ASSESSMENT CASE STUDY REPORT

KUNAL MEHTA

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Introduction

This report presents the analysis and findings from three assessments conducted to inform strategic

Objectives

1. Statistical Validation of the New Strategy

→ **Objective:** Determine whether a crash course in statistics leads to an average improvement of at least 10 percentage points in standardized test scores among freshman business majors.

→ **Approach:** Analyse pre-test and post-test scores from a pilot group to assess the effectiveness and statistical significance of the improvement.

2. Ensuring Fair Client Assignment in the Experiment

→ **Objective:** Verify that clients are assigned fairly and randomly to the experiment group, ensuring compliance with the requirement that approximately half of the clients participate.

→ **Approach:** Review and adjust the assignment code to correct any biases and validate the randomness of client assignments.

3. Vehicle Sales Forecasting and Staffing Plan Evaluation

→ **Objective:** Forecast vehicle sales for December 2019 and the year 2020 using historical data, and evaluate ACME Trucks' staffing plans based on these projections.

→ **Approach:** Analyse historical sales trends, identify seasonal patterns, and use time series forecasting models to predict future sales and provide staffing recommendations.

Statistical validation of the new strategy

Overview

A pilot group of 25 freshman business majors participated in a crash course in statistics. Pre-test and post-test scores were collected to assess whether the course improved standardized test scores by at least 10 percentage points on average

Data Summary

→ **Participants:** 25 students (3 did not take the post-test)
→ **Valid Pairings:** 22 students with both pre-test and post-test scores
→ **Average Pre-Test Score:** 66.64
→ **Average Post-Test Score:** 79.23
→ **Average Improvement:** 12.59

Visualization

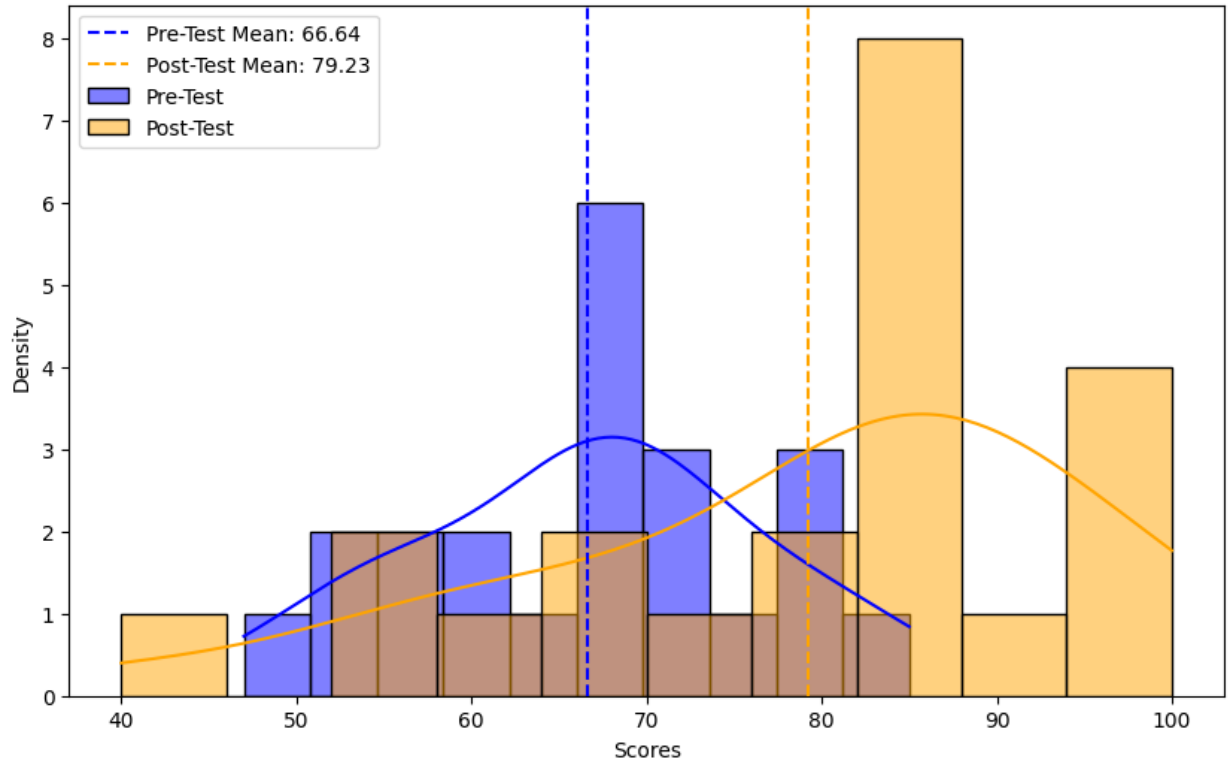


Figure 1 Pre-test vs Post-test Scores distribution with recalculated Mean (Cleaned Data)

Analysis and Validation

The average improvement was 12.59% points, above the target of 10% points.

