

ESD. 71 Application Portfolio

Evaluating flexibility – Grid Scale Solar PV Plants

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Application Portfolio - Overview

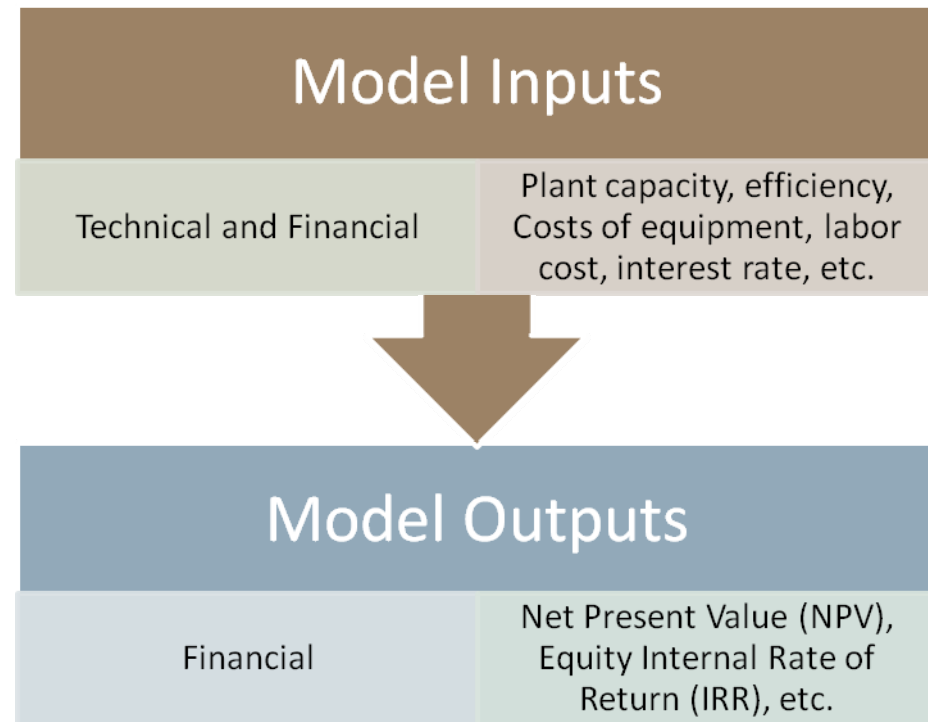
- System Description
- System Design
- Method of implementation
 - Uncertainty
 - Flexibility
 - Simulation
- Results
 - Fixed Design
 - Flexible Design
 - Target curves and other criteria
- Lessons Learned

Abstract:

This project aims to evaluate the introduction of flexibility into designing grid-scale solar power plants. There exist certain forms of tracking PV panels that can be manually tracked/ moved in order to increase the output of the plant. At the same time though, certain costs are incurred to introduce flexibility by employing manual labor and hence through this project, taking into account certain core uncertainties in this system, we hope to address whether employing manual labor will help the overall financials of the PV project.

