Software Model for Estimating Project Cost, Schedule, and Reliability Based on DSM Technique and Monte Carlo Simulation

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Agenda

• What is a Project?
• Project Activities Representations
• The Dependency Structure Matrix
• Cost, Schedule and Reliability Model
• Nano-Satellite Project Simulation Results
• Future Work
• Conclusion
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• What is a Project?
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What is a project?

“A temporary endeavor undertaken to create a unique product or service”

PMI
What is a project? - Efforts

Level of Activity

Start

Initiate

Plan

Execute

Control

Close

Finish

11/1/2012 Nagoya, Japan, October 10-13, 2012
What is a Project? – Cornerstones

Cost — Schedule
Scope — Quality
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Project Activities Representations

• Critical Path Method

• GANTT
Likelihood Schedule Estimate

• Program Evaluation and Review Technique

\[ t_e = \frac{a + 4m + b}{6} \]

where

- \( t_e \) = expected time
- \( a \) = optimistic time estimate
- \( m \) = most likely time estimate
- \( b \) = pessimistic time estimate
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Representation Complexity
The DSM - Relations

(a) Dependent (Serial)

(b) Independent (Parallel)

(c) Interdependent (Coupled)
### The DSM - Example

#### DSM Table

<table>
<thead>
<tr>
<th></th>
<th>task 1</th>
<th>task 2</th>
<th>task 3</th>
<th>task 4</th>
<th>task 5</th>
<th>task 6</th>
</tr>
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<tbody>
<tr>
<td>task 1</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>task 2</td>
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<td>X</td>
<td>X</td>
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<td>task 3</td>
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<td>X</td>
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<tr>
<td>task 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### DSM Diagram

```
  task 1
   ↓     ↓     ↓
  task 2  task 3  task 4
       ↓     ↓
  task 6  task 5
          ↓     ↓
           task 3  task 4
```

11/1/2012 Nagoya, Japan, October 10-13, 2012
# The DSM Analysis - Banding Algorithm

<table>
<thead>
<tr>
<th>Task Code</th>
<th>Task Description</th>
<th>Banding</th>
</tr>
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<tbody>
<tr>
<td>A4</td>
<td>Prepare UAV Preliminary DR&amp;O</td>
<td></td>
</tr>
<tr>
<td>A511</td>
<td>Create UAV Preliminary Design Configuration</td>
<td>1</td>
</tr>
<tr>
<td>A512</td>
<td>Prepare &amp; Distribute Surfaced Models &amp; Int. Arngmt. Drawings</td>
<td>2</td>
</tr>
<tr>
<td>A531</td>
<td>Perform Aerodynamics Analyses &amp; Evaluation</td>
<td>3</td>
</tr>
<tr>
<td>A521</td>
<td>Create Initial Structural Geometry</td>
<td>4</td>
</tr>
<tr>
<td>A522</td>
<td>Prepare Structural Geometry &amp; Notes for FEM</td>
<td>5</td>
</tr>
<tr>
<td>A5341</td>
<td>Develop Structural Design Conditions</td>
<td>6</td>
</tr>
<tr>
<td>A532</td>
<td>Perform Weights &amp; Inertias Analyses</td>
<td>7</td>
</tr>
<tr>
<td>A533</td>
<td>Perform S&amp;C Analyses &amp; Evaluation</td>
<td>8</td>
</tr>
<tr>
<td>A5342</td>
<td>Develop Balanced Freebody Diagrams &amp; Ext. Applied Loads</td>
<td>9</td>
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<tr>
<td>A5343</td>
<td>Establish Internal Load Distributions</td>
<td>10</td>
</tr>
<tr>
<td>A5344</td>
<td>Evaluate Structural Strength, Stiffness, &amp; Life</td>
<td>11</td>
</tr>
<tr>
<td>A54</td>
<td>Preliminary Manufacturing Planning &amp; Analyses</td>
<td>12</td>
</tr>
<tr>
<td>A6</td>
<td>Prepare UAV Proposal</td>
<td>13</td>
</tr>
</tbody>
</table>

[Matrix Diagram]

The diagram illustrates the banding algorithm for the DSM Analysis process, with tasks assigned to specific bands (1-14) for alignment and management purposes.
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Tri-Probability Distribution Function

PDF

TriPDF Area = \( \frac{b \cdot h}{2} = \frac{(WCV - BCV) \cdot P(MLV)}{2} = 1 \)

\[ P(MLV) = \frac{2}{(WCV - BCV)} \]

BCV: Best Case value
MLV: Most Likely Value
WCV: Worst Case Value
Cost, Schedule and Reliability Model

**LOADER**
Loading of Input Data
(DSM, Rework probabilities, Rework Impact, Learning Curve, TriPDF limits)

**GENERATOR**
TriPDF generator
For each process (PDF and CDF)

**SIMULATOR**
Simulation of activity running through propagating time step, summation of cost and schedule, and rework evaluation

**RELIABILITY**
Calculation of System reliability after all processes have finished running.

**GRAPHER**
Graphical representation of results
Total Cost and Schedule

\[ C_{Total} = \sum_{i=1}^{n} C_i \]

\[ S_{Total} = \sum_{i=1}^{n} S_i \]

Where \( n \) the number of processes in the DSM.

