Simulation and Modeling (CS302)

Lecture 06: Time Synchronization

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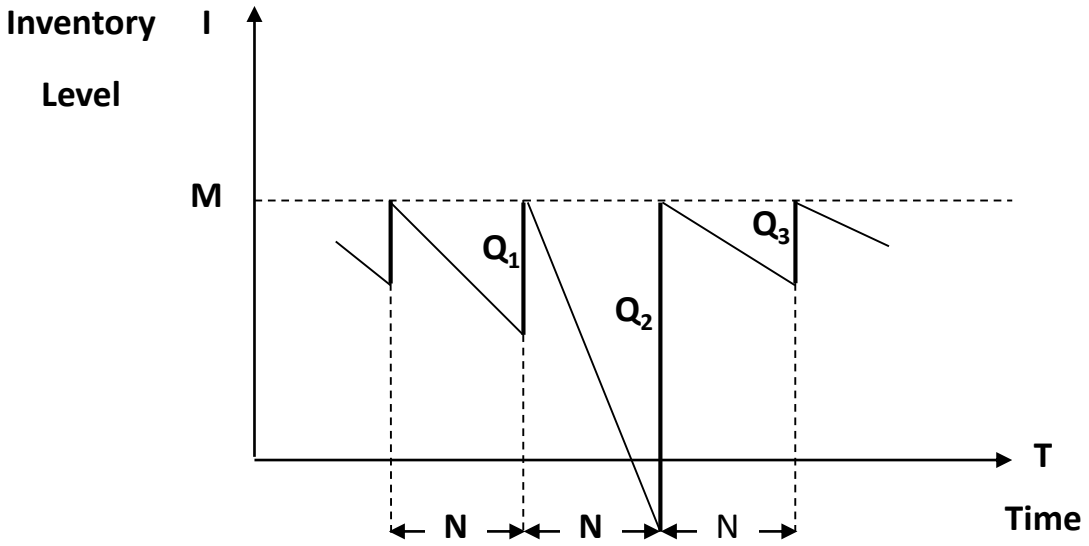
Agenda

- Simulation of Inventory Systems
  - Example: Simulation of an (M, N) Inventory System
- Lab Tutorial for Newsday System
- Task

Simulation of Inventory Systems

- A simple inventory system is shown in the figure below. This system has a periodic review length N, at which time the inventory level is checked. If the inventory level is less than the maximum level (M), then an order (Q) is made to bring the inventory up to the level M.

- In this inventory system, **the lead time** (i.e. the length of time between the placement and receipt of an order) is zero.



Probabilistic order-level inventory system.

Simulation of Inventory Systems

- Since demands are not usually known with certainty, the order quantities are probabilistic.
- At a review point, if the amount in inventory was below zero, indicating a shortage, then these units are backordered. When the order arrives, the demand for the backordered items is satisfied first.
- To avoid shortage, a safety stock would need to be kept. Keeping stock in inventory has associated costs such as:
  - The interests on the funds borrowed to buy the items.
  - Stock holding costs: renting of storage space, hiring guards, and so on.
  - An alternative to keeping high inventory is to make more frequent reviews, and consequently, more frequent purchases. This has an associated cost: the ordering cost.

Simulation of Inventory Systems

- Also, there is a cost in being short: Customers may get angry, with a subsequent loss of good will.
- These costs must be traded off in order to minimize the total cost of an inventory system.
- The total cost (or total profit) of an inventory system is its measure of performance. This can be affected by the policy alternatives, such as controlling:
  - the maximum inventory level, M, and
  - the length of the review period (cycle), N.

Simulation of Inventory Systems

- In an (M, N) inventory system:
  - The state variable is the inventory level.
- **The events that may occur are:**
  - The demand for items in the inventory,
  - The review of the inventory position, and
  - The receipt of an order at the end of each review period.
- When the lead time is zero, as in the previous figure (slide 3), the last two events occur simultaneously (review & receipt).

Simulation of an (M, N) Inventory System

- This example follows the pattern of the probabilistic order-level inventory system shown in figure (slide 3).
- **Suppose that:**
  - The maximum inventory level, M, is 11 units, and
  - The review period, N, is 5 days.
- **The problem is to estimate, by simulation:**
  - The average ending units in inventory, and
  - The number of days when a shortage condition occurs.
- **The random variables of this problem are:**
  - The number of units demanded per day, and
  - The lead time.

Simulation of an (M, N) Inventory System

The distribution of the number of units demanded per day is shown in the first table, and the distribution of the lead time is shown in the second table.

