



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

SUPPLY CHAIN ANALYTICS

Modelling flexibility in Supply chain

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Flexibility in Supply Chain

- **Adaptable:** Adjust the supply chain's design to meet structural shifts in markets, modify supply network strategies, products and technologies
- **Alignment:** Create incentives along the partners within the supply chain for better overall performance
- **Agility:** The ability of a supply chain to respond to short-term changes in demand or supply quickly and handle external disruptions smoothly

NPV Example: ABC Logistics

- How much space to lease in the next three years
- Demand = 100,000 units
- Requires 1,000 sq. ft. of space for every 1,000 units of demand
- Revenue = \$1.22 per unit of demand
- Decision is whether to sign a three-year lease or obtain warehousing space on the spot market
- Three-year lease: cost = \$1 per sq. ft.
- Spot market: cost = \$1.20 per sq. ft.
- $k = 0.1$



ABC Logistics: Three Options

- Get all warehousing space from the spot market as needed
- Sign a three-year lease for a fixed amount of warehouse space and get additional requirements from the spot market
- Sign a flexible lease with a minimum change that allows variable usage of warehouse space up to a limit with additional requirement from the spot market

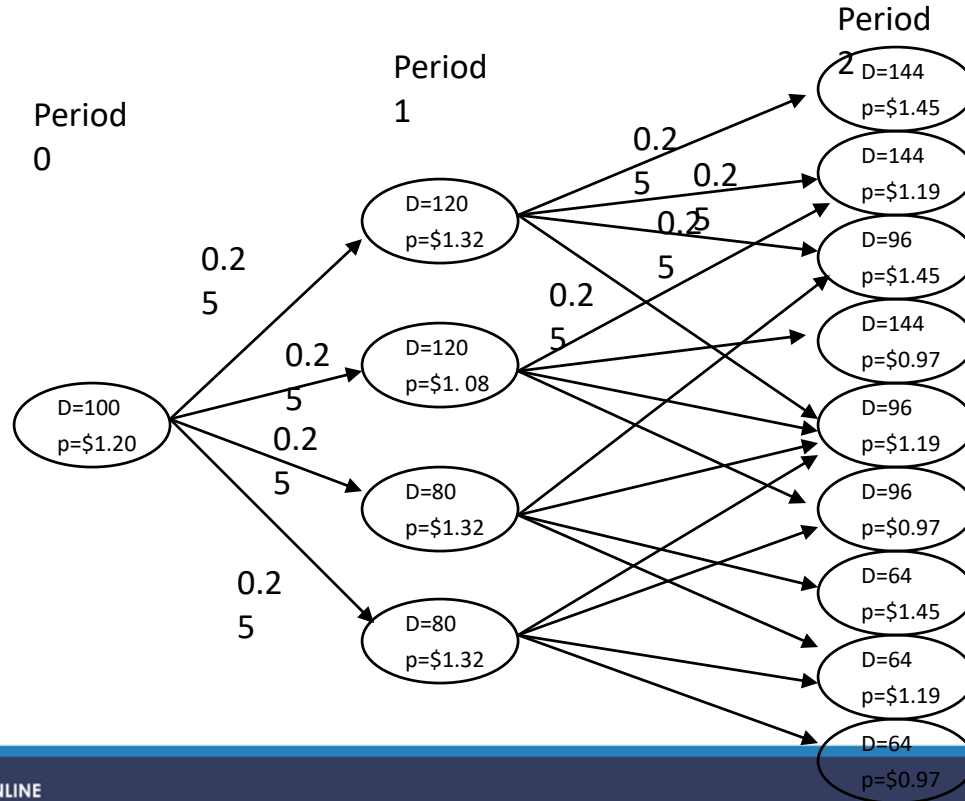


ABC Logistics

- 1000 sq. ft. of warehouse space needed for 1000 units of demand
- Current demand = 100,000 units per year
- Binomial uncertainty: Demand can go up by 20% with $p = 0.5$ or down by 20% with $1-p = 0.5$
- Lease price = \$1.00 per sq. ft. per year
- Spot market price = \$1.20 per sq. ft. per year
- Spot prices can go up by 10% with $p = 0.5$ or down by 10% with $1-p = 0.5$
- Revenue = \$1.22 per unit of demand
- $k = 0.1$



ABC Logistics Decision Tree



ABC Logistics Example

- Analyze the option of not signing a lease and obtaining all warehouse space from the spot market
- Start with Period 2 and calculate the profit at each node
- For $D=144$, $p=\$1.45$, in Period 2:

$$C(D=144, p=1.45, 2) = 144,000 \times 1.45 = \$208,800$$

$$P(D=144, p = 1.45, 2) = 144,000 \times 1.22 -$$

$$C(D=144, p=1.45, 2) = 175,680 - 208,800 = -\$33,120$$



ABC Logistics Example

- Expected profit at each node in Period 1 is the profit during Period 1 plus the present value of the expected profit in Period 2
- Expected profit $EP(D=, p=, 1)$ at a node is the expected profit over all four nodes in Period 2 that may result from this node
- $PVEP(D=, p=, 1)$ is the present value of this expected profit and $P(D=, p=, 1)$, and the total expected profit, is the sum of the profit in Period 1 and the present value of the expected profit in Period 2



