Project Management Methods and Tools In the Nuclear Energy Sector:

Tools to uncouple the schedule of large complex nuclear projects from regulatory changes

Edoardo Cavalieri d'Oro – MIT SDM 2010

Eric P. Loewen, Ph.D. - Chief Consulting Engineer at GE Hitachi Nuclear Energy

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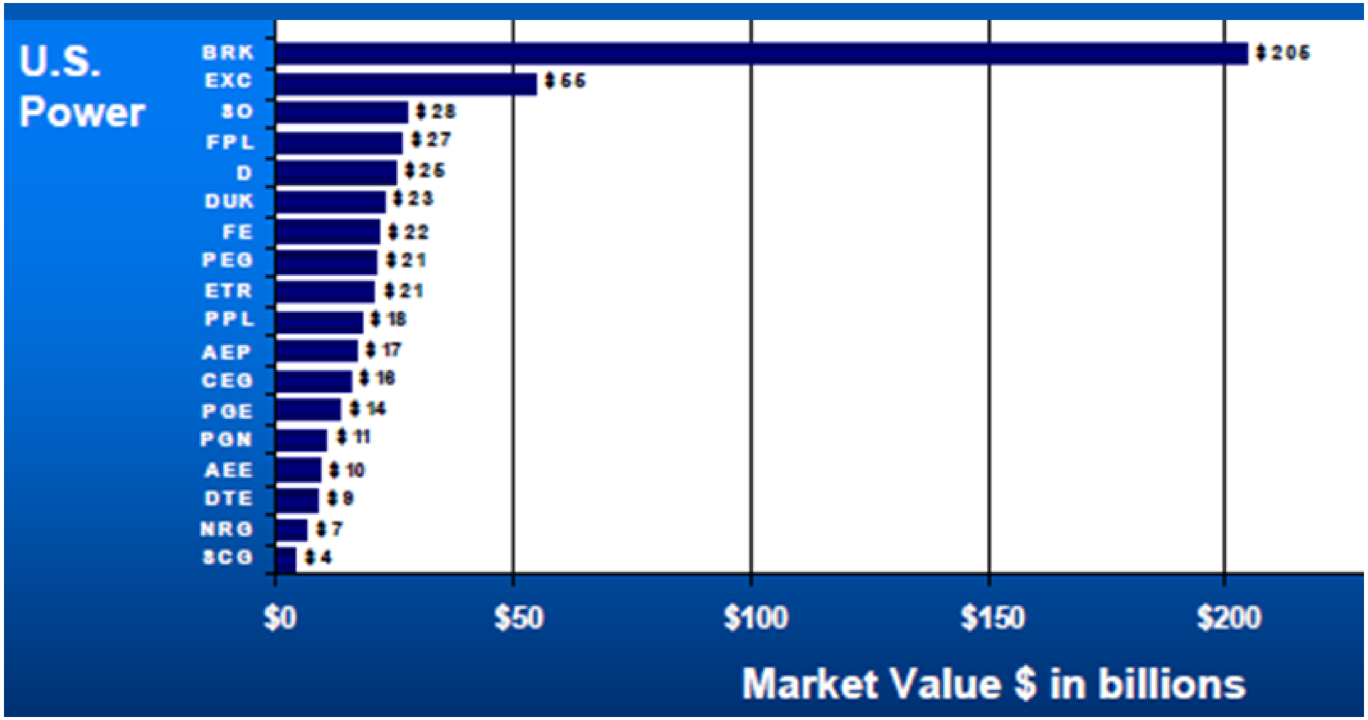
MITsdm system design and management

Motivations

- **Nuclear power plants are exposed to risk during the 3 phases of**
  - Licensing /Permitting → Construction → Operation
- **Nuclear Power Projects have huge upfront investments:**

  Nuclear plant Capital of € 4bn vs. € 600m to build a gas plant
- **A good portion of the risk is not controllable**

  Gambling on unpredictable energy markets is risky
- **Not all companies have the size to afford this initial risk**



Picture – Courtesy of GS

Outline

- **Topic and motivation of the project**
  - Example I: AREVA – EPR Plant, Finland
  - Example II: TOSHIBA - Cost/schedule assessment plan of Bellefonte, US
  - Example III: Analysis of a past ALMR Project, US (recently updated)
    - Application of DSM methods to the ALMR Master Schedule
    - Survey of risk management methods to assess risk in the nuclear sector

- **Approach and Methods**
  - *Data gathered:* ALMR Master Schedule & other documents provided by GEH
  - *Interview* conducted, *literature* Review, *examples* examined
  - DSM assembly steps used for the ALMR Analysis from the Master Schedule:
    - Determination of tasks, uncertainties in time, contingencies, task iterations
    - Setting up a resolution/ approach with Critical Path, PERT, SDM matrix, and NPV

Example I: Olkiluoto 3 (Finland) – Overrun in Costs & Schedule

Plant specific: Olkiluoto 3 is a 1600 MWe European Pressurized Water Reactor (EPR) and will be the **first Generation III+ nuclear power reactor in the world** when complete and the biggest reactor in terms of power and footprint (55 football fields = excavation site)

Constructor/supplier: Areva-Siemens consortium for Finnish operator TVO

Start date: permit obtained in February 2005, construction started in August 2005
Original completion date: summer 2009
Cost: fixed to €3 billion ($4.1 billion)

Delay on schedule: End of 2006 construction was about 18 months behind schedule postponed to summer 2011 (3 years delay on 4 years project). It is planned to go online in 2012.

