Dynamics of Project Performance

System Dynamics and Project Management

Lecture #20, SD Class Eight (11/13/00)
Gathering Data

Progress Can be Measured

Rework discovery can be measured and used to estimate split after the fact

But, the split cannot be determined as it is happening
**Topics**

- A System Dynamics View of Execution and Adaptation
- Project dynamics summary
- Strategic project management & learning
- Lessons Learned
- Broader issues – multi-project and market interactions
Managing Risks and Changes:
- Schedule adjustments
- Staffing strategies

A Strategic View – Deciding in advance the best way to handle problems if they arise
In the face of a projected schedule overrun, is it better to slip as soon as you know it or wait and see if corrective actions will help?
Graph for Cumulative Effort Expended

Cumulative Effort Expended : Class7x Base
Cumulative Effort Expended : Class7x Slip Late
Cumulative Effort Expended : Class7x Slip Early

No Slip
Slip Late
Slip Early (and all along)

Time (Month)
Conclusions

- If project priorities favor cost over schedule, it’s better to slip the schedule early rather than wait until the damage is done. [Note: if rework creation is high enough, not slipping early can make the project finish later!]

- Use buffers early.
Selected Staffing Issues

- Should staff be added to a late project (Homework 4 question)?
  - Unless new staff are 100% productive from day 1, adding staff increases cost;
  - And, can make project later if the quality hit is large enough

- Should you start with the expected full team, or staff up gradually?
Topics

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Examples of Behavior Modes on a Project

Project Staffing

Time

Typical Plan

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Examples (continued)

Fraction Complete

Typical Plan

Time
Project problems persist in spite of numerous advances in the last 30 years

- PERT and CPM (Critical Path Method)
- Waterfall, Spiral, …
- Emphasis on “soft,” people factors
- Microsoft Project

.. and Learning is not happening

**Why???”
Project performance problems are fundamentally dynamic problems, and Managers mental models and typical tools (computer models):

- take a partial view
- view a project statically
- treat projects as if they were unique
Systems thinking and dynamic modeling provide the means of...

... understanding the structure of projects, and how that structure creates behavior;

... designing robust projects

... learning across projects
Dynamics of Project Performance

- The "rework cycle"
  - Quality
  - Undiscovered rework
- Feedback effects on productivity and work quality
  - Positive, re-enforcing, often "vicious circles"
  - Negative, controlling
- Knock-on effects between work phases
The Rework Cycle

Key to Project Dynamics

People  Productivity  Quality

WORK TO BE DONE  WORK BEING DONE  WORK REALLY DONE

KNOWN REWORK  UNDISCOVERED REWORK

Rework Discovery

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A system dynamics model usually represents several phases of work, but is more aggregate than a CPM model.
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Corporate Strategy for the Project

Determining the fit of the project to business objectives (the “mission”)

- features / scope
- schedule milestones (time to market)
- delivered quality (defects)
- resources & budget

And the mix/timing of “projects” necessary to achieve corporate strategy

**Operationally, “projects” implement corporate strategy.**
Understanding how project “design” decisions affect project performance …

- Organization, process, ...
- Buffers, phase overlap, ...
- Staffing strategies, schedule slip, ...
- ...

… and how they affect other current projects (portfolio issues), and future projects.

*Operationally, “day-to-day project decisions” implement project strategy.*
An important part of strategic project management is *learning* from past projects ...
Why Do Organizations Seem So Poor at Learning Lessons From Prior Projects?
Action is a feedback process

Diagram:

- Goals → Decisions → Real World → Information Feedback → Goals

Real World

Decisions

Goals

Information Feedback
For example, controlling shower temperature
Or a project ...
Action is based on mental models …
Model for shower control

- **Real World**
- **Information Feedback**
- **Decisions**
  - **Strategy, Structure, Decision Rules**
  - **Mental Models of Real World**

Reduce hot water flow

"Reduce hot water flow when temp. too hot"

Temperature too hot

Temperature = hot flow + cold flow
And project control

Add people

Decisions

Strategy, Structure, Decision Rules

Mental Models of Real World

Information Feedback

“Add people when we fall behind.”

