A Prescriptive Model for Strategic Decision-making, An Inventory Management Decision Model

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Main Tool: Excel Secondary Tool: R Industry: Business Analytics

Introduction

Effective inventory management is a critical component of operational efficiency and financial success for any organization. The decision-making process surrounding inventory management involves determining the optimal order quantity and timing to minimize total inventory costs. These costs are primarily composed of holding costs, associated with storing inventory, and ordering costs, related to replenishing inventory.

The objective of this study is to develop and implement a prescriptive decision model to aid a manufacturing company in making informed inventory management decisions for a key engine component. The company faces a constant annual demand of 15,000 units, each unit costing $80. The opportunity cost for holding this item is 18% of its unit value per year, and the cost per order placed with the supplier is $220.

Background

Inventory decisions are influenced by various factors, including holding and ordering costs. Holding costs encompass all expenses related to storing inventory, such as interest, insurance, taxes, and warehousing. These costs are typically expressed in terms of dollars per unit per time period. Conversely, ordering costs include all costs incurred during the ordering process, such as clerical work, purchasing, and transportation, and are usually constant per order.

Objectives

The primary goal of this project is to create a decision model to assist managers in determining the most cost-effective order quantity and frequency. This involves:

1. Defining data, uncontrollable inputs, model parameters, and decision variables.
2. Developing mathematical functions to compute annual holding and ordering costs and formulating a total inventory cost model.
3. Implementing the model in both Excel and R and verifying results using Excel Solver.
4. Conducting sensitivity analyses to explore the impact of parameter changes on total cost.

Part 1: Completed in both Excel and R.

1. Defining the data, uncontrollable inputs, model parameters, and the decision variables that influence the total inventory cost.

The analysis of inventory cost management is critical for optimizing operations and reducing total costs. Based on the provided data, we can classify the necessary components into data, uncontrollable inputs, model parameters, and decision variables. This classification is essential for developing a robust inventory management model.

	Number	Unit	Type
Annual Demand	15000	pieces	Uncontrollable input
Unit Cost	80	dollars	Model Parameter
Opportunity Cost/ Holding Cost	18%	per unit value	Model Parameter
Cost per order	220	dollars	Model Parameter
Order Cost (S)	220	dollars	Model Parameter
Holding cost per unit (H)= Unit cost * Opportunity Cost	14.4	dollars	Model Parameter
Annual Quantity Demand(D)	15000	units	Uncontrollable input
Economic order quantity(EOQ)= √2SD/H	677.00	units	Decision variable
Volume per order(Q)	677.00	units	Decision variable
Number of times to order(N) = (D/ EOQ)	22.16	times	Decision variable

Figure 1 Data Classification

Data

The data provided in the table includes the following components:

1. Annual Demand (D): The total quantity of units required annually is 15,000 pieces.
2. Unit Cost: The cost per individual unit, set at $80.
3. Opportunity Cost/Holding Cost (% per unit value): The percentage representing the opportunity cost or holding cost, which is 18%.
4. Cost per Order (S): The fixed cost associated with placing an order is $220.

Uncontrollable Inputs

Uncontrollable inputs are those factors that cannot be influenced by the decision-makers but must be considered in the model:

1. Annual Demand (D): Fixed at 15,000 units.

Model Parameters

Model parameters are derived from the given data and used to compute various components of the inventory cost model:

1. Opportunity Cost/Holding Cost (%): Fixed at 18% of the unit cost.
2. Holding Cost per Unit (H): Calculated as the product of the unit cost and the opportunity cost percentage: H = Unit Cost × Opportunity Cost = 80 × 0.18 = 14.4 dollars
3. Economic Order Quantity (EOQ): The optimal order quantity that minimizes total inventory costs, calculated using the EOQ formula: EOQ = $\sqrt{}$(2DS/H) = $\sqrt{}$ (2 × 15000 × 220/14.4) = 677 units

Decision Variables

Decision variables are those that can be controlled or adjusted by the decision-makers to influence the total inventory cost:

1. Order Quantity (Q): The number of units ordered each time, which in this case is the EOQ of 677 units.
2. Number of Orders (N): The total number of orders placed annually, calculated as: N = D/EOQ = 15000/677 ≈ 22.16 times

Influence on Total Inventory Cost

The total inventory cost is influenced by the interplay of the holding cost, order cost, and the cost of the units themselves. The Economic Order Quantity (EOQ) model is used to determine the optimal order quantity that minimizes the total cost, which includes:

- Holding Costs: Costs associated with storing the inventory.
- Order Costs: Costs associated with placing orders.
- Purchase Costs: The total cost of purchasing the required units.

Conclusion

The given data provides a comprehensive overview of the inventory cost components, including the necessary calculations for determining the holding cost per unit, economic order quantity, and the frequency of orders. By optimizing these parameters, decision-makers can significantly influence and reduce the total inventory cost, thus enhancing operational efficiency.

This structured approach, grounded in the principles of operations management, ensures that the inventory levels are maintained at an optimal level, balancing the holding and ordering costs effectively.

2. **Develop mathematical functions that compute the annual ordering cost and annual holding cost based on average inventory held throughout the year and use them to develop a mathematical model for the total inventory cost.**

Inventory Management

The optimization of inventory costs is a critical aspect of supply chain management. This section will develop mathematical functions to compute these costs and provide a mathematical model for the total inventory cost.

Annual Demand
Unit Cost
Opportunity Cost/ Holding Cost
Cost per order
Order Cost (S)
ng cost per unit (H)= Unit cost * Opportunity Cost
Annual Quantity Demand(D)
Economic order quantity(EOQ)= √2SD/H
Volume per order(Q)
Number of times to order(N) = (D/EOQ)

PART I Question 2			
			Unit
AOC	Annual Ordering Cost = (D/Q)*S	4874.42	Dollars
AHC	Annual Holding Cost = (Q/2) * H	4874.42	Dollars
ATC	Annual Total Cost = (AOC+ AHC)	9748.85	Dollars
	OBJECTIVE: MINIMIZE THE ANNUAL TOTAL COST (ATC)		
S	220.00		
H	14.40		
D	15000.00		
EOQ	677.00		
Q	677.00		
N	22.16		
AOC	4874.42		
AHC	4874.43		
ATC	9748.846086		

Figure 2 Mathematical Model

```
> # Print initial results
> cat("EOQ:", EOQ, "\n")
EOQ: 677
> cat("Annual Ordering Cost:", AOC, "\n")
Annual Ordering Cost: 4874.446
> cat("Annual Holding Cost:", AHC, "\n")
Annual Holding Cost: 4874.4
> cat("Annual Total Cost:", ATC, "\n")
Annual Total Cost: 9748.846
```

Figure 3 Part 1 solved in R.

Components and Definitions

- **Annual Demand (D)**: The total quantity of units required annually.
- **Order Cost (S):** The fixed cost associated with placing an order.
- **Holding Cost per Unit (H):** The cost to hold one unit of inventory for a year.
- **Economic Order Quantity (EOQ):** The optimal order quantity that minimizes total inventory costs.
- **Order Quantity (Q):** The number of units ordered each time, ideally equal to EOQ.
- **Number of Orders (N):** The total number of orders placed annually.
- **Annual Ordering Cost (AOC):** The total cost of placing orders over a year.
- **Annual Holding Cost (AHC):** The total cost of holding inventory over a year.
- **Annual Total Cost (ATC):** The sum of annual ordering cost and annual holding cost.

Mathematical Functions

1. **Economic Order Quantity (EOQ)**

The Economic Order Quantity (EOQ) is calculated using the formula:
$EOQ = \sqrt{(2DS/H)}$

Where:
- D is the annual demand.
- S is the order cost.
- H is the holding cost per unit.

2. **Annual Ordering Cost (AOC)**

The Annual Ordering Cost (AOC) is calculated using the formula:
$AOC = (D/Q) * S$

Where:
- D is the annual demand.
- Q is the order quantity (EOQ).
- S is the order cost.

3. **Annual Holding Cost (AHC)**

The Annual Holding Cost (AHC) is calculated using the formula:
AHC = (Q/2) * H

Where:
- Q is the order quantity (EOQ).
- H is the holding cost per unit.

4. **Annual Total Cost (ATC)**

The Annual Total Cost (ATC) is the sum of AOC and AHC:
ATC = AOC + AHC

Application of the Model

Using the provided data:
- Annual Demand (D) = 15,000 units
- Order Cost (S) = $220
- Holding Cost per Unit (H) = $14.4

Step-by-Step Calculation

1. Calculate EOQ:
EOQ = √ (2 * 15000 * 220 / 14.4) ≈ 677 units
2. Calculate AOC:
AOC = (15000 / 677) * 220 ≈ 4874.42
3. Calculate AHC:
AHC = (677 / 2) * 14.4 ≈ 4874.43
4. Calculate ATC:
ATC = 4874.42 + 4874.43 ≈ 9748.85

Conclusion

The mathematical model developed for the total inventory cost integrates key cost components, allowing for the optimization of order quantity and minimization of total costs. By using the Economic Order Quantity (EOQ) model, businesses can effectively balance ordering and holding costs, leading to significant cost savings and improved operational efficiency. This approach is fundamental in the field of operations management and contributes to more effective inventory control strategies.

Inventory Level	Order Quantity	TOTAL COST (Dollars)
100	200	17940.00
140	280	13801.71
180	360	11758.67
220	440	10668.00
260	520	10090.15
300	600	9820.00
339	678	9748.86
340	680	9748.94
380	760	9814.11
420	840	9976.57
460	920	10210.96
500	1000	10500.00
540	1080	10831.56
580	1160	11196.83
620	1240	11589.29
660	1320	12004.00
700	1400	12437.14

Figure 4 Data Table.

Inventory management involves determining the optimal order quantity that minimizes total cost, balancing ordering and holding costs. The Economic Order Quantity (EOQ) model provides a basis for this determination. However, practical scenarios often necessitate the use of data tables to approximate the order quantity that results in the lowest total cost.

Methodology

To find the optimal order quantity, a data table approach was utilized. This involves calculating the total cost for various order quantities and identifying the quantity that results in the smallest total cost. The components considered in the cost calculation include:

1. Annual Demand (D): The total quantity of units required annually.
2. Order Cost (S): The fixed cost associated with placing an order.
3. Holding Cost per Unit (H): The cost to hold one unit of inventory for a year.
4. Order Quantity (Q): The number of units ordered each time.

Calculations

The data table includes the following columns:

1. Inventory Level: The average inventory level, calculated as half of the order quantity (Q/2).
2. Order Quantity (Q): The varying order quantities.

3. Total Cost (Dollars): The total cost for each order quantity, which includes both ordering and holding costs.

The total cost is calculated using the formula: Total Cost = Annual Ordering Cost (AOC) + Annual Holding Cost (AHC)

Where: AOC = (D/Q) × S AHC = (Q/2) × H

Example Calculations

Given the following data:

- Annual Demand (D) = 15,000 units
- Order Cost (S) = $220
- Holding Cost per Unit (H) = $14.4

Step-by-Step Example:

For an order quantity (Q) of 200 units:

1. Calculate AOC: AOC = (15000/200) × 220 = 16.5 × 220 = 3630
2. Calculate AHC: AHC = (200/2) × 14.4 = 100 × 14.4 = 1440
3. Calculate Total Cost: Total Cost = 3630 + 1440 = 5070

Results and Analysis

The data table presented reveals that the order quantity of 678 units results in the smallest total cost of $9748.86. This can be verified by comparing the total costs for different order quantities.

Comparison of EOQ Calculation and Data Table Results

The EOQ model calculated an optimal order quantity of 677 units. However, the data table approach, which involves evaluating the total cost for discrete order quantities, identified 678 units as the order quantity with the lowest total cost. This discrepancy arises due to the practical constraints and rounding involved in real-world applications. The EOQ formula provides a theoretical optimal quantity, while the data table method refines this by considering the actual costs at specific intervals, leading to a more precise practical solution.

Conclusion

Using data tables to approximate the optimal order quantity allows for a more nuanced understanding of inventory costs. The order quantity that minimizes the total cost in this scenario is approximately 678 units. This approach is crucial for effective inventory management, ensuring cost efficiency and optimal stock levels.

By applying these principles, businesses can make informed decisions about inventory policies, ultimately contributing to better resource allocation and cost savings.

Note: Further Data Tables have been implemented in the What-if Analysis pages of the excel spreadsheet.

5. Plot the Total Cost versus the Order Quantity

Inventory management aims to minimize the total cost associated with ordering and holding inventory. The relationship between total cost and order quantity can be visualized through plots, which help identify the optimal order quantity that minimizes total costs. Here, we analyze two plots: one created in R and the other in Excel, to explain the insights derived from these visualizations.

Plot Created in R

Figure 5 Plot in R.

The above plot, generated using R, illustrates the total cost as a function of order quantity. The x-axis represents the order quantity, while the y-axis represents the total cost.

Key Observations:

1. **U-Shaped Curve**: The plot demonstrates a U-shaped curve, which is characteristic of the total cost function in inventory management. Initially, as the order quantity increases, the total cost decreases due to the reduction in ordering costs. After reaching the optimal point, further increases in order quantity lead to higher holding costs, resulting in an increase in total cost.

2. **Optimal Order Quantity**: The plot marks the optimal order quantity at 677 units, where the total cost is at its minimum. This is indicated by the vertical dashed line and labeled point, showing the precise quantity where the cost is minimized.

