INDE2000 Supply Chain Modelling and Optimisation

Assignment Part II

Student Details:

Family Name:	[redacted]
Given Name:	[redacted]
Student ID:	[redacted]

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Name _[redacted]_________

Signature_______[redacted]_______

Question 1:

Sourcing:

When sourcing its materials, automotive company have two main goals, cost reduction as well as area diversification. For example, they may have their part manufactured in countries where cost is low such as China and Mexico but moreover have a portion of all the parts manufactured t each place, so that if an event outside their control happens, they do not have to stop production but rather slow it down.

Supply Management:

When ordering stock, automotive manufacturers generally use the push method, most of the car is build identically and a very low number of spec are optional which means that they can build to plan on demand and generally will build a portion of their fleet with some of the available options. They do sometime use the pull method, but this is rare and only happen when a car with a high level of customisation is ordered as they may not have it.

They will also forecast the need for spare part so that they can service the need for spare part may this be because of defect or maintenance purposes.

To build resilience in their supply chain, automotive manufacturers have contingency plans, proactive and reactive. Proactive; the company will assess the risk of each supplier, manufacturing plan \t and ahead of time decide where production should be directed to as to minimise the production in risky but necessary areas to minimis cost of disruption. Reactive; the company has plans to deal with the disruption to as economically as possible deal with the disruption.

Warehouse Management:

Most cars are delivered on a regular basis to the dealership (push), but those with high level of customisation will be stored at the manufacturing plant and only delivered when requested by a dealership (pull) as to not incur unnecessary transport and excess inventory cost. They will also stock spare parts in case of defect or for maintenance purposes.

When warehousing at dealership, the company looks at past sales as well as the environment for the dealership to forecast demand of common purchases. For example, socioeconomical average of nearby customers, their age, stage of life as well as future earning potential.

Transportation:

To lower transportation cost automotive companies try to build their manufacturing plant in emerging markets, such as India and China. However, existing large markets are generally reliant on importation as the company may have one or two Giga factories which services multiple large markets. Transported on road or sea freight.

Conclusion:

All of this allows for automotive company to satisfy most demand on time and order specific options if needed, in a safe, cost-efficient manner. Following a strategy aimed at reducing cost without compromising quality, target growing markets as well as having in place contingency plans to effectively deal with supply chain disruptions and risks.

Question 2:

a) I will be using python to program this problem the main purpose would be to minimise the following variables:
$(m = 1,2,3)$, $(i = 1,2,3,4,5)$
$Mill_{Capacity} = [1200,1500,900]$
$Market_{demand} = [600,100,500,800,500]$
$Mill_{cost} = [210,225,220]$
$Mill_{m,i} = Amount\ produced\ at\ Mill\ m\ \ for\ Market\ i$
$Cost_{m,i} = Cost\ of\ production\ at\ Mill\ m\ \ for\ Market\ i$
$Y_i = \{0,1\}$

Now I want to minimise the following
$$TC = \sum_{i=1}^{5}\sum_{m=1}^{3} Mill_{m,i} * Cost_{m,i} + \sum_{m=1}^{3}(Mill_{cost_m} * Y_i)$$
While withing the bounds of the following constraints
$0 = Market_{demand_i} - \sum_{m=1}^{3} Mill_{m,i}\ , \quad for\ i = 1,2,3,4,5$
$$0 \le Mill_{capacity_m} - \sum_{i=1}^{5} Mill_{m,i}\ , \qquad for\ m = 1,2,3$$
This will give us the minimum ordering cost needed to satisfy all market demand without going over each of our mill capacity

b) Codes

```
cost = np.array([[20, 25, 30, 15, 35],

                 [30, 20, 32, 28, 19],

                 [25, 18, 28, 23, 31],

                ])  # transport cost

Fh = np.array([210,225, 220])
D = np.array([600,100,500,800,500])  # market demand
Kh = np.array([1200,1500,900])

cFlat = cost.flatten('F')
c = np.append(cFlat, Fh)
c = c.astype(float)
print(np.rint(c.reshape((3,6), order = 'F')))

# Aeq = [Au; Ad]; % in balanced transportation version
def kron_Au(m,n):

  return np.kron(np.eye(n,dtype=int), np.ones(m,dtype=int))

def kron_Ad(m,n):

  return np.kron(np.ones(m,dtype=int), np.eye(n,dtype=int))

Au = kron_Au(3,5)
```

```
Ad = kron_Ad(5,3)

A = np.hstack([Ad, -np.diag(Kh)])
Aeq = np.hstack([Au, np.zeros((5,3))])
b = np.zeros(3)
beq = D.astype(float)

# Obtain result
from scipy.optimize import linprog
res = linprog(c, A_ub=A, b_ub=b, A_eq=Aeq, b_eq=beq, method='revised simplex')

answer = np.round(res.fun,0)
Dis= res.x
Dis_Map = np.rint(Dis.reshape((3,6), order = 'F'))
print('The minimum cost is ${} and occurs using the Distibution Map '.format(answer))
print(Dis_Map)
```

