Dynamics of Project Performance

System Dynamics and Project Management

Lecture #17, SD Class Six (10/30/00)
Topics

• Review Homework #4

• Managing Project Dynamics -- A Strategic View of Project Preparation (Review of last class)

• Managing Project Dynamics -- A Strategic View of Project Planning

• Schedule Adjustments & Homework #6
Example Response

- Boss: The project must finish as close to schedule as possible. Let’s hire more people if we fall behind in order to catch up.

- You: My analysis shows that if we hire people to catch up, we will finish sooner than not hiring, but the project will cost a lot more …
Staff level increases significantly and the project costs more.

Plan

Staff Level

Cumulative Effort Expended
Because hiring inexperienced people reduces quality …
Causing us to do more total work at lower productivity

Cumulative Work Done

Productivity

Cumulative Work Done : Hiring
Cumulative Work Done : No Hiring

Productivity : Hiring
Productivity : No Hiring
Well, okay, but why do we still finish late?
Because of delays in hiring people, and because we overestimate the net progress the new staff will make. Note that average productivity, the way we decide how many staff to hire, is always declining and hence we tend to underestimate staff needs.
Hiring generally costs more, but only makes project later if experience very low …

Graph for Staff Level

- Hire, 0.0 Initial Experience, Cost = 493
- Hire, 1.0 Initial Experience, Cost = 165
- Hire, 0.5 Initial Experience, Cost = 231
- No Hiring, Cost = 170

Staff Level: Class4 Hire 100
Staff Level: Class4 Hire 0
Staff Level: Class4
Staff Level: Class4 Hire

Time (Month)
What is your experience?

- Software vs. hardware vs. …

[Remember that in this relatively simple model experience is used as a proxy for a number of separate effects, including different types of experience (on the project, on similar projects, as an engineer); dilution of experienced staff time; size, and changes in the size, of the organization]
Topics

• Review Homework #4

• Managing Project Dynamics -- A Strategic View of Project Preparation (Review of last class)

• Managing Project Dynamics -- A Strategic View of Project Planning

• Schedule Adjustments & Homework #6
Typical project dynamics ...

... Result in schedule &/or budget overrun
What can we do to avoid/minimize in ...

- ... project preparation (design)
- ... project planning and risk management
- ... project execution and adaptation
Strategic “Project” Management Pertains to Both Preparation & Planning

Strategic Project Management

Project Preparation

Doing the right job

Project Planning

Project Execution

Project Adaptation

Doing the job right
How Do The Dynamics It Get Started?

- Inconsistent “mission” (scope/schedule/defects/budget)
- Late changes and other risks
- “Quality” problems

These are characteristics of “complex” (vs. “simple”) projects
## Priority & Specific Objectives

<table>
<thead>
<tr>
<th></th>
<th>High, Stretch</th>
<th>Medium</th>
<th>Low, Slack</th>
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</thead>
<tbody>
<tr>
<td><strong>Features / Scope</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>Time-to-Market/ Schedule</strong></td>
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<tr>
<td><strong>Defects/ Undiscovered Rework</strong></td>
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<tr>
<td><strong>Resources / Cost</strong></td>
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**What should the “objectives” be?**
**How many can be “high” priority?**
Late Project Changes Can Create the Dynamics As Well

- “Changes”
  - 20% of tasks done obsoleted at month 15
  - Put into undiscovered rework (what needs to be redone often not completely known when “change” is made).
What causes project “quality” problems?

- Remember, quality as used in the model is any work done incorrectly or incompletely, regardless of cause
What causes project “quality” problems?
What are differences between “changes” and “quality” problems?

- Changes represent truly unknowable, uncontrollable, exogenous impacts (though the fact that they often happen might be planned for)
  - competitor introduces a new feature
  - ...

- “Quality” problems can be anticipated and dealt with in the design and management of the project
  - buffers, prototypes, process, ...
How might we represent these “exogenous” factors in the model?

