Using Flexible Business Development Plans to Raise the Value of High-Technology Startups

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ESD 71: Engineering Systems Analysis for Design
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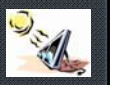
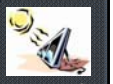


Slideshow format:

- Introduction
- Development of an Application Portfolio
- Comparison of Analysis methods: Decision Tree v. Lattice
- Conclusions



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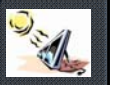
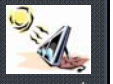


Introduction: The Engineering System

- Engineering Systems can take on different forms
  - A space station, computer motherboard, power plant, irrigation system, World Wide Web, complex organizational setups
- System Analyzing: a high-technology startup
  - *Central question: How does one model the development of such an uncertain system?*
    1. Identify system attributes/boundaries
    2. Identify key uncertainties
    3. Use a decision tree and/or lattice to model development of startup
       - Builds a business development "roadmap" that:
         - Proactively incorporates uncertainty recognition
         - Uses flexibility to mitigate/take advantage of uncertainty

    * Must recognize advantages/limitations of DT/lattice modeling methods to understand business development roadmap



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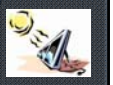


Application Portfolio 1: Describing the Engineering System

What is the system, what does it include and what does it exclude?

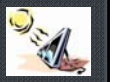
- ENI (an Italian state-owned petrochemical company) evaluating a specific technology startup company based on its strategic/financial value
- Analyzing a solar-thermal technology startup's potential future value

What are its principal design levers or variables?

- Amount, if any, of investment placed during a step in the development of the technology

What are the benefits of this system?

- The value of merging the expertise of a startup with the vast capabilities (financial and project based) of an investing company
- Investing firm's ability to provide startup with enough capital and other resources to rapidly launch product development and commercialization (ability to pursue "call option" on expansion of successful technology)



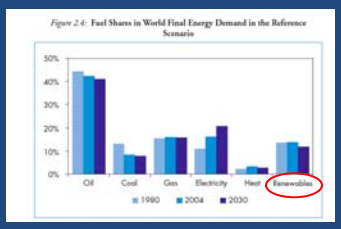
Application Portfolio 2: Key Uncertainty Identification

Critical Uncertainties incorporated into model:

1.Market size (use carbon tax rate as a proxy)

Future fuel shares (observe projected size of renewables market)

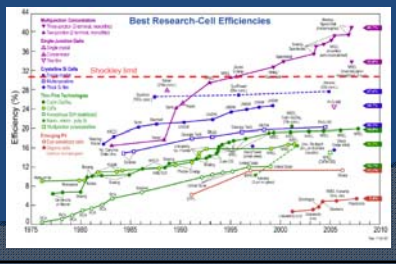
Source: IEA 2006, pp. 73



2. Success level of technology development (how good is product?)

Past and predicted future best lab cell efficiencies

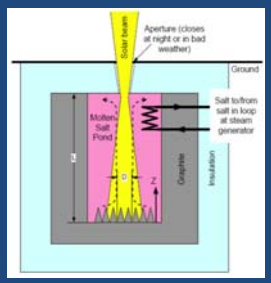
Source: Stanford E 104 Lecture, Benson



Application Portfolio 3: Defining the System

- The Players
  - Investing Firm (ENI, a large Italian energy company)
  - CSPond venture (a solar-thermal hi tech startup based in MIT)

- Basic Description of Technology (Slocum 2008):



CSPond's salt-filled tank (Slocum 2008)

