.
4. It informed a leadership and management model to train the future class of megaproject and mega-system leaders.

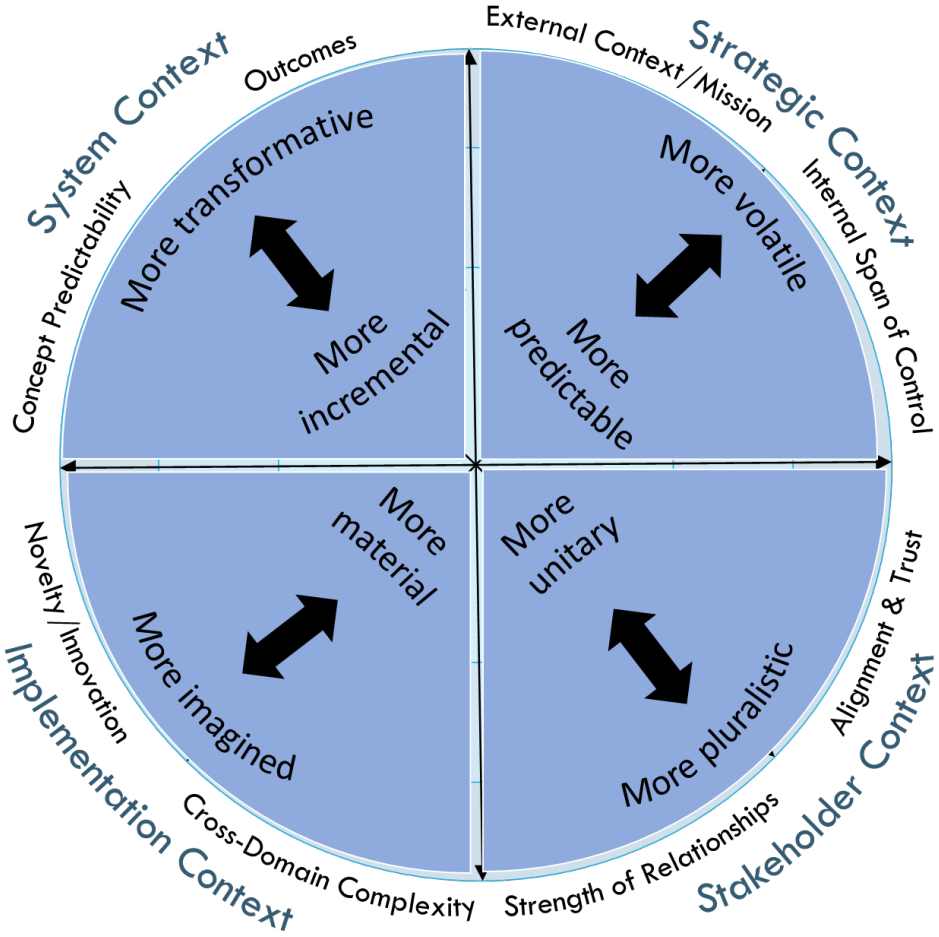
Issues with Risk and Uncertainty

- The management of risks fundamentally differs from the management of uncertainty, projects have both
- Classic project management has a long tradition of managing project risks (it is mature)
- The concept of uncertainty has neither been clearly addressed by classic project management, nor is it explicitly defined in widely accepted project management standards
- “Risk and uncertainty are not differentiated and are being used synonymously—or, more precisely, uncertainty is treated as a special case of risk*”

