CAL STATE EAST BAY

ENGR 610: Analytical Methods in Engineering Management

Quantitative Analysis of Tesla

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Contents

1 Introduction

This project analyses the Tesla automotive company strategies considering Decision Analysis, Forecasting and Inventory models. In decision analysis, we evaluate the most important electrical vehicle of Tesla based on maximum EMV value. Analyze the current demand of electrical vehicles and how to forecast the future demand of Tesla cars by forecasting methods. By applying Linear programming, we found optimum production of two models by Tesla which use the same resources.

Table 1: Literature Research Comparison

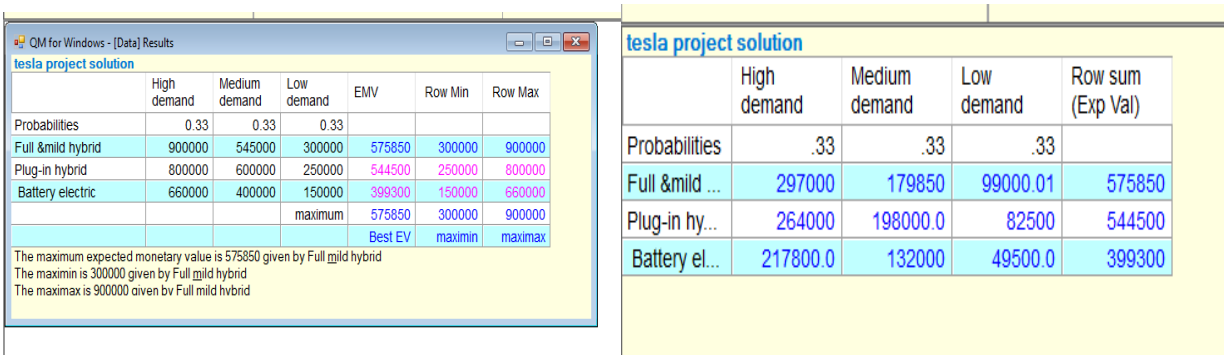
Reference	Topic	Method	Strength	Weakness
Giorgi Thesis Paper Year 2020	Financial Analysis and Valuation of Tesla.	Discounted Cash Flow, Evaluation of Financial performance metrics on Tesla	Used one Quantitative method on Discounted Cash flow method and	Most of the part of this paper was analyzed with a Qualitative method
Joseph Thesis Paper May-16	Tesla Model 3 Product Launch Forecast and Distribution Centre Analysis	Forecasting Method, Inventory Model	Well Explained by using Quantitative methods. And showed us how to choose which location minimized the cost for	Less theory.
Liu Conference Paper	Competition and Valuation. A case study of Tesla Motors	PEST(Politic,economic,society,technology)Analysis,Valuation of Electric Vehicles	They put Statistical data to get customer attention to TESLA.	No quantitative Method .
Scott Journal paper Jan-15	Changing the Fate of Fuel cell vehicles.Can lesson be learnt from Tesla Motors?	Market Strategy on Electric Car Vehicles	They put graphical view for improving customer satisfaction, they put executive summary and implementation	They focus on customer problems not on customer desires.

2 Quantitative Analysis

2.1 Decision Analysis on different Tesla Electric Vehicles

Tesla's electric motors are superior compared to the company's competitors. In our project we choose decision analysis to evaluate which electric car of tesla gives maximum expected monetary value. We make a decision table with the condition 3 states of nature like High demand, medium demand, Low demand with a probability of .33 for each state. Then we choose three alternatives of Tesla, Full and mild hybrids, Plug-in-hybrids, and battery electric hybrids. The payoff values are profits generated considering multiple criteria like customer requirement, gasoline savings cost, Car mileage cost and maintenance cost. The aim is to maximize profits and minimize loss.

After putting their demand on QM software decision, we get the maximum EMV $45800 for Full -mild hybrid electric car.



QM for Windows - [Data] Results

tesla project solution

	High demand	Medium demand	Low demand	EMV	Row Min	Row Max
Probabilities	0.33	0.33	0.33			
Full &mild hybrid	900000	545000	300000	575850	300000	900000
Plug-in hybrid	800000	600000	250000	544500	250000	800000
Battery electric	660000	400000	150000	399300	150000	660000
			maximum	575850	300000	900000
				Best EV	maximin	maximax

The maximum expected monetary value is 575850 given by Full mild hybrid
The maximin is 300000 given by Full mild hybrid
The maximax is 900000 given by Full mild hybrid

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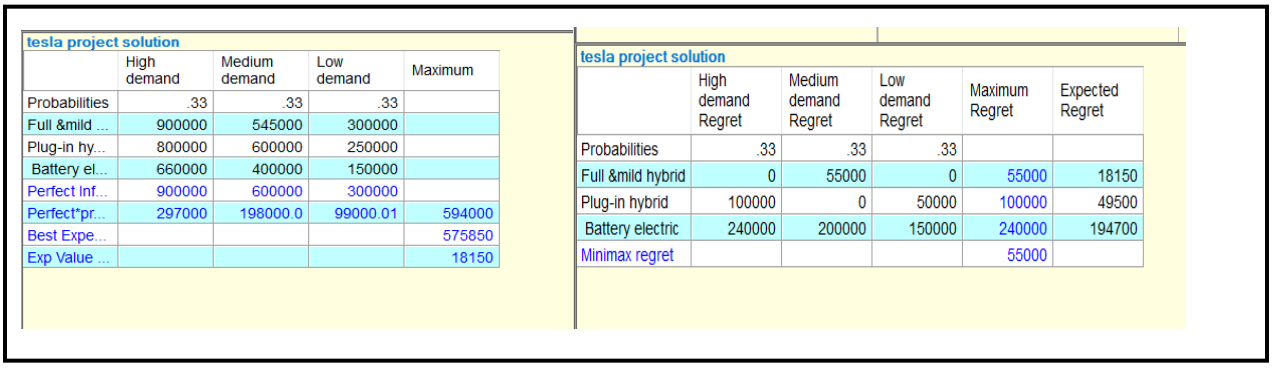
	High demand	Medium demand	Low demand	Row sum (Exp Val)
Probabilities	.33	.33	.33	
Full &mild ...	297000	179850	99000.01	575850
Plug-in hy...	264000	198000.0	82500	544500
Battery el...	217800.0	132000	49500.0	399300