Plot Created in Excel

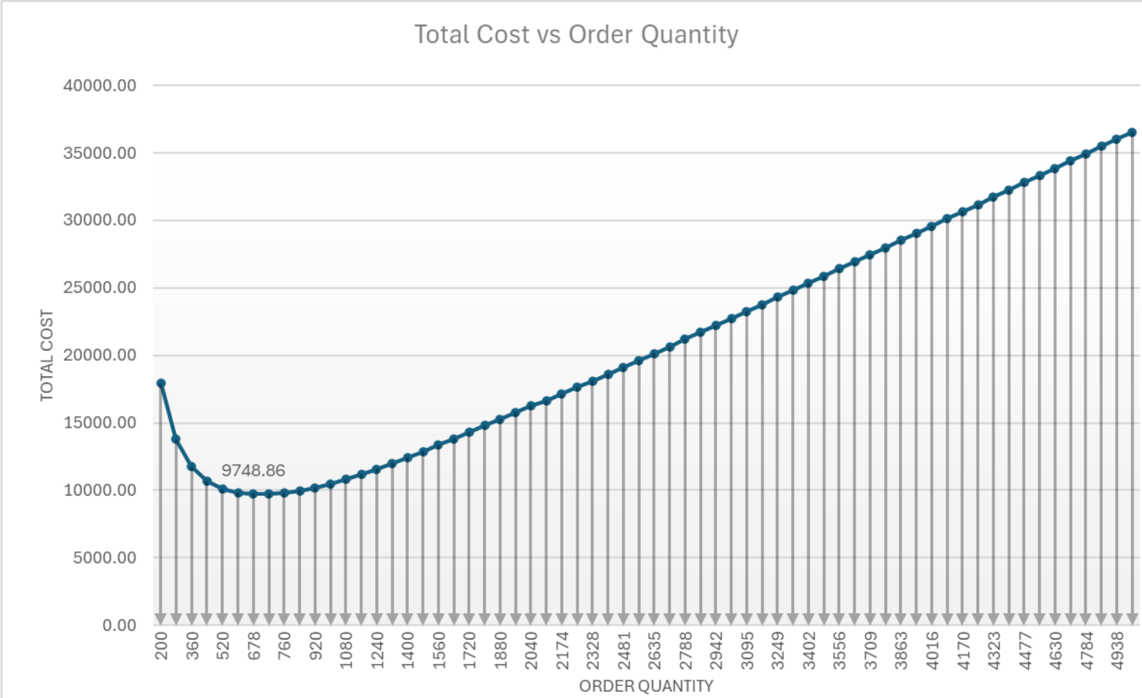


Figure 6 Plot in Excel.

The second plot, generated using Excel, also shows the relationship between total cost and order quantity, with similar axes: order quantity on the x-axis and total cost on the y-axis.

Key Observations:

1. **Detailed Data Points**: The Excel plot includes detailed data points for various order quantities, represented by dots connected with lines. This provides a clear view of how total cost varies with each specific order quantity.

2. **Approximate Optimal Order Quantity**: The Excel plot identifies the optimal order quantity at 678 units, with the corresponding total cost labeled as $9748.86. **This slight difference from the R plot (677 units) is due to the discrete nature of the data points evaluated in Excel.**

Comparison and Analysis

Both plots effectively illustrate the relationship between total cost and order quantity, emphasizing the importance of determining the optimal order quantity to minimize costs. The slight discrepancy between the optimal quantities (677 units in R and 678 units in Excel) highlights the practical considerations in inventory management:

- **EOQ Calculation**: The R plot uses the EOQ formula to find the theoretical optimal quantity, resulting in 677 units.

- **Data Table Approximation**: The **Excel plot relies on evaluating discrete order quantities**, leading to an optimal quantity of 678 units. This method considers practical constraints and real-world data points.

Conclusion

Visualizing total cost versus order quantity through these plots provides valuable insights into inventory management. The U-shaped curve clearly demonstrates the cost trade-offs involved in ordering and holding inventory. Identifying the optimal order quantity, whether through theoretical calculations or practical data table approximations, enables businesses to minimize total costs and achieve efficient inventory control.

By leveraging such visualizations, decision-makers can better understand the cost dynamics and make informed inventory management decisions, ultimately contributing to improved operational efficiency and cost savings.

6. Use the Excel Solver to verify your result of part 4 above; that is, find the order quantity which would yield a minimum total cost.

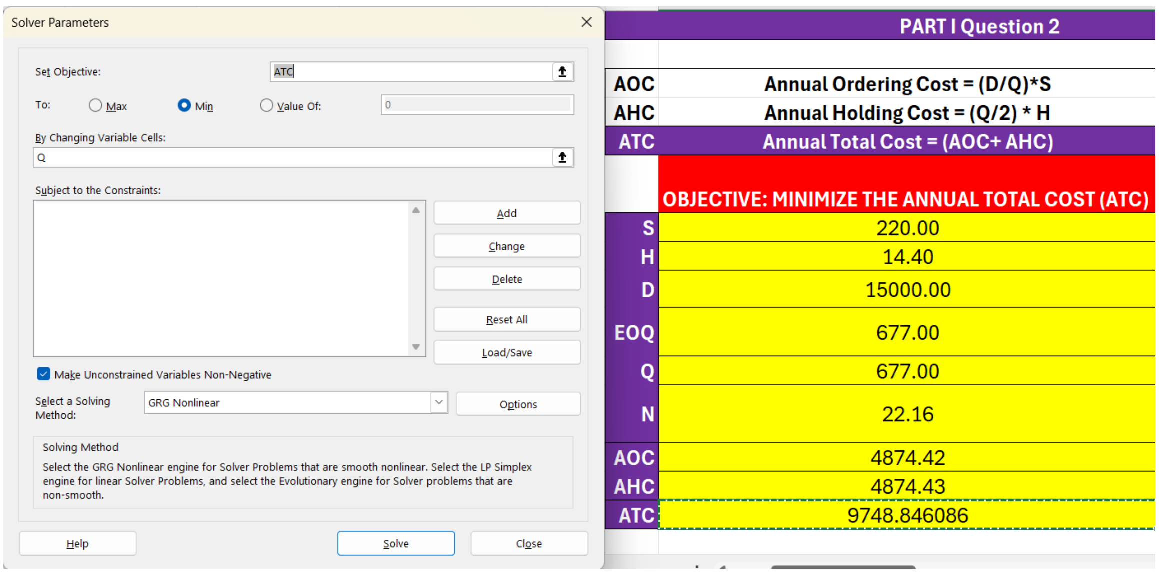


Figure 7 Solver in Excel.

To verify the result of the optimal order quantity calculated previously, Excel Solver was utilized. Solver is an optimization tool in Excel that adjusts values in cells to find the optimal solution for a given objective. In this case, the objective is to minimize the total cost (ATC) by adjusting the order quantity (Q).

Methodology

The Excel Solver was set up to minimize the Annual Total Cost (ATC) by changing the Order Quantity (Q). The constraints and parameters used were:

1. Objective: Minimize the Annual Total Cost (ATC).
2. Variable: Order Quantity (Q).
3. Constraints: Ensure that the variables are non-negative.

The relevant formulas used were:

- Annual Ordering Cost (AOC): AOC = (D/Q) × S

- Annual Holding Cost (AHC): AHC = (Q/2) × H
- Annual Total Cost (ATC): ATC = AOC + AHC

Where:

- D is the annual demand (15,000 units)
- S is the order cost ($220)
- H is the holding cost per unit ($14.4)

Solver Setup

In the Solver Parameters dialog:

1. Set Objective: ATC
2. To: Min (to minimize the total cost)
3. By Changing Variable Cells: Q (Order Quantity)
4. Subject to the Constraints: Ensure that Q is non-negative

Results

The Solver provided the following results:

- Annual Total Cost (ATC): $9,748.85
- Economic Order Quantity (EOQ): 677 units

Comparison with Manual Calculation

The manual calculation yielded the following results:

- Annual Total Cost (ATC): $9,748.85
- Economic Order Quantity (EOQ): 677 units

Analysis

The results from the Excel Solver matched exactly with the manually calculated values. This verification confirms that the manually derived Economic Order Quantity (EOQ) of 677 units indeed minimizes the total cost. The consistency between the Solver results and the manual calculations demonstrates the accuracy and reliability of the methods used.

Conclusion

Using Excel Solver to verify the optimal order quantity provides an additional layer of confidence in the results. The Solver's optimization process aligns perfectly with the theoretical calculations, ensuring that the chosen order quantity is optimal for minimizing total inventory costs. This approach highlights the importance of using both theoretical models and practical tools like Excel Solver for effective decision-making in inventory management.

7. Conduct what-if analyses by using two-way tables in Excel to study the sensitivity of total cost to changes in the model parameters.

What-if analysis 1

Holding cost for Inventory

Order Cost

	1.2	1.6	2	2.4	2.8	3.2	3.6	4	4.4
100	2621.847787	2757.2485	2892.649212	3028.049925	3163.450638	3298.851351	3434.252063	3569.652776	3705.053489
120	3064.976917	3200.377629	3335.778342	3471.179055	3606.579768	3741.98048	3877.381193	4012.781906	4148.182619
140	3508.106046	3643.506759	3778.907472	3914.308185	4049.708897	4185.10961	4320.510323	4455.911036	4591.311748
160	3951.235176	4086.635889	4222.036602	4357.437314	4492.838027	4628.23874	4763.639453	4899.040165	5034.440878
180	4394.364306	4529.765019	4665.165731	4800.566444	4935.967157	5071.36787	5206.768582	5342.169295	5477.570008
200	4837.493436	4972.894148	5108.294861	5243.695574	5379.096287	5514.496999	5649.897712	5785.298425	5920.699137
220	5280.622565	5416.023278	5551.423991	5686.824704	5822.225416	5957.626129	6093.026842	6228.427554	6363.828267
240	5723.751695	5859.152408	5994.553121	6129.953833	6265.354546	6400.755259	6536.155972	6671.556684	6806.957397
260	6166.880825	6302.281538	6437.68225	6573.082963	6708.483676	6843.884389	6979.285101	7114.685814	7250.086527
280	6610.009955	6745.410667	6880.81138	7016.212093	7151.612806	7287.013518	7422.414231	7557.814944	7693.215656
300	7053.139084	7188.539797	7323.94051	7459.341223	7594.741935	7730.142648	7865.543361	8000.944073	8136.344786
320	7496.268214	7631.668927	7767.06964	7902.470352	8037.871065	8173.271778	8308.67249	8444.073203	8579.473916
340	7939.397344	8074.798057	8210.198769	8345.599482	8481.000195	8616.400907	8751.80162	8887.202333	9022.603046
360	8382.526474	8517.927186	8653.327899	8788.728612	8924.129324	9059.530037	9194.93075	9330.331463	9465.732175
380	8825.655603	8961.056316	9096.457029	9231.857741	9367.258454	9502.659167	9638.05988	9773.460592	9908.861305
400	9268.784733	9404.185446	9539.586159	9674.986871	9810.387584	9945.788297	10081.18901	10216.58972	10351.99043
420	9711.913863	9847.314576	9982.715288	10118.116	10253.51671	10388.91743	10524.31814	10659.71885	10795.11956
440	10155.04299	10290.44371	10425.84442	10561.24513	10696.64584	10832.04656	10967.44727	11102.84798	11238.24869
460	10598.17212	10733.57283	10868.97355	11004.37426	11139.77497	11275.17569	11410.5764	11545.97711	11681.37782
480	11041.30125	11176.70196	11312.10268	11447.50339	11582.9041	11718.30482	11853.70553	11989.10624	12124.50695
500	11484.43038	11619.83109	11755.23181	11890.63252	12026.03323	12161.43395	12296.83466	12432.23537	12567.63608

	4.8	5.2	5.6	6	6.4	6.8	7.2	7.6
100	3840.454202	3975.854914	4111.255627	4246.65634	4382.057052	4517.457765	4652.858478	4788
120	4283.583331	4418.984044	4554.384757	4689.785469	4825.186182	4960.586895	5095.987608	5231
140	4726.712461	4862.113174	4997.513886	5132.914599	5268.315312	5403.716025	5539.116737	5675
160	5169.841591	5305.242303	5440.643016	5576.043729	5711.444442	5846.845154	5982.245867	6118
180	5612.97072	5748.371433	5883.772146	6019.172859	6154.573571	6289.974284	6425.374997	6561
200	6056.09985	6191.500563	6326.901276	6462.301988	6597.702701	6733.103414	6868.504127	7004
220	6499.22898	6634.629693	6770.030405	6905.431118	7040.831831	7176.232544	7311.633256	7447
240	6942.35811	7077.758822	7213.159535	7348.560248	7483.960961	7619.361673	7754.762386	7890
260	7385.487239	7520.887952	7656.288665	7791.689378	7927.09009	8062.490803	8197.891516	8333
280	7828.616369	7964.017082	8099.417795	8234.818507	8370.21922	8505.619933	8641.020646	8776
300	8271.745499	8407.146212	8542.546924	8677.947637	8813.34835	8948.749063	9084.149775	9220
320	8714.874629	8850.275341	8985.676054	9121.076767	9256.47748	9391.878192	9527.278905	9663
340	9158.003758	9293.404471	9428.805184	9564.205897	9699.606609	9835.007322	9970.408035	10106
360	9601.132888	9736.533601	9871.934314	10007.33503	10142.73574	10278.13645	10413.53716	10549
380	10044.26202	10179.66273	10315.06344	10450.46416	10585.86487	10721.26558	10856.66629	10992
400	10487.39115	10622.79186	10758.19257	10893.59329	11028.994	11164.39471	11299.79542	11435
420	10930.52028	11065.92099	11201.3217	11336.72242	11472.12313	11607.52384	11742.92455	11878
440	11373.64941	11509.05012	11644.45083	11779.85155	11915.25226	12050.65297	12186.05368	12321
460	11816.77854	11952.17925	12087.57996	12222.98068	12358.38139	12493.7821	12629.18281	12765
480	12259.90767	12395.30838	12530.70909	12666.1098	12801.51052	12936.91123	13072.31194	13208
500	12703.0368	12838.43751	12973.83822	13109.23893	13244.63965	13380.04036	13515.44107	13651

