

Application Portfolio: Buenaventura Port Expansion

Isabel Agudelo
ESD.71 Engineering Systems
Analysis for Design
December 2008



Agenda

1. Background
2. Sources of uncertainty
3. Port capacity drivers
4. Fixed vs Flexible
5. 2-Stage Decision Analysis
 - Cost structure
 - Demand
 - Strategies
 - Decision Tree
 - Results
6. Lattice Analysis
 - Assumptions
 - Lattice Fixed
 - Lattice Flexible
 - Results
7. Take aways



1. Background



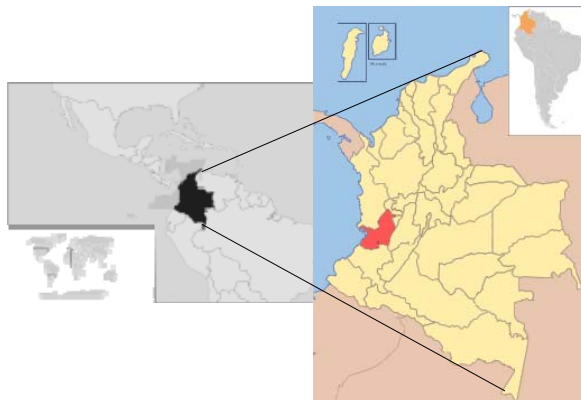
South America



Colombia



Colombia



Cauca Valley



Buenaventura Port



Quick facts



Drivers	Current Data
Terminal space	2000 meters
Number of terminals	14 docks
Cranes	16 container cranes

Source: Buenaventura Port Authority (2008)

Motivation

- Colombian economy is growing at 6% per year.
- 2005: Capacity utilization was 73.5%. Today passed 100%.
- Avoid bottleneck for import & exports.
- Colombian government limited resources.



2. Sources of uncertainty

- Economic:
 - Growth of the world economy extended to maritime transport. Concentration in Asia Pacific
- Politics
 - FTA (Free Trade Agreement) with US.
- Technology
 - Post Panamax ships
- Demand
 - Competition with the ports in the region.



3. Port capacity drivers

Category	Capacity Factor
Port	Terminal space
Infrastructure	Berth space
	Land for port expansion
	Gate capacity
	Port equipment
Labor	Terminal operator capacity
	Longshore labor efficiency
	Longshore labor costs
	Longshore labor capacity
	Other port labor efficiency
	Other port labor capacity
	Other port labor costs
Waterways	Channel depth
	Channel width
	Tug and tow
	Barge, short sea feeders
	Pilotage
	Bridge clearance
	Channel congestion
Truck and Rail	Local road capacity
	Rail – local capacity
	Local dray capacity
	Rail – on-dock capacity
Technology	Gate systems
	Scheduling
	Container tracking
	Data exchange with partners

Container
Cranes

Source: Jackson (2005)

Container cranes



Source: ww.gettyimages.com

Container Types



- TEU (20 ft)
 - ◆ Volume 33 M³
 - ◆ Total Payload 24.8 kkg

TEU: Twenty-Foot Equivalent Unit



- FEU (40 ft)
 - ◆ Volume 67 M³
 - ◆ Total Payload 28.8 kkg

FEU: Twenty-Foot Equivalent Unit



Fixed vs Flexible

- Fixed system: Increase the capacity by buying 5 container cranes in year one.
- Flexible system: In year one, buying 2 container cranes and buy another 3 containers cranes in year 5.



2-Stage cost structure

Issue	20' Container	40' Container
• Price (dollar per container)	\$140	\$200
• Current capacity	40,000	20,000
• Additional capacity per crane added (containers per year)	2800	1200
• Current port expenses (thousand per year)	\$300	
• Additional cost per crane added (thousand per year)	\$56	
• Investment per crane (Thousand dollars). No salvage value.	\$700	
• Discount rate	5%	

