Simulation and Modeling (CS302)

Lecture 05: Simulation of Inventory Systems

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Agenda

- Classical inventory problem
- Lab Tutorial for Newsday System
- Task

Simulation of Inventory Systems

- A classical inventory problem concerns the purchase and sale of newspapers.

The problem assumptions:

- Paper seller buys the papers for 33 cents each and sells them for 50 cents each.
- Newspapers not sold at the end of the day are sold as scrap for 5 cents each.
- Newspapers can be purchased in bundles of 10 (i.e. 50, 60, and so on).
- There are three types of newsdays, "good", "fair", and "poor", with probabilities of 0.35, 0.45, and 0.20, respectively. Example for distribution of papers demanded on each of these days is given in the table. Minimum bundles = 40 and maximum bundles = 100.

Distribution of Newspapers Demanded

Demand	Demand Probability Distribution		
	Good	Fair	Poor
40	0.03	0.10	0.44
50	0.05	0.18	0.22
60	0.15	0.40	0.16
70	0.20	0.20	0.12
80	0.35	0.08	0.06
90	0.15	0.04	0.00
100	0.07	0.00	0.00

Simulation of Inventory Systems

- The problem is to **determine the optimal number of papers the newspaper seller should purchase.**
- In this inventory problem, only a **single time period** of specified length is relevant, and only a **single order** is made.

- **From the problem statement:**
  - The revenue from sales is 50 cents for each paper sold.
  - The cost of newspapers is 33 cents for each paper purchased.
  - The lost profit from excess demand is 17 cents for each paper demanded that could not be provided.

The Newspaper Seller's Problem

- The salvage value of scrap papers is 5 cents each.
- The random variables are the type of newsday and the newspapers Demanded.
- The following tables provide the random-digit assignment for the types of newsdays and the demands for those newsdays.

Type of Newsday	Probability	Cumulative Probability	Random-Digit Assignment
Good	0.35	0.35	01 - 35
Fair	0.45	0.80	36 - 80
Poor	0.20	1.00	81 - 00

Demand	Cumulative Distribution			Random-Digit Assignment		
	Good	Fair	Poor	Good	Fair	Poor
40	0.03	0.10	0.44	01-03	01-10	01-44
50	0.08	0.28	0.66	04-08	11-28	45-66
60	0.23	0.68	0.82	09-23	29-68	67-82
70	0.43	0.88	0.94	24-43	69-88	83-94
80	0.78	0.96	1.00	44-78	89-96	95-00
90	0.93	1.00	1.00	79-93	97-00	
100	1.00	1.00	1.00	94-00		

The Newspaper Seller's Problem

- To solve this problem by simulation requires setting a policy of buying a certain number, Q, of papers each day, say 70, then simulating the demands for papers over a time period, say 20 days, to determine the total profit.
- The policy (no. of newspapers purchased) is changed to other values and the simulation is repeated until the best value is found.

- The profits are given by the following relationship:

$$\text{Profit} = \left[\begin{pmatrix} \text{Revenue} \\ \text{from} \\ \text{sales} \end{pmatrix} - \begin{pmatrix} \text{Cost of} \\ \text{newspapers} \end{pmatrix} - \begin{pmatrix} \text{Lost profit} \\ \text{from excess} \\ \text{demand} \end{pmatrix} + \begin{pmatrix} \text{Salvage from} \\ \text{sale of} \\ \text{scrap papers} \end{pmatrix} \right]$$

The Newspaper Seller's Problem

- The simulation table for a purchase policy (Q = 70) has the following fields:

A	B	C	D	E	F	G	H	I
Day	R.D. for Type of Newsday	Type of Newsday	R.D. for Demand	Demand	Revenue from Sales	Lost Profit from Excess Demand	Salvage from Sale of Scrap	Daily Profit

The Excel formulas:

- Lost Profit from Excess Demand for day_i (G_i) =
  IF(E_i > Q; (E_i – Q) * 0.17; "")
- Salvage from Sale of Scrap for day_i (H_i) =
  IF(E_i < Q; (Q - E_i) * 0.05; "")
- Profit for day_i (I_i) = F_i – Q * 0.33 – G_i + H_i