- Availability and quality of information from others (suppliers, other projects, platforms) (time-based effect on quality)
- Uncertain customer requirements (fraction-complete-based effect on quality)
- Uncertain technology, technology leap (normal quality)
- Scope (esp. number of features and resultant complexity) (normal quality)
- Other -- type of people available, tools, organization structure (normal quality)
Availability and Quality of Info from Others (suppliers, other projects)

Lookup - Table for Effect of Supplier Information

Table for Effect of Supplier Information

Effect of Supplier Information

Effect of Schedule Pressure on Quality

Effect of Prior Work Quality on Quality

Effect of Experience on Quality

Normal Quality

Project Time (month)
Graph for Staff Level

... Imposed on the Class4/Homework 4 Model

Uncertain Customer Requirements

Inconsistent Mission

Changes

Plan

Time (Month)

Staff Level : Plan
Staff Level : Plan Work 125
Staff Level : Changes
Staff Level : Uncertain Customer Requirements
How can we design a project that minimizes the chances of the dynamics getting started?

- Consistent mission?
- Reflects typical quality problems?
- Accounts for possible changes and risks?

*Note: Source of problem affects solution*
Lessons from 10/10 Class on Mission

- Getting a feasible project design 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 which varies with relative priority of mission elements.
Topics

• Review Homework #1

• Managing Project Dynamics -- A Strategic View of Project Preparation (Review of last class)

• Managing Project Dynamics -- A Strategic View of Project Planning

• Schedule Adjustments
Selected Issues in Project Planning

- Selecting the process model
- Defining teams and responsibilities
- Activity planning and resource allocation
- Scheduling
- Determining what to measure, monitor, exert pressure on (reward)
- Identifying risks and mitigation plans
Strategic Process & Organization Issues

- Waterfall vs. spiral vs. adaptive vs. …?
- Autonomous (dedicated) integrated product team vs. functional?
- System vs. modules?
- How much phase overlap and concurrency?
- How much to subcontract, make vs. buy?
Strategic Staffing Issues

- How much to rely on overtime (vs. adding staff)?
- Should you pay extra for experience?
- Generalists vs. specialists?
- Co-location vs. geographically dispersed?
- How much training?
- How much is it worth to reduce attrition?
How do you decide on a specific process?
The “Class 6” Base Case -- Suppose

- Uncertain customer requirements cause quality problems early in the project
  - normal quality = .95
  - all other parameters as in Homework4 Model

- Assume waterfall model with functional organization structure
Uncertain Customer Requirements

Table for Effect of Uncertain Customer Requirements

Fraction Perceived to Be Complete

Effect of Uncertain Customer Requirements

Effect of Experience

Effect of Schedule Pressure

Effect of Prior Work Quality

Quality

Normal Quality

- Table for Effect of Uncertain Customer Requirements

<table>
<thead>
<tr>
<th>Fraction Complete</th>
<th>0.0</th>
<th>0.5</th>
<th>1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality</td>
<td></td>
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<td></td>
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</tbody>
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James M. Lyneis
Uncertain Customer Requirements
(alternative allowing easy change of max)

Effect = (Maximum Effect of
Uncertain Customer
Requirements+(1-Maximum Effect
of Uncertain Customer
Requirements)*Elimination of
Uncertainty Based on Progress)

(0.85 in Class6
Model)

Effect of Prior Work
Quality on Quality

Effect of Sche
Pressure on Qu

Effect of Experience on
Quality

Effect of Uncertain
Customer
Requirements

Table for Effect of Uncertain Custor

Table for Effect of
Uncertain Customer
Requirements

Elimination of
Uncertainty Based on
Progress

Fraction Perceived
to be Complete

Fraction Complete

Normal Quality

Effect of Prior Work
Quality on Quality
Elimination of Uncertainty Reflects a “Waterfall” Approach to Development -- A Sequential Series of Tasks With Milestones & Handoffs

- Table for Effect of Uncertain Customer
Graph for Staff Level

Uncertain Customer Requirements

Completion: Month 38.875 (30 planned)
Cost: 263 Person-months (115 plan)

Time (Month)
Effects on Quality ...