Delay causes: it has suffered from **first-of-a-kind problems**:
- **Irregularities in foundation concrete**, which caused work to slow on site for months ('several months' delay in the construction of the concrete basemat)
- Work on the nuclear island has slowed markedly, due to a problem constructing the reactor's unique double-containment structure
- **Subcontractors** simply have not understood the very strict requirements for delivering to a nuclear project (had provided heavy forgings that were not up to project standards and which had to be re-cast)

Workforce: The work force on the construction site has doubled in 2008 to some 4000 while the total head count at the start date was about 600 people.

Situation at September 2009: 90% of procurement, 80% of engineering works and 73% of civil works were completed. 3.5 years behind schedule and more than 50% over-budget (€ 5.3 billion)

Regulatory burden: 160,000 documents stacked on five kilometers of shelving

Sources: public information available online

Example II: Bellefonte (Alabama) Cost/Schedule Approach

1. Construction Schedule (40 Months) methods:

- **Design completed**, assumed no regulatory "late" changes
- **3-D model in place** to minimize interferences
- Design is optimized based on the several ABWR projects completed
- **Enhanced Modularization** to meet the projects critical paths
- **Bulk materials and equipment in place** on the floor prior to placing the ceiling
- **Schedule logics are optimized** based on the ABWR projects completed
- **All materials available** as needed to support the construction sequence
- **Use of state of the art construction tools**, equipment and methods
- Working full back shift for the entire duration

2. Uncertainties & Contingency Assessment:

- **NRC certified design** with extensive construction and O&M experience
- **Item Risk table** developed by mean of expert's judgment
- **Cost reduction** due to international /contingent features of the project /markets:
  - Current price spike in the market
  - U.S. construction productivity
  - Government support

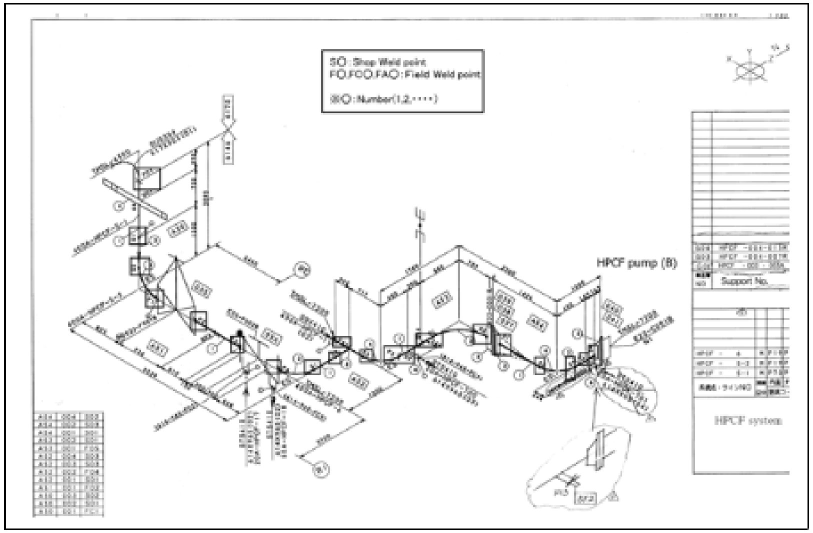
3. Cost evaluation key points:

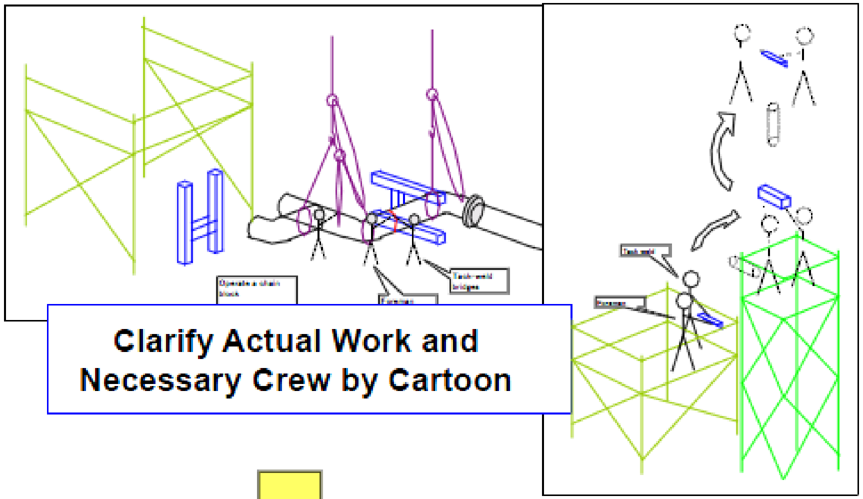
- **Minimization of regulatory risk:** 10CFR52-one step licensing will stabilize
- **Labor survey:** around the site area in Alabama
- **Application of U.S. codes and standards**
- **Estimating manual labor Cost and unit rate via VWPA**: Focusing at a typical process of a certain installation scope using punch or cartoon

