



كلية الحاسبات والذكاء الاصطناعي

# SC311

# Modeling and Simulation

## Lecture 05

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**Faculty of Computers and Artificial Intelligence  
Benha University**

**Spring 2023**



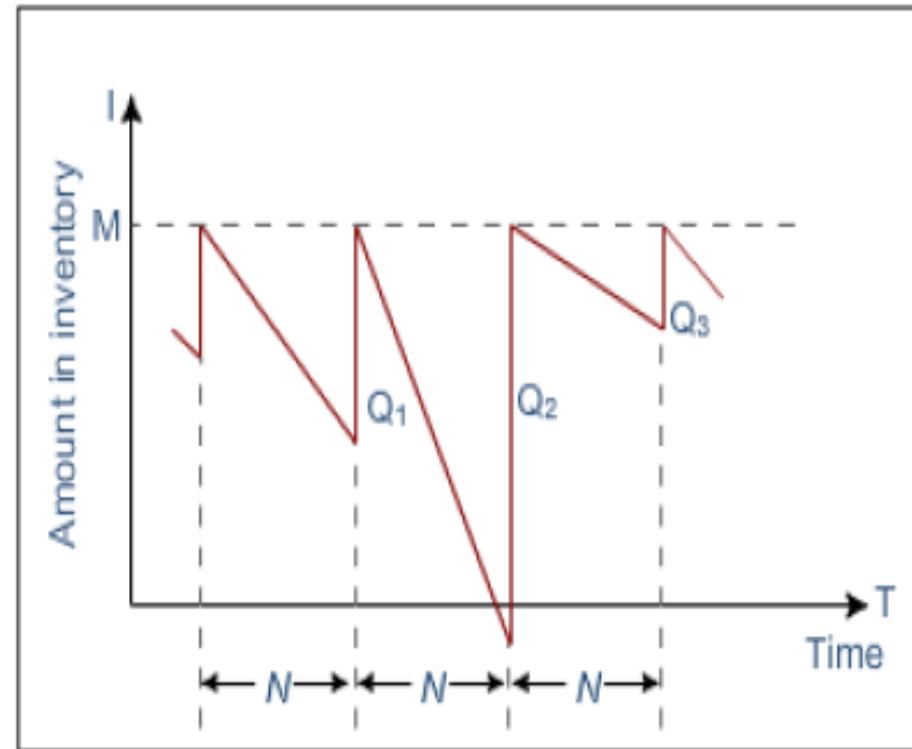
# Chapter 4: Inventory Simulation

- Introduction.
- Simulating of Inventory System.
- The Newspaper Seller's Problem.

# Introduction (1/4)

## Inventory System:

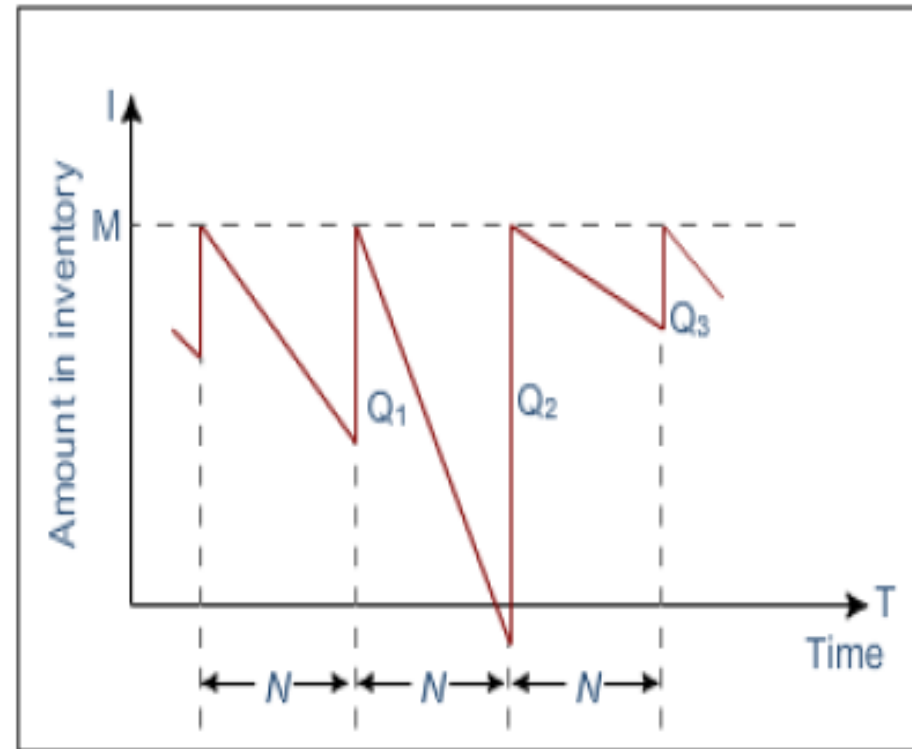
- $N$ : Periodic review length (months/days).
- $M$ : Standard inventory level.
- $Q_i$ : Quantity of order  $i$  to fill up to  $M$ .
  - In this example, Lead Time is zero.
- Since demands are not usually known with certainty, the order quantities are probabilistic.