Figure 1: EMV value

Depending upon EMV value, Full and mild hybrid gives the maximum EMV value, so Tesla should produce full and mild electric vehicles more than others.



tesla project solution

	High demand	Medium demand	Low demand	Maximum
Probabilities	.33	.33	.33	
Full &mild ...	900000	545000	300000	
Plug-in hy...	800000	600000	250000	
Battery el...	660000	400000	150000	
Perfect Inf...	900000	600000	300000	
Perfect*pr...	297000	198000.0	99000.01	594000
Best Expe...				575850
Exp Value ...				18150

tesla project solution

	High demand Regret	Medium demand Regret	Low demand Regret	Maximum Regret	Expected Regret
Probabilities	.33	.33	.33		
Full &mild hybrid	0	55000	0	55000	18150
Plug-in hybrid	100000	0	50000	100000	49500
Battery electric	240000	200000	150000	240000	194700
Minimax regret				55000	

Figure 2: EOL Value

Tesla sometimes third parties sell their product to customers which charges $60,000 for providing their service. However maximum info for perfect should be paid by QM results is EVPI= 594000-575850=$18150. So, Tesla should not spend more than $18150 for perfect information based upon decision analysis. Based on EOL or opportunity loss table, Full and hybrid give minimum value.

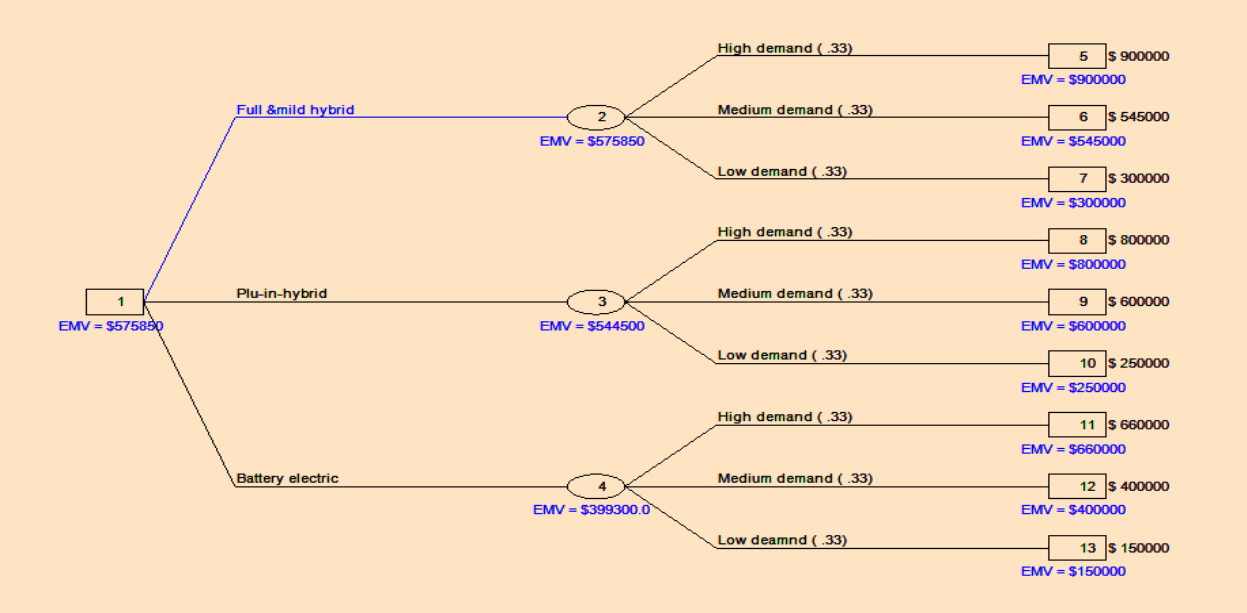


Figure 3: Decision Tree Analysis

Finally, using the decision tree we find the best alternative option among others based on maximum EMV value.

2.2 Forecasting using Quantitative Methods

The quantitative forecast method uses past data to forecast future data especially with numerical data and continuous pattern. This method is generally used for short term predictions. It is based on mathematical models and objective in nature. The forecast information and technique must match the intended application.

- For strategic decisions such as capacity or market expansion highly aggregated estimates of general trends are necessary
- Sales and operations planning activities require more detailed forecasts in terms of product families and time periods
- Master production scheduling and control demand highly detailed forecasts, which only need to cover a short period of time

In this project we use three quantitative methods:

- Regression analysis.
- Moving Average

- Exponential smoothing

2.2.1 Regression Model

Regression analysis is a very useful technique for today's management. Regression has been used to analyze and forecast demand for new products. The main objective to use this model is to understand the relationship between two variables one is dependent (response) and known and other is independent (explanatory)and unknown and has interest in. The second objective is to predict the dependent variable based on the independent variable. Where the estimated form of the equation is as follows,

