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**ENM 319&BIM213**

# PRODUCTION AND OPERATIONS PLANNING & DATA STRUCTURES AND ALGORİTHMS

# FINAL REPORT

**GROUP-7**

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**ABSTRACT**

This report is a joint project of the courses ENM319 and BIM213 coded Production and Operations Planning & Data Structures and Algorithms. The report includes the table of work packages, the flowchart developed for the problem, the software developed, the program outputs of the problem and analytical calculations for the solution of the problem. In addition to all these, the project was evaluated from the perspective of industrial and computer engineers.

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## 1. INTRODUCTION

The problem given within the scope of the ENM319 & BIM213 courses named Production and Operations Planning & Data Structures and Algorithms is given below.

You are working in the production planning department of a company manufacturing luxury SUV cars for the customers in various countries. This morning, your department manager request from you to work with two new friends from the IT department to develop a simple decision support system that will be used in the forecasting processes. The software must have the following characteristics:

• The software should first request the data about last two years (24 months) from the user.

• Based on the data, forecasts must be made by using all the following methods:

o Exponential smoothing ($\alpha$=0.2)

o Double-exponential smoothing ($\alpha$=0.2, $\beta$=0.2, $S_0$=200, $G_0$=50)

o Regression analysis

o Deseasonalized regression analysis

• MSE must be calculated for each forecasting method and the software must indicate the user that “based on the MSE comparisons, the best method for this data is …..”

• By using the best method for that data, the software must then provide the forecasts for the next two years (next 24 months).

## 2. MEETINGS AND WORK PACKAGES

For the successful completion of the project, four meetings were held until the delivery of the midterm report. Another meeting was held until the delivery of the final report. The first meeting is a general meeting between computer and industrial engineers. In this meeting, all the students got to know each other and explained the purpose of the project, what is aimed at the end of this project, etc. determined by the division of labor. The division of labor is given in Table 1.

**Table 1.** *Work Package*

| Task | Responsible Person | Task due to time |
|---|---|---|
| Solution of the problem with exponential smoothing and double exponential smoothing for Dataset 1 | Elifnaz ÖZBULAK | 12.11.2021 |
| Solution of the problem with regression analysis and deseasonalized regression analysis for Dataset 1 | Elif Melis GEÇGİNCİ | 12.11.2021 |
| Flow chart + checking + coding | Ramazan GENCER | 29.11.2021 |
| Solution of the problem with exponential smoothing and double exponential smoothing for Dataset 2 | Elif Melis GEÇGİNCİ | 06.12.2021 |
| Solution of the problem with regression analysis and deseasonalized regression analysis for Dataset 2 | Elifnaz ÖZBULAK | 06.12.2021 |
| Coding | Furkan ALLİŞ | 09.12.2021 |
| Coding | Radwan Rachid HOUSSEIN | 10.12.2021 |

The second meeting is the meeting of industrial engineers among themselves. In this meeting, the problem and the purpose of solving the problem were determined. Then, in the given problem, the first data set was solved with four different methods and the method with the least error was selected. In the third meeting, computer and industrial engineers came together again. In this meeting, industrial engineers explained to computer engineers how the problem was solved with four different methods for the first data set and how the best method was determined. The last meeting held before the interim report is between the computer engineers. In this meeting, computer engineers adopted the purpose of the question and decided which program to develop.

Following the completion of the work packages given in Table 1, industrial and computer engineers held another meeting. In this last meeting, the analytical solutions of the second data set and the developed program were discussed. The results obtained from the program were examined and evaluated in detail.

## 3. SOLUTIONS FOR DATASET 1

Dataset 1 is given in Table 2.

**Table 2**. *Dataset 1*

| Month | Jan. | Feb. | Mar. | Apr. | May. | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year 1 Demand | 300 | 350 | 330 | 340 | 390 | 430 | 480 | 460 | 490 | 510 | 550 | 560 |
| Year 2 Demand | 550 | 590 | 600 | 610 | 630 | 620 | 680 | 690 | 710 | 730 | 740 | 770 |

### 3.1. Exponential Smoothing Method

($\alpha$ = 0.2)

Formula : $F_{t+1} = \alpha D_t + (1- \alpha)F_t$

Calculation :

300 is accepted as a forecast 1 ($F_1$).

$F_2$ = 0.2*300+(1-0.2)*$F_1$

$F_2$ = 0.2*300+(1-0.2)*300 = 200

$F_3$ = 0.2*350+(1-0.2)*$F_2$

$F_3$ = 0.2*350+(1-0.2)*200 = 220

Other forecasts are calculated in the same way and are given in the Table 3.

**Table 3**. *Forecasts Calculated By Exponential Smoothing Method*

| Month (x) | Demand (y) | $F_t$ |
|---|---|---|
| 1 | 300 | 300 |
| 2 | 350 | 300 |
| 3 | 330 | 310 |
| 4 | 340 | 314 |
| 5 | 390 | 319 |
| 6 | 430 | 333 |
| 7 | 480 | 353 |
| 8 | 460 | 378 |
| 9 | 490 | 395 |
| 10 | 510 | 414 |
| 11 | 550 | 433 |
| 12 | 560 | 456 |
| 13 | 550 | 477 |
| 14 | 590 | 492 |
| 15 | 600 | 511 |
| 16 | 610 | 529 |
| 17 | 630 | 545 |
| 18 | 620 | 562 |
| 19 | 680 | 574 |
| 20 | 690 | 595 |
| 21 | 710 | 614 |
| 22 | 730 | 633 |
| 23 | 740 | 653 |
| 24 | 770 | 670 |

## 3.2. Mean Squared Error (MSE) for Exponential Smoothing Method

Formula : $\frac{\sum_{i=1}^{n}(\text{Actual}-\text{Forecast})^2}{n} = \frac{\sum_{i=1}^{n}(D_t-F_t)^2}{n}$

Calculation :

Firstly, squarred error was calculated.

1. For January : $(300-300)^2$ = 0
2. For February : $(350-300)^2$ = 2500
3. For March : $(330-310)^2$ = 400

Other squarred errors are calculated in the same way and are given in Table 4.

**Table 4**. *Squarred Errors for Exponential Smoothing Method*

| Month (x) | Demand (y) | Squarred Error |
|---|---|---|
| 1 | 300 | 0 |
| 2 | 350 | 2500 |
| 3 | 330 | 400 |
| 4 | 340 | 676 |
| 5 | 390 | 5041 |
| 6 | 430 | 9409 |
| 7 | 480 | 16384 |
| 8 | 460 | 6889 |
| 9 | 490 | 9409 |
| 10 | 510 | 9604 |
| 11 | 550 | 14161 |
| 12 | 560 | 11236 |
| 13 | 550 | 5625 |
| 14 | 590 | 10000 |
| 15 | 600 | 8100 |
| 16 | 610 | 6724 |
| 17 | 630 | 7396 |
| 18 | 620 | 3481 |
| 19 | 680 | 11664 |
| 20 | 690 | 9409 |
| 21 | 710 | 9604 |
| 22 | 730 | 9801 |
| 23 | 740 | 8100 |
| 24 | 770 | 10404 |

Sum of squarred error : (0+2500+400+676+5041+………………………9801 + 8100+10404) = 186017

Now, we can find mean squarred error for exponential smoothing method.

MSE = $\frac{\sum_{i=1}^{n}(D_t - F_t)^2}{n} = \frac{186017}{24}$ = 7750.71

### 3.3. Double Exponential Smoothing Method

($\alpha$ = 0.2, $\beta$ = 0.2, $S_0$ = 200, $G_0$ = 50)

Formulas :

$S_t = \alpha D_t + (1-\alpha)(S_{t-1} + G_{t-1})$

$G_t = \beta(S_t - S_{t-1}) + (1-\beta)G_{t-1}$

$F_{t,t+\tau} = S_t + \tau \times G_t$ (forecast for time $\tau$ into the future)

Where ;

$D_t$ is observed demand,

$S_t$ is current estimate of 'intercept',

$G_t$ is current estimate of slope,

$S_{t-1}$ is last estimate of 'intercept',

$G_{t-1}$ is the last estimate of slope.

Calculations :

1. For January :

$S_1 = 0.2*300 + (1-0.2)*(200 + 50) = 260$

$G_1 = 0.2*(260 - 200) + (1-0.2)*50 = 52$

$F_1 = 200 + 1*50=250$

2. For February :

$S_2 = 0.2*350 + (1-0.2)*(260 + 52) = 319.60$

$G_2 = 0.2*(319.60 - 260) + (1-0.2)*52 = 53.52$

$F_2 = 260 + 1*52 = 312$

3. For March :

$S_3 = 0.2*330 + (1-0.2)*(319.60 + 53.52) = 364.50$

$G_3 = 0.2*(364.50 - 319.60) + (1-0.2)*53.52 = 51.80$

$F_3 = 319.60 + 1*53.52 = 373$

Other intercepts,slopes and forecasts are calculated in the same way and are given in the Table 5.