Random Digit Assignments for Daily Demand

Demand	Probability	Cumulative Probability	Random Digit Assignment
0	0.10	0.10	01 – 10
1	0.25	0.35	11 – 35
2	0.35	0.70	36 – 70
3	0.21	0.91	71 – 91
4	0.09	1.00	92 – 00

Random Digit Assignments for Lead Time

Lead Time (Days)	Probability	Cumulative Probability	Random Digit Assignment
1	0.6	0.6	1 – 6
2	0.3	0.9	7 – 9
3	0.1	1.0	0

Simulation of an (M, N) Inventory System

- Assume that orders are placed at the close of business and are received for inventory at the beginning of business as determined by the lead time.
- To make an estimate of the mean units in ending inventory, many cycles would have to be simulated. For purposes of this example, only 5 cycles will be shown.
- The random-digit assignments for daily demand and lead time are shown in the rightmost columns of tables in previous slide.
- The simulation table includes the following columns:

A	B	C	D	E	F	G	H	I	J
Cycle	Day	Beginning Inventory	R.D. for Demand	Demand	Ending Inventory	Shortage Quantity	Order Quantity	R.D. for Lead Time	Days until order arrives

Cycle	Day	Beginning Inventory	R.D. for Demand	Demand	Ending Inventory	Shortage Quantity	Order Quantity	R.D. for Lead Time	Days until Order arrives
					3		8		2

Cycle	Day	Beginning Inventory	R.D. for Demand	Demand	Ending Inventory	Shortage Quantity	Order Quantity	R.D. for Lead Time	Days until Order arrives
					3		8		2
1	1	3	24	1	2	0			1
	2	2	35	1	1	0			0
	3	9	65	2	7	0			
	4	7	81	3	4	0			
	5	4	54	2	2	0	9	5	1
2	1	2	3	0	2	0			0
	2	11	87	3	8	0			
	3	8	27	1	7	0			
	4	7	73	3	4	0			
	5	4	70	2	2	0	9	0	3
3	1	2	47	2	0	0			2
	2	0	45	2	0	2			1
	3	0	48	2	0	4			0
	4	9	17	1	4	0			
	5	4	9	0	4	0	7	3	1
4	1	4	42	2	2	0			0
	2	9	87	3	6	0			
	3	6	26	1	5	0			
	4	5	36	2	3	0			
	5	3	40	2	1	0	10	4	1
5	1	1	7	0	1	0			0
	2	11	63	2	9	0			
	3	9	19	1	8	0			
	4	8	88	3	5	0			
	5	5	94	4	1	0	10	8	2
					88				

Simulation of an (M, N) Inventory System

- The simulation has been started with the inventory level at 3 units and an order of 8 units scheduled to arrive in 2 days' time.
- The order quantity and the shortage quantity are calculated as follows:

$$\text{The order quantity} = M - \text{Ending inventory}$$

$$\text{The shortage quantity} = \begin{cases} 0 & \text{if demand} \le \text{beginning inventory} \\ \text{previous shortage quantity} + & \\ \quad (\text{demand} - \text{beginning inventory}) & \text{Otherwise} \end{cases}$$

$$\text{The average ending inventory} = \frac{\text{Total ending inventory}}{\text{No. of days}} = \frac{88}{25} = 3.5$$

No. of days when shortage condition occurs
= No. of days when shortage quantity > 0
= 2

Lab Tutorial for Inventory System

	Demand				Lead Time			
Demand	Probability	Cumulative Probability	R.D Assignment From	R.D Assignment To	Lead Time (Days)	Probability	Cumulative Probability	R.D Assignment From	R.D Assignment To
0	0.1	0.1	0	10	1	0.45	0.45	0	45
1	0.25	0.35	11	35	2	0.35	0.8	46	80
2	0.35	0.7	36	70	3	0.2	1	81	100
3	0.21	0.91	71	91					
4	0.09	1	92	100					

Limits	
Q-Order	10

Cycle	Day	Beginning Inventory	R.D. for Demand	Demand	Ending Enventory	Shortage Quantity	Order Quantity	R.D. for lead time	Days untile order arrives
		1	39	2	-1	0			
1	1	-1	85	3	0	4	10	96	3
	2	0	31	1	0	5			2
	3	0	5	0	0	5			1
	4	10	83	3	2	0			0
	5	2	5	0	2	0			
2	1	2	3	0	2	0	10	65	2
	2	2	93	4	0	2			1
	3	10	66	2	6	0			0
	4	6	93	4	2	0			
	5	2	6	0	2	0			
3	1	2	99	4	0	2	10	88	3
	2	0	81	3	0	5			2
	3	0	95	4	0	9			1
	4	10	18	1	0	0			0
	5	0	91	3	0	3			
4	1	0	95	4	0	7	10	96	3

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Lab Tutorial for Newsday System

