Project of the Future Vision: Using System Dynamics to Achieve

'*Model-in-Loop*' Project Planning & Execution

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Abstract

The current work presents and discusses current insights from an ongoing BP Project Dynamics R&D program that supports a 'Project of the Future' vision enabled through the use of formal system dynamics modeling. The BP capital investment environment and the importance of effective capital project planning and execution is discussed. The role of system dynamics in BP's project training approach and early adoption trends favoring conceptual versus formal model tools are reviewed. A formal modeling application conducted in parallel with an actual project assessment that used a traditional approach is detailed and contrasted to provide a direct comparison. In particular, we describe the traditional project assessment approach, how a formal system dynamics model was introduced and used, and how the quantified results influenced both the project and participants. We then identify key learning's and how a 'model-in-loop' concept supports the 'Project of the Future' vision. Finally, we briefly discuss implications for future R&D efforts.

Keywords: system dynamics; capital projects, project management, project management training, model-in-loop, vision, capital project performance, project planning, project execution, project assurance

Overview of Paper

In this paper we will describe current insights from an ongoing BP research and development (R&D) program that points to and supports a vision of using formal system dynamics modeling technology to enable better planning and execution of large complex projects for improved business performance. We will first touch briefly on BP's business organization and the importance of large and increasingly complex capital investment projects. We then briefly describe BP's training approach for servicing the development needs of its 850 member project community: the BP Project Management College (PMC), in existence for over 10 years to provide general project management training; and the relatively new BP / MIT Projects Academy, an advanced training curriculum including system dynamics technology for approximately 150 individuals designated as major project leaders (MPL). Next we describe the BP Project Dynamics R&D program, including how its objectives align with both the PMC and BP / MIT Projects Academy and early observations about the preferential uptake of conceptual versus formal system dynamics modeling tools. The remaining portion of the paper takes a step at answering the question: ***what are the applications of formal system dynamics modeling that will best meet the needs of the BP projects community to improve capital project outcomes.***

We do this by describing a formal system dynamics project modeling application completed in parallel with a traditional project assessment process: what were the goals of the assessment and how was it organized and conducted; how did we think a formal model would improve the assessment; what did we do; what were the results; and how it was accepted by various project stakeholders. Finally, we draw some conclusions, identify aspirations for additional applications of system dynamics technology in the BP projects community and briefly suggest some potential research opportunities.

Specific details about the project that was the subject of the assessment, including the Vensim project model developed, are proprietary. We have, however, provided a brief description of the model sectors and a more detailed view of the actual stock and flow structure that was, with slight modifications, used for each of the three main sectors. This paper should be of interest to anybody involved in helping organizations expand the use of system dynamics technology into business areas where there are long-help practices, processes and tools in use: especially project management.

Background

BP Capital Project Investment Environment

BP is a global energy group employing approximately 100,000 people and operating in over 100 countries worldwide. In order to delivery energy products and services people need around the world BP's businesses are organized in three segments: Exploration and Production (E&P), Refining and Marketing (R&M), and Gas, Power, and Renewables (GP&R). The E&P segment takes oil and natural gas resources from discovery through to development and production while R&M focuses on supply and trading, refining, marketing and transportation of oil and petroleum products. Finally, GP&R maximizes the value of BP's gas products by integrated marketing and trading of energy and energy solutions. In 2005 GP&R launched BP Alternative Energy to consolidate all of BP's low-carbon activities in a single power sector to pursue high-growth objectives in solar, wind, hydrogen power and gas-fired power technologies.

In order to achieve E&P business objectives, BP routinely invests in the design and construction of new drilling, collection, processing, and transportation facilities. Due to the commodity nature of oil & gas, there is intense competition among industry participants to efficiently and safely build technologically advanced, safe facilities while balancing capital investment, operating costs, and availability. As stated in the BP 4Q 2004 Results and Strategy Update, published 8 February 2005, BP will continue to make appropriate investment for long term growth, at a rate of approximately $14bn/year capital expense in 2005-06, of which approximately 70% will occur in the E&P segment. The magnitude of these E&P capital investments demands that appropriate tools and techniques be used to continuously improve the quality of decisions and resulting shareholder value.