Whether this change is significant or not based on what we see or is it by any random chance

- → **Steps taken: -** Compared the scores before and after the course. Looked at how much the scores varied from one student to the next to understand how reliable the improvement was.
- → **Findings: -** When analysed the data, the improvement wasn't big enough to be confident that the course consistently led to a 10-point improvement across all students. In fact, the variation between student scores was quite large, making it harder to prove that the course had a significant impact.
- → **Conclusion: -** Although there was an improvement, it's not strong enough to say with confidence that the course should adopted for all business majors. We would need a larger group of students or a more consistent improvement across students to confirm that the course is effective

Recommendation

1. The university should reconsider implementing the crash course for all business majors based solely on this pilot study.
2. Collect more data to increase the sample size and statistical power.
3. Review and enhance the course content to achieve a more significant improvement.
4. Conduct additional studies to confirm the effectiveness of the course

Ensuring Fair Client Assignment in the Experiment

Overview

The goal is to confirm that the assignment of clients to the experiment group is done fairly, as per the requirements.

Validate if the current system correctly assigns half of the clients to the experiment and fix any discrepancies.

Expected Outcome

Approximately half of the clients are randomly assigned to the experiment group. This means that out of 100 clients, around 50 should be part of the experiment. There may be slight variations due to randomness, but on average, the split should be close to 50-50.

Observed Outcome

When the code was initially tested with 100 clients, the system assigned a higher proportion of clients to the experiment group, often skewed toward 70%. This was inconsistent with the executive's goal of a balanced assignment.

Analysis

Upon reviewing the code, it was found that the initial assignment probability favoured one outcome over the other (with a 70% chance). This discrepancy meant that more clients were being included in the experiment than intended.

After adjusting the code to ensure an even 50-50 chance for each client, we ran multiple tests. The new results showed that, on average, about 50 out of 100 clients were assigned to the experiment group, which aligns with the executive's request. While individual runs of the simulation may slightly vary, the overall pattern remains fair and balanced.

