Practical Steps for adopting AI-enabled Cost Estimating & Augmented Decision-making

James Arrow, ALDWP-SMO

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Speaker Bio:
James Arrow DRMP FRICS

- Chartered Quantity Surveyor (QS) and professionally certified project risk practitioner:
  - 25+ years Industrial / Commercial Engineering, Procurement, and Construction (EPC) experience working with Fortune 500 contractors and Oil & Gas Supermajors
  - Delivered projects across a broad range of market sectors that include oil and gas, mining, power generation, government operations, aerospace, pharma and IT program management
  - Fellow of the Royal Institution of Chartered Surveyors

- Project-Program Director, Risk Management at LANL, providing project risk management and executive advisory support.

- *Something you don't know about me*: My interest in diving (sky & scuba) helped kick-start my interest in Risk Management.

Agenda

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- ***WHY*** **– The case for change**
  - Digital Disruption & *Revolutionary Change*
  - NSE Inflection Point & the Need for *Evolutionary Change*
- ***WHAT*** **– Opportunities for machine-assisted cost prediction**
  - An Overview of AI, ML & Advanced Analytical Modules
    - The investment funnel and limitations of "narrow AI"
  - Evolving Cost Estimate Methodologies
    - Conventional Probabilistic Cost Estimate Outputs to better Comprehend *Confidence*
  - Cost Prediction in the 21st Century & Our Biggest Risk
- ***HOW*** **– Methodologies for data-driven decision-making**
  - Evolving Cost Prediction & our Prediction Capability Golden Triangle
  - Promoting Risk Data Literacy & Augmented Project Delivery
  - Standards Enabling Data-driven Decision-making
- ***Q&A***

Why (Section 1 of 3):
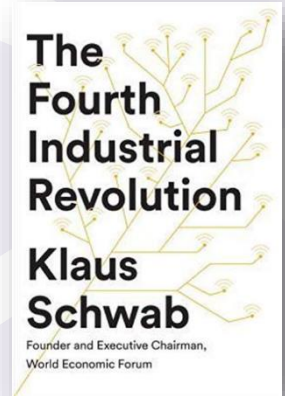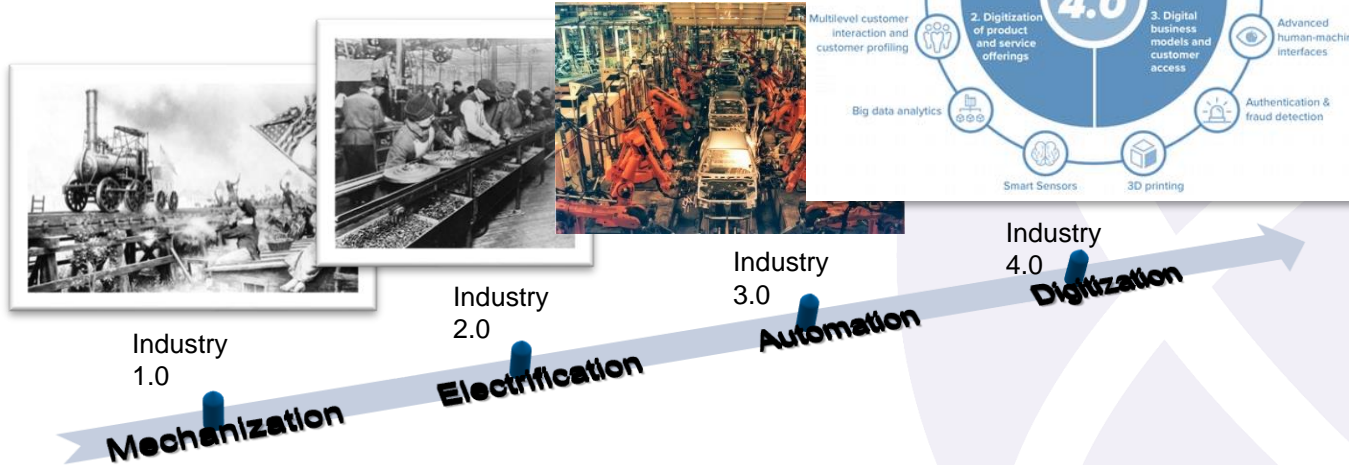# The NSE at the Inflection Point

- Our new era of geopolitics, deterrence, LANL's "fourth age" and the need for *Capability Improvement Planning,* "Toward a Risk Management Culture"

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We live in a transitory world…
The only thing that is certain is change

A Brief History of Industrial Progress

Industry 1.0 — Mechanization
Industry 2.0 — Electrification
Industry 3.0 — Automation
Industry 4.0 — Digitization

INDUSTRY 4.0
1. Digitization / Integration of value chains
2. Digitization of product and service offerings
3. Digital business models and customer access

Mobile Devices
IoT platforms
Location detection technologies
Advanced human-machine interfaces
Authentication & fraud detection
3D printing
Smart Sensors
Big data analytics
Multilevel customer interaction and customer profiling
Augmented Reality
Cloud Computing

The Fourth Industrial Revolution

Klaus Schwab

Founder and Executive Chairman, World Economic Forum

In the new world, it is not the big fish which eats the small fish, it's the fast fish which eats the slow fish

Klaus Schwab
Founder and Executive Chairman
World Economic Forum

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"Toward a Risk Management Culture"

- "According to Darwin's Origin of Species, it is not the most intellectual of the species that survives; it is not the strongest that survives; but the species […] that is able best to **adapt and adjust** to the changing environment in which it finds itself.
  - Megginson, 'Lessons from Europe for American Business', Southwestern Social Science Quarterly (1963) 44(1): 3-13, at p. 4.

- Cost compliance and risk elimination must give way to:
  - innovation,
  - maximized risk awareness and
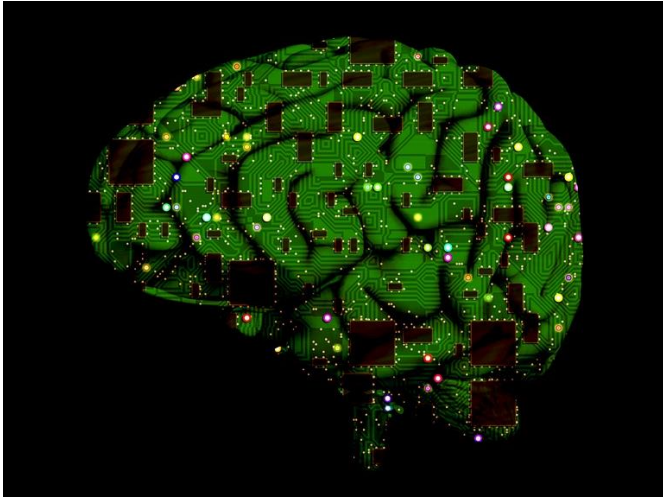 - optimized risk tolerance.