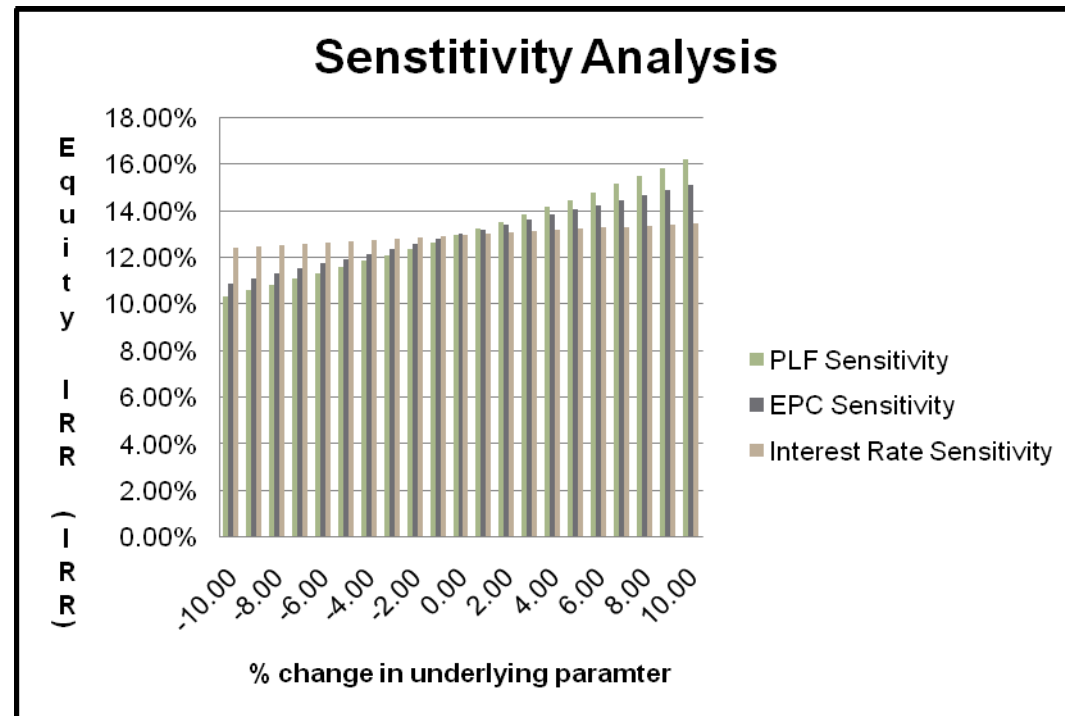
Application Portfolio - Description

- Grid connected 5MW PV project, operational for 25 years
- Based on financial model built while interning this summer at an Independent Power Producer
- Technical and Financial inputs; Financial outputs
- Economic Evaluation metric of choice – Equity Internal Rate of Return (IRR); ease of comparison to large cost of capital (interest rate)