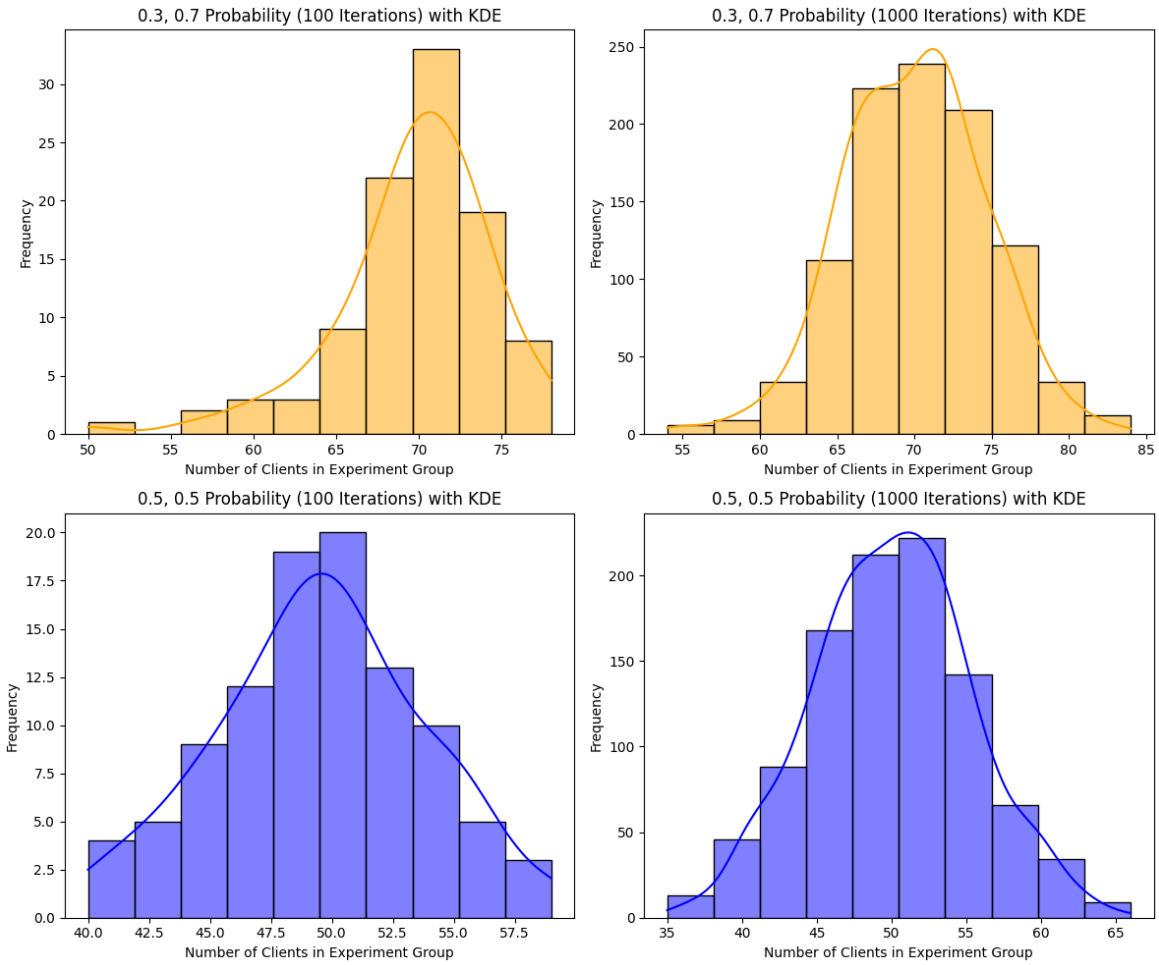


Figure 2 Validation

Recommendation

The updated system reflects the goal of a fair 50-50 client assignment for the experiment group. The corrected version of the system should be implemented to ensure that future client assignments meet the desired outcome.

Additionally, it is suggested to run the simulation several times to demonstrate the natural variation and provide transparency in the random assignment process as shown in the above visualization. This will allow for accurate data collection and a fair experiment without favouring one group over another

Vehicle Sales Forecasting and Staffing Plan Evaluation

Overview

Analysis of historical vehicle sales data from January 1976 to November 2019 to forecast sales for December 2019 and the year 2020. Backed by the analysis, insights into sales trends and offer recommendations regarding ACME Trucks' staffing plans for 2020.

Historical Trend Analysis

Over the past four decades, from January 1976 to November 2019, vehicle sales have demonstrated a consistent upward trajectory. This growth, while steady, has experienced periodic declines, reflecting broader economic cycles and industry-specific factors. Notably, there is a strong seasonal pattern in sales, with certain months consistently outperforming others year after year.