# Introduction (1/4)

## Inventory System:

- $N$ : Periodic review length (months/days).
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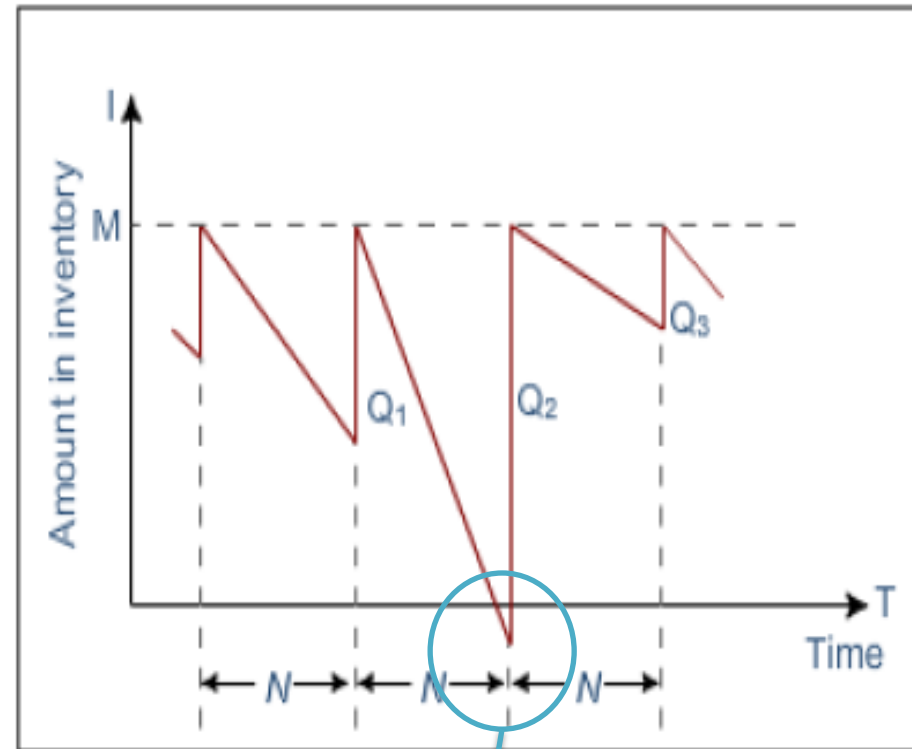


The length of time between the **placement** and **receipt** of an order.

# Introduction (1/4)

## Inventory System:

- $N$ : Periodic review length (months/days).
- $M$ : Standard inventory level.
- $Q_i$ : Quantity of order  $i$  to fill up to  $M$ .
  - In this example, Lead Time is zero.
- Since demands are not usually known with certainty, the order quantities are probabilistic.



**Shortage**



# Introduction (2/4)

- To avoid shortages, a buffer stock is needed.
- Carrying stock in inventory has an associated cost:
  - Funds to buy the items,
  - Renting of storage space,
  - Hiring guards.

# Introduction (3/4)

- An alternative to carrying high inventory is to make more frequent reviews. This has an associated cost:
  - The ordering cost.
  - Delivery.
  - Expiry date in some items.
- The **total cost** (or **total profit**) of an inventory system is the measure of *performance*. The decision maker can control the maximum inventory level,  $M$ , and the length of the cycle,  $N$ . What effect does changing  $N$  have on the various costs?



# Introduction (4/4)

- Events in an  $(M, N)$  inventory system are:
  - Demand for items,
  - Review of the inventory,
  - Receipt of an order at the end of each review.



## Simulation of an $(M, N)$ Inventory System:

- The problem is to estimate, by simulation, the average ending units in inventory and the number of days when a shortage condition occurs. This helps us to choose a good  $(M, N)$ .
- Given that:
  - The distribution of the number of units demanded per day.
  - The distribution of the lead time.



## Example:

Suppose that the maximum inventory level,  $M$ , is 11 units and the periodic review length,  $N$ , is 5 days.

$M$ : Standard inventory level = 11 units  
 $N$ : Periodic review length = 5 days

## Random-Digit Assignments for Daily Demand

<i>Demand</i>	<i>Probability</i>	<i>Cumulative Probability</i>	<i>Random-Digit Assignment</i>
0	0.10		
1	0.25		
2	0.35		
3	0.21		
4	0.09		

## Random-Digit Assignments for Lead Time

<i>Lead Time (Days)</i>	<i>Probability</i>	<i>Cumulative Probability</i>	<i>Random-Digit Assignment</i>
1	0.6		
2	0.3		
3	0.1		



# Sim. of Inventory System(3/13)

## Random-Digit Assignments for Daily Demand

<i>Demand</i>	<i>Probability</i>	<i>Cumulative Probability</i>	<i>Random-Digit Assignment</i>
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

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



## Simulation:

- $M$ : Standard inventory level = 11 units.
- $N$ : Periodic review length = 5 days.
- We perform the simulation for 5 cycles.

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- $M$ : Standard inventory level = 11 units.
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**5 cycles of periodic review length  $N$**

Cycle 1:  $N$  days/months/...

Cycle 2:  $N$  days/months/...

...

Cycle 5:  $N$  days/months/...



## Simulation:

- M: Standard inventory level = 11 units.
- N: Periodic review length = 5 days.
- We perform the simulation for 5 cycles.
- Initial state:
  - The inventory level start at 3 units.
  - An order of 8 units scheduled to arrive in 2 days' time.

## Simulation:

- M: Standard inventory level = 11 units.
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- We perform the simulation for 5 cycles.
- Initial state:
  - The inventory level start at 3 units.
  - An order of 8 units scheduled to arrive in 2 days' time.

