

## Flexible Assembly Systems for SUV and small car production

A Decision Tree and Binomial Lattice Analysis of flexibility



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### Preamble

- ▶ Automotive demand is highly uncertain, making flexibility an interesting and valuable approach to system design
- ▶ Two vehicle productions are under investigation from the perspective of an assembly plant: SUV and small cars
- ▶ Combining both assembly systems into one assembly plant using shared tools may yield more profits under uncertainty
- ▶ Delaying plant capacity decisions may also be more profitable

## System Definition

- ▶ Hypothetical automotive assembly system for manufacturing SUV and small cars using either separate facilities or shared facilities.
- ▶ Two sources of flexibility:
  - Capacity decision making flexibility over time: can we adjust capacity investments?
  - Production flexibility: can both cars be produced on same line?

		Capacity decision making flexibility	
		Yes	No
Assembly line production flexibility	Yes	I	II
	No	III	IV

## Source of Uncertainty

- ▶ Sources of uncertainty: first year demand and subsequent growth rates for either product given alongside probabilities
- Demand projections are based on automotive market volatility up to date

	Expected Demand in first period	S.Dev. of Exp.Demand	Subsequent growth rate
small cars	300000	10%	-5% to +4%
SUVs	130000	10%	-4 to -15%

Market Demand	SUV		Small Car	
	Demand	P(D)	Demand	P(D)
Very High	200000	0.10	425,000	0.10
High	160000	0.25	375,000	0.25
Average	130000	0.30	300,000	0.30
Low	100000	0.25	220,000	0.25
Very Low	60000	0.10	180,000	0.10
EV	130000		300,000	
S.Dev.	12,665		28,755	
Standard Deviation (%)	10%		10%	

YR 1 Market Demand / Growth rate	SUV growth rates and probabilities				
	-0.30	-0.20	-0.10	0.00	0.10
Very High	0.05	0.1	0.275	0.325	0.25
High	0.05	0.15	0.35	0.3	0.15
Average	0.1	0.2	0.3	0.225	0.175
Low	0.15	0.225	0.35	0.2	0.075
Very low	0.2	0.3	0.3	0.15	0.05

YR1 Market Demand/Growth rate	Small Car growth rates and probabilities				
	-0.20	-0.10	0.00	0.08	0.15
Very High	0.05	0.1	0.275	0.325	0.25
High	0.05	0.15	0.35	0.3	0.15
Average	0.1	0.2	0.3	0.225	0.175
Low	0.15	0.225	0.35	0.2	0.075
Very low	0.2	0.3	0.3	0.15	0.05

Figure 8: Prices, variable costs of product types and annual capacities and equipment costs per line of single vehicle style assemblies and multistyle assembly.

## Design Levers for Analysis

- In scenarios I–IV the primary decision variable is assembly line capacity given in # lines where each line can produce a fixed number of vehicles and each has its own cost

	SUV	Small Car	Multiproduct assembly
Unit Price (\$k)	30	20	-
Capacity of line (1000s)	30	50	40
Variable Cost (\$k)	20	12	-
Cost of Equipment/line (\$m)	60	50	75

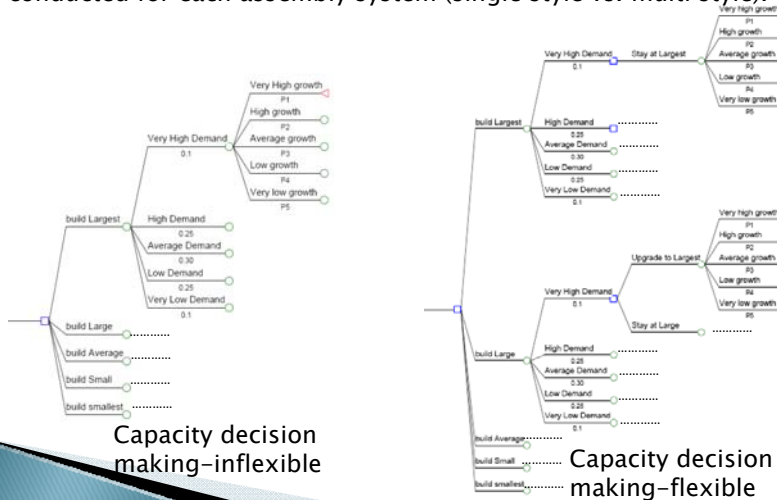
Summary of important system parameters

Plant Design	SUV_Single	SMALL	
	Style	CAR_Single Style	MultiStyle
Largest	7	9	16
Large	6	8	14
Average	5	6	11
Small	4	5	8
Smallest	2	4	6