What (Section 2 of 3): Opportunities For Machine-assisted Cost Prediction

- An overview of AI, ML & Advanced Analytical Modules

- AI and the investment funnel

- Federal best practice for comprehending confidence

- From deterministic to probabilistic cost estimates

- Cost prediction in the 21st century

- Our biggest risk

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AI & ML – What's the Difference?

AI concept: building machines that are capable of thinking like humans

Machine Learning (ML) represents the current state-of-the art in the wider field of AI

By Unknown Artist - CC0 Public Domain,
http://maxpixel.freegreatpicture.com/Processing-Artificial-Brain-Intelligence-Circuit-1845944
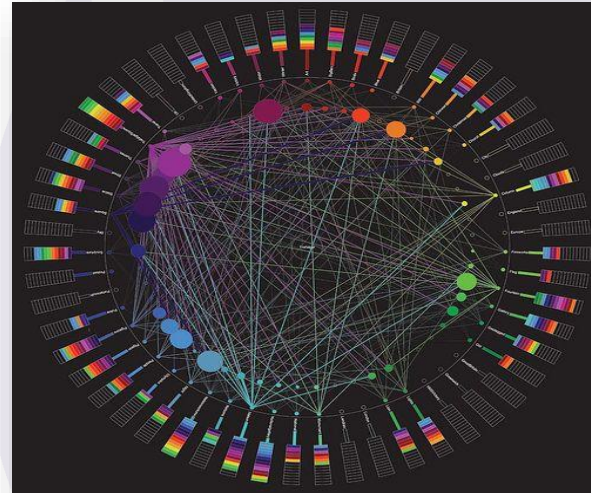

Image courtesy of Booz Allen Hamilton

Source: The Complete Beginners' Guide to Artificial Intelligence, Forbes, 2017

Advanced Analytical Modules

The case for Secondary Modelling & employing *Data Science* methodologies

- No single model holds ***the answer*** to a question.
- Using the conventional, probabilistic analysis of project outcomes as a ***Primary Model,*** project professionals must embrace unconventional data streams and advanced analytical techniques to develop ***Secondary Modelling*** to:
  - **Corroborate** initial uncertainty ranging
  - **Validate** preliminary risk analysis results
  - **Predict** outcomes given current performance
  - **Optimize** outcomes with given current resources

Pouring relevant risk artifacts, **structured *and* unstructured**, into a Data Lake enables organizations to discover new connections and patterns.
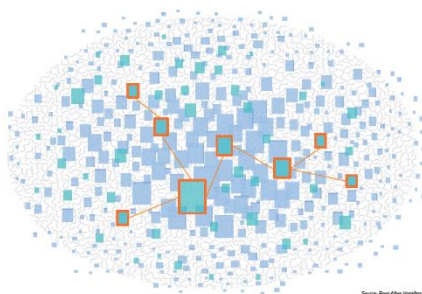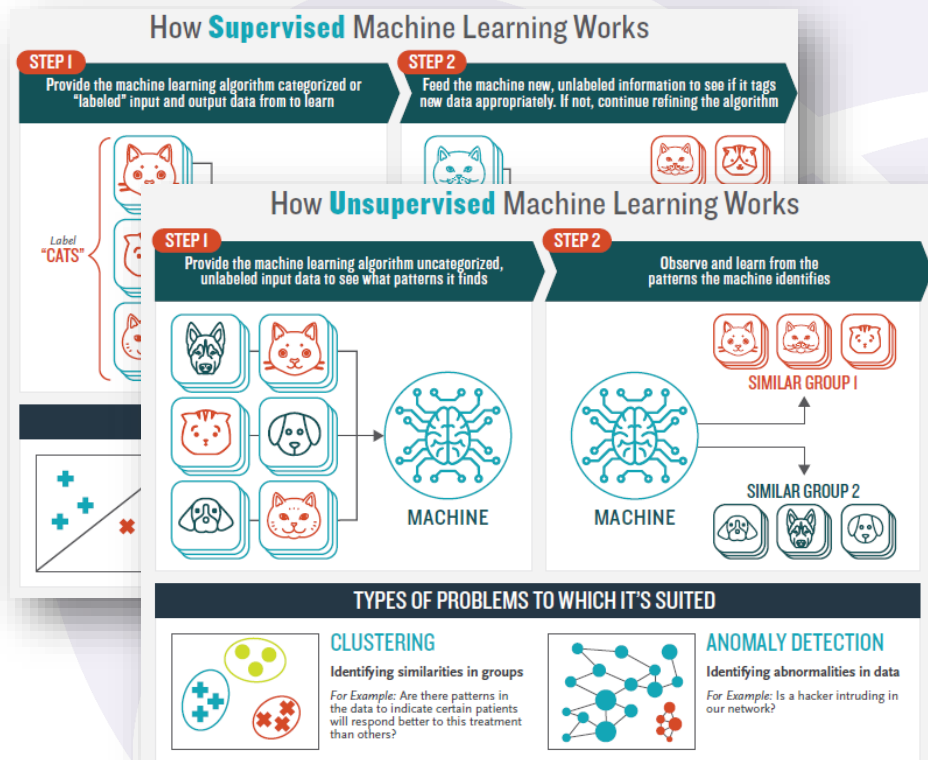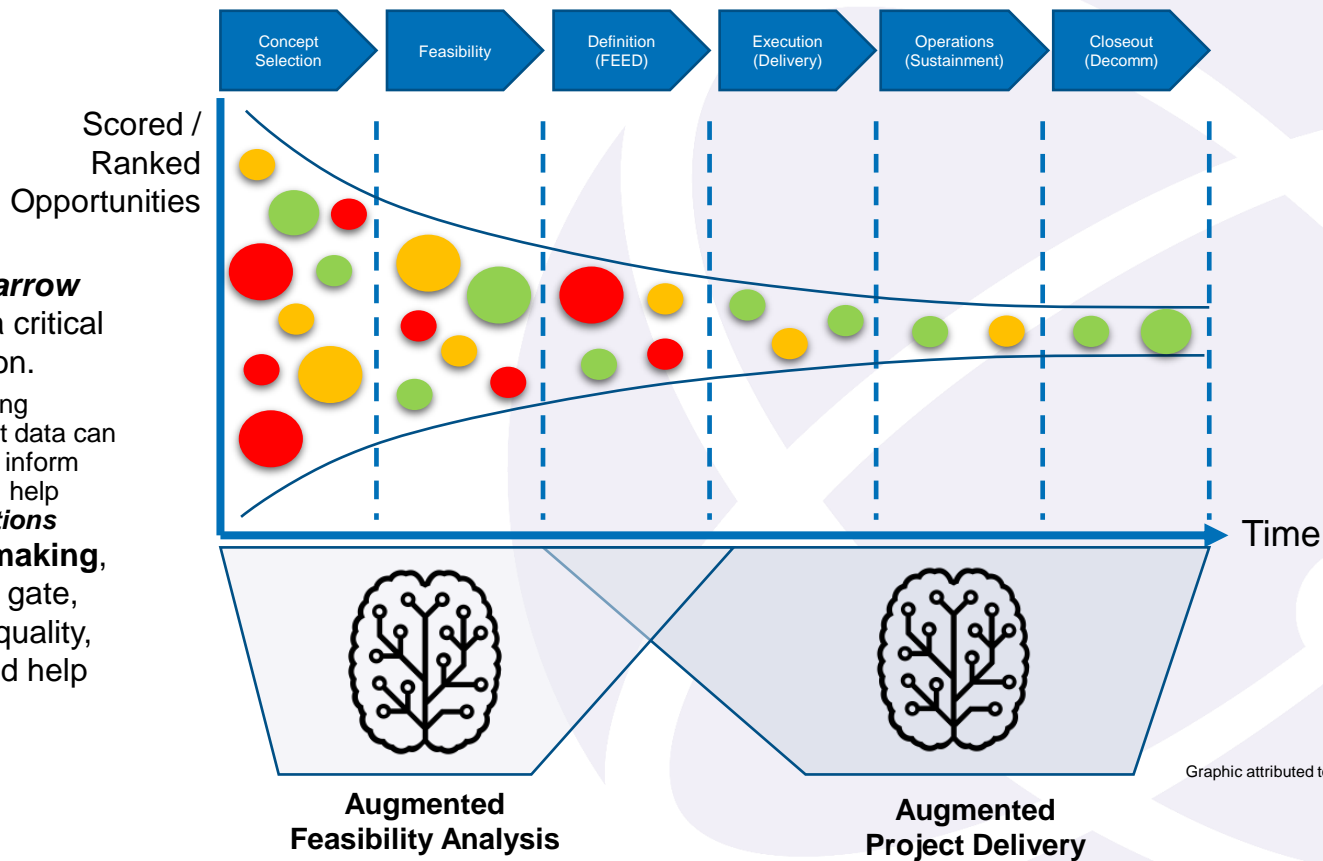
Image courtesy of Booz Allen Hamilton