Beginning Inventory = 3

After 2 days, we will receive 8 units





# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

Cycle	Day	Beginning Inventory	<i>Random</i>		Ending Inventory	Shortage Quantity	Order Quantity	<i>Random</i>	
			Digits for Demand	Demand				Digits for Lead Time	Days until Order Arrives
1	1								
	2								
	3								
	4								
	5								



# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

Cycle	Day	Beginning Inventory	<i>Random</i>	Ending Inventory	Shortage Quantity	Order Quantity	<i>Random</i>	Days until Order Arrives
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	3							
	4							
	5							



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# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

<i>Cycle</i>	<i>Day</i>	<i>Beginning Inventory</i>	<i>Random Digits for Demand</i>	<i>Demand</i>	<i>Ending Inventory</i>	<i>Shortage Quantity</i>	<i>Order Quantity</i>	<i>Random Digits for Lead Time</i>	<i>Days until Order Arrives</i>
1	1								
	2								
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## Simulation Table (Cycle 1)

<i>Cycle</i>	<i>Day</i>	<i>Beginning Inventory</i>	<i>Random Digits for Demand</i>	<i>Demand</i>	<i>Ending Inventory</i>	<i>Shortage Quantity</i>	<i>Order Quantity</i>	<i>Random Digits for Lead Time</i>	<i>Days until Order Arrives</i>
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# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

Cycle	Day	Beginning Inventory	<i>Random</i>	Demand	<i>Ending Inventory</i>	Shortage Quantity	Order Quantity	<i>Random</i>	Days until Order Arrives
			Digits for Demand		Digits for Lead Time				
1	1								
	2								
	3								
	4								
	5								



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## Simulation Table (Cycle 1)

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			Digits for Demand				Digits for Lead Time	
1	1							
	2							
	3							
	4							
	5							

**At the end of each cycle**





# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

Cycle	Day	Beginning Inventory	Random Digits for Demand	Demand	Ending Inventory	Shortage Quantity	Order Quantity	Random Digits for Lead Time	Days until Order Arrives
1	1								
	2								
	3								
	4								
	5								

**Determined at the beginning and **decreases** every day**



# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

Cycle	Day	Beginning Inventory	<i>Random</i>		Ending Inventory	Shortage Quantity	Order Quantity	<i>Random</i>	
			Digits for Demand	Demand				Digits for Lead Time	Days until Order Arrives
1	1								
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## Simulation Table (Cycle 1)

<i>Cycle</i>	<i>Day</i>	<i>Beginning Inventory</i>	<i>Random Digits for Demand</i>	<i>Demand</i>	<i>Ending Inventory</i>	<i>Shortage Quantity</i>	<i>Order Quantity</i>	<i>Random Digits for Lead Time</i>	<i>Days until Order Arrives</i>
1	1	3							
	2								
	3								
	4								
	5								

➤ The inventory level start at 3 units.



# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

<i>Cycle</i>	<i>Day</i>	<i>Beginning Inventory</i>	<i>Random Digits for Demand</i>	<i>Demand</i>	<i>Ending Inventory</i>	<i>Shortage Quantity</i>	<i>Order Quantity</i>	<i>Random Digits for Lead Time</i>	<i>Days until Order Arrives</i>
1	1	3	24						
	2		35						
	3		65						
	4		81						
	5		54						



# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

Cycle	Day	Beginning Inventory	Random Digits for Demand	Demand	Demand	Probability	Cumulative Probability	Random-Digit Assignment
1	1	3	24		0	0.10	0.10	01–10
	2		35		1	0.25	0.35	11–35
	3		65		2	0.35	0.70	36–70
	4		81		3	0.21	0.91	71–91
	5		54		4	0.09	1.00	92–00



# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

Cycle	Day	Beginning Inventory	Random Digits for Demand	Demand	Demand Probability Distribution		
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				2	0.35	0.70	36-70
				3	0.21	0.91	71-91
				4	0.09	1.00	92-00
1	1	3	24				
	2		35				
	3		65				
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# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

Cycle	Day	Beginning Inventory	Random		Ending Inventory	Shortage Quantity	Order Quantity	Random	
			Digits for Demand	Demand				Digits for Lead Time	Days until Order Arrives
1	1	3	24	1					
	2		35						
	3		65						
	4		81						
	5		54						



# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

Cycle	Day	Beginning Inventory	Random		Ending Inventory	Shortage Quantity	Order Quantity	Random	
			Digits for Demand	Demand				Digits for Lead Time	Days until Order Arrives
1	1	3	24	1	2				
	2		35						
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			Digits for Demand	Demand				Digits for Lead Time	Days until Order Arrives
1	1	3	24	1	2	0			
	2		35						
	3		65						
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Cycle	Day	Beginning Inventory	Random		Ending Inventory	Shortage Quantity	Order Quantity	Random	
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	2		35						
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1	1	3	24	1	2	0	-	-	
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	5								

Recall:

An order of 8 units scheduled to arrive in 2 days' time.



