A Theory and Process for Value-Based Software Engineering (VBSE)

Barry Boehm, Apurva Jain
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Outline

• VBSE Theory Motivation and Context
• “Theory” Definitions and Criteria
• VBSE Theory and Process
  – Elements and Contributions
  – Theory-driven process
  – Supply chain example
• Conclusions and Future Research
VBSE Theory Motivation and Context

• Most software engineering practices are value-neutral
• Leads to missed opportunities, misguided effort
• Why a theory of VBSE?
  – Framework for reasoning, practice, method evaluation
  – Principles for applying value considerations
  – Understanding the “whys” as well as the “whats” and hows”
  – Academic respectability
  – Managed expectations about universality, formality
“Theory” Definitions

• 1960 definition: System of general laws
  – Spatially and temporally unrestricted; nonaccidental

• 1997 definition: System for explaining a set of phenomena
  – Specifies key concepts, laws relating concepts
  – Not spatially and temporally unrestricted
  – Better for people-intensive activities
Criteria for a Good Theory

• Utility: Addresses critical success factors vs. trivia
• Generality: Covers a wide range of situations and concerns
  – Procedural, technical, economic, human
• Practicality: Helps address user’s needs
  – Prediction, diagnosis, solution synthesis, best-practice generation
• Preciseness: Situation-specific, accurate guidance
• Parsimony: Avoids excess complexity; simple to learn and use
• Falsifiability: Coherent enough to be empirically refuted
VBSE Theory: 4+1 Structure

- Utility Theory
  - How important are the values?
  - How do values determine decision choices?

- Dependency Theory
  - How do dependencies affect value realization?
  - How to adapt to change and control value realization?

- Decision Theory
  - How is success assured?

- Control Theory
  - What values are important?

Theory W: SCS Win-Win
Theory W: Enterprise Success Theorem – And informal proof

Theorem: Your enterprise will succeed if and only if it makes winners of your success-critical stakeholders

• Proof of “if”: Everyone that counts is a winner. Nobody significant is left to complain.

• Proof of “only if”: Nobody wants to lose. Prospective losers will refuse to participate, or will counterattack. The usual result is lose-lose.
Outline

• VBSE Theory Motivation and Context
• “Theory” Definitions and Criteria
• VBSE Theory and Process
  – Elements and Contributions
  Theory-driven process
  – Supply chain example
• Conclusions and Future research
Initial VBSE Theory: 4+1 Process
– With a great deal of concurrency and backtracking

Utility Theory

5a, 7b. Option, solution development & analysis
3. SCS Value Propositions (Win conditions)
4. SCS expectations management
5a, 7b. Prototyping
5. SCS Win-Win Negotiation

Dependency Theory

2a. Results Chains
3b, 5a, 7b. Cost/schedule/performance tradeoffs
2. Identify SCSs
3b, 7a. Solution Analysis

Theory W: SCS Win-Win

1. Protagonist goals
3a. Solution exploration
7. Risk, opportunity, change management

Decision Theory

5a. Investment analysis, Risk analysis

Control Theory

6, 7c. Refine, Execute, Monitor & Control Plans
6a, 7c. State measurement, prediction, correction; Milestone synchronization

5a, 7b. Prototyping

SCS: Success-Critical Stakeholder
Example Project: Sierra Mountainbikes

- Based on what would have worked on a similar project
  - Quality leader in specialty area
  - Competitively priced
  - Major problems with order processing
    - Delivery delays and mistakes
    - Poor synchronization of order entry, confirmation, fulfillment
    - Disorganized responses to problem situations
    - Excess costs; low distributor satisfaction
Order Processing Project Goals

**Goals:** Improve profits, market share, customer satisfaction via improved order processing

**Questions:** Current state? Root causes of problems? Keys to improvement?

**Metrics:** Balanced Scorecard of benefits realized, proxies

- Customer satisfaction ratings; key elements (ITV: in-transit visibility)
- Overhead cost reduction
- Actual vs. expected benefit and cost flows, ROI
Initial VBSE Theory: 4+1 Process, Step 1
– With a great deal of concurrency and backtracking