**Table 5.** *Intercepts, Slopes and Forecasts Calculated By Exponential Smoothing Method*

| Month (x) | Demand (y) | Double Exponential Smoothing Method | | |
|---|---|---|---|---|
| | | St | Gt | Ft |
| 1 | 300 | 260.00 | 52 | 250 |
| 2 | 350 | 319.60 | 53.52 | 312 |
| 3 | 330 | 364.50 | 51.80 | 373 |
| 4 | 340 | 401.03 | 48.74 | 416 |
| 5 | 390 | 437.82 | 46.35 | 450 |
| 6 | 430 | 473.34 | 44.19 | 484 |
| 7 | 480 | 510.02 | 42.68 | 518 |
| 8 | 460 | 534.16 | 38.98 | 553 |
| 9 | 490 | 556.51 | 35.65 | 573 |
| 10 | 510 | 575.73 | 32.36 | 592 |
| 11 | 550 | 596.48 | 30.04 | 608 |
| 12 | 560 | 613.21 | 27.38 | 627 |
| 13 | 550 | 622.47 | 23.76 | 641 |
| 14 | 590 | 634.98 | 21.51 | 646 |
| 15 | 600 | 645.19 | 19.25 | 656 |
| 16 | 610 | 653.55 | 17.07 | 664 |
| 17 | 630 | 662.50 | 15.44 | 671 |
| 18 | 620 | 666.35 | 13.13 | 678 |
| 19 | 680 | 679.58 | 13.15 | 679 |
| 20 | 690 | 692.19 | 13.04 | 693 |
| 21 | 710 | 706.18 | 13.23 | 705 |
| 22 | 730 | 721.53 | 13.65 | 719 |
| 23 | 740 | 736.14 | 13.85 | 735 |
| 24 | 770 | 753.99 | 14.65 | 750 |

### 3.4. Mean Squared Error (MSE) for Double Exponential Smoothing Method

Formula : $\frac{\sum_{i=1}^{n}(\text{Actual}-\text{Forecast})^2}{n} = \frac{\sum_{i=1}^{n}(D_t - F_t)^2}{n}$

Calculation :

Firstly, squarred error was calculated.

1. For January : $(300 - 250)^2$ = 2500
2. For February : $(350 - 312)^2$ = 1444
3. For March : $(330 - 373)^2$ = 1849

Other squarred errors are calculated in the same way and are given in Table 6.

**Table 6**. *Squarred Errors for Double Exponential Smoothing Method*

| Month (x) | Demand (y) | Squarred Error |
|---|---|---|
| 1 | 300 | 2500 |
| 2 | 350 | 1444 |
| 3 | 330 | 1849 |
| 4 | 340 | 5776 |
| 5 | 390 | 3481 |
| 6 | 430 | 2916 |
| 7 | 480 | 1369 |
| 8 | 460 | 8464 |
| 9 | 490 | 6889 |
| 10 | 510 | 6724 |
| 11 | 550 | 3364 |
| 12 | 560 | 4356 |
| 13 | 550 | 8100 |
| 14 | 590 | 3136 |
| 15 | 600 | 3136 |
| 16 | 610 | 2916 |
| 17 | 630 | 1600 |
| 18 | 620 | 3249 |
| 19 | 680 | 1 |
| 20 | 690 | 4 |
| 21 | 710 | 25 |
| 22 | 730 | 121 |
| 23 | 740 | 25 |
| 24 | 770 | 441 |

Sum of squarred error : (2500+1444+1849+5776+………………………121 +25 +441) = 71886

Now, we can find mean squarred error for exponential smoothing method.

MSE = $\frac{\sum_{i=1}^{n}(D_t - F_t)^2}{n} = \frac{71886}{24}$ = 2995.25

### 3.5. Regression Analysis Method

Formula : $y_i = a + bx_i$

Where ;

$y_i$ is actual observations,

$a + bx_i$ is prediction.

Calculation :

A and b values need to be calculated before forecasting for other months. The data required to calculate these values are given in Table 7.

**Table 7.** *Values to be Calculated for Data a and b*

| | Month (x) | Demand (y) | $x^2$ | xy |
|---|---|---|---|---|
| | 1 | 300 | 1 | 300 |
| | 2 | 350 | 4 | 700 |
| | 3 | 330 | 9 | 990 |
| | 4 | 340 | 16 | 1360 |
| | 5 | 390 | 25 | 1950 |
| | 6 | 430 | 36 | 2580 |
| | 7 | 480 | 49 | 3360 |
| | 8 | 460 | 64 | 3680 |
| | 9 | 490 | 81 | 4410 |
| | 10 | 510 | 100 | 5100 |
| | 11 | 550 | 121 | 6050 |
| | 12 | 560 | 144 | 6720 |
| | 13 | 550 | 169 | 7150 |
| | 14 | 590 | 196 | 8260 |
| | 15 | 600 | 225 | 9000 |
| | 16 | 610 | 256 | 9760 |
| | 17 | 630 | 289 | 10710 |
| | 18 | 620 | 324 | 11160 |
| | 19 | 680 | 361 | 12920 |
| | 20 | 690 | 400 | 13800 |
| | 21 | 710 | 441 | 14910 |
| | 22 | 730 | 484 | 16060 |
| | 23 | 740 | 529 | 17020 |
| | 24 | 770 | 576 | 18480 |
| Sum | 300 | 13110 | 4900 | 186430 |
| Mean | 13 | 546 | | |

$$b = \frac{n\sum_i x_i y_i - (\sum_i x_i)(\sum_i y_i)}{n\sum_i x_i^2 - (\sum_i x_i)^2} = \frac{24*186430-(300)*(13110)}{24*4900-(300)^2} = 19.61$$

$$a = \bar{y} - b\bar{x} = 546 - 19.61*13 = 301.09$$

$$y(x) = 301.09 + 19.61x$$

1. For January :

$x = 1$

y(1) = 301.09 + 19.61*1 = 320

2. For February :

x = 2

y(2) = 301.09 + 19.61*2 = 340

3. For March :

x = 3

y(3) = 301.09 + 19.61*3 = 359

Other forecasts are calculated in the same way and are given in the Table 8.

**Table 8**. *Forecasts Calculated By Regression Analysis Method*

| Month (x) | Demand (y) | Ft |
|---|---|---|
| 1 | 300 | 320 |
| 2 | 350 | 340 |
| 3 | 330 | 359 |
| 4 | 340 | 379 |
| 5 | 390 | 399 |
| 6 | 430 | 418 |
| 7 | 480 | 438 |
| 8 | 460 | 457 |
| 9 | 490 | 477 |
| 10 | 510 | 497 |
| 11 | 550 | 516 |
| 12 | 560 | 536 |
| 13 | 550 | 556 |
| 14 | 590 | 575 |
| 15 | 600 | 595 |
| 16 | 610 | 614 |
| 17 | 630 | 634 |
| 18 | 620 | 654 |
| 19 | 680 | 673 |
| 20 | 690 | 693 |
| 21 | 710 | 712 |
| 22 | 730 | 732 |
| 23 | 740 | 752 |
| 24 | 770 | 771 |

### 3.6. Mean Squared Error (MSE) for Regression Analysis Method

Formula : $\frac{\sum_{i=1}^{n}(\text{Actual}-\text{Forecast})^2}{n} = \frac{\sum_{i=1}^{n}(D_t - F_t)^2}{n}$

Calculation :

Firstly, squared error was calculated.

1. For January : $(300 - 320)^2$ = 400
2. For February : $(350 - 340)^2$ = 100
3. For March : $(330 - 359)^2$ = 841

Other squarred errors are calculated in the same way and are given in Table 9.

**Table 9.** *Squarred Errors for Regression Analysis Method*

| Month (x) | Demand (y) | Squarred Error |
|---|---|---|
| 1 | 300 | 400 |
| 2 | 350 | 100 |
| 3 | 330 | 841 |
| 4 | 340 | 1521 |
| 5 | 390 | 81 |
| 6 | 430 | 144 |
| 7 | 480 | 1764 |
| 8 | 460 | 9 |
| 9 | 490 | 169 |
| 10 | 510 | 169 |
| 11 | 550 | 1156 |
| 12 | 560 | 576 |
| 13 | 550 | 36 |
| 14 | 590 | 225 |
| 15 | 600 | 25 |
| 16 | 610 | 16 |
| 17 | 630 | 16 |
| 18 | 620 | 1156 |
| 19 | 680 | 49 |
| 20 | 690 | 9 |
| 21 | 710 | 4 |
| 22 | 730 | 4 |
| 23 | 740 | 144 |
| 24 | 770 | 1 |

Sum of squarred error : (400+100+841+1521+………………………4 +144 +1) = 8615

Now, we can find mean squarred error for regression analysis method.

MSE = $\frac{\sum_{i=1}^{n}(D_t - F_t)^2}{n} = \frac{8615}{24}$ = 358.96

### 3.7. Deseasonalized Regression Analysis Method

In order to be able to find a solution with deseasonal regression analysis method, first of all, seasonal data must be deseasonalized. Then it is solved according to the regression analysis method. Finally, the obtained data is converted back to seasonal data.

Calculation :

Expected Demand $Q1_{year3}$ = (300+550)/2 = 425

Expected Demand $Q2_{year3}$ = (350+590)/2 = 470

Expected Demand $Q3_{year3}$ = (330+600)/2 = 465

Overall average demand = $(\sum_i D_i)/24$ = (300+350+330+340+……..+740+770) / 24

= 546.25

Other expected demands are calculated in the same way and are given in Table 10.