AI & the Investment Funnel

Guarding against the limitations of *Narrow AI*

- Due the limitations of **Narrow AI,** human oversight is a critical element of any AI solution.
  - An appreciation for existing convention, and how cost data can be used to feedback and inform stage gate decisions, will help guard against **hallucinations**
- **Augmented decision-making**, employed at each stage gate, can help raise decision quality, reduce risk exposure and help deliver ***increasingly predictable outcomes***

| Concept Selection | Feasibility | Definition (FEED) | Execution (Delivery) | Operations (Sustainment) | Closeout (Decomm) |

Scored / Ranked Opportunities

Time

Augmented Feasibility Analysis

Augmented Project Delivery

Graphic attributed to author

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# Federal Best Practices for Credible Cost Estimating

- For our cost estimates to be considered credible, GAO requires us to **conduct risk and uncertainty analysis**.
- We have an opportunity to use machines to **better comprehend** *confidence* in our estimates *and* cost forecasts.

Evolving Project Controls

From Deterministic to Probabilistic Cost Estimates

- * Probabilistic risk analysis, particularly **Integrated Cost & Schedule Risk Analysis** (ICSRA) is widely recognized as best practice today

Input Type: Probabilistic / Deterministic
System Type: Static / Dynamic
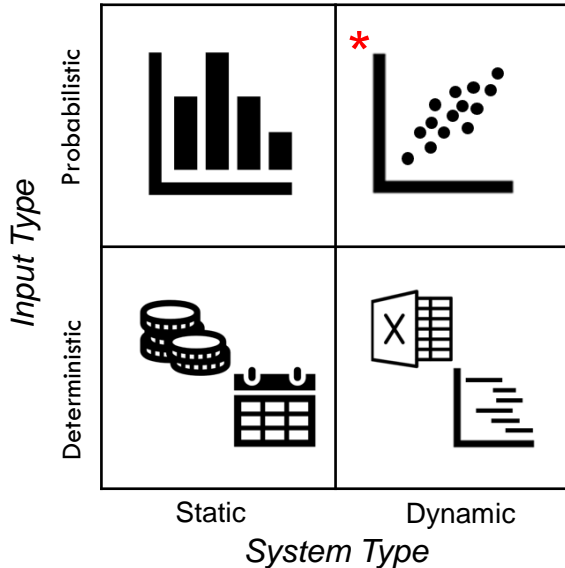
- In Project Controls, *Dynamic Probabilistic* models typically utilize three-point estimates as inputs and these are applied in one of two ways:

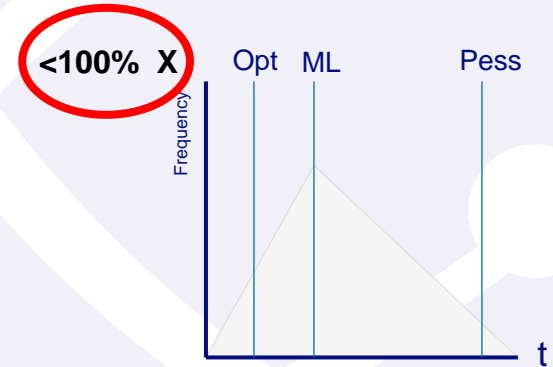### A: Continuous Uncertainty
(aka *General Estimate Uncertainty*)

Uncertainty tied to conditions that are 100% likely
(e.g., assumptions within the underlying Cost &/or Schedule Basis).