ABC Logistics Example

- From node D=120, $p=\$1.32$ in Period 1, there are four possible states in Period 2
- Evaluate the expected profit in Period 2 over all four states possible from node D=120, $p=\$1.32$ in Period 1 to be

$$\begin{aligned} EP(D=120, p=1.32, 1) &= 0.25 \times P(D=144, p=1.45, 2) + \\ &\quad 0.25 \times P(D=144, p=1.19, 2) + \\ &\quad 0.25 \times P(D=96, p=1.45, 2) + \\ &\quad 0.25 \times P(D=96, p=1.19, 2) \\ &= 0.25 \times (-33,120) + 0.25 \times 4,320 + 0.25 \times (-22,080) + 0.25 \times 2,880 \\ &= -\$12,000 \end{aligned}$$



ABC Logistics Example

- The present value of this expected value in Period 1 is
$$\begin{aligned} \text{PVEP}(D=12, p=1.32, 1) &= \text{EP}(D=120, p=1.32, 1) / (1+k) \\ &= -\$12,000 / (1+0.1) \\ &= -\$10,909 \end{aligned}$$
- The total expected profit $P(D=120, p=1.32, 1)$ at node $D=120, p=1.32$ in Period 1 is the sum of the profit in Period 1 at this node, plus the present value of future expected profits possible from this node
$$\begin{aligned} P(D=120, p=1.32, 1) &= [(120,000 \times 1.22) - (120,000 \times 1.32)] + \\ &\quad \text{PVEP}(D=120, p=1.32, 1) \\ &= -\$12,000 + (-\$10,909) = -\$22,909 \end{aligned}$$



ABC Logistics Example

- For Period 0, the total profit $P(D=100, p=1.20, 0)$ is the sum of the profit in Period 0 and the present value of the expected profit over the four nodes in Period 1

$$\begin{aligned} EP(D=100, p=1.20, 0) &= 0.25 \times P(D=120, p=1.32, 1) + \\ &\quad = 0.25 \times P(D=120, p=1.08, 1) + \\ &\quad = 0.25 \times P(D=96, p=1.32, 1) + \\ &\quad = 0.25 \times P(D=96, p=1.08, 1) \\ &= 0.25 \times (-22,909) + 0.25 \times 32,073 + 0.25 \times (-15,273) + 0.25 \times 21,382 \\ &= \$3,818 \\ PVEP(D=100, p=1.20, 0) &= EP(D=100, p=1.20, 0) / (1+k) \\ &= \$3,818 / (1 + 0.1) = \$3,471 \end{aligned}$$



ABC Logistics Example

$$\begin{aligned} P(D=100, p=1.20, 0) &= 100,000 \times 1.22 - 100,000 \times 1.20 + \\ &\quad PVEP(D=100, p=1.20, 0) \\ &= \$2,000 + \$3,471 = \$5,471 \end{aligned}$$

- Therefore, the expected NPV of not signing the lease and obtaining all warehouse space from the spot market is given by $NPV(\text{Spot Market}) = \$5,471$



ABC Logistics Example

- Using the same approach for the lease option, $NPV(\text{Lease}) = \$38,364$
- Recall that when uncertainty was ignored, the NPV for the lease option was \$60,182
- However, the manager would probably still prefer to sign the three-year lease for 100,000 sq. ft. because this option has the higher expected profit



Evaluating Flexibility Using Decision Trees

- Decision tree methodology can be used to evaluate flexibility within the supply chain
- Suppose the manager at ABC Logistics has been offered a contract where, for an upfront payment of \$10,000, the company will have the flexibility of using between 60,000 sq. ft. and 100,000 sq. ft. of warehouse space at \$1 per sq. ft. per year. ABC must pay \$60,000 for the first 60,000 sq. ft. and can then use up to 40,000 sq. ft. on demand at \$1 per sq. ft. as needed.
- Using the same approach as before, the expected profit of this option is \$56,725
- The value of flexibility is the difference between the expected present value of the flexible option and the expected present value of the inflexible options
- The three options are listed in a Table , where the flexible option has an expected present value \$8,361 greater than the inflexible lease option (including the upfront \$10,000 payment)



XYZ Ltd.: Evaluation of Supply Chain Design Decisions Under Uncertainty

- Dedicated Capacity of 100,000 in the Gujarat and 50,000 in NCR
 - Period 2 Evaluation
 - Period 1 Evaluation
 - Period 0 Evaluation
- Flexible Capacity of 100,000 in the Gujarat and 50,000 in NCR
 - Period 2 Evaluation
 - Period 1 Evaluation
 - Period 0 Evaluation



Evaluating Facility Investments: XYZ Ltd

Plant	Dedicated Plant		Flexible Plant	
	Fixed Cost	Variable Cost	Fixed Cost	Variable Cost
Gujrat 100,000	\$1 million/yr.	\$15 / tire	\$1.1 million / year	\$15 / tire
NCR 50,000	\$4 million/yr	\$11 / tire	\$4.4 illion/ yr	\$11 / tire