**Table 10.** *Calculated Expected Demands for Deseasonal Regression Analysis Method*

| Season | Cycle | Demand | Season | Cycle | Demand | Season | Cycle | Expected Demand |
|---|---|---|---|---|---|---|---|---|
| Q1 | Year 1 | 300 | Q1 | Year 2 | 550 | Q1 | Year 3 | 425 |
| Q2 | Year 1 | 350 | Q2 | Year 2 | 590 | Q2 | Year 3 | 470 |
| Q3 | Year 1 | 330 | Q3 | Year 2 | 600 | Q3 | Year 3 | 465 |
| Q4 | Year 1 | 340 | Q4 | Year 2 | 610 | Q4 | Year 3 | 175 |
| Q5 | Year 1 | 390 | Q5 | Year 2 | 630 | Q5 | Year 3 | 510 |
| Q6 | Year 1 | 430 | Q6 | Year 2 | 620 | Q6 | Year 3 | 525 |
| Q7 | Year 1 | 480 | Q7 | Year 2 | 680 | Q7 | Year 3 | 580 |
| Q8 | Year 1 | 460 | Q8 | Year 2 | 690 | Q8 | Year 3 | 575 |
| Q9 | Year 1 | 490 | Q9 | Year 2 | 710 | Q9 | Year 3 | 600 |
| Q10 | Year 1 | 510 | Q10 | Year 2 | 730 | Q10 | Year 3 | 620 |
| Q11 | Year 1 | 550 | Q11 | Year 2 | 740 | Q11 | Year 3 | 645 |
| Q12 | Year 1 | 560 | Q12 | Year 2 | 770 | Q12 | Year 3 | 665 |

Seasonal Demand Factors:

Q1: 425/546.25 = 0.78

Q2: 470/546.25 = 0.86

Q3: 465/546.25 = 0.85

Deseasonal demand data should be obtained from seasonal data. Therefore, the demand values should be divided by the seasonal demand factors.

Deseason Demand:

Q1: 300 /0.78 = 385.59

Q2: 350/0.86 = 406.78

Q3: 330/0.85 = 387.78

The other seasonal demand factors and deaseason demands are calculated in the same way. These values are given in Table 11.

**Table 11.** *Calculated Values to Work on Deaseasonal Data*

| Month | Actual Demand | Period Average | Period Factor | Deseason Demand (y) | Period in (x) | xy | $x^2$ |
|---|---|---|---|---|---|---|---|
| 1 | 300 | 425 | 0.78 | 385.59 | 1 | 385.6 | 1 |
| 2 | 350 | 470 | 0.86 | 406.78 | 2 | 813.6 | 4 |
| 3 | 330 | 465 | 0.85 | 387.66 | 3 | 1163 | 9 |
| 4 | 340 | 475 | 0.87 | 391 | 4 | 1564 | 16 |
| 5 | 390 | 510 | 0.93 | 417.72 | 5 | 2088.6 | 25 |
| 6 | 430 | 525 | 0.96 | 447.40 | 6 | 2684.4 | 36 |
| 7 | 480 | 580 | 1.06 | 452.07 | 7 | 3164.5 | 49 |
| 8 | 460 | 575 | 1.05 | 437 | 8 | 3496 | 64 |
| 9 | 490 | 600 | 1.10 | 446.10 | 9 | 4014.9 | 81 |
| 10 | 510 | 620 | 1.14 | 44933 | 10 | 4493.3 | 100 |
| 11 | 550 | 645 | 1.18 | 465.79 | 11 | 5123.7 | 121 |
| 12 | 560 | 665 | 1.22 | 460 | 12 | 5520 | 144 |
| 13 | 550 | 425 | 0.78 | 706.91 | 13 | 9189.9 | 169 |
| 14 | 590 | 470 | 0.86 | 685.72 | 14 | 9600.1 | 196 |
| 15 | 600 | 465 | 0.85 | 704.84 | 15 | 10572.6 | 225 |
| 16 | 610 | 475 | 0.87 | 701.50 | 16 | 11224 | 256 |
| 17 | 630 | 510 | 0.93 | 674.78 | 17 | 11471.3 | 289 |
| 18 | 620 | 525 | 0.96 | 645.10 | 18 | 11611.7 | 324 |
| 19 | 680 | 580 | 1.06 | 640.43 | 19 | 12168.2 | 361 |
| 20 | 690 | 575 | 1.05 | 655.50 | 20 | 13110 | 400 |
| 21 | 710 | 600 | 1.10 | 646.40 | 21 | 13574.3 | 441 |
| 22 | 730 | 620 | 1.14 | 643.17 | 22 | 14149.6 | 484 |
| 23 | 740 | 645 | 1.18 | 626.71 | 23 | 14414.2 | 529 |
| 24 | 770 | 665 | 1.22 | 632.50 | 24 | 15180 | 576 |
| | | | SUM | 13110 | 300 | 180777.5 | 4900 |
| | | | MEAN | 546 | 13 | | |

A and b values need to be calculated before forecasting for other months.

$b = \frac{n\sum_i x_i y_i - (\sum_i x_i)(\sum_i y_i)}{n\sum_i x_i^2 - (\sum_i x_i)^2} = \frac{24*180777.5-(300)*(13110)}{24*4900-(300)^2} = 14.70$

$a = \bar{y} - b\bar{x}$ = 546 – 14.70*13 = 362.53

y(x) = 362.53 + 14.70x

The results from this equation should be seasonalized. Therefore, it should be multiplied by the period factor.

y(x) = period factor * (362.53 + 14.70x)

1. For January :

x = 1

y(1) = 0.78*(362.53 + 14.70*1) = 293

2. For February :

x = 2

y(2) = 0.86*(362.53 + 14.70*2) = 337

3. For March :

x = 3

y(3) = 0.85*(362.53 + 14.70*3 )= 346

Other forecasts are calculated in the same way and are given in the Table 12.

**Table 12.** *Forecasts Calculated By Deseasonal Regression Analysis Method*

| Month (x) | Demand (y) | Ft |
|---|---|---|
| 1 | 300 | 293 |
| 2 | 350 | 337 |
| 3 | 330 | 346 |
| 4 | 340 | 366 |
| 5 | 390 | 407 |
| 6 | 430 | 433 |
| 7 | 480 | 494 |
| 8 | 460 | 505 |
| 9 | 490 | 543 |
| 10 | 510 | 578 |
| 11 | 550 | 619 |
| 12 | 560 | 656 |
| 13 | 550 | 431 |
| 14 | 590 | 489 |
| 15 | 600 | 496 |
| 16 | 610 | 520 |
| 17 | 630 | 572 |
| 18 | 620 | 603 |
| 19 | 680 | 681 |
| 20 | 690 | 691 |
| 21 | 710 | 737 |
| 22 | 730 | 778 |
| 23 | 740 | 827 |
| 24 | 770 | 871 |

### 3.8. Mean Squared Error (MSE) for Deseasonalized Regression Analysis Method

Formula : $\frac{\sum_{i=1}^{n}(\text{Actual}-\text{Forecast})^2}{n} = \frac{\sum_{i=1}^{n}(D_t - F_t)^2}{n}$

Calculation :

Firstly, squarred error was calculated.

1. For January : $(300 - 293)^2$ = 49
2. For February : $(350 - 337)^2$ 169
3. For March : $(330 - 346)^2$ = 256

Other squarred errors are calculated in the same way and are given in Table 13.

**Table 13**. *Squarred Errors for Regression Analysis Method*

| Month (x) | Demand (y) | Squarred Error |
|---|---|---|
| 1 | 300 | 49 |
| 2 | 350 | 169 |
| 3 | 330 | 256 |
| 4 | 340 | 676 |
| 5 | 390 | 289 |
| 6 | 430 | 9 |
| 7 | 480 | 196 |
| 8 | 460 | 2025 |
| 9 | 490 | 2809 |
| 10 | 510 | 4624 |
| 11 | 550 | 4624 |
| 12 | 560 | 9216 |
| 13 | 550 | 14400 |
| 14 | 590 | 10404 |
| 15 | 600 | 10816 |
| 16 | 610 | 8281 |
| 17 | 630 | 3481 |
| 18 | 620 | 324 |
| 19 | 680 | 1 |
| 20 | 690 | 1 |
| 21 | 710 | 729 |
| 22 | 730 | 2304 |
| 23 | 740 | 7569 |
| 24 | 770 | 10000 |

Sum of squarred error : (49+169+256+676+………………………2304+7569+10000) = 93252

Now, we can find mean squarred error for regression analysis method.

$$\text{MSE} = \frac{\sum_{i=1}^{n}(D_t - F_t)^2}{n} = \frac{93252}{24} = 3885.50$$

## 4. SOLUTIONS FOR DATASET 2

Dataset 2 is given in Table 14.

**Table 14**. *Dataset 2*

| Month | Jan. | Feb. | Mar. | Apr. | May. | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year 1 Demand | 200 | 300 | 250 | 600 | 650 | 670 | 400 | 440 | 430 | 900 | 980 | 990 |
| Year 2 Demand | 300 | 370 | 380 | 710 | 730 | 790 | 450 | 480 | 490 | 930 | 960 | 980 |

### 4.1. Exponential Smoothing Method

($\alpha$ = 0.2)

Formula : $F_{t+1} = \alpha D_t + (1- \alpha)F_t$

Calculation :

200 is accepted as a forecast 1 ($F_1$).

$F_2$ = 0.2*200+(1-0.2)*$F_1$

$F_2$ = 0.2*200+(1-0.2)*200= 200

$F_3$ = 0.2*300+(1-0.2)*$F_2$

$F_3$ = 0.2*300+(1-0.2)*200 = 220

Other forecasts are calculated in the same way and are given in the Table 15.