Opt   ML   Pess
Frequency
t
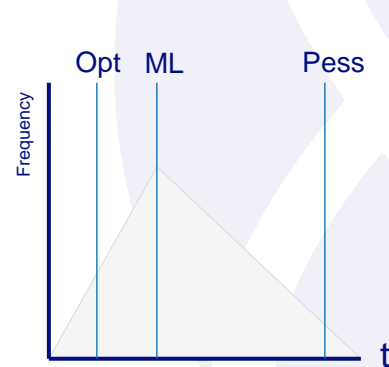
B: Discontinuous Uncertainty
(aka *Discrete Risk Event*)

Uncertainty tied to discrete events that are less than 100% likely.

<100% X

Opt   ML   Pess
Frequency
t

Conventional Probabilistic Cost Estimate Outputs

Estimating simple *Cost Forecast Confidence*

- **Contingency** will depend on the company's or project's required Confidence Level or **Risk Appetite** (sometimes set at P50, P70 or, for example, P80 as shown here).

- In some cases, a **Management Reserve** may be withheld at P90. The delta, from P80 to P90 in this example, is typically intended to account for uncertainty outside the team's control.
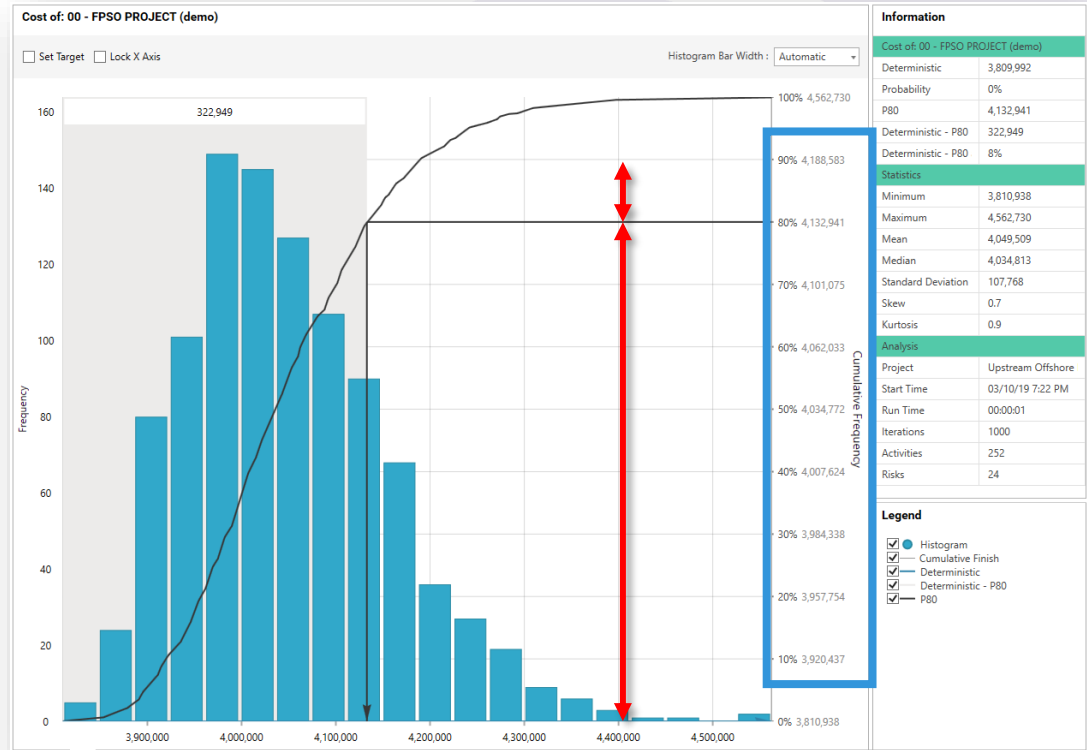
con·fi·dence in·ter·val

/ˈkänfəd(ə)ns ˈin(t)ərvəl/

noun STATISTICS

a range of values so defined that there is a specified probability that the value of a parameter lies within it.
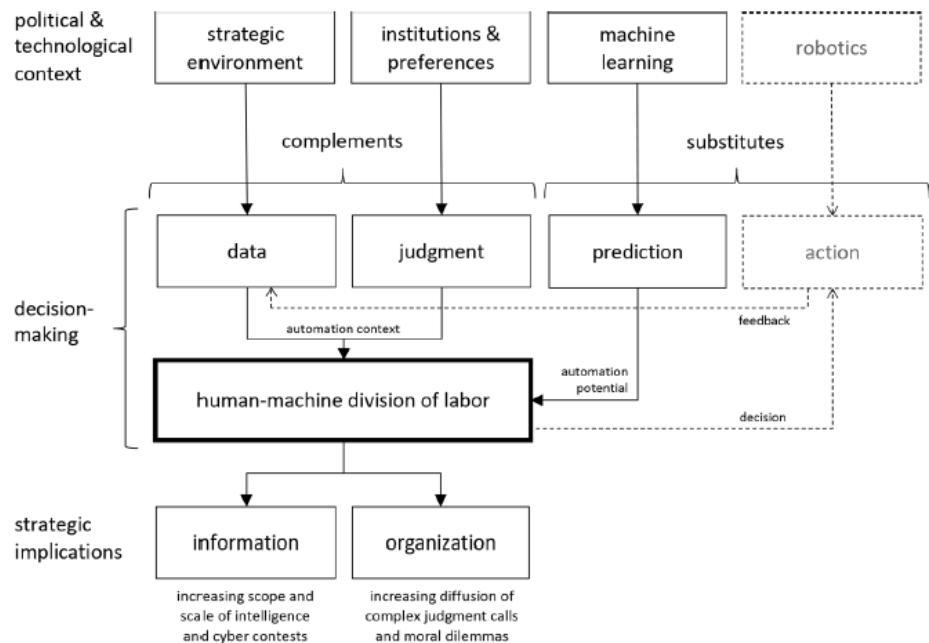
At the 80% confidence interval, our project will cost between $3.9MM & $4.2MM or +3% to +10%.

Data, Judgement & Cost Prediction in the 21ˢᵗ Century

The ongoing need for *Domain Expertise & Data Curation*

Figure 1. The Strategic Context of Decision-Making in Military Organizations

"'The ability of a machine to perceive, evaluate, and act more quickly and accurately than a human represents a competitive advantage in any field— civilian or military. AI technologies will be a source of enormous power for the companies and countries that harness them.' A lack of clarity over basic concepts, however, complicates an assessment of the security implications of AI."