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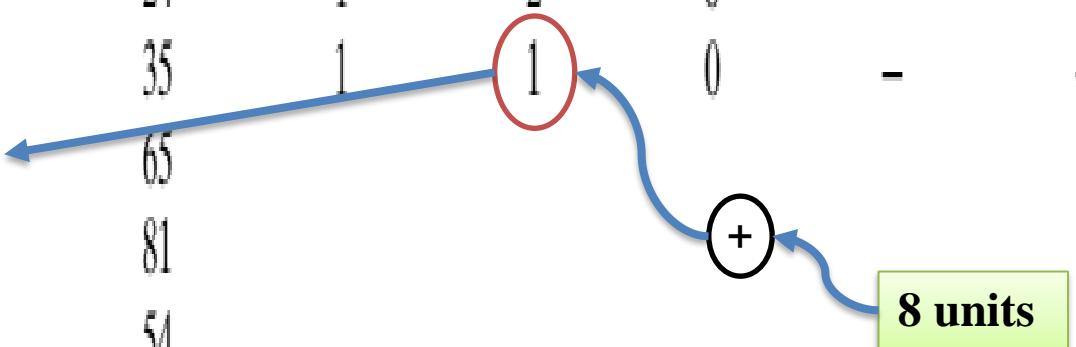
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		Beginning Inventory	Digits for Demand				Digits for Lead Time	Days until Order Arrives	
1	1	3	24	1	2	0	-	-	1
	2	2	35	1	1	0	-	-	0
	3		65						
	4		81						
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## Simulation Table (Cycle 1)

Cycle	Day	Beginning Inventory	Random		Ending Inventory	Shortage Quantity	Order Quantity	Random	
			Digits for Demand	Demand				Digits for Lead Time	Days until Order Arrives
1	1	3	24	1	2	0	-	-	1
	2	2	35	1	1	0	-	-	0
	3	9	65						
	4		81						
	5		54						



# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

Cycle	Day	Beginning Inventory	Random Digits for Demand	Demand	Inventory	Order	Quantity	Lead Time	Quantity	Inventory	Demand Probability Distribution								
											Demand	Probability	Cumulative Probability	Random-Digit Assignment					
1	1	3	24	1	2	0	-	-	1										
	2	2	35	1	1	0	-	-	0										
	3	9	65																
	4		81																
	5		54																

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
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			Digits for Demand	Demand				Digits for Lead Time	Days until Order Arrives
1	1	3	24	1	2	0	-	-	1
	2	2	35	1	1	0	-	-	0
	3	9	65	2					
	4		81						
	5		54						



# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

Cycle	Day	Beginning Inventory	Random		Ending Inventory	Shortage Quantity	Order Quantity	Random	
			Digits for Demand	Demand				Digits for Lead Time	Days until Order Arrives
1	1	3	24	1	2	0	-	-	1
	2	2	35	1	1	0	-	-	0
	3	9	65	2	7				
	4		81						
	5		54						



# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

Cycle	Day	Beginning Inventory	Random		Ending Inventory	Shortage Quantity	Order Quantity	Random	
			Digits for Demand	Demand				Digits for Lead Time	Days until Order Arrives
1	1	3	24	1	2	0	-	-	1
	2	2	35	1	1	0	-	-	0
	3	9	65	2	7	0	-	-	
	4		81						
	5		54						





# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

Cycle	Day	<i>Random</i>			<i>Random</i>			<i>Days until</i>	
		<i>Beginning</i>	<i>Digits for</i>	<i>Ending</i>	<i>Shortage</i>	<i>Order</i>	<i>Digits for</i>		
		<i>Inventory</i>	<i>Demand</i>	<i>Demand</i>	<i>Inventory</i>	<i>Quantity</i>	<i>Quantity</i>	<i>Lead Time</i>	<i>Order</i>
									<i>Arrives</i>
1	1	3	24	1	2	0	-	-	1
	2	2	35	1	1	0	-	-	0
	3	9	65	2	7	0	-	-	-
	4		81						
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Cycle	Day	Beginning Inventory	Random		Ending Inventory	Shortage Quantity	Order Quantity	Random	
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# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

Cycle	Day	Beginning Inventory	Random Digits for Demand	Demand	Inventory	Order	Quantity	Lead Time	Arrival	Demand Probability Distribution			
										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
1	1	3	24	1	2	0	-	-	1				
	2	2	35	1	1	0	-	-	0				
	3	9	65	2	7	0	-	-	-				
	4	7	81										
	5		54										

Demand	Probability	Cumulative Probability	Random-Digit Assignment
0	0.10	0.10	01-10
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4	0.09	1.00	92-00

Diagram showing the mapping of random digits to demand values. A blue circle highlights the digit '3' in the demand column. A blue box highlights the range '71-91' in the Random-Digit Assignment column. Arrows indicate the mapping from the digit '3' to the range '71-91' and from the range '71-91' to the demand value '3'.



# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

Cycle	Day	Beginning Inventory	Random Demand		Ending Inventory	Shortage Quantity	Order Quantity	Random Lead Time	
			Digits for Demand	Demand				Digits for Lead Time	Days until Order Arrives
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					
	5		54						



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	3	9	65	2	7	0	-	-	-
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	3	9	65	2	7	0	-	-	-
	4	7	81	3	4	0	-	-	-
	5	4	54						



# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

Cycle	Day	Beginning Inventory	Random Digits for Demand	Demand	Inventory	Order	Lead Time	Quantity Received	Inventory	Demand Probability Distribution			
										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
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										





# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

Cycle	Day	Beginning Inventory	<i>Random</i>		Ending Inventory	Shortage Quantity	Order Quantity	<i>Random</i>	
			Digits for Demand	Demand				Digits for Lead Time	Days until Order Arrives
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					



# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

Cycle	Day	Beginning Inventory	Random		Ending Inventory	Shortage Quantity	Order Quantity	Random	
			Digits for Demand	Demand				Digits for Lead Time	Days until Order Arrives
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				



# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

Cycle	Day	Beginning Inventory	Random		Ending Inventory	Shortage Quantity	Order Quantity	Random	
			Digits for Demand	Demand				Digits for Lead Time	Days until Order Arrives
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			



# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

Cycle	Day	<i>Random</i>			<i>Random</i>			<i>Days until Order Arrives</i>	
		<i>Beginning Inventory</i>	<i>Digits for Demand</i>	<i>Demand</i>	<i>Ending Inventory</i>	<i>Shortage Quantity</i>	<i>Order Quantity</i>		<i>Lead Time</i>
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	-	-	-

**End of Cycle**

**Complete to M = 11**

## Simulation Table (Cycle 1)

Cycle	Day	Random			Random			Days until Order Arrives	
		Beginning Inventory	Digits for Demand	Demand	Ending Inventory	Shortage Quantity	Order Quantity		Digits for Lead Time
1	1	3	24	1	2	0	-	-	1
	2	2	35	1	1	0	-	-	0
	3	9	65	2					
	4	7	81	3	4	0		-	-
	5	4	54	2	2	0		-	-

$Q = M - \text{End Inventory} + \text{Shortage}$



End of Cycle

Complete to  $M = 11$

## Simulation Table (Cycle 1)

Cycle	Day	<i>Random</i>			<i>Random</i>			<i>Days until Order Arrives</i>	
		<i>Beginning Inventory</i>	<i>Digits for Demand</i>	<i>Demand</i>	<i>Ending Inventory</i>	<i>Shortage Quantity</i>	<i>Order Quantity</i>		<i>Lead Time</i>
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	-	-

End of Cycle

$$Q = 11 - 2 + 0 = 9$$

## Simulation Table (Cycle 1)

Cycle	Day	Random			Random			Days until Order Arrives	
		Beginning Inventory	Digits for Demand	Demand	Ending Inventory	Shortage Quantity	Order Quantity		Digits for Lead Time
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	-

**End of Cycle**

**Random Number**



# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

<i>Random</i>				<i>Order</i>	<i>Random</i>	<i>Days until</i>
<i>Lead Time</i> <i>(Days)</i>	<i>Probability</i>	<i>Cumulative</i> <i>Probability</i>	<i>Random-Digit</i> <i>Assignment</i>	<i>Quantity</i>	<i>Digits for</i> <i>Lead Time</i>	<i>Order</i> <i>Arrives</i>
1	0.6	0.6	1-6	-	-	1
2	0.3	0.9	7-9	-	-	0
3	0.1	1.0	0	-	-	-
2	2	55	1	1	0	-
3	9	65	2	7	0	-
4	7	81	3	4	0	-
5	4	54	2	2	0	9
					5	



## Simulation Table (Cycle 1)

<i>Random</i>				<i>Order</i>	<i>Random</i>	<i>Days until</i>
<i>Lead Time</i> <i>(Days)</i>	<i>Probability</i>	<i>Cumulative</i> <i>Probability</i>	<i>Random-Digit</i> <i>Assignment</i>	<i>Quantity</i>	<i>Digits for</i> <i>Lead Time</i>	<i>Order</i> <i>Arrives</i>
1	0.6	0.6	1-6	-	-	1
2	0.3	0.9	7-9	-	-	0
3	0.1	1.0	0	-	-	-
2	2	55	1	1	0	0
3	9	65	2	7	0	-
4	7	81	3	4	0	-
5	4	54	2	2	0	9
				9	5	



# Sim. of Inventory System(6/13)

## Simulation Table (Cycle 1)

Cycle	Day	Beginning Inventory	Random		Ending Inventory	Shortage Quantity	Order Quantity	Random	
			Digits for Demand	Demand				Digits for Lead Time	Days until Order Arrives
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



# Sim. of Inventory System(7/13)

## Simulation Table (Cycle 2)

Cycle	Day	Beginning Inventory	Random	Ending Inventory	Shortage Quantity	Order Quantity	Random	Days until Order Arrives
			Digits for Demand				Digits for Lead Time	
2	1		03				-	
	2		87				-	
	3		27				-	
	4		73				-	
	5		70				0	



# Sim. of Inventory System(7/13)

## Simulation Table (Cycle 2)

Cycle	Day	Beginning Inventory	Random Demand		Ending Inventory	Shortage Quantity	Order Quantity	Random Lead Time	
			Digits for Demand	Demand				Digits for Lead Time	Lead Time Arrives
	5	4	54	2	2	0	9	5	1
2	1		03					-	
	2		87					-	
	3		27					-	
	4		73					-	
	5		70					0	



# Sim. of Inventory System(7/13)

## Simulation Table (Cycle 2)

Cycle	Day	Beginning Inventory	Random Demand		Ending Inventory	Shortage Quantity	Order Quantity	Random Lead Time	
			Digits for Demand	Demand				Digits for Lead Time	Days until Order Arrives
2	5	4	54	2	2	0	9	5	1
	1		03					-	
	2		87					-	
	3		27					-	
	4		73					-	
	5		70					0	

