ALY6015: Introduction to Enterprise Analytics

Module 4: Decision Modeling

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Introduction

Since inventory represents a sizable investment, managing it is essential for any business. To reduce overall inventory costs, managers must decide how much additional inventory to order or produce and when to order or produce it. Holding costs and ordering costs make up total inventory costs. While ordering costs are incurred when replenishing inventory and include overhead, clerical work, and transportation costs, holding costs are related to maintaining inventory and include storage, warehousing, and inventory-related expenses. Holding costs are measured in terms of dollars per unit of inventory and per unit of time and are based on the quantity of items kept and the length of time they are kept. In contrast, ordering costs, which are expressed in terms of dollars per order, are not based on the quantity of items ordered but rather on the total number of orders. Insufficient inventory can result in business failure, while excess inventory can have a negative impact on financial and operational management. To reduce overall inventory costs, effective inventory management involves achieving the ideal balance between ordering and holding costs. To ensure the financial stability and operational effectiveness of their businesses, organizations must carefully evaluate their inventory costs and balance the risks of stockouts and excess inventory.

Analysis

Part-1

From the Figure 1, it can be observed that the Annual Demand cannot be controlled by the Organization and hence it is an Uncontrollable Input. The Unit Cost, Carrying Cost Rate and Order Cost are the given parameters for further operations. The Order Quantity (Q), Inventory per Order (Q/2) and Number of Times to Order (N) are the decision variables which can be further used to provide Annual Ordering Cost, Holding Cost and Total Cost. The Order Quantity (Q) is 818, the Inventory per Order (Q/2) is 430.52 and the Number of Times to Order (N) is 20, which is observed in figure 1.

Annual Demand	**16500**	**Uncontrolable Input**
Unit cost	**$79.00**	**Parameter**
Carrying cost rate	**12.5%**	**Parameter**
Order cost	**$200.00**	**Parameter**
Holding Cost	**$9.88**	
Order Quantity Q	**818**	**Decision variable**
Inventory per Order Q/2	**430.5263158**	**Decision variable**
Number of Times to Order N	**20.17114914**	**Decision variable**

Fig. 1

In Figure 2, the Annual Ordering Cost, Annual Holding Cost, and Total Cost can be seen at $4034.23, $4038.88, and $8073.10, respectively. These costs are meant to be minimized for the Organization to spend as little as possible.

Annual Ordering Cost = Annual Demand * Order Cost / Order Quantity	**$4,034.23**	
Annual Holding Cost (Opportunity Cost) = Order Quantity * Holding Cost / 2	**$4,038.88**	
Total Cost = Ordering Cost + Holding Cost	**$8,073.10**	**Objective: To be Minimized**

Fig. 2

After the implementation of Model in R, the Economic Order Quantity and Reorder Point has been determined at 817.53 and 1553.3 respectively. The Annual Order Cost, Annual Holding Cost and Total Inventory Cost in both the workbooks are about the same at 4036.5, 4036.5 and 8073.1 respectively, which can be depicted in figure 3.

```
> cat("Economic Order Quantity:", Economic_OQ, "\n")
Economic Order Quantity: 817.5295
> cat("Reorder Point:", Reorder_Point, "\n")
Reorder Point: 1553.306
> cat("Annual Order Cost:", Annual_OC, "\n")
Annual Order Cost: 4036.552
> cat("Annual Holding Cost:", Annual_HC, "\n")
Annual Holding Cost: 4036.552
> cat("Total Inventory Cost:", Total_IC, "\n")
Total Inventory Cost: 8073.103
```

Fig. 3

From the previous figures, the required total cost for Inventory Level is 430.52 and Order Quantity is 818. The Total Cost achieved from Q and 2Q is $8285.42 which can be observed from figure 4. Hence, it can be concluded that the Total Cost by using Data Tables has around $200 difference with the Total Cost by using Mathematical Functions.

Inventory Level Q	Order Quantity (2Q)	Total Cost (C)
421	799.9	$8,282.89
422	801.8	$8,282.99
423	803.7	$8,283.13
424	805.6	$8,283.33
425	807.5	$8,283.56
426	809.4	$8,283.84
427	811.3	$8,284.17
428	813.2	$8,284.54
429	815.1	$8,284.96
$430	**$817.0**	**$8,285.42**
431	818.9	$8,285.92
432	820.8	$8,286.47
433	822.7	$8,287.06
434	824.6	$8,287.69
435	826.5	$8,288.37
436	828.4	$8,289.08

Fig. 4

A line plot of the total cost and order quantity is shown in figure 5. Excel was used to create the graph below. The graph shows that there was a noticeable increase in order quantity at the beginning of total cost, which was around $8283. The significant increase in Order Quantity, however, did not last long, and there was a gradual increase later.