Reference: Avi Goldfarb and Jon R. Lindsay, "Prediction and Judgment, Why Artificial Intelligence Increases the Importance of Humans in War", MIT Press, 2023

- *Data curation*, in support of key decision-makers, is arguably *our most important task today*.

Cognitive Illusion & Our Biggest Risk

Cost Estimating, Underestimating Risk and the evolving influence of Behavioral Science

- Recent advances in behavioral science make one thing clear:

  - "**Your biggest risk is you**"
    Flyvbjerg et al., 2018. Five Things You Should Know about Cost Overrun

  - When calculating contingency, data-driven, evidence-based estimates should be used in place of gut-based intuition.

  - Two systems drive the way we think:
    - **System 1** – fast, intuitive, effortless & emotional
    - **System 2** – slow, deliberate, effortful & logical

- Müller-Lyer optical illusion:
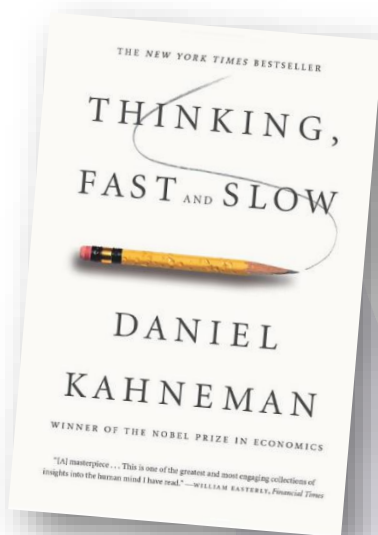
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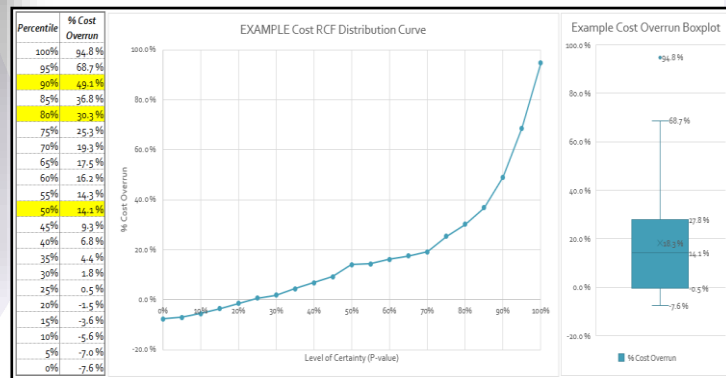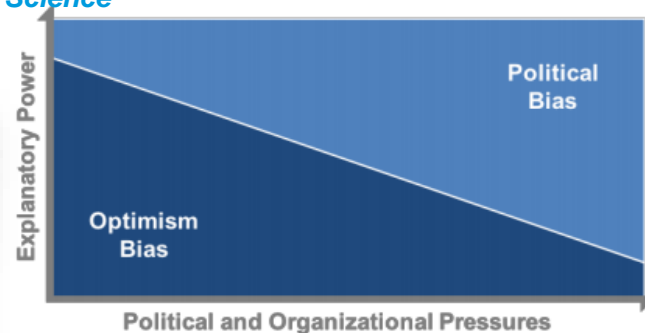
Reference: Transportation Research Part A: Policy and Practice, vol. 118, December 2018, pp. 174-190)
Retrieved March 23, 2021, from https://www.sciencedirect.com/science/article/abs/pii/S0965856418309157?via%3Dihub

Reference: Quantitative Cost and Schedule Risk Analysis of Nuclear Waste Storage - Swiss Energy, DEC 2018, Oxford Global Projects
https://www.researchgate.net/publication/330776007_Quantitative_Cost_and_Schedule_Risk_Analysis_of_Nuclear_Waste_Storage (accessed 12-JAN-22)

Reference: D. T. Hulett Ph.D. FACCE & J. Arrow DRMP FRICS, "RISK-3822 Principles for Quantitative Risk Management", in AACE International Technical Paper, Morgantown, WV, 2022

How (Section 3 of 3): Methodologies for Data-driven Decision-making

- Evolving cost prediction capability

- The cost prediction capability golden triangle

- Promoting risk data literacy

- Augmented Project Delivery Value Model

- Secondary modelling & tools for enabling an *Outside View*

- The ABC of Reference Class Forecasting (and acknowledging *Regression to the Tail*)

- *AI in Action* (use case example; prediction vs mitigation)

- *Standards enabling data-driven decision-making*

Evolving Cost Prediction Capability

Characteristics:

1. **Naïve** – Pre-determined contingency levels.
2. *Ad-hoc* – One or more assessments using external experts.
3. **Descriptive** – Frequent, centralized analyses utilizing standardized inputs.
4. **Dynamic** – Monthly analyses, updated using *Big Data* derived from conventional and unconventional streams.
5. **Adaptive** – Near real-time analyses utilizing *Fast Data* streams from across the *risk ecosystem*.