	8	8.4	8.8	9.2	9.6	10	10.4	10.8	11.2	11.6	12	12.4
100	4923.659903	5059.060616	5194.461329	5329.862042	5465.262754	5600.663467	5736.06418	5871.464893	6006.865605	6142.266318	6277.667031	6413.067743
120	5366.789033	5502.189746	5637.590459	5772.991171	5908.391884	6043.792597	6179.19331	6314.594022	6449.994735	6585.395448	6720.79616	6856.196873
140	5809.918163	5945.318876	6080.719588	6216.120301	6351.521014	6486.921727	6622.322439	6757.723152	6893.123865	7028.524577	7163.92529	7299.326003
160	6253.047293	6388.448005	6523.848718	6659.249431	6794.650144	6930.050856	7065.451569	7200.852282	7336.252994	7471.653707	7607.05442	7742.455133
180	6696.176422	6831.577135	6966.977848	7102.378561	7237.779273	7373.179986	7508.580699	7643.981411	7779.382124	7914.782837	8050.18355	8185.584262
200	7139.305552	7274.706265	7410.106978	7545.50769	7680.908403	7816.309116	7951.709828	8087.110541	8222.511254	8357.911967	8493.312679	8628.713392
220	7582.434682	7717.835395	7853.236107	7988.63682	8124.037533	8259.438245	8394.838958	8530.239671	8665.640384	8801.041096	8936.441809	9071.842522
240	8025.563812	8160.964524	8296.365237	8431.76595	8567.166663	8702.567375	8837.968088	8973.368801	9108.769513	9244.170226	9379.570939	9514.971652
260	8468.692941	8604.093654	8739.494367	8874.89508	9010.295792	9145.696505	9281.097218	9416.49793	9551.898643	9687.299356	9822.700069	9958.100781
280	8911.822071	9047.222784	9182.623497	9318.024209	9453.424922	9588.825635	9724.226347	9859.62706	9995.027773	10130.42849	10265.8292	10401.22991
300	9354.951201	9490.351914	9625.752626	9761.153339	9896.554052	10031.95476	10167.35548	10302.75619	10438.1569	10573.55762	10708.95833	10844.35904
320	9798.080331	9933.481043	10068.88176	10204.28247	10339.68318	10475.08389	10610.48461	10745.88532	10881.28603	11016.68675	11152.08746	11287.48817
340	10241.20946	10376.61017	10512.01089	10647.4116	10782.81231	10918.21302	11053.61374	11189.01445	11324.41516	11459.81587	11595.21659	11730.6173
360	10684.33859	10819.7393	10955.14002	11090.54073	11225.94144	11361.34215	11496.74287	11632.14358	11767.54429	11902.945	12038.34572	12173.74643
380	11127.46772	11262.86843	11398.26915	11533.66986	11669.07057	11804.47128	11939.872	12075.27271	12210.67342	12346.07413	12481.47485	12616.87556
400	11570.59685	11705.99756	11841.39827	11976.79899	12112.1997	12247.60041	12383.00113	12518.40184	12653.80255	12789.20326	12924.60398	13060.00469
420	12013.72598	12149.12669	12284.5274	12419.92812	12555.32883	12690.72954	12826.13026	12961.53097	13096.93168	13232.33239	13367.73311	13503.13382
440	12456.85511	12592.25582	12727.65653	12863.05725	12998.45796	13133.85867	13269.25939	13404.6601	13540.06081	13675.46152	13810.86224	13946.26295
460	12899.98424	13035.38495	13170.78566	13306.18638	13441.58709	13576.9878	13712.38852	13847.78923	13983.18994	14118.59065	14253.99137	14389.39208
480	13343.11337	13478.51408	13613.91479	13749.31551	13884.71622	14020.11693	14155.51764	14290.91836	14426.31907	14561.71978	14697.1205	14832.52121
500	13786.2425	13921.64321	14057.04392	14192.44464	14327.84535	14463.24606	14598.64677	14734.04749	14869.4482	15004.84891	15140.24963	15275.65034

	12.8	13.2	13.6	14	14.4	14.8	15.2	15.6	16	16.4
100	6548.468456	6683.869169	6819.269882	6954.670594	7090.071307	7225.47202	7360.872733	7496.273445	7631.674158	7767.074871
120	6991.597586	7126.998299	7262.399011	7397.799724	7533.200437	7668.60115	7804.001862	7939.402575	8074.803288	8210.204001
140	7434.726716	7570.127428	7705.528141	7840.928854	7976.329567	8111.730279	8247.130992	8382.531705	8517.932418	8653.33313
160	7877.855845	8013.256558	8148.657271	8284.057984	8419.458696	8554.859409	8690.260122	8825.660835	8961.061547	9096.46226
180	8320.984975	8456.385688	8591.786401	8727.187113	8862.587826	8997.988539	9133.389252	9268.789964	9404.190677	9539.59139
200	8764.114105	8899.514818	9034.91553	9170.316243	9305.716956	9441.117669	9576.518381	9711.919094	9847.319807	9982.720519
220	9207.243235	9342.643947	9478.04466	9613.445373	9748.846086	9884.246798	10019.64751	10155.04822	10290.44894	10425.84965
240	9650.372364	9785.773077	9921.17379	10056.5745	10191.97522	10327.37593	10462.77664	10598.17735	10733.57807	10868.97878
260	10093.50149	10228.90221	10364.30292	10499.70363	10635.10435	10770.50506	10905.90577	11041.30648	11176.7072	11312.10791
280	10536.63062	10672.03134	10807.43205	10942.83276	11078.23347	11213.63419	11349.0349	11484.43561	11619.83633	11755.23704
300	10979.75975	11115.16047	11250.56118	11385.96189	11521.3626	11656.76332	11792.16403	11927.56474	12062.96546	12198.36617
320	11422.88888	11558.2896	11693.69031	11829.09102	11964.49173	12099.89245	12235.29316	12370.69387	12506.09459	12641.4953
340	11866.01801	12001.41873	12136.81944	12272.22015	12407.62086	12543.02158	12678.42229	12813.823	12949.22371	13084.62443
360	12309.14714	12444.54786	12579.94857	12715.34928	12850.74999	12986.15071	13121.55142	13256.95213	13392.35284	13527.75356
380	12752.27627	12887.67699	13023.0777	13158.47841	13293.87912	13429.27984	13564.68055	13700.08126	13835.48197	13970.88269
400	13195.4054	13330.80612	13466.20683	13601.60754	13737.00825	13872.40897	14007.80968	14143.21039	14278.6111	14414.01182
420	13638.53453	13773.93524	13909.33596	14044.73667	14180.13738	14315.5381	14450.93881	14586.33952	14721.74023	14857.14095
440	14081.66366	14217.06437	14352.46509	14487.8658	14623.26651	14758.66723	14894.06794	15029.46865	15164.86936	15300.27008
460	14524.79279	14660.1935	14795.59422	14930.99493	15066.39564	15201.79636	15337.19707	15472.59778	15607.99849	15743.39921
480	14967.92192	15103.32263	15238.72335	15374.12406	15509.52477	15644.92548	15780.3262	15915.72691	16051.12762	16186.52834
500	15411.05105	15546.45176	15681.85248	15817.25319	15952.6539	16088.05461	16223.45533	16358.85604	16494.25675	16629.65747

What-if analysis 2

Holding Cost (H)

Annual Demand (D)

	1.2	1.6	2	2.4	2.8	3.2	3.6	4	4.4	4.8	5.2	5.6	6
1000	731.1635	866.5642	1001.965	1137.366	1272.766	1408.167	1543.568	1678.968	1814.369	1949.77	2085.171	2220.571	2355.972
2000	1056.125	1191.526	1326.926	1462.327	1597.728	1733.128	1868.529	2003.93	2139.331	2274.731	2410.132	2545.533	2680.933
3000	1381.086	1516.487	1651.888	1787.288	1922.689	2058.09	2193.491	2328.891	2464.292	2599.693	2735.093	2870.494	3005.895
4000	1706.048	1841.448	1976.849	2112.25	2247.65	2383.051	2518.452	2653.853	2789.253	2924.654	3060.055	3195.455	3330.856
5000	2031.009	2166.41	2301.81	2437.211	2572.612	2708.013	2843.413	2978.814	3114.215	3249.615	3385.016	3520.417	3655.818
6000	2355.97	2491.371	2626.772	2762.172	2897.573	3032.974	3168.375	3303.775	3439.176	3574.577	3709.977	3845.378	3980.779
7000	2680.932	2816.332	2951.733	3087.134	3222.535	3357.935	3493.336	3628.737	3764.137	3899.538	4034.939	4170.34	4305.74
8000	3005.893	3141.294	3276.694	3412.095	3547.496	3682.897	3818.297	3953.698	4089.099	4224.499	4359.9	4495.301	4630.702
9000	3330.854	3466.255	3601.656	3737.057	3872.457	4007.858	4143.259	4278.659	4414.06	4549.461	4684.862	4820.262	4955.663
10000	3655.816	3791.216	3926.617	4062.018	4197.419	4332.819	4468.22	4603.621	4739.021	4874.422	5009.823	5145.224	5280.624
11000	3980.777	4116.178	4251.579	4386.979	4522.38	4657.781	4793.181	4928.582	5063.983	5199.384	5334.784	5470.185	5605.586
12000	4305.738	4441.139	4576.54	4711.941	4847.341	4982.742	5118.143	5253.543	5388.944	5524.345	5659.746	5795.146	5930.547
13000	4630.7	4766.101	4901.501	5036.902	5172.303	5307.703	5443.104	5578.505	5713.906	5849.306	5984.707	6120.108	6255.508
14000	4955.661	5091.062	5226.463	5361.863	5497.264	5632.665	5768.065	5903.466	6038.867	6174.268	6309.668	6445.069	6580.47
15000	5280.623	5416.023	5551.424	5686.825	5822.225	5957.626	6093.027	6228.428	6363.828	6499.229	6634.63	6770.03	6905.431
16000	5605.584	5740.985	5876.385	6011.786	6147.187	6282.587	6417.988	6553.389	6688.79	6824.19	6959.591	7094.992	7230.392
17000	5930.545	6065.946	6201.347	6336.747	6472.148	6607.549	6742.95	6878.35	7013.751	7149.152	7284.552	7419.953	7555.354
18000	6255.507	6390.907	6526.308	6661.709	6797.11	6932.51	7067.911	7203.312	7338.712	7474.113	7609.514	7744.914	7880.315
19000	6580.468	6715.869	6851.269	6986.67	7122.071	7257.472	7392.872	7528.273	7663.674	7799.074	7934.475	8069.876	8205.277
20000	6905.429	7040.83	7176.231	7311.632	7447.032	7582.433	7717.834	7853.234	7988.635	8124.036	8259.437	8394.837	8530.238
21000	7230.391	7365.791	7501.192	7636.593	7771.994	7907.394	8042.795	8178.196	8313.596	8448.997	8584.398	8719.799	8855.199

