Construction Challenges and Success in Mega-Projects

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Some Key Thoughts

- Optimism Bias
- Cognitive Bias
- Bias Confirmation
- Strategic Misrepresentation
- Deception, Manipulation, Lies
- Scope definition
- Risk Management
- Lessons Learned
- Independent Assessments and Estimates
- Owner Involvement
  - Owner expertise

Two “Challenged” Projects: Olkiluoto 3 Nuclear Power Plant in Finland

Olkiluoto 3 Nuclear Power Plant in Finland

Flamanville Nuclear Power Plant, France
-both are the first European Pressurised Reactors (EPR)
-Areva, EDF and Siemens: 1,600 megawatt reactors

Olkiluoto 3

- Construction started in August 2005
- Unit 3 was initially scheduled to go online in 2009
- Initial cost estimates were about €3.2 billion
- Current cost estimate is about €9 billion (281% of the original estimate)
- Current online date 2018–2020, over nine years late

Flamanville

- Construction started in December 2007
- Was initially scheduled to go online in 2012
- Initial cost estimate was € 3.3 billion
- Current cost estimate is € 10.5 billion (318% of the original estimate)
- Current completion of *construction* is 2017 at best
- Startup late 2018 at best

Olkiluoto 3

- **Major problems:**
  - concrete
  - heavy forged components
  - Welding
- **Impact:**
  - Finland cancels Olkiluoto 4 nuclear reactor – is the EPR finished? Finland cancelled its option for a second European Pressurised Reactor

Flamanville

- **Major problems:**
  - reinforced concrete
  - Fabrication defects in the reactor pressure vessel
  - faulty valves

Flamanville Nuclear Power Plant, France

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- **Impact:**
- *"If the weakness of the steel is proved, I don't hold out much hope for the survival of the [Flamanville] EPR project."*

Flamanville Nuclear Power Plant, France

- On 7 April 2015, the French Nuclear Safety Authority (ASN) announced that fabrication defects had been found in the reactor vessel of the Flamanville EPR, forged by Areva's Creusot Forge subsidiary. Tests revealed areas with high carbon concentration resulting in *"lower than expected mechanical toughness values"*.
- Pierre-Franck Chevet, head of ASN, said: *"It is a serious fault, even a very serious fault, because it involves a crucial part of the nuclear reactor."*
- The results of further tests are expected by October 2015. In one scenario, ASN will not require any remedial action and there will be minimal consequences for Areva. But if remedial action or replacement is required, it could be extremely expensive and problematic for Areva, all the more so because the pressure vessel has already been installed in the Flamanville EPR.

  In a worst-case scenario for Areva, the pressure vessel problem would kill the Flamanville reactor project. A former senior nuclear safety official told *Le Parisien*: ***"If the weakness of the steel is proved, I don't hold out much hope for the survival of the [Flamanville] EPR project."*** *

*Dr Jim Green & Oliver Tickell, The Ecologist, 15 May 2015

Flamanville Nuclear Power Plant, France

- **"Areva, France's nuclear giant, has been aware *since 2006* that the steel vessel of its flagship new-generation reactor that confines radioactivity is faulty, it was reported on Wednesday.**
- "Until now, it was thought that Areva had only recently become aware of 'very serious' anomalies in its €9* billion European Pressurised Reactor, or EPR – the same model sold to Britain.
- "In April, it was revealed that excessive amounts of carbon in the steel in the top and bottom of the reactor's vessel, which forms a shell around it, could cause cracks which could prove disastrous, since the vessel, which houses nuclear fuel, cannot be replaced during the lifespan of the reactor.
- "…a document from the **French Institute for Radiological Protection and Nuclear Safety (IRSN)**…states that certain parts of the reactor vessel contain twice the permitted norm of carbon, running the risk of it being too brittle to sustain massive pressure increases.
- "Areva's 'incomprehensible' silence over the anomalies meant that it proceeded with installing the 160 ton part, which takes six years to complete, instead of forging a new one…"

Flamanville Nuclear Power Plant, France

- "Areva said on Wednesday 'If you're asking whether anything has been hidden, the answer is categorically no.' a spokesman told Le Monde. However, it said it could not rule out a quality control lapse and that management had launched an internal review and an external audit of two of its factories."