Sources: public report

Construction Plan & Cost Estimation with simulated Cartoon

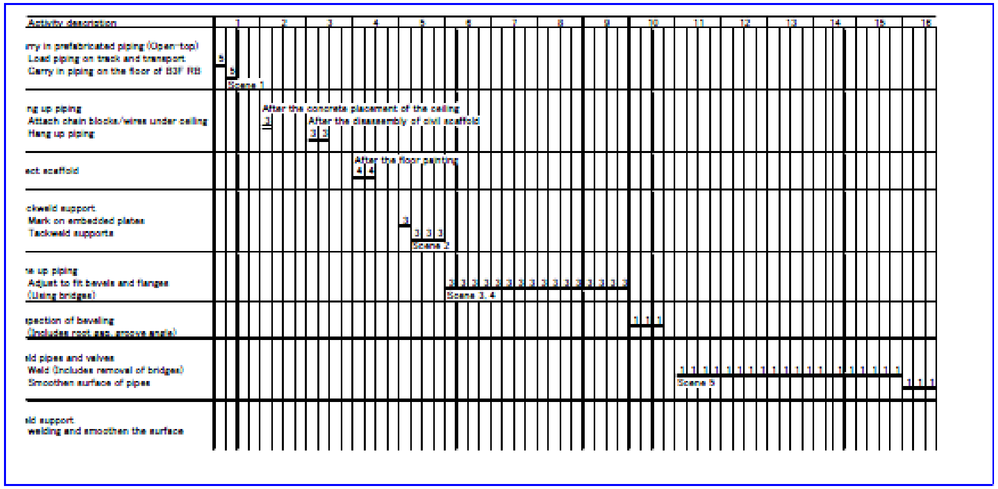
Evaluation Item; Ex. Piping





Clarify Actual Work and Necessary Crew by Cartoon

Detail Time Schedule & Crew Arrangement



Required Man – Hour
- Minimum Unit Rate -

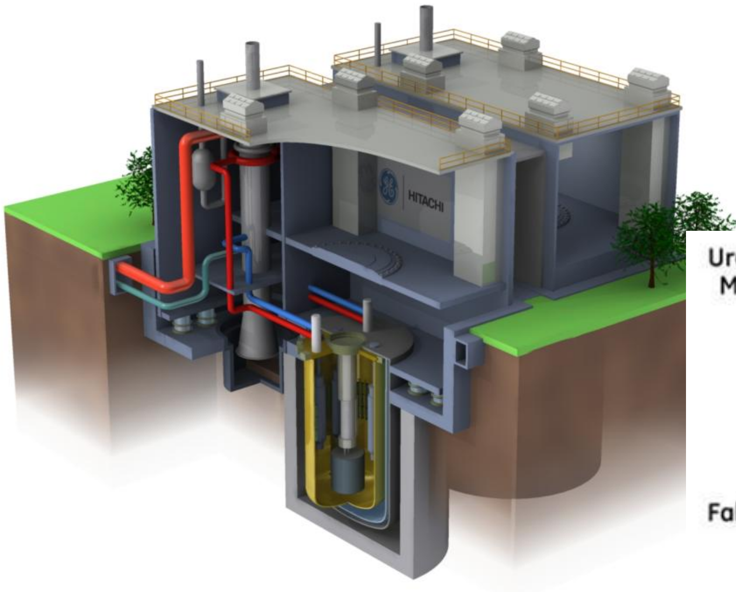
Construction Plan & Cost Estimation

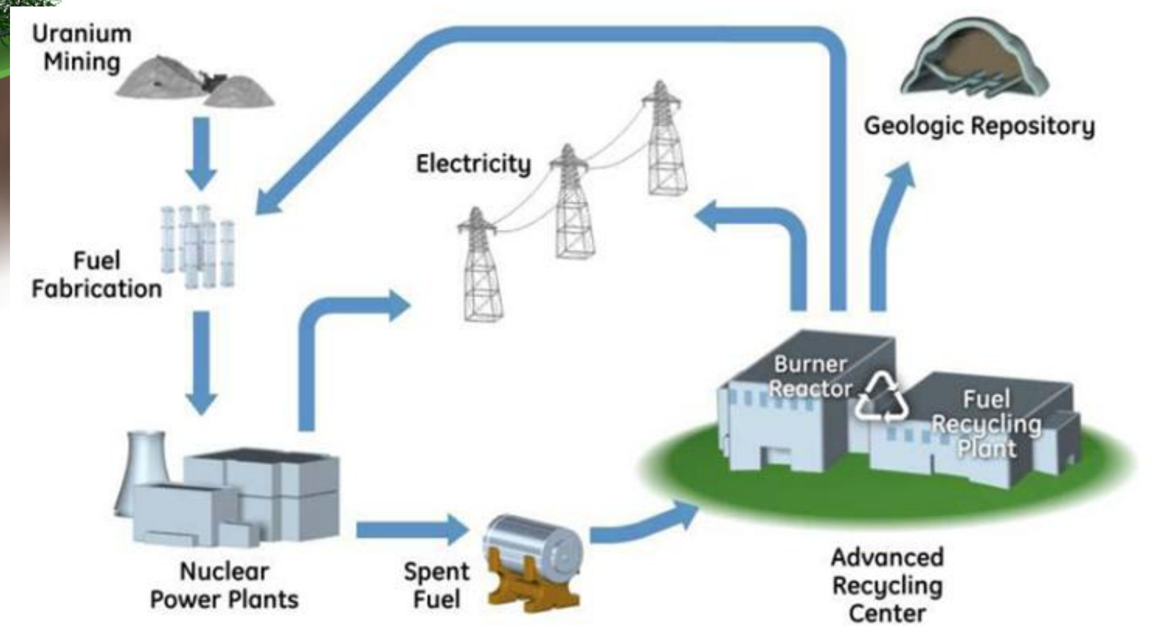
Figure 4.2-4 VWPA: Visualized Work Process Analysis - Large Bore Piping

Sources: public report

Example III: DOE ALMR Project 1985 to 1995

ALMR = Advanced Liquid Metal Reactor – ALMR project schedule updated and revised by GE Hitachi Nuclear Energy during the 2007 GNEP (Global Nuclear Energy Partnership Program) grant.