BP Project Community Training

To deliver BP business objectives through capital projects, BP utilizes a combination of BP project professionals and contractors. The BP global projects community currently consists of approximately 850 dedicated project professionals with a wide range of experience and skills. These professionals display a high-level of professionalism and a positive culture of continuous improvement in the area of conceptualizing, planning, designing, and executing projects. The BP PMC, in existence for over 10 years, is organized to meet general project management skill development needs of this entire community. The BP PMC offers a mix of virtual and classroom training along with specialty workshop for some more advanced topics.

To further support this community, in 2003 BP implemented the BP / MIT Projects Academy to provide a distinctive, business acumen building environment for approximately 150 individuals designated as current or future MPLs. An individual is selected for a MPL role after demonstrating mastery of project management basics. While specific details of the curriculum are confidential, we can say that the entire population of MPLs were organized into cadres of 25 individuals and then scheduled to attend three, two-week, in resident sessions at the MIT campus over a 12 month period. After Terms I and II, these cadres will each select a real business issue and work to identify solutions using what they have learned.

MIT's expertise in system dynamics technology is one of the principle reasons why this institution was selected to jointly develop and then run the BP / MIT Projects Academy. Nelson Repenning developed and now delivers the system dynamics curriculum in the first two terms. In Term I he introduces the participants to system dynamics concepts and explains how causal loop diagramming can be useful for reframing project issues. In

Term II a simulated project environment, implemented in Vensim, is used to illustrate the impact of various project management choices. Working in teams, the participants analyze some project benchmarking data, submit a bid on cost and schedule, and then manage the project to achieve their stated objective. There is sufficient time for multiple simulation attempts after which Nelson leads the group through a debrief structured to surface and reinforce key messages from their experience.

BP Project Dynamics R&D Program

At the time the BP / MIT Projects Academy was formed in 2003, this BP author recommended a multi-year Project Dynamics R&D program. Initially, this R&D effort was focused on building infrastructure and system dynamics knowledge within the greater projects community to equip them with the requisite skills to work with the MPLs. Infrastructure developed included causal loop diagramming tool aids, concept demonstration models and a Project Dynamics workshop offered through the BP PMC. In addition, a limited-scope pilot application to increase awareness was completed in 2004.

The pilot application was conducted with members of a small project planning team on a very large project to explore how the system dynamics technology could compliment traditional project planning and risk management processes. The first step was to conduct a two-day workshop for the BP project members to introduce system dynamics concepts. Following the workshop, a model purpose and scope of work was agreed and BP partners in the subject project were invited to participate. The goal was to understand how the initial ramp-up phase of the subject project could potentially impact the remaining nine project phases. This was accomplished in a relatively short period of time by making small modifications to the project model developed by David N Ford as part of his MIT Ph.D. dissertation. The resultant model was then parameterized to meet the needs of the current evaluation.

The range of feedback from participants in the 2004 pilot can be represented by three key observations:

- "Prior to coming to this meeting today, we spent a couple of hours reviewing the risk register for another project. We sat in a room, had some conversation and then assigned each of the risks to various team members. Using the system dynamics approach on this project to carefully think through what could happen is much more satisfying!"
- "The jury is still out for me as I do not understand how system dynamics is any better than what we already do".
- "I will never look at another Gantt chart again without thinking about concurrent work activity and potential knock-on effects".

In early 2005 we observed that there had been many examples of MPLs utilizing their new knowledge about system dynamics to improve their projects. Principally the applications have been around using causal loop diagramming to explore and communicate chronic project problems. The use of formal system dynamic modeling technology, however, has been much less common, even with the completion of the pilot project designed to illustrate techniques and business benefits. In order for BP to achieve the full potential of system dynamics technology to improve project planning and execution, additional work is required to better understand how best to reach the BP projects community. To complete this goal the Project Dynamics R&D effort was refocused to answer the question: ***what are the applications of formal system dynamics modeling that will best meet the needs of the projects community to improve capital project outcomes?***

Project Assessment Example – What Was Planned?