$$\hat{Y} = b_0 + b_1 X$$

where

$\hat{Y}$ = predicted value of Y

b_0 = estimate of β_0, based on sample results

b_1 = estimate of β_1, based on sample results

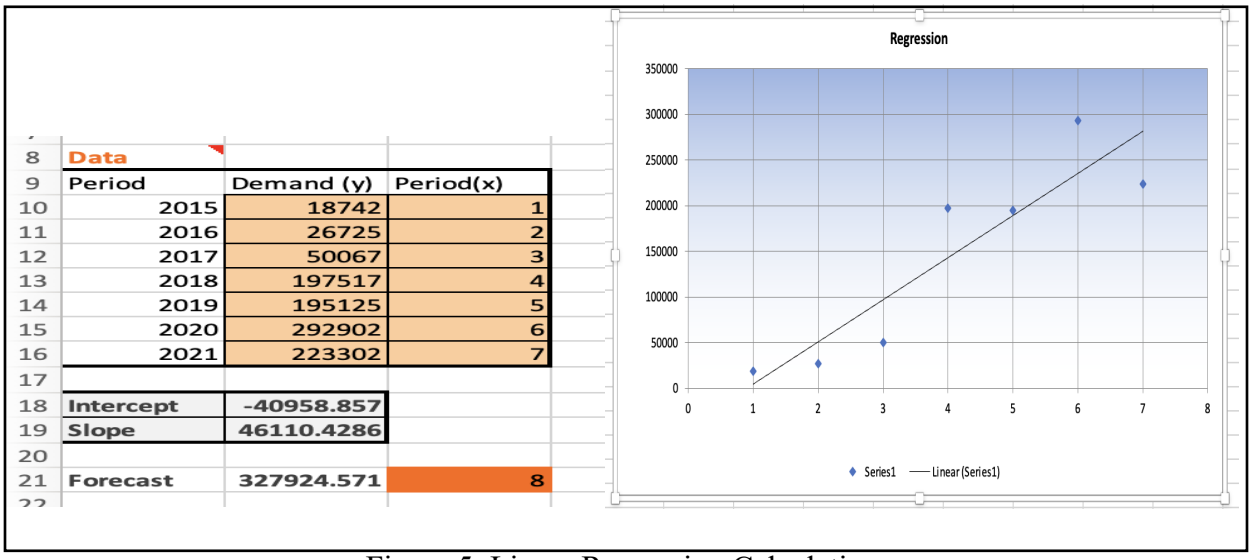
Figure 4: Linear Regression

Q. Problem statement: Production team of Tesla feels that demand for S3 cars can be related to the years, develop the regression model that could be used to predict the demand for year 2022 and check if demand will increase in upcoming years and depend on year? Using the data, test to see if there is a statistically significant relationship between demand and the years.

Tesla's regression model is shown below,

Y cap = -40958.4286+46110.4286 *X,

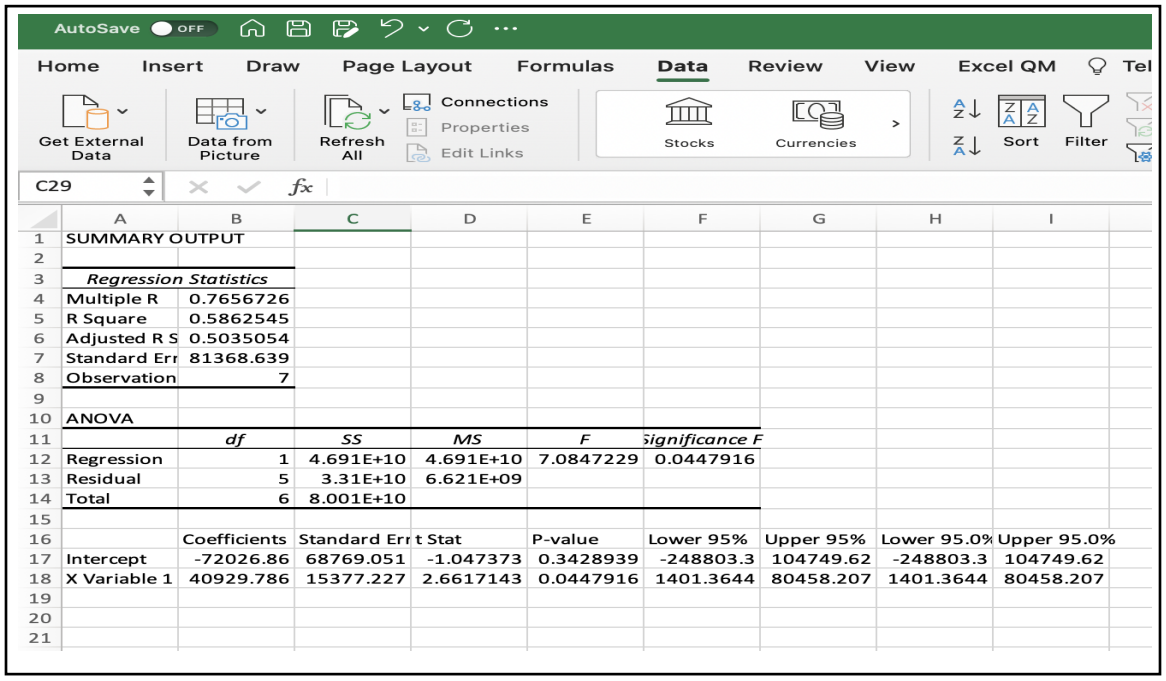
we can use this equation to forecast the related demand for future years by putting their values as a X in the above equation. Next period forecast for period 8 is 327924.571, This means that in the year 2022 the demand for S3 tesla cars is predicted to be 327924. 571. Demand has positive linear relationship with years.



8	Data		
9	Period	Demand (y)	Period(x)
10	2015	18742	1
11	2016	26725	2
12	2017	50067	3
13	2018	197517	4
14	2019	195125	5
15	2020	292902	6
16	2021	223302	7
17			
18	Intercept	-40958.857	
19	Slope	46110.4286	
20			
21	Forecast	327924.571	8

Figure 5: Linear Regression Calculations

Usability of the model



	A	B	C	D	E	F	G	H	I
1	SUMMARY OUTPUT								
2									
3	*Regression Statistics*								
4	Multiple R	0.7656726							
5	R Square	0.5862545							
6	Adjusted R S	0.5035054							
7	Standard Err	81368.639							
8	Observation	7							
9									
10	ANOVA								
11		*df*	*SS*	*MS*	*F*	*Significance F*			
12	Regression	1	4.691E+10	4.691E+10	7.0847229	0.0447916			
13	Residual	5	3.31E+10	6.621E+09					
14	Total	6	8.001E+10						
15									
16		Coefficients	Standard Err	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
17	Intercept	-72026.86	68769.051	-1.047373	0.3428939	-248803.3	104749.62	-248803.3	104749.62
18	X Variable 1	40929.786	15377.227	2.6617143	0.0447916	1401.3644	80458.207	1401.3644	80458.207
19									
20									
21									

Figure 6: Linear Regression Calculations

To test the significance of the model. We assume that the errors are independent, normally distributed with the zero mean and have a constant variance.