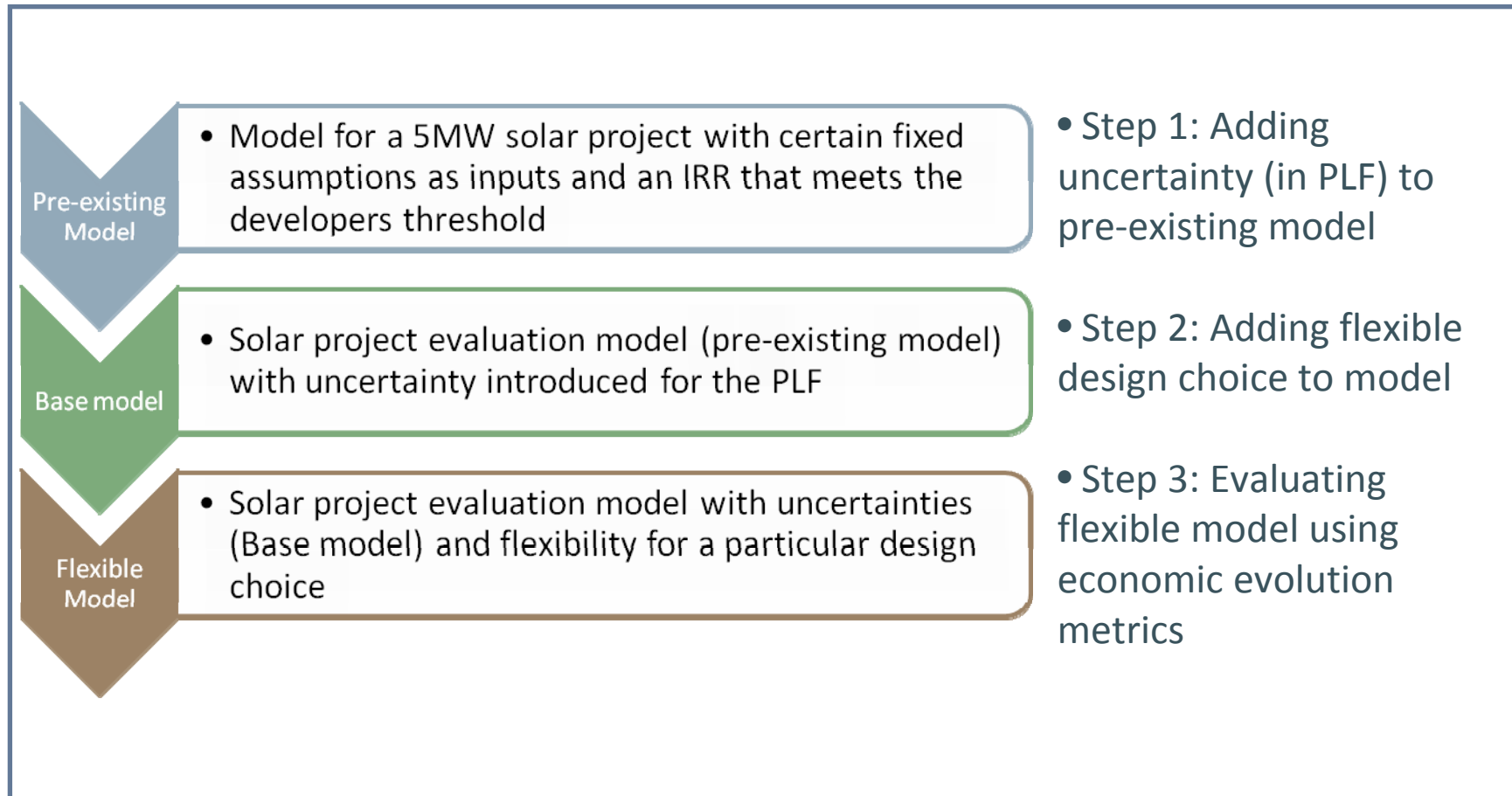


Application Portfolio – System Design

- Three underlying variables evaluated
 - Plant load factor (PLF)
 - Engineering, Procurement and Construction costs (EPC)
 - Interest rates
- PLF evaluated to be most sensitive – hence PLF to be modeled as an uncertain distribution



Application Portfolio - Implementation



Application Portfolio – Implementation Step 1

- Using existing data to model distribution of uncertainty
- Modeled as normal distribution with mean as predicted and variance of 1%
- Utilizing other existing input and output parameters from a benchmarked case

Time Period	Base PLF without Uncertainty	Base with PLF Uncertainty
Yrs 1-5	19.6%	S.D. with mean = 19.6%, Variance = 1%
Yrs 6-10	18.8%	S.D. with mean = 18.8%, Variance = 1%
Yrs 11-15	18.1%	S.D. with mean = 18.1%, Variance = 1%
Yrs 16-20	17.4%	S.D. with mean = 17.4%, Variance = 1%
Yrs 21-25	16.6%	S.D. with mean = 16.6%, Variance = 1%

Variable	Type	Number
EPC Cost	Input	Rs. 103 Million/MW
PLF	Input	19.6%
Interest rate	Input	10% 1 yr after Commission
Equity IRR	Output	13%

Application Portfolio – Implementation Step 2

- Flexibility in question: employing labor to manually track panels and increase output
- Divided into 5 steps of 5 years each
- Cost of flexibility: 3.5% of total project cost
- Gain from flexibility: additional output i.e. potentially increased PLF

There exist certain PV panels that are manually tracked i.e. they can be moved by manual labor in order to increase the output they can capture. Hence, project developers have the ability to make a decision on whether they will employ manual labor with an expectation of extracting a greater amount of energy from such panels. It is not atypical for panels to be manually moved as seasons change in order to allow the panels to face as large as possible amount of incident rays from the sun.

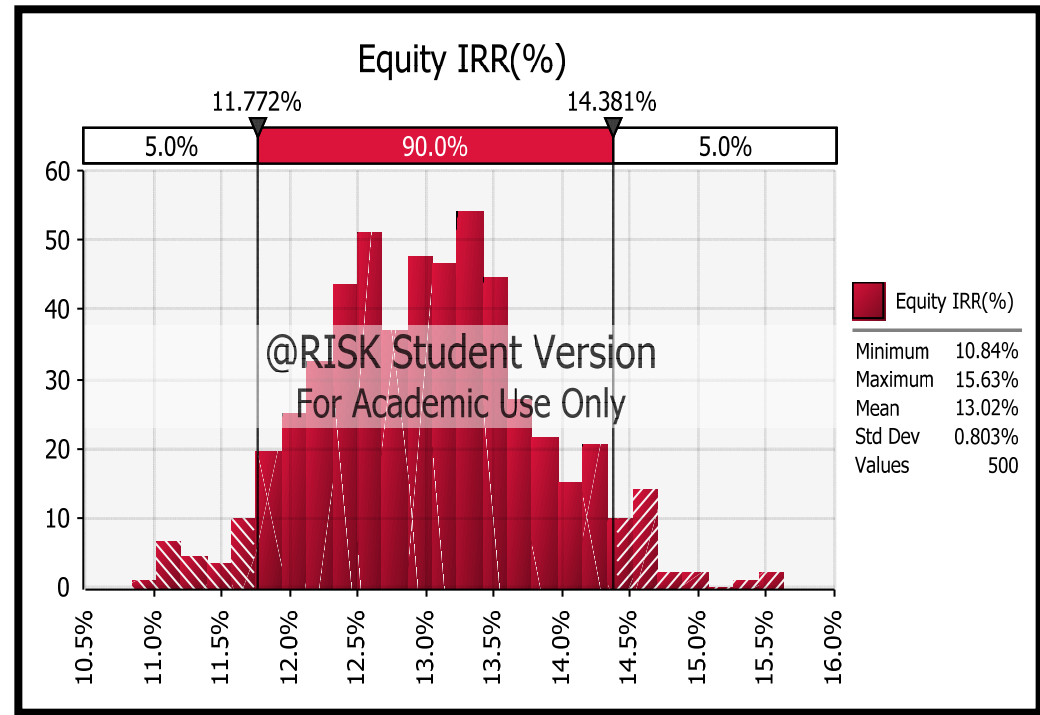
Application Portfolio – Implementation Step 3