**Table 15**. *Forecasts Calculated By Exponential Smoothing Method*

| Month (x) | Demand (y) | $F_t$ |
|---|---|---|
| 1 | 200 | 200 |
| 2 | 300 | 200 |
| 3 | 250 | 220 |
| 4 | 600 | 226 |
| 5 | 650 | 300 |
| 6 | 670 | 370 |
| 7 | 400 | 430 |
| 8 | 440 | 424 |
| 9 | 430 | 427 |
| 10 | 900 | 427 |
| 11 | 980 | 521 |
| 12 | 990 | 612 |
| 13 | 300 | 687 |
| 14 | 370 | 609 |
| 15 | 380 | 561 |
| 16 | 710 | 524 |
| 17 | 730 | 561 |
| 18 | 790 | 594 |
| 19 | 450 | 633 |
| 20 | 480 | 596 |
| 21 | 490 | 572 |
| 22 | 930 | 555 |
| 23 | 960 | 630 |
| 24 | 980 | 696 |

## 4.2. Mean Squared Error (MSE) for Exponential Smoothing Method

Formula : $\frac{\sum_{i=1}^{n}(\text{Actual}-\text{Forecast})^2}{n} = \frac{\sum_{i=1}^{n}(D_t-F_t)^2}{n}$

Calculation :

Firstly, squarred error was calculated.

1. For January : $(200-200)^2$ = 0
2. For February : $(300-200)^2$ = 10000
3. For March : $(250-220)^2$ = 900

Other squarred errors are calculated in the same way and are given in Table 16.

**Table 16**. *Squarred Errors for Exponential Smoothing Method*

| Month (x) | Demand (y) | Squarred Error |
|---|---|---|
| 1 | 200 | 0 |
| 2 | 300 | 10000 |
| 3 | 250 | 900 |
| 4 | 600 | 139876 |
| 5 | 650 | 122500 |
| 6 | 670 | 90000 |
| 7 | 400 | 900 |
| 8 | 440 | 256 |
| 9 | 430 | 9 |
| 10 | 900 | 223729 |
| 11 | 980 | 210681 |
| 12 | 990 | 142884 |
| 13 | 300 | 149769 |
| 14 | 370 | 57121 |
| 15 | 380 | 32761 |
| 16 | 710 | 34596 |
| 17 | 730 | 28561 |
| 18 | 790 | 38416 |
| 19 | 450 | 33489 |
| 20 | 480 | 13456 |
| 21 | 490 | 6724 |
| 22 | 930 | 140625 |
| 23 | 960 | 108900 |
| 24 | 980 | 80656 |

Sum of squarred error : (0+10000+900+139876+122500+………………………+ 108900+80656) = 1666809

Now, we can find mean squarred error for exponential smoothing method.

MSE = $\frac{\sum_{i=1}^{n}(D_t - F_t)^2}{n}$ = $\frac{1666809}{24}$ = 69450.375

### 4.3. Double Exponential Smoothing Method

($\alpha$ = 0.2, $\beta$ = 0.2, $S_0$ = 200, $G_0$ = 50)

Formulas :

$S_t = \alpha D_t + (1-\alpha)(S_{t-1} + G_{t-1})$

$G_t = \beta(S_t - S_{t-1}) + (1-\beta)G_{t-1}$

$F_{t,t+\tau} = S_t + \tau \times G_t$ (forecast for time $\tau$ into the future)

Where ;

$D_t$ is observed demand,

$S_t$ is current estimate of 'intercept',

$G_t$ is current estimate of slope,

$S_{t-1}$ is last estimate of 'intercept',

$G_{t-1}$ is the last estimate of slope.

Calculations :

1. For January :

$S_1 = 0.2*200 + (1-0.2)*(200 + 50) = 240$

$G_1 = 0.2*(240 - 200) + (1-0.2)*50 = 48$

$F_1 = 200 + 1*50=250$

2. For February :

$S_2 = 0.2*300 + (1-0.2)*(240 + 48) = 290.4$

$G_2 = 0.2*(290.4 - 240) + (1-0.2)*48 = 48.48$

$F_2 = 240 + 1*48 = 288$

3. For March :

$S_3 = 0.2*250 + (1-0.2)*(290.4 + 48.48) = 321.10$

$G_3 = 0.2*(321.10 - 290.4) + (1-0.2)*48.48= 44.92$

$F_3 = 290.4 + 1*48.48 = 338$

Other intercepts,slopes and forecasts are calculated in the same way and are given in the Table 17.

**Table 17.** *Intercepts, Slopes and Forecasts Calculated By Exponential Smoothing Method*

| Month (x) | Demand (y) | Double Exponential Smoothing Method | | |
|---|---|---|---|---|
| | | St | Gt | Ft |
| 1 | 200 | 240 | 48 | 250 |
| 2 | 300 | 290.40 | 48.48 | 288 |
| 3 | 250 | 321.10 | 44.92 | 338 |
| 4 | 600 | 412.82 | 54.28 | 366 |
| 5 | 650 | 503.69 | 61.60 | 467 |
| 6 | 670 | 586.23 | 65.79 | 565 |
| 7 | 400 | 601.61 | 55.71 | 652 |
| 8 | 440 | 613.86 | 47.01 | 657 |
| 9 | 430 | 614.70 | 37.78 | 660 |
| 10 | 900 | 701.98 | 47.68 | 652 |
| 11 | 980 | 795.73 | 56.89 | 749 |
| 12 | 990 | 880.10 | 62.39 | 852 |
| 13 | 300 | 813.99 | 36.69 | 942 |
| 14 | 370 | 754.54 | 17.46 | 850 |
| 15 | 380 | 693.61 | 1.78 | 772 |
| 16 | 710 | 698.31 | 2.37 | 695 |
| 17 | 730 | 706.54 | 3.54 | 700 |
| 18 | 790 | 726.06 | 6.74 | 710 |
| 19 | 450 | 676.24 | -4.58 | 732 |
| 20 | 480 | 633.33 | -12.24 | 671 |
| 21 | 490 | 594.87 | -17.49 | 621 |
| 22 | 930 | 647.91 | -3.38 | 577 |
| 23 | 960 | 707.62 | 9.24 | 644 |
| 24 | 980 | 769.49 | 19.76 | 716 |

### 4.4. Mean Squared Error (MSE) for Double Exponential Smoothing Method

Formula : $\frac{\sum_{i=1}^{n}(\text{Actual}-\text{Forecast})^2}{n} = \frac{\sum_{i=1}^{n}(D_t - F_t)^2}{n}$

Calculation :

Firstly, squarred error was calculated.

1. For January : $(200-250)^2$ = 2500
2. For February : $(300-288)^2$ = 144
3. For March : $(250-338)^2$ = 7744

Other squarred errors are calculated in the same way and are given in Table 18.

**Table 18**. *Squarred Errors for Double Exponential Smoothing Method*

| Month (x) | Demand (y) | Squarred Error |
|---|---|---|
| 1 | 200 | 2500 |
| 2 | 300 | 144 |
| 3 | 250 | 7744 |
| 4 | 600 | 54756 |
| 5 | 650 | 33489 |
| 6 | 670 | 11025 |
| 7 | 400 | 63504 |
| 8 | 440 | 47089 |
| 9 | 430 | 52900 |
| 10 | 900 | 61504 |
| 11 | 980 | 53361 |
| 12 | 990 | 19044 |
| 13 | 300 | 412164 |
| 14 | 370 | 230400 |
| 15 | 380 | 153664 |
| 16 | 710 | 225 |
| 17 | 730 | 900 |
| 18 | 790 | 6400 |
| 19 | 450 | 79524 |
| 20 | 480 | 36481 |
| 21 | 490 | 17161 |
| 22 | 930 | 124609 |
| 23 | 960 | 99856 |
| 24 | 980 | 69696 |

Sum of squarred error : (2500+144+7744+54756+……………………….+99856 +69696) = 1638140

Now, we can find mean squarred error for exponential smoothing method.

MSE = $\frac{\sum_{i=1}^{n}(D_{t}-F_{t})^2}{n}$ = $\frac{1638140}{24}$ = 68255.8

### 4.5. Regression Analysis Method

Formula : $y_i = a + bx_i$

Where ;

$y_i$ is actual observations,

$a + bx_i$ is prediction.

Calculation :

A and b values need to be calculated before forecasting for other months. The data required to calculate these values are given in Table 19.

**Table 19.** *Values to be Calculated for Data a and b*

| | Month (x) | Demand (y) | $x^2$ | xy |
|---|---|---|---|---|
| | 1 | 200 | 1 | 200 |
| | 2 | 300 | 4 | 600 |
| | 3 | 250 | 9 | 750 |
| | 4 | 600 | 16 | 2400 |
| | 5 | 650 | 25 | 3250 |
| | 6 | 670 | 36 | 4020 |
| | 7 | 400 | 49 | 2800 |
| | 8 | 440 | 64 | 3520 |
| | 9 | 430 | 81 | 3870 |
| | 10 | 900 | 100 | 9000 |
| | 11 | 980 | 121 | 10780 |
| | 12 | 990 | 144 | 11880 |
| | 13 | 300 | 169 | 3900 |
| | 14 | 370 | 196 | 5180 |
| | 15 | 380 | 225 | 5700 |
| | 16 | 710 | 256 | 11360 |
| | 17 | 730 | 289 | 12410 |
| | 18 | 790 | 324 | 14220 |
| | 19 | 450 | 361 | 8550 |
| | 20 | 480 | 400 | 9600 |
| | 21 | 490 | 441 | 10290 |
| | 22 | 930 | 484 | 20460 |
| | 23 | 960 | 529 | 22080 |
| | 24 | 980 | 576 | 23520 |
| Sum | 300 | 14380 | 4900 | 200340 |
| Mean | 13 | 599 | | |

$$b = \frac{n\sum_i x_i y_i - (\sum_i x_i)(\sum_i y_i)}{n\sum_i {x_i}^2 - (\sum_i x_i)^2} = \frac{24*200340-(300)*(14380)}{24*4900-(300)^2} = 17.90$$

$a = \bar{y} - b\bar{x} = 599 – 17.90*13 = 375.36$

$y(x) = 375.36 + 17.90x$

1. For January :

x = 1

y(1) = 375.36+ 17.90*1 = 393

2. For February :

x = 2

y(2) = 375.36+ 17.90*2 = 411

3. For March :

x = 3

y(3) = 375.36+ 17.90*3 = 429

Other forecasts are calculated in the same way and are given in the Table 20.