Real World

Project behind schedule

Progress = People * Productivity

Add people when we fall behind.”
Learning also results from feedback ("experience")
Action, and learning, become difficult when there are significant time delays.

Reduce hot water flow

Delay

Decisions

Strategy, Structure, Decision Rules

Real World

Information Feedback

Mental Models of Real World

Temperature = hot flow + cold flow

“Reduce hot water flow when temp. too hot”
... and where the cause effect chains are many ("side effects")

“Add people when we fall behind.”
Learning is difficult in a complex world

Real World
- Unknown structure
- Dynamic complexity
- Time delays
- Inability to conduct controlled experiments

Decisions
- Implementation failure
- Game playing
- Inconsistency
- Performance is goal

Information Feedback
- Selective perception
- Missing feedback
- Delay
- Bias, distortion, error
- Ambiguity

Strategy, Structure, Decision Rules
- Inability to infer dynamics from cognitive maps

Mental Models
- Misperceptions of feedback
- Unscientific reasoning
- Judgmental biases
- Defensive routines

Adapted from Sterman, Business Dynamics, etc.
Models can play a significant role

Real World
- Unknown structure
- Dynamic complexity
- Time delays
- Inability to conduct controlled experiments

Virtual Worlds
- Known structure
- Variable level of complexity
- Controlled experiments

Decisions
- Real World
  - Implementation failure
  - Game playing
  - Inconsistency
  - Performance is goal
- Virtual World
  - Perfect implementation
  - Consistent incentives
  - Consistent application of decision rules
  - Learning can be goal

Information Feedback
- Virtual World
  - Complete, accurate, immediate feedback
- Real World
  - Selective perception
  - Missing feedback
  - Delay
  - Bias, distortion, error
  - Ambiguity

Strategy, Structure, Decision Rules
- Simulation used to infer dynamics of cognitive maps correctly

Mental Models
- Mapping of feedback structure
- Disciplined application of scientific reasoning
- Discussability of group process, defensive behaviour

Adapted from Sterman, *Business Dynamics*, etc.
Steps in Learning – Scientific Method

1. Gather data
2. Develop model(s)
3. Validate/Calibrate
4. Evaluate lessons: what would have happened if …
   - Unplanned events (risks), changes, … did not occur
   - Management changes had not been made
5. Systematize via data base, benchmarks, rules of thumb, training, game?

*This is not easy and takes effort over multiple projects on an on-going basis to be successful!*
“But my project is different!”

- The rework cycle, with dynamic productivity and work quality, is one generic model (or framework).
- Benchmarking, lessons, and learning can be transferred across projects.
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Getting a feasible project design (consistent mission) is the first step to avoiding adverse project dynamics

Prior projects are the best source of information with which to design a robust project

There is an optimal tradeoff among scope, budget, schedule, and delivered defects

*Bid & plan project right*
Lessons -- 2

- Recognize the rework cycle and plan to minimize its consequences:
  - Quality -- do it right the first time
  - Undiscovered rework -- avoid quality on quality surprises (estimate real progress)
  - Rework discovery time -- prioritize rework detection and correction over new work

*It’s the undiscovered rework!*
Actions to Reduce Rework Discovery Delay (and minimize mistakes)

1. Recognizing the existence of the rework cycle and the costs of undiscovered rework is half the battle
   - Professor Eppinger’s DSM example
   - F-18
F-18 Program (on budget and ahead of schedule)

“I used your work and advice from the start. You made us understand the importance of rework, of finding it early, of reducing it, as well as how we could go about doing it. As a result, we cut our rework effort to one-quarter of what we expected. Not many may know how important your work was, but I do…. Every time someone asked me how we managed to succeed, I take them to the model diagram I keep on my wall, and use that to explain it to them.” Lou Carrier, VP Northrop-Grumman and former F-18 project manager.
F-18 Actions

- Model diagram – clear picture, highlighted importance of rework (minimize “kill the messenger”)
- Integrated product teams, including internal HR consultants to facilitate design-mfg. dialogue
- Real time reporting of staff, costs, progress
Reducing Rework Discovery Delay (and minimizing mistakes)

