Economic Analysis of the Reconfigurable/Dedicated Manufacturing Decision
Optimal Policies and Option Values

John R. Birge
University of Michigan

Outline

• Traditional approaches
• Missing elements in traditional methods
• Examples of reconfigurability
  misevaluations
• Model with option value
• Results and conclusions
Traditional Methods for System Evaluation

- Focus on:
  - Cost orientation
  - Single program
  - NPV - often payback
  - Piece rates
- Result: support of traditional, fixed systems

Trends Limiting Traditional Analysis

- Market changes
  - Former competition:
    - Cost
    - Quality
  - New competition:
    - Customization
    - Responsiveness
Limitations of Traditional Methods for New Trends

- Myopic - ignoring long-term effects
- Often missing time value of cash flow
- Excluding potential synergies
- Ignoring uncertainty effects
- Not capturing option value of capacity

Effect on Reconfigurable Systems

- Reconfigurable system characteristics:
  - Able to adapt quickly to new products and new technologies over many periods (model years, seasons)
- Problems with traditional evaluation:
  - No value for scalability, reusability, and adaptability
Key RMS Characteristics

- **Scalability:**
  - can add capacity in varying increments
- **Reusability:**
  - can use existing equipment in new configurations
- **Adaptability:**
  - can process different products or incorporate new technology as market varies

Examples of Traditional Method Failure

- **Scalability**
- Suppose a five year program
  - Cost of fixed capacity is $100M
  - Cost of RMS is $150M for same capacity
  - Predicted cash flow stream:

<table>
<thead>
<tr>
<th>Year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net</td>
<td>25</td>
<td>50</td>
<td>75</td>
<td>50</td>
<td>25</td>
</tr>
</tbody>
</table>
Scalability Example

- Assume 15% opportunity cost of capital:
  - NPV(Traditional) = $50M
  - NPV(RMS) = 0
- Problem: RMS can be configured over time:

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spend $50M for capacity to $25M</td>
<td>Spend $50M for cap. to $50M</td>
<td>Spend $50M for cap. to $75M</td>
</tr>
</tbody>
</table>

Scalability Result

- Cash flow for RMS:

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net</td>
<td>-50</td>
<td>-25</td>
<td>0</td>
<td>75</td>
<td>50</td>
<td>25</td>
</tr>
</tbody>
</table>

Now, NPV(RMS) = $75M > NPV(Fixed)

Traditional approach misses scalability advantage.
Reusability Example

• Assume:
  – Same conditions as before for fixed system
  – Two consecutive 5-year programs
  – Suppose for RMS
    • No scalability
    • Initial cost of $125 M
    • Can reconfigure for second program at cost of $25M

Reusability Example cont.

• Traditional approach
  – Single program evaluation
  – NPV(Fixed) = $50M
  – NPV(RMS) = $25M
  – Choose Fixed

• Problem: Missing the second program
### Reusability Two-Program Cash Flows

- Fixed cash flow, NPV(Fixed)=$75M
  
<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
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<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
<tr>
<td>-100</td>
<td>25</td>
<td>50</td>
<td>75</td>
<td>50</td>
<td>-75</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>50</td>
<td>75</td>
<td>50</td>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>

- RMS Cash Flow, NPV(RMS) =$87M
  
<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-125</td>
<td>-25</td>
<td>50</td>
<td>75</td>
<td>50</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>7</td>
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<td>9</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>50</td>
<td>75</td>
<td>50</td>
<td>25</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Traditional method misses two-program advantage

### Adaptability Example

- Difficulty: Single forecast ignoring uncertainty
  - Example: Products A, B
    - Forecast demand: 100 for each; Margin: 2
    - Dedicated capacity cost: 1
    - RMS capacity cost: 1.1

<table>
<thead>
<tr>
<th></th>
<th>Dedicated</th>
<th>RMS (Flexible)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>Cost</td>
<td>200</td>
<td>220</td>
</tr>
<tr>
<td>Profit</td>
<td>200</td>
<td>180</td>
</tr>
</tbody>
</table>

Choose dedicated
Multiple Scenario Effect

Suppose two demand possibilities: 50 or 150 equally likely - *Four scenarios*

<table>
<thead>
<tr>
<th>Dedicated</th>
<th>生产A:</th>
<th>生产B:</th>
<th>RMS:</th>
<th>补充生产</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1: 50, 50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 2: 50, 150</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 3: 150, 50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scenario 4: 150, 150</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**Evaluation with Scenarios**

- Four scenarios: 50 or 150 on each
- **Dedicated**
  - Sell (50,50), (50,100), (100,50), (100, 100)
  - Expected revenue: 300
- **RMS**
  - Sell (50,50), (50,150), (150,50), (100, 100)
  - Expected revenue: 350

<table>
<thead>
<tr>
<th></th>
<th>Dedicated</th>
<th>RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp. Revenue:</td>
<td>300</td>
<td>350</td>
</tr>
<tr>
<td>Cost:</td>
<td>200</td>
<td>220</td>
</tr>
<tr>
<td>Profit:</td>
<td>100</td>
<td>130</td>
</tr>
</tbody>
</table>

Choose RMS
Conclusions from Examples

• Traditional approaches miss:
  – scalability advantage
  – reusability advantage
  – adaptability (multipleproduct - uncertain demand) advantage

• How to include these advantages?