Quality : Class 5 Uncertain Customer Requirements
Effect of Prior Work Quality on Quality : Class 5 Uncertain Customer Requirements
Effect of Experience on Quality : Class 5 Uncertain Customer Requirements
Effect of Schedule Pressure on Quality : Class 5 Uncertain Customer Requirements
Effect of Uncertain Customer Requirements : Class 5 Uncertain Customer Requirements

Time (Month)

Quality
Strategic Process & Organization Issues

- Waterfall vs. spiral vs. adaptive vs. …?
- Autonomous (dedicated) integrated product team vs. functional?
- System vs. modules?
- How much phase overlap and concurrency?
- How much to subcontract, make vs. buy?

*How do we assess what is right for our project?*
# Waterfall vs. Spiral: Spiral ...

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
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Waterfall vs. Spiral: Spiral … (comments from an earlier class)

**Pros**
- Early feedback from customer
- Deliver parts of system earlier
- Start building sooner
- ...

**Cons**
- Costs more -- greater scope, bigger team, more co-ordination
- Fuzzier definition of project tasks and deliverables
- Harder to define when done
- ...

[Image of spiral and waterfall diagrams]
What are the pros and cons of the above alternatives \textit{in the context of the model framework}?

- Direct impacts of alternatives (steady-state vs. dynamic) --
  - Scope
  - productivity
  - quality
  - rework discovery
  - strength of productivity and quality effects
  - ...

- Secondary impacts (assessed via simulation)
An Iterative Development Process -- How might it affect elimination of uncertainty?
Waterfall vs. Spiral: Sample Test

- Spiral of 3 phases
- Maximum Time to Discover Rework
  - Waterfall = 12 months
  - Spiral = 4 months

Continued ...
Elimination of Uncertainty Based on Progress …

Waterfall

Spiral

"Table for Effect of Uncertain Custome

Fraction Complete

Fraction Complete
Elimination of Uncertainty Based on Progress …

Waterfall

Spiral

"Table for Effect of Uncertain Customer"
How do we know these values?

- First time, you don’t ==> make educated guesses. Remember --
  - Better than mental models alone
  - Can do sensitivities -- how bad would the scope increase have to be before Spiral was not helpful for this type of project

- Once project finishes, can get a good estimate of the impact for use in future planning
### Waterfall vs. Spiral

<table>
<thead>
<tr>
<th>Test</th>
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<th>Cost(person-mos)</th>
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<tbody>
<tr>
<td>Plan</td>
<td>29.875</td>
<td>116.7</td>
</tr>
<tr>
<td>Waterfall</td>
<td>38.875</td>
<td>263.3</td>
</tr>
<tr>
<td>Spiral</td>
<td>31.45</td>
<td>171.5</td>
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*Note: alternative process, etc. generally do not allow you to achieve an inconsistent plan, but they can improve performance along one or more mission objectives.*
## Waterfall vs. Spiral (added scope)

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<tr>
<td>Spiral</td>
<td>31.45</td>
<td>171.5</td>
</tr>
<tr>
<td>Spiral + 10% more scope</td>
<td>32.1</td>
<td>216.1</td>
</tr>
<tr>
<td>Spiral + 20%</td>
<td>32.625</td>
<td>261.2</td>
</tr>
<tr>
<td>Spiral + 30%</td>
<td>33.1</td>
<td>307.7</td>
</tr>
</tbody>
</table>
Graph for Staff Level

Staff Level: Class6 Spiral + More Scope
Staff Level: Class6 Spiral
Staff Level: Class6 Waterfall
Staff Level: Class6 Plan

Time (Month)

Spiral + 10% More Scope
Spiral
Waterfall
Plan
Graph for Quality

Time (Month)