1. Recognizing the existence of the rework cycle and the costs of undiscovered rework is half the battle
2. Make maximum use of integrated product teams, including customers and all functions (Peace Shield, F-18)
3. Focus on quality even if it means delaying interim milestones or start of downstream work
   - Peace Shield (delayed staff roll off; reduced phase overlap)
   - Auto (design reviews, prototypes, CAE, physical tests)
Corollary: don’t charge ahead on a design phase if upstream (or supplier) information is not available or of high quality
Lessons -- 3

- Minimize the vicious circles; avoid, within a phase, ...
  - aggressive staffing
  - sustained overtime
  - schedule pressure (measuring and rewarding the wrong behaviors)
- ... and between phases
  - rigidly sticking to scheduled start without necessary prerequisites (use buffers early)
Lessons -- 4

- Identify *key* risks and ...
  - put effort into avoidance and early detection
  - alternative processes (e.g. spiral), staffing strategies (e.g., integrated teams), tools, etc. can improve performance in the right situation, but involve both short-term (implementation) and long-term (greater scope, lower productivity) costs and are not right for every project
Lessons -- 5

- Manage changes and problems wisely
  - Replan and price changes immediately (don’t hope you can make it up, then discovery trouble 6 months later)
  - Negotiate to reduce scope if schedule is critical
Lessons -- 6

- Learn ...
  - Identify leverage points and policies
  - Share across projects (individual managers learn, but few share)
  - Reuse what works
Selling System Dynamics (Modeling)

- Must be a persistent and costly dynamic problem
- Illustrate causes (use rework cycle and feedback examples)
- Provide an example of use relevant to your organization

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Topics

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• Broader issues – multi-project and market interactions
Broader Issues

- Is what’s best for the project best for the company?
- Issues in product portfolios
- Market and Customer Dynamics -- setting the mission dimension as a part of corporate strategy
Is What’s Best for the Project Best for the Company?

Examples of conflicting practices --

- 
- 
- 
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While some projects are nearly self-contained with dedicated staff and technical independence, most often projects:

- Share staff resources with other projects
- Are impacted by technical progress on other projects, and impact the technical progress on other projects

And, ...
Projects Rarely Operate in Isolation

- Sometimes projects are part of “programs” -- groups of projects managed in a co-ordinated way to obtain benefits not available from managing them individually, e.g.:
  - large development effort broken into pieces for easier management
  - build off common platforms
  - phased upgrades
Issues in Product Portfolios

Portfolio interactions --

- staffing and other resources
- technical interdependencies

What happens on one project has significant knock-on effects to other projects. Aggressive project assumptions ("inconsistent mission") adversely affect more than the one project.
Portfolio Resourcing Issues

- Constraints on Shared Resources
  - Late and over-budget projects delay ramp-up of downstream projects
  - Shared resources (e.g. test facilities) can also create bottlenecks
  - Staff working simultaneously on multiple projects create inefficiencies and delays
Staff working simultaneously on multiple projects ...

- ... may increase total “output” per person as more time is productive ...
Staff working simultaneously on multiple projects ...

- ... but often slows progress on the portfolio of projects:
  - Productivity reduced by need to refamiliarize with a project with every shift
  - Average lead time for an individual’s tasks = Workload Total / Total Time Available
  - Even if a person is not overloaded in the aggregate, there will be some times when multiple projects need simultaneous input
Time per project with more projects

Figure by MIT OCW.
What happens when Project 1 fails to meet plan?
Phasing of Project Staffing

Project Staffing

Time

Project 1

Typical Plan

Project 2
Not only are resources constrained, but
Because of technical interdependencies, failure to adequately complete the first project causes more work and rework on the second project.
Two kinds of development work

1. **conception development work** - take place two years prior to launch
2. **detailed design work** - takes place one year prior to launch

- Launch date is fixed (this is relaxed in subsequent work).
Model Feedback Structure cont.

Delays:

- Concept Development Activities on Next Year's Product
- Design Problems in This Year's Product
- Goal for Number of Design Problems

Feedback Loops:

- Tipping Loop: Resources Dedicated to Next Year's Product
- Rework Loop: Resources Dedicated to This Year's Product
- Problem Gap: Resources

Arrows indicate the direction of feedback.
Response to Unplanned Increases in Workload

% of Concept Development Work Completed

Quality of Finished Design (% Defective)

Model Year

Model Year
Linking SD Project Models: A Multi-Project Portfolio Model, Or Exogenously-Linked Single Project Models?