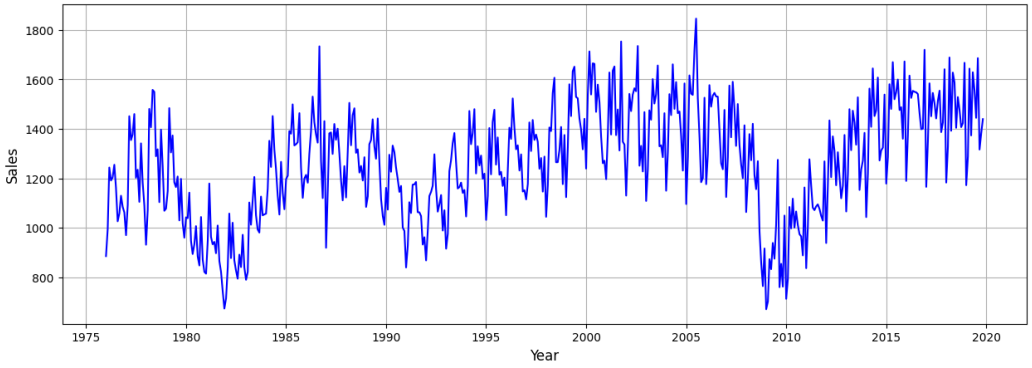


Figure 3 Monthly vehicle sales from 1976 to 2019

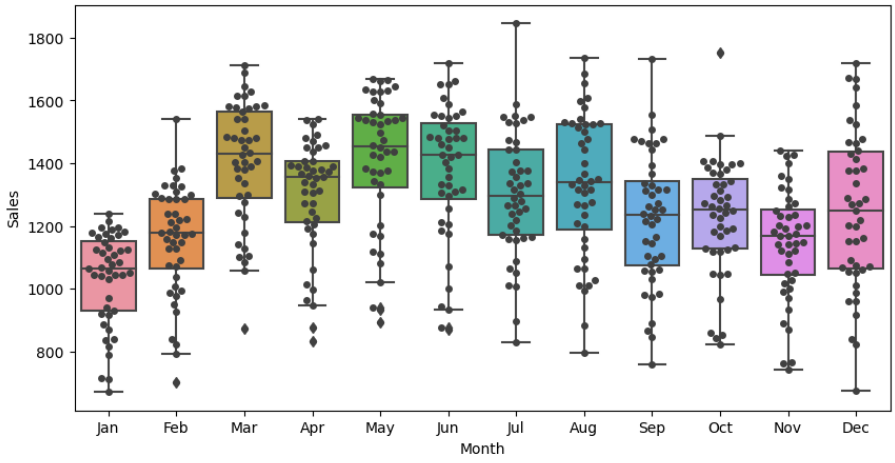


Figure 4 Seasonal monthly vehicle sales

Factors Influencing Current Sales

The current sales figures are influenced by two primary components:

1. **Long-Term Growth Trend:** The overall increase in vehicle sales is indicative of economic growth, rising consumer confidence, and increased demand for vehicles over time.
2. **Seasonal Variations:** Sales tend to peak during specific times of the year due to factors such as new model releases, promotional periods, and consumer buying behaviours aligned with holidays and fiscal years
   - → **Summer Peaks (May-August)-** Sales often rise during the summer months due to promotions
   - → **Year-End Peaks (October-December)-** The end of the fiscal year and the holiday season
   - → **Early Spring Dips (January-February)-** After the holiday season, there tends to be a dip in vehicle sales

Methodology for forecasting

To forecast future vehicle sales, choose a modeling approach that considers both recent trends and recurring season patterns.

Recent Sales Trends: - Observed that sales in a particular month are influenced by the sales in the preceding months. For instance, strong sales over the past few months often indicate continued momentum. The model captures these short-term relationships to predict immediate future sales.

Seasonal Patterns: - Identified consistent fluctuation in sales that occur at the same time each year. Certain months regularly experience higher or lower sales due to predictable factors like holidays, new model releases, or annual promotions. By identifying these patterns, the model adjusts forecasts to account for expected seasonal changes

To confirm the reliability of the forecasting model, it was tested against the actual sales data from the past 12 months. On average, our monthly predictions differed from the actual sales by only **55.6 units,** which is minimal given the overall sales volume. This results in a **mean absolute percentage error (MAPE) of just 3.8%,** meaning our forecasts were within 3.8% of the actual sales figures on average. Such a low error rate demonstrates that our model is highly accurate and can be trusted to provide dependable sales forecasts for 2020.

Sales Forecast for December 2019 and 2020

→ **Forecasted Total Sales for 2020:** 17,633.76 units.