5 possible optimal capacity decisions for each system

## Decision Tree Analysis

- Two decision tree analyses over two years corresponding to both flexible and inflexible capacity decision making cases were conducted for each assembly system (single style vs. multi style).



## Decision Tree Analysis Results

- Optimal capacity flexible and capacity inflexible strategies are derived for each assembly system (based on ENPV)

Assembly System	Best Strategy	# Lines	NPV of Expected Profit
SUV Single Style	Build Large	6	\$1,756,057,475
Small Car Single Style	Build Large	8	\$3,424,910,740
Multi Style	Build Large	14	\$4,391,184,914

Optimal capacity decisions for capacity inflexible scenarios

### Surprising result:

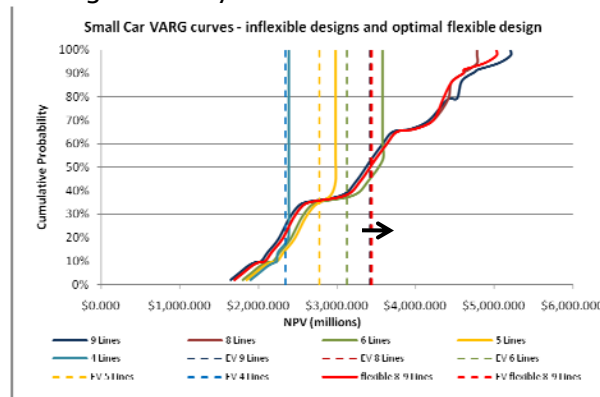
In all cases, production flexibility is not as profitable as keeping separate lines!

SUV Single Style ULTIMATE FLEXIBLE STRATEGY			
D1	followed by	D2	NPV of Expected Profits
6 lines		6-Large	Very Low
"Build Large"		6-Large	Low
		6-Large	Average
		6-Large	High
		7- Largest	Very High
\$1,759,733,287			
Small Car Single Style ULTIMATE FLEXIBLE STRATEGY			
D1	followed by	D2	NPV of Expected Profits
8 lines		8-Large	Very Low
"Build Large"		8-Large	Low
		8-Large	Average
		8-Large	High
		9- Largest	Very High
\$3,440,404,665			
Multi style ULTIMATE FLEXIBLE STRATEGY			
D1	followed by	D2	NPV of Expected Profits
14 lines		14- Large	Very Low
"Build Large"		14- Large	Low
		14- Large	Average
		14- Large	High
		16- Largest	Very High
\$4,419,756,155			

Optimal capacity decisions for capacity flexible scenarios

## Decision Tree Analysis Results

- Small Car Single Style assembly system demonstrates the highest increase in ENPV and highest value of capacity decision making flexibility: ~\$15.5m



## Decision Tree Analysis: Multiple Criteria

- Increases in ENPV indicate value of capacity flexibility is positive, but return on investments (ENPV/CapEx) suggest flexibility not worth pursuing!

