Economic Analysis of the Reconfigurable/ Dedicated Manufacturing Decision

Optimal Policies and Option Values

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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

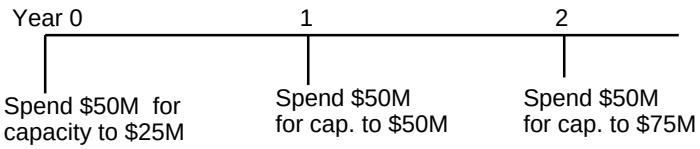
Examples of Traditional Method Failure

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

Year	1	2	3	4	5
Net	25	50	75	50	25

Scalability Example

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



Scalability Result

- Cash flow for RMS:

Year	0	1	2	3	4	5
Net	-50	-25	0	75	50	25

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

0	1	2	3	4	5
-100	25	50	75	50	-75

6	7	8	9	10
25	50	75	50	25

- RMS Cash Flow, NPV(RMS) =$87M

0	1	2	3	4	5
-125	25	50	75	50	0

6	7	8	9	10
25	50	75	50	25

- Traditional method misses two-program advantage

Adaptability Example

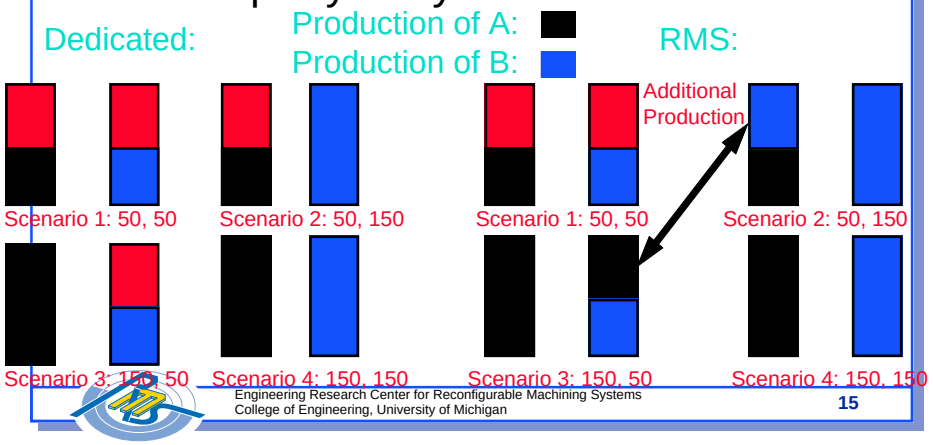
- Difficulty: Single forecast ignoring uncertainty
  - Example: Products A, B
    - Forecast demand: 100 for each; Margin: 2
    - Dedicated capacity cost: 1
    - RMS capacity cost: 1.1

	Dedicated:	RMS (Flexible):
Revenue:	400	400
Cost:	200	220
Profit:	200	180

Choose dedicated

Multiple Scenario Effect

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



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

	Dedicated:	RMS:
Exp. Revenue:	300	350
Cost:	200	220
Profit:	100	130

→ 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

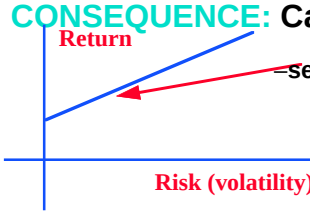
- Maximize value of the enterprise
- Questions
  - How to measure value?
  - Whose value?
  - How does this affect capacity evaluation?

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?

Determing 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

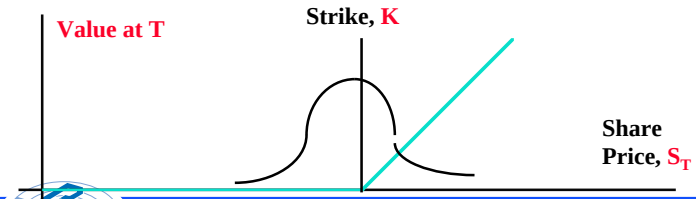
RESULTS FROM FINANCE:

- **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: σ; 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

Call value at t = $C_t = e^{-rf(T-t)}\int(S_T-K)^+ dF_f(S_T)$



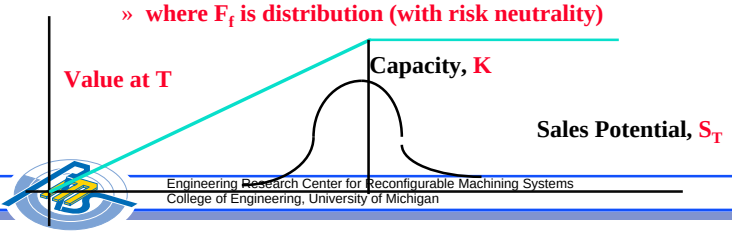
Relation to Capacity Evaluation

- 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

$\infty \Rightarrow$ Model like share minus call

Computing Capacity Value

- **Goal: Production value with capacity K**
  - **Compute uncapacitated value based on CAPM:**
    - » $S_t = e^{-r(T-t)} \int c_T S_T dF(S_T)$
    - » **where c_T=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 = $S_t - C_t = e^{-rf(T-t)} \int c_T \min(S_T,K) dF_f(S_T)$**
    - » **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

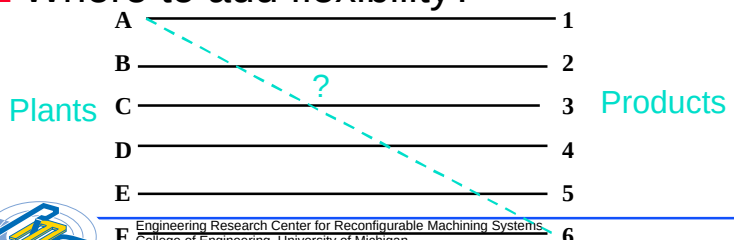
- Rapid Product Shift
  - Can find threshold limit that triggers RMS investment
- Gradual New Product Rise
  - Whenever below lower trigger level, order RMS up to an upper level
- New Products and Unreliable Systems
  - Structure of region for decisions from keeping old capacity, reconfiguring, or buying 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

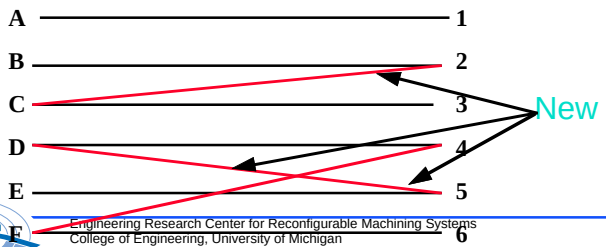
Example of Method

- 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

Model 1 Model 2

Changeover

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