1. Protagonist goals

SCS: Success-Critical Stakeholder
## Frequent Protagonist Classes

<table>
<thead>
<tr>
<th>Protagonist Class</th>
<th>Goals</th>
<th>Authority</th>
<th>Ideas</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leader with Goals, Baseline Agenda</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Leader with Goals, Open Agenda</td>
<td>X</td>
<td>X</td>
<td></td>
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<tr>
<td>Entrepreneur with Goals, Baseline Agenda</td>
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<td>Entrepreneur with Goals, Open Agenda</td>
<td>X</td>
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<td></td>
<td>X</td>
</tr>
<tr>
<td>Inventor with Goals, Ideas</td>
<td>X</td>
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<td>X</td>
</tr>
<tr>
<td>Consortium with Shared Goals</td>
<td>X</td>
<td>(X)</td>
<td>(X)</td>
<td>(X)</td>
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</tbody>
</table>
Initial VBSE Theory: 4+1 Process, Step 2
– With a great deal of concurrency and backtracking

1. Protagonist goals

2. Identify SCSs
   2a. Results Chains

Utility Theory
Dependency Theory
Theory W: SCS Win-Win
Decision Theory
Control Theory

SCS: Success-Critical Stakeholder
DMR/BRA* Results Chain

**INITIATIVE**

Implement a new order entry system

**OUTCOME**

Reduce time to process order

Reduced order processing cycle (intermediate outcome)

**OUTCOME**

Order to delivery time is an important buying criterion

**ASSUMPTION**

Contribution

Reduce time to deliver product

Increased sales

*DMR Consulting Group’s Benefits Realization Approach

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Expanded Order Processing System Results Chain

Assumptions
- Increasing market size
- Continuing consumer satisfaction with product
- Relatively stable e-commerce infrastructure
- Continued high staff performance

Distributors, retailers, customers

New order fulfillment system

New order fulfillment processes, outreach, training

Safety, fairness inputs

Interoperability inputs

Developers

New order-entry system

Less time, fewer errors in order processing

Faster, better order fulfillment system

Increased customer satisfaction, decreased operations costs

Increased sales, profitability, customer satisfaction

Increased profits, growth

Faster order-entry steps, errors

On-time assembly

New order-entry processes, outreach, training

Suppliers

Improved supplier coordination

Sales personnel, distributors

Success-critical stakeholders

Increased sales, fewer errors per order fulfillment system
Initial VBSE Theory: 4+1 Process, Step 3
– With a great deal of concurrency and backtracking

1. Protagonist goals
   3a. Solution exploration

2. Identify SCSs
   2a. Results Chains
   3b. Solution Analysis
   3b. Cost/schedule/performance tradeoffs

3. SCS Value Propositions (Win conditions)

Theory W: SCS Win-Win

Utility Theory

Dependency Theory

Decision Theory

Control Theory

SCS: Success-Critical Stakeholder
Initial VBSE Theory: 4+1 Process, Step 4
– With a great deal of concurrency and backtracking

1. Protagonist goals

2a. Results Chains
3b. Cost/schedule/performance tradeoffs

2. Identify SCSs

3a. Solution exploration
3b. Solution Analysis

4. SCS expectations management

Utility Theory

Dependency Theory

Theory W: SCS Win-Win

1. Protagonist goals
2. Identify SCSs
3. SCS Value Propositions (Win conditions)
4. SCS expectations management

Decision Theory

Control Theory

SCS: Success-Critical Stakeholder
# The Model-Clash Spider Web: Master Net

- Stakeholder value propositions (win conditions)