## Simulation Table (Cycle 2)

Cycle	Day	<i>Random</i>		<i>Ending Inventory</i>	<i>Shortage Quantity</i>	<i>Order Quantity</i>	<i>Random</i>		<i>Days until Order Arrives</i>
		<i>Beginning Inventory</i>	<i>Digits for Demand</i>				<i>Demand</i>	<i>Digits for Lead Time</i>	
	5	4	54	2	0	9	5	1	
2	1	2	03				-	0	
	2		87				-		
	3		27				-		
	4		73				-		
	5		70				0		



# Sim. of Inventory System(7/13)

## Simulation Table (Cycle 2)

Cycle	Day	Beginning Inventory	Random Demand		Ending Inventory	Shortage Quantity	Order Quantity	Random Lead Time	
			Digits for Demand	Demand				Digits for Lead Time	Days until Order Arrives
	5	4	54	2	2	0	9	5	1
2	1	2	03	0	2	0	-	-	0
	2		87					-	
	3		27					-	
	4		73					-	
	5		70					0	



# Sim. of Inventory System(7/13)

## Simulation Table (Cycle 2)

Cycle	Day	<i>Random</i>			<i>Random</i>			<i>Days until Order Arrives</i>	
		<i>Beginning Inventory</i>	<i>Digits for Demand</i>	<i>Demand</i>	<i>Ending Inventory</i>	<i>Shortage Quantity</i>	<i>Order Quantity</i>		<i>Lead Time</i>
	5	4	54	2	2	0	9	5	1
2	1	2	03	0	2	0	-	-	0
	2	11	87	3	8	0	-	-	-
	3		27					-	
	4		73					-	
	5		70					0	





# Sim. of Inventory System(7/13)

## Simulation Table (Cycle 2)

Cycle	Day	Beginning Inventory	Random Demand		Ending Inventory	Shortage Quantity	Order Quantity	Random Lead Time		Days until Order Arrives
			Digits for Demand	Demand				Digits for Lead Time	Lead Time	
	5	4	54	2	2	0	9	5	1	
2	1	2	03	0	2	0	-	-	0	
	2	11	87	3	8	0	-	-	-	
	3	8	27	1	7	0	-	-	-	
	4		73					-		
	5		70					0		

## Simulation Table (Cycle 2)

Cycle	Day	<i>Random</i>			<i>Ending Inventory</i>	<i>Shortage Quantity</i>	<i>Order Quantity</i>	<i>Random</i>	
		<i>Beginning Inventory</i>	<i>Digits for Demand</i>	<i>Demand</i>				<i>Digits for Lead Time</i>	<i>Days until Order Arrives</i>
	5	4	54	2	2	0	9	5	1
2	1	2	03	0	2	0	-	-	0
	2	11	87	3	8	0	-	-	-
	3	8	27	1	7	0	-	-	-
	4	7	73	3	4	0	-	-	-
	5			70					0

## Simulation Table (Cycle 2)

Cycle	Day	Beginning Inventory	Random Demand		Ending Inventory	Shortage Quantity	Order Quantity	Random Lead Time		Days until Order Arrives
			Digits for Demand	Demand				Digits for Lead Time	Lead Time	
2	5	4	54	2	2	0	9	5	1	
	1	2	03	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	-	



# Sim. of Inventory System(7/13)

## Simulation Table (Cycle 2)

Cycle	Day	<i>Random</i>			<i>Random</i>			<i>Days until Order Arrives</i>	
		<i>Beginning Inventory</i>	<i>Digits for Demand</i>	<i>Demand</i>	<i>Ending Inventory</i>	<i>Shortage Quantity</i>	<i>Order Quantity</i>		<i>Lead Time</i>
	5	4	54	2	2	0	9	5	1
2	1	2	03	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



# Sim. of Inventory System(8/13)

## Simulation Table (Cycle 3)

Cycle	Day	Beginning Inventory	Random Demand		Ending Inventory	Shortage Quantity	Order Quantity	Random Lead Time	
			Digits for Demand	Demand				Digits for Lead Time	Days until Order Arrives
	5	4	70	2	2	0	9	0	3
3	1		47					-	
	2		45					-	
	3		48					-	
	4		17					-	
	5		09					3	



# Sim. of Inventory System(8/13)

## Simulation Table (Cycle 3)

Cycle	Day	Beginning Inventory	Random		Ending Inventory	Shortage Quantity	Order Quantity	Random	
			Digits for Demand	Demand				Digits for Lead Time	Days until Order Arrives
	5	4	70	2	2	0	9	0	3
3	1		47					-	2
	2		45					-	1
	3		48					-	0
	4		17					-	-
	5		09						



# Sim. of Inventory System(8/13)

## Simulation Table (Cycle 3)

Cycle	Day	Beginning	Random	Ending	Shortage	Order	Random	Days until	
		Inventory	Digits for				Demand		Demand
	5	4	70	2	2	0	9	0	3
3	1		47					-	2
	2		45					-	1
	3		48					-	0
	4		17					-	-
	5		09						



# Sim. of Inventory System(8/13)

## Simulation Table (Cycle 3)

Cycle	Day	Beginning Inventory	Random Demand		Ending Inventory	Shortage Quantity	Order Quantity	Random Lead Time	
			Digits for Demand	Demand				Digits for Lead Time	Days until Order Arrives
	5	4	70	2	2	0	9	0	3
3	1	2	47	2	0	0	-	-	2
	2		45					-	1
	3		48					-	0
	4		17					-	-
	5		09						





