Dynamics of Project Performance

System Dynamics and Project Management

Class Two (9/25/03)
Topics

• Dynamic project problems and the system dynamics viewpoint

• The dynamics of project performance -- the rework cycle

• The dynamics of project performance -- feedback effects

• Practice for 9/30
Topics

- Dynamic project problems and the system dynamics viewpoint
- The dynamics of project performance -- the rework cycle
- The dynamics of project performance -- feedback effects
- Practice for 9/30
Examples of Behavior Modes on a Project

Project Staffing

Time

Typical Plan

Copyright © 2003 James M. Lyneis
Examples (continued)

Fraction Complete

 Typical Plan

Time

0.5 1
Examples (continued)

Productivity (Normalised)

Time

Typical Plan

1

2
System Dynamics Concepts

- Focus on dynamic behavior
- System structure as cause of that behavior
- Emphasis on internal dynamics and how we can change structure
- A model is an integral part of organizational learning
Examples of Behavior Modes

Growth

Stability

Project Staffing

"Plan"
The basic element of system structure is the feedback loop...

This one a “positive,” or reinforcing feedback loop.

Adapted from Professor John Sterman, MIT
Loops of effects interact with one another, making traditional diagnosis quite difficult...

...Such as with this “negative,” or balancing, feedback loop, which may slow or reverse growth
Effects interacting makes traditional diagnosis quite difficult in a business setting as well.
System Dynamics Tools

“Soft” tools --
- behaviour-over-time graphs
- causal-loop diagramming
- system archetypes
- mental simulation

“Systems Thinking”

“Hard” tools --
- computer models
- computer simulation
- calibration to data
- sensitivity and what-if analyses
Causal loop diagrams -- causal links

An arrow with a positive sign (+) or an “s” means that, all else remaining equal, an increase (decrease) in the first variable increases (decreases) the second variable above (below) what it would otherwise have been.

Bank Balance $\rightarrow s \rightarrow$ Interest Earned

$\rightarrow +$
Causal loop diagrams -- causal links

An arrow with a positive sign (+) or an “s” means that, all else remaining equal, an increase (decrease) in the first variable increases (decreases) the second variable **above (below)** what it would otherwise have been.

- Bank Balance \( \rightarrow \) Interest Earned
  - Bank Balance \( + \) Interest Earned

An arrow with a negative sign (-) or an “o” means that, all else remaining equal, an increase (decrease) in the first variable decreases (increases) the second variable **below (above)** what it otherwise would have been.

- Price \( \rightarrow \) Orders
  - Price \( - \) Orders
Exercise -- link and loop polarity

Production → Inventory → Shipments → Price
Superordinate

Salesforce → Ordered Books → Population → Deaths Subordinate
Causal loop diagrams -- loop polarity

- **Reinforcing loops** -- loops with all positive or an even number of negative causal links

- **Balancing loops** -- loops with an odd number of negative causal links
Reinforcing or Balancing?

Attractiveness of Market

Profits

Number of Competitors

Industry Price

Copyright © 2003 James M. Lyneis
Reinforcing or Balancing?

Price

Unit Cost of Production

Demand

Cumulative Production

Price

Unit Cost of Production

Demand

Cumulative Production
The “dominant” loop on a project may be a controlling loop ...

![Diagram showing feedback loops involving Staff, Progress, Desired Progress, and Time.](chart)
With “reinforcing” loops complicating that control...
With “reinforcing” loops complicating that control ...

- Experience

+ Productivity

Staff

+ Progress

Desired Progress

- Overtime

+ Delay

+ Fatigue
The main elements within feedback loops are...

**Cause-effect relationships**

Experience → Productivity

**Time delayed action**

- New Staff
- Productivity vs. Time

**Non-linear responses**

- Productivity vs. Years of experience
As the final element of system structure, there are two kinds of variables ...

- **Stocks or “levels”** -- define the state of the system
  
  ![Diagram of Bank Account Balance](image)

- **Flows or “rates”** -- define the rate of change in system states
  
  ![Diagram of Deposits](image)

Copyright © 2003 James M. Lyneis
Connecting stocks and flows ... "Clouds" represent stocks outside the system boundary.

- Bank Account Balance
- Deposits
- Withdrawals

- Staff
- Hiring
- Firing
Interacting positive and negative feedback loops of cause-effect relationships, with stocks, flows, delays, and non-linearities, are capable of generating all observed modes of behavior.
The Drivers of Project Dynamics --

- The “rework cycle”
- Feedback effects on productivity and work quality (often “vicious circles”)
- Knock-on effects between work phases
- Knock-on effects between projects
Emphasis on Internal Dynamics

System-as-cause thinking

- What can we do to improve our performance and accomplish our objectives ...
- Proactive and offensive

Vs.

System-as-effect thinking

- Others did it to us
- Predictive, reactive, defensive
Topics

• Dynamic project problems and the system dynamics viewpoint

• *The dynamics of project performance -- the rework cycle*

• The dynamics of project performance -- feedback effects

• Practice for 9/30
What are typical stocks & flows on a project?

- **Stocks**
- **Flows**
The Traditional View of a Program

WORK TO BE DONE → WORK BEING DONE → WORK DONE

PEOPLE → PRODUCTIVITY

WORK TO DO

STAFF

% DONE

TIME

TIME

TIME
The traditional view, expanded to multiple tasks with logical links ...

... becomes a Critical Path Network
Definitions

- **Productivity** --
  Work accomplished per hour of effort, regardless of completeness or correctness

- **Quality** --
  Fraction of work just accomplished that is correct and complete, i.e. will not need rework.
But traditional approaches fail to consider rework.
Or Undiscovered Rework

People | Productivity | Quality

Work to Be Done | Work Being Done | Work Really Done

Known Rework | Undiscovered Rework

Rework Discovery

Work to Do | Staff | % Done

Time | Time | Time

RWK | UR | Really

Copyright © 2003 James M. Lyneis
Rework shows up as revisions to work products

Accomplishment of Revisions to Design Products (e.g., Drawings)

Virtually all complex projects have revisions cycles
On typical development projects ...