→ **Sales in 2019 with forecasted Dec 2019:** 17547.35 units

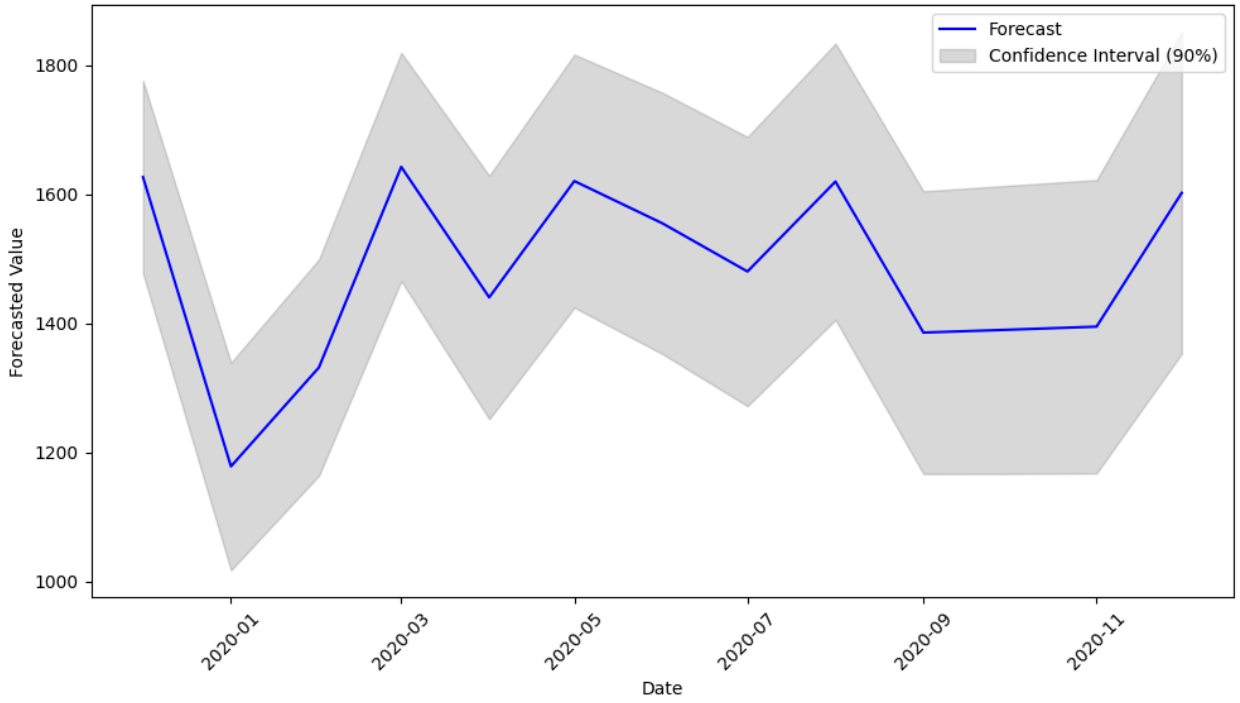


Figure 5 Forecast with confidence intervals

- The blue line is our best estimate of monthly vehicle sales in 2020.
- The gray area provides a cushion for uncertainty, showing the possible range where actual sales could fall.
- The interval helps in understanding potential risks and making informed decisions, knowing that actual sales might be higher or lower than predicted but should fall within this range 90% of the time.

Recommendation for ACME Truck's staffing plan

Current Market Share: ACME Trucks sold approximately 175.47 units in 2019, representing 1% of the total vehicle sales.

Projected 2020 Sales: Expected to sell about 176.34 units, maintaining a 1% market share.

Growth Analysis:

→ **Sales Increase:** The projected increase in sales is approximately 0.49% compared to 2019.
→ **Staffing Implications:** A planned staffing increase of 10% is significantly higher than the projected sales growth.

Recommendation:

Adjust Staffing Plans:- We recommend that ACME Trucks reconsider the 10% staffing increase. A more appropriate adjustment would be an increase of around 0.5% to align with the anticipated sales growth.

Potential Errors and Considerations:

→ **Forecast Margin of Error:** The model has a Mean Absolute Percentage Error (MAPE) of 3.8%, suggesting good accuracy but acknowledging potential deviations.
→ **External Factors:** Unforeseen events (e.g., economic downturns, supply chain disruptions) in 2020 could affect actual sales.
→ **Market Share Variability:** ACME Trucks' market share could change due to competitive actions, marketing strategies, or shifts in consumer preferences.
→ **Model Limitations:** The forecasting model is based on historical data and may not fully account for emerging trends or anomalies.

Appendices

Appendix A: Statistical Analysis of Crash Course Effectiveness

Mean Difference (d): 12.59

Standard Deviation of Differences: 11

1. Statistical Test

Test Selection: A paired sample t-test is used to compare the mean difference in scores before and after the crash course for the same students.

Hypotheses:

→ **Null Hypothesis -** The mean improvement is less than or equal to 10 percentage points.

→ **Alternative Hypothesis -** The mean improvement is greater than 10 percentage points

→ **Significance Level –** Alpha: 0.05

2. Calculations: -

t-Statistic

t = 1.10

sample mean difference = 12.59

mean difference under null hypothesis = 10

sample size = 22

degrees of freedom = 21

t critical = 1.721

p-Value = 0.142

3. Results Interpretation

Comparison with Critical Value:

→ t=1.10<t critical=1.721

Decision Rule:

→ If t>t critical, reject H0.
→ Since t=1.10 is less than t critical=1.721, we fail to reject H0.

p-Value Approach:

→ p=0.142>α=0.05
→ The p-value is greater than the significance level, indicating insufficient evidence to reject H0.

Appendix B: Verification of Experiment Code and Expected Outcomes

1. Key Findings:

Expected Result: The expected number of successful flips for 100 trials is approximately 70.

→ Expected value=100×0.7=70

Standard Deviation: The standard deviation helps quantify variability in the results.

→ $\sigma = 100 \times 0.7 \times 0.3 \approx 4.58$

Range of Outcomes: We expect the number of successes to typically fall within the range of:

→ $70 \pm (2 \times 4.58) = 61$ to 79

Error in the system: Probabilities were changed to 0.5 each to remove the unfairness

Experiment: Experimented with increasing the number of iterations to converge it to the fair value

Appendix C: Time Series Analysis of Vehicle Sales Data

1. Data Collection and Overview

Dataset: Total vehicle sales in the United States from January 1, 1976, to November 1, 2019.