Day	R.D. for Type of Newsday	Type of Newsday	R.D. for Demand	Demand	Revenue from Sales	Lost Profit From Excess Demand	Salvage From Sale of Scrap	Daily Profit

Day	R.D. for Type of Newsday	Type of Newsday	R.D. for Demand	Demand	Revenue from Sales	Lost Profit From Excess Demand	Salvage From Sale of Scrap	Daily Profit
1	94	Poor	80	60	$30.00	-	$0.50	$7.40
2	77	Fair	20	50	$25.00	-	$1.00	$2.90
3	49	Fair	15	50	$25.00	-	$1.00	$2.90
4	45	Fair	88	70	$35.00	-	-	$11.90
5	43	Fair	98	90	$35.00	$3.40	-	$8.50
6	32	Good	65	80	$35.00	$1.70	-	$10.20
7	49	Fair	86	70	$35.00	-	-	$11.90
8	0	Poor	73	60	$30.00	-	$0.50	$7.40
9	16	Good	24	70	$35.00	-	-	$11.90
10	24	Good	60	80	$35.00	$1.70	-	$10.20
11	31	Good	60	80	$35.00	$1.70	-	$10.20
12	14	Good	29	70	$35.00	-	-	$11.90
13	41	Fair	18	50	$25.00	-	$1.00	$2.90
14	61	Fair	90	80	$35.00	$1.70	-	$10.20
15	85	Poor	93	70	$35.00	-	-	$11.90
16	8	Good	73	80	$35.00	$1.70	-	$10.20
17	15	Good	21	60	$30.00	-	$0.50	$7.40
18	97	Poor	45	50	$25.00	-	$1.00	$2.90
19	52	Fair	76	70	$35.00	-	-	$11.90
20	78	Fair	96	80	$35.00	$1.70	-	$10.20
					$645.00	**$13.60**	**$5.50**	**$174.90**

The Newspaper Seller's Problem

- The profit for the 20-day period is the sum of the daily profit (column I).
- It can also be computed from the totals for the 20 days of the simulation as follows:

$$\text{Total Profit} = \sum_{i=1}^{20} F_i - Q \times 0.33 \times 20 - \sum_{i=1}^{20} G_i + \sum_{i=1}^{20} H_i$$

Lab Tutorial for Newsday System

Newsday Type

Type of Newsdays	Probability	Cumulative Probability	Random-Digit Assignment	
			From	To
Good	0.35	0.35	0	35
Fair	0.45	0.8	36	80
Poor	0.2	1	81	100

Limits	
Days	20
Q	70
Cost	0.17
Salvage	0.05

Newsday Distribution

Demand	Cumulative Distribution			Random-Digit Assignment					
	Good	Fair	Poor	Good		Fair		Poor	
				From	To	From	To	From	To
40	0.03	0.1	0.44	0	3	0	10	0	44
50	0.08	0.28	0.66	4	8	11	28	45	66
60	0.23	0.68	0.82	9	23	29	68	67	82
70	0.43	0.88	0.94	24	43	69	88	83	94
80	0.78	0.96	1	44	78	89	96	95	100
90	0.93	1	1	79	93	97	100	101	100
100	1	1	1	94	100	101	100	101	100

Day	R.D. for Type of Newsday	Type of Newsday	R.D. for Demand	Demand	Revenue From Sales	Lost Profit From Excess Demand	Salvage From Scrap Sale	Daily Profit	# of remaining newspapers	Net Profit	True Lost	Full true lost
1	10	Good	1	40	6.8	0	1.5	8.3	30	8.3	3.6	3.6
2	85	Poor	14	40	6.8	0	1.5	8.3	30	8.3	3.6	3.6
3	16	Good	71	80	11.9	1.7	0	10.2	0	11.9	FALSE	1.7
4	24	Good	83	90	11.9	3.4	0	8.5	0	11.9	FALSE	3.4
5	50	Fair	21	50	8.5	0	1	9.5	20	9.5	2.4	2.4
6	31	Good	72	80	11.9	1.7	0	10.2	0	11.9	FALSE	1.7
7	53	Fair	58	60	10.2	0	0.5	10.7	10	10.7	1.2	1.2
8	13	Good	9	60	10.2	0	0.5	10.7	10	10.7	1.2	1.2
9	86	Poor	13	40	6.8	0	1.5	8.3	30	8.3	3.6	3.6
10	83	Poor	98	80	11.9	1.7	0	10.2	0	11.9	FALSE	1.7
11	4	Good	68	80	11.9	1.7	0	10.2	0	11.9	FALSE	1.7
12	33	Good	61	80	11.9	1.7	0	10.2	0	11.9	FALSE	1.7

