IE 500 Supply Chain Engineering

**Demand Forecasting of Medical Supplies**

Group No:10

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**Abstract**

Demand forecasting is necessary to understand the consumer behavior for any products in order to estimate the expected demand in the future. It helps to stock the optimum quantity of products as per the requirement. The understock or overstock of products will lead to a loss for any company. So, estimating the optimum quantity/sales of the products would increase the efficiency of a company’s revenue. The COVID-19 crisis has made the demand for medical supplies increase exponentially. Medical supplies like masks, ventilators, hand sanitizer, testing swabs, and surgical gowns are in a critical shortage all over the world. This project will focus on the demand forecasting of some medical supplies over a certain period of time in USA. We plan to use different forecasting methods such as averaging method, 3-month moving average, exponential smoothing method or any other appropriate method that is required. After that, we plan to collect the data and compare all the results of the forecast. MAD, MSE and MAPE will be calculated in order to find the minimum error from the forecasting methods. The final step will be to validate and implement results to estimate the sales in health care and personal care stores in USA. However, it is very difficult to achieve this goal of ordering the estimated sales and get it delivered in a required time in this realistic world.

Keywords: Medical supplies, Forecasting Methods, Forecasted Demand, MAS, MSE, MAPE.

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# Introduction

Our aim of this project is to predict the sales of healthcare & personal care stores. Using different forecasting methods, we will calculate forecasts and infer the best method out of those in such a catastrophic scenario. Medical supplies like masks, ventilators, hand sanitizer, testing swabs, and surgical gowns are in a critical shortage all over the world. Healthcare & personal care stores sell many medical supplies like masks, hand sanitizers, paper towels, medicines and many more things. So, we will predict the sales of a store for March 2020.

# Data Collection

We used the data of seasonally adjusted monthly sales for healthcare & personal care stores in USA. The data since the year 1992 until February 2020 is used to predict the sales of March 2020. Data shown here is in millions of dollars[1].