2. Exploratory Data Analysis

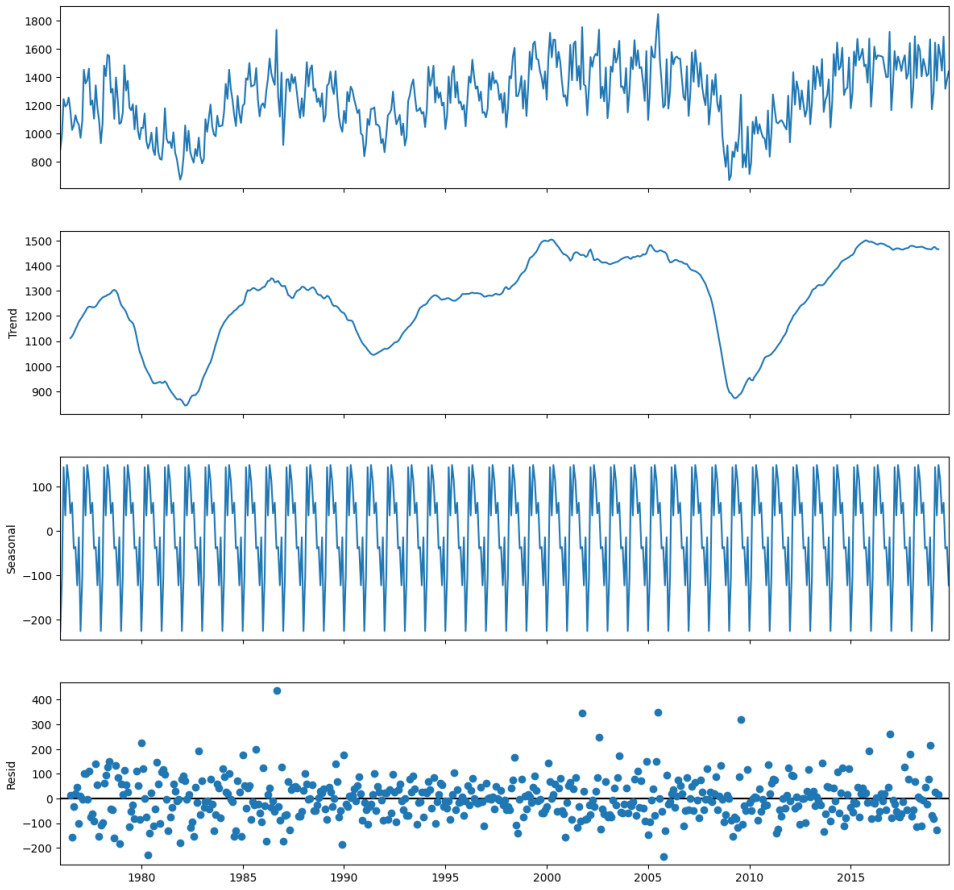
Trend Analysis: Identified an overall upward trend in vehicle sales with periodic drops.

Seasonality Detection: Detected strong seasonal patterns recurring annually.

Residual Analysis: Observed that the mean of the residuals is approximately zero, indicating no significant bias in the errors.

3. Time Series Decomposition

Method: Performed seasonal decomposition to separate the series into trend, seasonal and residual component.



4. Stationarity Testing and Differencing

Seasonal Differencing:

→ Applied a seasonal difference to remove seasonal effects.
→ Data remained non-stationary after seasonal differencing.

First Differencing:

→ Performed an additional first difference to achieve stationarity.

Augmented Dickey-Fuller Test:

→ Test Statistic: -8.3646
→ p-value: 2.7652e-13
→ Conclusion: Rejected the null hypothesis of a unit root; the series is stationary.