– The Telegraph (UK), 7 February 2016

*Flamanville plant now reported to be €10.5 billion

Flamanville Nuclear Power Plant, France

- **Faulty valves in new-generation EPR nuclear reactor pose meltdown risk, inspectors warn***
- Flamanville third-generation EPR nuclear reactor – the same model Britain plans to use for two new plants at Hinkley Point – has multiple faults in crucial safety valves
- France's nuclear safety watchdog found "multiple" malfunctioning valves in the Flamanville EPR that could cause its meltdown, in a similar scenario to the 1979 Three Mile Island nuclear accident in the US.
- The faulty safety relief valves are situated on the pressuriser, which regulates the high pressure within the primary circuit where water cools the nuclear fuel by releasing steam when necessary. The failure of a pilot-operated relief valve in the primary circuit was a key factor in the partial meltdown of a reactor at the Three Mile Island plant in the US in March 1979, and which led to the halting of America's civil nuclear power programme.
- This is the latest setback for what is supposed to be France's atomic energy showcase abroad, following the revelation last month that its steel reactor vessel has "very serious anomalies" that raise the risk of it cracking. The vessel houses the plant's nuclear fuel and confines its radioactivity.
- On Tuesday, **IRSN** confirmed tests conducted by EDF showed "difficulties in opening and shutting valves".

*The Telegraph (UK) 15 September 2015

Flamanville Nuclear Power Plant, France – Additional Impacts

- Last week, the French government announced Areva NP, the nuclear reactor arm of state-controlled Areva, is to be sold to EDF, its former client which also operates all of France's 58 nuclear reactors.
- The move followed Areva's announcement in March that it had racked up record losses in 2014 of €4.8 billion.
- EDF is in the final phase of negotiations with the British government on building the two Hinkley plants in Britain, which in February it said would be "possible in the next few months".* However as of March 2016, legally binding contracts had not been agreed.**
- Designed to be the safest reactors in the world and among the most energy-efficient, the €9 billion (£6.5 billion) EPR has suffered huge delays in models under construction in France, Finland and China.

*The Telegraph (UK) 15 September 2015

*The Guardian (UK) 9 March 2016

Fallout from these troubled mega-projects: "A global collapse in confidence"

- Two EPRs under construction in China are *13-15 months behind schedule*. China will not fuel the reactors until the open issues with the reactor pressure vessel fabrication in France are resolved.
- The UK government has been keen to press ahead with a twin EPR reactor 3.2GW power plant at Hinkley Point in Somerset supported by the most generous nuclear subsidy package ever assembled, but no order has yet been signed – even though Areva subsidiary Creusot Forge has already forged its pressure vessels.
- In the US, a total of seven EPRs were planned at six sites. Four EPR construction license applications were submitted to the Nuclear Regulatory Commission (NRC) but all four applications have been abandoned or suspended. In February 2015, Areva asked the NRC to suspend work on EPR design certification until further notice.
- EPRs were considered at various sites in Canada – including Alberta and Darlington, Ontario – but those plans were shelved and a generic licensing process by the Canadian Nuclear Safety Commission was terminated.*

*Dr Jim Green & Oliver Tickell, The Ecologist, 15 May 2015

The Major Drivers of Risk

- Professor Bent Flyvbjerg of Oxford University and Martin Wachs of University of California, Los Angeles have shown that big public-works projects often have cost overruns due to strategic misrepresentation—"that is, lying", as Flyvbjerg defines the term.