Lab Tutorial for Newsday System

	A	B	C	D	E	F
2				Newsday Type		
3		Type of Newsdays	Probability	Cumulative Probability	Random-Digit Assignment	
4					From	To
5		Good	0.35	0.35	0	35
6		Fair	0.45	0.8	36	80
7		Poor	0.2	1	81	100
8						
9						
10		Limits				
11		Days	20			
12		Q	70			
13		Cost	0.17			
14		Salvage	0.05			

Equations of auxiliary tables:

- E5=0, E6=F5+1
- F5= D5*100

- Limits are given in as inputs to the model

Lab Tutorial for Newsday System

	H	I	J	K	L	M	N	O	P	Q
2				Newsday Distribution						
3	Demand	Cumulative Distribution			Random-Digit Assignment					
4		Good	Fair	Poor	Good		Fair		Poor	
5					From	To	From	To	From	To
6	40	0.03	0.1	0.44	0	3	0	10	0	44
7	50	0.08	0.28	0.66	4	8	11	28	45	66
8	60	0.23	0.68	0.82	9	23	29	68	67	82
9	70	0.43	0.88	0.94	24	43	69	88	83	94
10	80	0.78	0.96	1	44	78	89	96	95	100
11	90	0.93	1	1	79	93	97	100	101	100
12	100	1	1	1	94	100	101	100	101	100

Equations of auxiliary table:

- L5=0, L6=M6+1
- M6=I6*100
- N5=0, N6=O6+1
- O6=J6*100
- P5=0, P6=Q6+1
- Q6=K6*100

Lab Tutorial for Newsday System

	Day	R.D. for Type of Newsday	Type of Newsday	R.D. for Demand	Demand	Revenue From Sales	Lost Profit From Excess Demand	Salvage From Scrap Sale	Daily Profit	# of remaining newspapers	Net Profit	True Lost	Full true lost
18	1	10	Good	1	40	6.8	0	1.5	8.3	30	8.3	3.6	3.6
19	2	85	Poor	14	40	6.8	0	1.5	8.3	30	8.3	3.6	3.6
20	3	16	Good	71	80	11.9	1.7	0	10.2	0	11.9	FALSE	1.7
21	4	24	Good	83	90	11.9	3.4	0	8.5	0	11.9	FALSE	3.4
22	5	50	Fair	21	50	8.5	0	1	9.5	20	9.5	2.4	2.4
23	6	31	Good	72	80	11.9	1.7	0	10.2	0	11.9	FALSE	1.7
24	7	53	Fair	58	60	10.2	0	0.5	10.7	10	10.7	1.2	1.2
25	8	13	Good	9	60	10.2	0	0.5	10.7	10	10.7	1.2	1.2
26	9	86	Poor	13	40	6.8	0	1.5	8.3	30	8.3	3.6	3.6
27	10	83	Poor	98	80	11.9	1.7	0	10.2	0	11.9	FALSE	1.7
28	11	4	Good	68	80	11.9	1.7	0	10.2	0	11.9	FALSE	1.7
29	12	33	Good	61	80	11.9	1.7	0	10.2	0	11.9	FALSE	1.7

Equations of Simulation table:

- B18=0, B19=sum(B18,1)
- C18=INT(RAND()*100)
- D18=LOOKUP(C18,$E$5:$F$7,$B$5:$B$7)
- E18=ROUND((RAND()*100),0)
- F18=IF(D18="Good",LOOKUP(E18,$L$6:$M$12,$H$6:$H$12),IF(D18="Fair", LOOKUP(E18,$N$6:$O$12,$H$6:$H$12),LOOKUP(E18,$P$6:$Q$12,$H$6:$H$12)))