(a) Total Size of plant:	5MW
(b) Size of each panel:	200W
(c) No. of panels:	~25000 (a)/(b)
(d) Total hrs/shift:	~6250 hrs (assuming 15 mins per panel shift) (c)/6
(e) No. of days/shift:	10 days (assume each tracking operation lasts for two weeks)
(f) No. of hrs/day	~625 (d)/(e)
(g) No. of labor	~78 (assuming 8 hr working days) (f)/8
(h) No. of shifts a yr:	4 (once a quarter)
(i) Cost of Labor/Hr:	Rs 30/hr
(j) Total Cost:	~Rs 750,000 (e)*(f)*(h)*(i)
(k) Cost/MW:	~Rs 150,000 (j)/(a)

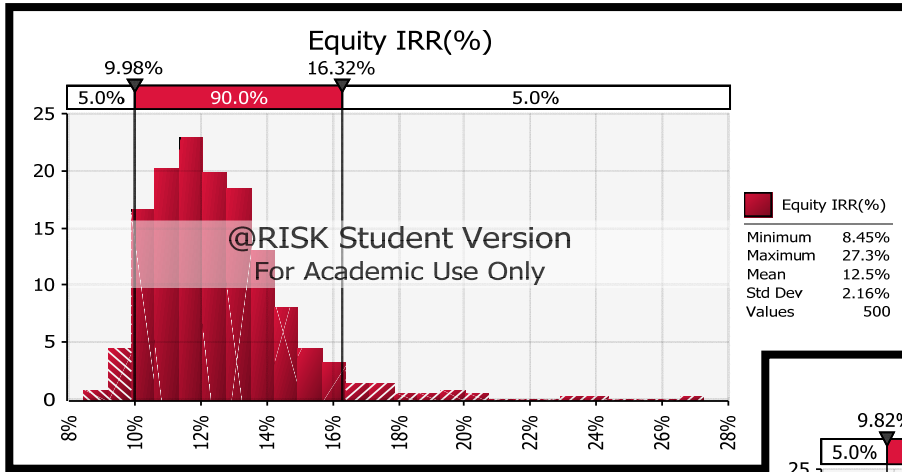
- Implemented choices
 - Decision tree (~~discrete distributions~~)
 - Lattice Model (~~stationary uncertainty~~)
 - Simulation
- Decision – if the expected value of using flexibility > expected value of base case, then exercise flexible choice

Application Portfolio – Results Fixed Design

- Fixed Design
 - IRR of 13%
- Flexible Design
 - Expected value **always** less than 13%!
 - Hand picked cases to evaluate target curves and other criteria (four cases)