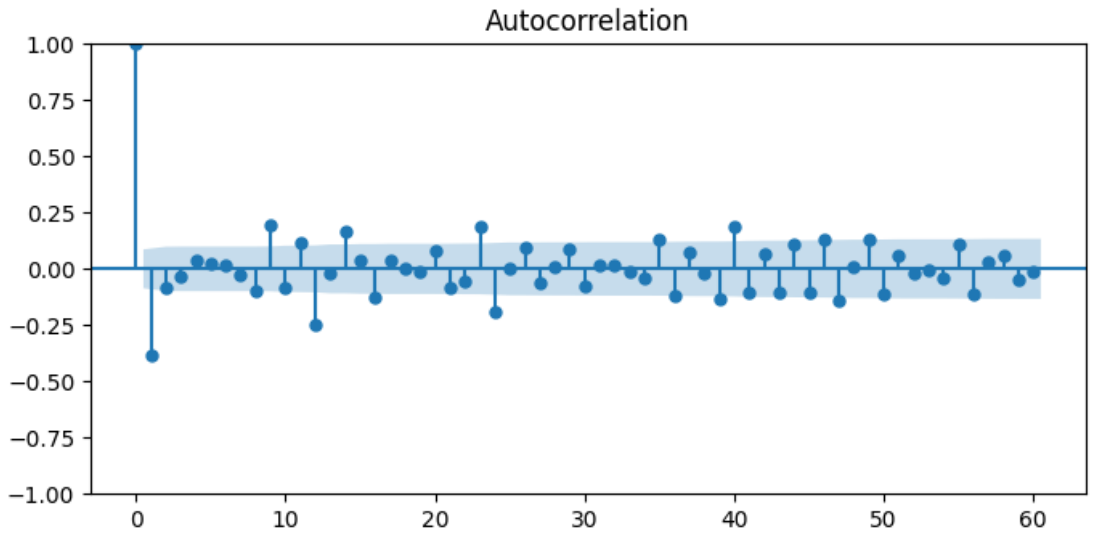
5. Autocorrelation and Partial Autocorrelation Analysis

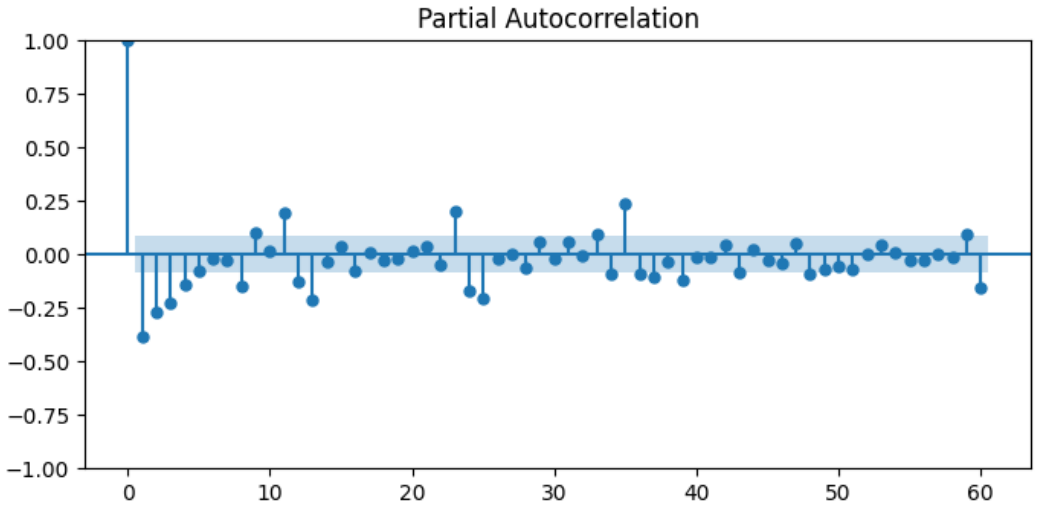
Autocorrelation Function (ACF):

→ Significant spike at lag 1 suggests a non-seasonal MA(1) component.
→ Significant spike at lag 12 suggests a seasonal MA(1) component.

Partial Autocorrelation Function (PACF):

→ Significant spikes at lags 1 to 4 suggest a non-seasonal AR(4) component.
→ Significant spike at lag 12 suggests a seasonal AR(1) component.





6. Model Selection

Chosen Model: Seasonal ARIMA (SARIMA)

→ Order (p, d, q): (4, 1, 1)
→ Seasonal Order (P, D, Q, s): (1, 1, 1, 12)

Rationale: Captures both short-term (monthly) and long-term (annual) patterns, accommodating non-seasonal and seasonal autoregressive and moving average components.

SARIMAX Results

Dep. Variable:	y	No. Observations:	527
Model:	SARIMAX(4, 1, 1)x(1, 1, 1, 12)	Log Likelihood	-3053.766
Date:	Wed, 02 Oct 2024	AIC	6123.533
Time:	18:54:36	BIC	6157.471
Sample:	01-01-1976 - 11-01-2019	HQIC	6136.834
Covariance Type:	opg		

	coef	std err	z	P>|z|	[0.025	0.975]
ar.L1	0.3984	0.035	11.448	0.000	0.330	0.467
ar.L2	0.1534	0.044	3.462	0.001	0.067	0.240
ar.L3	0.1876	0.043	4.315	0.000	0.102	0.273
ar.L4	0.1635	0.035	4.665	0.000	0.095	0.232
ma.L1	-0.9999	0.666	-1.501	0.133	-2.305	0.306
ar.S.L12	0.2861	0.053	5.349	0.000	0.181	0.391
ma.S.L12	-0.8734	0.039	-22.430	0.000	-0.950	-0.797
sigma2	8207.9903	5376.301	1.527	0.127	-2329.366	1.87e+04

Ljung-Box (L1) (Q):	0.22	Jarque-Bera (JB):	107.50
Prob(Q):	0.64	Prob(JB):	0.00
Heteroskedasticity (H):	0.65	Skew:	0.03
Prob(H) (two-sided):	0.01	Kurtosis:	5.24

Significance: Parameters are statistically significant, and diagnostics indicate a good fit.