A good opportunity to investigate this question surfaced when this BP author was asked to participate in a review of a project that appeared to be experiencing performance issues. The project in question was being planned and executed by a joint-venture company set up by BP and the other owners of the asset. As such, the project was not in the direct control of the asset owners or subject to the many well-established and proven project management processes used by the respective owners in the planning and execution of their projects. Instead, the owners had to provide oversight by relying on monthly project reports and occasional conversations with members of the joint venture project team.

Approximately nine months into the detailed engineering phase the owners became concerned that the project may have performance problems that could ultimately cause it to overrun both authorized cost and schedule. Specifically, the owners were concerned with how late engineering and new scope would impact permitting, procurement and early construction activities. The owners exercised their oversight rights and called for an assessment. The goal of the assessment was to examine and report back actual project state and recommended interventions to the owner leadership. Representative focus areas included the health of the organization, quality of processes being used, capability and quality of engineering, construction planning, etc. The owners were mainly interested in finding out if the project would be completed safely, within authorized cost and schedule, and ultimately deliver the desired level of performance during the operating phase.

Each of three owner organizations provided several project experts to participate in the two-week assessment. Since each of the owner organizations had different project processes, we meet as a group before the formal assessment started to develop a terms of reference (TOR). The TOR contained the objectives from our respective owner leadership and a detailed description of what we would evaluate, in what priority, and how we would report our results. The agreed assessment TOR represented an approach that was highly qualitative as this is the current practice within each of the owner companies. As originally conceived, this qualitative approach would consist of conducting group interviews and listening to presentations from the different project function areas such as program management, procurement, engineering, controls, construction, etc. At the end of each day the assessment team would meet in private to discuss what was heard and observed so that recommendations for improvement could be recorded. At the end of the two-week assessment, the plan was to prepare a final report with observations and specific recommendations for improvement. The final report would go to both the leadership of the project and owner leadership that originally initiated the assessment.

Problem Statement

Given this background, this BP author wanted to introduce elements of the system dynamics approach and a formal Vensim project model to see what kind of difference it would make to the traditional project assessment process. Since the TOR did not include using system dynamics approaches or modeling technology, David Peterson, Ventana Systems, Inc., was contracted to work along side this BP author to simultaneously participate as an observer and build a high-level Vensim project model. Our objective was to listen, ask appropriate questions, and then build an appropriate model that could provide insight, and possibly help shape the quality of the assessment team conclusions and recommendations. In particular, we were looking for answers to, or at least insights into, the following questions:

- What are some practical ways in which the system dynamics methods can be used to improve traditional project assessments?
- How would a Vensim project model support the TOR?
- What benefits were perceived by the sponsor?
- What were the features of Vensim that reinforced the value of using this technology?
- What are the primary areas where system dynamics can aid project assessments?

Results

Project Assessment Example – Phase I

The two-week project assessment was initiated as planned and agreed in the TOR. The assessment team totaled 14 members that, combined, represented a wide range of expertise in all of the required project functional areas of the project. It is worth noting that David Peterson was introduced as a Ventana consultant who would participate as a BP representative. We did tell the other assessment team members that we would be building a Vensim project model to help BP better assess the true state of the project but that we would not, unfortunately, be in a position to share the results. This naturally raised the curiosity of the other members of the assessment team as they were not familiar with system dynamics technology.

While the assessment team had access to a great deal of pre-read, the majority of the first week was spent listening to a variety of status presentations from the joint-venture project team. The message across the project team was that, although challenged, the project would be completed on schedule and within authorized costs.

In response to the presentations the questions from the non-BP assessment team members were traditional in the sense they largely addressed project organization, roles and accountabilities, skills, resource levels, content of plans and procedures, and the existence and adherence to process for managing risk, change, and status reporting. After listening to the responses to assessment team questions, there typically was an open discussion about the answers and implications for project performance. The main quantification efforts were completed by assessment team members with cost and schedule expertise when they inspected project documents and offered a qualitative assessment of likely outcomes.

