ME 308 Project : Demand Prediction of Automobile Spare Parts

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Introduction & Motivation

The challenge that auto parts manufacturing companies face is to manufacture the right amount of spare parts to meet the demand while keeping inventory and manufacturing costs at an optimal level. In this project, we aim to create a model that can help auto parts manufacturing companies determine the optimal amount of spare parts to manufacture in order to meet the demand of various auto service centers in multiple regions.

The motivation behind this project is to help auto parts manufacturing companies improve their inventory and manufacturing management systems. Currently, most companies rely on their experience and intuition to determine the amount of spare parts to manufacture, which can lead to overproduction or underproduction. Overproduction can lead to excess inventory, which increases storage costs and reduces profit margins. On the other hand, underproduction can lead to stockouts, which can result in lost sales and dissatisfied customers.

Problem Statement

There is a need for a data-driven approach that can help auto parts manufacturing companies optimize their production and inventory management systems to meet the demand of auto service centers across different regions. The challenge is to develop a model that considers the demand patterns of various auto service centers in different regions with different features/climates, production costs, and inventory costs to determine the optimal amount of spare parts to manufacture.

The goal of this project is to provide auto parts manufacturing companies with a data-driven approach to optimize their production and inventory management systems, resulting in increased efficiency, profitability, and customer satisfaction.

Research

Spare Parts Classification There are several Criterias & classification models, including ABC analysis & FSN analysis to classify spare parts based on their criticality, demand, and other factors.These criterias are :-

- The law of degradation and analysis of failure modes, effects and criticality.
- Reliability is the probability that the system fulfilled the function, for which it was designed.
- Maintenance cost includes direct and indirect costs.The selected components are those with the ratio of costs higher than 1.

Models commonly used for Estimation of Demand

- **Moving averages:** Essentially, the moving average method tries to estimate the next period's value by averaging the value of the last couple of periods immediately prior. The moving average forecast (MA) is the mean of the previous N months, where N is the number of months used in the forecast.

$$\hat{x}_{t+1} = \frac{1}{N}\sum_{i=1}^{N} d_{t-N+i}$$

  A class of models called ARIMA models (autoregressive integrated moving averages) is based on using moving averages for predictions.

- **Exponential smoothing**: Exponential smoothing is simply an adjustment technique which takes the previous period's forecast, and adjusts it up or down based on what actually occurred in that period. It accomplishes this by calculating a weighted average of the two values.

$$\hat{x}_{t+1} = (1-\alpha)\hat{x}_t + \alpha d_t$$

- More methods like Croston forecasting method, Syntetos-Boylan approximation, Teunter-Syntetos-Babai forecasting method were studied but since their results were not significantly better (according to the studied paper), we did not implement them in code. Also, without correct data, it was impossible to compare their performance for our purpose.

- **Regression Model:** Firstly, the contributing factors of the demand are found. Then, assuming that the all the factors have a linear correlation with demand, variable coefficients are trained.

$$Y_i = a + bX_i + \varepsilon_i$$

- **Grey Prediction Model GM(1, 1):** x is a series of cumulative generation of the historical requirement of spare parts, t is time, and a and u are the parameters to be estimated.

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = u$$

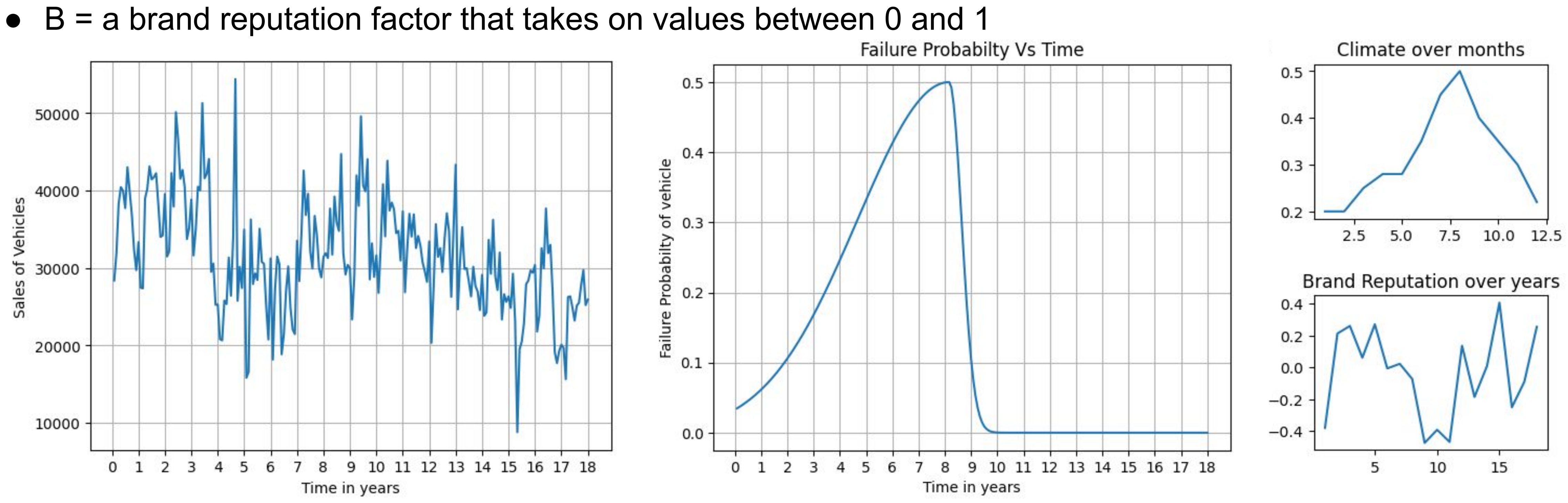
- **Mathematical Probabilistic Model:** By tracking the active installed base and estimating the part failure behaviour, it provide a forecast of the distribution of the future spare parts demand during the upcoming lead time. Larger set of spare part demand drivers, takes into account the evolution of the active installed base over time, which can increase through the sales of new machines that are serviced and decrease through the end-of-use of old machines.the part reliability, which defines when a part in the installed base will fail and require a corrective replacement. It refer to this collection of information used as Service Maintenance Information.
  i = part age , j = machine age , t = current time , T_p = lifetime part , T_m = lifetime Machine , L = lead time

$$p_{i,j,t,L} = P(T_p \le i + L | T_p > i) \cdot P(T_m > j + L | T_m > j)$$
$$= p^{p}_{i,t,L} \cdot p^{m}_{j,t,L}.$$