	6.4	6.8	7.2	7.6	8	8.4	8.8	9.2	9.6	10	10.4	10.8	11.2
1000	2491.373	2626.773	2762.174	2897.575	3032.976	3168.376	3303.777	3439.178	3574.578	3709.979	3845.38	3980.781	4116.181
2000	2816.334	2951.735	3087.136	3222.536	3357.937	3493.338	3628.738	3764.139	3899.54	4034.941	4170.341	4305.742	4441.143
3000	3141.295	3276.696	3412.097	3547.498	3682.898	3818.299	3953.7	4089.1	4224.501	4359.902	4495.303	4630.703	4766.104
4000	3466.257	3601.658	3737.058	3872.459	4007.86	4143.26	4278.661	4414.062	4549.463	4684.863	4820.264	4955.665	5091.065
5000	3791.218	3926.619	4062.02	4197.42	4332.821	4468.222	4603.622	4739.023	4874.424	5009.825	5145.225	5280.626	5416.027
6000	4116.18	4251.58	4386.981	4522.382	4657.782	4793.183	4928.584	5063.985	5199.385	5334.786	5470.187	5605.587	5740.988
7000	4441.141	4576.542	4711.942	4847.343	4982.744	5118.145	5253.545	5388.946	5524.347	5659.747	5795.148	5930.549	6065.949
8000	4766.102	4901.503	5036.904	5172.304	5307.705	5443.106	5578.507	5713.907	5849.308	5984.709	6120.109	6255.51	6390.911
9000	5091.064	5226.464	5361.865	5497.266	5632.667	5768.067	5903.468	6038.869	6174.269	6309.67	6445.071	6580.472	6715.872
10000	5416.025	5551.426	5686.826	5822.227	5957.628	6093.029	6228.429	6363.83	6499.231	6634.631	6770.032	6905.433	7040.834
11000	5740.986	5876.387	6011.788	6147.189	6282.589	6417.99	6553.391	6688.791	6824.192	6959.593	7094.994	7230.394	7365.795
12000	6065.948	6201.348	6336.749	6472.15	6607.551	6742.951	6878.352	7013.753	7149.153	7284.554	7419.955	7555.356	7690.756
13000	6390.909	6526.31	6661.711	6797.111	6932.512	7067.913	7203.313	7338.714	7474.115	7609.516	7744.916	7880.317	8015.718
14000	6715.87	6851.271	6986.672	7122.073	7257.473	7392.874	7528.275	7663.675	7799.076	7934.477	8069.878	8205.278	8340.679
15000	7040.832	7176.233	7311.633	7447.034	7582.435	7717.835	7853.236	7988.637	8124.038	8259.438	8394.839	8530.24	8665.64
16000	7365.793	7501.194	7636.595	7771.995	7907.396	8042.797	8178.197	8313.598	8448.999	8584.4	8719.8	8855.201	8990.602
17000	7690.755	7826.155	7961.556	8096.957	8232.357	8367.758	8503.159	8638.56	8773.96	8909.361	9044.762	9180.162	9315.563
18000	8015.716	8151.117	8286.517	8421.918	8557.319	8692.719	8828.12	8963.521	9098.922	9234.322	9369.723	9505.124	9640.524
19000	8340.677	8476.078	8611.479	8746.879	8882.28	9017.681	9153.082	9288.482	9423.883	9559.284	9694.684	9830.085	9965.486
20000	8665.639	8801.039	8936.44	9071.841	9207.241	9342.642	9478.043	9613.444	9748.844	9884.245	10019.65	10155.05	10290.45
21000	8990.6	9126.001	9261.401	9396.802	9532.203	9667.604	9803.004	9938.405	10073.81	10209.21	10344.61	10480.01	10615.41

	11.6	12	12.4	12.8	13.2	13.6	14	14.4	14.8	15.2	15.6	16	16.4
1000	4251.582	4386.983	4522.383	4657.784	4793.185	4928.586	5063.986	5199.387	5334.788	5470.188	5605.589	5740.99	5876.391
2000	4576.543	4711.944	4847.345	4982.746	5118.146	5253.547	5388.948	5524.348	5659.749	5795.15	5930.551	6065.951	6201.352
3000	4901.505	5036.905	5172.306	5307.707	5443.108	5578.508	5713.909	5849.31	5984.71	6120.111	6255.512	6390.913	6526.313
4000	5226.466	5361.867	5497.268	5632.668	5768.069	5903.47	6038.87	6174.271	6309.672	6445.073	6580.473	6715.874	6851.275
5000	5551.427	5686.828	5822.229	5957.63	6093.03	6228.431	6363.832	6499.232	6634.633	6770.034	6905.435	7040.835	7176.236
6000	5876.389	6011.79	6147.19	6282.591	6417.992	6553.392	6688.793	6824.194	6959.595	7094.995	7230.396	7365.797	7501.197
7000	6201.35	6336.751	6472.152	6607.552	6742.953	6878.354	7013.754	7149.155	7284.556	7419.957	7555.357	7690.758	7826.159
8000	6526.312	6661.712	6797.113	6932.514	7067.914	7203.315	7338.716	7474.117	7609.517	7744.918	7880.319	8015.719	8151.12
9000	6851.273	6986.674	7122.074	7257.475	7392.876	7528.276	7663.677	7799.078	7934.479	8069.879	8205.28	8340.681	8476.081
10000	7176.234	7311.635	7447.036	7582.436	7717.837	7853.238	7988.639	8124.039	8259.44	8394.841	8530.241	8665.642	8801.043
11000	7501.196	7636.596	7771.997	7907.398	8042.799	8178.199	8313.6	8449.001	8584.401	8719.802	8855.203	8990.603	9126.004
12000	7826.157	7961.558	8096.958	8232.359	8367.76	8503.161	8638.561	8773.962	8909.363	9044.763	9180.164	9315.565	9450.966
13000	8151.118	8286.519	8421.92	8557.321	8692.721	8828.122	8963.523	9098.923	9234.324	9369.725	9505.126	9640.526	9775.927
14000	8476.08	8611.48	8746.881	8882.282	9017.683	9153.083	9288.484	9423.885	9559.285	9694.686	9830.087	9965.488	10100.89
15000	8801.041	8936.442	9071.843	9207.243	9342.644	9478.045	9613.445	9748.846	9884.247	10019.65	10155.05	10290.45	10425.85
16000	9126.002	9261.403	9396.804	9532.205	9667.605	9803.006	9938.407	10073.81	10209.21	10344.61	10480.01	10615.41	10750.81
17000	9450.964	9586.365	9721.765	9857.166	9992.567	10127.97	10263.37	10398.77	10534.17	10669.57	10804.97	10940.37	11075.77
18000	9775.925	9911.326	10046.73	10182.13	10317.53	10452.93	10588.33	10723.73	10859.13	10994.53	11129.93	11265.33	11400.73
19000	10100.89	10236.29	10371.69	10507.09	10642.49	10777.89	10913.29	11048.69	11184.09	11319.49	11454.89	11590.29	11725.7
20000	10425.85	10561.25	10696.65	10832.05	10967.45	11102.85	11238.25	11373.65	11509.05	11644.45	11779.86	11915.26	12050.66
21000	10750.81	10886.21	11021.61	11157.01	11292.41	11427.81	11563.21	11698.61	11834.01	11969.42	12104.82	12240.22	12375.62

What-if analysis 3

Annual Demand (D)

Order Cost

	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000	16000	17000	18000	19000	20000
100	5022.135	5169.845	5317.555	5465.264	5612.974	5760.684	5908.394	6056.103	6203.813	6351.523	6499.232	6646.942	6794.652	6942.362	7090.071	7237.781	7385.491	7533.2	7680.91	7828.62
120	5051.677	5228.929	5406.181	5583.432	5760.684	5937.936	6115.187	6292.439	6469.691	6646.942	6824.194	7001.445	7178.697	7355.949	7533.2	7710.452	7887.704	8064.955	8242.207	8419.459
140	5081.219	5288.013	5494.806	5701.6	5908.394	6115.187	6321.981	6528.774	6735.568	6942.362	7149.155	7355.949	7562.742	7769.536	7976.33	8183.123	8389.917	8596.71	8803.504	9010.298
160	5110.761	5347.097	5583.432	5819.768	6056.103	6292.439	6528.774	6765.11	7001.445	7237.781	7474.117	7710.452	7946.788	8183.123	8419.459	8655.794	8892.13	9128.465	9364.801	9601.136
180	5140.303	5406.181	5672.058	5937.936	6203.813	6469.691	6735.568	7001.445	7267.323	7533.2	7799.078	8064.955	8330.833	8596.71	8862.588	9128.465	9394.343	9660.22	9926.098	10191.98
200	5169.845	5465.264	5760.684	6056.103	6351.523	6646.942	6942.362	7237.781	7533.2	7828.62	8124.039	8419.459	8714.878	9010.298	9305.717	9601.136	9896.556	10191.98	10487.39	10782.81
220	5199.387	5524.348	5849.31	6174.271	6499.232	6824.194	7149.155	7474.117	7799.078	8124.039	8449.001	8773.962	9098.923	9423.885	9748.846	10073.81	10398.77	10723.73	11048.69	11373.65
240	5228.929	5583.432	5937.936	6292.439	6646.942	7001.445	7355.949	7710.452	8064.955	8419.459	8773.962	9128.465	9482.969	9837.472	10191.98	10546.48	10900.98	11255.49	11609.99	11964.49
260	5258.471	5642.516	6026.561	6410.607	6794.652	7178.697	7562.742	7946.788	8330.833	8714.878	9098.923	9482.969	9867.014	10251.06	10635.1	11019.15	11403.19	11787.24	12171.29	12555.33
280	5288.013	5701.6	6115.187	6528.774	6942.362	7355.949	7769.536	8183.123	8596.71	9010.298	9423.885	9837.472	10251.06	10664.65	11078.23	11491.82	11905.41	12319	12732.58	13146.17
300	5317.555	5760.684	6203.813	6646.942	7090.071	7533.2	7976.33	8419.459	8862.588	9305.717	9748.846	10191.98	10635.1	11078.23	11521.36	11964.49	12407.62	12850.75	13293.88	13737.01
320	5347.097	5819.768	6292.439	6765.11	7237.781	7710.452	8183.123	8655.794	9128.465	9601.136	10073.81	10546.48	11019.15	11491.82	11964.49	12437.16	12909.83	13382.5	13855.18	14327.85
340	5376.639	5878.852	6381.065	6883.278	7385.491	7887.704	8389.917	8892.13	9394.343	9896.556	10398.77	10900.98	11403.19	11905.41	12407.62	12909.83	13412.05	13914.26	14416.47	14918.69
360	5406.181	5937.936	6469.691	7001.445	7533.2	8064.955	8596.71	9128.465	9660.22	10191.98	10723.73	11255.49	11787.24	12319	12850.75	13382.5	13914.26	14446.01	14977.77	15509.52
380	5435.723	5997.019	6558.316	7119.613	7680.91	8242.207	8803.504	9364.801	9926.098	10487.39	11048.69	11609.99	12171.29	12732.58	13293.88	13855.18	14416.47	14977.77	15539.07	16100.36
400	5465.264	6056.103	6646.942	7237.781	7828.62	8419.459	9010.298	9601.136	10191.98	10782.81	11373.65	11964.49	12555.33	13146.17	13737.01	14327.85	14918.69	15509.52	16100.36	16691.2
420	5494.806	6115.187	6735.568	7355.949	7976.33	8596.71	9217.091	9837.472	10457.85	11078.23	11698.61	12319	12939.38	13559.76	14180.14	14800.52	15420.9	16041.28	16661.66	17282.04
440	5524.348	6174.271	6824.194	7474.117	8124.039	8773.962	9423.885	10073.81	10723.73	11373.65	12023.58	12673.5	13323.42	13973.34	14623.27	15273.19	15923.11	16573.03	17222.96	17872.88
460	5553.89	6233.355	6912.82	7592.284	8271.749	8951.214	9630.678	10310.14	10989.61	11669.07	12348.54	13028	13707.47	14386.93	15066.4	15745.86	16425.32	17104.79	17784.25	18463.72
480	5583.432	6292.439	7001.445	7710.452	8419.459	9128.465	9837.472	10546.48	11255.49	11964.49	12673.5	13382.5	14091.51	14800.52	15509.52	16218.53	16927.54	17636.54	18345.55	19054.56

Figure 8 3 What-if Analysis tables in Excel.

What-if analysis is a powerful tool used in decision-making to evaluate how changes in key parameters affect outcomes. In inventory management, understanding the sensitivity of total cost to variations in model parameters such as order cost, holding cost, and annual demand is crucial for effective planning. This section details the use of two-way tables in Excel to conduct what-if analyses and study the impact on total cost.

Methodology

Two-way tables in Excel were utilized to explore the sensitivity of total cost to changes in order cost, holding cost, and annual demand. Each table examines the interaction between two variables while keeping other parameters constant.

Analysis 1: Sensitivity to Order Cost and Holding Cost

This analysis examines how changes in order cost and holding cost affect the total cost. The table is structured with order cost values in the rows and holding cost values in the columns.

Key Observations:

- **Order Cost**: Ranges from 100 to 500.
- **Holding Cost**: Ranges from 1.2 to 16.4.
- **Total Cost**: Calculated for each combination of order cost and holding cost.

Insights:

- As the holding cost increases, the total cost also increases for any given order cost.
- The total cost is highly sensitive to changes in holding cost compared to changes in order cost.
- For instance, at an order cost of 220 and holding cost of 14, the total cost is minimized at $9,748.85.

Analysis 2: Sensitivity to Holding Cost and Annual Demand

This analysis explores the effect of varying holding cost and annual demand on the total cost. The table has holding cost values in the columns and annual demand values in the rows.

Key Observations:

- **Holding Cost**: Ranges from 1.2 to 16.4.
- **Annual Demand**: Ranges from 1,000 to 21,000 units.
- **Total Cost**: Computed for each combination of holding cost and annual demand.

Insights:

- Higher holding costs significantly increase the total cost, especially at higher levels of annual demand.
- The impact of annual demand on total cost is more pronounced when holding costs are high.
- For example, at an annual demand of 15,000 units and holding cost of 14, the total cost is $9,748.85.

Analysis 3: Sensitivity to Order Cost and Annual Demand

This analysis focuses on the interaction between order cost and annual demand, and their combined effect on total cost. The table features order cost values in the rows and annual demand values in the columns.

Key Observations:

- **Order Cost**: Ranges from 100 to 500.
- **Annual Demand**: Ranges from 1,000 to 20,000 units.
- **Total Cost**: Determined for each combination of order cost and annual demand.

Insights:

- Increases in annual demand led to higher total costs for all levels of order cost.
- Total cost is less sensitive to changes in order cost compared to changes in annual demand.
- For instance, at an order cost of 220 and annual demand of 15,000 units, the total cost is $9,748.85.