On the other hand, the questions raised by the BP representatives were probing at structural issues we knew could activate rework structures:

- how many errors have been detected in the engineering drawings and where are the metrics that track this
- what is the average experience level in the engineering contractor organization and how has it changed over the course of the detailed engineering
- has anybody been working overtime and for how long
- if errors are detected, what fraction of the total will be found by engineering, regulators, procurement, functional checkout (FCO), commissioning, and startup, construction, etc.
- how much change has been introduced – where, when, by whom, etc.

Development of the Vensim project model was completed by working before and after the full-day assessment activities and during the two-day weekend in the middle of the assessment.

By the middle of the second week the assessment team had to stop gathering more information and focus on preparing a consensus view of the project. The final PowerPoint presentation contained multiple recommendations that would increase the likelihood that the project would be completed as authorized. This recommendation was based on a qualitative, consensus view. It is important to note that the assessment team could only conjecture about when the project would finish and how much it would ultimately cost.

Also by the middle of the second week the BP assessment team members had to stop model development and begin preparing presentation results for a final review with our BP sponsor. We prepared two PowerPoint presentations that delivered the same message: expect a five month schedule slippage with corresponding loss of operational benefits and at least a 60% cost overrun. One presentation contained technical information about system dynamics while the other did not. We supported our conclusion by explaining that we were using information obtained from the project members and specifically accounting for the rework that is and was continuing to occur. We also qualified that the results could be improved through specific data gathering and analysis activities: interviewing the engineering contractors to confirm estimates of their overtime obtained from the project team; gathering and analyzing engineering drawing data and calibrating the model; confirming the magnitude and timing of engineering changes; etc.

Again, due to the perceived experimental nature of system dynamics in BP, we decided to withhold specific details from the other members of the assessment team other than to say that the model was confirming schedule delays and higher costs. It is worth noting that the high-level Vensim project model forecasted significantly more schedule slippage and higher costs than the assessment team.

Project Assessment Example – Phase II

At the completion of Phase I, our BP sponsor and his direct reports had better understand and more confidence in system dynamics technology. As a consequence, a second scope of work to be completed over a two-week period was requested to tighten the confidence bounds on model projections and begin to quantify the consequences of possible mitigations and interventions. Specific actions included:

- getting estimates of engineering error impacts on construction,
- obtaining clarification of progress data and changes,
- reviewing FCO, Commission, and Startup scenarios and sensitivities,
- aligning the model with the new data, and
- adding the ability to look at phase construction and other mitigations

We expanded the modeling team to included two project engineers: one from BP and one from another asset owner company. These engineers were involved in the planning and conduct of interviews with engineering contractors and members of the project delivery team. By including these individuals we believed we would produce a better model because of their domain knowledge. In addition, this provided a good opportunity to transfer more knowledge about the system dynamics approach and technology to the project engineers.

The results produced by Phase II were directionally consistent with Phase I results but demonstrated an even longer schedule delay and higher costs than were produced by the phase I analysis. During the time period covered by phase II, the joint-venture project team revised their cost and schedule forecast towards the Phase I results but stopped short of agreeing with Phase II results.

Project Assessment Example – Phase III

Following the completion of Phase II, a scope of work was prepared to conduct Phase III to incrementally improve our understanding. The main objective of Phase III was to improve our analysis of the engineering drawing data as it was key step to calibrating the model. A requirement for moving into Phase III that was established by our BP sponsor was the active participation by the other asset owners in the model validation process. This provided some assurance that our partners also found value in the system dynamics project. We also had a goal of involving the leadership of the joint-venture PMT with the hope they would find enough value in the modeling process to take an active interest and begin requesting sensitivities to test recovery strategies.

We did successfully secure the active participation of the other two asset owners. In both cases there were very skeptical voices questioning the value even though a majority opinion prevailed and they both eventually participated. The perspective of BP and its partners is illustrated by the following representative comments:

- "Even a small insight has the potential to return significant value if we can change the course of the project!"
- "How can you be sure that this simple model is capable of producing a better answer than the collective wisdom of the entire joint-venture PMT?"
- "It has been a long time since I have been presented with a new technology as exciting as system dynamics. I am more than willing to get involved."
- "I think we should give this a try."
- "I see value but if the joint-venture PMT is not willing to get involved, we are probably wasting our time."
    - It is important to note that the joint-venture project management team is completely accountable for the delivery of the project. As such, the asset owners were continuously challenged to find the right balance of owner oversight and interventions.