**Table 1**: Data of sales for health and personal care stores in USA.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **U.S. Census Bureau** | |  |  |  |  |  |  |  |  |  |
| |  | | --- | |  | | A picture containing food, drawing  Description automatically generated | **Source: Advance Monthly Sales for Retail and Food Services** | | | | | |  |  |  |  |  |
|  |  | **446: Health and Personal Care Stores: U.S. Total** | | | | |  |  |  |  |  |  |
|  |  | **Seasonally Adjusted Sales - Monthly [Millions of Dollars]** | | | | |  |  |  |  |  |  |
|  |  | **Period: 1992 to 2020** | |  |  |  |  |  |  |  |  |  |
|  |  | **Data Extracted on: May 11, 2020 (4:51 pm)** | | | |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Year** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** |
| **1992** | 7,421 | 7,425 | 7,443 | 7,516 | 7,458 | 7,417 | 7,292 | 7,508 | 7,420 | 7,535 | 7,497 | 7,526 |
| **1993** | 7,518 | 7,651 | 7,605 | 7,683 | 7,666 | 7,680 | 7,756 | 7,678 | 7,772 | 7,758 | 7,784 | 7,989 |
| **1994** | 7,865 | 7,729 | 7,911 | 7,838 | 7,955 | 8,014 | 8,084 | 8,126 | 8,190 | 8,214 | 8,190 | 8,287 |
| **1995** | 8,306 | 8,304 | 8,304 | 8,450 | 8,424 | 8,482 | 8,431 | 8,488 | 8,611 | 8,584 | 8,691 | 8,761 |
| **1996** | 8,546 | 8,782 | 8,991 | 8,922 | 9,076 | 9,072 | 9,134 | 9,237 | 9,190 | 9,363 | 9,414 | 9,505 |
| **1997** | 9,448 | 9,649 | 9,922 | 9,578 | 9,722 | 9,916 | 9,950 | 9,989 | 10,077 | 10,058 | 10,217 | 10,201 |
| **1998** | 10,382 | 10,406 | 10,393 | 10,620 | 10,645 | 10,672 | 10,828 | 11,019 | 10,985 | 11,106 | 11,232 | 11,311 |
| **1999** | 11,415 | 11,498 | 11,595 | 11,619 | 11,741 | 11,837 | 11,857 | 11,848 | 11,993 | 12,155 | 12,258 | 12,801 |
| **2000** | 12,381 | 12,386 | 12,580 | 12,733 | 12,814 | 12,864 | 12,967 | 13,034 | 13,233 | 13,302 | 13,340 | 13,527 |
| **2001** | 13,413 | 13,582 | 13,650 | 13,643 | 13,812 | 13,843 | 13,879 | 14,004 | 13,894 | 14,298 | 14,280 | 14,350 |
| **2002** | 14,525 | 14,747 | 14,745 | 14,940 | 14,903 | 14,947 | 15,004 | 15,120 | 15,288 | 15,298 | 15,348 | 15,293 |
| **2003** | 15,441 | 15,534 | 15,677 | 15,705 | 15,791 | 15,934 | 16,182 | 16,345 | 16,339 | 16,434 | 16,500 | 16,648 |
| **2004** | 16,287 | 16,133 | 16,526 | 16,476 | 16,462 | 16,570 | 16,554 | 16,610 | 16,635 | 16,739 | 16,813 | 16,882 |
| **2005** | 17,116 | 17,292 | 17,245 | 17,350 | 17,413 | 17,392 | 17,635 | 17,548 | 17,707 | 17,742 | 17,859 | 18,005 |
| **2006** | 18,000 | 18,124 | 18,222 | 18,294 | 18,466 | 18,584 | 18,640 | 18,757 | 18,933 | 19,044 | 19,276 | 19,385 |
| **2007** | 19,423 | 19,401 | 19,540 | 19,572 | 19,650 | 19,880 | 19,831 | 20,014 | 20,132 | 19,988 | 19,938 | 19,825 |
| **2008** | 20,120 | 20,279 | 20,288 | 20,172 | 20,536 | 20,497 | 20,640 | 20,620 | 20,654 | 20,659 | 20,789 | 20,682 |
| **2009** | 20,753 | 20,906 | 20,908 | 21,059 | 21,121 | 21,055 | 21,027 | 21,070 | 21,231 | 21,278 | 21,288 | 21,195 |
| **2010** | 21,144 | 21,199 | 21,363 | 21,492 | 21,378 | 21,683 | 21,755 | 21,841 | 21,933 | 22,105 | 22,180 | 22,312 |
| **2011** | 22,579 | 22,451 | 22,584 | 22,448 | 22,585 | 22,630 | 22,728 | 22,822 | 22,718 | 22,783 | 22,782 | 22,717 |
| **2012** | 22,857 | 23,022 | 22,967 | 23,021 | 22,883 | 22,471 | 22,770 | 22,763 | 22,608 | 22,482 | 22,684 | 22,940 |
| **2013** | 23,230 | 23,093 | 23,146 | 23,065 | 23,201 | 23,196 | 23,464 | 23,506 | 23,914 | 23,933 | 23,990 | 24,022 |
| **2014** | 24,027 | 24,158 | 24,293 | 24,553 | 24,894 | 25,076 | 25,142 | 25,254 | 25,400 | 25,289 | 25,430 | 25,588 |
| **2015** | 25,818 | 25,617 | 26,216 | 25,806 | 25,804 | 25,984 | 26,257 | 26,440 | 26,807 | 26,578 | 26,728 | 27,009 |
| **2016** | 26,819 | 27,357 | 27,226 | 27,445 | 27,368 | 27,557 | 27,508 | 27,414 | 27,413 | 26,559 | 26,806 | 26,931 |
| **2017** | 26,898 | 27,221 | 27,367 | 27,563 | 27,598 | 27,796 | 27,859 | 28,118 | 28,224 | 28,359 | 28,446 | 28,383 |
| **2018** | 28,429 | 28,207 | 28,392 | 28,612 | 29,069 | 28,850 | 29,078 | 29,310 | 29,239 | 29,517 | 29,923 | 28,801 |
| **2019** | 29,699 | 29,887 | 29,907 | 29,820 | 30,065 | 30,017 | 29,897 | 29,824 | 29,933 | 30,241 | 29,819 | 29,770 |
| **2020** | 30,017 | 29,867 | 31,113 | NA | NA | NA | NA | NA | NA | NA | NA | NA |

**Model Development**

We have used different forecasting methods such as averaging method, 3-month moving average, weighted average method and exponential smoothing method. MAD, MSE and MAPE will be calculated in order to find the minimum error from the forecasting methods. Choose the best forecasting model based on the least error and predicted sales.