Sustained with Conventional & Unconventional Data Streams

Sustained with Conventional Dollar & Day Inputs

1: Naïve

2: Ad-hoc

3: Descriptive

4: Dynamic

5: Adaptive

TCMA
(*Total Cost Management Analytics*)
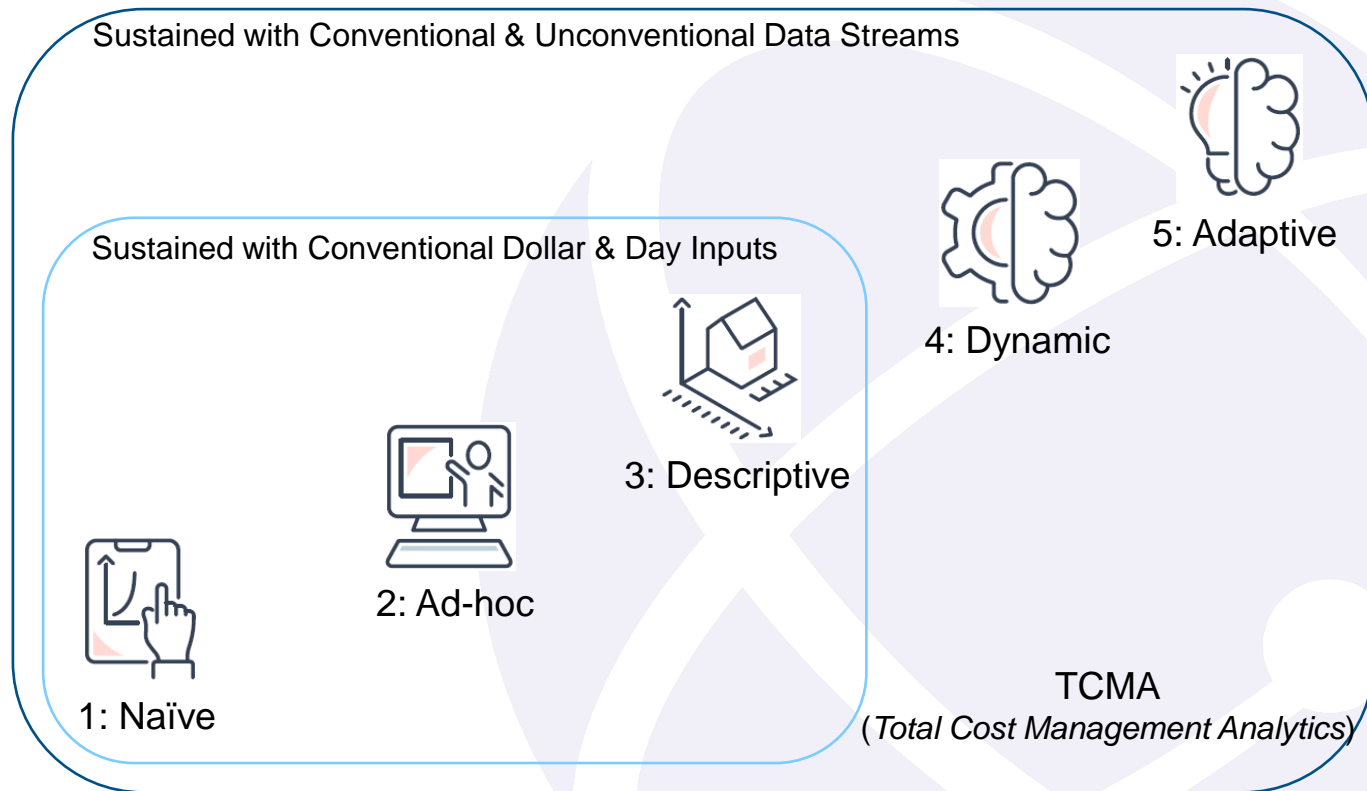
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The Cost Prediction Capability Golden Triangle

- Best outcomes achieved via an optimal balance between *People, Process & Technology*:

  – *Benefit attributes* (within center triangle)
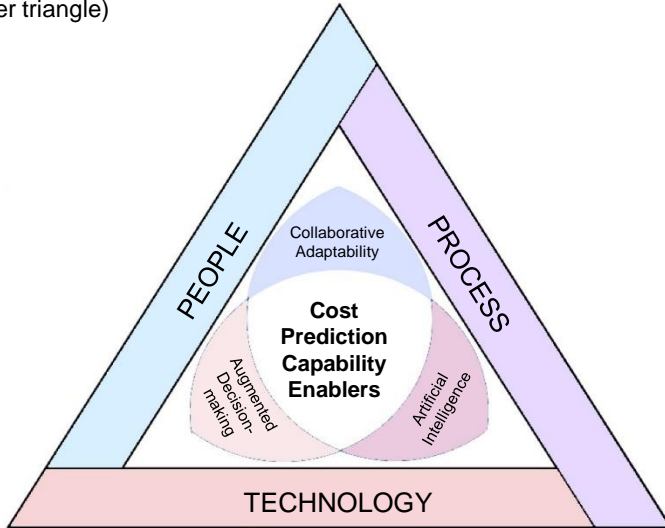
- **Strategies to optimize team performance** can be framed in terms of *people*, *process* and *technology*:

  − People
    - **Risk Management Culture** -- We have a responsibility to manage "uncertainty that matters" within our sphere of influence and recognize the value in curating risk data, throughout project delivery lifecycle.
    - **Data Literacy** -- We actively develop our ability to analyze probable outcomes, learn from past experience and deliver increasingly predictable results.

  − Process
    - **Data Standards** -- We employ data standards that ensure good data quality and timely development of *minimally viable metrics* to facilitate data-driven decision-making.
    - **Portfolio Risk Management** -- We ensure the efficient allocation of resources, both by accurately quantifying risk and by providing resilience against business-as-usual threats, at an enterprise level.

  − Technology
    - **Advanced Analytics** -- We seek to employ technologies that utilize diverse data sources, facilitate inductive reasoning and reveal, conventionally hidden, opportunities to leverage actionable insight.

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Promoting Risk Data Literacy

Image Credit & License; By Matěj Baťha (Own work) [CC BY-SA 2.5 (https://creativecommons.org/licenses/by-sa/2.5)], via Wikimedia Commons

- We don't know exactly what will happen but, **with the right data, the likelihood of future events can be calculated**.

- Numerical forecasting is one of the greatest intellectual achievements of the past century.

  - A ten-day weather forecast today, is as accurate as a three-day forecast was ten years ago.

- Team-wide **data literacy better facilitates probabilistic controls**.

  - Probabilistic project controls enable ever-improving prediction accuracy.

- Probability theory and the scientific method can help minimize bias and **avoid the underestimation of risk**.

- A risk-based competitive advantage can be secure by achieved via an optimal balance between *People, Process & Technology*

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Value Model for Augmented Project Delivery

Developing Processes and Standards for Analyzing *Relevant Risk Signals*

Feedback mechanisms for improving predictability…

Conventional Inputs: e.g. % Complete, CPI & SPI

Data Quality

Data Science Capability

Standard Performance Metrics

Data Curation

Data Management

Advanced Data Analysis e.g. Predictive Analytics

Augmented EAC / Forecast

Increasingly *Predictable* Project Outcomes

Exploratory Measurements

Hardware / Software Configuration

Stakeholder Expectations

Proprietary KPI & KRI Metrics

Knowledge Management *Feedback* Loop

KEY

Primary or dependent variable

Driving forces

Area for research / site collaboration

Technologies for Secondary Modelling

Tools for enabling an Outside View

Quantity Uncertainty *x 5,000 iterations*

Productivity Uncertainty *x 5,000 iterations*

Unit Cost Rate Uncertainty *x 5,000 iterations*

Duration Uncertainty *x 5,000 iterations*

CRA
Cost Risk Analysis

SRA
Schedule Risk Analysis

CONVENTIONAL
Data Streams
(Primary Modelling)