<table>
<thead>
<tr>
<th>Users</th>
<th>Acquirers</th>
<th>Developers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Many features</td>
<td>Mission cost/effectiveness</td>
<td>Flexible contract</td>
</tr>
<tr>
<td>Changeable requirements</td>
<td>Limited development budget, schedule</td>
<td>Ease of meeting budget and schedule</td>
</tr>
<tr>
<td>Applications compatibility</td>
<td>Government standards compliance</td>
<td>Stable requirements</td>
</tr>
<tr>
<td>High levels of service</td>
<td>Political correctness</td>
<td>Freedom of choice: process</td>
</tr>
<tr>
<td>Voice in acquisition</td>
<td>Development visibility and control</td>
<td>Freedom of choice: team</td>
</tr>
<tr>
<td>Flexible contract</td>
<td>Rigorous contact</td>
<td>Freedom of choice: COTS/reuse</td>
</tr>
<tr>
<td>Early availability</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Maintainers                  |                                    |                                                 |
| Ease of transition           |                                    |                                                 |
| Ease of maintenance          |                                    |                                                 |
| Applications compatibility   |                                    |                                                 |
| Voice in acquisition         |                                    |                                                 |

PC: Process  
PD: Product  
PP: Property  
S: Success
EasyWinWin OnLine Negotiation Steps

1. **Review and Expand Negotiation Topics (Group Outliner)**
   
   Jointly review and define the scope of the negotiation. Identify the negotiation topics for your EasyWinWin activity.

2. **Brainstorm Stakeholder Interests (Electronic Brainstorming)**
   
   Collect ideas about Win Conditions for your EasyWinWin activity.

3. **Converge on Win Conditions (Categorizer)**
   
   Jointly craft and organize a succinct list of win conditions.

4. **Capture Glossary of Terms (Topic Commenter)**
   
   Define important terms of the domain.

5. **Prioritize Win Conditions (Alternative Analysis)**
   
   Determine the business importance and the ease of implementation of all win conditions. Reveal issues and constraints.

6. **WinWin Tree (Group Outliner)**
   
   Identify Issues and Options. Negotiate Agreements.

7. **Organize Negotiation Results (Categorizer)**
   
   Categorize the results using the negotiation topics.
Red cells indicate lack of consensus.
Oral discussion of cell graph reveals unshared information, unnoticed assumptions, hidden issues, constraints, etc.
Initial VBSE Theory: 4+1 Process, Step 5
– With a great deal of concurrency and backtracking

Utility Theory

Dependency Theory

Decision Theory

Control Theory

Theory W: SCS Win-Win

1. Protagonist goals
3a. Solution exploration

2a. Results Chains
3b, 5a. Cost/schedule/performance tradeoffs

2. Identify SCSs

3b. Solution Analysis

3. SCS Value Propositions (Win conditions)

4. SCS expectations management

5a. Option, solution development & analysis

5a. Prototyping

5a. Investment analysis, Risk analysis

5. SCS Win-Win Negotiation

SCS: Success-Critical Stakeholder
Project Strategy and Partnerships

• Partner with eServices, Inc. for order processing and fulfillment system
  – Profit sharing using jointly-developed business case
• Partner with key distributors to provide user feedback
  – Evaluate prototypes, beta-test early versions, provide satisfaction ratings
• Incremental development using MBASE/RUP anchor points
  – Life Cycle Objectives; Architecture (LCO; LCA)
  – Core Capability Drivethrough (CCD)
  – Initial; Full Operational Capability (IOC; FOC)
• Architect for later supply chain extensions
Business Case Analysis

- Estimate costs and schedules
  - COCOMO II and/or alternative
- Estimate financial benefits
  - Increased profits
  - Reduced operating costs
- Compute Return on Investment
  - ROI = (Benefits – Costs) / Costs
  - Normalized to present value
- Identify quantitative metrics for other goals
  - Customer satisfaction ratings
    - Ease of use; In-transit visibility; overall
  - Late delivery percentage
## Order Processing System Schedules and Budgets

