Identifying best EVM-based Risk Management policies through Dynamic Simulation

Alexandre G. Rodrigues, Ph.D.

Assistant Professor
Department of Information Systems
The University of Minho, 4800 Guimarães, Portugal
Alex.Rodrigues@dsi.uminho.pt / Alex.Rodrigues@PMO-Consulting.org

PMI® Risk Management Specific Interest Group

Agenda

◆ Overview of Earned Value Management
◆ System Dynamics Modeling
◆ Developing an SD project model
◆ Modeling EVM-based control policies
◆ Practical Example: EVM vs. Traditional Control
  ↓Managing the impacts of risks
  ↓Exploring opportunities
  ↓Managing the project objectives
◆ Conclusions
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Earned Value Management

Overview

- The Challenge of Control
- Basic Metrics
- Variance and Performance Indices
- “At Completion” forecasts
Earned Value Management
The Challenge of Control

Cost  Time
Quality
Scope

Earned Value Management
The Challenge of Control

Cost  Time
Quality
Scope
Earned Value Management

Basic Metrics

Earned Value Management System

Variance Indices

Earned Value Management System
Earned Value Management

Variance Indices

\[ \text{AV} = \text{PV} - \text{AC} \]
Cost difference on a time based perspective

\[ \text{CV} = \text{EV} - \text{AC} \]
Cost difference on a work based perspective

\[ \text{SV} = \text{EV} - \text{PV} \]
Cost difference on a work and time based perspective

Performance Indices

\[ \text{API} = \frac{\text{PV}}{\text{AC}} \]
Relative rate at which funds are being spent

\[ \text{CPI} = \frac{\text{EV}}{\text{AC}} \]
Relative productivity

\[ \text{SPI} = \frac{\text{EV}}{\text{PV}} \]
Relative rate at which work is being accomplished (speed)
**Earned Value Management**

**Performance Indices**

- **CPI** = \( \frac{EV}{AC} \)
  - 0.75  
  - 1 
  - 1.25

- **SPI** = \( \frac{EV}{PV} \)
  - 0.5  
  - 0.75  
  - 1 
  - 1.25

**At Completion** Forecasts

- **ESAC** = Baseline Schedule / SPI
- **ECAC** = Baseline Cost / CPI
- **ECAC(2)** = AC + (Baseline Cost - EV) / (CPI x SPI)
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System Dynamics Modeling

Overview

- Introduction
- Modeling Feedback Dynamics
  - Positive Feedback
  - Negative and Positive Feedback
  - Complex Dynamics
- Feedback Dynamics in Business Systems
- Feedback Dynamics in Projects
System Dynamics Modeling

**Introduction**

- Developed in the late 50s by Forrester (MIT):
  - A *simulation* based modelling approach
  - Aimed at analysing the behaviour of complex social systems
  - Feedback structure as the primary responsible for behaviour
  - Management laboratory:
    - Models supports policy improvement through "what-if" scenario analyses
- A two-phase modelling process:
  - Qualitative Influence Diagrams
  - Quantitative Simulation Models
- Growing application to real life business problems and to Project Management

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**System Dynamics Modeling**

**Positive Feedback**

\[
\text{Infected People} (t) = \text{Infected People} (t - dt) + (\text{Contagion Rate}) \times dt
\]

\[
\text{INIT Infected People} = 1
\]

INFLOWS:

\[
\text{Contagion Rate} = \text{Infected People} \times \text{Contagion Factor}
\]

\[
\text{Contagion Factor} = 0.5
\]
System Dynamics Modeling

Negative and Positive Feedback

- Healthy People
- Infected People
- Contacts
- Contagion Rate
- Contagion Factor

System Dynamics Modeling

Complex Feedback

- Healthy People
- Infected People
- Contacts
- Contagion Rate
- Contagion Factor
- People in Hospital
- To Hospital Rate
- Treatment Rate
- Treatment Delay
- Time to Hospital
System Dynamics Modeling