Conclusion

The what-if analyses conducted using two-way tables in Excel provide valuable insights into the sensitivity of total cost to variations in order cost, holding cost, and annual demand. The analyses highlight the following:

- Holding cost has a significant impact on total cost, with higher holding costs leading to substantial increases in total cost.
- Annual demand also greatly influences total cost, particularly when holding costs are high.
- Order cost, while still impactful, has a relatively smaller effect on total cost compared to holding cost and annual demand.

By understanding these sensitivities, businesses can make more informed decisions about inventory management strategies, optimizing order quantities, and controlling costs effectively.

8. In the word document, explain your results and analyses to the vice president of operations.

Executive Summary of the report for the vice president of operations.

The report provides a comprehensive analysis of inventory cost management by classifying essential components into data, uncontrollable inputs, model parameters, and decision variables. The essential data includes an annual demand of 15,000 pieces, a unit cost of $80 per unit, an opportunity cost/holding cost of 18% per unit value, and a cost per order of $220. The uncontrollable input identified is the fixed annual demand of 15,000 units. Model parameters derived from the data include an opportunity cost/holding cost percentage of 18%, leading to a holding cost per unit calculated as $14.4. The Economic Order Quantity (EOQ) is determined to be 677 units using the formula EOQ = $\sqrt{(2DS/H)}$. The decision variables influencing the total inventory cost are the order quantity, set as the EOQ of 677 units, and the number of orders, approximately 22.16 times annually.

The total inventory cost is influenced by holding costs, order costs, and purchase costs. The EOQ model determines the optimal order quantity to minimize these total costs. Key components and definitions in the mathematical model include the annual demand of

15,000 units, an order cost of $220, a holding cost per unit of $14.4, an economic order quantity of 677 units, and 22.16 orders annually. The annual ordering cost (AOC) and annual holding cost (AHC) are calculated using specific formulas. The annual total cost (ATC) is the sum of AOC and AHC, approximately $9748.85.

Verification using Excel Solver involved setting the objective to minimize the total cost (ATC) by changing the order quantity (Q) and ensuring Q is non-negative. The Solver confirmed the annual total cost as $9,748.85 and the EOQ as 677 units. Further, what-if analyses using two-way tables were conducted to study the sensitivity of total cost to changes in order cost, holding cost, and annual demand. The first analysis showed that total cost increases with higher holding costs and is highly sensitive to changes in holding cost. The second analysis indicated that higher holding costs significantly increase the total cost, with the impact of annual demand on total cost being more pronounced when holding costs are high. The third analysis demonstrated that increases in annual demand lead to higher total costs, with total cost being less sensitive to changes in order cost.

In conclusion, the developed mathematical model for total inventory cost integrates key cost components to optimize order quantity and minimize total costs. By using the EOQ model, businesses can balance ordering and holding costs effectively, resulting in cost savings and improved operational efficiency. This model provides a structured approach to maintaining optimal inventory levels, ensuring that ordering and holding costs are managed efficiently.

Recommendations

1. **Optimize Inventory Management**: Implement the EOQ model to determine the optimal order quantity of 677 units. This will minimize total inventory costs, balancing order and holding costs effectively.

2. **Monitor Holding Costs**: Given the high sensitivity of total costs to holding costs, it is crucial to monitor and manage holding costs diligently. This could involve improving storage efficiency, reducing waste, and leveraging better inventory control technologies.

3. **Evaluate Supplier Agreements**: Reevaluate supplier agreements to potentially reduce order costs. Negotiating better terms or consolidating suppliers could lower the fixed costs associated with placing orders, further reducing total inventory costs.

4. **Implement Regular Reviews**: Conduct regular reviews of the EOQ calculations to account for changes in demand, order costs, and holding costs. This ensures that the inventory strategy remains aligned with current business conditions and cost structures.

5. **Leverage Technology**: Invest in advanced inventory management systems that automate order calculations and provide real-time data on inventory levels, costs, and demand patterns. This will enhance decision-making and operational efficiency.

6. **Consider What-If Scenarios**: Regularly perform what-if analyses to understand the impact of potential changes in demand, order costs, and holding costs. This proactive approach will help in preparing for various business scenarios and maintaining cost control.

7. **Train Staff**: Ensure that the staff involved in inventory management are trained in using the EOQ model, Excel Solver, and other relevant tools. Knowledgeable staff can effectively implement the strategies and contribute to reducing overall costs.

By adopting these recommendations, the company can enhance its inventory management practices, achieve significant cost savings, and improve overall operational efficiency.

Part 2:
Completed in R

Question:

Assume that all problem parameters have the same values as those in part I, but that the annual demand has a triangular probability distribution between 13000 and 17000 units with a mode of 15000 units.

1. Perform a simulation consisting of 1000 occurrences and calculate the minimum total cost for each occurrence.

```r
# set seed for reproducibility
set.seed(314)
# Define the triangular distribution parameters for demand
demand_min <- 13000
demand_max <- 17000
demand_mode <- 15000

# Define other constants
holding_cost <- 14.4
order_cost <- 220

# Define function to calculate total inventory cost
total_cost <- function(demand, order_qty) {
  AHC <- (order_qty / 2) * holding_cost
  AOC <- (demand / order_qty) * order_cost
  total_cost <- AHC + AOC
  return(total_cost)
}

# Simulate 1000 occurrences
simulations <- 1000
min_cost <- numeric(simulations)
order_qty <- numeric(simulations)
n_order <- numeric(simulations)
demand_values <- numeric(simulations)

for (i in 1:simulations) {
  demand <- rtriangle(n = 1, a = demand_min, b = demand_max, c = demand_mode)
  demand_values[i] <- demand
  order_qty[i] <- optimize(f = total_cost, interval = c(1, demand), demand = demand)$minimum
  min_cost[i] <- total_cost(demand, order_qty[i])
  n_order[i] <- demand / order_qty[i]
}
```

To address the problem of determining the minimum total cost under the condition of annual demand following a triangular probability distribution, we performed a simulation consisting of 1000 occurrences. The triangular distribution parameters were defined as follows: a minimum demand of 13,000 units, a maximum demand of 17,000 units, and a mode of 15,000 units. The holding cost per unit was set at $14.4, and the order cost was set at $220, maintaining the same values as those in part I of the analysis.

Simulation Methodology

Step 1: Define the Triangular Distribution Parameters

The triangular distribution was characterized by:

- Minimum demand (D_{min}): 13,000 units
- Maximum demand (D_{max}): 17,000 units
- Mode (D_{mode}): 15,000 units

Step 2: Define the Constants

- Holding cost per unit (H): $14.4
- Order cost (S): $220

Step 3: Total Inventory Cost Calculation Function

A function was defined to calculate the total inventory cost (TC) based on the given demand and order quantity. This function incorporates both the annual holding cost (AHC) and the annual ordering cost (AOC), calculated as follows:

- AHC = (Q / 2) * H
- AOC = (D / Q) * S

Where Q is the order quantity and D is the annual demand.

Step 4: Simulation Execution A simulation of 1000 occurrences was executed, with each iteration involving the following steps:

1. Generating a random demand value from the triangular distribution.
2. Determining the order quantity, which minimizes the total cost using the optimize function.
3. Calculating the minimum total cost for the generated demand.
4. Recording the number of orders placed and the minimum total cost.

Results

The simulation results were captured and exported in csv form comprising the following columns:

1. **Simulation**: The occurrence number.
2. **Demand**: The generated annual demand.
3. **Order Quantity**: The optimal order quantity that minimizes the total cost for the given demand.
4. **Number of Orders**: The total number of orders placed annually.
5. **Total Cost**: The minimum total cost calculated for the given demand and order quantity.

```
> summary(simulation_results$TotalCost)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
   9098    9562    9747    9744    9931   10370 
>
> # Estimate the mean minimum cost
> Estimate_min_cost <- mean(min_cost)
> Estimate_min_cost
[1] 9744.368
>
```

Figure 9 Simulation results in R.

The above obtained simulation results provide a comprehensive summary of the total inventory cost across 1000 occurrences, with annual demand characterized by a triangular distribution between 13,000 and 17,000 units, and a mode of 15,000 units. The key statistical measures of the total cost (TC) are as follows:

- **Minimum Total Cost**: The minimum cost observed across the simulations is $9,098. This represents the lowest possible total cost under the given demand conditions and cost parameters.
- **First Quartile (1st Qu.)**: The first quartile value is $9,562. This indicates that 25% of the simulated total costs are below this amount, providing a measure of the lower spread of the cost distribution.
- **Median**: The median total cost is $9,747. This is the middle value in the distribution of total costs, showing that half of the occurrences resulted in a total cost less than or equal to this amount.
- **Mean**: The mean total cost is $9,744. This is the average total cost across all simulations, offering a central tendency measure of the inventory costs.
- **Third Quartile (3rd Qu.)**: The third quartile value is $9,931. This indicates that 75% of the simulated total costs are below this amount, highlighting the upper spread of the cost distribution.
- **Maximum Total Cost**: The maximum cost observed across the simulations is $10,370. This represents the highest possible total cost under the given demand conditions and cost parameters.

Additionally, the estimated mean minimum cost was calculated to be approximately $9,744.37. This estimate is derived from the mean of the minimum costs obtained in each simulation iteration, providing a reliable measure of the expected minimum inventory cost under the specified conditions.

These statistical measures are crucial for understanding the variability and expected range of total inventory costs, allowing for more informed decision-making in inventory management. The results highlight the importance of considering cost fluctuations and demand variability when planning for optimal inventory levels and cost minimization strategies.

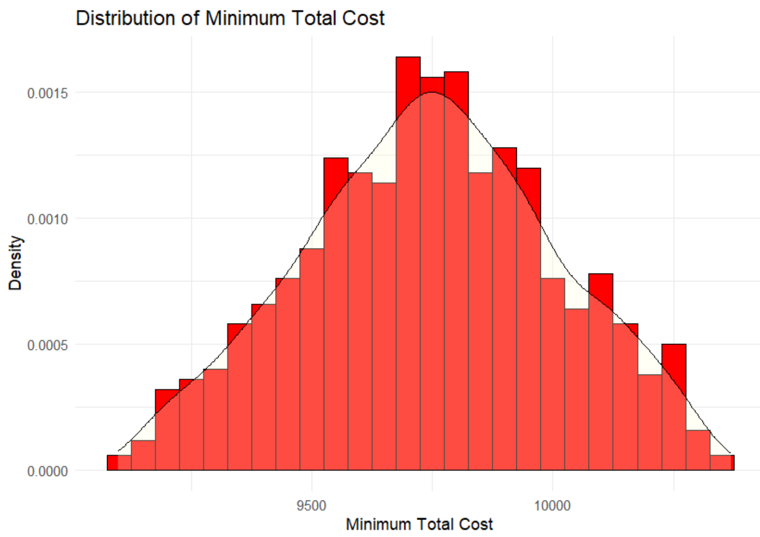


Figure 10 Distribution of Minimum cost simulation.

The attached plot represents the distribution of the minimum total cost obtained from a simulation study. This histogram, overlaid with a density curve, provides a comprehensive view of the frequency and distribution of the minimum total cost values generated from the simulation. The following points summarize the key characteristics and insights derived from the plot:

Histogram and Density Plot

- **Horizontal Axis (X-axis)**: The X-axis represents the minimum total cost values, ranging approximately from 9000 to 10500 units.
- **Vertical Axis (Y-axis)**: The Y-axis represents the density of occurrences of the minimum total cost, facilitating the visualization of the distribution's shape and spread.

Shape and Spread

- **Distribution Shape**: The histogram exhibits a roughly bell-shaped curve, indicating a symmetric distribution centered around the most frequent values of the minimum total cost. The peak of the distribution occurs around the value of 9800 units. There is also a slight right skew in the data.
- **Density Curve**: The overlaid density curve provides a smooth approximation of the distribution, highlighting the central tendency and variability of the minimum total cost values.

Central Tendency and Variability

- **Central Tendency**: The central region of the histogram, where the bars are tallest, suggests that the most frequent minimum total cost values lie between 9500 and 10000 units. This region represents the central tendency of the distribution.
- **Variability**: The spread of the histogram indicates the variability in the minimum total cost values. The density gradually decreases towards the tails of the

distribution, indicating fewer occurrences of extreme values (both lower and higher).

Interpretation

- The bell-shaped curve of the distribution suggests that the minimum total cost values follow a roughly normal distribution. However, further statistical tests (e.g., Kolmogorov-Smirnov test, Shapiro-Wilk test) and goodness-of-fit evaluations are necessary to confirm the exact nature of the distribution.
- The plot indicates that the majority of the simulation outcomes resulted in minimum total costs within a narrow range around the central tendency, implying consistency in the cost minimization process under the simulated conditions.

Question (i)

Use the results of your simulation to:

(i) Estimate the expected minimum total cost by constructing a 95% confidence interval for it and determine the probability distribution that best fits its distribution. Verify the validity of your choice.

```
> cat("Minimum total cost:", Estimate_min_cost, "\n")
Minimum total cost: 9744.368
> cat("95% confidence interval for expected minimum total cost: (", lower, ", ", upper, ")", "\n")
95% confidence interval for expected minimum total cost: ( 9728.07 ,  9760.666 )
>
```

Figure 11 Confidence Intervals of Minimum Cost.

Estimated Minimum Total Cost

The estimated mean minimum total cost from the simulation is $9744.37. Constructing a 95% confidence interval for the expected minimum total cost, we find it to be between $9728.07 and $9760.67. This interval provides a range within which we can be 95% confident that the true mean minimum total cost lies.