- A project's budgeted costs should always include cost contingency funds to cover risks.
- As has been shown in cost engineering research, poor risk analysis and contingency estimating practices account for many project cost overruns.
- Numerous studies have found that the greatest cause of cost growth was poorly-defined scope at the time that the budget was established. The *cost growth* can be predicted by rating the extent of scope definition, even on complex projects with new technology.

The Major Drivers of Risk – My take on the information:

- The problems are related to fabrication of components, and construction quality issues on site.
- Nuclear engineers who develop reactor technology are not the engineers who will have to design, and construct, the entire plant.
- From first hand experience, the European approach by owners to management of construction by their contractors is not the same as we know in the USA.
- The utilities company owners in Georgia and South Carolina certainly know about the experiences in Europe.
- Are we too putting too much of an over-reliance on factory fabrication, called “manufactured” items, and certifications?
- Is there sufficient owner evaluation of risk, involvement in planning, and active construction project management?

A Success Story: USACE West Closure Complex Hurricane Protection

USACE West Closure Complex Hurricane Protection

- Includes a 225 feet navigable floodgate.
- When the gate is closed during a storm event, the 19,426 cubic feet per second (cfs) 11 bay pump station is required to evacuate the rainwater that is pumped into the Harvey and Algiers canals by 9 other pump stations along the canals.
- The pump station complex, which is the largest of its type in the world, consists of 11 each 5444 horsepower Caterpillar engines.
- Project includes a floodwall of 4,216 feet plus extensive levees.

USACE West Closure Complex Hurricane Protection

- Design and selective CM contract awarded in April 2008 to Bioengineering Group & ARCADIS.
- Project used the Early Contractor Involvement – the first time for a Civil Works project. Contractor was Kiewit/Traylor Brothers JV, chosen by best value source selection.
  - ~ $1 billion
- Driver was useable completion by June 2011, in time for the hurricane season
- Success Story – all issues resolved bilaterally
  - Independent Review and Cost Estimate

USACE Employs Best Practices

- Hands-on management by the USACE office as the owner
- "The Nation's trusted professionals"
- Utilization of their staffing model to assure the right mix of expertise, and the numbers of oversight personnel at the project level
- Employment of support contractors, and detailed Feds, to meet requirements of project phases
- Meaningful owner-contractor interaction with well qualified owner team
- ATRs – Agency Technical Reviews (internal)
- IEPRs – Independent External Peer Reviews (external)

Nuclear Plant Construction in the USA – Toshiba-Westinghouse AP1000

- Each plant will have 2 AP1000 reactors at 1,200 megawatts each, for a total of 2,400 megawatt capacity.
- "The Vogtle nuclear facility in Georgia and the V.C. Summer nuclear facility in South Carolina are both some three years behind schedule in construction and each is expected to come in billions of dollars over their original budgets. These poor performances are expected to discourage further U.S. Investment in nuclear power in the near term."

-Utility Dive, August 24, 2015

Plant Vogtle – Georgia USA

Southern Co. Photo

Plant Vogtle – Georgia USA

Southern Co. Photo

Virgil C. Summer Nuclear Plant

Plant Vogtle

- COL issued Feb 2012
- 2009 estimate: $14.1 billion
- 2015 estimate: $21 billion

- Unit 3 original online date: April 1, 2016
- Current Unit 3 estimated date: June 2019

- Unit 4 original online date: April 1, 2017
- Current Unit 4 estimated date: June 2020

Plant Vogtle

- **Major problems:**
  - Georgia Power's filing (with the PSC) blames the additional costs on Westinghouse delays in…**major equipment fabrication** and deliveries…as well as CB&I's **delays in module fabrication** and deliveries and **field construction performance."**
  - Supposed integration of "lessons learned" from (Vogtle) Unit 3 apparently was also not resulting in reducing schedule delays for Unit 4.