Plan
Spiral
Spiral + 10% More Scope
Waterfall

Quality : Class6 Spiral + More Scope
Quality : Class6 Spiral
Quality : Class6 Waterfall
Quality : Class6 Plan

Fraction
Fraction
Fraction
Fraction
Graph for Undiscovered Rework

Undiscovered Rework: Class6 Spiral + More Scope
Undiscovered Rework: Class6 Spiral
Undiscovered Rework: Class6 Waterfall
Undiscovered Rework: Class6 Plan

Time (Month)
Graph for Work Done

Work Done: Class6 Spiral + More Scope
Work Done: Class6 Spiral
Work Done: Class6 Waterfall
Work Done: Class6 Plan

Plan Waterfall
Spiral
Spiral + 10% More Scope

Time (Month)
0 3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60

0 10 50 100 150 200
Conclusions re. Waterfall vs. Spiral

A spiral or similar development process can improve performance if project conditions would otherwise cause significant undiscovered rework.

The benefits of these approaches increase with the uncertainty (risk) in the development, i.e., the amount of potential rework.

Cautions -- alternative processes may ...
- … not help for truly “exogenous” changes
- … involve additional scope
- … involve short-term implementation costs (for new processes/tools/structures)
Even with better processes, there are tradeoffs among the mission objectives.

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<tr>
<td>Spiral</td>
<td>31.45</td>
<td>171.5</td>
</tr>
<tr>
<td>Waterfall + Schedule = 47</td>
<td>46.5</td>
<td>185.7</td>
</tr>
<tr>
<td>Spiral + Schedule = 35</td>
<td>34.2</td>
<td>135.9</td>
</tr>
</tbody>
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Graph for Staff Level

Time (Month)

Staff Level: Class6 Waterfall
Staff Level: Class6 Spiral
Staff Level: Class6 Waterfall Sched 40 No Hire
Staff Level: Class6 Spiral No-Hire
Strategic Process & Organization Issues

Waterfall vs. spiral vs. adaptive vs. …?
Autonomous (dedicated) integrated product team vs. functional?
System vs. modules?
How much phase overlap and concurrency?
[How much to subcontract, make vs. buy?]

*How do we assess what is right for our project?*
Autonomous Integrated Teams vs. Functional: Autonomous Teams ...

<table>
<thead>
<tr>
<th><strong>Pros</strong></th>
<th><strong>Cons</strong></th>
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Autonomous Integrated Teams vs. Functional: Sample Test

- Maximum effect of uncertain customer requirements = .85
- Waterfall-style Elimination of Uncertain Customer Requirements
- Integrated Teams:
  - Reduce Max effect of customer uncertainty to .925
  - Reduce Maximum rework discovery time to 4 months (from 12 months)
  - Reduce Normal productivity to .9 (from 1)
Graph for Staff Level

Staff Level: Class6 Plan
Staff Level: Class6 Waterfall
Staff Level: Class6 Integrated Teams

Time (Month)
Graph for Quality

Quality : Class6 Plan
Quality : Class6 Waterfall
Quality : Class6 Integrated Teams

Time (Month)
Graph for Undiscovered Rework

Undiscovered Rework: Class6 Plan
Undiscovered Rework: Class6 Waterfall
Undiscovered Rework: Class6 Integrated Teams
## Autonomous Integrated Teams vs. Functional

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<td>116.7</td>
</tr>
<tr>
<td>Waterfall (functional)</td>
<td>38.875</td>
<td>263.3</td>
</tr>
<tr>
<td>Integrated Product Team</td>
<td>31.625</td>
<td>189.38</td>
</tr>
</tbody>
</table>
Conclusions re. Integrated Teams

- An integrated product team or similar organization structure can improve performance if project conditions would otherwise cause significant undiscovered rework.

- The benefits of these structures increase with the uncertainty (risk), and likely project overrun with traditional development approaches.