Distribution Analysis

Histogram and Density Plot

The histogram of the minimum total cost, along with a density plot, which was described in the previous page, reveals the distribution shape. The plot suggests a roughly symmetric distribution with a peak around the mean value.

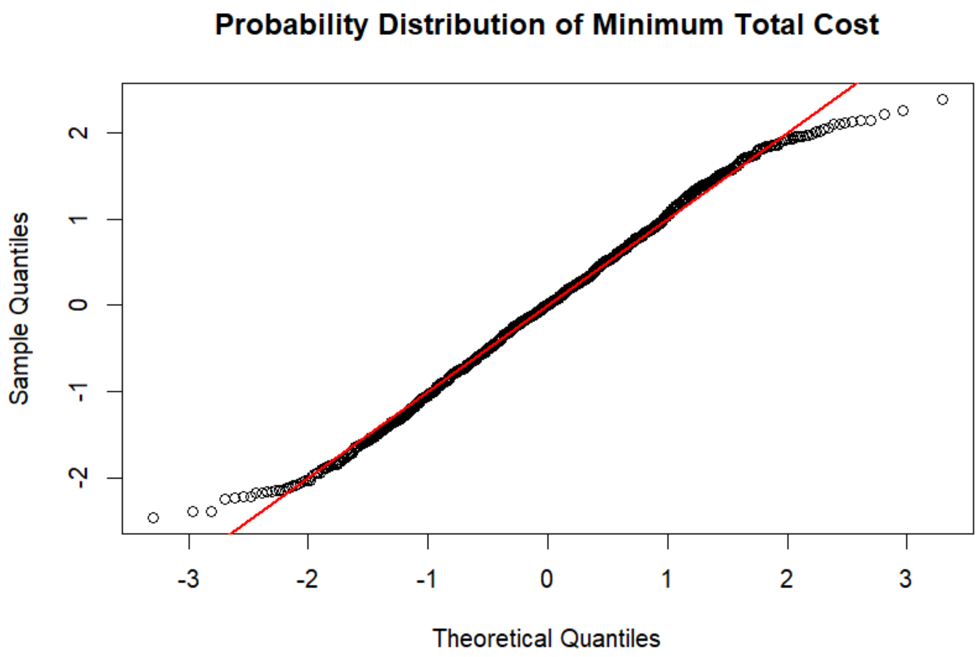


Figure 12 QQ Plot Minimum cost.

Quantile-Quantile (Q-Q) Plot

The Q-Q plot for the normal distribution shows that the data points closely follow the reference line, suggesting that the minimum total cost data is approximately normally distributed. However, the tails show significant discrepancy from the reference line suggesting non-normality at the tails.

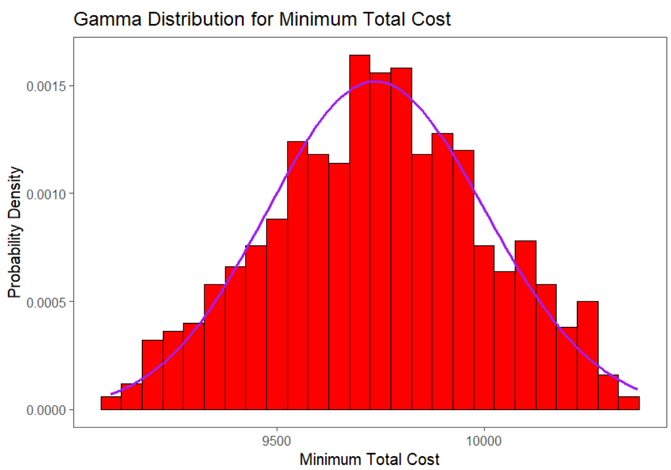


Figure 13 Gamma Distribution nfit on min cost.

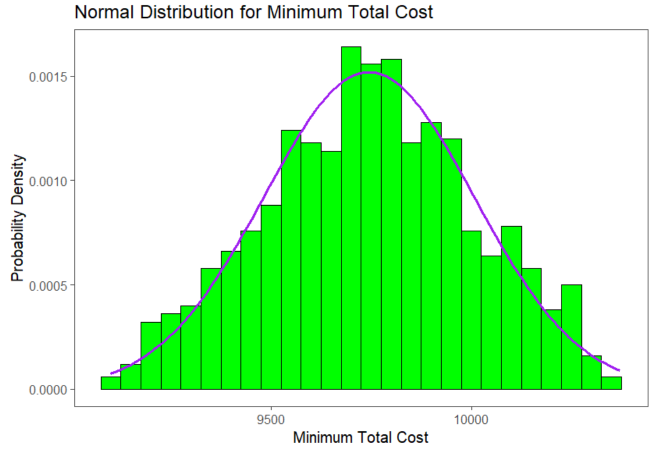


Figure 14 Normal distribution fit on min cost.

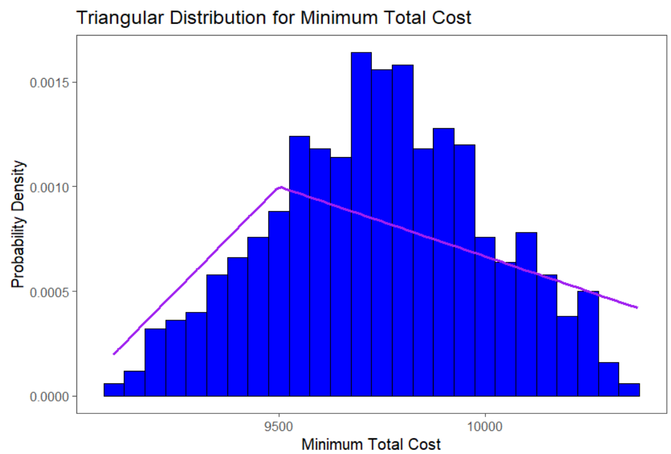


Figure 15 Triangular distribution fit on min total cost.

Probability Distribution Fitting

To determine the best-fitting probability distribution, we fit the Gamma, Normal, and Triangular distributions to the data.

1. **Gamma Distribution**: The histogram with the Gamma distribution overlay shows a good fit, indicating that the Gamma distribution could be a plausible model for the minimum total cost.

2. **Normal Distribution**: The histogram with the Normal distribution overlay appears to fit the data well, except for the fact that the distribution has less thicker tails as compared to the normal distribution.

3. **Triangular Distribution**: The histogram with the Triangular distribution overlay does not fit the data as well as the Gamma and Normal distributions. The triangular fit is less smooth and does not capture the tails of the distribution accurately.

```
> ks_gamma

        Asymptotic one-sample Kolmogorov-Smirnov test

data:  min_cost
D = 0.019673, p-value = 0.8337
alternative hypothesis: two-sided

> ks_normal

        Asymptotic one-sample Kolmogorov-Smirnov test

data:  min_cost
D = 0.020718, p-value = 0.784
alternative hypothesis: two-sided

> ks_tri

        Asymptotic one-sample Kolmogorov-Smirnov test

data:  min_cost
D = 0.1765, p-value < 0.00000000000000022
alternative hypothesis: two-sided

>
> #Shapiro Wilk for normality
> shapiro.test(min_cost)

        Shapiro-Wilk normality test

data:  min_cost
W = 0.99285, p-value = 0.00009551

>
> # compare AIC for Gamma and Normal as KS and Shapiro test results conflict
>
> AIC(fit_gamma)
[1] 13983.55
> AIC(fit_normal)
[1] 13982.43
```

Figure 16 Goodness of fit tests on min cost.

Statistical Tests

To statistically validate the distribution fitting, we performed the Kolmogorov-Smirnov (K-S) test and Shapiro-Wilk test for normality:

1. **Kolmogorov-Smirnov Test**:

    - **Gamma Distribution**: D = 0.019673, p-value = 0.8337

- **Normal Distribution**: D = 0.020718, p-value = 0.784
- **Triangular Distribution**: D = 0.1765, p-value < 0.00000000000000000022

2. **Shapiro-Wilk Test for Normality**:
   - W = 0.99285, p-value = 0.00009551

The K-S test results show high p-values for both the Gamma and Normal distributions, indicating that we cannot reject the hypothesis that the data comes from these distributions. However, the low p-value in the Shapiro-Wilk test for normality indicates that the data is not normally distributed.

Model Comparison Using AIC

The Akaike Information Criterion (AIC) values for the Gamma and Normal distributions are compared:

- **Gamma Distribution AIC**: 13983.55
- **Normal Distribution AIC**: 13982.43

The lower AIC value for the Normal distribution suggests a marginally better fit compared to the Gamma distribution, but the Shapiro-Wilk test indicates that the Normal distribution is not an appropriate model.

Conclusion

While the visual inspection of histograms, density plots, and Q-Q plots suggest that the Normal distribution fits well, the Shapiro-Wilk test results indicate otherwise. Given the high p-value in the K-S test and a reasonably low AIC, the Gamma distribution might be a more appropriate fit for the minimum total cost data. This conclusion is drawn by balancing the test results and the AIC values, indicating that **the Gamma distribution provides a better overall** fit despite the close competition with the Normal distribution. Thus, we conclude that the minimum total cost data can be effectively modeled using a Gamma distribution, providing a reliable estimation of inventory costs under the given simulation conditions.

(ii) Estimate the expected order quantity by constructing a 95% confidence interval for it and determine the probability distribution that best fits its distribution. Verify the validity of your choice.

```
>
> cat("95% confidence interval for expected order quantity: (", lower_oq, ", ", upper_oq, ")", "\n")
95% confidence interval for expected order quantity: ( 675.5604 ,  677.824 )
> Estimate_order_qty <- mean(order_qty)
> cat("Estimate order quantity:", Estimate_order_qty, "\n")
Estimate order quantity: 676.6922
```

Figure 17 Confidence interval for Order Quantity.

Estimating Expected Order Quantity

Simulation Results

To estimate the expected order quantity, a simulation consisting of 1000 occurrences was conducted. The results of the simulation provided the following key metrics:

- Mean Order Quantity: 676.6922 units
- 95% Confidence Interval for Order Quantity: 675.5604 to 677.824 units

These values were derived from the repeated sampling of order quantities based on the given triangular distribution parameters for demand.

Figure 18 Distribution for Order Quantity.

Histogram and PDF Analysis

- **Histogram:**

- The histogram of the order quantity distribution exhibited a bell-shaped curve, suggesting a potential normal distribution.

- **Probability Density Function (PDF) Plot:**
    - The PDF plot further illustrated this observation by showing that the empirical data aligns closely with the theoretical quantiles of a normal distribution.

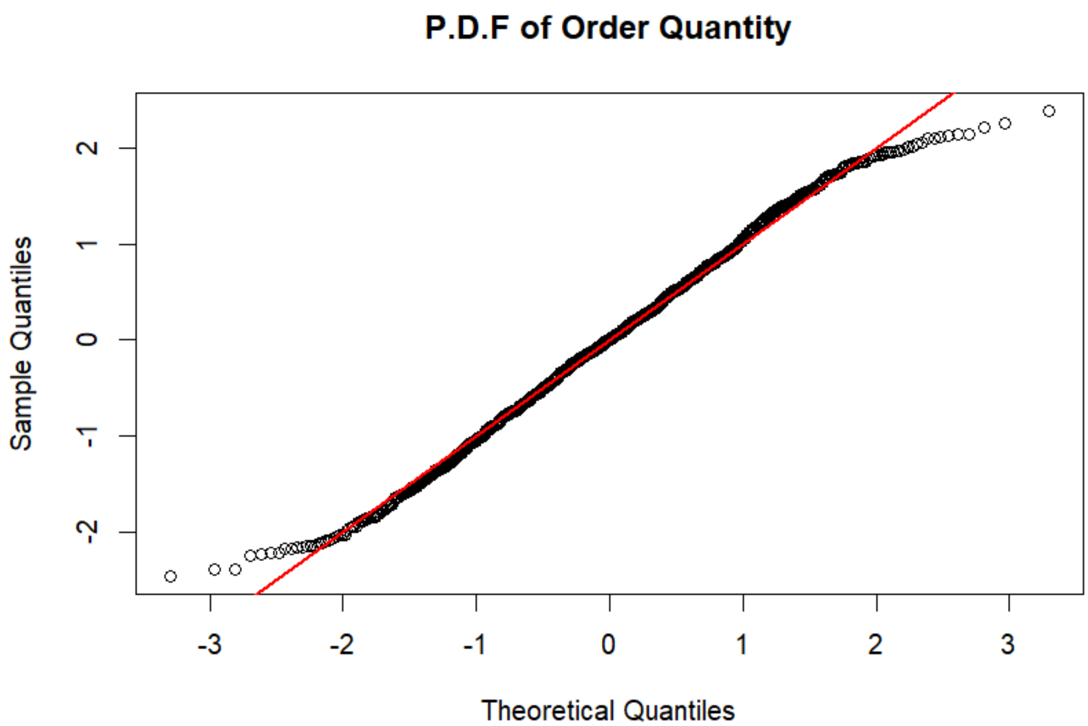


Figure 19 QQ Plot for Order Quantity.

Quantile-Quantile (Q-Q) Plot

- **Q-Q Plot:**
    - The Q-Q plot compared the sample quantiles of the order quantity data to the theoretical quantiles of a normal distribution.
    - The data points closely followed the straight line representing the normal distribution at the middle range while deviating at the extremes.