7. Model Diagnostics

Residual Analysis:

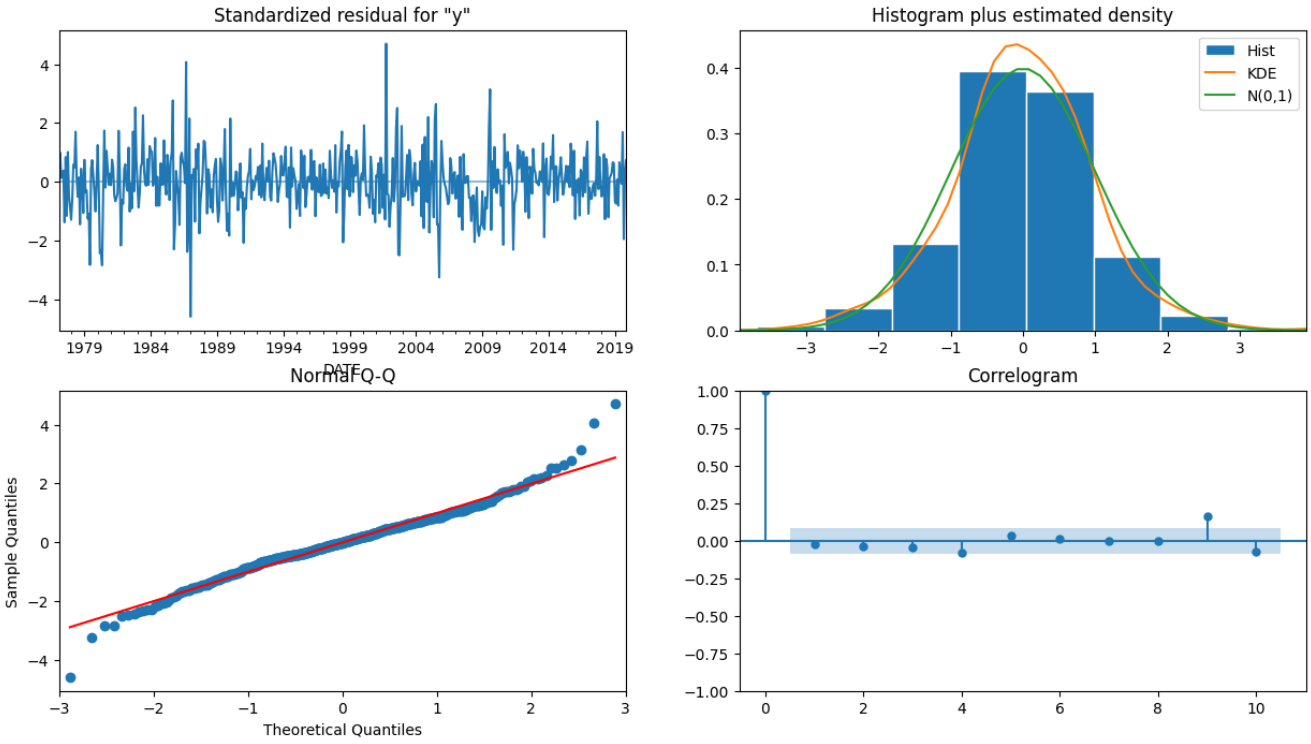
→ Plotted residuals to verify normal distribution and homoscedasticity.
→ Residuals appear randomly scattered around zero with constant variance.

Ljung-Box Test:

→ Assessed autocorrelation in residuals.
→ Results suggest residuals are uncorrelated, supporting model adequacy.

Normality Test:

→ Jarque-Bera (JB) Statistic: 107.50
→ p-value: < 0.01
→ Slight deviations from normality noted but acceptable for forecasting purposes.



8. Model Evaluation

Evaluated model performance by forecasting the last 12 months and comparing predictions to actual data.

Error Metrics:

- → Mean Absolute Error (MAE): 55.7
- → Mean Absolute Percentage Error (MAPE): 3.8%
- → Interpretation: Low MAE and MAPE indicate high predictive accuracy of the model.