Complex Feedback

- Infected People
- Contagion Rate
- Potential Contacts
- Contagion Factor
- Healthy People
- People in Hospital
- To Hospital Rate
- Time to Hospital
- Treatment Rate
- Treatment Delay

System Dynamics Modeling

Feedback in Business Systems

- Projects in Backlog
- Effort spent in Marketing and Sales
- Income Generated
- Investment in Resources
- Capacity
- Waiting Time
- Project Sales
- Client Satisfaction
System Dynamics Modeling

Complexity in Social Systems

- **Systemic:**
  - Everything affects everything, directly or indirectly
- **Dynamic:**
  - They do not take place at one point in time. They unfold over-time.
- **Feedback effects:**
  - Causes lead to effects, which over-time will affect the causes
- **Long-term effects (delayed):**
  - The impacts of actions and events remain unperceived in the short-term
- **Non-linear:**
  - Relationships between causes and effects are rarely linear
- **Subjective, intangible, secondary, undesired effects:**
  - Many factors involved are of social human nature and difficult to anticipate

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Developing a SD Project Model

SYDPIM Methodology

Causal Analysis

Validation

Requirements Definition

Verification

Formal Design

Feedback Structure

Developing a SD Project Model

SYDPIM Methodology: Formal Design

Specification of Model Architecture

Task Classification and Identification of Generic Structures

Specify Task Dependencies

Specify Control Decisions

Mapping of Causal Structure to Model Architecture

Model Architecture

Feedback Structure
Developing a SD Project Model
SYDPIM Methodology: Implementation

1. Project feedback structure is identified and is captured in the simulation model
2. Project is simulated and its behaviour over-time is produced
3. Project behaviour is analysed under a feedback perspective
4. Solutions are devised and the SD model is re-calibrated for testing them
Developing a SD Project Model

Using the Model (SYDPIM)

Developing a SD Project Model

Using the Model (SYDPIM)
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Modeling EVM-based control policies

- Concept
- Overview of the SD model used
  - Process Structure
  - Key feedback effects
  - The Project Plan
  - Base Control Policies
- Modeling of EVM Control
  - EVM metrics and indices
  - EVM in the control policies
Modeling EVM policies

Concept

Results

EVM Based Control Policies

Decisions

The SD Project Model

Process Structure: work-flow
The SD Project Model

Process Structure: defects-flow

Process Structure (complex)
The SD Project Model

Process Structure (simpler)

The SD Project Model

Key Feedback Effects

- Schedule pressure:
  - ↓ Productivity, Cost to Rework
  - ↓ Quality
- Communication Overheads (team size)
  - ↓ Productivity, Cost to Rework
- Work Progress
  - ↓ Productivity, Quality, Cost to Detect, Cost to Rework
- Error Density
  - ↓ Quality
  - ↓ Cost to Detect
- Managerial
  - ↓ Schedule Adjustment
  - ↓ Staff Adjustment
  - ↓ QA Level Adjustment
The SD Project Model

The Project Plan

- Objectives:
  - Scope, Cost, Schedule, Quality
  - Priority and importance of each objective
- Staff Profile
  - Planned Allocation Over-Time
- Planned QA Effort
  - As fraction of total effort
  - Over-time
- Planned Rework Fraction
  - As fraction of total effort
- Expected Productivity Variation Over Progress
  - This the expected learning curve, which should have an impact on the Earned Value estimation based on % progress

The SD Project Model

Base Control Policies

- Schedule Adjustment. Depends on:
  - Progress
  - Perceived slippage
  - Schedule priority
  - Delay to adjust
- Staff Adjustment. Depends on:
  - Progress
  - Perceived Staff Gap
  - Budget Priority
  - Delay to adjust (increase / decrease)
- QA Level Adjustment. Depends on:
  - Schedule Pressure
  - Quality Priority
- Weight Given to Baseline. Depends on:
  - Progress
The SD Project Model
Modeling of EVM Control