Fig. 5

The figure below is also a Line Plot on Total Cost and Order Quantity done in R. The graph is observed to be like the previous graph done in Excel. This figure 6, also has a similar trend like the previous graph showing significant increase in Order Quantity and then gradual increase further on.

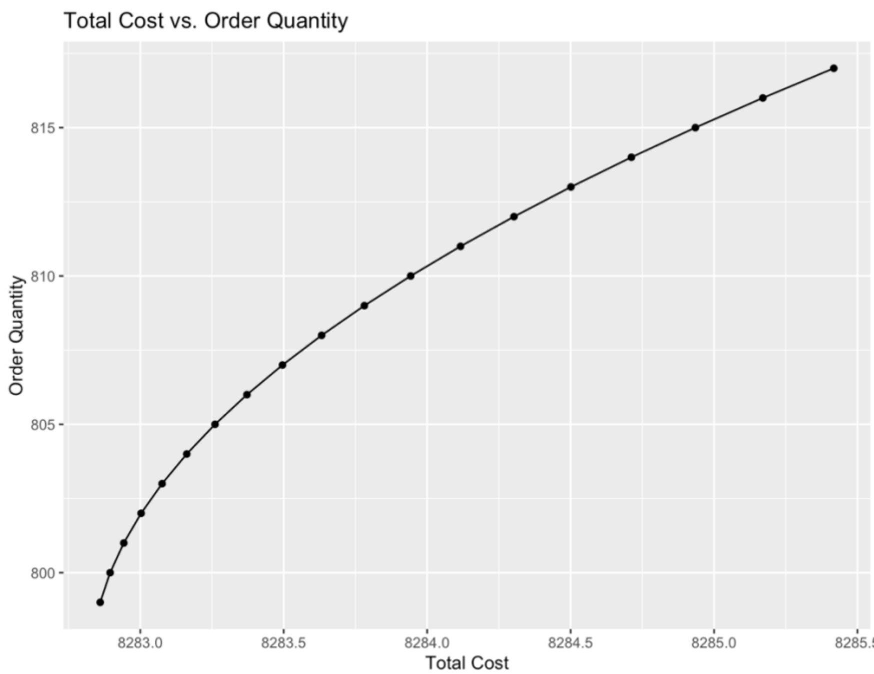

Fig. 6

In the below figure 7, the Excel SOLVER has been utilized for obtaining the values of the decision variables such as Order Quantity, Inventory Per Order and Number of Times to Order (N). The Total Cost of $8073 is been observed in figure 7, representing the summation of Annual Ordering Cost of $4034 and Annual Holding Cost of $4038.

Annual Demand	16500	Uncontrolable Input
Unit cost	$79.00	Parameter
Carrying cost rate	12.5%	Parameter
Order cost	$200.00	Parameter
Holding Cost	$9.88	
Order Quantity Q	818	Decision variable
Inventory per Order Q/2	430.5263158	Decision variable
Number of Times to Order N	20.17114914	Decision variable
Annual Ordering Cost = Annual Demand * Order Cost / Order Quantity	$4,034.23	
Annual Holding Cost (Opportunity Cost) = Order Quantity * Holding Cost / 2	$4,038.88	
Total Cost = Ordering Cost + Holding Cost	$8,073.10	Objective: To be Minimized

Fig. 7

The What-if Analysis was conducted between Carrying Cost Rate and Order Cost to find out the Total Cost which can be observed in figure 8. The highlighted sensitivity analysis has the Carrying Cost Rate of 12.5% and Order Cost as $200, which depicts the Total Cost of 8285.5 in figure 8. The figure below also represents Sensitivity Analysis representing the rest of the values in the Table.

	What-if Analysis							
	160	170	180	190	200	210	220	230
8.5%	6855.425736	6840.761002	6832.692074	6659.441211	6657.251685	6659.232715	6664.81245	6673.513147
9.5%	7247.47574	7231.972355	7223.44198	7040.283197	7037.968457	7040.062779	7045.961609	7055.159883
10.5%	7619.379712	7603.080771	7594.11266	7401.555091	7399.121569	7401.323361	7407.52489	7417.195173
11.5%	7973.956972	7956.89954	7947.514086	7745.995612	7743.448844	7745.753099	7752.243224	7762.363525
12.5%	8313.424828	8295.641226	8285.856214	8075.758682	8285.553584	8075.505844	8082.272267	8092.823411
13.5%	8639.564512	8621.083251	8610.914368	8392.574608	8389.815254	8392.311852	8399.343724	8410.308795
14.5%	8953.832562	8934.679037	8924.140256	8697.858289	8694.998562	8697.585975	8704.873635	8716.237565
15.5%	9257.438098	9237.635117	9226.738989	8992.784278	8989.827585	8992.50273	9000.0375	9011.786756