Virgil C. Summer Nuclear Generating Station

- **Major problems:**
  - "We are not pleased with the delays in the construction schedule for our new nuclear plants. These delays and related cost increases are principally due to design and fabrication **issues associated with the production of submodules** used in construction of the units," Kevin Marsh, chairman and CEO of SCANA Corp. (SCE&G's parent company), said in a press release.
  - The NRC (2013) found that the **anchorage and spacing of rebar in the floor and walls** of a new unit at the V.C. Summer nuclear station didn't comply with code requirements.

Plant Vogtle – Georgia, USA

- "The delays are indicative of restarting the nuclear industry after a 30 year hiatus."
  - William Jacobs, independent monitor as quoted in the Atlanta Business Chronicle, June 23, 2015.

Impacts

- Westinghouse announced in October 2015 that it will acquire CB&I, the lead sub-contractor that has experienced major problems with module construction, even after taking over for Shaw
- Westinghouse has brought in Fluor Corp. to manage the four Toshiba-Westinghouse AP1000 reactors (Vogtle and V.C.Summer)

Impacts

- "South Carolina Electric & Gas customers are now saddled with the 8th nuclear prepayment fee rate hike, amounting to 15.5% of their monthly electric bill."

  – CleanEnergy.org, (Southern Alliance for Clean Energy), October 1, 2015

  "(Georgia) customers are already paying more than 9.4% on their monthly bills…due to state legislation passed in 209 to incentivize building new reactors."

  – NC Warn.org, December 11, 2015

Impacts and Ripple Effects

- "TVA said today it will tell regulators it is giving up its plans to build a pair of Westinghouse AP1000 reactors at the Bellefonte Nuclear Power Plant in Hollywood, Ala." (Note: Bellefonte 3 and 4)

  – (Chattanooga) TimesFreePress.com, February 12, 2016

  "The TVA, which planned a decade ago to begin an American renaissance in nuclear power by building the first next-generation nuclear reactors in Alabama, is abandoning those plans because of shrinking power demand and rising nuclear construction costs."

  – (Chattanooga) TimesFreePress.com, February 13, 2016

Impacts and Ripple Effects

- Is this the end of new nuclear power in the USA, at least for the foreseeable future?
- Certainly, demand for power plays a key role
- As do the trends for the price of oil and other fossil power plant costs
- BUT: Did America's project managers and engineers, by failure to realistically apply lessons learned and best practices, ourselves contribute to the current state of affairs?

Only Two Owner Behaviors that show strong correlation to success!

- The Answer Up Front:
  - Owner engagement at a level not common in most organizations.
  - Independent assessments, estimates, and progress reviews from planning through completion of the project.

Major Publications Resources

- **Megaprojects and Risk: An Anatomy of Ambition**
  - By Bent Flyvbjerg, Nils Bruzelius, Werner Rothengatter, 2003
- **The Major Drivers of Risk**
  - By Bent Flyvbjerg, Martin Wachs
- **Predicting Construction Contract Failure Prior to Contract Award**
  - By Jeffrey S. Russell and Edward J. Jaselskis
- **Optimal Allocation of Project Management Resources for Achieving Success**
  - By Edward J. Jaselskis and David B. Ashley
- **Determination of Construction Project Success**
  - By David Ashley, Clive Lurie, Edward J. Jaselskis

Error or Lie?
Bent Flyvbjerg, Mette Skamris Holm, and Søren Buhl

- Based on a sample of 258 transportation infrastructure projects worth US$90 billion and representing different project types, geographical regions, and historical periods, it is found with overwhelming statistical significance that the cost estimates used to decide whether such projects should be built are highly and systematically misleading. Underestimation cannot be explained by error and is best explained by strategic misrepresentation, that is, lying.