# Trend of Actual Sales

**Figure 1**: Trend of actual sales.

The trend of actual sales observed in Figure 1 is increasing over the years. Here, we aim to predict the demand of Health care and Personal care stores in USA.

# Forecasting Methods

4 forecasting methods we are going to use are as follow:

* Averaging Method
* Weighted Average Method
* 3-Month Moving Average Method
* Exponential Smoothing Method

## Averaging Method

The first forecasting method we used to forecast the sales of medical supplies for March 2020 was the averaging method. The averaging method assumes that the future values of demand will be similar to historical demands. It is useful in determining short term trends in the data set. To use this method, we simply took an average of the sales from the sales data. We used equation 1 shown below.

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Where Fn+1 represents the forecast for March 2020, Dtx is the demand for month t in year x. For this data set we spanned the years from 1992 to 2020. Finally, n is the total number of months from January 1992 to February 2020 which was 338. We simply took an average by summing all the demands and dividing by 338 which gave us a forecast for March 2020 of $17,964 (in millions). A drawback of the averaging method is that it assumes past data is applicable to the future, therefore the result of the forecast may be off because data from several years may not be relevant. From our result using this method, we can see that using almost 30 years’ worth of data made our forecast a bit off. From this, we calculated forecast errors using MAD, MSE and MAPE to evaluate the averaging method. We calculated MAD by taking the absolute value of the actual demand and subtracting our forecast from it giving us a value of 13,616. For MSE we took the MAD-squared and divided by the total number of sales, 338, to get an average value of 548,507. Finally, for MAPE, we took MAD divided by the actual forecast and multiplied by 100 giving us a value of 43.1 error.

## Weighted Average Method

This method has more emphasis on the recent demands and forecasts using weights and less priority to the past data. A rising average supports the demand, but a falling average resists the demand. Depending on the number of demands to be considered, the number of weights is to be chosen accordingly.

**New Forecast=w\*(Previous demand) +(1-w) \*(Previous forecast)** ---(2)

Where w= weight given to demand according to the priority level and minimum error.

Here we took w = 0.1, 0.2 up to 0.9, then calculated the forecast for the entire dataset up to March. We calculated the errors using MAD, MSE and MAPE. Then we observed an increase in MAD, MSE and MAPE values from 0.2 to 0.3.

After this we used the trial and error method again with values from w=0.21, 0.22 up to 0.29. There was an increase in only MSE value from 0.21 to 0.22. Hence, we got our optimal weight at 0.21.

When we used w=0.21 and calculated the forecasts of the entire dataset, the error amounts found were:

MAD=647.0089

MSE=1070889

MAPE=0.03561413

This was the least achievable error amount using weighted averaging method using recent data and 2 weights with near previous data for accuracy during such scenarios. The predicted demand for March 2020 is $29,973 (in million USD).

## 3 Month Moving Average Method

Another method we used to forecast sales for March 2020 was the 3-month moving average method. Moving average uses the most recent data to forecast the demand. In our project, we used a 3-month moving average taking the most recent 3 months of sales data to forecast for the month of March. From the data of the three recent months, we took the average to get our forecast. The calculation was as follows,

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=

= 30,598

As shown above, we took the sales data of December 2019, January 2020, and February 2020 to get a forecast of $30,598 (in million USD). This method also assumes that all the demands have equal weights. With the 3-month moving average, we were closer to the actual demand in March 2020 because we used recent data. For this method we also calculated the forecast errors using MAD, MSE, and MAPE. We calculated MAD, MSE, and MAPE in the same way as for the averaging method. For MAD, we got an error of 982. MSE we got an error of 321,441. Finally, MAPE we got a 3.1 error. Out of all the methods, the 3-month moving average method was found to have the smallest MSE and MAPE. This is worth noting because this shows this method can be a reasonable method to forecast the sales data for our project.