Coefficient of determination: Coefficient of determination also known as a R square answer, how much of the data does this model explain? This value must be in the range of 0 to 1. In the case of tesla, the R square value is 0.5862, this means that more than half of the data is explained by this model. 58.62% of variability in the data is explained by the regression model.

Coefficient of correlation: Coefficient of correlation also known as a r expresses the degree of strength of linear relationship between 2 variables. It is square root of determination coefficient, and it should be between - 1 to + 1. It is positive when slope of the line is positive in Tesla's case r=0.76566 and it shows the slope of the line is positive.

P- values: We test the coefficients by calculating the T-statistics and then P -values. P- value for X is 0.04479 which is less than the alpha 0.05 and we can say that the coefficient is acceptable, and we can reject the null hypothesis.

F-statistics: This model has F- statistics 7.084 and the significance if it is 0.0447. If we consider an alpha 0.05 then the significance of f value is less than 0.05 which means this model is acceptable. If we test the same model for alpha 0.10 then also, we can reject the null hypothesis and say this model is acceptable.

MAD: In the analysis we have performed, the MAD value from regression analysis is 37244.1633, which is less than the rest of the forecasting models which states that the linear regression model is good to analyze the results and has less spread out from the mean.

Forecasts and Error Analysis

Forecast	Error	Absolute	Squared	Abs Pct Err
5151.57143	13590.4286	13590.4286	184699749	72.51%
51262	-24537	24537	602064369	91.81%
97372.4286	-47305.429	47305.4286	2237803572	94.48%
143482.857	54034.1429	54034.1429	2919688594	27.36%
189593.286	5531.71429	5531.71429	30599862.9	02.83%
235703.714	57198.2857	57198.2857	3271643889	19.53%
281814.143	-58512.143	58512.1429	3423670862	26.20%
Total	1.0914E-10	260709.143	1.267E+10	334.73%
Average	**1.5591E-11**	**37244.1633**	**1810024414**	**47.82%**
	Bias	**MAD**	**MSE**	**MAPE**
		SE	**50339.1913**	
		Correlation	**0.90803089**	
		Coefficient of determination	**0.8245201**	

Figure 7: Linear Regression calculations

2.2.2 Moving Average

A moving average is **a calculation used to analyze data points by creating a series of averages of different subsets of the full data set**. By calculating the moving average, the impacts of random, short-term fluctuations on the price of a stock over a specified time frame are mitigated.

$$Moving\ Average\ Forecast\ (MAF_t) = \frac{\sum_{i=t-n+1}^{t} ActualDemand_i}{n}$$

Figure 8: Moving Average

Based on raw data sales of tesla from year 2015-2021 calculation are made as follows

Num pds	2										
Data		Forecasts and Error Analysis					Tracking Signal				
Period	Demand	Forecast	Error	Absolute	Squared	Abs Pct Err	Cum Error	Cum Abs E	Mad	Track Signal (Cum Error/MAD)	
Period 1	18742										
Period 2	26725						0	0	#DIV/0!	#DIV/0!	
Period 3	50067	22733.5	27333.5	27333.5	7.47E+08	54.59%	27333.5	27333.5	27333.5	1	
Period 4	197517	38396	159121	159121	2.53E+10	80.56%	186454.5	186454.5	93227.25	2	
Period 5	195125	123792	71333	71333	5.09E+09	36.56%	257787.5	257787.5	85929.17	3	
Period 6	292902	196321	96581	96581	9.33E+09	32.97%	354368.5	354368.5	88592.13	4	
Period 7	223302	244013.5	-20711.5	20711.5	4.29E+08	09.28%	333657	375080	75016	4.447811	
		Total	333657	375080	4.09E+10	2.13961					
		Average	66731.4	75016	8.18E+09	0.427922					
			Bias	MAD	MSE	MAPE					
				SE	116778.8						
Next perio	258102										