c) The optimal solution is:

Market / Mill	1	2	3	4	5
A	400	0	0	800	0
B	0	0	0	0	500
C	200	100	500	0	0

This is the minimum cost of transportation as well as manufacturing.

Ordering Cost = 540500
Shipping Cost = 50300
Total Cost = 590800
This model considers the pros and cons of manufacturing at a particular mill for a particular market since because of shipping it may not be the best option to use the mill with the lowest production cost or vice versa.
I used Excel Solver to double check my answers.

Data	Market							Cost Per Mill	Mill
	Mill	1	2	3	4	5		210	A
Shipping Cost	A	20	25	30	15	35	1200	225	B
	B	30	20	32	28	19	1500	220	C
	C	25	18	28	23	31	900		
		600	100	500	800	500			

Orders	Market						Total Per Mill	
	Mill	1	2	3	4	5		
Shipping Cost	A	400	0	0	800	0	1200	0
	B		0	0	0	500	500	1000
	C	200	100	500		0	800	100
	Filled	0	0	0	0	0		

Orders	Market						
	Mill	1	2	3	4	5	Ordering
Shipping Cost	A	8000	0	0	12000	0	252000
	B	0	0	0	0	9500	112500
	C	5000	1800	14000	0	0	176000
	Shipping	13000	1800	14000	12000	9500	
			Best				
	Total Shipp	50300	50300				
	Total Orde	540500	540500				
	Total Cost	590800	590800				

Question 3:

I used Excel to solve the problem, so a small discrepancy is to be expected as all of the calculation use exact Value.

The table below are structure as a tree diagram where D is demand and M is price which Molectron charges. Year on year these will change as per the question, the likelihood of each node is shown in the table next to the tree diagram, where D implies Demand increased and M implies cost of production by Molectron increased. It follows that DM implies both increased and DDMM implies both increased twice over the first and second year. To the right of the probability table is a number ranging from 1 to 4, these represent the number of ways which can be taken to arrive to this outcome.

Each node is calculated separately and is discounted to its respective year. Once we know the Node's PV we multiply it by its likelihood of occurring as per the probability table. Once this is done, we add everything together, keeping in mind there may be a small difference as we have used exact value throughout the calculations

Part A: Molectron Price change Y1 and Y2

tron				Dis Y2	0.82645	
				A	Total PV of Decision Tree	
					$ 166,252,317.92	
					Total Y1 PV	$ 76,715,909.09
		1	D	15500	Value	Presnt V
			M	2500	$ 89,750,000	$ 81,590,909.09
	Senario					
		2	D	15500	Value	Presnt V
			M	2000	$ 92,500,000	$ 84,090,909.09
D	10000					
M	2000					
		3	D	10000	Value	Presnt V
			M	2500	$ 65,000,000	$ 59,090,909.09
e		4	D	10000	Value	Presnt V
			M	2000	$ 65,000,000	$ 59,090,909.09

1	D	24025	Value	Present V
	M	3125	$ 119,346,875	$ 98,633,780.99
2	D	24025	Value	Present V
	M	2500	$ 128,112,500	$ 105,878,099.17
3	D	24025	Value	Present V
	M	2000	$ 135,125,000	$ 111,673,553.72
4	D	15500	Value	Present V
	M	3125	$ 86,312,500	$ 71,332,644.63
				$ -
5	D	15500	Value	Present V
	M	2500	$ 89,750,000	$ 74,173,553.72
6	D	15500	Value	Present V
	M	2000	$ 92,500,000	$ 76,446,280.99
7	D	10000	Value	Present V
	M	3125	$ 65,000,000	$ 53,719,008.26
8	D	10000	Value	Present V
	M	2500	$ 65,000,000	$ 53,719,008.26
9	D	10000	Value	Present V
	M	2000	$ 65,000,000	$ 53,719,008.26