Lab Tutorial for Newsday System

	Day	R.D. for Type of Newsday	Type of Newsday	R.D. for Demand	Demand	Revenue From Sales	Lost Profit From Excess Demand	Salvage From Scrap Sale	Daily Profit	# of remaining newspapers	Net Profit	True Lost	Full true lost
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21	4	24	Good	83	90	11.9	3.4	0	8.5	0	11.9	FALSE	3.4
22	5	50	Fair	21	50	8.5	0	1	9.5	20	9.5	2.4	2.4
23	6	31	Good	72	80	11.9	1.7	0	10.2	0	11.9	FALSE	1.7
24	7	53	Fair	58	60	10.2	0	0.5	10.7	10	10.7	1.2	1.2
25	8	13	Good	9	60	10.2	0	0.5	10.7	10	10.7	1.2	1.2
26	9	86	Poor	13	40	6.8	0	1.5	8.3	30	8.3	3.6	3.6
27	10	83	Poor	98	80	11.9	1.7	0	10.2	0	11.9	FALSE	1.7
28	11	4	Good	68	80	11.9	1.7	0	10.2	0	11.9	FALSE	1.7
29	12	33	Good	61	80	11.9	1.7	0	10.2	0	11.9	FALSE	1.7

Equations of Simulation table:

- G18=IF(F18<$C$12,F18*$C$13,$C$12*$C$13)
- H18=IF(F18>$C$12,(F18-$C$12)*$C$13,0)
- I18=IF(F18<$C$12,($C$12-F18)*$C$14,0)
- J18=G18+I18-H18
- K18=IF($C$12>F18,$C$12-F18,0)
- L18=G18+I18

Lab Tutorial for Newsday System

	Day	R.D. for Type of Newsday	Type of Newsday	R.D. for Demand	Demand	Revenue From Sales	Lost Profit From Excess Demand	Salvage From Scrap Sale	Daily Profit	# of remaining newspapers	Net Profit	True Lost	Full true lost
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20	3	16	Good	71	80	11.9	1.7	0	10.2	0	11.9	FALSE	1.7
21	4	24	Good	83	90	11.9	3.4	0	8.5	0	11.9	FALSE	3.4
22	5	50	Fair	21	50	8.5	0	1	9.5	20	9.5	2.4	2.4
23	6	31	Good	72	80	11.9	1.7	0	10.2	0	11.9	FALSE	1.7
24	7	53	Fair	58	60	10.2	0	0.5	10.7	10	10.7	1.2	1.2
25	8	13	Good	9	60	10.2	0	0.5	10.7	10	10.7	1.2	1.2
26	9	86	Poor	13	40	6.8	0	1.5	8.3	30	8.3	3.6	3.6
27	10	83	Poor	98	80	11.9	1.7	0	10.2	0	11.9	FALSE	1.7
28	11	4	Good	68	80	11.9	1.7	0	10.2	0	11.9	FALSE	1.7
29	12	33	Good	61	80	11.9	1.7	0	10.2	0	11.9	FALSE	1.7

Equations of Simulation table:

- M18=IF(F18<$C$12,($C$12-F18)*($C$13-$C$14))
- N18=M18+H18

Task: Simulation of Inventory Systems

- **Suppose** you have the following daily life details on newspaper sales system:
- **Build** suitable simulation table the implement the following rules:
  - Build auxiliary tables from daily life events
  - Order is demanded by package (as indicated in lab example) <= maximum level (70)

- **Hints**:
  - Build charts that reflect sales on each type of events (good, fair, …).
  - Get average of net profit per day
  - Get average of lost profit per day
  - Get average of salvage sales per day
  - Get optimized quantity that seller has to purchase for each type.

	A	B	C	D	E	F	G
1							
2		Quantity	70				
3		Purchase	30				
4		Full_Sale	60				
5		Salvage_Sale	15				
6							
7		Day	Event	Demand	Full_Sales	Salvage_Sales	Total Profit
8		1	political	40	40	30	2850
9		2	economic	50	50	20	3300
10		3	sport	80	70	0	4200
11		4	sport	60	60	10	3750
12		5	economic	65	65	5	3975
13		6	normal	40	40	30	2850
14		7	political	75	70	0	4200