Figure 9: Moving Average-By Excel

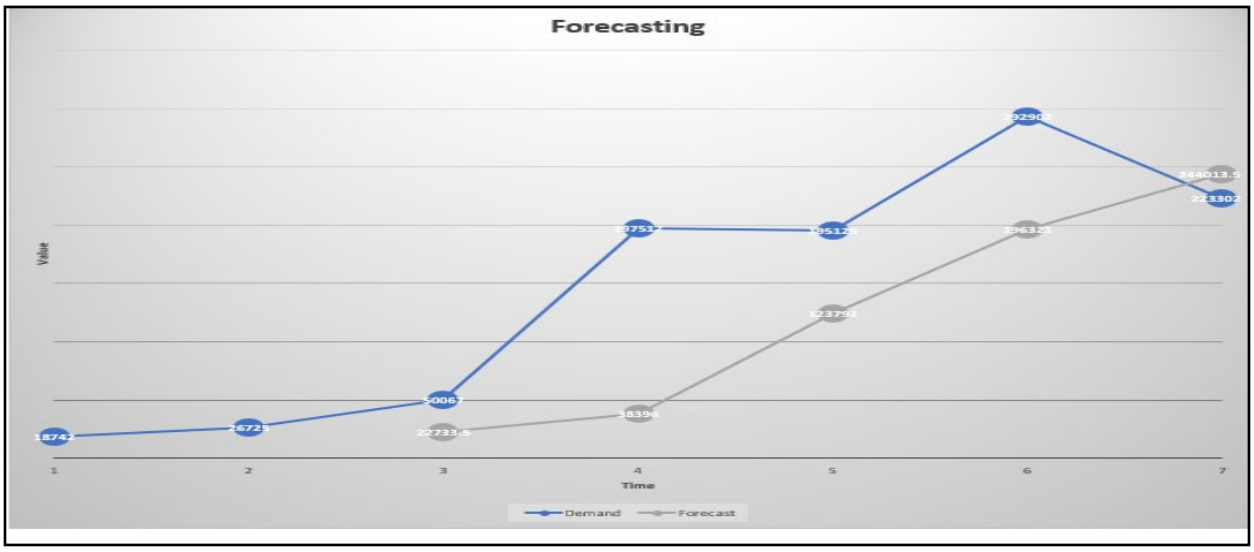
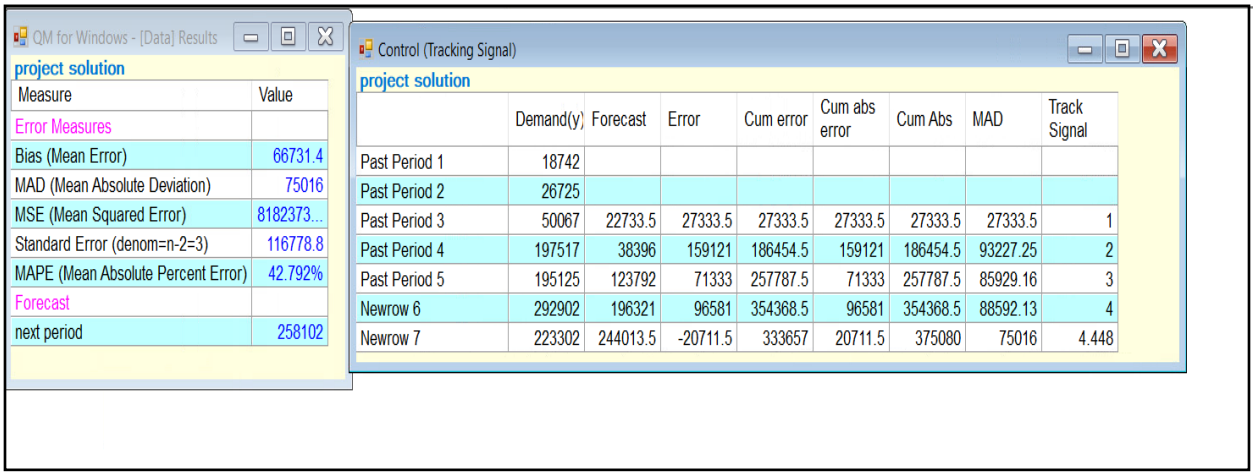


Figure 10: Moving Average- Graph by Excel



QM for Windows - [Data] Results

project solution

Measure	Value
Error Measures	
Bias (Mean Error)	66731.4
MAD (Mean Absolute Deviation)	75016
MSE (Mean Squared Error)	8182373...
Standard Error (denom=n-2=3)	116778.8
MAPE (Mean Absolute Percent Error)	42.792%
Forecast	
next period	258102

Control (Tracking Signal)

project solution

	Demand(y)	Forecast	Error	Cum error	Cum abs error	Cum Abs	MAD	Track Signal
Past Period 1	18742							
Past Period 2	26725							
Past Period 3	50067	22733.5	27333.5	27333.5	27333.5	27333.5	27333.5	1
Past Period 4	197517	38396	159121	186454.5	159121	186454.5	93227.25	2
Past Period 5	195125	123792	71333	257787.5	71333	257787.5	85929.16	3
Newrow 6	292902	196321	96581	354368.5	96581	354368.5	88592.13	4
Newrow 7	223302	244013.5	-20711.5	333657	20711.5	375080	75016	4.448

Figure 11: Moving Average by QM

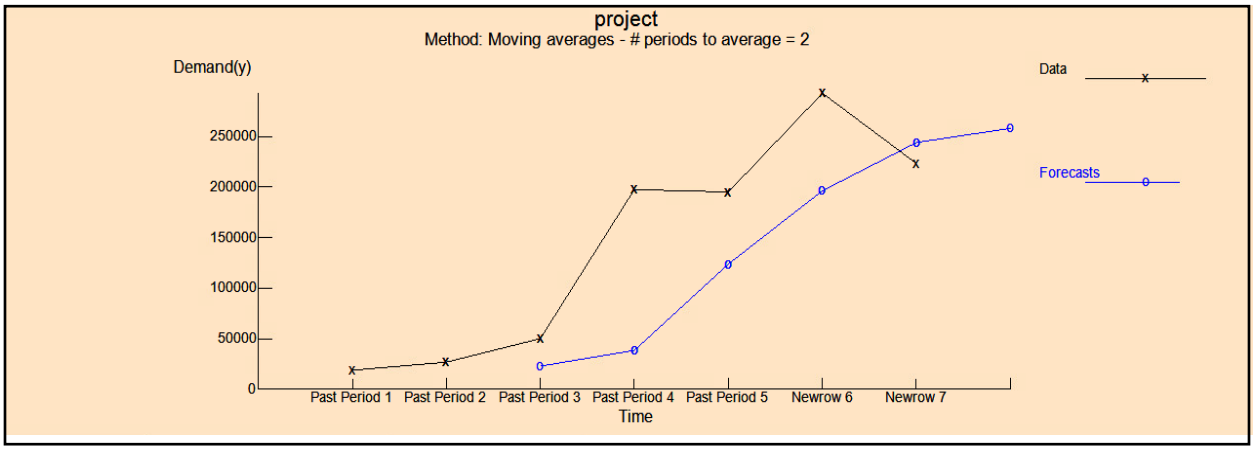


Figure 12: Moving Average- Graph By QM

After applying the moving average on Tesla sales data from 2015 to 2021, we got forecasts for next year 2022 -**258102** sales. (Using both method by excel and QM)**.** MAD for moving average is 75018.