# Sim. of Inventory System(8/13)

## Simulation Table (Cycle 3)

Cycle	Day	<i>Random</i>			<i>Ending Inventory</i>	<i>Shortage Quantity</i>	<i>Order Quantity</i>	<i>Random</i>	
		<i>Beginning Inventory</i>	<i>Digits for Demand</i>	<i>Demand</i>				<i>Digits for Lead Time</i>	<i>Days until Order Arrives</i>
	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		48					-	0
	4		17					-	-
	5		09						

## Simulation Table (Cycle 3)

Cycle	Day	<i>Random</i>			<i>Ending Inventory</i>	<i>Shortage Quantity</i>	<i>Order Quantity</i>	<i>Random</i>	
		<i>Beginning Inventory</i>	<i>Digits for Demand</i>	<i>Demand</i>				<i>Digits for Lead Time</i>	<i>Days until Order Arrives</i>
	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		48					-	0
	4		17					-	-
	5		09						

**Shortage**



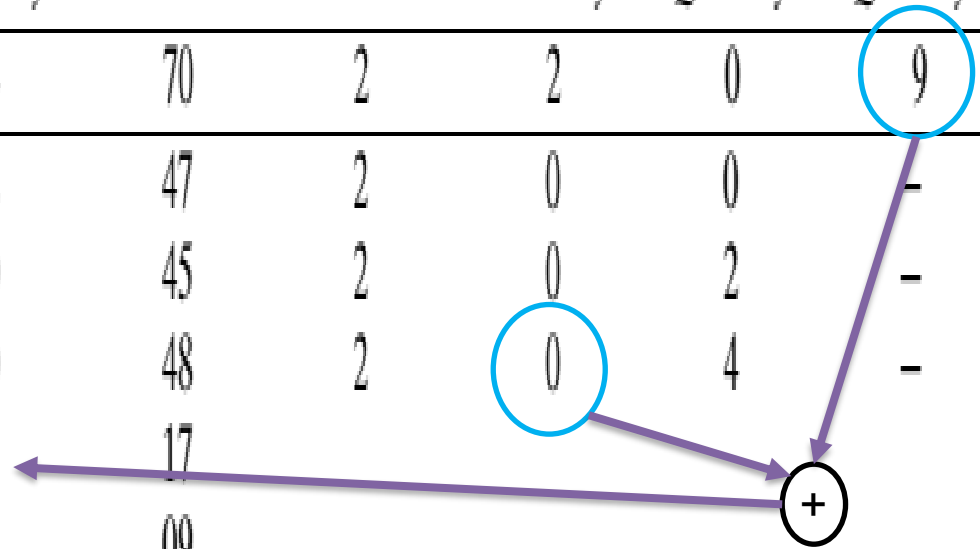
# Sim. of Inventory System(8/13)

## Simulation Table (Cycle 3)

Cycle	Day	<i>Random</i>		<i>Ending Inventory</i>	<i>Shortage Quantity</i>	<i>Order Quantity</i>	<i>Random</i>		<i>Days until Order Arrives</i>
		<i>Beginning Inventory</i>	<i>Digits for Demand</i>				<i>Demand</i>	<i>Digits for Lead Time</i>	
	5	4	70	2	0	9	0	3	
3	1	2	47	0	0	-	-	2	
	2	0	45	0	2	-	-	1	
	3	0	48	0	4	-	-	0	
	4		17				-	-	
	5		09						

## Simulation Table (Cycle 3)

Cycle	Day	Random		Ending Inventory	Shortage Quantity	Order Quantity	Random	Days until Order Arrives
		Beginning Inventory	Digits for Demand				Digits for Lead Time	
3	5	4	70	2	0	9	0	3
	1	2	47	0	0	-	-	2
	2	0	45	0	2	-	-	1
	3	0	48	0	4	-	-	0
	4		17					
5			09			+		





# Sim. of Inventory System(8/13)

## Simulation Table (Cycle 3)

Cycle	Day	<i>Random</i>		<i>Ending Inventory</i>	<i>Shortage Quantity</i>	<i>Order Quantity</i>	<i>Random</i>		<i>Days until Order Arrives</i>
		<i>Beginning Inventory</i>	<i>Digits for Demand</i>				<i>Demand</i>	<i>Digits for Lead Time</i>	
	5	4	70	2	0	9	0	3	
3	1	2	47	0	0	-	-	2	
	2	0	45	0	2	-	-	1	
	3	0	48	0	4	-	-	0	
	4	9	17				-	-	
	5		09						

## Simulation Table (Cycle 3)

Cycle	Day	Beginning	Random	Demand	Ending	Shortage	Order	Random	Days until
		Inventory	Digits for		Inventory	Quantity	Quantity	Digits for	Order
			Demand					Lead Time	
	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					-	-
	5			09					



# Sim. of Inventory System(8/13)

## Simulation Table (Cycle 3)

Cycle	Day	Random		Ending Inventory	Shortage Quantity	Order Quantity	Random		Days until Order Arrives
		Beginning Inventory	Digits for Demand				Demand	Digits for Lead Time	
	5	4	70	2	0	9	0	3	
3	1	2	47	0	0	-	-	2	
	2	0	45	0	2	-	-	1	
	3	0	48	0	4	-	-	0	
	4	<del>9</del>	5	17					
	5			09					