Finally, the delivery of Phase III results were similar to Phase II results in terms of forecasted cost and schedule. The main difference was the quality of data analysis and model calibration that provided a much higher level of confidence in the results.

Cost and Schedule Model

While the specific details of the Vensim project model are proprietary, we are including two illustrative diagrams below: one showing a high-level representation of the model sectors included; and the other a more detailed view of the actual stock and flow structure that was, with slight modifications, used for each of the three sectors initially included: Engineering, Procurement, and Construction (FCO, Commissioning, and Startup were aggregated into Construction).

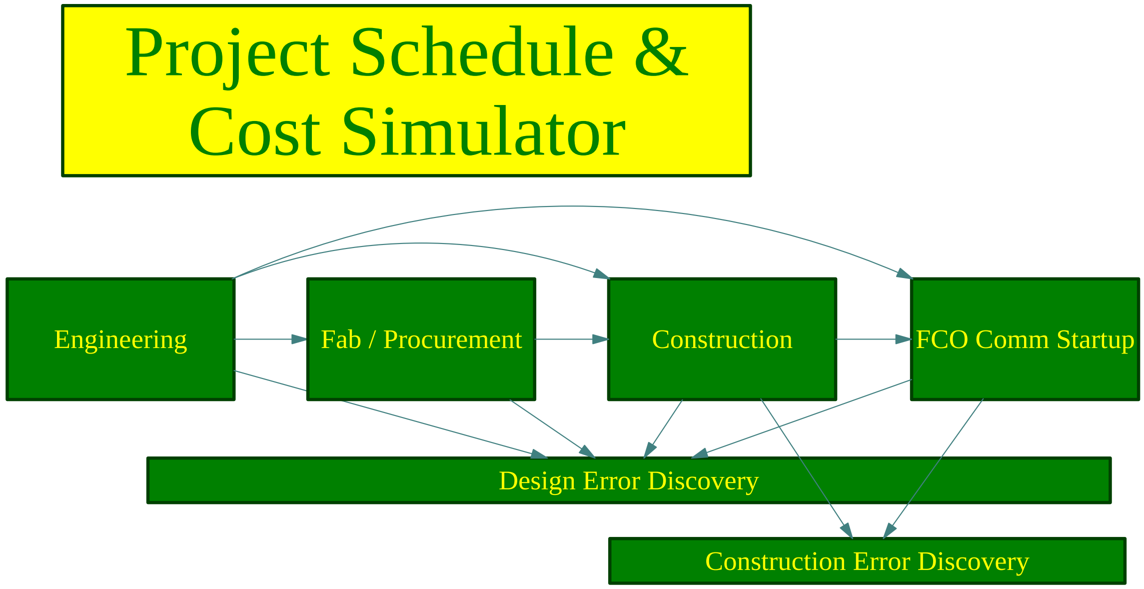


Diagram 1 – Schedule & Cost Model Sectors

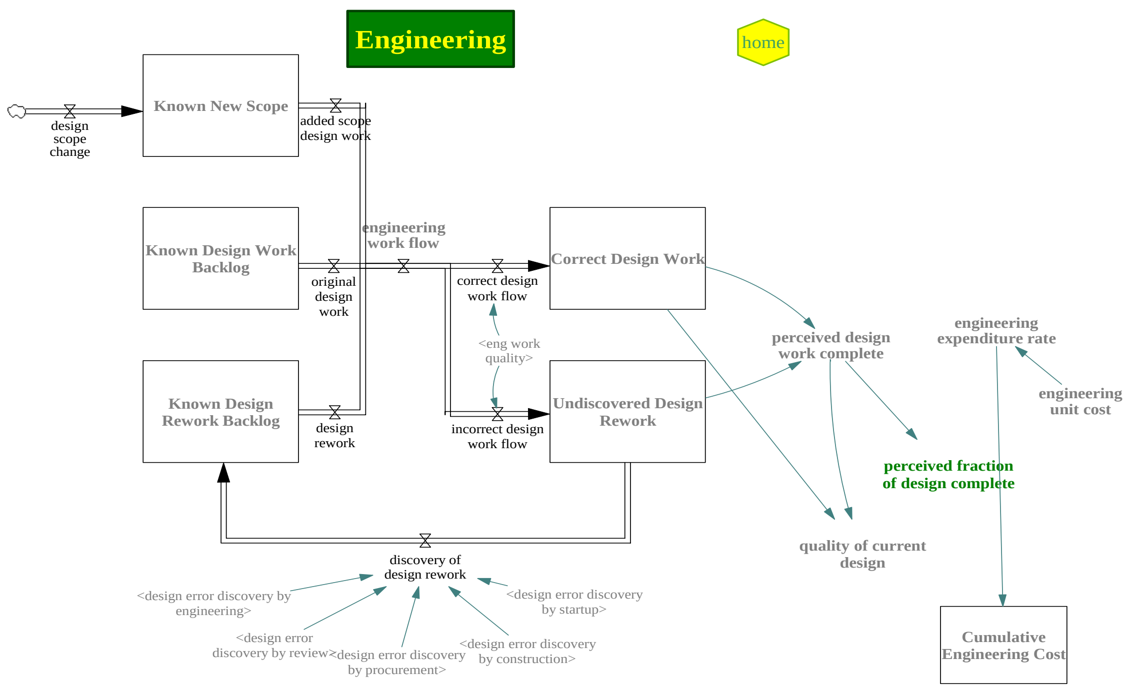


Diagram 2 – Schedule & Cost Model Stock and Flow Structure

Conclusions & Extensions

This paper has described the importance of planning and delivering high-quality capital investment projects in BP. We then talked about how system dynamics technology is being introduced to the global BP projects community as a means to reframe and quantify important aspects of project planning and delivery and how there appears to be a preference for conceptual versus formal modeling applications. In order to better learn where and how formal modeling can help the projects community, we described how a Vensim project model was used to support initial and ongoing objectives to assess and improve a real project. We had the good fortune for the opportunity to complete this work in parallel with the traditional project assessment approach used by large energy companies. This has enabled us to directly compare and contrast the system dynamics approach with a long-held assessment practice of large energy companies and, consequently, learn about complimentary and supplementary areas for formal system dynamics applications.

What Did We Learn?

- “There are helpful hints everywhere for project teams but they will largely rely on their experience to get them through. Unless they have to write something down they will continue to deliver the same level of performance. Providing input into a system dynamics model and considering the output forces people to think more carefully and consider alternatives. This should be a requirement for every medium to large project.”
- “Participating in the process of building and analyzing a formal system dynamics model is a valuable form of risk management.”
- “I am hoping that this schedule and cost model can help us understand how best to intervene in the project to turn around performance!”
- Getting access to right data, analyzing it, and preparing it to be used for model calibration accounted for 60% of our total effort. This is consistent with the experience of Ventana Systems, Inc.
- When confronted with the type of data needed to calibrate the system dynamics model, Project Controls Engineers stated that “this is the type of data we should be collecting and analyzing ourselves. We know that it is important but we rarely have quality time to do this!”

These learning’s strongly suggests that the projects community needs a simple, highly compelling vision that describes how formal system dynamics modeling can benefit the planning and execution of their large, complex projects. The ‘Project of the Future’ vision detailed on the next page is our attempt to satisfy this objective:

Project of the Future Vision: '*Model-in-Loop*' Planning & Execution

Why do we need 'model-in-loop' project management?

