Analysis of TurboBM Battery Data

Introduction

This report presents the analysis of the TurboBM battery data provided by Batmobile. The analysis is divided into three main tasks, each addressing specific questions related to the usage lifetime of TurboBM batteries in various conditions and comparisons with the BMClassic battery. The goal is to assess Batmobile's claims about the TurboBM battery's performance.

Main Body

Task 1: Usage Data Analysis

Question

What is the usage lifetime of TurboBM batteries in mobile devices produced by manufacturers A, B, and C?

Methods

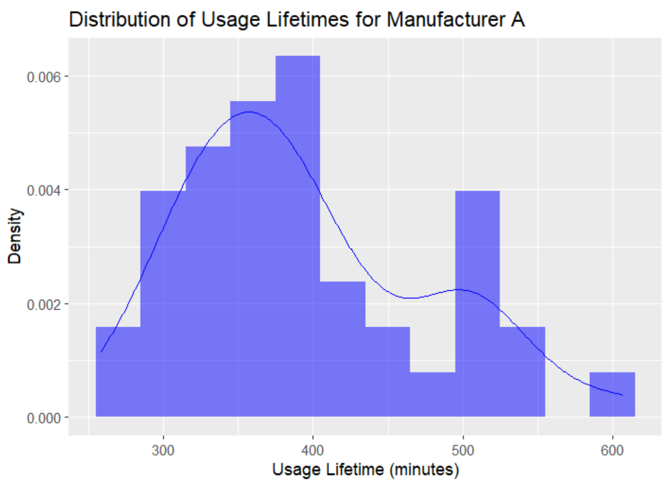
- Exploratory Analysis: Summarize the data and visualize the distribution of usage lifetimes.
- Confidence Interval: Construct a 98% confidence interval for the mean usage lifetime of TurboBM batteries for manufacturer B.
- Gamma Distribution Test: Test if a Gamma (25, 0.0632) distribution is appropriate for the usage lifetime of TurboBM batteries for manufacturer C.

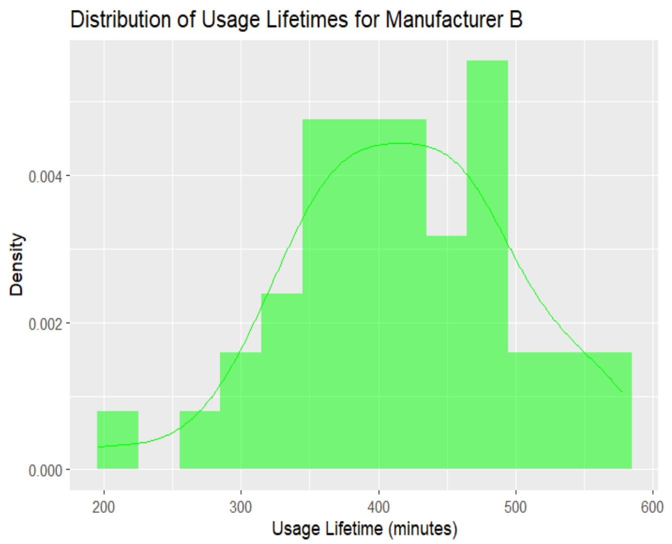
Results

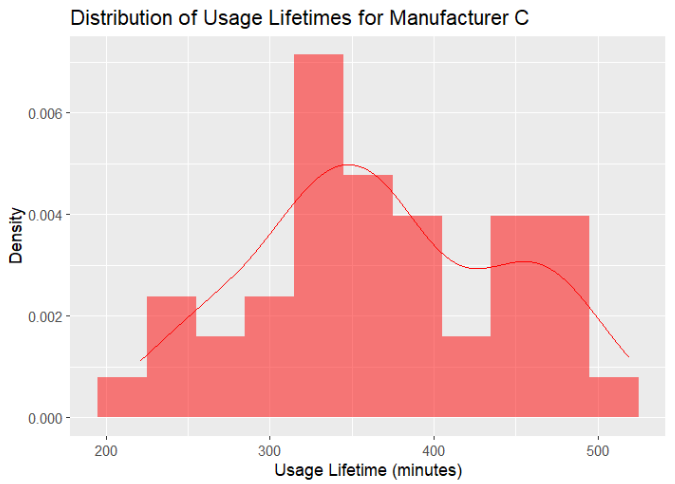
Exploratory Analysis

Metric	A	B	C
Mean	394.5	418.0	368.7
Standard Deviation	81.2	81.5	76.4

Distribution of Usage Lifetimes for Each Manufacturer:-







98% Confidence Interval for Manufacturer B

- Mean = 418.0476 minutes
- 98% Confidence Interval: (387.589, 448.5063)

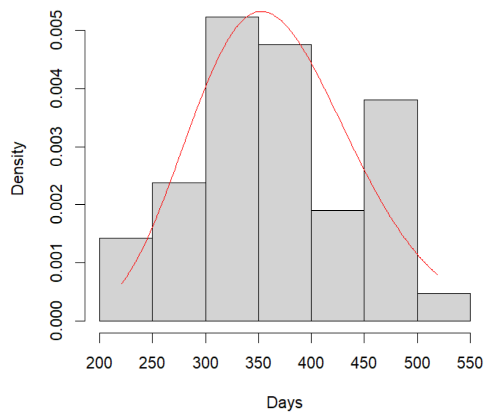
Gamma Distribution Test for Manufacturer C

Null Hypothesis (H0): The data follows gamma distribution.

Alternative Hypothesis (H1): The data does not follow gamma distribution.