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Due Date</th>
<th>Budget ($K)</th>
<th>Cumulative Budget ($K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inception Readiness</td>
<td>1/1/2004</td>
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<td>0</td>
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<tr>
<td>Life Cycle Objectives</td>
<td>1/31/2004</td>
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<td>120</td>
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<tr>
<td>Life Cycle Architecture</td>
<td>3/31/2004</td>
<td>280</td>
<td>400</td>
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<tr>
<td>Core Capability Drivethrough</td>
<td>7/31/2004</td>
<td>650</td>
<td>1050</td>
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<tr>
<td>Initial Oper. Capability: SW</td>
<td>9/30/2004</td>
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<td>Initial Oper. Capability: HW</td>
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<td>Developed IOC</td>
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<td>4000</td>
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<tr>
<td>Responsive IOC</td>
<td>3/31/2005</td>
<td>500</td>
<td>4500</td>
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<tr>
<td>Full Oper. Cap’y CCD</td>
<td>7/31/2005</td>
<td>700</td>
<td>5200</td>
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<td>FOC Beta</td>
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<td>5600</td>
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<tr>
<td>FOC Deployed</td>
<td>12/31/2005</td>
<td>400</td>
<td>6000</td>
</tr>
<tr>
<td>Annual Oper. &amp; Maintenance</td>
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<td></td>
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</tr>
<tr>
<td>Annual O&amp;M; Old System</td>
<td></td>
<td></td>
<td>7600</td>
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</table>
## Order Processing System: Expected Benefits and Business Case

<table>
<thead>
<tr>
<th>Date</th>
<th>Market Size ($M)</th>
<th>Market Share %</th>
<th>Sales</th>
<th>Profits</th>
<th>Sales</th>
<th>Profits</th>
<th>Cost Savings</th>
<th>Change in Profits</th>
<th>Cum. Cost</th>
<th>ROI</th>
<th>Late Delivery %</th>
<th>Customer Satisfaction (0-5)</th>
<th>In-Transit Visibility (0-5)</th>
<th>Ease of Use (0-5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/31/03</td>
<td>360</td>
<td>20</td>
<td>72</td>
<td>7</td>
<td>20</td>
<td>72</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>12.4</td>
<td>1.7</td>
<td>1.0</td>
<td>1.8</td>
</tr>
<tr>
<td>12/31/04</td>
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<td>80</td>
<td>8</td>
<td>20</td>
<td>80</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>11.4</td>
<td>3.0</td>
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<td>12/31/05</td>
<td>440</td>
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<td>9</td>
<td>22</td>
<td>97</td>
<td>10</td>
<td>3.2</td>
<td>3.2</td>
<td>6</td>
<td>-0.47</td>
<td>7.0</td>
<td>4.0</td>
<td>3.5</td>
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<td>12/31/06</td>
<td>480</td>
<td>20</td>
<td>96</td>
<td>10</td>
<td>25</td>
<td>120</td>
<td>13</td>
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<td>9.4</td>
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<td>4.3</td>
<td>4.0</td>
<td>4.3</td>
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<td>1.63</td>
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<td>4.5</td>
<td>4.3</td>
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<td>168</td>
<td>19</td>
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<td>7.5</td>
<td>2.97</td>
<td>2.5</td>
<td>4.6</td>
<td>4.6</td>
</tr>
</tbody>
</table>
Initial VBSE Theory: 4+1 Process, Step 6
– With a great deal of concurrency and backtracking

1. Protagonist goals
3a. Solution exploration
3b, 5a. Cost/schedule/performance tradeoffs
5a. Option, solution development & analysis
6a. State measurement, prediction, correction; Milestone synchronization

Utility Theory
3. SCS Value Propositions (Win conditions)
4. SCS expectations management
5a. Prototyping

Decision Theory

Dependency Theory
2a. Results Chains
2. Identify SCSs
3b. Solution Analysis
3. SCS Value Propositions (Win conditions)

Theory W:
SCS Win-Win

Control Theory
6. Refine, Execute, Monitor & Control Plans

Dependency Theory

Control Theory

Utility Theory
Initial VBSE Theory: 4+1 Process, Step 7
– With a great deal of concurrency and backtracking