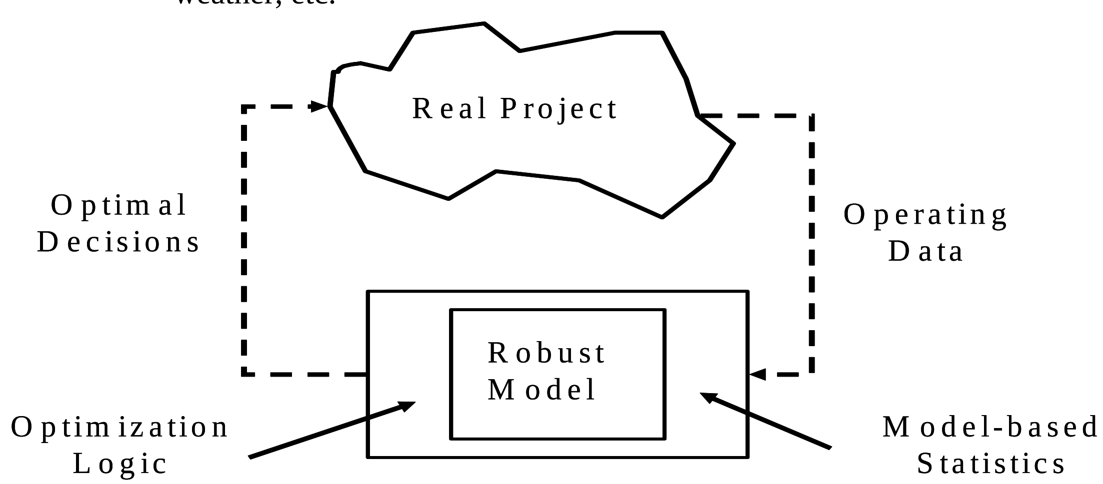
- Project outcomes are inherently high-variance (risky)
- At outset, key drivers are only approximately known:
  - Technological challenge
  - Skill and talent levels of people (especially at contractors)
  - Future changes in specs, requirements, or design constraints
  - Regulatory, legal, environmental & weather conditions
- Project management, therefore, can't operate from a fixed plan – it must be able to decide what is best from week to week in response to the latest information
- Project management must also be able to tell when to accept proposed improvements and when to reject them

What must project management do?

- Know, from week to week, the most likely project outcomes (cost, time, quality)
- Know the range of uncertainty (variance) in the outcomes
- Have a wide spectrum of potential interventions
- Know the likely impact of each intervention on the outcomes and variances (in order to choose the best interventions and minimize risk)
- Choose the interventions which maximize the expected outcomes and minimize the variances

How can system dynamics models help?

- While not intended to be an exhaustive list, following are the key areas where modeling and data analysis can add rigor to the project planning and execution process and improve capital outcomes:
  - Predict most likely outcomes
  - Quantify the variances of the outcomes
  - Cross-check key project data and estimates for consistency
  - Find the best interventions & decisions
  - Perform what-if on proposed improvements or design changes
  - Evaluate impact of unexpected events from contractors, environment, weather, etc.



Implications for Additional R&D

The learning's gathered by the Project Dynamics R&D program work suggests that the adoption of formal system dynamics modeling within the project community will be greatly influenced by conducting more applications in parallel with the execution of current project management practice and then publishing the results. While not an exhaustive list, our work suggests the following focus areas:

- Front-End-Loading (FEL) activities
    - Early in a project there are many questions and uncertainties that can be categorized into four separate but tightly coupled areas: resource; facility; market; and stakeholder. Starting with a high-level, top-down system dynamics model and incrementally improving it based on what is learned is an ideal way to help ensure that limited resources are focused on the most important areas. This approach should be very appealing to a business asset as there is typically reluctance to staff a new project that may eventually be discontinued once the FEL activities are concluded.
- Project Services
    - In order to understand which project dynamic behaviors are likely to surface, simple tools are required to help team identify risk areas. Once these areas are identified, tools for collection, presentation in time-series format, manipulation, and analysis are need to speed this critical but time consuming activity.
- Project Assessments
    - Appropriate system dynamics models need to be available to managers and assessment teams to quickly quantify project dynamics impacts.
- Procurement and Contract Claims Administration
    - The availability of appropriate models to speed the understanding of equipment supplier supply and demand will add significant value.

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