Our Model for Demand Prediction

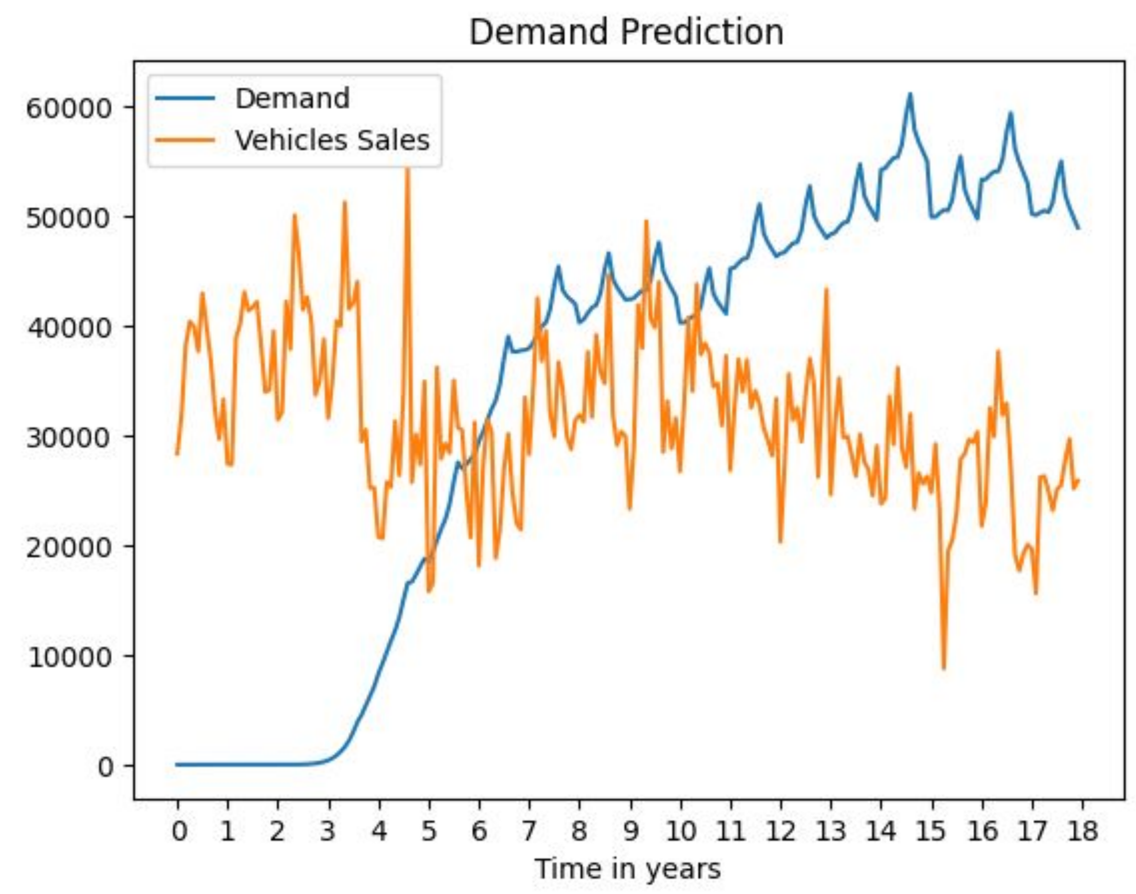
We chose to employ a mathematical model that would forecast demand for a time period of the estimated life of the spare component in the future because we wanted to be able to foresee the demand for spare parts in the future.Let's assume that demand for auto parts is influenced by several factors,

- V = the number of vehicles on the road that need repair
- C = a climate factor that takes on values between 0 and 1
- E = an economic factor that takes on values between 0 and 1
- B = a brand reputation factor that takes on values between 0 and 1



The failure probability function above was defined using maximum failure probability at a time and expected failure time of part.The probability decrease gradually on both sides. Now, let's assume that demand for auto parts is given by the following nonlinear function:

$$D = V * (1 + C^x)(1 + E^y)(1 + B^z)$$



Assumptions / Limitations

- Due to lack of demand data we couldn't validate our model
- The model assumes that historical patterns are representative of future patterns.
- The model takes into only some factors, but there could other factors such as demographic changes, changes in government policies, or changes in technology which may also affect the demand for spare parts.
- The model does not take into account the impact of external events such as natural disasters or economic downturns, which can significantly affect the demand for spare parts.

Conclusion

We have developed a mathematical model that considers the demand patterns of various auto service centers in different regions with different features/climates, production costs, and inventory costs to determine the optimal amount of spare parts to manufacture. Our model takes into account the relevant climate and geographical features of each region, as well as manufacturing and inventory costs, to generate an optimal production plan that minimizes costs while meeting the demand of auto service centers for future.

In summary, our project offers a solution to the significant challenge faced by auto parts manufacturing companies in managing their inventory and production processes, and we believe that our model can make a significant contribution to the industry.