Investment Analysis of Software Assets for Product Lines

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Product Line Systems Program

Our goal is to enable widespread product line practice through architecture-based development.

Emerging Initiatives
- Product Line Practice
- Architecture Tradeoff Analysis
Agenda

Resource allocation
Issues
Investment analysis approach
  • criteria
  • techniques

Focus

<table>
<thead>
<tr>
<th>Group</th>
<th>Activity</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senior managers</td>
<td>Strategic planning</td>
<td>Company performance</td>
</tr>
<tr>
<td>Middle managers</td>
<td>Resource allocation</td>
<td>Return on investment</td>
</tr>
<tr>
<td>Project managers</td>
<td>Cost estimation</td>
<td>Cost and schedule performance</td>
</tr>
<tr>
<td>Engineers</td>
<td>Product evaluation</td>
<td>Product quality</td>
</tr>
</tbody>
</table>
Resource Allocation Decisions

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shorter time-to-market</td>
<td>Limited funds</td>
</tr>
<tr>
<td>Lower costs</td>
<td>Limited time</td>
</tr>
<tr>
<td>Greater flexibility</td>
<td>Limited talent</td>
</tr>
<tr>
<td>Higher quality</td>
<td>Low risk</td>
</tr>
</tbody>
</table>

Questions

To define an investment
- Which software assets are likely to shorten time-to-market, increase quality and lower costs?
- What is the best way to phase in software assets so that exposure to uncertainties in technology and the market is reduced?

To evaluate an investment
- Given the time, money and risks involved to develop and deploy software assets, what is the return?
- How does the return compare to other investment opportunities?
Issues

- Asset selection
- Economies of scope
- Opportunity costs
- Investment uncertainty
- Asset portfolio
- Deployment strategy

Asset Selection

Product Line

<table>
<thead>
<tr>
<th>Segments</th>
<th>Forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>rosy market</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assets</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domain models</td>
<td></td>
</tr>
<tr>
<td>Architectures</td>
<td></td>
</tr>
<tr>
<td>Documentation</td>
<td></td>
</tr>
<tr>
<td>Code generators</td>
<td></td>
</tr>
<tr>
<td>Components</td>
<td></td>
</tr>
<tr>
<td>Test cases</td>
<td></td>
</tr>
</tbody>
</table>

Activity costs

![Activity costs chart]

Activities
Economies of Scope

<table>
<thead>
<tr>
<th>Economies of Scope</th>
<th>Economies of Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition when fewer inputs are needed to produce a greater variety of products</td>
<td>Condition when fewer inputs are needed to produce greater quantities of a single product</td>
</tr>
<tr>
<td>Joint production of single items</td>
<td>Single batch production</td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimate by comparing input quantities or revenue streams</td>
<td>Estimate using cost function based on marginal unit costs</td>
</tr>
<tr>
<td>Management emphasis</td>
<td>Management emphasis</td>
</tr>
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<td></td>
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</tbody>
</table>

Opportunity Costs

Opportunity cost is the value of a resource in a competing use.

Opportunity cost of current process

- basis for estimating economies of scope

\[ S_m = \sum_{i,j}^{M,V} C_{ij} w_i y_j \]

where:
- \( M \) = set of assets
- \( V \) = number of planned products
- \( y \) = quantity of effort
- \( w \) = hourly rate

Opportunity cost of capital

- basis for discount rate of future cash flows
Investment Uncertainty

Technical uncertainty refers to unknowns involved in completing an investment.
- actual costs
- usability
- benefits

Economic uncertainty refers to events that affect investment return and are beyond the direct control of managers.
- changes in demand
- economic recession
- change in interest rates

Asset Portfolio

<table>
<thead>
<tr>
<th>Products</th>
<th>house arrest</th>
<th>home security</th>
<th>police staffing</th>
<th>car navigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>geographic database</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>remote control interface test suite</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>locator specification language</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

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Deployment Strategy

A deployment strategy is a plan of action for phasing in a portfolio of assets. It consists of a series of steps that reduce risk and give management the flexibility to respond to contingent events.