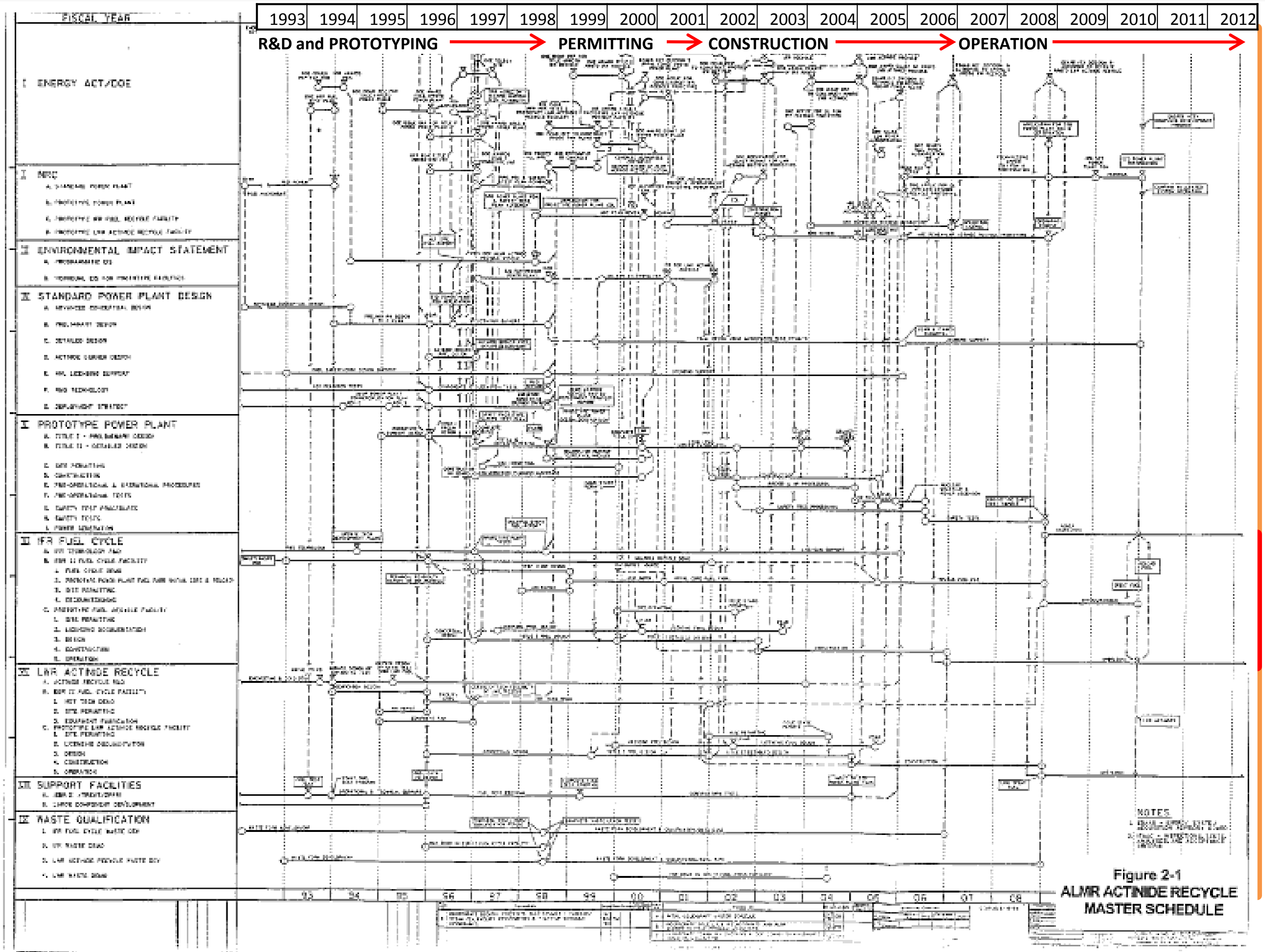




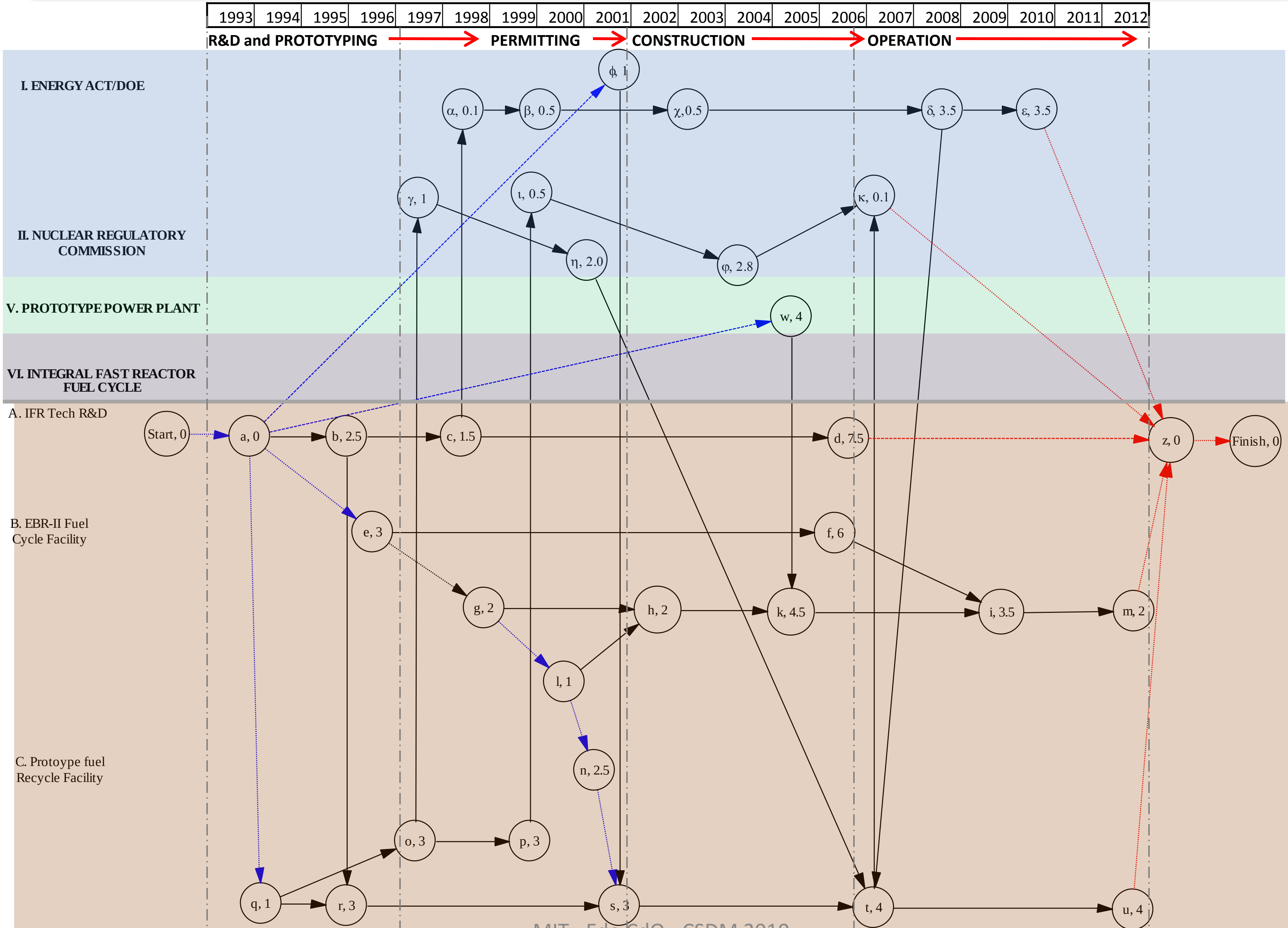
1981-1984	1985-1987	1988	1989-1995	1995-2002	2007-2014
GE Program	PRISM	PRDA	ALMR	S-PRISM	GNEP
GE funded	DOE funded $30M	DOE funded $5M	DOE funded $42M	GE Funded	

Sources: GE Hitachi

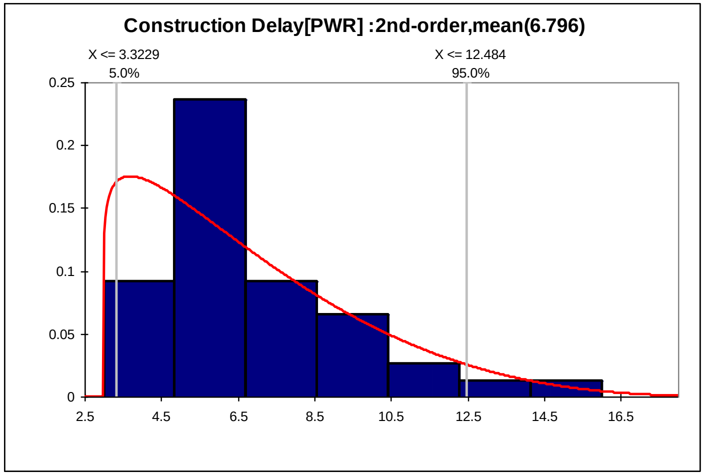
ALMR Master Schedule - Zones

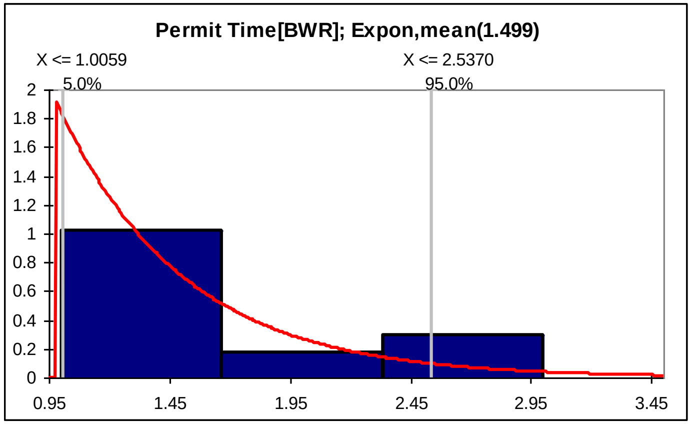


Method I: Network Planning Diagram – Critical Path



Method II: System Dynamics to capture market/regulations changes





SD to model US Nuclear Market and the construction re-work and quality of nuclear Plants:

The nuclear enterprise in the US counts of 104 installed plants characterized by a unique broad spectrum of plant capital costs.