- The model calculates at any point in time:
  - AC, EV, and PV
  - CPI, SPI, TCPI, TSPI, CPI Modified, SPI Modified
  - ECAC, ESAC, ECTC
  - Average Staff Level Currently Available
- Based on these EVM indices, it calculates:
  - Average Staff Level Needed to Complete on Planned Schedule
  - Staff Gap = Staff Needed – Staff Available
  - Schedule Pressure = Staff Gap / Staff Currently Working
- These metrics drive management decisions, along with the Base Policies:
  - Staff Gap drives Staff Adjustment
  - Schedule Pressure Drives Schedule Adjustment
  - Schedule Pressure Drives QA Level Adjustment

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Practical Example

EVM vs. Traditional Control

- The SD model was calibrated to reproduce a set of scenarios, aimed at:
  - Comparing the performance of EVM-based control vs. traditional operational control
  - Analyzing how the project objectives (schedule, budget quality) should be managed in terms of priority throughout the project, in order to maximize the overall project performance (which depends on the importance of the objectives)

EVM vs. Traditional Control

Scenarios Analyzed

- Base Case:
  - Project implemented as planned
- Scope Risk:
  - 30% addition of new scope, over a period of time
- Scope Risk + Staff Risk:
  - Scope Risk
  - Staff leaving the project at certain moments in time
- Productivity Opportunity:
  - Constant productivity increase
  - Varying productivity increase
EVM vs. Traditional Control

Base Case

Project Outcome vs. Plan

<table>
<thead>
<tr>
<th>Schedule (month)</th>
<th>Budget (person-month)</th>
<th>Quality (% Def. Work)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planned</td>
<td>10.00</td>
<td>33.20</td>
</tr>
<tr>
<td>Base w/ EV</td>
<td>9.92</td>
<td>33.18</td>
</tr>
<tr>
<td>Base w/ OC</td>
<td>9.95</td>
<td>33.30</td>
</tr>
</tbody>
</table>

EVM vs. Traditional Control

Base Case With EVM Control
EVM vs. Traditional Control

Scope Risk

Project Outcome vs. Plan: With Scope Addition

<table>
<thead>
<tr>
<th></th>
<th>Schedule (month)</th>
<th>Budget (person-month)</th>
<th>Quality (% Def. Work)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base w/ EV</td>
<td>9.92</td>
<td>33.18</td>
<td>26.30</td>
</tr>
<tr>
<td>Scope Addition w/ EV</td>
<td>11.65</td>
<td>43.58</td>
<td>28.70</td>
</tr>
<tr>
<td>Scope Addition w/ OC</td>
<td>11.38</td>
<td>44.56</td>
<td>30.70</td>
</tr>
</tbody>
</table>
EVM vs. Traditional Control

Scope Risk + Staff Risk

Project Outcome vs. Plan: With Scope and Staff Risk

<table>
<thead>
<tr>
<th>Schedule (month)</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Base w/ EV</td>
<td>9.50</td>
<td>33.18</td>
</tr>
<tr>
<td>Staff+Scope Risk w/ EV</td>
<td>13.64</td>
<td>41.60</td>
</tr>
<tr>
<td>Staff+Scope Risk w/ OC</td>
<td>16.50</td>
<td>39.57</td>
</tr>
</tbody>
</table>

EVM vs. Traditional Control

Scope Risk + Staff Risk With EVM
EVM vs. Traditional Control

Scope Risk + Staff Risk

Project Performance: Scope and Staff Risk Scenarios

<table>
<thead>
<tr>
<th>Schedule % Deviation</th>
<th>Budget % Deviation</th>
<th>Work % With Defects</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base w/ EV</td>
<td>-15.5%</td>
<td>31.3%</td>
<td>85.7%</td>
</tr>
<tr>
<td>Base w/ OC</td>
<td>-13.8%</td>
<td>34.2%</td>
<td>85.0%</td>
</tr>
<tr>
<td>Staff+Scope Risk w/ EV</td>
<td>36.40%</td>
<td>25.97%</td>
<td>79.50%</td>
</tr>
<tr>
<td>Staff+Scope Risk w/ OC</td>
<td>64.10%</td>
<td>22.10%</td>
<td>70.80%</td>
</tr>
</tbody>
</table>