Quantitative Risk Management
(Frequent reconciliation of strategic and tactical analyses)

ICSRA
Integrated Cost & Schedule Risk Analysis

UNCONVENTIONAL
Data Streams
(Secondary &/or Ensemble Modelling)

aconex

ALICE TECHNOLOGIES

AUTODESK

ZEBRA

Rombit
CONNECT THE FUTURE

INDUS.AI
CONSTRUCTION INTELLIGENCE

PRECISIONHAWK

Time dependent & time independent cost uncertainty blend

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Reference: D. T. Hulett Ph.D. FACCE & J. Arrow DRMP FRICS, "RISK-3822 Principles for Quantitative Risk Management", in AACE International Technical Paper, Morgantown, WV, 2022
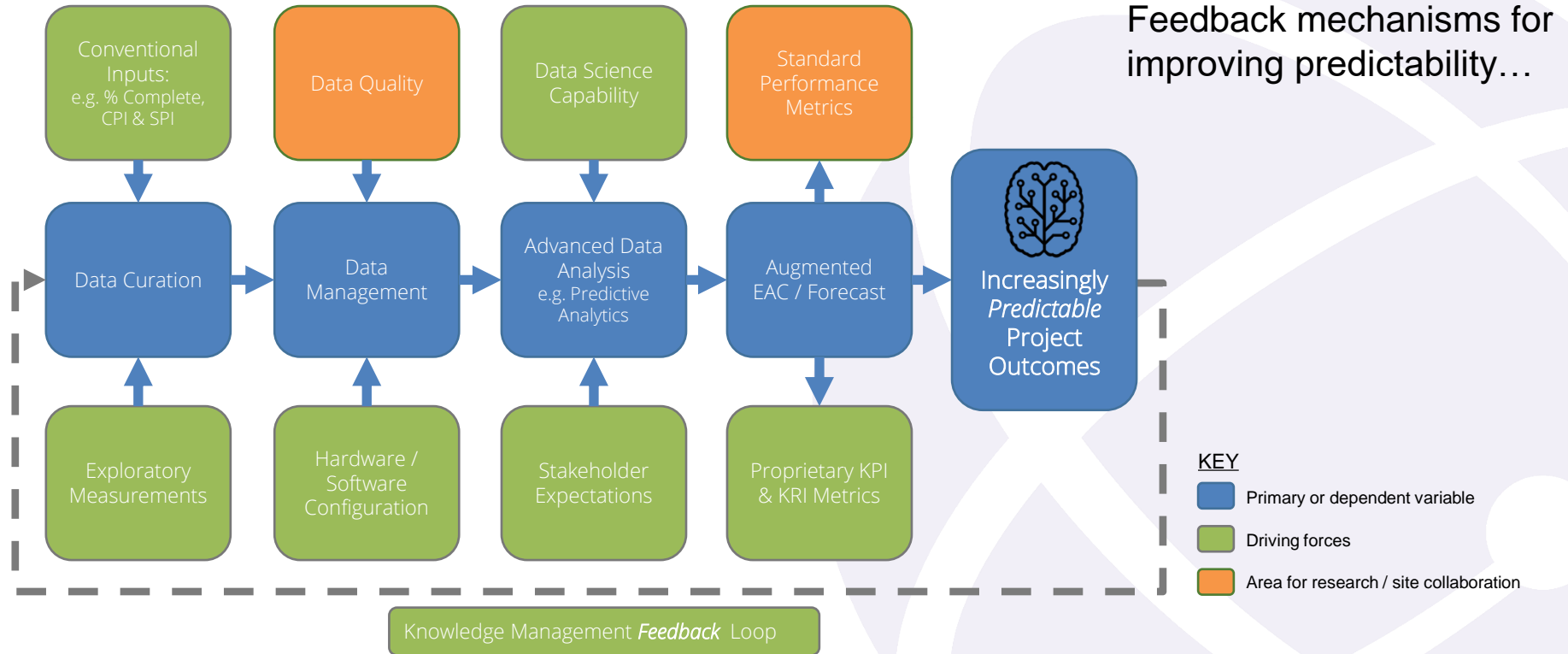
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Narrow Results & The ABC of RCF

Regression to the Tail & steps for establishing an Outside View

- Reference Class Forecasting (RCF) is comprised of three steps:

  A. Assemble a reference class of past, similar projects (while avoiding uniqueness bias!)

  B. Establish the cumulative probability of outcomes under review

  C. Adjust the original estimate (inside view) by comparing the project under analysis with the reference class (outside view)