Change	Prob Y1		Prob Year :	Prob Complete	
DM	0.45	DDMM	0.2025	0.2025	1
D	0.3	DDM	0.135	0.27	2
M	0.15	DD	0.09	0.09	1
None	0.1	DMM	0.0675	0.135	2
Sum	1	DM	0.045	0.18	4
		D	0.03	0.06	2
		MM	0.0225	0.0225	1
		M	0.015	0.03	2
		None	0.01	0.01	1
		Sum		1	16

Part B: Molectron Price change only in Y2

				Sell Price	15000						
				Material	8000						
				Dis Y1	0.90909						
				Dis Y2	0.82645						
				B	Total PV of Decision Tree						
					$ 170,214,746.90					Total Y2 PV	$ 92,373,837.81
							1	D	24025	Value	Present V
								M	2500	$ 128,112,500	$ 105,878,099.17
							2	D	24025	Value	Present V
					Total Y1 PV	$ 77,840,909.09		M	2000	$ 135,125,000	$ 111,673,553.72
	Senario										
		1	D	15500	Value	Present V	3	D	15500	Value	Present V
			M	2000	$ 92,500,000	$ 84,090,909.09		M	2500	$ 89,750,000	$ 74,173,553.72
D	10000										
M	2000						4	D	15500	Value	Present V
		2	D	10000	Value	Present V		M	2000	$ 92,500,000	$ 76,446,280.99
			M	2000	$ 65,000,000	$ 59,090,909.09					$ -
							5	D	10000	Value	Present V
								M	2500	$ 65,000,000	$ 53,719,008.26
Change	Prob Y1		Prob Year :	Prob Complete							
D	0.75	DDM	0.3375	0.3375	1		6	D	10000	Value	Present V
None	0.25	DD	0.225	0.225	1			M	2000	$ 65,000,000	$ 53,719,008.26
Sum	1	DM	0.1125	0.225	2						
		D	0.075	0.15	2						
		M	0.0375	0.0375	1						
		None	0.025	0.025	1						
		Sum		1	8						

Value of adding capacity to its Santa Clara plant:

				Seel Price	15000	Warehouse Cost					
				Material	8000	$ 10,000,000.00					
				Labour	500						
				Dis Y1	0.90909						
				Dis Y2	0.82645						
				B	Total PV of Decision Tree						
					$ 161,126,033.06						
										Total Y2 PV	$ 86,751,033.06
					Total Y1 PV	$ 74,375,000.00					
	Senario						1	D	24025	Value	Present V
		1	D	15500	Value	Present V				$ 120,000,000	$ 99,173,553.72
					$ 90,750,000	$ 82,500,000.00					
D	0						2	D	15500	Value	Present V
M	D									$ 90,750,000	$ 75,000,000.00
		2	D	10000	Value	Present V					
					$ 55,000,000	$ 50,000,000.00	3	D	10000	Value	Present V
										$ 55,000,000	$ 45,454,545.45
Change	Prob Y1		Prob Year :	Prob Complete							
D	0.75	DD	0.5625	0.5625	1						
None	0.25	D	0.1875	0.375	2						
Sum	1	None	0.0625	0.0625	1						
		Sum		1	4						

Present Value:

Adding Capacity to Santa Clara plant: $161,126,033.06

Option A: $166,252,317.92

Option B: $170,214,746.90

Hence it is actually better to contract out the extra demand then it is to satify it by increasing our plant's capacity, of course Option B is better than A as fixed prices for year 1 increases profits.

First the set cost of the addign capacity is only worth it if the demand increases at least once as well as if demand incrreases both years to 24025 the limit of the plant is 20000 and so Moon misses out on 4025 sells.

Second, in Option A and B id demand does not increase and stays at 10000, then Moon still makes the same profit as the previous year as only the servers they cannot build at their plant are required to be built by Molectron, and if demand increases twice Molectron can help Moon satisfy the demand entirely which generates more profit than if Moon did it itslef even if the margins are lower.

Something not explored is the shipping cost as as well as lon term company growth, as it may be better for the long run to increase Santa Clara's capacity as otherwise, future demand growth will always need to be contracted out which could slow down company growth.