**Table 20.** *Forecasts Calculated By Regression Analysis Method*

| Month (x) | Demand (y) | Ft |
|---|---|---|
| 1 | 200 | 393 |
| 2 | 300 | 411 |
| 3 | 250 | 429 |
| 4 | 600 | 446 |
| 5 | 650 | 464 |
| 6 | 670 | 482 |
| 7 | 400 | 500 |
| 8 | 440 | 518 |
| 9 | 430 | 536 |
| 10 | 900 | 554 |
| 11 | 980 | 572 |
| 12 | 990 | 590 |
| 13 | 300 | 608 |
| 14 | 370 | 626 |
| 15 | 380 | 643 |
| 16 | 710 | 661 |
| 17 | 730 | 679 |
| 18 | 790 | 697 |
| 19 | 450 | 715 |
| 20 | 480 | 733 |
| 21 | 490 | 751 |
| 22 | 930 | 769 |
| 23 | 960 | 787 |
| 24 | 980 | 805 |

### 4.6. Mean Squared Error (MSE) for Regression Analysis Method

Formula : $\frac{\sum_{i=1}^{n}(\text{Actual}-\text{Forecast})^2}{n} = \frac{\sum_{i=1}^{n}(D_t - F_t)^2}{n}$

Calculation :

Firstly, squarred error was calculated.

1. For January : $(200 - 393)^2$ = 37249
2. For February : $(300 - 411)^2$ = 12321
3. For March : $(250 - 429)^2$ = 32041

Other squarred errors are calculated in the same way and are given in Table 21.

**Table 21.** *Squarred Errors for Regression Analysis Method*

| Month (x) | Demand (y) | Squarred Error |
|---|---|---|
| 1 | 200 | 37249 |
| 2 | 300 | 12321 |
| 3 | 250 | 32041 |
| 4 | 600 | 23716 |
| 5 | 650 | 34596 |
| 6 | 670 | 35344 |
| 7 | 400 | 10000 |
| 8 | 440 | 6084 |
| 9 | 430 | 11236 |
| 10 | 900 | 119716 |
| 11 | 980 | 166464 |
| 12 | 990 | 160000 |
| 13 | 300 | 94864 |
| 14 | 370 | 65536 |
| 15 | 380 | 69169 |
| 16 | 710 | 2401 |
| 17 | 730 | 2601 |
| 18 | 790 | 8649 |
| 19 | 450 | 70225 |
| 20 | 480 | 64009 |
| 21 | 490 | 68121 |
| 22 | 930 | 25921 |
| 23 | 960 | 29929 |
| 24 | 980 | 30625 |

Sum of squarred error :

(37249+12321+32041+23716………………………+25921+29929+30625) = 1180817

Now, we can find mean squarred error for regression analysis method.

MSE = $\frac{\sum_{i=1}^{n}(D_t - F_t)^2}{n} = \frac{1180817}{24}$ = 49200.71

### 4.7. Deseasonalized Regression Analysis Method

In order to be able to find a solution with deseasonal regression analysis method, first of all, seasonal data must be deseasonalized. Then it is solved according to the regression analysis method. Finally, the obtained data is converted back to seasonal data.

Calculation :

Expected Demand Q1$_{year3}$ = (200+300)/2 = 250

Expected Demand Q2$_{year3}$ = (300+370)/2 = 335

Expected Demand Q3$_{year3}$ = (250+380)/2 = 315

Overall average demand = $(\sum_i D_i)\,/24$ = (200+300+250+……..+960+980) / 24

= 599.17

Other expected demands are calculated in the same way and are given in Table 22.

**Table 22.** *Calculated Expected Demands for Deseasonal Regression Analysis Method*

| Season | Cycle | Demand | Season | Cycle | Demand | Season | Cycle | Expected Demand |
|---|---|---|---|---|---|---|---|---|
| Q1 | Year 1 | 200 | Q1 | Year 2 | 300 | Q1 | Year 3 | 250 |
| Q2 | Year 1 | 300 | Q2 | Year 2 | 370 | Q2 | Year 3 | 335 |
| Q3 | Year 1 | 250 | Q3 | Year 2 | 380 | Q3 | Year 3 | 315 |
| Q4 | Year 1 | 600 | Q4 | Year 2 | 710 | Q4 | Year 3 | 655 |
| Q5 | Year 1 | 650 | Q5 | Year 2 | 730 | Q5 | Year 3 | 690 |
| Q6 | Year 1 | 670 | Q6 | Year 2 | 790 | Q6 | Year 3 | 730 |
| Q7 | Year 1 | 400 | Q7 | Year 2 | 450 | Q7 | Year 3 | 425 |
| Q8 | Year 1 | 440 | Q8 | Year 2 | 480 | Q8 | Year 3 | 460 |
| Q9 | Year 1 | 430 | Q9 | Year 2 | 490 | Q9 | Year 3 | 460 |
| Q10 | Year 1 | 900 | Q10 | Year 2 | 930 | Q10 | Year 3 | 915 |
| Q11 | Year 1 | 980 | Q11 | Year 2 | 960 | Q11 | Year 3 | 970 |
| Q12 | Year 1 | 990 | Q12 | Year 2 | 980 | Q12 | Year 3 | 985 |

Seasonal Demand Factors:

Q1: 250/599.17 = 0.42

Q2: 335/599.17 = 0.56

Q3: 315/599.17 = 0.53

Deseasonal demand data should be obtained from seasonal data. Therefore, the demand values should be divided by the seasonal demand factors.

Deseason Demand:

Q1: 200 /0.42 = 479.33

Q2: 300/0.56 = 536.57

Q3: 250/0.53 = 475.53

The other seasonal demand factors and deaseason demands are calculated in the same way. These values are given in Table 23.

**Table 23.** *Calculated Values to Work on Deaseasonal Data*

| Month | Actual Demand | Period Average | Period Factor | Deseason Demand (y) | Period in (x) | xy | $x^2$ |
|---|---|---|---|---|---|---|---|
| 1 | 200 | 250 | 0.42 | 479.33 | 1 | 479.3 | 1 |
| 2 | 300 | 335 | 0.56 | 536.57 | 2 | 107.1 | 4 |
| 3 | 250 | 315 | 0.53 | 475.53 | 3 | 1426.6 | 9 |
| 4 | 600 | 655 | 1.09 | 548.85 | 4 | 2195.4 | 16 |
| 5 | 650 | 690 | 1.15 | 564.43 | 5 | 2822.2 | 25 |
| 6 | 670 | 730 | 1.22 | 549.92 | 6 | 3299.5 | 36 |
| 7 | 400 | 425 | 0.71 | 563.92 | 7 | 3947.5 | 49 |
| 8 | 440 | 460 | 0.77 | 573.12 | 8 | 4584.9 | 64 |
| 9 | 430 | 460 | 0.77 | 560.09 | 9 | 5040.8 | 81 |
| 10 | 900 | 915 | 1.53 | 589.34 | 10 | 5893.4 | 100 |
| 11 | 980 | 970 | 1.62 | 605.34 | 11 | 6658.8 | 121 |
| 12 | 990 | 985 | 1.64 | 602.21 | 12 | 7226.5 | 144 |
| 13 | 300 | 250 | 0.42 | 719.00 | 13 | 9347.0 | 169 |
| 14 | 370 | 335 | 0.56 | 661.77 | 14 | 9264.7 | 196 |
| 15 | 380 | 315 | 0.53 | 722.80 | 15 | 10842.1 | 225 |
| 16 | 710 | 655 | 1.09 | 649.48 | 16 | 10391.7 | 256 |
| 17 | 730 | 690 | 1.15 | 633.90 | 17 | 10776.3 | 289 |
| 18 | 790 | 730 | 1.22 | 648.41 | 18 | 11671.4 | 324 |
| 19 | 450 | 425 | 0.71 | 634.41 | 19 | 12053.8 | 361 |
| 20 | 480 | 460 | 0.77 | 625.22 | 20 | 12504.3 | 400 |
| 21 | 490 | 460 | 0.77 | 638.24 | 21 | 13403.1 | 441 |
| 22 | 930 | 915 | 1.53 | 608.99 | 22 | 13397.8 | 484 |
| 23 | 960 | 970 | 1.62 | 592.99 | 23 | 13638.8 | 529 |
| 24 | 980 | 985 | 1.64 | 596.13 | 24 | 14307 | 576 |
| | | | SUM | 14380 | 300 | 186246.07 | 4900 |
| | | | MEAN | 599 | 13 | | |

A and b values need to be calculated before forecasting for other months.

$$b = \frac{n\sum_i x_i y_i - (\sum_i x_i)(\sum_i y_i)}{n\sum_i x_i{}^2 - (\sum_i x_i)^2} = \frac{24*186246.07-(300)*(14380)}{24*4900-(300)^2} = 5.65$$

$a = \bar{y} - b\bar{x}$ = 599 – 5.65*13 = 528.56

y(x) = 528.56+ 5.65x

The results from this equation should be seasonalized. Therefore, it should be multiplied by the period factor.

y(x) = period factor * (528.56 + 5.65x)

1. For January :

x = 1

y(1) = 0.42*(528.56 + 5.65*1) = 222

2. For February :

x = 2

y(2) = 0.56*(528.56 + 5.65*2) = 301

3. For March :

x = 3

y(3) = 0.53*(528.56 + 5.65*3 )= 288

Other forecasts are calculated in the same way and are given in the Table 24.