Utility Theory
- 5a, 7b. Option, solution development & analysis
- 3. SCS Value Propositions (Win conditions)
- 4. SCS expectations management
- 5a, 7b. Prototyping

Dependency Theory
- 2a. Results Chains
- 3b, 5a, 7b. Cost/schedule/performance tradeoffs
- 2. Identify SCSs
- 3b, 7a. Solution Analysis

Decision Theory
- 1. Protagonist goals
- 3a. Solution exploration
- 7. Risk, opportunity, change management
- 5a, 7b. Prototyping

Theory W: SCS Win-Win
- 4. SCS expectations management
- 5. SCS Win-Win Negotiation

Control Theory
- 6, 7c. Refine, Execute, Monitor & Control Plans
- 6a, 7c. State measurement, prediction, correction; Milestone synchronization

SCS: Success-Critical Stakeholder

5a. Investment analysis, Risk analysis

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A Real Earned Value System

- Current “earned value” systems monitor cost and schedule, not business value
  - Budgeted cost of work performed (“earned”)
  - Budgeted cost of work scheduled (“yearned”)
  - Actual costs vs. schedule (“burned”)
- A real earned value system monitors benefits realized
  - Financial benefits realized vs. cost (ROI)
  - Benefits realized vs. schedule
    - Including non-financial metrics
  - Actual costs vs. schedule
## Value-Based Expected/Actual Outcome Tracking Capability

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Schedule</th>
<th>Cost ($K)</th>
<th>Op’l Cost Savings</th>
<th>Market Share %</th>
<th>Annual Sales ($M)</th>
<th>Annual Profits ($M)</th>
<th>Cum. Profits</th>
<th>ROI</th>
<th>Late Delivery %</th>
<th>Customer Satisfaction</th>
<th>ITV</th>
<th>Ease of Use</th>
<th>Risks/Opportunities</th>
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<tr>
<td>Life Cycle Architecture</td>
<td>3/31/04</td>
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<td>12.4</td>
<td>1.7</td>
<td>1.0</td>
<td>1.8</td>
<td></td>
<td>Increased COTS ITV risk, fallback identified.</td>
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<tr>
<td></td>
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<td>72</td>
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<td>1.0</td>
<td>1.8</td>
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<td>Core Capability Demo (CCD)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>2.4*</td>
<td>1.0*</td>
<td></td>
<td></td>
<td>2.7*</td>
<td>Using COTS ITV fallback; new HW competitor; renegotiating HW.</td>
</tr>
<tr>
<td></td>
<td>7/20/04</td>
<td>1096</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td>Software Initial Op’l Capability (IOC)</td>
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<td>9/30/04</td>
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<td>2.7*</td>
<td>1.4*</td>
<td></td>
<td></td>
<td>2.8*</td>
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<td>Deployed IOC</td>
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<td>80</td>
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<td>-1.0</td>
<td>11.4</td>
<td>3.0</td>
<td>2.5</td>
<td>3.0</td>
<td></td>
<td>New COTS ITV source identified, being prototyped.</td>
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<td></td>
<td>12/20/04</td>
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<td>3.3</td>
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<td>3.8</td>
<td></td>
<td></td>
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<tr>
<td>Full Op’l Capability CCD</td>
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<td>1000</td>
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<td></td>
<td></td>
<td></td>
<td>3.5*</td>
<td>2.5*</td>
<td></td>
<td></td>
<td>3.8*</td>
<td>New COTS ITV source initially integrated.</td>
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Conclusions and Future Research

• The VBSE theory applied well to the supply chain example.
  – Application to other domains, situations should further uncover its underlying capabilities, shortcomings and assumptions.

• It satisfies the main criteria for a good theory (utility, generality, practicality, preciseness, parsimony, and falsifiability) reasonably well so far.

• Future work is geared towards testing the theory per se, and also its fitness/applicability to systems engineering.
References - I


References - II