- Cautions ...
Strategic Staffing Issues

How much to rely on overtime (vs. adding staff)?
Should you pay extra for experience?
Generalists vs. specialists?
Co-location vs. geographically dispersed?
How much training?
How much is it worth to reduce attrition?

How do we assess what is right for our project?
How do we assess what is right for our project?

Specify the direct impacts of alternatives (steady-state vs. dynamic) on --

- Scope
- productivity
- quality
- rework discovery
- strength of productivity and quality effects
- ...

Secondary impacts (assessed via simulation)
Strategic Process & Organization Issues

Waterfall vs. spiral vs. adaptive vs. …?
Autonomous (dedicated) integrated product team vs. functional?
System vs. modules?
How much phase overlap and concurrency?
How much to subcontract, make vs. buy?
…defer until next class?
What can we do to avoid/minimize the dynamics …

… in project preparation (design) and project planning? √ (except risk management)

… in project execution and adaptation
Lessons

- It’s the undiscovered rework that creates problems.
- Alternative development processes can improve performance if project conditions would otherwise cause significant undiscovered rework.
- Strategic issues (process, staffing, phase overlap, etc.) involve tradeoffs -- costs as well as benefits -- that can only be evaluated in the context of their effect on the ability of the project to meet its mission objectives -- *There is no one best way for all projects.*
Topics

• Review Homework #1

• Managing Project Dynamics -- A Strategic View of Project Preparation (Review of last class)

• Managing Project Dynamics -- A Strategic View of Project Planning

• Schedule Adjustments & Homework #6
Strategic Issues in Execution and Adaptation

Doing the right job

Project Preparation

Doing the job right

Project Planning

Project Execution

Project Adaptation
Managing Risks and Changes:

- Schedule adjustments
- Staffing strategies

* A Strategic View – Deciding in advance the best way to handle problems if they arise
Schedule Adjustments
Staffing and Scheduling Are Driven By the Same Basic Structure ...

Hiring and/or Schedule Slip are governed by “Willingness to Hire” and “Willingness to Slip”
Schedule Slip Formulation

Willingness to Slip

Table for Schedule Slip

Scheduled Completion Date

Perceived Real Completion Date

Indicated Completion Date Based on Progress

Change in Schedule

Time to Slip Schedule

 Fraction Perceived to be Complete >
Schedule Slip Formulation (cont.)

- Scheduled Completion Date = Integral of Schedule Slip over Time to Slip Schedule [Dimensions -- Month]

- Schedule Slip = Willingness to Slip * MAX(0,(Perceived Real Completion Date - Scheduled Completion Date)) * Table for Schedule Slip [Dimensions -- Months]

- The desired schedule slip is determined by the difference between perceived real completion date and the current schedule. Willingness to slip and table for schedule slip allow you to control the degree and timing of any slip.
Schedule Slip Formulation (cont.)

- Perceived Real Completion Date = SMOOTHI(Indicated Completion Date Based on Progress, 1, Scheduled Completion Date) [Dimensions -- Month]
  - Perceived real completion date reflects the time required to perceive changes in project conditions, using VENSIM's SMOOTHI function.

- Indicated Completion Date Based on Progress -- see schedule pressure
Schedule Slip Formulation (cont.)

- Willingness to Slip Schedule -- varies between 0 and 1; a value of 0 means no schedule slip, staff up to get the project done; a value of 1 means slip the schedule as indicated to allow the current staff to get the job done.

- Table for Schedule Slip -- a function of Fraction Perceived to be Complete. When Willingness is set above 0, allows you to control when in the project the slip occurs.
Graph Lookup - Table for Schedule Slip
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?
Homework #6 has been posted, due 11/14
What causes project “quality” problems?

- Endogenous feedback effects
- Exogenous factors (“normal quality”)
  - Availability and quality of information from others (suppliers, other projects, platforms)
  - Uncertain customer requirements
  - Uncertain technology, technology leap
  - Scope (esp. number of features and resultant complexity)
  - Other -- type of people available, tools, organization structure