2.2.3 Exponential smoothing

Exponential smoothing is a type of moving average that is easy to use and requires little record keeping of data.

New forecast = Last period's forecast + *a* (Last period's actual demand – Last period's forecast).

Mathematically: $F_{t+1} = F_t + \alpha(Y_t - F_t)$

Selecting the Smoothing Constant:1) Selecting the appropriate value for *a* is key to obtaining a good forecast.2) The objective is always to generate an accurate forecast.3) The general approach is to develop trial forecasts with different values of *a* and select a that results in the lowest *MAD.*

Exponential smoothing - Finding Alpha Value

Alpha value =**.94**

			alpha	1-alpha	
			0.94008	0.059920018	
Period	Demand	ForecastDemand	|Error|	Error^2	Absulute %error
2015	18742				
2016	26725	18742	7983	63728289	29.87090739
2017	50067	26246.6585	23820.34	567408669.2	47.57692991
2018	197517	48639.68472	148877.3	22164455006	75.3744312
2019	195125	188596.2686	6528.731	42624333.06	3.345922538
2020	292902	194733.7983	98168.2	9636995825	33.51571573
2021	223302	287019.7596	63717.76	4059952892	28.53434346
			58182.56	6089194169	36.36970837
			MAD	MSE	MSPE

Figure 13: Finding Alpha Value

The changing in tread/ demand in sales, error occurs to smoothing the errors we need the alpha. However, after comparing alpha with MAD, MSE, MSPE we got lowest alpha =.94008. To predict better forecasting of upcoming years.

Alpha	0.94											
Data		Forecasts and Error Analysis					Tracking Signal			
Period	Demand	Forecast	Error	Absolute	Squared	Abs Pct Err	Cum Error	Cum Abs E	Mad	Track Signal (Cum Error/MAD)
Period 1	18742	18742	0	0	0	00.00%				
Period 2	26725	18742	7983	7983	63728289	29.87%	7983	7983	3991.5	2
Period 3	50067	26246.02	23820.98	23820.98	5.67E+08	47.58%	31803.98	31803.98	10601.33	3
Period 4	197517	48637.74	148879.3	148879.3	2.22E+10	75.38%	180683.2	180683.2	45170.81	4
Period 5	195125	188584.2	6540.756	6540.756	42781483	03.35%	187224	187224	37444.8	5
Period 6	292902	194732.6	98169.45	98169.45	9.64E+09	33.52%	285393.4	285393.4	47565.57	6
Period 7	223302	287011.8	-63709.8	63709.83	4.06E+09	0.285308	221683.6	349103.3	49871.9	4.445061
		Total	221683.6	349103.3	3.65E+10	218.22%				
		Average	31669.09	49871.9	5.22E+09	31.17%				
			Bias	MAD	MSE	MAPE				
				SE	85481.19					
Next perio	227124.6									

Figure 14: Exponential smoothing - By Excel

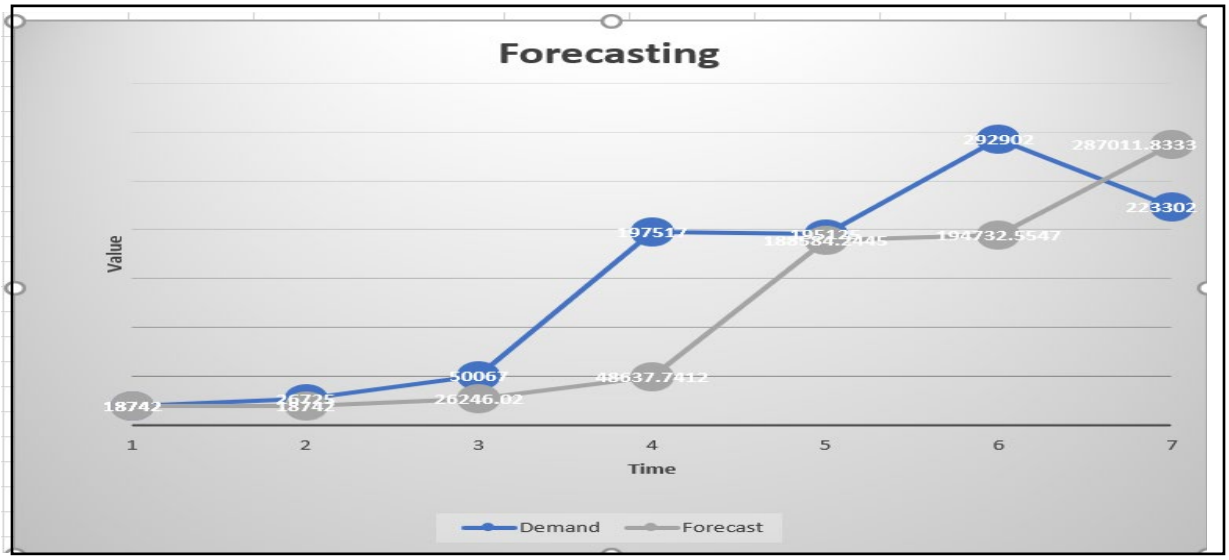
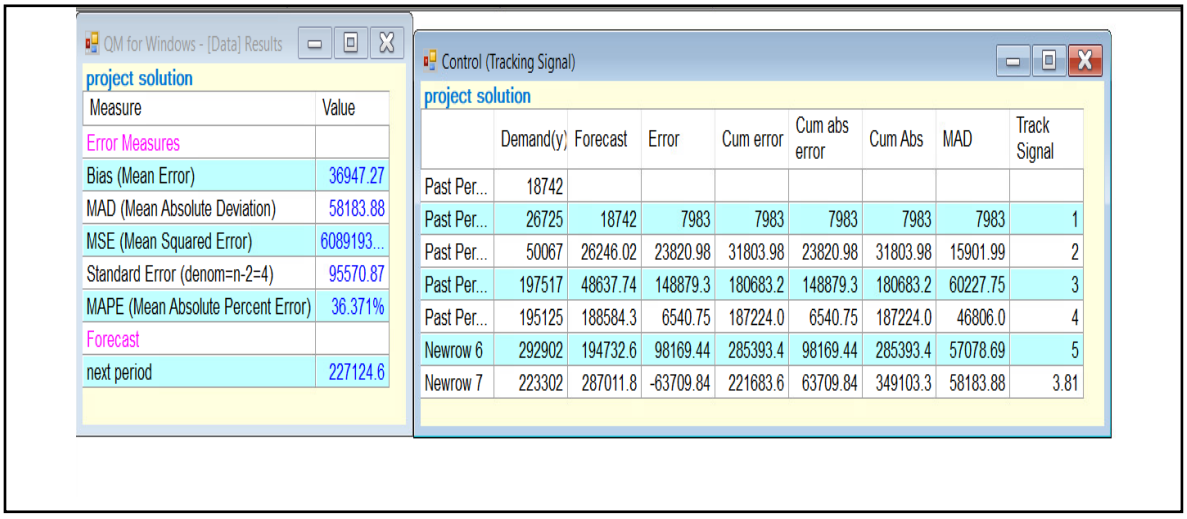