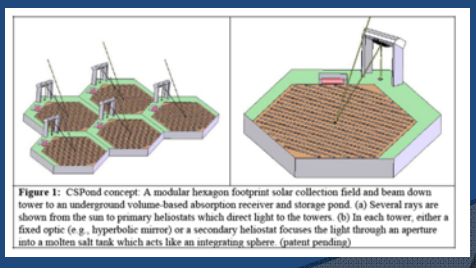


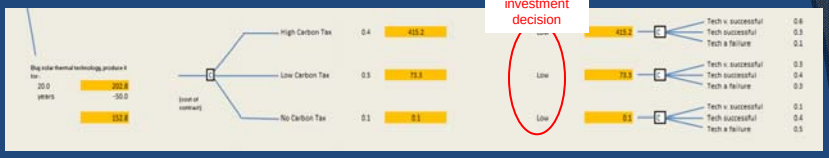
Figure 1: CSPond concept: A modular hexagon footprint solar collection field and beam down tower to an underground volume-based absorption receiver and storage pond. (a) Several rays are shown from the sun to primary heliostats which direct light to the towers. (b) In each tower, either a fixed optic (e.g., hyperbolic mirror) or a secondary heliostat focuses the light through an aperture into a molten salt tank which acts like an integrating sphere. (patent pending)

CSPond illustration of basic concept (Slocum 2008)

Application Portfolio 3: Defining the System

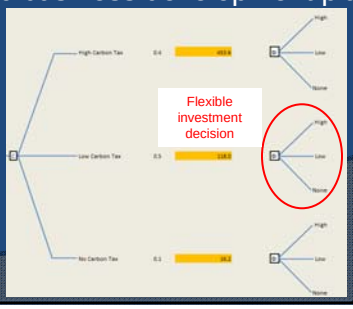
The Fixed Design: A fixed business development plan

Analyze the uncertainties relevant to startup's successful development, and then create a fixed "optimal" business plan



A Flexible Design: A dynamic business development plan

A flexible, dynamic model gives management the ability to decide on the level of investment in the technology after more information is learnt.
The following figure is a part of the decision tree which illustrates management's ability to decide on investment strategy given uncertainty in the carbon tax:



Application Portfolio 4: Building a Decision Tree

The Tree

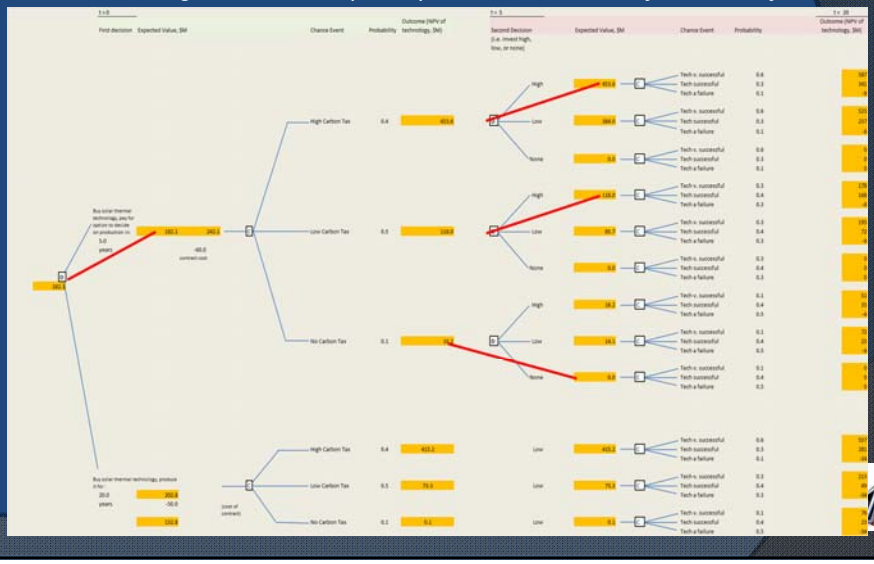
- Inputs: an intelligently linked model
  - Critical parameters (i.e. cost of the flexible/inflexible contract, discount rate, length of company/product operation, and probabilities associated with the carbon tax and technology development uncertainties) defined as variables for easy manipulation
- Structure
  - 2 Decision-Chance pairs:

Decision 1	Chance Event 1	Decision 2	Chance Event 2
Flexible: Buy right to develop technology and produce product in 5 years (for 15 years). Can decide how heavily to invest depending on new information obtained @ year 5.	Carbon Tax is: High Low Nonexistent *this chance node is a surrogate for "market" uncertainty identified in AP 3	Decide to either invest: High Low No Investment	Technology is: Very Successful Successful A failure * this chance node represents "technology" uncertainty identified in AP 3
Inflexible: Buy technology and commit to producing products for 20 years (given investment strategy)		Cannot decide, must choose an investment strategy @ year 0. Here, we have decided in the "Low" investment strategy.	