- Recommendations to account for bias need to align with the organization's risk appetite (defined within the *risk policy*)
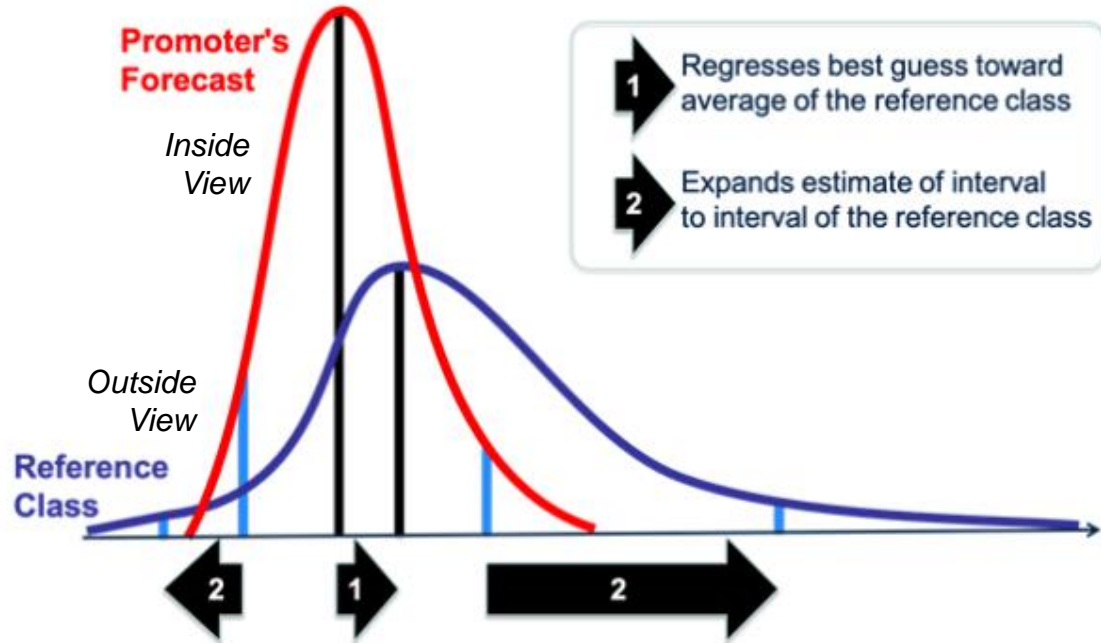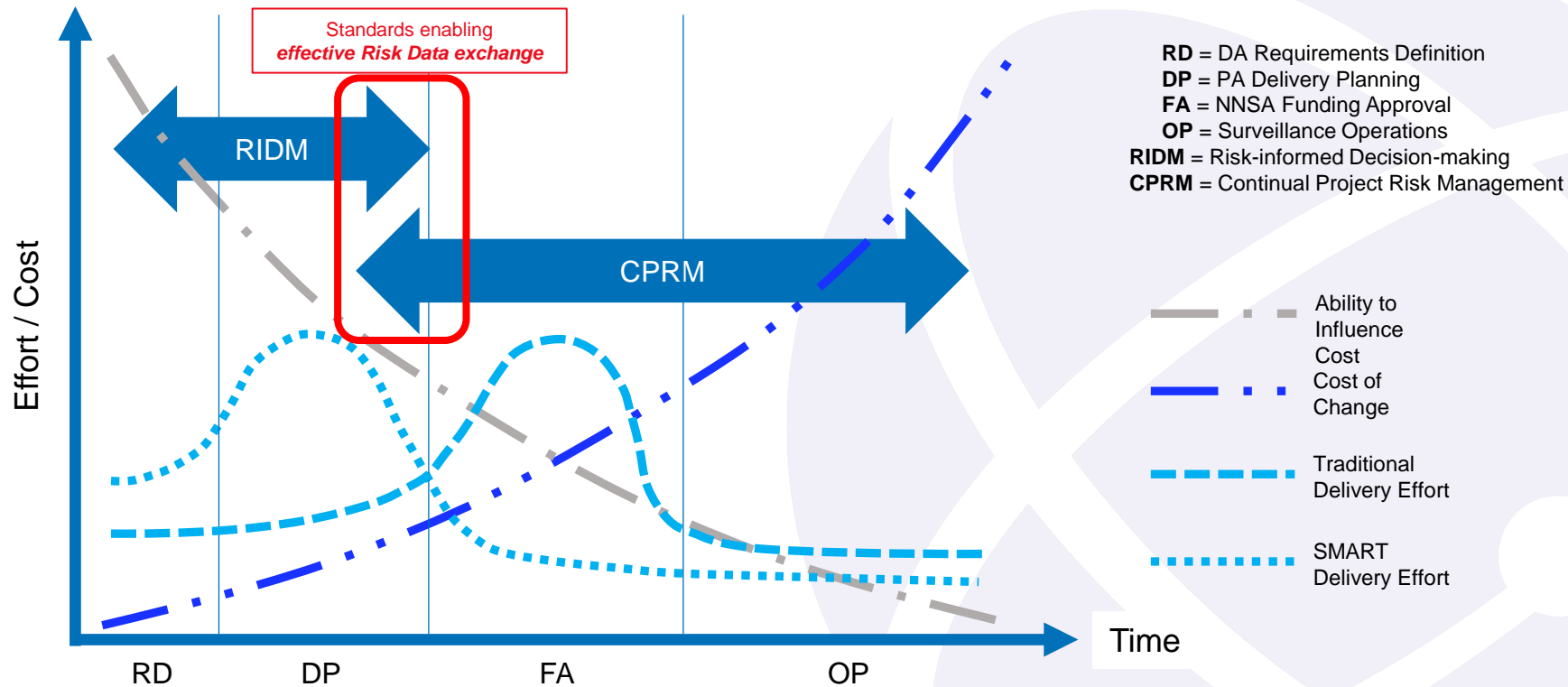

Flyvbjerg, B. (2009). Survival of the unfittest: Why the worst infrastructure gets built—and what we can do about it. *Oxford Review of Economic Policy, 25*(3), 344-367. Retrieved April 8, 2021, from http://www.jstor.org/stable/23607068

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AI-driven Project Supervision System (PSS)

- "Senior managers lack the daily and deep involvement in their projects. They need the right monitoring tools and early-warning systems to help them in their supervision."

- One of the key challenges is, "the sensitivity to timescales in taking corrective action."

- AI (artificial intelligence) can play a part in accurately predicting project outcomes and proactively ID when a project is going off track, allowing early intervention.

- "**AI needs only a very small amount of data to make good predictions**".

    - The algo only knew cashflow & project type. "Adding more data in the future will certainly improve the accuracy."

- On average, forecasted outturn cost was within ±8%.

Ref.: Flyvbjerg, Bent, et al. "AI in Action: How the Hong Kong Development Bureau Built the PSS, an Early-Warning-Sign System for Public Works Projects." Papers.ssrn.com, 17 Aug. 2022, papers.ssrn.com/sol3/papers.cfm?abstract_id=4192906 . Accessed 15 Dec. 2022.

Standards enabling Data-Driven Decision-Making

Standards enabling *effective Risk Data exchange*

RIDM

CPRM

RD = DA Requirements Definition
DP = PA Delivery Planning
FA = NNSA Funding Approval
OP = Surveillance Operations
RIDM = Risk-informed Decision-making
CPRM = Continual Project Risk Management

Effort / Cost

Time

RD   DP   FA   OP

Ability to Influence Cost

Cost of Change

Traditional Delivery Effort

SMART Delivery Effort

Adapted from Ilozor & Kelly, CC BY-NC-ND 4.0
https://bit.ly/2Gyio15 & MacLeamy.com, accessed 10/JAN/22

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Summary

Conclusion

The virtues of a Risk-based Kaizen philosophy

Human & Robot
Concept of the future

- Mathematical probability can help us better predict project outcome.
- Data is not someone else's job; **raising your level of *Data Literacy* is crucial** if we are to unlock the full potential of data in our industry.
- A continual improvement program can deliver *risk-based competitive advantage*.
- ***AI won't replace Project Professionals but Project Professionals who use AI will replace those who don't.***

Follow-up questions
or other feedback:
jearrow@lanl.gov