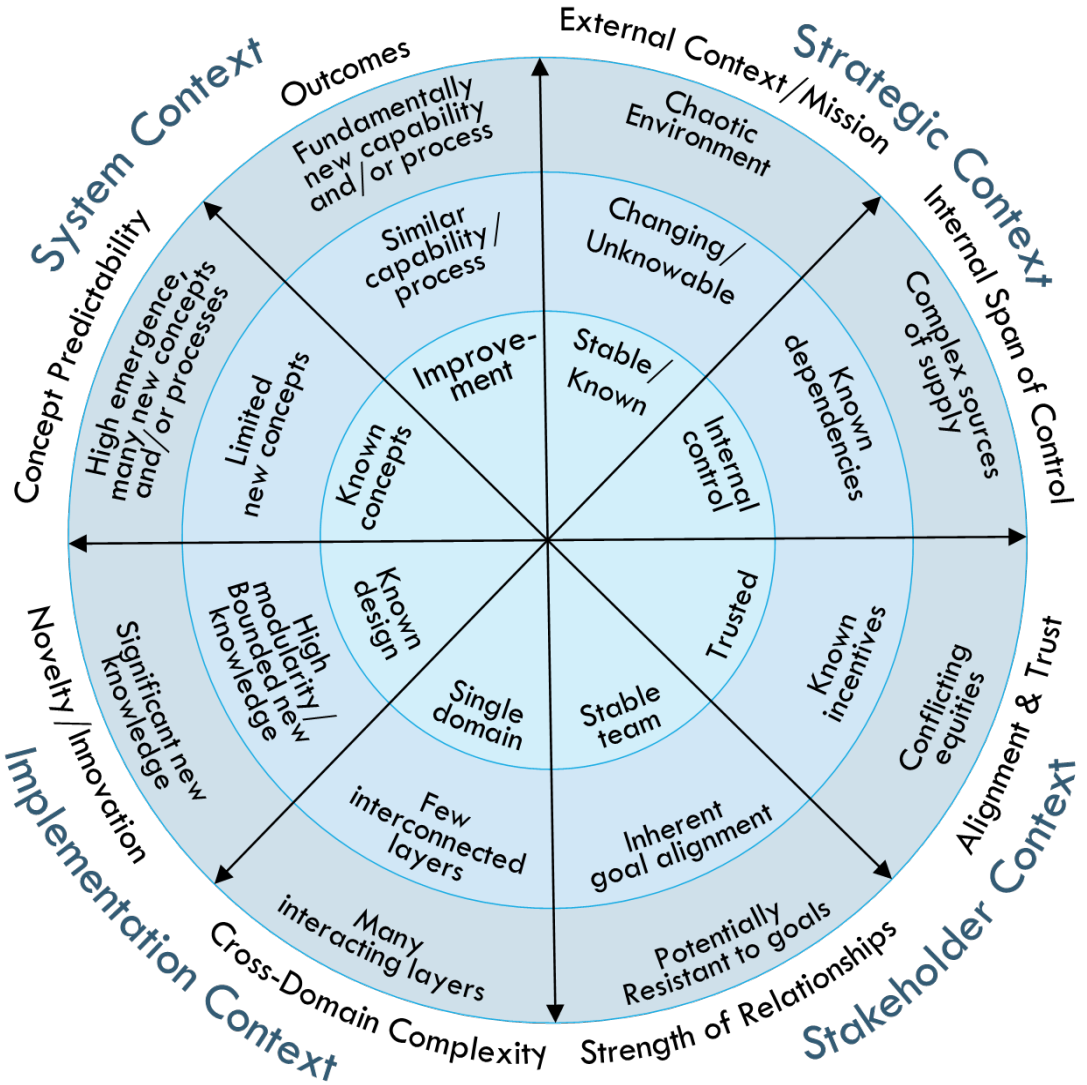
*Thomas G. Lechler, Ting Gao, Barbara Edington, The Silver Lining of Project Uncertainties, Project Management Institute 2013