Productivity Opportunity: Constant

Project Outcome vs. Plan: Higher Productivity (Constant)

<table>
<thead>
<tr>
<th>Schedule (months)</th>
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<th>Quality (% Def. Work)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base w/ EV</td>
<td>9.92</td>
<td>33.18</td>
</tr>
<tr>
<td>High Pdy w/ EV</td>
<td>8.78</td>
<td>27.88</td>
</tr>
<tr>
<td>High Pdy w/ OC</td>
<td>9.50</td>
<td>27.53</td>
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EVM vs. Traditional Control

Productivity Opportunity: Constant

Project Performance: Productivity Opportunity (Constant)

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<tr>
<td>High Pdy w/ EV</td>
<td>-12.20%</td>
<td>15.00%</td>
<td>107.70%</td>
</tr>
<tr>
<td>High Pdy w/ OC</td>
<td>-5.00%</td>
<td>26.30%</td>
<td>105.70%</td>
</tr>
</tbody>
</table>

Objectives
EVM vs. Traditional Control

Productivity Opportunity: Varying

Project Outcome vs. Plan: Varying Productivity

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<td>Base w/ EV</td>
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<td>33.18</td>
</tr>
<tr>
<td>Varying Pdy w/ EV</td>
<td>8.60</td>
<td>26.73</td>
</tr>
<tr>
<td>Varying Pdy w/ OC</td>
<td>11.31</td>
<td>36.69</td>
</tr>
</tbody>
</table>

Objectives

Project Performance: Productivity Opportunities (Varying)

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</tr>
</thead>
<tbody>
<tr>
<td>Varying Pdy w/ EV</td>
<td>-14.00%</td>
<td>-19.50%</td>
<td>30.30%</td>
</tr>
<tr>
<td>Varying Pdy w/ OC</td>
<td>13.10%</td>
<td>10.50%</td>
<td>31.90%</td>
</tr>
</tbody>
</table>
EVM vs. Traditional Control

Productivity Opportunity: Varying

The base scenario considered:
- EVM-based control
- Previous Scope and Staff Risks
- Priority of the objectives equals to their importance

The priorities were then changed
- All “Very High” – full pressure to minimize impacts
- Budget, Schedule and Quality priorities were progressively relaxed to search for an “optimal” solution
EVM vs. Traditional Control
Managing the Objectives Priority

Project Outcome: Managing Objectives Priority

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</thead>
<tbody>
<tr>
<td>Staff+Scope Risk w/ EV</td>
<td>13.64</td>
<td>41.60</td>
</tr>
<tr>
<td>Full Pressure</td>
<td>14.49</td>
<td>50.45</td>
</tr>
<tr>
<td>Optimal</td>
<td>11.60</td>
<td>35.02</td>
</tr>
</tbody>
</table>

EVM vs. Traditional Control
Managing the Objectives Priority

Project Performance: Managing Objectives

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<td>52.00%</td>
<td>35.00%</td>
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<td>Optimal</td>
<td>16.00%</td>
<td>5.50%</td>
<td>39.80%</td>
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EVM vs. Traditional Control

Managing the Objectives Priority
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Conclusions

- When compared with more traditional operational control, in general EVM-based control policies perform better
- In scenarios of uncertainty, EVM appears to provide robust indicators of performance on the basis of which good “at completion” estimates can be produced
- EVM provides indices of status and estimates of “at completion”, but it does not tell what you should do in face of deviations
- Simulation is essential for testing, improving and exploring control policies (it’s too expensive and slow to do it in the real world). System Dynamics modeling provides an excellent means to do this
Identifying best EVM-based Risk Management policies through Dynamic Simulation

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Thank you!!

Any Questions?

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