Figure 15: Exponential Smoothing-Graph by Excel.



QM for Windows - [Data] Results

project solution

Measure	Value
Error Measures	
Bias (Mean Error)	36947.27
MAD (Mean Absolute Deviation)	58183.88
MSE (Mean Squared Error)	6089193...
Standard Error (denom=n-2=4)	95570.87
MAPE (Mean Absolute Percent Error)	36.371%
Forecast	
next period	227124.6

Control (Tracking Signal)

project solution

	Demand(y)	Forecast	Error	Cum error	Cum abs error	Cum Abs	MAD	Track Signal
Past Per...	18742							
Past Per...	26725	18742	7983	7983	7983	7983	7983	1
Past Per...	50067	26246.02	23820.98	31803.98	23820.98	31803.98	15901.99	2
Past Per...	197517	48637.74	148879.3	180683.2	148879.3	180683.2	60227.75	3
Past Per...	195125	188584.3	6540.75	187224.0	6540.75	187224.0	46806.0	4
Newrow 6	292902	194732.6	98169.44	285393.4	98169.44	285393.4	57078.69	5
Newrow 7	223302	287011.8	-63709.84	221683.6	63709.84	349103.3	58183.88	3.81

Figure 16: Exponential Smoothing-By QM

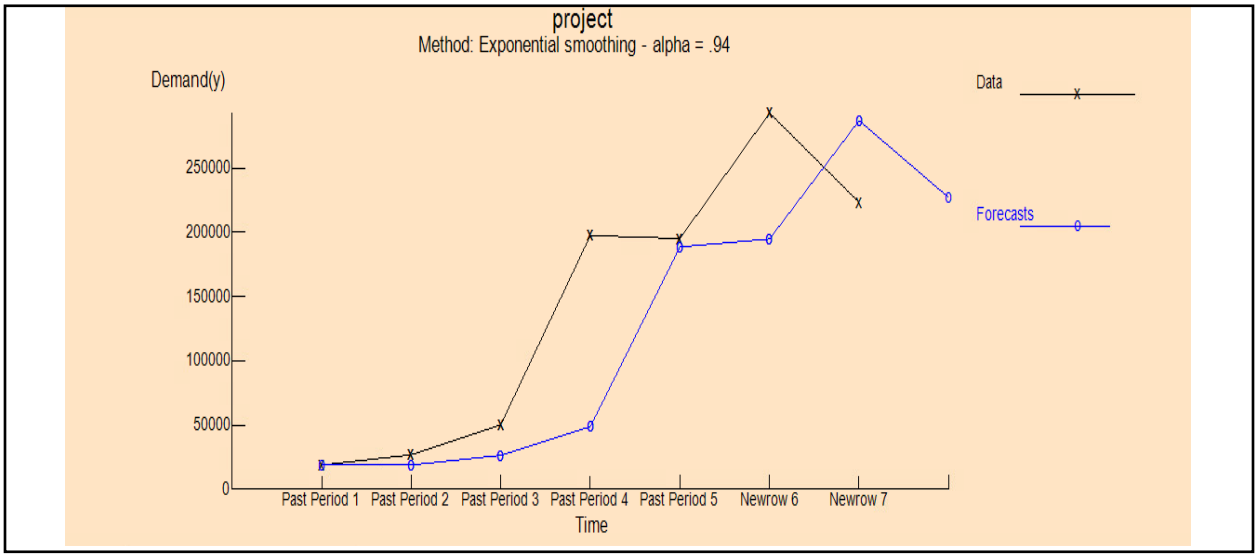


Figure 17: Exponential smoothing - Graph by QM.

After applying the moving average on Tesla sales data from 2015 to 2021, we got forecasts for next year 2022 -**227124.6** sales (using both method by excel and QM). MAD for moving average is 58183.88.

2.3 Linear Programming Application

Linear programming establishes a plan that efficiently allocates limited resources to achieve the desired objective. The linear programming problems aim to find the most, or least, of some quantity. Often profit or expenses. Steps in Linear Programming include:

1) Understand the problem.

2) Identify the objective and the constraints.

3) Define decision variables.

4) Use the decision variables to write mathematical expressions for the objective function and constraints.

The following problem is the most common Linear Programming application- Product Mix problem. Product mix problems use LP to decide how much of each product to make given a series of resource restrictions.

Problem: Tesla Motors produces two types of electric cars, the *Model S* and the *Model X*. The *Model S* is sold for $70,000 and the *Model X* is sold for $120,000. Raw materials for the *Model S* cost $40,000 per unit and for the *Model X* cost $35,000 per unit. Only 60 *Model S* can be produced per week. The weekly demand of *Model X* is 300 units. There are W, X, Y and Z types of resources used in the manufacturing of electric cars. Each of these resources are available to operate for 1800, 2400, 1500, 1000 min/week respectively. *Model S* uses Resource W for 16min, Resource X for 16 min, Resource Y for 18 min, resource Z for 8min.*Model S* uses Resource W for 16min, Resource X for 16 min, Resource Y for 18 min, resource Z for 8min. *Model X* uses Resource W for 11 min, Resource X for 32 min, Resource Y for 7 min, resource Z for 6 min and all the enterprise's costs and expenses - except for those associated with raw materials - amount to $5,000,000/week. How many *Model S* and *Model X* should Tesla produce so that the enterprise's profit is maximized?