Disguised results from actual aerospace project

... Staffing experiences an extended tail
Caused by the need to accomplish rework

Work Assignments of Staff to...

Total

Rework

Original Work

Caused by the need to accomplish rework
On typical development projects ...

Program Staff, Simulated vs. Data (Equivalent Staff)

Disguised results from actual vehicle project

... A second staffing peak
Again caused by the need to execute rework

Work Assignments of Staff to...

Disguised results from actual vehicle project
The Rework Cycle

Key to Project Dynamics

- WORK TO BE DONE
- WORK BEING DONE
- WORK REALLY DONE

People ➔ Productivity ➔ Quality

- KNOWN REWORK ➔ Rework Discovery ➔ UNDISCOVERED REWORK

Copyright © 2003
James M. Lyneis
As a result, typical projects experience "The Lost-Year"...
Perceived vs. Actual Progress: SRS Development

Disguised results from actual aerospace project

Or Two Years!!
and the “90% Syndrome” ---

Design Progress (Percent Complete)

Disguised results from actual aerospace project
The rework cycle concept was originally developed by Pugh-Roberts Associates, but is now common...


Examples from other models --


Topics

• Dynamic project problems and the system dynamics viewpoint

• The dynamics of project performance -- the rework cycle

• The dynamics of project performance -- feedback effects

• Practice for 10/1
On a Typical Project, Productivity & Quality Vary Over Time

Why??

Productivity (Normalised)

Time

Typical Plan

Why??
On a Typical Project, Productivity & Quality Vary Over Time

Productivity: AC Design

<table>
<thead>
<tr>
<th>TIME</th>
<th>Yr 1</th>
<th>Yr 2</th>
<th>Yr 3</th>
<th>Yr 4</th>
<th>Yr 5</th>
<th>Yr 6</th>
<th>Yr 7</th>
<th>Yr 8</th>
<th>Yr 9</th>
<th>Yr 10</th>
<th>Yr 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>5.0</td>
<td>5.2</td>
<td>5.5</td>
<td>5.8</td>
<td>6.1</td>
<td>6.4</td>
<td>6.7</td>
<td>7.0</td>
<td>7.3</td>
<td>7.6</td>
<td>8.0</td>
</tr>
</tbody>
</table>

Why??
On a Typical Project, Productivity & Quality Vary Over Time

Why??

With respect to AC Design:

- Quality (%): AC Design
- Average Quality to Date

Why??

Quality (%): AC Design

Average Quality to Date

TIME

Yr 1  Yr 2  Yr 3  Yr 4  Yr 5  Yr 6  Yr 7  Yr 8  Yr 9  Yr 10 Yr 11

0.  25.  50.  75.  100.
Why ?? -- Drivers of Dynamics

- The “rework cycle”
- Feedback effects on productivity and work quality
  - Positive, reinforcing, often “vicious circles”
  - Negative, controlling
- Knock-on effects between work phases
What drives productivity & quality?
Develop a causal diagram for the effects ...
Project Dynamics
A system dynamics model usually represents several phases of work, but is more aggregate than a CPM model.
Summary -- 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
Management Actions ??

[Diagram with various nodes and arrows indicating relationships between concepts such as work quality, productivity, skill & experience, schedule pressure, availability of prerequisites, etc.]
Lessons

- Rework is the most important single factor driving schedule and budget overruns
- Project problems can quickly “snowball”
- “Soft Factors” such as overtime and morale can be big drivers of rework
- Management actions are a key part of the feedback loops
Hard tools force us to be more explicit, and accurately simulate the consequences of our models...

“Soft” tools --
- behaviour-over-time graphs
- causal-loop diagramming
- system archetypes
- mental simulation

“Hard” tools --
- computer models
- computer simulation
- calibration to data
- sensitivity and what-if analyses
Topics

• Dynamic project problems and the system dynamics viewpoint

• The dynamics of project performance -- the rework cycle

• The dynamics of project performance -- feedback effects

• Practice for 9/30
1. Building from the Class1 Step 3 model (or your own version if desired), complete the equations for the rework cycle model as illustrated in the following diagram.

2. Assume that staff, productivity, quality, and rework discovery time are constants. A VENSIM diagram of the model, plus some hints, follows. Assume that there are 100 tasks to be done; set the normal values for productivity, quality, and rework discovery time at 1 task/month/person, 1.0, and 4 months, respectively.
2. Simulate the model, and verify that the results match the Class1 Step3 model.

3. Now set normal quality to 0.75, and simulate the model. When does the project finish? What happens to undiscovered rework?

4. Which has a greater impact on the project, a 33% increase in quality (from the 0.75 base) or a 33% increase in productivity?
If the world consists only of stocks and flows, what are those other variables indicated on the diagrams??

- “Auxillaries” -- components of rates
- Constants (e.g., factors which may be stocks or flows, but which do not change over the time span of the simulation)
- External inputs
Example of an Auxiliary

The Rate:

Work Accomplishment = Feasible Work Rate * Quality

The Auxillaries:

Feasible Work Rate = Min(Maximum Work Rate, Potential Work Rate)

Potential Work Rate = Staff Level * Productivity * Project Finished Switch

The Constant: Quality = .75
Hints

- Representing a delay:
- Rework Discovery = Undiscovered Rework / Time to Discover Rework

[This equation produces a delay between the time when rework is created and when it is discovered; in steady state, the delay time equals Time to Discover Rework. We will look at delays in more detail later.]