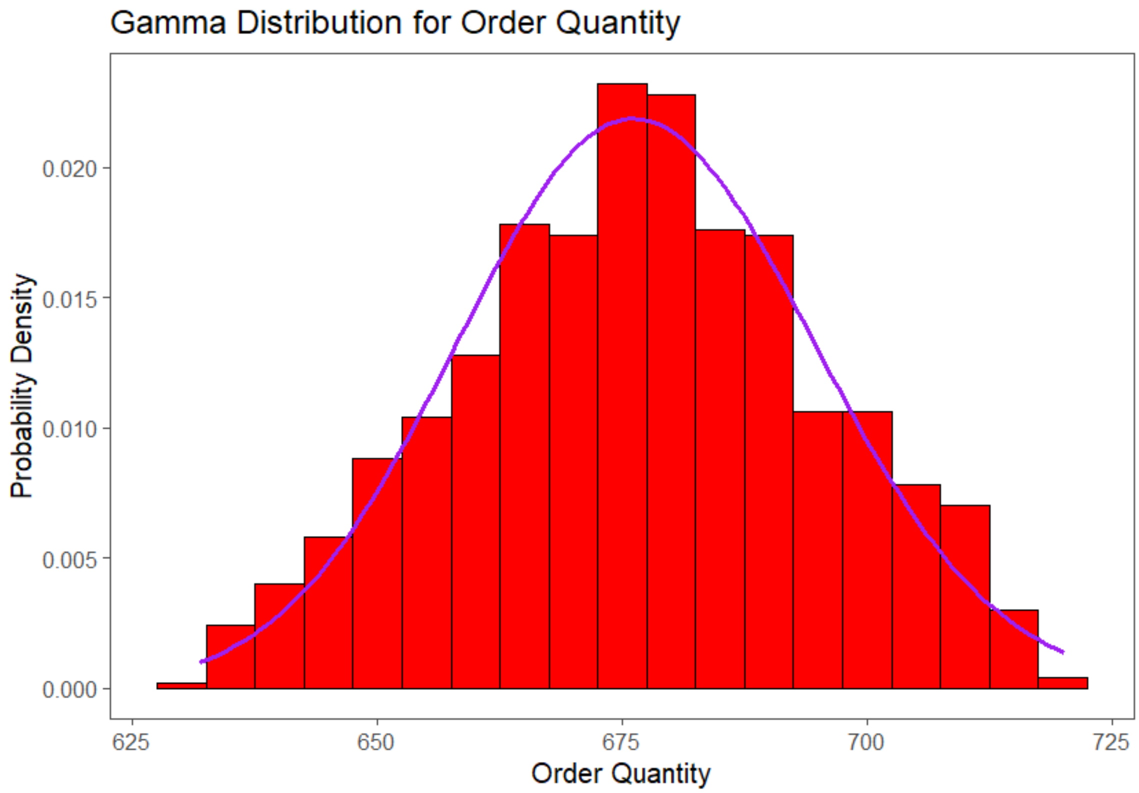


Figure 20 Gamma Distribution fit on Order Quantity.

Fitting Probability Distributions

Gamma Distribution Fit

- **Gamma Distribution Histogram:**
    - The gamma distribution was fitted to the order quantity data, and its fit was visually assessed using a histogram overlayed with the gamma distribution curve.

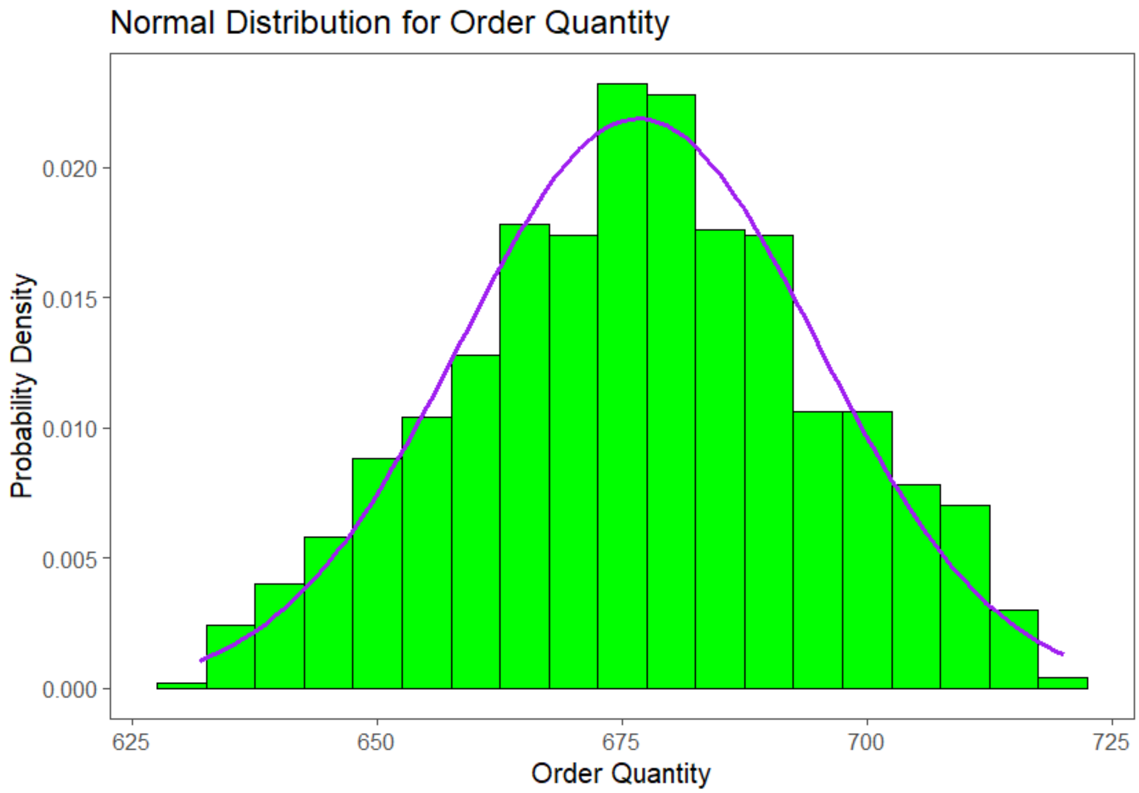


Figure 21 Normal Distribution for Order Quantity.

Normal Distribution Fit

- **Normal Distribution Histogram:**
  - The normal distribution was also fitted to the order quantity data and assessed using a histogram overlayed with the normal distribution curve.

```
> ks_gamma_oq

        Asymptotic one-sample Kolmogorov-Smirnov test

data:  order_qty
D = 0.019673, p-value = 0.8337
alternative hypothesis: two-sided

> ks_normal_oq

        Asymptotic one-sample Kolmogorov-Smirnov test

data:  order_qty
D = 0.020718, p-value = 0.784
alternative hypothesis: two-sided

>
> #Shapiro Wilk
>
> shapiro.test(order_qty)

        Shapiro-Wilk normality test

data:  order_qty
W = 0.99285, p-value = 0.00009551

>
>
> #Comparing AIC
> AIC(fit_gamma_oq)
[1] 8649.098
> AIC(fit_normal_oq)
[1] 8647.977
>
```

Figure 22 Goodness of fit tests for Order Quantity.

Statistical Tests for Goodness-of-fit

- **Kolmogorov-Smirnov (K-S) Test for Gamma distribution:**
  - The K-S test for the gamma distribution yielded a p-value of 0.8337, indicating a good fit.
- **Kolmogorov-Smirnov (K-S) Test for Normal distribution:**

  - The K-S test for the normal distribution yielded a p-value of 0.784, indicating a good fit.

- **Shapiro-Wilk Test:**
  - The Shapiro-Wilk test for normality resulted in a p-value of 0.00009551, suggesting significant deviation from normality.

Model Comparison Using Akaike Information Criterion (AIC)

- **AIC for Gamma Distribution:**
  - The AIC value for the gamma distribution was calculated to be 8649.098.
- **AIC for Normal Distribution:**
  - The AIC value for the normal distribution was slightly lower at 8647.977.

Interpretation and Conclusion

Summary of Findings

- **Mean Order Quantity:** The estimated mean order quantity from the simulation is 676.6922 units, with a 95% confidence interval ranging from 675.5604 to 677.824 units.
- **Distribution Fit:**
  - Both the gamma and normal distributions were found to fit the order quantity data well, based on the K-S test results.
  - The normal distribution, however, showed a slight edge over the gamma distribution in terms of the AIC values, suggesting a marginally better fit.

Validity of Distribution Fit

- **Shapiro-Wilk Test:**
  - Despite the normal distribution fitting well in visual assessments and K-S test results, the Shapiro-Wilk test indicated a significant deviation from normality, which cannot be ignored.
- **AIC Comparison:**
  - The AIC comparison favored the normal distribution, but the difference was minimal, suggesting that both distributions are plausible fits.

Final Recommendation

- **Best Fit Distribution:**
  - Considering the AIC values and visual assessments, the normal distribution appears to provide a good fit for the order quantity data.

- However, given the significant p-value from the Shapiro-Wilk test, it is recommended to consider the gamma distribution as a viable alternative.

In summary, while the normal distribution is suggested by the AIC comparison and visual assessments, the significant deviation indicated by the Shapiro-Wilk test calls for a cautious approach. Both normal and gamma distributions should be considered for modeling the order quantity, with **a preference for the gamma distribution based on the current analysis.**

(iii) Estimate the expected annual number of orders by constructing a 95% confidence interval for it and determine the probability distribution that best fits its distribution. Verify the validity of your choice.

```
95% confidence interval for expected Annual Number of Orders: ( 22.10925 ,  22.18333 )
>
> Estimate_n_order <- mean(n_order)
> cat("Estimate Annual Order Number:", Estimate_n_order, "\n")
Estimate Annual Order Number: 22.14629
>
```

Figure 23 Confidence Interval for Annual Number of Orders.

Estimation of Expected Annual Number of Orders and Fitting Probability Distribution

Confidence Interval for Expected Annual Number of Orders

Using the simulation results, we estimated the expected annual number of orders. A 95% confidence interval for this estimate was constructed to provide a range within which the true expected value lies with a 95% probability. The summary statistics derived from the simulation results are as follows:

- 95% Confidence Interval: [22.10925, 22.18333]
- Estimate of Expected Annual Number of Orders: 22.14629

This confidence interval suggests that, based on the simulation, the expected annual number of orders is very likely to fall between approximately 22.11 and 22.18 orders per year.

Distribution Analysis

To determine the best-fitting probability distribution for the annual number of orders, we compared the observed data against theoretical distributions using several diagnostic tools, including probability density functions (PDFs), quantile-quantile (Q-Q) plots, and statistical goodness-of-fit tests.

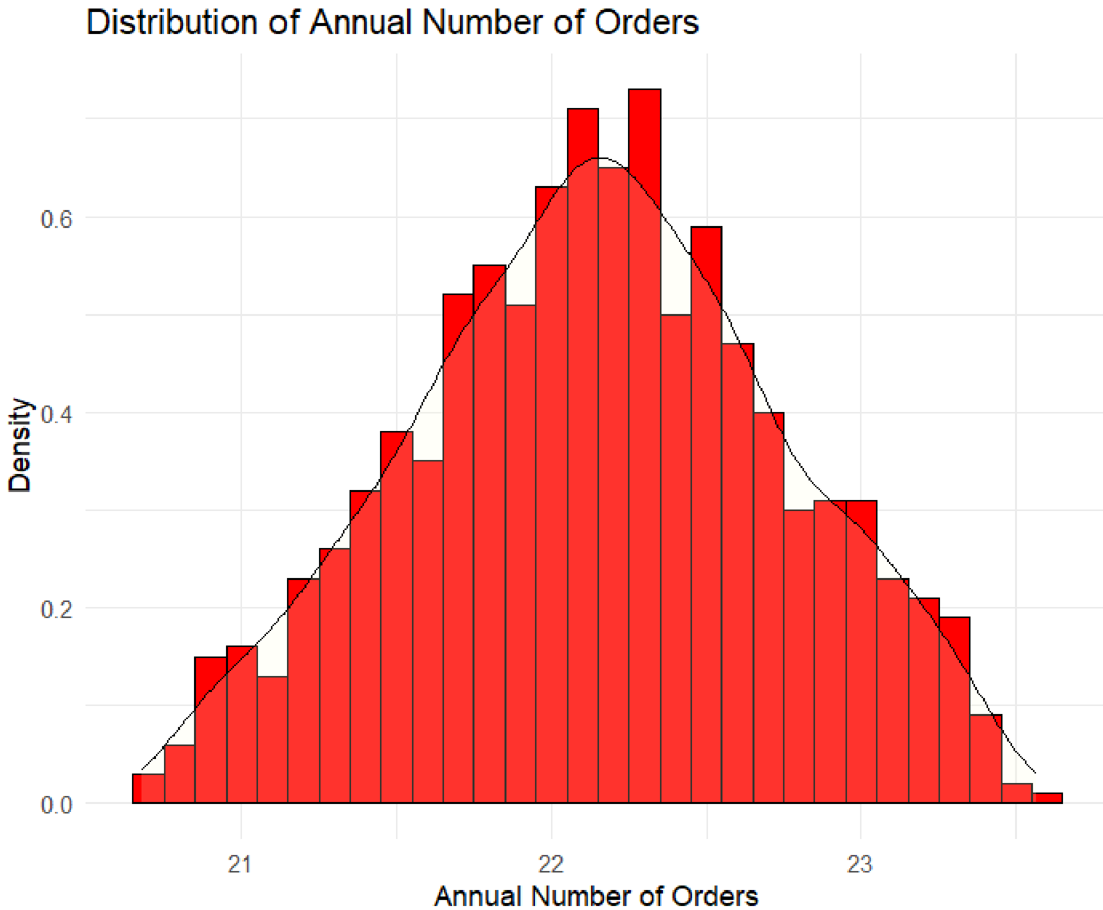


Figure 24 Distribution of Annual Number of Orders.