Model Needs

• Must include evaluation of advantages
• Model must have:
  – State of system capacity and unit sizes for scalability
  – Long-term view for reusability (lifetime of equipment)
  – Explicit consideration of uncertainty for adaptability advantage
Model Needs cont.

• Additional requirements
  – All cost factors
    • Capital - initial, ongoing, disposal or salvage
    • Labor
    • Operating
  – All revenue factors
    • Market effects
    • Sales potential, meeting customer desires

Model Goals

• Maximize value of the enterprise
• Questions
  – How to measure value?
  – Whose value?
  – How does this affect capacity evaluation?
Utility Function Approach

- **Observation:**
  - Most decision makers are adverse to risk

- **Assume:**
  - Outcomes can be described by a utility function
  - Decision makers want to maximize expected utility

- **Difficulties:**
  - Is the decision maker the sole stakeholder?
  - Whose utility should be used?
  - How to define a utility?
  - How to solve?

- **Alternative to decision maker - investor**

Measuring Investor Value

- **Attitude toward risk:**
  - Assume investors prefer lower risk
  - Investors can diversify away unique risk
  - Only important risk is market - contribution to portfolio

- **CONSEQUENCE: Capital asset pricing model (CAPM)**

- NEED: Portfolio contribution
  - How to determine?
Determining Risk Contribution

• USE CORRELATION?
  – Can measure for known markets (beta values)
  – If capacitated, depends on decisions
    » Constrained resources
    » Correlations among demands

• ALTERNATIVES?
  – Option Theory
    » Allows for non-symmetric risk
    » Explicitly considers constraints -
      » As if selling excess to competitors at a given price
    » Explicitly incorporates option value of the RMS

Use of Options

• Capacity limits potential sales
• View: option sold to competitor

RESULTS FROM FINANCE:

• Assumption: risk free hedge
  – Can evaluate as if risk neutral
  – As in Black-Scholes model

• Steps in modeling:
  – Adjust revenue to risk-free equivalent
  – Discount at riskless rate
### Valuing an Option

- **(European) Call Option on Share assuming:**
  - Buy at \( K \) at time \( T \); Current time: \( t \); Share price: \( S_t \)
  - Volatility: \( \sigma \); Riskfree rate: \( r_f \); No fees; Price follows Ito process

- **Valuing option:**
  - Assume risk neutral world (annual return=\( r_f \) independent of risk)
  - Find future expected value and discount back by \( r_f \)

\[
\text{Call value at } t = C_t = e^{-r_f(T-t)}(S_T-K) + dF(S_t)
\]

### Relation to Capacity Evaluation

- **What is the value of a plant with capacity \( K \)?**
  - Discounted value of production up to \( K \)?

- **Problems:**
  - Production is limited by demand also (may be > \( K \))
  - How to discount?

- **Resolution:**
  - Model as an option
  - Assume:
    - Market for demand (substitutes)
    - Forecast follows Ito process
    - No transaction costs

\[\Rightarrow\] **Model like share minus call**
Computing Capacity Value

**Goal:** Production value with capacity K
- Compute uncapacitated value based on CAPM:
  - $S_t = e^{r(T-t)}|c_0|S_t dF(S_t)$
  - where $c_0 =$ margin, $F$ is distribution (with risk aversion),
  - $r$ is rate from CAPM (with risk aversion)
- Assume $S_t$ now grows at riskfree rate, $r_f$; evaluate as if risk neutral:
  - Production value = $S_t - C_t = e^{r_f(T-t)}|c_0|\min(S_t, K)dF_f(S_t)$
  - where $F_f$ is distribution (with risk neutrality)

**Overall Model**

- Model includes
  - Scalability
  - Reusability
  - Adaptability
  - All financial factors
  - Measure of overall value of enterprise
- Implementation: spreadsheet for simplified
Model Results - Management Insights

- **Rapid Product Shift**
  - Can find threshold limit that triggers RMS investment

- **Gradual New Product Rise**
  - Whenever below lower trigger level, order RMS up to an upper level

- **New Products and Unreliable Systems**
  - Structure of region for decisions from keeping old capacity, reconfiguring, or buying new fixed

Summary and Conclusions

- Traditional methods do not capture key advantages of RMSs
- A comprehensive option-based model can include the key factors
- Early indications for management insight
- Need for further exploration of decision regions and computation for complex models
Example of Method

- Major manufacturer
- Multiple plants and products
- Originally all dedicated capacity
- Where to add flexibility?

Using the Option Model

- Assuming 1 Year Lifetimes
  - Complete re-tooling next year
  - All new product lines (fashion)

Solution:
Key Observations on Flexible Capacity

- Need multiple scenarios instead of single forecast
- Adjust discounting for capacity cutoffs of revenue (option evaluation)
- Can observe effects of pricing, margin, cost changes
- Can quantify effect of organization structure

Reconfigurability differences

- Changes over time - not just at current time

If changeover time is fixed and new model known, can prepare and plan for new dedicated purchase

Uncertainty of time, new model -> value of reconfigurability