- If the number of projects active at one time is small, exogenous (time-dependent) inputs could connect single project models
  - staff available given needs of other projects
  - precedence and other constraints
- With a larger number of projects and complex technical interdependencies, a multi-project model is warranted
Upstream - Downstream Projects

**Upstream Project**

- Time Remaining
- Skill & Experience
- Staff
- Turnover
- Hiring
- Equivalent Staff on Project
- Overtime
- Staffing Requested
- Equivalized Work
- Work Quality to Date
- Work To Be Done
- Added Work
- Required Progress
- Upstream Rework
- Discovery
- Downstream Progress

**Downstream Project**

- Time Remaining
- Skill & Experience
- Staff
- Turnover
- Hiring
- Equivalent Staff on Project
- Overtime
- Staffing Requested
- Equivalized Work
- Work Quality to Date
- Work To Be Done
- Added Work
- Required Progress
- Upstream Rework
- Discovery
- Downstream Progress

**Effect of Upstream P&Q on Downstream**

- Staff Available
- Start Downstream
- Required Upstream Progress

**Upstream Progress & Quality**

- Perceived Progress
- Schedule Pressure
- Out-of-Sequence Work
- Work Existed
- Hours Expended to Date
- Hours Remaining
- Hours at Completion
- Duration
- Expected Completion Time
- Work Real Done
- Undiscovered Rework
- Known Rework
- Remaining Work To Be Done
- Overtime
- Time Remaining

**Upstream Project**

- Work Real Done
- Undiscovered Rework
- Known Rework
- Remaining Work To Be Done
- Overtime
- Time Remaining

**Downstream Project**

- Work Real Done
- Undiscovered Rework
- Known Rework
- Remaining Work To Be Done
- Overtime
- Time Remaining
Parallel Projects (Resource Competition not shown)

**Project 1**

- **Phase 1 Progress & Quality**
- **Phase 2 Rework Discovery**
- **Effect of Phase 2 Progress**
- **Req'd. Phase 1 Progress**
- **Phase 1 Rework Discovery**
- **Effect of Phase 2 P&Q On Phase 1**

**Phase 2 Progress & Quality**

**Project 2**

- **Effect of Phase 1 P&Q on Phase 2**
- **Req'd. Phase 1 P&Q On Phase 1**
- **Phase 2 Rework Discovery**

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Possible Solutions

- Realistic planning and budgeting!
- Maintaining a buffer of surge capacity
- Reducing the number of projects and/or the scope per project
Company Strategy as it Affects the Portfolio

- Mix of projects that allow company to remain competitive over time
- Developing new technologies and skills
- How much diversification is needed to reduce risk (and is it worth it if short of resources?)

**Addressing these issues requires a different model.**
### Mission Dimensions

#### Priority & Specific Objectives

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<th>High, Stretch</th>
<th>Medium</th>
<th>Low, Slack</th>
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**What should the “objectives” be?**

**How many can be “high” priority?**
Revenue and Profit Drivers …

- Market Demand
  - Sales
    - Revenue
    - Price
    - Profit
  - Market Share
  - Costs
  - Price
“Mission” Elements Affect Attractiveness

Market Demand

Sales

Revenue

Profit

Market Share

Product Attractiveness

Product Newness

Time to Market

Price

Costs

Quality

Scope
“Mission” elements have negative impacts as well ...
Market Model with feedbacks through profit and budget

Mission Tradeoffs
Why Do Organizations Seem So Poor at Learning Lessons From Prior Projects?

- Belief that every project is different
- Projects are transient phenomena -- companies often do not have organizations, money, systems, etc. that span projects, esp. to learn the lessons
- Limited span and career path of good project managers
- Lack of a framework (model) for comparing
Is What’s Best for the Project Best for the Company?

- Examples of conflicting practices --
  - Using the best people only
  - Using only experienced people
  - Introducing new processes (Sterman and Repenning work at Sloan School)