# Sim. of Inventory System(8/13)

## Simulation Table (Cycle 3)

Cycle	Day	Random			Random			Days until Order Arrives	
		Beginning Inventory	Digits for Demand	Demand	Ending Inventory	Shortage Quantity	Order Quantity		Digits for Lead Time
3	5	4	70	2	2	0	9	0	3
	1	2	47	2	0	0	-	-	2
	2	0	45	2	0	2	-	-	1
	3	0	48	2	0	4	-	-	0
	4	<del>9</del> 5	17	1					
5			09						



## Simulation Table (Cycle 3)

Cycle	Day	<i>Random</i>			Ending Inventory	Shortage Quantity	Order Quantity	<i>Random</i>	
		Beginning Inventory	Digits for Demand	Demand				Digits for Lead Time	Days until Order Arrives
3	5	4	70	2	2	0	9	0	3
	1	2	47	2	0	0	-	-	2
	2	0	45	2	0	2	-	-	1
	3	0	48	2	0	4	-	-	0
	4	<del>9</del> 5	17	1	4		-	-	
	5		09						



# Sim. of Inventory System(8/13)

## Simulation Table (Cycle 3)

Cycle	Day	Random		Ending Inventory	Shortage Quantity	Order Quantity	Random		Days until Order Arrives
		Beginning Inventory	Digits for Demand				Demand	Digits for Lead Time	
	5	4	70	2	0	9	0	3	
3	1	2	47	0	0	-	-	2	
	2	0	45	0	2	-	-	1	
	3	0	48	0	4	-	-	0	
	4	<del>9</del> 5	17	4	0	-	-	-	
	5		09						



# Sim. of Inventory System(8/13)

## Simulation Table (Cycle 3)

Cycle	Day	Beginning Inventory	Random Demand		Ending Inventory	Shortage Quantity	Order Quantity	Random Lead Time		Days until Order Arrives
			Digits for Demand	Demand				Digits for Lead Time	Lead Time	
	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	09							



# Sim. of Inventory System(8/13)

## Simulation Table (Cycle 3)

Cycle	Day	Beginning Inventory	Random		Ending Inventory	Shortage Quantity	Order Quantity	Random		Days until Order Arrives
			Digits for Demand	Demand				Digits for Lead Time	Lead Time	
3	5	4	70	2	2	0	9	0	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	09	0	4	0	-	-	-	

## Simulation Table (Cycle 3)

Cycle	Day	Beginning Inventory	Random		Ending Inventory	Shortage Quantity	Order Quantity	Random		Days until Order Arrives
			Digits for Demand	Demand				Digits for Lead Time	Lead Time	
3	5	4	70	2	2	0	9	0	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	09	0	4	0	7	-	-	



# Sim. of Inventory System(9/13)

## Simulation Table (Cycle 3)

Cycle	Day	Beginning Inventory	Random Demand		Ending Inventory	Shortage Quantity	Order Quantity	Random Lead Time		Days until Order Arrives
			Digits for Demand	Demand				Digits for Lead Time	Lead Time	
3	5	4	70	2	2	0	9	0	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	09	0	4	0	7	3	1	



# Sim. of Inventory System(10/13)

## Simulation Table (Cycle 4)

Cycle	Day	<i>Random</i>			<i>Random</i>			<i>Days until Order Arrives</i>	
		<i>Beginning Inventory</i>	<i>Digits for Demand</i>	<i>Demand</i>	<i>Ending Inventory</i>	<i>Shortage Quantity</i>	<i>Order Quantity</i>		<i>Lead Time</i>
	5	4	09	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



# Sim. of Inventory System(11/13)

## Simulation Table (Cycle 5)

Cycle	Day	<i>Random</i>			<i>Ending Inventory</i>	<i>Shortage Quantity</i>	<i>Order Quantity</i>	<i>Random</i>	
		<i>Beginning Inventory</i>	<i>Digits for Demand</i>	<i>Demand</i>				<i>Digits for Lead Time</i>	<i>Days until Order Arrives</i>
	5	3	40	2	1	0	10	4	1
5	1	1	07	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
					$\overline{88}$				





# Sim. of Inventory System(12/13)

## Simulation Table (5 Cycles)

Cycle	Day	Beginning Inventory	Random Digits for Demand	Demand	Ending Inventory	Shortage Quantity	Order Quantity	Random Digits for Lead Time	Days until Order Arrives
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	03	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	09	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	07	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	<u>1</u>	0	10	8	2

88



## Performance analysis:

- Based on five cycles of simulation, the average ending inventory is approximately 3.5 ( $88 \div 25$ ) units.
- On 2 of 25 days a shortage condition existed.
- For large number of cycles, the computer is used.



# Video Lectures

All Lectures: <https://www.youtube.com/playlist?list=PLxIvc-MG0s6geFJmdvD0IN5zE89-Hq8Ij>

Lecture #5: <https://www.youtube.com/watch?v=w0DCunLFtFA&list=PLxIvc-MG0s6geFJmdvD0IN5zE89-Hq8Ij&index=16>

<https://www.youtube.com/watch?v=IMGdylaQMdk&list=PLxIvc-MG0s6geFJmdvD0IN5zE89-Hq8Ij&index=17>

# Thank You

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