**Table 24.** *Forecasts Calculated By Deseasonal Regression Analysis Method*

| Month (x) | Demand (y) | Ft |
|---|---|---|
| 1 | 200 | 222 |
| 2 | 300 | 301 |
| 3 | 250 | 286 |
| 4 | 600 | 602 |
| 5 | 650 | 641 |
| 6 | 670 | 685 |
| 7 | 400 | 402 |
| 8 | 440 | 440 |
| 9 | 430 | 444 |
| 10 | 900 | 893 |
| 11 | 980 | 956 |
| 12 | 990 | 980 |
| 13 | 300 | 251 |
| 14 | 370 | 339 |
| 15 | 380 | 322 |
| 16 | 710 | 676 |
| 17 | 730 | 719 |
| 18 | 790 | 767 |
| 19 | 450 | 451 |
| 20 | 480 | 492 |
| 21 | 490 | 496 |
| 22 | 930 | 996 |
| 23 | 960 | 1066 |
| 24 | 980 | 1091 |

## 4.8. Mean Squared Error (MSE) for Deseasonalized Regression Analysis Method

Formula : $\frac{\sum_{i=1}^{n}(\text{Actual}-\text{Forecast})^2}{n} = \frac{\sum_{i=1}^{n}(D_t - F_t)^2}{n}$

Calculation :

Firstly, squarred error was calculated.

5. For January : $(200 - 222)^2$ = 484
6. For February : $(300 - 301)^2$ =1
7. For March : $(250 - 286)^2$ = 1296

Other squarred errors are calculated in the same way and are given in Table 25.

**Table 25.** *Squarred Errors for Regression Analysis Method*

| Month (x) | Demand (y) | Squarred Error |
|---|---|---|
| 1 | 200 | 484 |

| | | |
|---|---|---|
| 2 | 300 | 1 |
| 3 | 250 | 1296 |
| 4 | 600 | 4 |
| 5 | 650 | 81 |
| 6 | 670 | 225 |
| 7 | 400 | 4 |
| 8 | 440 | 0 |
| 9 | 430 | 196 |
| 10 | 900 | 49 |
| 11 | 980 | 576 |
| 12 | 990 | 100 |
| 13 | 300 | 2401 |
| 14 | 370 | 961 |
| 15 | 380 | 3364 |
| 16 | 710 | 1156 |
| 17 | 730 | 121 |
| 18 | 790 | 529 |
| 19 | 450 | 1 |
| 20 | 480 | 144 |
| 21 | 490 | 36 |
| 22 | 930 | 4356 |
| 23 | 960 | 11236 |
| 24 | 980 | 12321 |

Sum of squarred error : (484+1+1296+4+………………………4356+11236+12321) = 39643

Now, we can find mean squarred error for regression analysis method.

MSE = $\frac{\sum_{i=1}^{n}(D_t - F_t)^2}{n} = \frac{39643}{24}$ = 1651.75

## 5. THE FLOWCHART OF THE PROBLEM

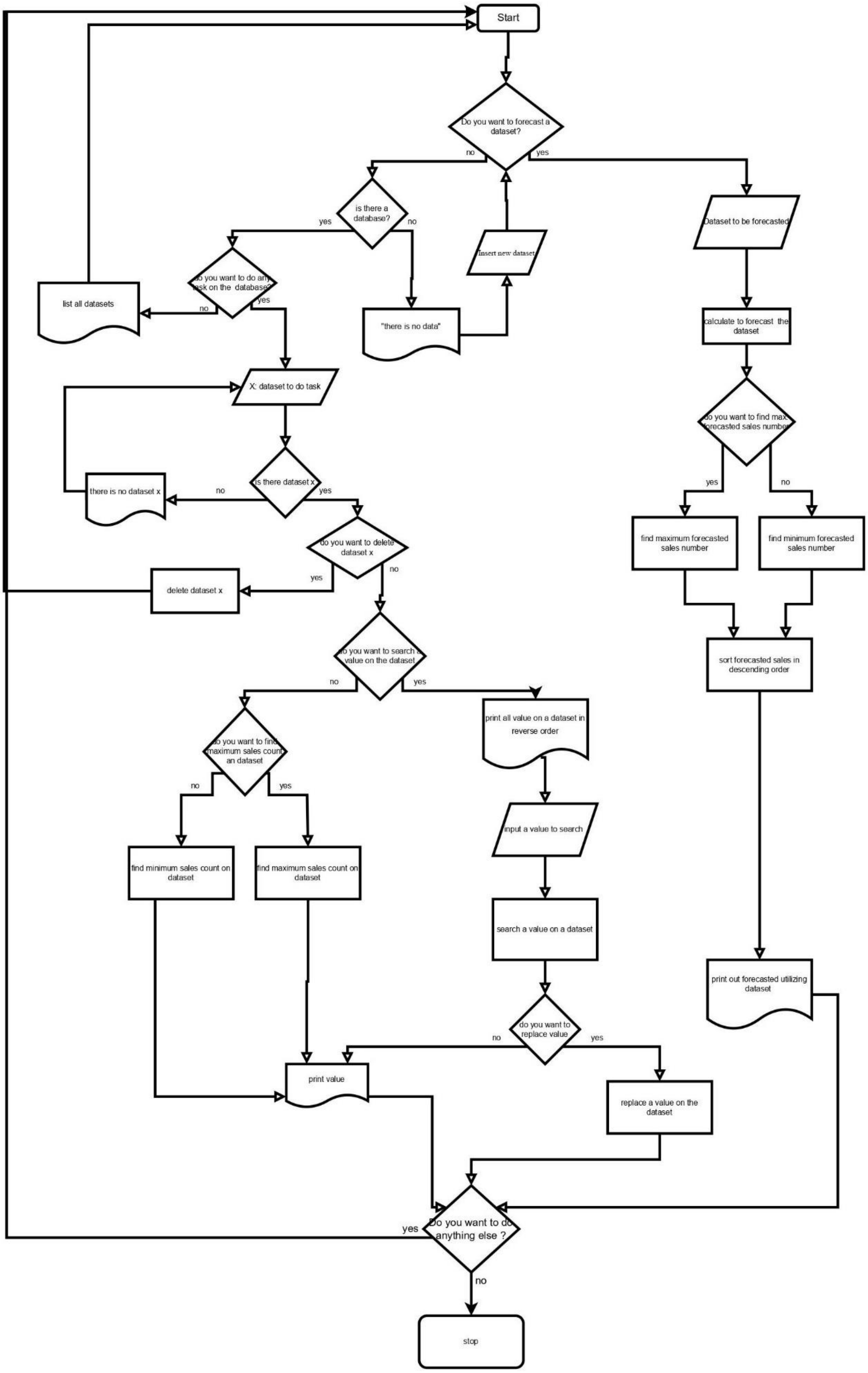



**Figure 1.** *The flowchart developed for the problem*

Computer engineers are developing a simple decision support system that a luxury SUV car manufacturer will use in forecasting processes. The system requests data from the user for the last two years and tries to predict forecasts for the next two years by analyzing and calculating with appropriate methods, based on the given data. The flowchart for this system to be developed is given in Figure 1 and the language of the program to be used is JAVA.

## 6. THE DEVELOPED PROGRAM

```java
import java.io.*;

public class FirstMethod {
    private static  double α= 0.2;
    static Ft gess=new Ft();

    public static Ft calculation() throws IOException {

        //Formula : Ft+1 = α Dt + (1- α)Ft
        // 300 is accepted as a forecast 1 (F1).
        // f1 , f2 ,f3 aylardır tahminler

        gess.insert(300, 0);
        int f=0;
        for (int i = 0; i<24; i++){
            f=(int) (α*Home.data1()[i]+(1-α)*gess.getByPosition(0).getName());
            gess.insert(f);
        }
        return gess;
    }

    public static double error() throws IOException {
        return Mse.Mse(gess,Home.data1());
    }
}
```

**Figure-1 Exponential Smoothing Method**

This is implementation code of the first method that was calculated in the first report.