Predictors of Success Jaselskis and Russell

- No empirical aids that include the interaction of key inputs to the evaluation process such as project, owner, contractor…exist to assist.. . in the decision process. No prior investigations have attempted to develop failure models for predicting construction project outcomes. **Input from both owner and contractor are the primary focus of this investigation.**
- 36 projects were included in the study. The top two owner behaviors are the strong predictors of contractor (success or) failure: The amount of **owner** evaluation and interaction; and whether or not regularly scheduled cost monitoring was performed by the **owner.**
- The **owner** should perform periodic performance monitoring, including cost monitoring, unit pricing for work items prior to the start of construction (*NB:* an element of EVMS), measurements to be used to measure progress (*NB:* also an element of EVMS), progress reviews, and job site tours, at least twice per month.

Jaselskis and Ashley

- Successful owners tend to expend more effort in terms of monitoring and appraising performance of the construction project, especially in the areas of quality and safety. In these two areas, successful owners had conducted about twice as many quality and safety inspections per month on their outstanding projects. Moreover, both owners and contractors seem to have more budget and schedule updates on their successful projects.

Management Behaviors for Success Jaselskis and Ashley

- Despite seemingly endless hurdles, it is nevertheless possible for a project manager to consistently achieve outstanding project results.
- 75 construction projects were included in the study; about half were classed as outstanding, and about half as average. Mostly in the U.S., some were international. The largest segment was **process plants**, with the balance being manufacturing, office, power, pipeline, dams. 60% were cost plus; 36% were fixed price.
- The probability of achieving "outstanding" goes to 99 percent if there are 8 face to face review meetings per month. The probability of achieving outstanding **drops** to two percent if there are only two face to face review meetings per month. Four such meetings per month results in a 75 percent probability of an outstanding outcome.

Determination of Construction Project Success – David Ashley, Clive Lurie, Ed Jaselskis

- Studied 16 projects in great detail.
- The top 6 factors that correlated to success all related to the **qualifications, (pertinent) experience, skills and behaviors of the top project manager.**
- Project manager goal commitment; capabilities/experience; engagement in planning; motivation and orientation of the team; focus on scope and work definition; **personal involvement in regular reviews.**
- The next three – objectives, control systems, and safety, are high on the list of personal face to face reviews.
- Note there are 46 elements on the list, but the higher correlation to success drops off after you pass the top 15 or so.

Recommendations

- **Planning Phase:**
  - Commit to scope, cost and schedule baseline only at proper design maturity, with validated estimate.
  - Include risk analysis and quantification to determine cost and schedule ranges.
  - Consider local culture and type of work, in their broadest context, in estimates and risk analysis.
  - Drive out optimistic assumptions, and strive for "most likely" scenario.
  - Require that "Critical Decisions" or "Stage Gate Decisions" be made by higher level officials in the owner organization.
  - Utilize External Independent Reviews, and Independent Cost Estimates by qualified professionals.
  - Be sure to have a project management organization with the appropriate skills and knowledge to cover the general and specific aspects of the project.
  - For larger projects, utilize the Earned Value Management System (EVMS).

Recommendations

- **Execution Phase:**
  - Mandate that only professionals with the appropriate skills, pertinent experience and knowledge be placed in key positions.
  - Require periodic project performance reporting.
  - If EVMS is being utilized, require an independent certification of the contractor's system, and a compliant implementation of that system.
  - Perform face-to-face reviews, using a specified format, so that the **owner**, the CM organization, and the contractor are all using the "same sheet of music."
  - Utilize Periodic External Independent Reviews to assess management performance, technical and quality performance, and forward-looking risk.

Recommendations on Project Reviews – My own practice

- Personally conduct face-to-face project performance reviews on a periodic basis.
- Each project review is briefed by the PM/CM, with staff participation as appropriate.
- The cover slide for each review is identical in format.
- The ***real reason*** to do project performance reviews: Drive home the importance of quality owner interaction and reviews with the contractor.