Application Portfolio 4: Building a Decision Tree

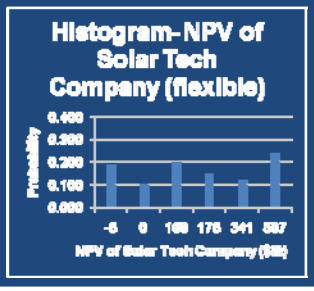
Visual of Decision Tree

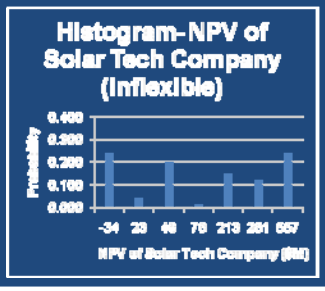
- Red lines indicate best decision for each decision node
  - This gives a “roadmap” of optimal decision for any uncertainty outcome

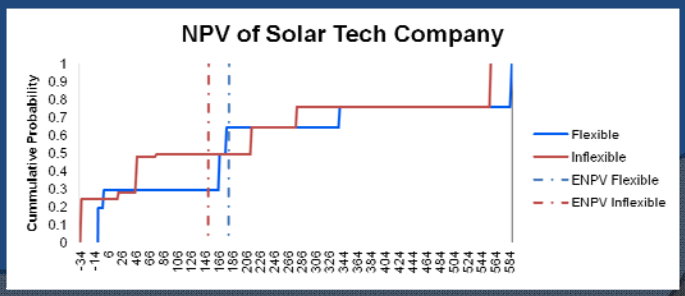


Application Portfolio 4: Building a Decision Tree

Outcome distributions and VARG







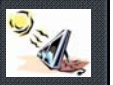
Application Portfolio 4: Building a Decision Tree

Key Values

Q: Which business development plan (flexible v. inflexible) is better?

A: It depends on which value one is most interested in:

($, millions)	Design		Which is better?
	Flexible	Inflexible	
		152.75405	
ENPV	182.0746098	9	Flexible
Minimum NPV	-8	-34	Flexible
Maximum NPV	587	557	Flexible
Initial CAPEX	60	50	Inflexible
NPV/CAPEX	3.0345	3.0550	Inflexible



Application Portfolio 5&6: Creating a Lattice model

The Method: *To build our model, must build:*

1. "Profits" lattice
   - Small profits in beginning, grow according to up, down, and p values

2. "Probabilities" lattice
   - *Depends on p and (1-p) values*

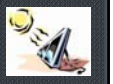
3. "Cashflow" lattice
   - Values from "profits" lattice – yearly operating costs (fixed+variable)

4. Baseline "Yearly contribution to ENPV" lattice
   - Multiplies yearly discounted cashflows by appropriate p, sum all cell multiplications to get ENPV

5. "Dynamic programming-based inflexible" lattice
   - "looking into the future" method; ENPV should be the same as in (4)

6. "Dynamic programming-based inflexible" lattice
   - Same as above, but now insert "put option" flexibility to stop operations
   - When stop operations, incur only fixed costs
   - Similar to flexibility option in decision tree: amount invested

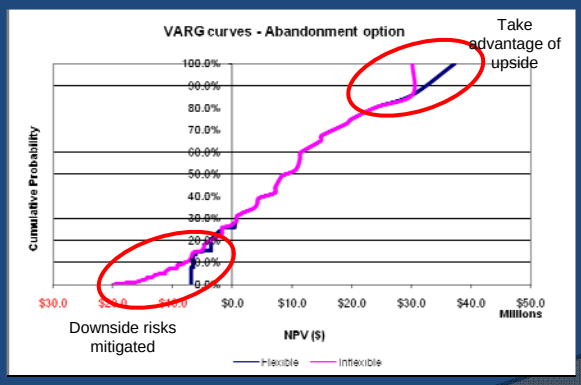
7. "Continue or stop" company operations" lattice



Application Portfolio 5&6: Creating a Lattice model

Key Results:

- Note: this VARG only models first 6 years of company operations



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Advantages/limitations of “decision tree analysis” modeling

- **Structure**:
  - Uses a “tree” approach that iterates an uncertainty-decision node sequence

    Strength- clearly illustrates a visual roadmap of the many different paths that the business development could take in the future
    Strength- the shape (i.e. number of decision options and uncertainty outcomes) is not constrained by any limitations (in the lattice model, we are constrained to a binomial decision process)

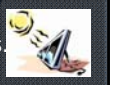
- No **regularity** constraints:

  While the binomial model is limited by “regularity” (it assumes that the diffusion process is “stationary” in that the probability of the next state remains constant throughout the periods considered), the decision tree is not limited to this constraint

- No **outcome** constraints:

  A major limitation of the lattice is that it can only generate lattices with purely positive or negative state values. the decision tree does not require additional analysis: a user simply inputs the relevant outcome values in the end stage, and conducts a folding-back analysis to evaluate the tree

- Conclusion:
  - Decisions analysis approach is the **more flexible approach** because of its lack of regularity and outcome constraints, as well as its “unlimited” uncertainty/decision node outcome possibilities.
    Decision trees are more suitable when we have complex (i.e. more than one outcome) and irregular (requires changing of probabilities) processes.



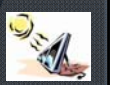
Advantages/limitations of “lattice ” modeling

- **Structure**: Similar to a decision tree analysis in that it uses a “tree” approach to model uncertainties and decisions, thus developing multiple paths.
  - *Key limitation*: in order to keep the number of states increasing linearly with the number of stages, we must assume path independence (since in this case all paths to a state have the same result)
    - In our system, barring the extreme cases (such as no projects acquired, or a truly explosive growth of work that causes relocation to a much bigger office) we can assume that this system is a relatively path independent process. That is, the order in which our company grows (i.e. slow growth then faster growth, or vice versa) will not affect the current state since we can adjust (to a certain degree) the number of employees working; hence our system can respond to changes without being fundamentally altered.

- *Limitation:* the **evolution of one state** can only be into **two future states**.
  - Solution: if we want to model several outcomes (states), we can do this by introducing several stages (which will progressively double the number of states).

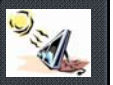
- *Limitation:* “curse” of **regularity**.
  - In the lattice model, the diffusion process is necessarily stationary: the probability of “up” or “down” states does not change with time.

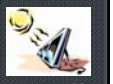
- *Limitation:* **only positive or negative values** generated
  - Solution: Define our *initial* lattice to have only positive values. Then transform these necessarily positive values into potentially negative values by subtracting the relevant operational costs in each state



Advantages/limitations of “lattice ” modeling

- Powerful *advantage*: lattice approach models **single decisions** over **many stages** very **effectively**
  - It is thus useful in its ability to assess, at any given year and state, whether the option to stop investment should be pursued (decision tree analysis cannot do this as effectively, would have to create a very complicated tree)
  - How relevant is thus advantage to our solution? If we can simplify our model to an “invest” or “stop investment” scenario (currently it has 3 levels of investment), then this advantage could be used to gain detailed (yearly) information about when to continue/stop investment





Conclusions

1. There are of course advantages and limitations for the use of either modeling method. The key to successful use of these models is in understanding the mechanism behind which they operate
   - Models are *not* black boxes that somehow magically transform input data into perfectly correct output results

2. In the decision tree, based on our extensive financial analyses (36 cashflow statements for each decision tree outcome) and model setup:
   - The flexible and inflexible business development plans predict an expected value of ~$185 M and $153 M, respectfully. This correlates to an improved system performance (NPV of the CSPond-based startup) of ~ 21%

3. How flexibility was incorporated to raise system value:
   - By giving management the flexibility to vary the amount of investment they make into the development of the technology at any given stage, they can use new information learned to make better decisions

4. What is the "best" design: Depends on user
   - The optimal choice may change depending on the circumstances of the user (i.e. if cash-strapped then minimum initial CAPEX very important)
   - The only criteria in which the inflexible model performs better than the flexible model is in the CAPEX required (because the cost of a flexible contract versus a similar contract is at a 20% premium)

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