Fig. 8

Summary: The first part discusses various ways to improve inventory management for a company. The annual demand is a variable that cannot be controlled, whereas unit cost, carrying cost rate, and order cost have set limits. To reduce annual ordering costs, holding costs, and total costs, one can use decision variables like order quantity, inventory per order, and number of orders. R was used to calculate the economic order quantity and reorder point. The total cost obtained by using data tables and mathematical functions differs. The ideal inventory management approach was also determined using line plots and sensitivity analyses. The decision variable values were obtained using Excel Solver. To determine the total cost between carrying cost and order costs, a what-if analysis was done.

Part-2:

The annual demand for the triangular probability distribution between 12000 and 21000 with a mode of 19000. At confidence interval of 95%, the Minimum Total Cost is $8252 to $8277, the Order Quantity is 835 to 838.26 and Annual Number of Orders is from 20.63 to 20.69 which can be observed in figure 9.

```
> cat("Confidence Interval for Minimum Total Cost:", Confidence_C, "\n")
Confidence Interval for Minimum Total Cost: 8252.094 8277.844
> cat("Confidence interval for Order Quantity:", Confidence_OQ, "\n")
Confidence interval for Order Quantity: 835.655 838.2626
> cat("Confidence interval for Annual Number of Orders:", Confidence_AO, "\n")
Confidence interval for Annual Number of Orders: 20.63023 20.69461
```

Fig. 9

After performing a simulation of 5000 occurrences, the Histogram is visualized of the Minimum Total Cost, Order Quantities and Annual Number of Orders in figure 10. It can be observed that the minimum total cost data is skewed to the right and has a long tail by looking at the histogram.