Location: XYZ

Project: 001

Title: Process Special Chemicals

Assessment

R

Acquisition Executive: ABC
Status: CD-3a

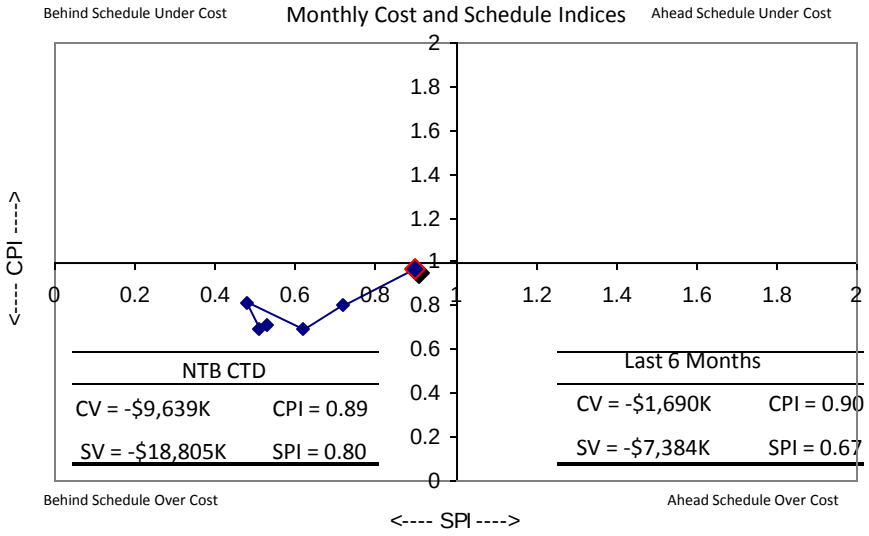
Scheduled Term: FY07 – FY10

Prior Costs = $0K
Cost Range = $360,849K- $384,821K
Projected Cost at Completion =
$360,848K

Federal Project Director: John Doe, Certified Level III
Contractor: PPP&T

Project Narrative Description: Design and Construct process plant to convert chemicals bcd to constituents b and d, discarding c as a waste at an approved disposal site..

EARNED VALUE MANAGEMENT
Monthly Cost and Schedule Indices



KEY PROJECT RISK and RISK MITIGATION

Risk: New: Existing: X
Prime contractor fails to deliver the final design on schedule and within budget.
Planned Action:

Management action:
Upon agency approval, PPP&T issued and awarded A&E Services contract. Plan to evaluate documents and utilize existing design to the extent possible to meet 60% design review in 4-09.

SAFETY PERFORMANCE

Occurrence Category	Assessment
Ttotal Injury Rate	Green
Lost Time Injury Rate	Green
Electrical	Green
Industrial Operations	Green
Mechanical Control	Green
Near Misses	Green
Authorization Basis	Green
Significant Injuries	Green
Quality Assurance Profile	Green
Operational	Green
Environmental Release	Green
Conduct of Operations	Green
Equipment Degradation/Failure	Green
Fire Protection	Green
OS/IH	Green

Legend
Green – No Attention Required
Yellow – Requires Some Attention
Red – Attention Required

Are There Keys to Success? A Recap:

- Common attributes of lessons learned:
  - The **owner** must be involved and engaged
  - Solid cost estimates to drive out "optimism bias"
    - Independent cost estimates by qualified professionals
  - Approval of "Stage Gate Decisions" by a senior official in the owner organization, predicated on objective assessment and information
  - Avoid fractured team of owner, PM/CM, contractor
    - Guaranteed difficulty
  - Communicate honestly and often
    - Reports
    - Quarterly substantive reviews/Construction Project Reviews
      - What is the real purpose of these?
  - Sometimes, a fresh look is necessary to resolve issues

Recommended Reading

- **Megaprojects and Risk: An Anatomy of Ambition**
  - By Bent Flyvbjerg, Nils Bruzelius, Werner Rothengatter
    - Mega-project development today is not a field of what has been called 'honest numbers.'
    - In more antagonistic situations the words used….are 'deception', 'manipulation', and even 'lies'…..
- Flyvbjerg recommends independent teams to review and drive out optimism bias, better assess risks, etc. in the early planning stages.

Discussion

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