Solution: In formulating this problem, the objective is to maximize profit. There are 4 constraints indicating the available resources, 1 constraint each indicating maximum production for model S and demands for model X. The variables are defined as:

S = number of units of Model S, X = number of units of Model X.

But first Tesla Motors must establish the profit per car:

1. The Model S is sold for $70,000. The raw material for the car costs $40,000. The profit per Model S $70,000 - $40,000 = $30,000.

2. The Model X is sold for $120,000. The raw material for the car costs $35,000. The profit per Model X $120,000 - $35,000 = $85,000.

The objective function may now be stated as:

Maximize Profit: 30000S + 85000X

Subject to: 16S + 11X <= 1800…… (Resource W)

16S + 32X <= 2400…… (Resource X)

18S + 7X <=1500……..… (Resource Y)

8S + 6X <= 1000…….... (Resource Z)

S = 60……..…… (Model S Production)

X <= 300…… (Model X Demand)

Solving in QM software,

Tesla Quantitative Analysis Solution					
	S	X		RHS	Dual
Maximize	30000	85000			
Resource W	16	11	<=	1800	0
Resource X	16	32	<=	2400	2656.25
Resource Y	18	7	<=	1500	0
Resource Z	8	6	<=	1000	0
Model S Production	1	0	=	60	-12500
Model X Demand	0	1	<=	300	0
Solution->	60	45		5625000	

Figure 18: Linear Programming Solution

The optimum solution is 60 units of Model S and 45 Units Model X for maximum profit.

Net Profit = Optimum Solution – Weekly enterprise's expenses and cost

Net Profit = $5,625,000 - $5,000,000 = $625,000.

Sensitivity Analysis:

As there is always some uncertainty in the input data, it is useful to know the range and under what conditions the components of a particular solution remain the same. The sensitivity of a

solution to changes in the data gives us insight into possible technological improvements in the process being modeled.

Tesla Quantitative Analysis Solution					
Variable	Value	Reduced ...	Original Val	Lower Bou...	Upper Bou...
S	60	0	30000	-Infinity	Infinity
X	45	0	85000	0	Infinity
	Dual Value	Slack/Surp...	Original Val	Lower Bou...	Upper Bou...
Resource W	0	345	1800	1455	Infinity
Resource X	2656.25	0	2400	960	2880
Resource Y	0	105	1500	1395	Infinity
Resource Z	0	250	1000	750	Infinity
Model S Production	-12500	0	60	0	67.24
Model X Demand	0	255	300	45	Infinity

Figure 19: LP Sensitivity analysis

The profit on Model S is $30000, which is indicated as the original value in the output. The profit on Model S has a lower bound of negative infinity (it may decrease by any amount) and an upper bound of infinity (it may increase by any amount). This means that there is only one optimum solution. The profit on Model X has an upper bound of infinity and lower bound of $0. The current optimal solution will stay the same in this range.

At the optimum solution (60,45) the resource X and Model S production are binding constraints. If additional units of resource X and model S production are made available, then profits will increase. Resource W, Resource Y, Resource Z, Model X demand are non-binding constraints as there are extra units available that are not being used. For a nonbinding constraint, obtaining additional units of that resource will not result in higher profits and will only increase the slack.

Graphical Solution: The graphical solution works well with two decision variables. It provides valuable insight on how larger problems are structured. The following image is a graphical solution for Tesla Motors' product mix problem.

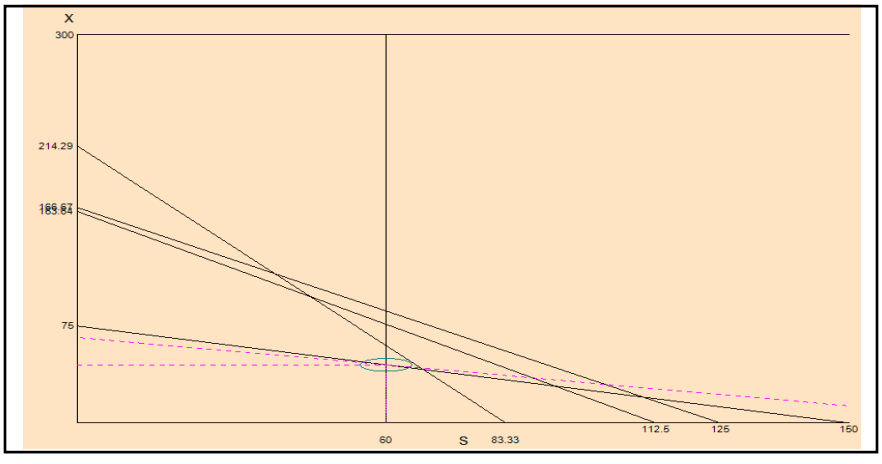


Figure 20: LP Graphical Solution

The above graphical solution is (60,45). For maximum profit, 60 Model S and 45 Model X need to be produced.

3 Conclusion

- From the Decision tree we can say that Tesla should produce Full and mild hybrid cars based on its Max EMV value to minimize loss among others.
- Linear regression model shows that demand and year have positive linear relationship and when year increases demand increases. The acceptance test of this model says that the significance of f is less than the alpha 0.05 and we can reject the null hypothesis and accept the model. The p-value of coefficient is less than alpha, and it is a good value. More than half of the data is being used to determine this result says r square value.
- With quantitative techniques used in our project we can conclude that they can be used for optimizing production of electric cars, accurate forecasting of sales.

4 References

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