At each Simulation run a value for \( (S_{total}, C_{total}, R_{total}) \) will be generated.
Total Reliability

\[ R_i = 1 - P_{\text{failure}} \quad \text{where } i \text{ denotes a subsystem} \]

\[ R_{\text{System}} = \prod_{i=1}^{n} R_i \]

\[ P_{\text{failure after rework}} = \frac{P_{\text{failure before rework}}}{2^x} \]

where \( x \) is total number of rework for subsystem processes

\[ x = \sum_{h=1}^{m} \text{process rework count}_h \times \text{effect weight of process (h)} \]
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Simulation – Nano Satellite Case
Simulation – Rework Effect

Random Rework

No Rework
Simulation – Distributions

Reliability PMF, 9 Subsystems at 95% each

Cost PMF, 9 Subsystems at 95% each

Schedule PMF, 9 Subsystems at 95% each
Simulation – Processes Importance

![Graph showing the relationship between process order and importance impact (weight).]
Simulation – Equal Weights

Cost PMF and CDF

Schedule PMF and CDF
Simulation – Equal Weights

Reliability PMF and CDF
Simulation – Equal Weights

Cost, Schedule, Reliability Trend

Cost (Thousands of Yen)

Reliability

Schedule (days)

510 520 530 540 550 560

3.26 3.28 3.30 3.32 3.34 3.36 3.38 3.40 3.42

x 10^5

0.4 0.45 0.5 0.55 0.6 0.65
Simulation – Equal Weights

Cost, Schedule, Reliability Trend

Schedule (days)

Reliability

Cost (Thousands of Yen)
Simulation – Equal Weights

Cost, Schedule, Reliability Trend

Cost (Thousands of Yen) vs Schedule (days) with reliability trend overlay.
Simulation – Equal Weights

Cost, Schedule, Reliability Trend

Reliability

Cost (Thousands of Yen)

Schedule (days)

Cost (Thousands of Yen)
Simulation – Equal Weights

Joint Cost and Schedule PDF Probability

Cost (Thousands of Yen)

Relative Probability

Schedule (days)

Cost (Thousands of Yen)
Simulation – Summary

<table>
<thead>
<tr>
<th></th>
<th>Weight</th>
<th>Max</th>
<th>Min</th>
<th>Std. Dev.</th>
<th>Mean</th>
<th>Median</th>
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<tbody>
<tr>
<td>Cost</td>
<td>Equal</td>
<td>34159.44</td>
<td>32755.75</td>
<td>187.78</td>
<td>33502.71</td>
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<td>34199.86</td>
<td>32788.88</td>
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<td>33499.4</td>
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<tr>
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<td>Dec.</td>
<td><strong>34241.34</strong></td>
<td>32712.80</td>
<td>188.27</td>
<td>33501.61</td>
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<tr>
<td>Schedule</td>
<td>Equal</td>
<td><strong>568.20</strong></td>
<td>503.20</td>
<td>9.375</td>
<td>528.01</td>
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<td>Reliability</td>
<td>Equal</td>
<td>0.6403</td>
<td>0.4305</td>
<td>0.0366</td>
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<td>0.0567</td>
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</tbody>
</table>

- Cost is estimated in (10,000 Yen – Japanese).
- Increasing and Decreasing Curves are linear with slope 60 Degrees.
- Schedule is in days.
- Reliability is estimated for 8 subsystems, each of which has an initial failure rate of 0.1.
What the numbers say?

• Focus on the early design stages:
  1. Defining sufficient, consistent and matching technical requirements.
  2. Accurate interface control documents.
  3. Full coverage of technical requirements in verification control matrices.
  4. Follow a formal design method instead of best practices.
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Future Work

• Currently we finished the development of the model and its validation and verification.
• Run the model on more realistic data for Nano-Satellite project and estimate more accurate Cost, Schedule and Reliability under different processes configurations.
• Study the effect of removing some test processes on overall project reliability. (i.e. Qualification testing)
• Enhance the model to include optimization, cost modeling, quantitative risk estimation and scheduling under constrained resources.
• Deploy Kyutech Project Schedule, Cost, Risk and Reliability calculator as an (online) tool.
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Conclusion

• DSM is a very useful technique used for modeling, analyzing and planning complex engineering systems.

• Reasonable project schedule, cost and reliability point can be reached by studying different project processes’ configurations using the developed model.

• If more focus is given to early design stages that would suffice for better reliability, cost and schedule.
Thank You