Investment Analysis

Investment analysis is a process for defining and evaluating an investment that involves:
- specifying the investment
- analyzing the uncertainties
- constructing a deployment strategy
- quantifying the costs and benefits.

Two step process
- construct asset portfolio
- Estimate portfolio investment
Construct Asset Portfolio

Characterize Product Variety
Screen Patterns
Select Assets
Evaluate Portfolio

Characterize Product Variety

<table>
<thead>
<tr>
<th>Segments</th>
<th>customer profile 1</th>
<th>car trip planner</th>
<th>taxies, couriers</th>
<th>class 2 4x4s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rosy market</td>
<td>2</td>
<td>3</td>
<td>9</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Segments</th>
<th>customer profile 1</th>
<th>car trip planner</th>
<th>taxies, couriers</th>
<th>class 2 4x4s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key Features</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>City streets</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Road segments</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Terrain overlay</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>
Screen Patterns

Patterns are shared solutions (e.g. algorithms) or knowledge (e.g. requirements). They are identified or synthesized through software modeling.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope</td>
<td>Proportion of product variety having pattern</td>
</tr>
<tr>
<td>Span</td>
<td>Proportion of system description encapsulated in pattern</td>
</tr>
<tr>
<td>Stability</td>
<td>Description of pattern is cohesive and variations across products are well-defined.</td>
</tr>
<tr>
<td>Encapsulation</td>
<td>Changes are local to pattern and not propagated.</td>
</tr>
</tbody>
</table>

Select Assets

Cost drivers

- % Total cost
- Comprehension
- Implementation
- Integration
- Maintenance activities

Required flexibility
- range of changes that must be accommodated

Skill set of asset users
- domain experts
- C++ software engineers
Evaluate Portfolio

Use criteria that optimize potential for achieving economies of scope

Two examples

![Diagram showing expected scope and asset variation in scope across different spans and development times.]

Estimate Portfolio Investment

Dynamic net present value
- management flexibility
- decision trees
Traditional Net Present Value (NPV)

\[ NPV = \sum_{t=0}^{n} \frac{C_{t}^{\text{inflow}} - C_{t}^{\text{outflow}}}{(1+r)t} \]

where:
- \( C_{t}^{\text{inflow}} \) = cash inflows for period \( t \)
- \( C_{t}^{\text{outflow}} \) = cash outflows for period \( t \)
- \( r \) = opportunity cost of capital
- \( t \) = time period
- \( n \) = number of periods in planning horizon

Decision rule:
- If NPV is positive, invest
- If NPV is negative, do not invest

Management Flexibility

Traditional NPV

During an investment project, management has the option to
- make follow-on investments
- abandon the project or
- wait until favorable conditions

These options are included in the investment estimate by building decision trees.
Dynamic Net Present Value

Calculation using decision tree
- working backwards from the future to the present, include best decision of previous step in the NPV calculation of current step.

Decision rule
- invest when the risk-adjusted upside return exceeds the cost of the first step.
- invest if NPV of the option to wait is less than the option to proceed.

Example

where:
- \( I_{\text{architecture}} \) = expense for architecture
- \( I_{\text{components}} \) = expense for components
- \( A, B \) = uncertainties corresponding to points in time
- \( q^* \) = likelihood that architecture meets requirements
- \( q^b \) = likelihood that market is rosy
- \( S^{\text{high}} \) = economies of scope from components in rosy market
- \( S^{\text{low}} \) = economies of scope from components in dismal market
- \( 1, 2 \) = management decision points
Net Present Value Equation

\[ NPV_{\text{step}2} = -I \text{ components } + q^b (S_{\text{high}} e^{-r(T-B)}) + (1-q^b) (S_{\text{low}} e^{-r(T-B)}) \]

\[ NPV_{\text{step}1} = -I \text{ architecture } + q^a (NPV_{\text{step}2} e^{-r(T-A)}) + (1-q^a)(0) \]

where:  
- \( r \) = opportunity cost of capital for investment step  
- \( T \) = end date of planning horizon

Conclusion

Avoid  
- "paralysis by analysis"  
- "extinct by instinct"

Provide  
- flexibility in decisions  
- comparison of alternatives  
- understanding and traceability  
- what-if analysis