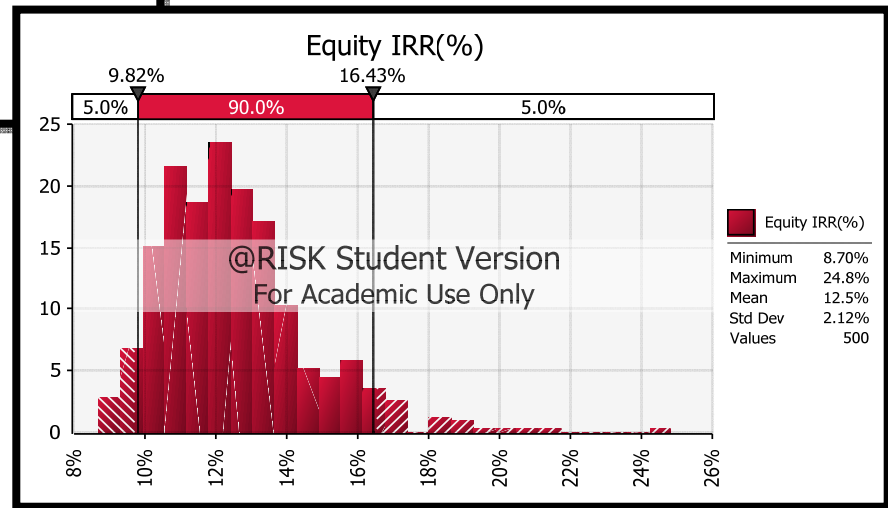


Application Portfolio - Results Flexible Design

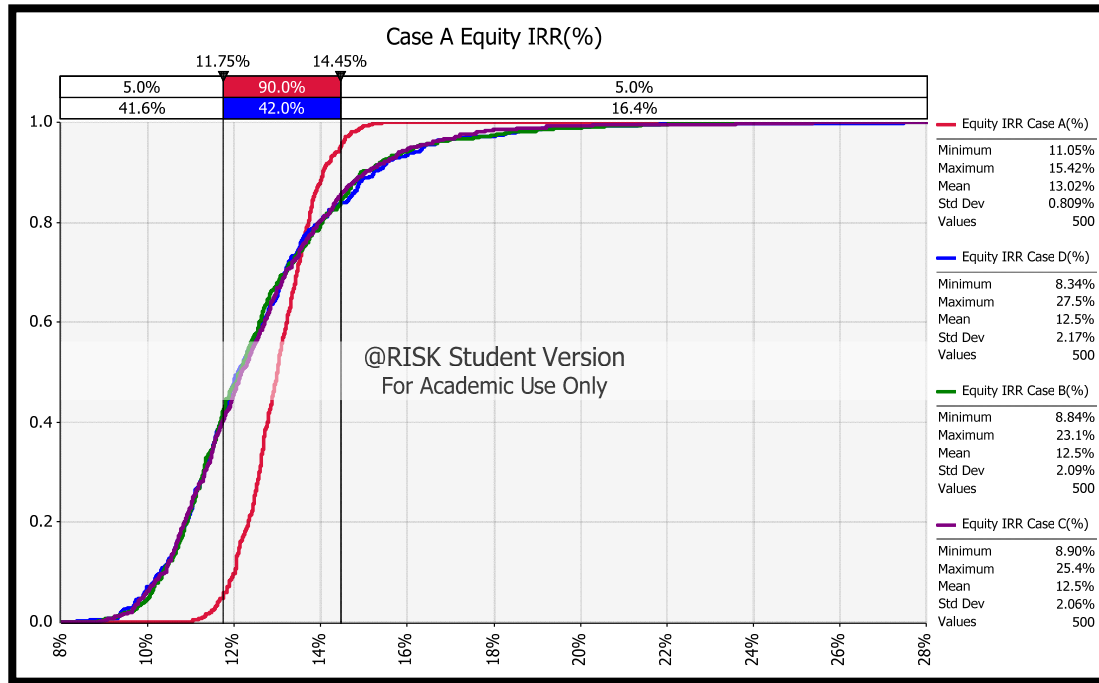


Flexibility exercised in years 1-5
(time block 1 only)