1. **Histogram and Density Plot:**
   - The above histogram of the simulated annual number of orders overlaid with the estimated density curve shows a roughly symmetric distribution centered around 22 orders per year.

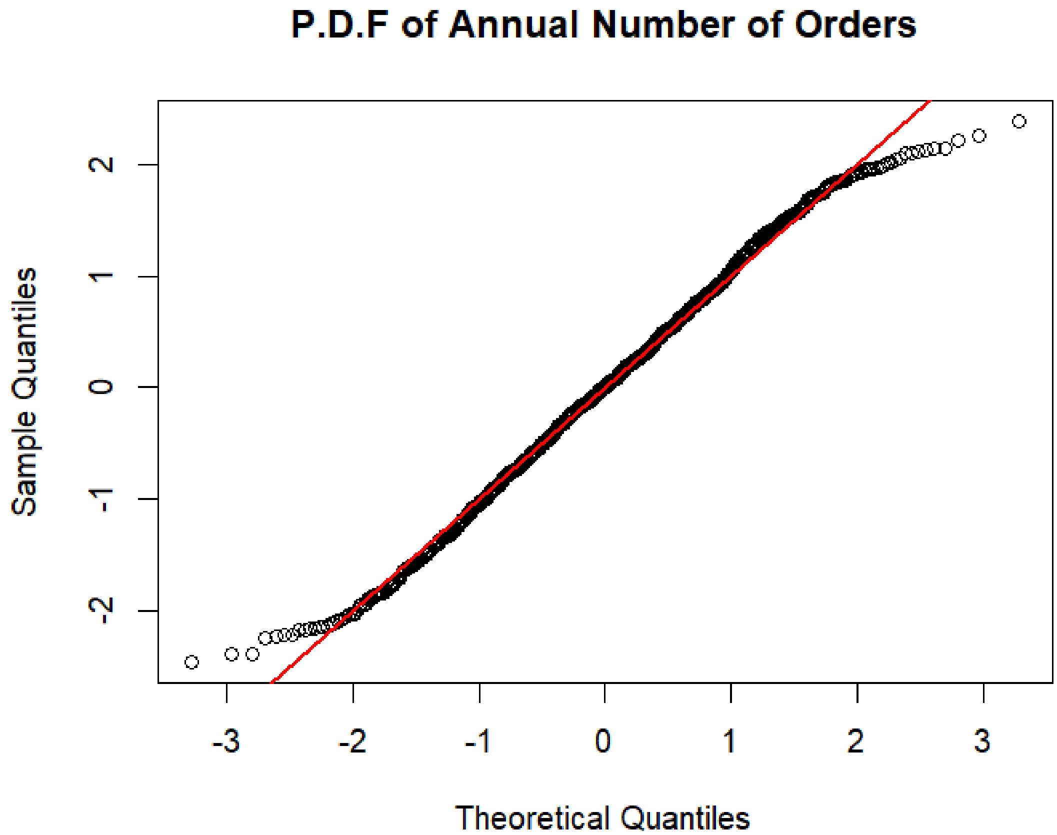
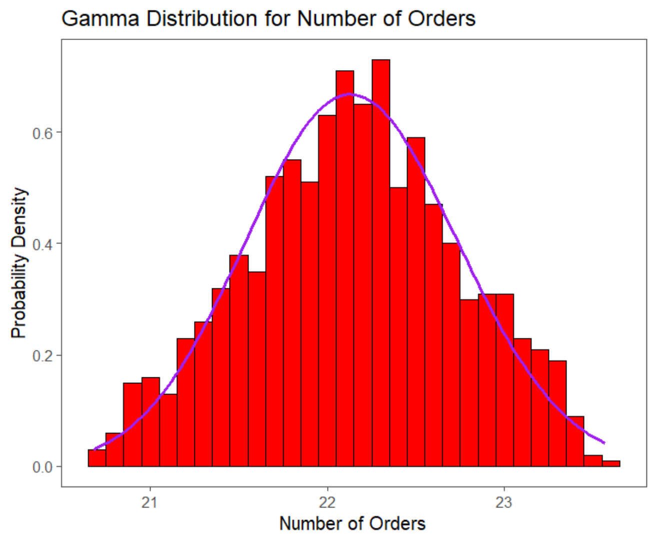


Figure 25 QQ Plot of Annual Number of Orders.

1. **Q-Q Plot:**

   - The Q-Q plot compares the quantiles of the observed data with the quantiles of a normal distribution. The points closely follow the 45-degree line, suggesting that the distribution of the annual number of orders approximates a normal distribution at the middle. However, tails deviate at both ends suggesting caution while fitting a normal distribution.



○

Figure 26 Gamma Distribution fit on Annual Number of Orders.

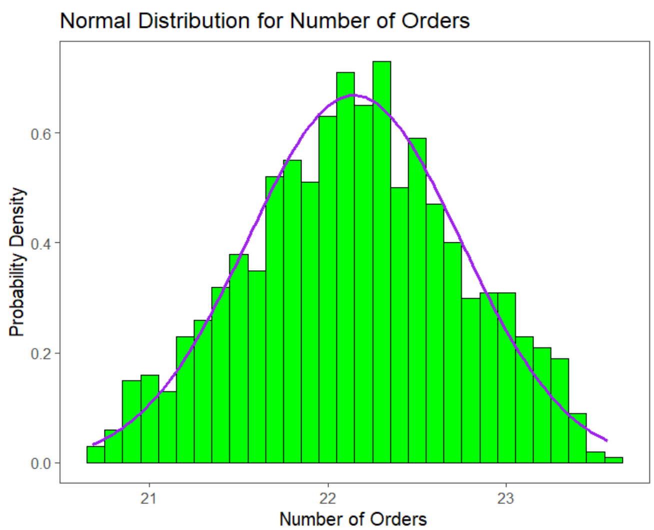


Figure 27 Normal Distribution fit on Annual Number of Orders.

1. **Gamma and Normal Distributions:**

   - Both gamma and normal distributions were fitted to the data. The fit was evaluated using visual inspection of density plots

   - Both Gamma and Normal distributions seem to be reasonably good fits for the data. However, as noted earlier the QQ Plot recommends a preference for the Gamma distribution as the ends in the QQ Plot deviated from the reference line.

```
> ks_gamma_no

        Asymptotic one-sample Kolmogorov-Smirnov test

data:  n_order
D = 0.019673, p-value = 0.8337
alternative hypothesis: two-sided

> ks_normal_no

        Asymptotic one-sample Kolmogorov-Smirnov test

data:  n_order
D = 0.020719, p-value = 0.7839
alternative hypothesis: two-sided

> 
> #Shapiro Wilk test
> 
> shapiro.test(n_order)

        Shapiro-Wilk normality test

data:  n_order
W = 0.99285, p-value = 0.00009551

> 
> #AIC Comparison
> AIC(fit_gamma_no)
[1] 1810.003
> AIC(fit_normal_no)
[1] 1808.882
> 
```

Figure 28 Goodness of Fit tests for Annual Number of Orders.

Goodness-of-Fit Tests

To formally test the fit of the gamma and normal distributions, we used the Kolmogorov-Smirnov (KS) test and the Shapiro-Wilk test.

- **Kolmogorov-Smirnov Test**:
    - Gamma Distribution: KS statistic = 0.019673, p-value = 0.8337
    - Normal Distribution: KS statistic = 0.020719, p-value = 0.7839
    - Both p-values are greater than 0.05, indicating no significant difference between the sample distribution and the theoretical distributions.
- **Shapiro-Wilk Test:**
    - Normal Distribution: W = 0.99285, p-value = 0.00009551
    - The low p-value indicates that the data deviates from a perfect normal distribution. The Shapiro-Wilk test is particularly sensitive to deviations from normality in large sample sizes, which suggests that the normal distribution may not be the best fit despite visual indications.

- **Akaike Information Criterion (AIC):**
  - Gamma Distribution: AIC = 1810.003
  - Normal Distribution: AIC = 1808.882
  - The AIC values suggest that the normal distribution provides a slightly better fit to the data compared to the gamma distribution, as indicated by the lower AIC value.

Conclusion

While the AIC values suggest that the normal distribution provides a slightly better fit, the significantly low p-value from the Shapiro-Wilk test indicates a deviation from normality that cannot be ignored. The Kolmogorov-Smirnov test for the gamma distribution shows a higher p-value compared to the normal distribution, suggesting that the gamma distribution may be a more suitable model for the annual number of orders.

Considering the sensitivity of the Shapiro-Wilk test and the higher p-value of the KS test for the gamma distribution, we conclude that the gamma distribution is preferred for modeling the annual number of orders. This conclusion is supported by:

- Visual inspection: The histogram and Q-Q plots suggest a good fit for the gamma distribution.
- Goodness-of-fit tests: The KS test indicates no significant difference for the gamma distribution, and the Shapiro-Wilk test suggests deviation from normality.

Therefore, for practical purposes and based on the evidence provided, the gamma distribution is chosen as the best fit for the annual number of orders. This allows us to make reliable predictions and inferential statistics regarding the ordering process in inventory management.

Recommendations

To address the problem of determining the minimum total cost under the condition of annual demand following a triangular probability distribution, we conducted a simulation with 1000 occurrences. The triangular distribution parameters were set with a minimum demand of 13,000 units, a maximum demand of 17,000 units, and a mode of 15,000 units. The holding cost per unit was $14.4, and the order cost was $220, consistent with the values used in part I of the analysis.

In the simulation, the triangular distribution was defined with minimum, maximum, and mode values of 13,000 units, 17,000 units, and 15,000 units, respectively. The total inventory cost was calculated using a function that incorporated both the annual holding cost and the annual ordering cost. The annual holding cost was computed as (Q / 2) * H, while the annual ordering cost was calculated as (D / Q) * S, where Q represents the order quantity and D denotes the annual demand.

The simulation was executed in 1000 iterations, where each iteration involved generating a random demand value from the triangular distribution, determining the order quantity that minimized the total cost using the optimize function, calculating the minimum total cost for the generated demand, and recording the number of orders placed and the minimum total cost. The results of the simulation were captured in a CSV file, which included the occurrence number, generated annual demand, optimal order quantity, total number of orders placed annually, and the minimum total cost for each iteration.

The key statistical measures derived from the simulation results included the minimum total cost, first quartile, median, mean, third quartile, and maximum total cost. The minimum total cost observed across the simulations was $9,098, representing the lowest possible total cost under the given demand conditions and cost parameters. The first quartile value was $9,562, indicating that 25% of the simulated total costs were below this amount. The median total cost was $9,747, showing that half of the occurrences resulted in a total cost less than or equal to this amount. The mean total cost was $9,744, offering a central tendency measure of the inventory costs. The third quartile value was $9,931, highlighting the upper spread of the cost distribution, and the maximum total cost observed was $10,370, representing the highest possible total cost under the given conditions.

Additionally, the estimated mean minimum cost was approximately $9,744.37, providing a reliable measure of the expected minimum inventory cost under the specified conditions. These statistical measures are crucial for understanding the variability and expected range of total inventory costs, aiding in more informed decision-making in inventory management.

To estimate the expected minimum total cost, a 95% confidence interval was constructed, resulting in a range between $9728.07 and $9760.67. The distribution analysis involved fitting Gamma, Normal, and Triangular distributions to the data. The Gamma and Normal distributions showed a good fit, with high p-values in the Kolmogorov-Smirnov test, indicating no significant difference from the sample distribution. However, the Shapiro-Wilk test for normality showed a low p-value, suggesting a deviation from normality.

Comparing the Akaike Information Criterion (AIC) values for the Gamma and Normal distributions, the Normal distribution had a slightly lower AIC, indicating a marginally better fit. Despite this, the Gamma distribution was considered more appropriate due to the Shapiro-Wilk test results. Thus, the Gamma distribution provides a more reliable model for the minimum total cost data, balancing the test results and AIC values.
Similarly, Confidence intervals were constructed for Order Quantity and Number of Orders. The 95% confidence interval for the expected annual number of orders is given as (22.10925,22.18333). This interval suggests that we are 95% confident that the true mean annual number of orders lies within this range. It means if we were to take many samples and compute a confidence interval for each, approximately 95% of those intervals would contain the true mean annual number of orders. Similarly, the 95% confidence interval for the expected order quantity is given as (675.5604,677.824). This interval indicates that we are 95% confident that the true mean order quantity falls within this range. This implies that if we repeated the sampling process numerous times, 95% of the calculated confidence intervals would encompass the actual mean order quantity. In both cases, the mean values (22.14629 for the annual number of orders and 676.6922 for the order quantity) are point estimates derived from the sample data. The confidence intervals provide a range of values that likely include the population means, accounting for the variability and uncertainty inherent in sample data.

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