Megaproject Uncertainty Framework

4 Contexts



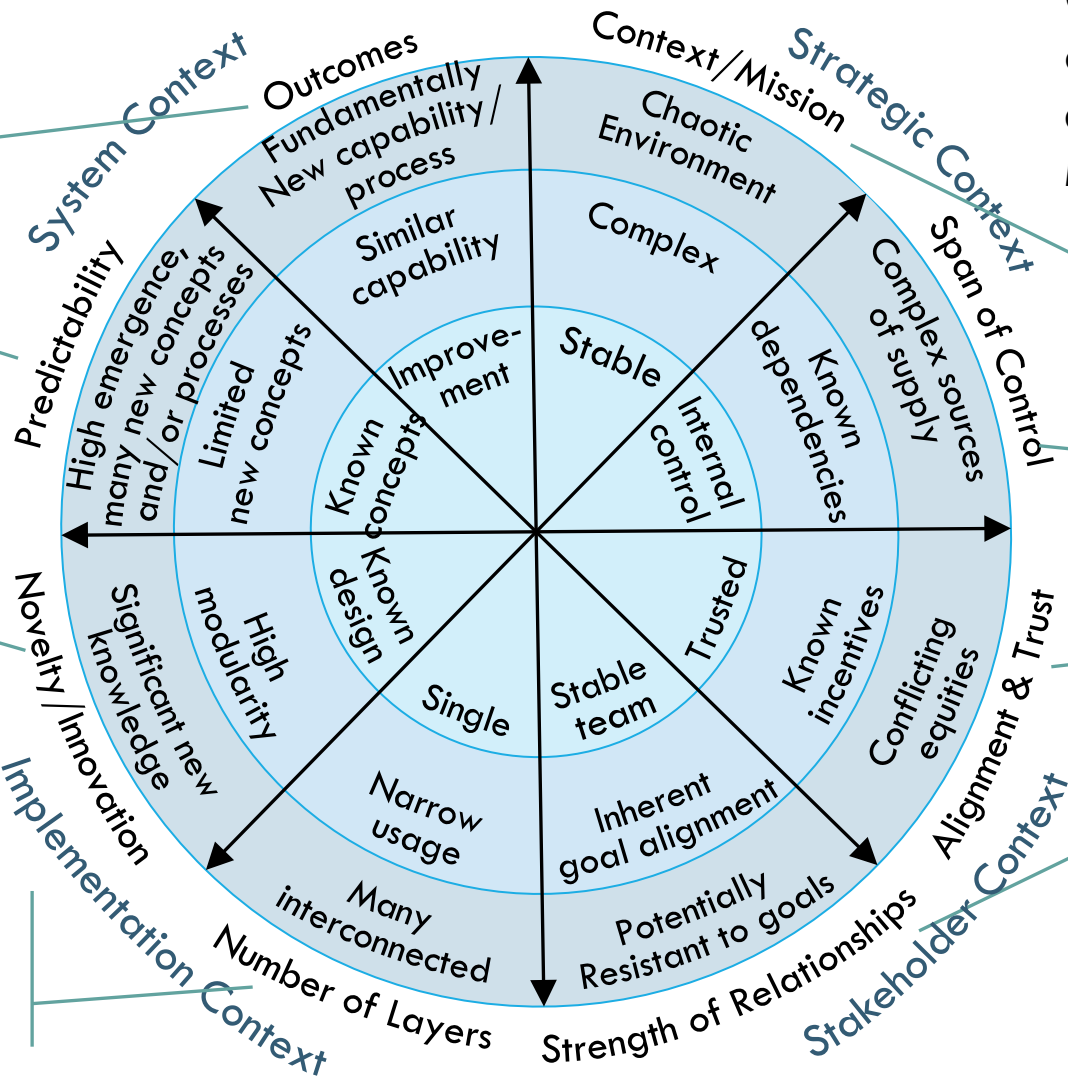
8 Strategies



Adapted from Stevens, R. (2011). Engineering Mega-Systems: The Challenge of Systems Engineering in the Information Age.
Schindler, S. (2019). Contemporary Megaprojects: Organization, Vision, and Resistance in the 21st Century.

4 Contexts and 8 Strategies

Consolidated Framework for evaluating current uncertainties in the megaproject, derived from the Mega-systems and Megaproject literature review



Transformative aspects of megaproject outcomes

Newness of megaproject technologies, processes, and uses

Megaproject state of knowledge associated with concepts & assumptions

Interdependencies across differing disciplines and domains of use

State of the external socio-political environment

Complexity of the leader's control over and project's sources of supply

Potential for conflict between stakeholders

State of leader's relationship with stakeholders

Adapted from Stevens, R. (2011). Engineering Mega-Systems: The Challenge of Systems Engineering in the Information Age. Auerbach Publications.