Question 4:

Part A :

$h = 1, \quad A = 25, \quad D = 200,$

$$Q^{\circ} = \sqrt{\frac{2*200*25}{1}} = 100, \quad TC_{STORAGE} = \frac{100}{2}*1 = 50, \quad TC_{SETUP} = \frac{200}{100}*25 = 50$$

Optimum Quantity : 100, Total Cost of Storage per month: $50, Total Set-up Cost per month: $50

Part B:

$Prod = 2500, \quad D = 18000, \quad D_{pMonth} = 1500, \quad h = 18, \quad h_{pmonth} = 1.5$

$A = 800, \quad L = 5\ days, \quad Day_{Work} = 20,$

$$Q^{\circ} = \sqrt{\frac{2*1500*800}{1.5*(1-1500/2500)}} = 2000, \quad TC_{STORAGE} = \frac{2000}{2}*1.5*\left(1-\frac{1500}{2500}\right) = 600,$$

$$TC_{SETUP} = \frac{1500}{2000}*800 = 600, \quad T = \frac{2000}{1500} = 1.33$$

$$Aveg_{Q^{\circ}} = \frac{1500}{2}*\left(1-\frac{1500}{2500}\right) = 300$$

i. Most economic batch is Q = 2000
ii. The $Aveg_{Q^{\circ}}$ = 300
iii. Minimum Inventory Cost = 600 per month
iv. Reorder Piont is 21.9 days
v. If production is infinite, then Q will increase

Part C:

```
D = 8000
A = 12000
h = 0.3
P = 10
S = 1.1
###Shortage equations
Q = math.sqrt((2*D*A/h)*(S+h)/S)
T = Q/D
OP_ST = Q*(S/(S+h))
Short = Q-OP_ST
Q,T,OP_ST,Short = np.round([Q,T,OP_ST,Short],2)
print('The optimal order size is ',Q,' the time between orders woudl be',T,'
the optimal storage amount is ', OP_ST,' and the optimal shortage is thus ',
Short)
```

They should order 28540.24 items every 3.57 months

Question 5:

Part A:

Part A			Optimal	242663.1									
Demand	240000		Price	0.978974									
A	400		Cycle Inv	39600									
I	20%												
	Price	AVG P	H	Order Cost	R_i	Q	Cycle Inventory	Number of Orders	Order Cycle	Ordering Cost	Holding Cost	Production Cost	Total Cost
0	1	1	0.2	30983.87	0	30983.87	15491.93	7.75	47.12	3098.3867	3098.3867	240000	246196.773
20000	0.98	0.98904	0.197807	43777.41	20000	44262.67	22131.33	5.42	67.32	2168.8707	4377.7413	237368.871	243915.483
40000	0.96	0.97897	0.195795	61915.73	39600	63245.55	31622.78	3.79	96.19	1517.8933	6191.5731	234953.68	242663.146

When we look at Q* for the entry price it is clear to see that it is more adventageous to have big orders, additionally we can see that the main factor in the decrease of the Total Cost is the Production cost wher as the saving from the OC and HC are marginal, so it is lodgical that the hisghest discount leads to the best option.

Hence Optimal Lot size is 63246, Annual Cost is $242663.15 and the cycle inventory is 31622.78.

Part B:

Wagner Within	A	h	C	I						
Last Period to Order	100	1	10	1%						
Demand	20	50	10	50	50	10	20	40	20	30
Week	1	2	3	4	5	6	7	8	9	10
1	100	150	170	320	520	570	690	970	1,130	1,400
2		200	210	310	460	500	600	840	980	1,220
3			250	300	400	430	510	710	830	1,040
4				270	320	340	400	560	660	840
5					370	380	420	540	620	770
6						420	440	520	580	700
7							440	480	520	610
8								500	520	580
9									580	610
10										620
Zt	100	150	170	270	320	340	400	480	520	580
Jt	1	1	1	4	4	4	4	7	7	8
							Manual	500	520	
							Change	8	8	

The best policy to order stock assuming it has a fixed lead it as shown above. It shows that the minimum total cost is $580 and can be acehived by ordring in week 1 stock for week 1 to 3, order in week 4 stock for week 4 to 7. We then have to adjust for week 7, as we know it would be better to order week 7 stock during week 5 and pay to carry inventory however because for week 5 it is cheaper to order stock in week 4 we will go to the next best option which is order stock in week 7. This also means that stock for week 9 and wo are ordered in week 7. Over all the change does not affect the best option, as the best option orders stock in week 7 anyway.