Gujrat related Expected Demand = 100,000;

NCR Expected Demand = 50,000

Demand goes up or down by 20 percent with probability

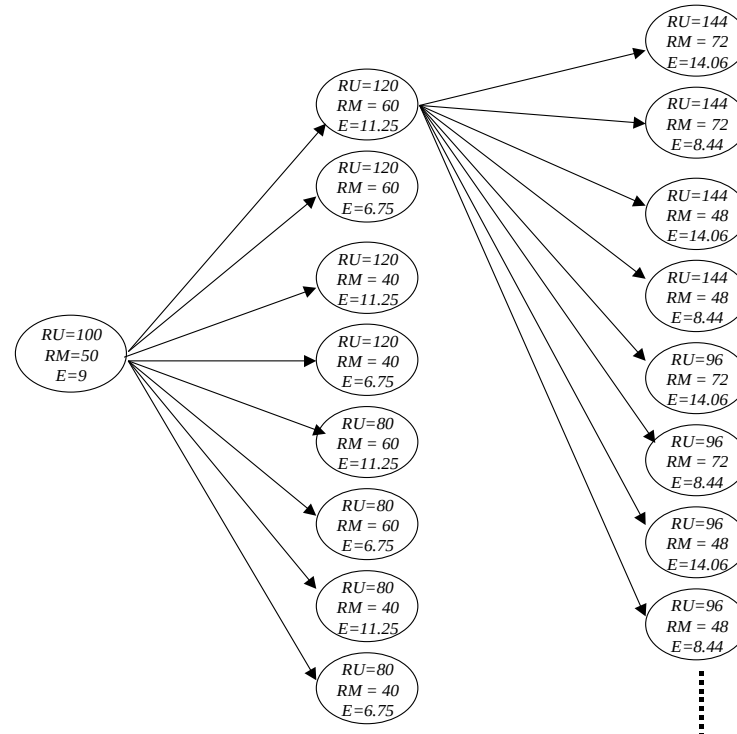


XYZ Ltd

Period 0

Period 1

Period 2



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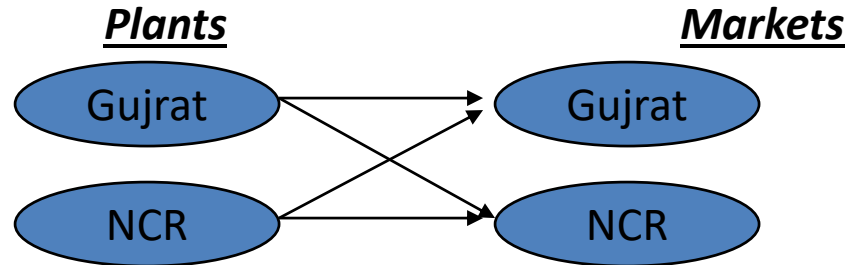
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Four possible capacity scenarios:

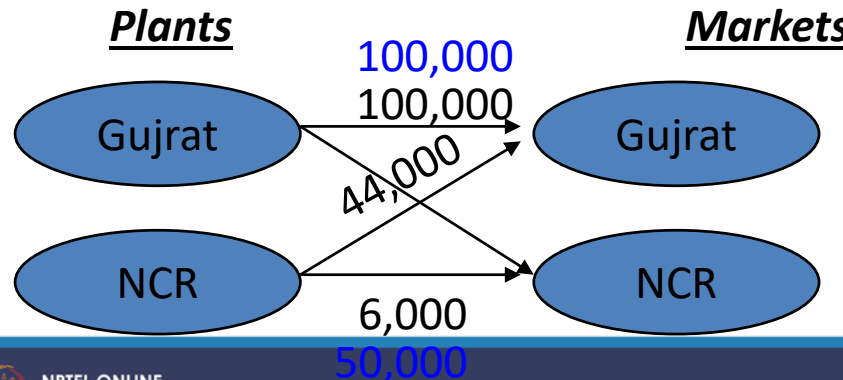
- Both dedicated
- Both flexible
- Gujrat flexible, NCR dedicated
- Gujrat dedicated, NCR flexible

For each node, solve the demand allocation model:



XYZ Ltd: Demand Allocation for RU = 144; RM = 72, E = 14.06

Source	Destination	Variable cost	Shipping cost	<i>E</i>	Sale price	Margin (\$)
Gujrat	Gujrat	\$15	0	14.06	\$30	\$15
Gujrat	NCR	\$15	\$1	14.06	\$24	\$1.1
Mexico	Gujrat	\$11	\$1	14.06	\$30	\$21.2
Mexico	NCR	\$11	0	14.06	\$24	\$9.2



Profit (flexible) = \$1,075,055
Profit (dedicated) = \$649,360

Facility Decision at XYZ Ltd

Plant Configuration		NPV
Gujrat	NCR	
Dedicated	Dedicated	\$1,629,319
Flexible	Dedicated	\$1,514,322
Dedicated	Flexible	\$1,722,447
Flexible	Flexible	\$1,529,758



THANK YOU