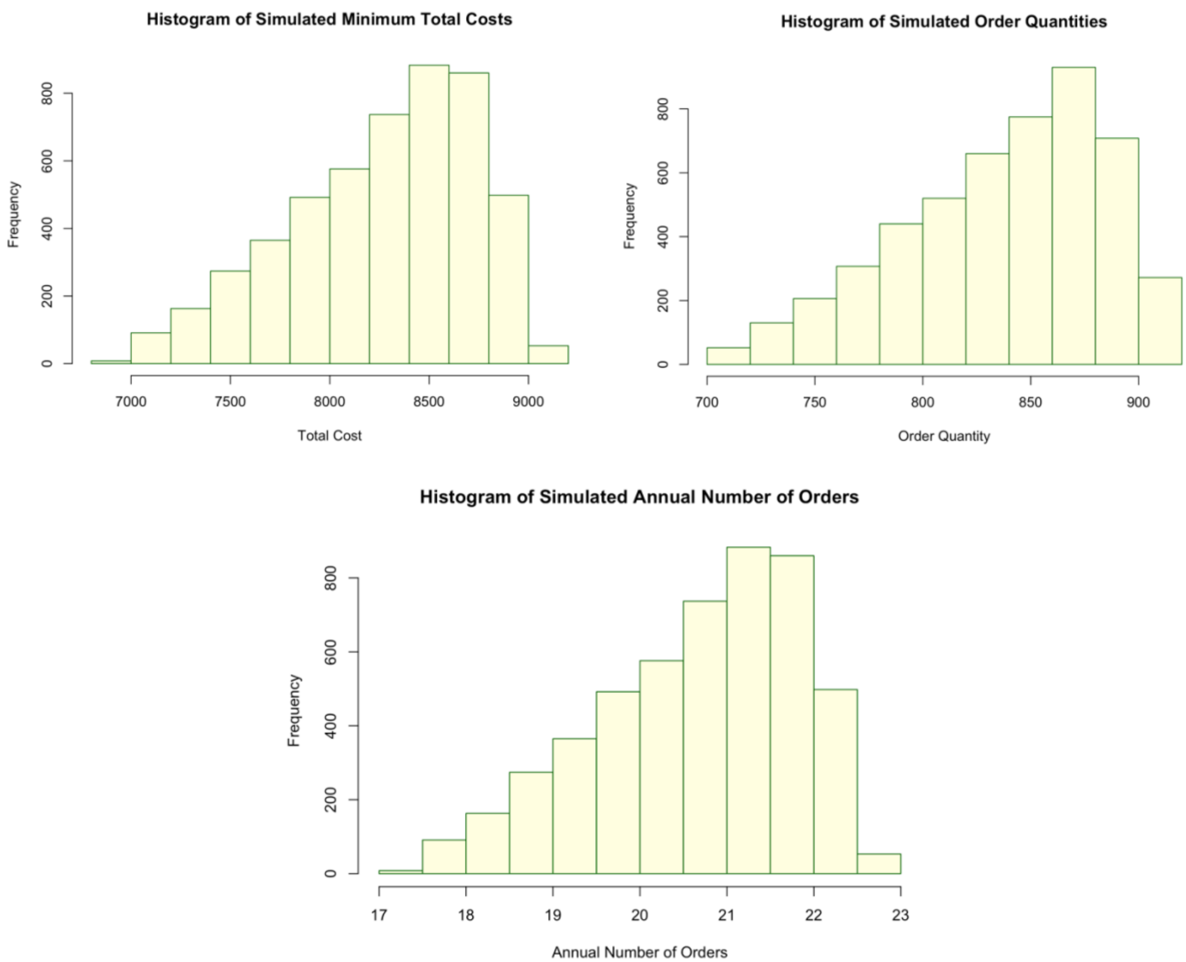

Fig. 10

It must first choose a probability distribution that best fits the minimum total cost data to conduct a Goodness-of-fit test. The lognormal distribution is a potential distribution that matches these data. The Kolmogorov-Smirnov (KS) test can be used to evaluate the goodness-of-fit. Null Hypothesis is that the data follows a lognormal distribution, and it is the valid fit. Alternative Hypothesis holds that a lognormal distribution is not the best fit for the data. The KS test's p-value is 0.038 for Minimum Total Cost, Order Quantities and Annual Number of Orders, which is less than the alpha value of 0.05. Hence, the alternative hypothesis is rejected while supporting the claim of Null Hypothesis that lognormal distribution is the valid fit for the data. The AIC and BIC values of Minimum Total Cost, Order Quantities and Annual Number of Orders can be observed in figure 11.

```
Goodness-of-fit statistics
                             1-mle-weibull
Kolmogorov-Smirnov statistic    0.03801215
Cramer-von Mises statistic      2.70109255
Anderson-Darling statistic     17.77983261

Goodness-of-fit criteria
                               1-mle-weibull
Akaike's Information Criterion      75101.20
Bayesian Information Criterion      75114.23
```

```
Goodness-of-fit statistics
                             1-mle-weibull
Kolmogorov-Smirnov statistic    0.03799688
Cramer-von Mises statistic      2.69438151
Anderson-Darling statistic     17.74388237

Goodness-of-fit criteria
                               1-mle-weibull
Akaike's Information Criterion      52201.14
Bayesian Information Criterion      52214.17
```

```
Goodness-of-fit statistics
                             1-mle-weibull
Kolmogorov-Smirnov statistic    0.03858645
Cramer-von Mises statistic      2.80796132
Anderson-Darling statistic     18.84767277

Goodness-of-fit criteria
                               1-mle-weibull
Akaike's Information Criterion      15304.99
Bayesian Information Criterion      15318.03
```

Fig. 11

Summary: The optimization of costs related to ordering and maintaining inventory are covered in the Part 2 along with the analysis of the annual demand for a product. In the analysis, decision variables like order quantity and inventory per order are determined, and annual ordering costs, holding costs, and total costs are computed. A sensitivity analysis is done to assess the effects of carrying cost rate and order cost on total cost after comparing the results obtained using mathematical functions and data tables. The article also discusses how to calculate the minimum total cost, order quantities, and annual number of orders using a triangular probability distribution and a simulation of 5000 occurrences. The Kolmogorov-Smirnov (KS) test is used to assess the lognormal distribution's goodness of fit, and the results confirm that the lognormal distribution is the proper fit for the data.

Conclusion

The use of decision variables like order quantity, inventory per order, and order number to lower annual ordering costs, holding costs, and total costs is discussed in the conclusion as well as other ways to improve inventory management for a business. The economic order quantity and reorder point are calculated using R and Excel Solver, and line plots and sensitivity analyses are used to identify the best inventory management strategy. The optimization of costs associated with ordering and maintaining inventory is covered in Part 2. This includes analyzing the yearly demand for a product using decision variables and computing the annual ordering costs, holding costs, and total costs. This also discusses how to determine the minimum total cost, order quantities, and annual number of orders using a triangular probability distribution and a simulation of 5000 occurrences. The lognormal distribution is found to be the best fit for the data, and the Kolmogorov-Smirnov (KS) test is used to evaluate the goodness of fit of the distribution.

References

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Peltier, C. (2016, June 17). "What If" analysis: Benefits of utilizing a "What If" analysis in excel. *Communications in Statistics - Theory and Methods*, *46*(12), 6119–6129. https://doi.org/10.1080/03610926.2015.1118511