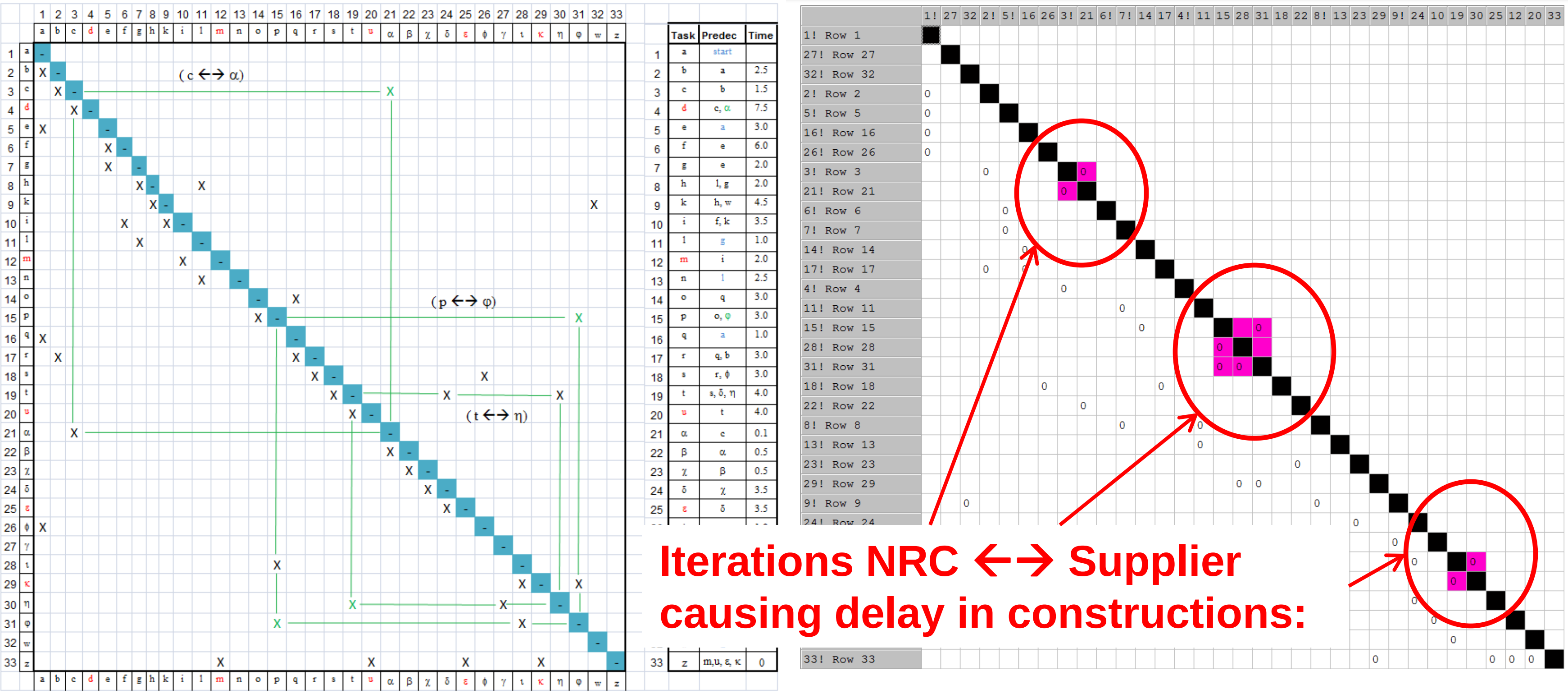
These changes in capital costs and delays in the construction and licensing phase characterize the past US industry after the TMI accident.

System Dynamics can be used [7], [8] to explore the causes of these overruns to show:

1) The effects of new regulations or regulatory changes when imposed upon a project under development [7]

2) The effects on the nuclear supply chain due to contingent events such as TMI, Oil shock crises, or lock-in effects [8]

Method III: Iterations – Design Structure Matrix



Introducing iterations:

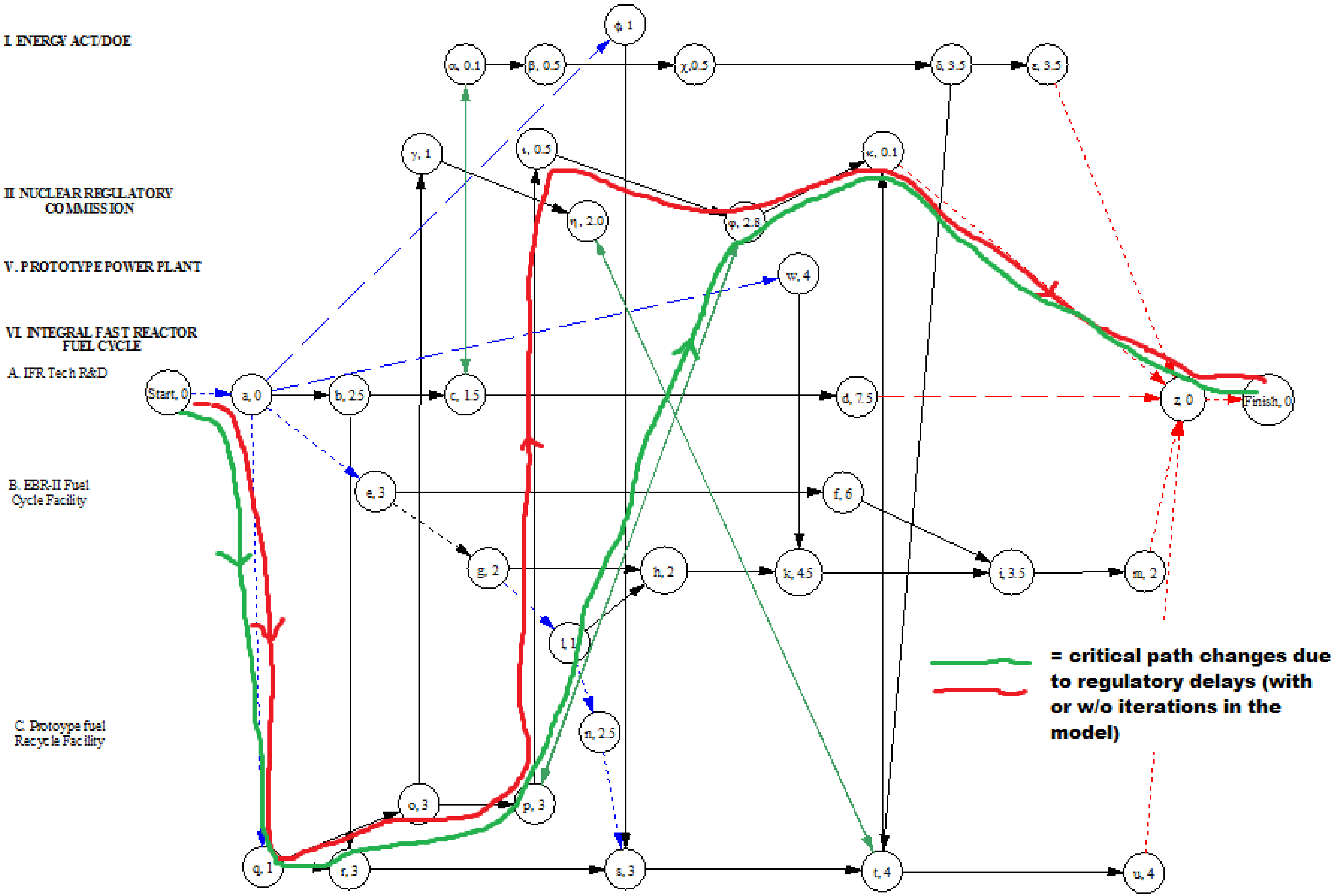
Nuclear projects interruptions, or delay are generated very often by the iteration between the regulation system and construction and planning processes.

Three major iterations between the upper and the lower layer have been introduced:

(c ←→ a) = multiple cycle report iterates with DOE collection of all the documentation
(p ←→ j) = licensing final design iterates with NRV reviews of the cycle
(t ←→ h) = Construction iterates with NRC constructions permits

The distributions of time in constructions given by the SD Models can be used to calculate the critical path with PERT → change of time contingencies **also change the critical path**

Method IV: Iterations and PERT– Design Structure Matrix



Method V: NPV and Uncontrollable Risk in Nuclear Power Projects

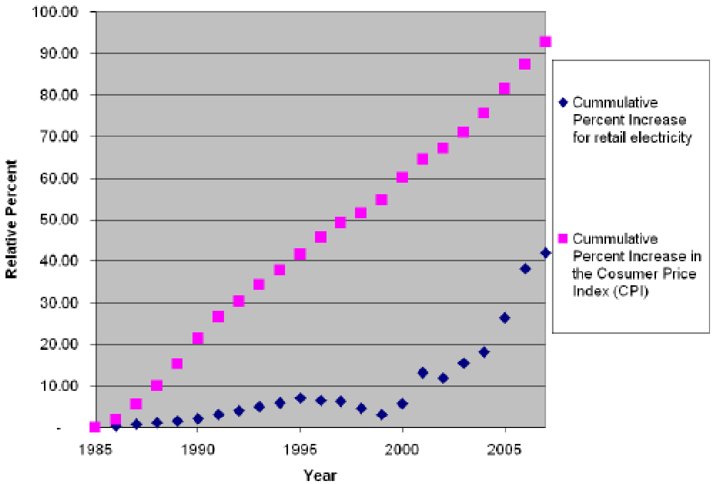


Figure 3: U.S. Inflation Since 1985

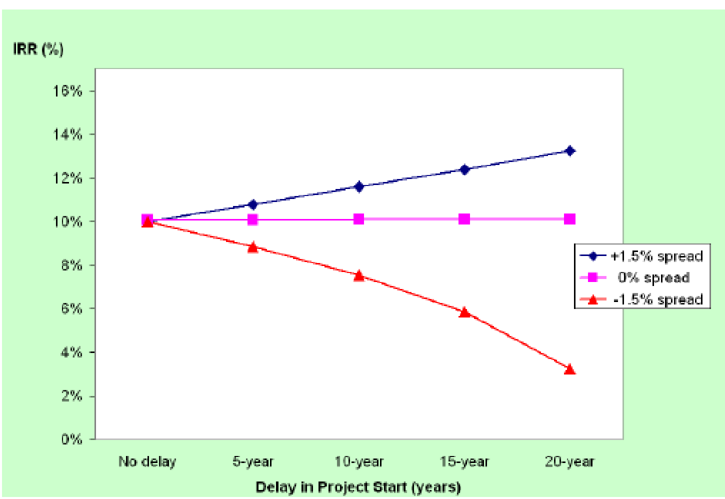


Figure 4: Sensitivity of Project Internal Rate of Return to Spread in Long-Term Inflation and Electricity Price Rates