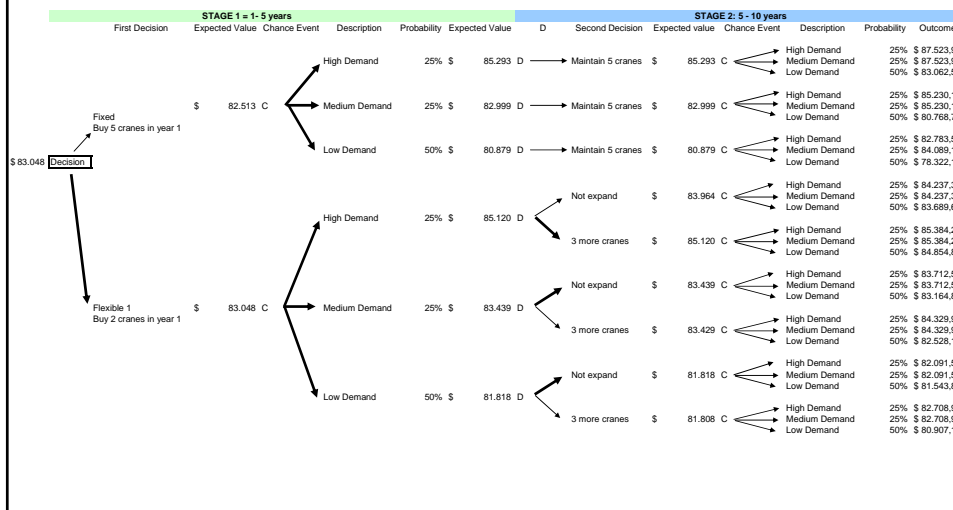
Note: Data is fictional



2-Stage strategies

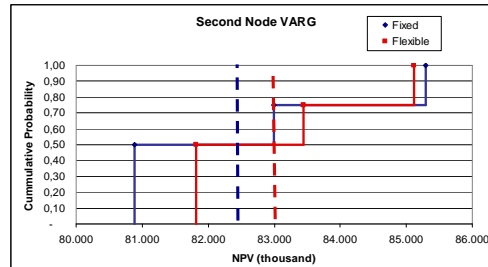
- 2-Stage: 1-Stage (1-5) 2-Stage (5-10) because the expansion is in year 5.
- Demand growth per year: High (15%), Medium (7%), Low (2%).
- Probability of the random scenarios: High (25%), Medium (25%), Low (50%).
- 27 demand combinations to consider over 10 years: 9 Fixed, 18 Flexible since Flexible has option to expand in year 5.

2-Stage Decision tree



2-Stage results

- Fixed: 82.5 M
- Flexible: 83 M
- The best strategy is the acquisition of two cranes in year one and if demand increases to a high level expand to a high level expand to 3 cranes.
- Value of flexibility has a value of 536,000 dollars. If the port gets a discount of this magnitude is good to buy five cranes in year 5.



	CAPEX t=0	Mean ENPV	Min ENPV	Max ENPV
Fixed Buy 5 cranes from year 0	3.5 million	82.513	80.879	85.293
Flexible Buy 2 cranes in year 1 and 3 additional cranes in year 5	3.04 million	83.048	81.818	85.120

Lattice Analysis Assumptions

- Assumes demand increases exponentially year to year.
- Simplifications:
 - Only 20' containers demand
 - Annual cost adjusted

$$v_{year} = 0.5266$$

$$\sigma_{year} = 0.0234$$

$$\Delta t = 1 \text{ year}$$

$$u = e^{\sigma \Delta t} = 1.69$$

$$d = 1/u = 0.59$$

$$p = 0.5 + 0.5 \times (v / \sigma) \times \sqrt{\Delta t} = 0.52$$

$$\text{Value to start} = 34200$$

Lattice Analysis:

Fixed: 5 cranes in year 1



CASH FLOW FIXED LATTICE - 5 cranes in year 1						
0	1	2	3	4	5	6
4.601.967	3.874.000	7.094.000	7.094.000	7.094.000	7.094.000	7.094.000
	-858.088	4.321.967	7.094.000	7.094.000	7.094.000	7.094.000
		1.204.247	2.361.912	4.321.967	7.094.000	7.094.000
			520.497	1.204.247	2.361.912	4.321.967
				116.654	520.497	1.204.247
					-121.868	116.654
						-262.746

CASH FLOW * PROBABILITY LATTICE						
0	1	2	3	4	5	6
4601967	2022900	1934286	1010033	527412	275401	143807
	-410017	2156734	2772760	1930482	1260058	789562
		274952	844774	1614369	2306089	1806267
			56784	274411	702594	1342662
				6081	70841	256754
					-3036	9104
						-3127

	0	1	2	3	4	5	6	7	8	9	10
E [Cash Flow]	4601967	1612883	4365971	4684350	4352755	4611946	4345029	4570941	4343107	4546524	4345332
PV [E(Cash Flow)]	4601967	1536079	3960064	4046518	3581022	3613581	3242328	3248483	2939586	2930730	2667657
ENPV over 10 years		36368014									

Lattice Analysis:

Flexible Portion



- 5 steps
 1. Step 1: CF of 2 cranes during 10 years.
 2. Step 2: Lattice for 2 cranes during 10 years.
 3. Step 3: CF of 2 cranes in year 1 and 3 cranes in year 5.
 4. Step 4: Lattice for 2 cranes year 1 and 3 cranes in year 5.
 5. Step 5: Comparison of Step 2 and Step 4 in year 5 to decide expansion in year 5.
 6. Step 6: Measure the value of the Call Option and the value of flexibility.

Lattice Analysis

Value of call option & Value of flexibility



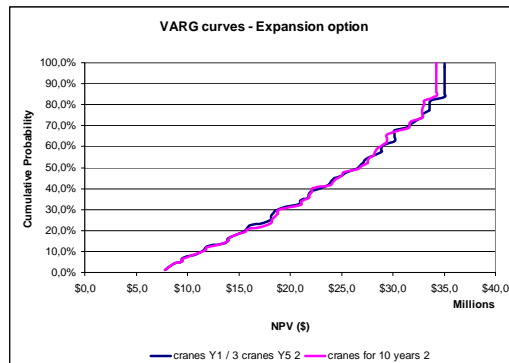
	0	1	2	3	4	5
WITH EXPAND OPTION in year 5	NO	NO	NO	NO	NO	YES
Dynamic programming		NO	NO	NO	NO	YES
approach			NO	NO	NO	YES
(check next year)				NO	NO	YES
					NO	NO
						NO

ENPV - 2 cranes in year 1	35.395.321
ENPV - 2 in year 1 and 3 in year 5	36.764.076
Value of (call) option to expand	1.368.755
ENPV (fixed) - 5 cranes in year 1	36.368.014
ENPV (flexible) - 2 in year 1 and 3 in year 5	36.764.076
Value of flexibility	396.062

Results for Lattice



- Lattice confirm the intuition that is good to opt for expansion when demand is high.



Take away



- In this case, Decision Analysis and Lattice are not comparable.
- In both cases, flexibility also proved to add value to the process.
- Decision analysis seems more adequate for situations with several sources of uncertainty like port expansion.

Questions?