Time complexity is O(n) because of the for loop.

```java
import java.io.IOException;

public class SecondMethod {

    static Ft gess=new Ft();

    public static Ft calculation() throws IOException {
        // (α = 0.2, β = 0.2, S0 = 200, G0 = 50)
        //  Formulas :
        //St = αDt + (1-α)(St-1 + Gt-1 )
        // Gt = β(St – St-1 ) + (1- β)Gt-1
        // Ft,t+♦ = St + ♦×Gt (forecast for time ♦ into the future)
        // Where ;
        // Dt is observed demand,
        // St is current estimate of ‘intercept’,
        // Gt is current estimate of slope,
        //St-1 is last estimate of ‘intercept’,
        // Gt-1 is the last estimate of slope.
        double B = 0.2;
        double[] St = new double[24];
        double[] Gt = new double[24];

        St[0]=200;
        Gt[0]=50;
        for (int i = 0; i<24; i++){
            if(i==0){
                St[0]=200;
                Gt[0]=50;
            }else {
                double a=0.2;
                St[i]=  a*Home.data1()[i-1]+(1-a)*(St[i-1] + Gt[i-1]);


               Gt[i]=  B*(St[i]-St[i-1])+(1-B)*Gt[i-1];
            }

            gess.insert((int) (St[i]+Gt[i]));
            // System.out.println(St[i]+"    "+Gt[i]+"    "+ft[i]);
        }
        return gess;
    }
    public static double error() throws IOException {
        return Mse.Mse(gess,Home.data1());
    }
}
```

**Figure-2 Double-Exponential Smoothing**

This is implementation code of the second method that was calculated in the first report.

Time complexity is O(n) because of the for loop.

```java
import java.io.IOException;

public class ThirdMethod {

    static Ft gess = new Ft();

    public static Ft calculation() throws IOException {

        int[] xy = new int[24];
        int[] xx = new int[24];

        int xytoplam = 0;
        for (int i = 0; i < 24; i++) {
            xy[i] = Home.data1()[i] * (i + 1);
            xytoplam = xytoplam + xy[i];
        }


        int xxtoplam = 0;
        for (int i = 0; i < 24; i++) {
            xx[i] = (i + 1) * (i + 1);
            xxtoplam = xxtoplam + xx[i];
        }

        double ytoplam = 0;
        for (int i = 0; i < 24; i++) {
            ytoplam = Home.data1()[i] + ytoplam;
        }

        int xtoplam = 0;
        for (int i = 0; i < 24; i++) {
            xtoplam = xtoplam + i + 1;
        }

        double q = (24 * xytoplam - xtoplam * ytoplam);
        double w = (24 * xxtoplam - xtoplam * xtoplam);
        double b = q / w;
        double z = ytoplam / 24;

        double aa = (z) - ((b * xtoplam) / 24);

        for (int i = 0; i < 48; i++) {
            gess.insert((int) (aa + b * (i + 1)));
        }
        return gess;
    }

    public static double error() throws IOException {
        return Mse.Mse(gess, Home.data1());
    }
}
```

**Figure-3 Regression Analysis**

This is implementation code of the third method that was calculated in the first report.

Time complexity is O(n) because of the for loop.

```java
import java.io.IOException;

public class FourthMethod {
    static Ft gess = new Ft();

    public static Ft calculation() throws IOException {

        double overall = 0;
        for (int i = 0; i < 24; i++) {
            overall = Home.data1()[i] + overall;
        }

        overall = overall / 24;

        double[] Seasonal = new double[12];
        for (int i = 0; i < 12; i++) {
            Seasonal[i] = ((Home.data1()[i] + Home.data1()[i + 12]) / 2) / overall;
        }

        double[] Deseason = new double[24];
        for (int i = 0; i < 24; i++) {
            Deseason[i] = Home.data1()[i] / Seasonal[i % 12];
        }

        double ytoplam = 0;
        for (int i = 0; i < 24; i++) {
            ytoplam = Deseason[i] + ytoplam;
        }

        int xtoplam = 0;
        for (int i = 0; i < 24; i++) {
            xtoplam = xtoplam + i + 1;
        }

        double[] xy = new double[24];
        int[] xx = new int[24];
        int xxtoplam = 0;
        for (int i = 0; i < 24; i++) {
            xx[i] = (i + 1) * (i + 1);
            xxtoplam = xxtoplam + xx[i];
        }
        double xytoplam = 0;
        for (int i = 0; i < 24; i++) {
            xy[i] = Deseason[i] * (i + 1);
            xytoplam = xytoplam + xy[i];
        }

        double b = (24 * xytoplam - xtoplam * ytoplam) / (24 * xxtoplam - xtoplam * xtoplam);

        double aa = ytoplam / 24 - b * xtoplam / 24;

        for (int i = 0; i < 48; i++) {
            gess.insert((int) ((aa + b * (i + 1)) * Seasonal[i % 12]));
        }

        return gess;
    }
    public static double error() throws IOException {
        return Mse.Mse(gess, Home.data1());
    }
}
```

**Figure-4 Deseasonalized Regression Analysis**

This is implementation code of the fourth method that was calculated in the first report.

Time complexity is O(n) because of the for loop

```java
public class Mse {
    public static double Mse(Ft ft, int[] dt){
        double MSE=0;
        //MSE = (∑_(i=1)^n▒〖〖(D〗_(t-) F_t)〗^2 )/n
        double toplam=0;
        double[] SquarredError = new double[24];

        for (int i = 0; i<24; i++){
            SquarredError[i]=(dt[i]-ft.getByPosition(i).getName())*(dt[i]-ft.getByPosition(i).getName());
            toplam= (toplam+SquarredError[i]);
        }

        MSE=toplam/24;

return MSE;
    }
}
```

**Figure-5 MSE**

This is implementation code of the fourth method that was calculated in the first report.

Time complexity is O(n) because of the for loop.

```java
public class LinkList {

        private int name;
    LinkList next;
    LinkList previous;
        //Constructor
        public LinkList(int n){
            this.name = n;
            this.next=null;
            this.previous=null;
        }
        //Getter method
        public int getName() { return this.name; }
}
```

**Figure-6 LinkedList**

We chose doubly LinkedList because we are assuming that we do not know the size of dataset before the user inserts it.

## 7. THE RESULTS OF THE PROBLEM

```
Welcome to the forecasting system
Please choose what you want to do :
 1: Add New Dataset                2: Forecast Datasets
 3: List All Datasets              4: Delete All Datasets
 5: Search Value On DataSet        6: Find Max Sales Count
 7: Find Min Sales Count           8: Replace Value On Dataset
 9: Print Dataset In Reverse       10: Sort Forecasted Sales
11: exit
```

**Figure-7**

This is the first page that the user will encounter to choose what operation they want to execute**.**

```
1
please input 1. mounth
300
please input 2. mounth
350
please input 3. mounth
330
please input 4. mounth
340
please input 5. mounth
390
please input 6. mounth
430
please input 7. mounth
480
please input 8. mounth
460
please input 9. mounth
490
please input 10. mounth
510
please input 11. mounth
550
please input 12. mounth
560
```

```
please input 13. mounth
550
please input 14. mounth
590
please input 15. mounth
600
please input 16. mounth
610
please input 17. mounth
630
please input 18. mounth
620
please input 19. mounth
680
please input 20. mounth
690
please input 21. mounth
710
please input 22. mounth
730
please input 23. mounth
740
please input 24. mounth
770
Record is added.
```

**Figure-8**

This is the first operation which is adding new dataset.

```
The values resulting from the estimations according to the most optimal method:
 Deseasonalized Regression Analysis Method
1. month: 222
2. month: 301
3. month: 286
4. month: 602
5. month: 641
6. month: 685
7. month: 402
8. month: 440
9. month: 444
10. month: 893
11. month: 956
12. month: 980
13. month: 251
14. month: 339
15. month: 322
16. month: 676
17. month: 719
18. month: 767
19. month: 451
20. month: 492
21. month: 496
22. month: 996
23. month: 1066
24. month: 1091
Record is added.
```

**Figure-8.a Dataset-1**.

This is the forecasted dataset

```
The values resulting from the estimations according to the most optimal method:
 Regression Analysis Method
1. month: 320
2. month: 340
3. month: 359
4. month: 379
5. month: 399
6. month: 418
7. month: 438
8. month: 457
9. month: 477
10. month: 497
11. month: 516
12. month: 536
13. month: 556
14. month: 575
15. month: 595
16. month: 614
17. month: 634
18. month: 654
19. month: 673
20. month: 693
21. month: 712
22. month: 732
23. month: 752
24. month: 771
Record is added.
```

**Figure-8.b Dataset-2**

This is the forecasted dataset.

```
Please choose what you want to do :
 1: Add New Dataset              2: Forecast Datasets
 3: List All Datasets            4: Delete All Datasets
 5: Search Value On DataSet      6: Find Max Sales Count
 7: Find Min Sales Count         8: Replace Value On Dataset
 9: Print Dataset In Reverse     10: Sort Forecasted Sales
11: exit

3
dataset 1: 300  350 330 340 390 430 480 460 490 510 550 560 550 590 600 610 630 620 680 690 710 730 740 770
dataset 2: 200  300 250 600 650 670 400 440 430 900 980 990 300 370 380 710 730 790 450 480 490 930 960 980
```

**Figure-9**

This options lists all datasets.

```
Welcome to the forecasting system
Please choose what you want to do :
 1: Add New Dataset              2: Forecast Datasets
 3: List All Datasets            4: Delete All Datasets
 5: Search Value On DataSet      6: Find Max Sales Count
 7: Find Min Sales Count         8: Replace Value On Dataset
 9: Print Dataset In Reverse     10: Sort Forecasted Sales
11: exit

5
Enter the value to find
390
5. month 390
```