Uncontrollable risk:

Uncontrollable risk is risk outside the ability of an enterprise to influence or effectively manage: largest uncontrollable risk is the commodity inflation that is not offset by sale price inflation

• sale price inflation < commodity inflation = consumer benefit → overall standard of living to increase

• sale price inflation > commodity inflation = producer benefit → long-term projects unattractive

Permitting Phase: decisions to invest are continually re-assessed due to market uncertainty in commodity and labor inflation, → increase project costs → decrease anticipated project returns.

Example, assuming that long-term electricity prices are expected to increase at an annual rate of 1.6%, and core inflation is also expected to run at 3.1% (yielding a notional -1.5% spread), a 5 year delay reduces the project's Internal Rate of Return (IRR) by approximately 2%, which is significant.

Conclusions

- **Key Results and Nuggets**

Example I (EPR)

- ➢ **No methods to approach First-Of-A-Kind projects**
- ➢ **Project maturity to Limit the number of iterations with the safety authority**
- ➢ **International projects have criticalities which are often neglected**

Example II (ABWR)

- ➢ **International coordination is important**
- ➢ **Simulation techniques are efficient tools in complex construction projects**

Example III (ALMR)

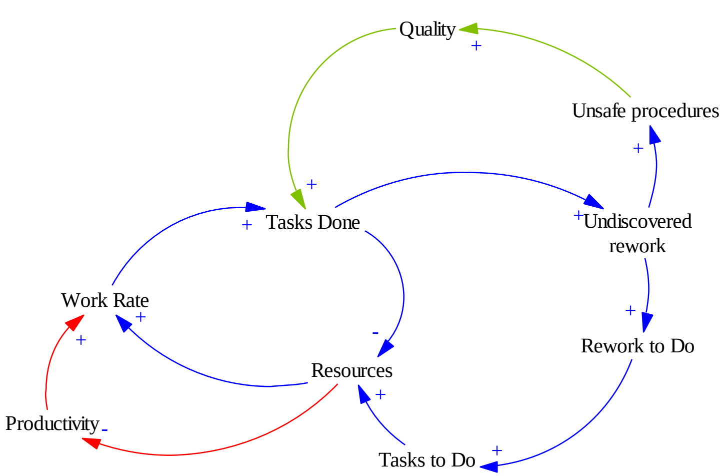
- ➢ **Emphasis of nuclear project is on the initial expenditure just after permission to build is released**
- ➢ **Regulatory iterations are the major cause of time contingency**
- ➢ **Iterations among tasks and dynamics are reflected in contingencies**
- ➢ **Emphasis is on Cost contingencies & Critical Paths**

- ➢ **Risk-Informed and Performance-based tools can reduce costs and improve understanding of complex projects**

New Projects: Safety and Performance

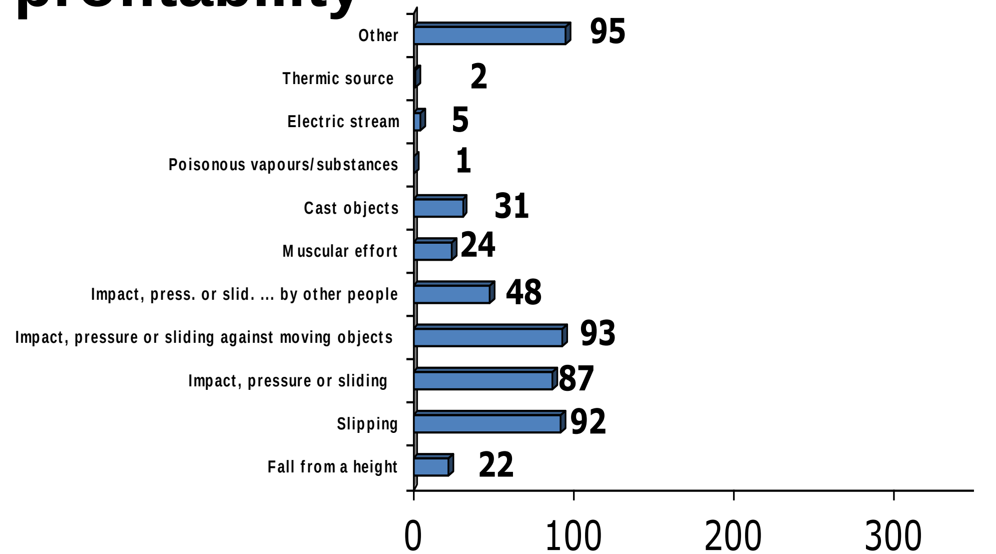
Sensible labs at MIT looking at the relationship between **rework, quality, productivity and safety:**

- **are important variables to control during construction.**
- **are correlated**
- **all concur to determine profitability**



Relating performance and safety on site might reduce extra costs and over runs

Causes of injury on NPP Construction sites 92006- 2009) - Courtesy of Enel Power



Back-up Slides

References and Acknowledgements

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Acknowledgments
Eric P. Loewen, Ph.D. - Chief Consulting Engineer at GE Hitachi Nuclear Energy