	Capacity Decision involving Flexibility	SUV		Small Car		<del>Multi-style*</del>		Single-Style SUV+Small Car	
		Inflexible	Flexible	Inflexible	Flexible	Inflexible	Flexible	Inflexible	Flexible
		ENPV (\$M)	1.736	1.700	1.615	1.648	<del>4.305</del>	<del>4.626</del>	5.161
PM (Min)	0.700	0.700	2.004	2.004	<del>3.620</del>	<del>3.620</del>	2.793	2.793	
PDG (Min)	1.681	1.294	4.626	4.696	<del>6.287</del>	<del>6.287</del>	7.621	7.681	
Max NPV (\$M)	2.701	2.620	4.781	5.623	<del>6.994</del>	<del>7.290</del>	7.822	7.935	
Min NPV (\$M)	0.528	0.528	1.694	1.694	<del>0.617</del>	<del>0.617</del>	2.284	2.284	
CapEx (Min)*	Actual	0.90	-	0.95	-	<del>1.079</del>	-	0.900	-
	Min	-	0.90	-	0.95	-	1.085	-	0.900
	Max**	-	0.90	-	0.97	-	1.121	-	0.961
ENPV/CapEx (%)	Actual	89	-	86	-	<del>85</del>	-	88	-
	Max	-	89	-	89	-	87	-	88
	Min	-	89	-	74	-	78	-	87

\*production flexibility not profitable

## Lattice Analysis

- 6 year period lattice analysis was conducted on single style assembly systems to explore value of adding capacity decision making flexibility
- Important derived parameters: (system modeled in monthly periods):

	Average Growth rates		Standard Deviations	
	g(annual)	g(monthly)	sdev(annual)	sdev(monthly)
SUV	-0.09	-0.00783	0.03	0.0087
Small Car	0	0	0.025	0.0072

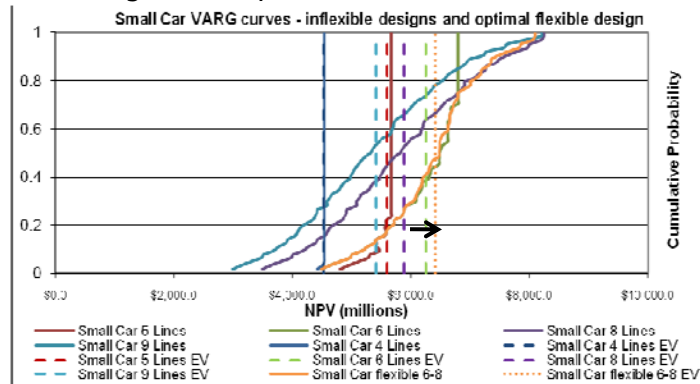
Annual u,d,p values	SUV	Small Car
u	1.00870	1.00724
d	0.99138	0.99281
p	0.04803	0.50000

Monthly u,d,p values	SUV	Small Car
u	1.1095	1.0905
d	0.9012	0.9170
p	0.05	0.5



## Lattice Analysis Results

- Again, Small Car Single Style assembly system demonstrates the highest increase in ENPV and highest value of capacity decision making flexibility: ~\$148m



## Lattice Analysis: Multiple Criteria

- Again, increases in ENPV indicate value of capacity flexibility is positive in all cases, but return on investments (ENPV/CapEx) suggest flexibility not worth pursuing!

	Capacity Decision making flexibility	SUV		Small Car		Multi-style	
		Inflexible	Flexible	Inflexible	Flexible	Inflexible	Flexible
ENPV (\$bn)		2.079	2.079	6.299	6.407		
P10 (\$bn)		1.973	1.973	6.299	6.299		
P90 (\$bn)		2.467	2.467	6.799	7.479		
Max NPV (\$bn)		2.626	3.261	6.799	8.101		
Min NPV (\$bn)		1.973	1.973	4.492	4.492		
CapEX (\$bn)*	Actual	2.42	-	3.02	-		
	Min	-	2.42	-	3.02		
	Max**	-	2.87	-	3.71		
ENPV/CapEX (%)	Actual	85.95	-	207.06	-		
	Max	-	85.95	-	211.99		
	Min	-	72.42	-	172.61		

Decision tree analysis has shown that production flexibility is not profitable in all criteria (see Figure 18). Therefore, no further analysis was conducted.

## Discussion

- ▶ Value of production flexibility depends on demand projections (in this example it isn't worth pursuing)
- ▶ Value of capacity decision making flexibility depends on system parameters: demand projections, uncertainty, capital costs, profit margin, project lifetime to name a few (in this example most valuable for small car assemblies)
- ▶ Value of capacity decision making also depends on criteria for evaluation. ENPV and ROI may give different rankings
- ▶ Lattice Analysis easier to use but more approximate than decision tree analysis