**Figure-10**

This option is for searching a data in the dataset.

```
Please choose what you want to do :
 1: Add New Dataset              2: Forecast Datasets
 3: List All Datasets            4: Delete All Datasets
 5: Search Value On DataSet      6: Find Max Sales Count
 7: Find Min Sales Count         8: Replace Value On Dataset
 9: Print Dataset In Reverse     10: Sort Forecasted Sales
11: exit

6
770
```

**Figure-11**

This option is for finding the max sales count in the dataset.

```
Please choose what you want to do :
 1: Add New Dataset                 2: Forecast Datasets
 3: List All Datasets               4: Delete All Datasets
 5: Search Value On DataSet         6: Find Max Sales Count
 7: Find Min Sales Count            8: Replace Value On Dataset
 9: Print Dataset In Reverse        10: Sort Forecasted Sales
11: exit


7
300
```

**Figure-12**

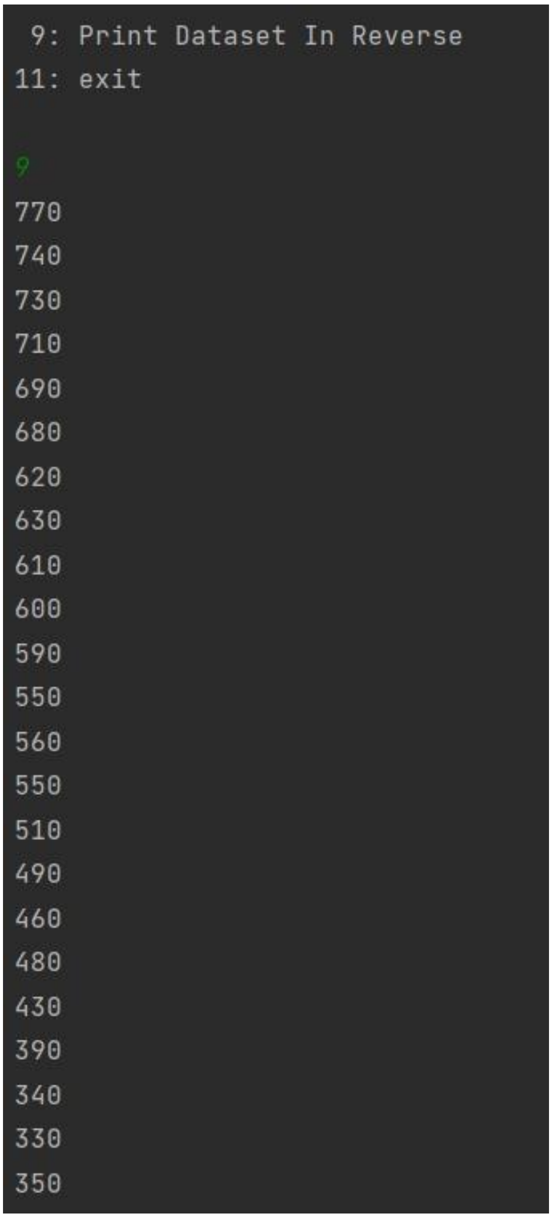
This option is for finding the min sales count in the dataset.

```
Please choose what you want to do :
 1: Add New Dataset                 2: Forecast Datasets
 3: List All Datasets               4: Delete All Datasets
 5: Search Value On DataSet         6: Find Max Sales Count
 7: Find Min Sales Count            8: Replace Value On Dataset
 9: Print Dataset In Reverse        10: Sort Forecasted Sales
11: exit


8
Enter the value to be replace
300
Enter the the new value you to replace with
450
```

**Figure-13**

This option is for replacing a data in the dataset.

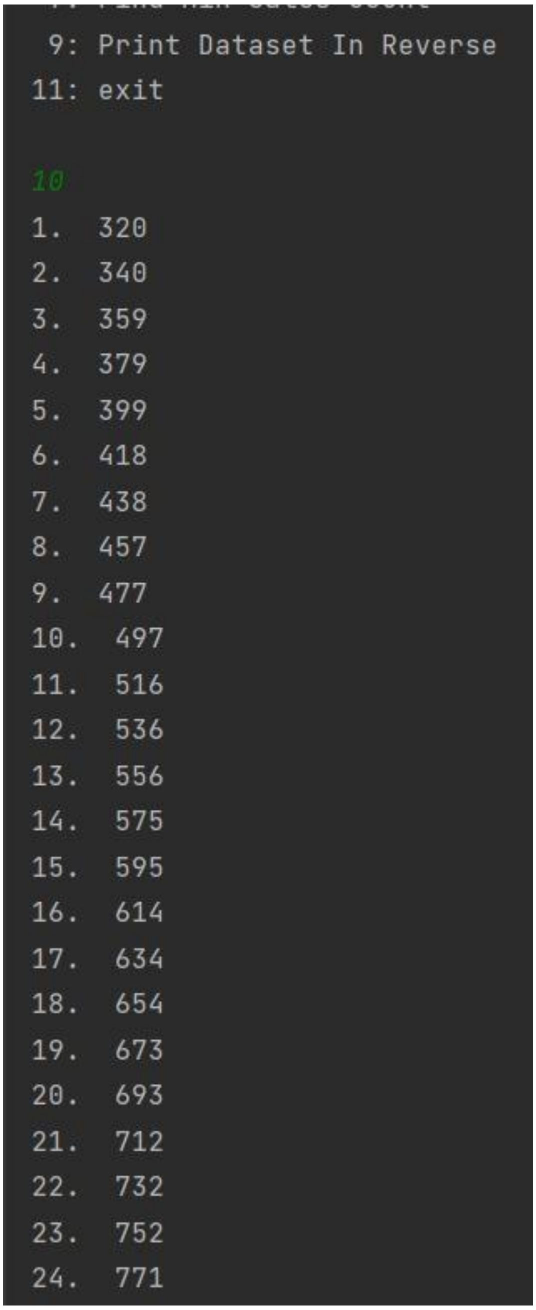


```
 9: Print Dataset In Reverse
11: exit

9
770
740
730
710
690
680
620
630
610
600
590
550
560
550
510
490
460
480
430
390
340
330
350
```

**Figure-14**

This option is for printing dataset in reverse.



```
 9: Print Dataset In Reverse
11: exit

10
1.  320
2.  340
3.  359
4.  379
5.  399
6.  418
7.  438
8.  457
9.  477
10.  497
11.  516
12.  536
13.  556
14.  575
15.  595
16.  614
17.  634
18.  654
19.  673
20.  693
21.  712
22.  732
23.  752
24.  771
```

**Figure-15**

This option is for sorting forecasted datasets.

```
The values resulting from the estimations according to the most optimal method:
 Regression Analysis Method
1. month of next date: 791
2. month of next date: 811
3. month of next date: 830
4. month of next date: 850
5. month of next date: 869
6. month of next date: 889
7. month of next date: 909
8. month of next date: 928
9. month of next date: 948
10. month of next date: 967
11. month of next date: 987
12. month of next date: 1007
13. month of next date: 1026
14. month of next date: 1046
15. month of next date: 1065
16. month of next date: 1085
17. month of next date: 1105
18. month of next date: 1124
19. month of next date: 1144
20. month of next date: 1164
21. month of next date: 1183
22. month of next date: 1203
23. month of next date: 1222
24. month of next date: 1242
Record is added.
```

**Figure-16**

The outputs here are the forecast of dataset 1 data for the next two years resulting from the program..

```
The values resulting from the estimations according to the most optimal method:
 Deseasonalized Regression Analysis Method
1. month of next date: 279
2. month of next date: 377
3. month of next date: 358
4. month of next date: 750
5. month of next date: 797
6. month of next date: 850
7. month of next date: 499
8. month of next date: 544
9. month of next date: 548
10. month of next date: 1100
11. month of next date: 1175
12. month of next date: 1203
13. month of next date: 307
14. month of next date: 415
15. month of next date: 393
16. month of next date: 824
17. month of next date: 875
18. month of next date: 933
19. month of next date: 547
20. month of next date: 596
21. month of next date: 600
22. month of next date: 1203
23. month of next date: 1285
24. month of next date: 1314
Record is added.
```

**Figure-16**

The outputs here are the forecast of dataset 2 data for the next two years resulting from the program..

## 8. CONCLUSION

The problem given within the scope of ENM319 & BIM213 courses named Production and Operation Planning & Data Structures and Algorithms has been solved and the requirements have been completed.

A project was carried out with the cooperation of industrial engineers working in the production planning department of a company that produces luxury SUVs for customers in various countries and computer engineers working in the IT department. Within the scope of the project, a simple decision support system has been developed to be used in estimation processes.

Industrial engineers solved the given problem analytically for each dataset. In line with the solution methods solved by industrial engineers, Regression Analysis Method was determined as the best method for the first data set and Deseasonalized Regression Analysis Method for the second data set. Mean Squarred Errors (MSE) calculated for the selection of the best method were examined and the methods with the least error were selected. Here, MSE values were calculated as 358.96 in Regression Analysis Method for the first data set and as 1651.75 in the Deseasonalized Regression Analysis Method for the second data set.

Industrial engineers transferred all calculations and evaluations to computer engineers and helped them to develop programs. With this program developed by computer engineers, in line with the demand values entered by the user, the program will be able to determine the appropriate method according to these data and make the necessary estimation for the cars. In addition, in this report, the automobile demand forecasts for the next two years were calculated by the program in line with the appropriate method with the two data sets examined within the scope of the project.