## Exponential Smoothing Method

Exponential smoothing method is being used in forecasting to predict the future demand values based on the most recent demands. In exponential Smoothing the most recent demand holds the most weightage whereas, the predecessors tend to reduce in terms of weight imposed on their importance over the current prediction. The weights here referred as ***smoothing constant*** was selected based on the various methods. Later we will discuss about the way which we opted to select the optimal smoothing constant value based on the data set we are provided with. The formula for the exponential smoothing is as follows,

FORMULA:

---(4)

### *Smoothing Constant Selection*

Smoothing constant is considered as the weight which decides the amount of importance each predecessor demand holds on forecasting the future demand based on the nature of the predecessor. Smoothing constant values ranges from 0.1 to 1, represented as follows,

Here the data set nature plays the role in its smoothing constant selection process. In order to select the smoothing constant ranging from 0.1 to 1, the data from 1992 to 2020 till February month was considered with each month as a period. Forecast errors were considered to evaluate the forecast from January 1992 to February 2020 data under a list of smoothing constants ranging from 0.1 to 1. The forecast errors were evaluated by the following forecast evaluation terms,

* Mean Absolute Deviation (MAD)
* Mean Squared Error (MSE)
* Standard Deviation (STD)
* Bias
* Mean Absolute Percentage Error (MAPE)

After analyzing the data with the exponential smoothing method, 0.2 and 0.3 smoothing constant was found as optimal smoothing constants with minimal MAD, MSE and MAPE values.

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**Figure 2**: Forecast Error calculated on a range of smoothing constants.

### *Results of Exponential Smoothing*

From the figure 2, we can see that the 0.2 and 0.3 smoothing constant values provide the appropriate results. Hence the smoothing constants 0.2 and 0.3 were used for forecasting the period of ***March 2020.*** The result are as follows,

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**Figure 3:** Forecast done for March 2020.

The above forecast values were compared with the March 2020 demand value to calculate the accuracy of forecasting done using exponential smoothing method with smoothing constant values found from the data set itself instead of going for random values. The Spikes in demand was due to various external factors affecting the demand, which could be considered in future improvement process to provide the most appropriate demand to meet the actual demands in future.

# Comparison of Actual and Predicted Demand

The below table compares the value of actual and predicted demand of March 2020 in millions of USD.

**Table 2**: Comparison of actual and predicted demand.

|  |  |  |
| --- | --- | --- |
|  | **Actual Demand** | **Predicted Demand** |
| Averaging Method | 31,113 | 17,964 |
| Weighted Average Method | 31,113 | 29,973 |
| 3 Month Moving Average Method | 31,113 | 30,598 |
| Exponential Smoothing Method | 31,113 | 29,968 |

# Comparison of Forecast Errors

The below table compares the forecast errors of different method.

**Table 3**: Comparison of forecast errors.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **MAD** | **MSE** | **MAPE** |
| Averaging Method | 13616 | 548507 | 43.1 |
| Weighted Average Method | 647.00 | 1070889 | 3.561 |
| 3 Month Moving Average Method | 982 | 321441 | 3.1 |
| Exponential Smoothing Method | 673 | 1113919 | 3.7428 |

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# Verification and Validation

* From the forecast done with various methods, it was found that the weighted average method provides the minimum value in terms of MAD error.
* Forecast using the Weighted average found that the weight of 0.21 provides the forecast of **29,973 million USD,** which completely depends on the previous forecast.
* Also, MSE and MAPE error value is found to be the least for 3 months moving average method with predicted sales of **30,598 million USD.**
* Actual demand for the month of March 2020 is 31,113 million USD which is near to the predicted demand.
* The difference observed could be because of other factors affecting the sales due to the present situation (Covid-19).

# Conclusion and Future Work

* The analysis done on the **personal care and medical supplies** was focused on Demand Forecasting techniques, whereas, the demand here was the turnover in million dollars per month.
* Predicted demand could be improvised by considering other factors affecting the sales.
* In future the data could be analyzed further in depth with various techniques considering various **logistics factors** that would help forecast future turnover in order to maintain the **inventory** as required to meet the upcoming **uncertain demand spikes**.

# References

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