Megaproject Characteristics and Management Strategies (1)

Megaproject Characteristics	Potential Management Strategies
1) inherently risky because of long planning horizons and complex interfaces	practice risk management but also rigorously evaluate project uncertainties that may lead to risks in later stages
2) often led by planners and managers without deep domain experience, who keep changing throughout the long project cycles	select leadership with skills for megaproject leadership, and carefully manage leadership changes over time
3) multi-actor pluralistic decision making, planning, and management involving multiple stakeholders with conflicting interests	build integrated teams and leadership strategies that create alignment to larger project goals and instill trust
4) often non-standard technology and design, leading to uniqueness bias among planners and managers	limit technical risk, and mature critical technologies outside of project schedule and cost
5) overcommitment at the early project stages, leading to lock-in, poor alternatives analysis, and escalated commitment in later stages	involve critical external and internal stakeholders in incremental decision processes

Bent Flyvbjerg, 2017, "Introduction: The Iron Law of Megaproject Management," in Bent Flyvbjerg, ed., The Oxford Handbook of Megaproject Management (Oxford: Oxford University Press), Chapter 1, pp. 1-18

Derived from project literature reviews and interviews

Megaproject Characteristics and Management Strategies (2)

Megaproject Characteristics	Potential Management Strategies
6) involve large sums of money, leading to principal-agent problems, rent-seeking behaviors, and optimism bias	structure contracts to emphasize management of uncertainty and problem-solving instead of assumed successful outcomes
7) project scope and ambitions typically change significantly over time	employ incremental decision making at the “last responsible moment”
8) project delivery is a high-risk stochastic activity with overexposure to extreme events with massively negative outcomes	“execute fast” – reduce exposure by accelerating schedule when burn rates are high; exercise scenarios for extreme events and build resilience strategies for project execution
9) complexity and unplanned events are often unaccounted for, leading to inadequate budget and time contingencies	build centralized risk pools and monetary incentives for problem solving
10) misinformation about costs, schedules, benefits and risks is the norm throughout project development and decision making	employ emerging technologies for data analysis and visualization that can monitor and alert for emerging project risks

Bent Flyvbjerg, 2017, "Introduction: The Iron Law of Megaproject Management," in Bent Flyvbjerg, ed., The Oxford Handbook of Megaproject Management (Oxford: Oxford University Press), Chapter 1, pp. 1-18

Derived from project literature reviews and interviews

Mega-System Characteristics and Management Strategies

Mega-system Characteristics	Potential Management Strategies
11) decentralized execution and leadership creates diffusion of leadership and authorities	develop strategies for multi-organizational alignment to larger project goals, often set by central authorities (governments)
12) envisioned large-scale system transformations defy traditional development and management processes	develop transformative decision making processes to execute the projects in addition to the system transformation
13) concept of equifinality: there are multiple routes to a specific set of outcomes	conduct multiple planning cases, invest in parallel development of alternatives
14) difficult to predict which concepts will survive to the mega-system completion	invest in experimentation to build knowledge and reduce uncertainties
15) difficult to predict the interactions between different systems and related disciplines, leading to non-holistic decisions	model the adjunct relationships between different systems and decisions

Derived from project literature reviews and interviews

Derived from project literature reviews and interviews

Megaproject Playbook: 12 Best Practices/Lessons Learned for Megaproject Management

1. Establish clarity in the role of “the client”
2. Continuously engage and manage stakeholders
3. Integrate and coordinate across the supply chain, maintain flexibility
4. Use standardized project management processes
5. Decide at the “Last Responsible Moment” (LRM)
6. Plan and define flexible project decision-making behaviors
7. Invest in flexibility to manage risk and uncertainty
8. Invest in digital models and environments for design and project execution
9. Invest in experimentation and test
10. Choose leaders with megaproject skills
11. Maintain and share strategic knowledge
12. Deploy integrated project teams

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QUESTIONS?