Flexibility exercised in all periods



Application Portfolio – Results Target Curve



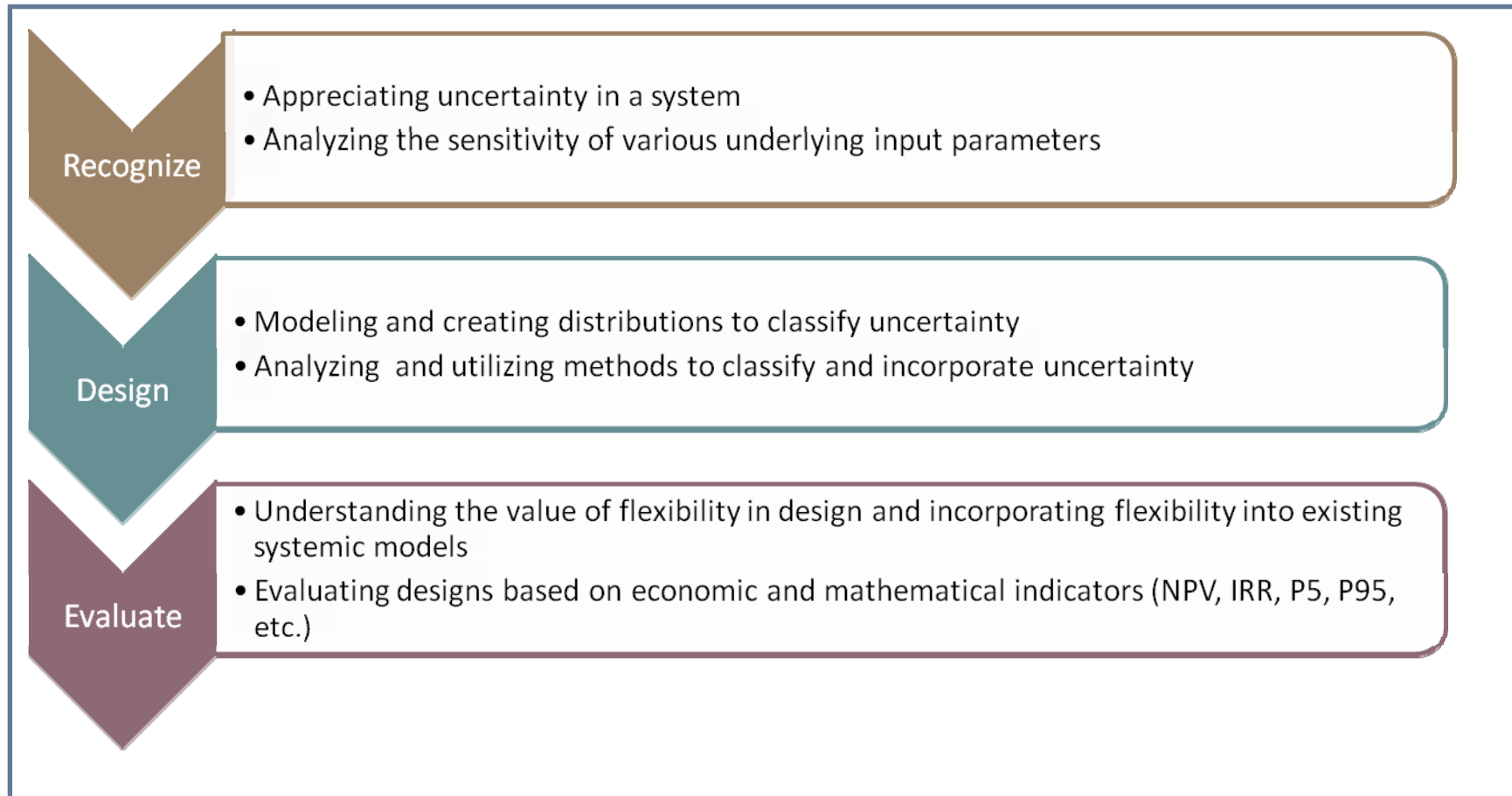
- Fixed design – highest expected IRR
- Flexible design – *better* about 25% of the time
 - Risk nature of developer
 - Ability to extract and utilize information
- Cases – all flexible cases similar – low sensitivity to timing of flexibility

Application Portfolio – Results Other Evaluation Criteria

- The fixed design always provides a greater expected value.
- Based on the target curves, there is a 60% probability for the flexible cases to return an IRR less than the mean of the base case (13%)
- As expected, the standard deviation is higher for the flexible projects.
- The P5 and P95 numbers demonstrate the variation b/w the fixed and flexible designs. A risk taking developer looking to capture some of the low probability upside would find this information exciting!

	Mean	Min.	Max.	Std. Dev.	P5	P95
Base Case (Case A)	13.02%	10.90%	15.42%	0.825%	11.05%	14.45%
Flex in years 1-5 (Case B)	12.5%	8.45%	23.1%	2.16%	10.03%	16.15%
Flex in years 1-10 (Case C)	12.5%	9.05%	25.4%	2.04%	9.89%	16.07%
Flex in years 1-25 (Case D)	12.5%	8.70%	27.5%	2.12%	9.89%	16.34%

Application Portfolio – Main Lessons



Application Portfolio – Questions?



Source: <http://www.coachwithjeremy.com/>

**Why are we doing this?
What problem are we solving?
Is this actually useful?
Are we adding value?
Will this change behavior?
Is there an easier way?
What's the opportunity cost?
Is it really worth it?**

Source: <http://37signals.com/>