	A	B	C	D	E	F	G	H	I	J	K	L
2			Demand						Lead Time			
3		Demand	Probability	Cumulative Probability	R.D Assignment			Lead Time (Days)	Probability	Cumulative Probability	R.D Assignment	
4					From	To					From	To
5		0	0.1	0.1	0	10		1	0.45	0.45	0	45
6		1	0.25	0.35	11	35		2	0.35	0.8	46	80
7		2	0.35	0.7	36	70		3	0.2	1	81	100
8		3	0.21	0.91	71	91						
9		4	0.09	1	92	100						
10												
11		Limits										
12		Q-Order	10									

Equations of table (Demand):

- D5=C5, D6=D5+C6
- E5=0, E6=F5+1
- F5= D5*100

Equations of table (Lead Time):

- J5=I5, J6=J5+I6
- K5=0, K6=L5+1
- L5=J5*100

- Q-order is a fixed number initialized by the user as an input parameter

Lab Tutorial for Newsday System

	A	B	C	D	E	F	G	H	I	J	K	L
11		Limits										
12		Q-Order	10									
13												
14		Cycle	Day	Beginning Inventory	R.D. for Demand	Demand	Ending Enventory	Shortage Quantity	Order Quantity	R.D. for lead time	Days untile order arrives	
15				1	39	2	-1	0				
16		1	1	-1	85	3	0	4	10	96	3	
17			2	0	31	1	0	5			2	
18			3	0	5	0	0	5			1	
19			4	10	83	3	2	0			0	
20			5	2	5	0	2	0				
21		2	1	2	3	0	2	0	10	65	2	
22			2	2	93	4	0	2			1	
23			3	10	66	2	6	0			0	
24			4	6	93	4	2	0				
25			5	2	6	0	2	0				
26		3	1	2	99	4	0	2	10	88	3	

Equations of Simulation table:

- B15="", B16=1, B17=IF(C17=1,MAX(B16)+1,"")
- C15="", C16=1, C17=IF(C16>=5,1,C16+1)
- D15=1, D16=G15+IF(K16=0,10,0)
- E15=INT(RAND()*100)
- F15=LOOKUP(E15,$E$5:$F$9,$B$5:$B$9)
- G15=D15-F15, G16=IF(D16>=(F16+H15),D16-(F16+H15),0)

Lab Tutorial for Newsday System

	A	B	C	D	E	F	G	H	I	J	K	L
11		Limits										
12		Q-Order	10									
13												
14		Cycle	Day	Beginning Inventory	R.D. for Demand	Demand	Ending Enventory	Shortage Quantity	Order Quantity	R.D. for lead time	Days untile order arrives	
15				1	39	2	-1	0				
16		1	1	-1	85	3	0	4	10	96	3	
17			2	0	31	1	0	5			2	
18			3	0	5	0	0	5			1	
19			4	10	83	3	2	0			0	
20			5	2	5	0	2	0				
21		2	1	2	3	0	2	0	10	65	2	
22			2	2	93	4	0	2			1	
23			3	10	66	2	6	0			0	
24			4	6	93	4	2	0				
25			5	2	6	0	2	0				
26		3	1	2	99	4	0	2	10	88	3	

Equations of Simulation table:

- H15=0, H16=IF(H15+F16-D16>0,(H15+F16-D16),0)
- I15=“”, I16=if(B16=1,10, “”)
- J15=IF(I15<>"",INT((RAND()*100)),"")
- K15=“”, K16=IF(J16<>"",LOOKUP(J16,$K$5:$L$7,$H$5:$H$7),
  IF(K15<>"",IF(K15>0,K15-1,""),""))

Task: Simulation of Inventory Systems

- **Suppose** you have the following daily life details on inventory system:
  - Level 01: single entry per day (i.e., day by day)
  - Level 02: single entry per week (i.e., every week).
- **Build** suitable simulation table the implement the following rules:
  - Trigger an order if shortage has been occurred
  - Order <= inventory capacity
  - Shortage has to be full filled at first.
- **Hints**:
  - build auxiliary tables for sales per (day or week).
  - Improve simulation table to simulate weekend impact on sales.

Max Capacity (items)	20		Review Length (days)	7

Week	Sales	Date	Order	Shortage
1	15	01-01-21	5	0
2	23	08-01-21	-3	3
3	7	15-01-21	13	0
4	12	22-01-21	8	0
5	26	29-01-21	-6	6
6	20	05-02-21	0	0
7	9	12-02-21	11	0
8	18	19-02-21	2	0
9	17	26-02-21	3	0

Date	Sales		Order	Shortage
01-01-21	2			
02-01-21	3			
03-01-21	5			
04-01-21	1			
05-01-21	5			
06-01-21	2			
07-01-21	5	23	20	3
08-01-21	18			
09-01-21	17			