Estimated Alpha(α) and Beta(β) values using MLE:-

- Alpha(α): 23.4245
- Beta(β): 0.0636



Using these values for KS Test:-

- Kolmogorov-Smirnov Test Statistic: 0.096199
- P-value: 0.8318
- Conclusion: A high P-value (>0.05) means that there is not enough data to reject the null hypothesis. The KS test does not find significant evidence to suggest that the data deviates from the gamma distribution. Thus, the gamma distribution appears to be a reasonable fit for the data.

Interpretation

The exploratory analysis shows that manufacturer B has the highest mean usage lifetime. The confidence interval for manufacturer B indicates that we are 98% confident that the true mean usage lifetime lies between 387.59 and 448.51 minutes. The KS distribution test for manufacturer C suggests that the usage lifetime data fits a gamma distribution.

Task 2: Comparison Data Analysis

Question

How does the usage lifetime of TurboBM batteries compare to BMClassic batteries?

Methods

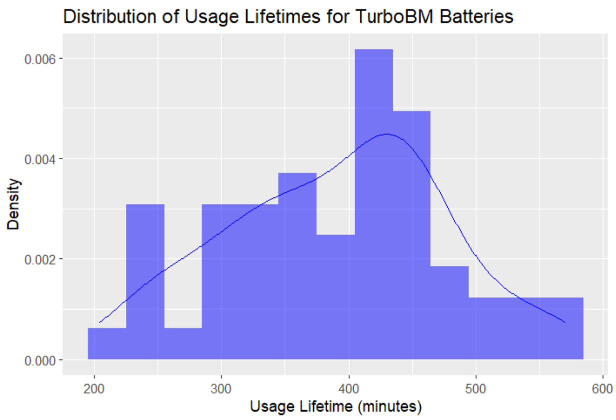
- Visual Summary: Summarize and visualize the data.
- Correlation: Assess the correlation between the usage lifetimes of TurboBM and BMClassic batteries.
- Variance Test: Test if the variances of the usage lifetimes of TurboBM and BMClassic batteries are the same.
- Mean Difference Test: Test if the mean usage lifetime of TurboBM is at least 65 minutes longer than BMClassic.

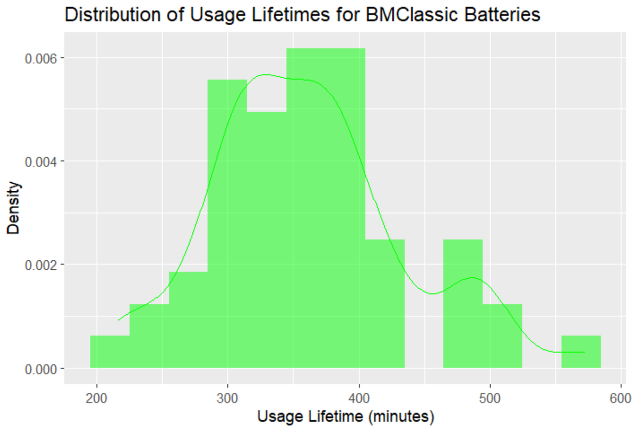
Results

Visual Summary

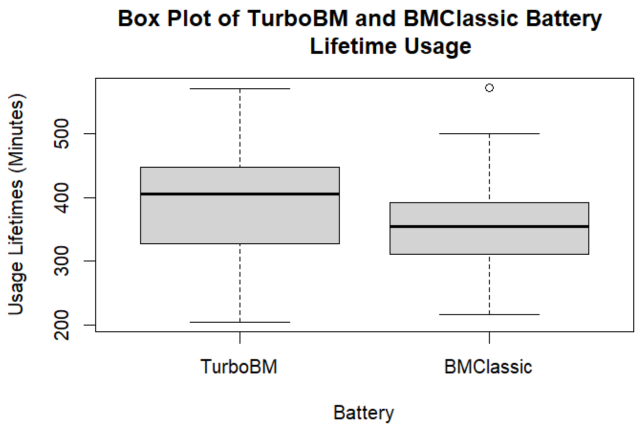
Metric	TurboBM	BMClassic
Mean	390.76	360.93
Standard Deviation	86.48	74.16

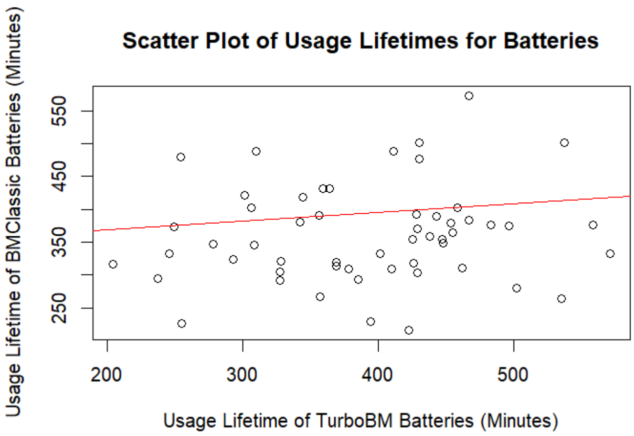
Distribution of Usage Lifetimes for TurboBM and BMClassic Batteries: -





Boxplot and Scatter Plot of Usage Lifetimes for TurboBM and BMClassic Batteries: -





Correlation

- Correlation Coefficient: 0.113 (This indicates a very weak positive linear relationship between the usage lifetimes of TurboBM and BMClassic batteries.)
- Null Hypothesis (H0): The true correlation is equal to 0.

  Alternative Hypothesis (H1): True correlation is not equal to 0.
- P-value in Pearson's product-moment correlation test : 0.4171
- Since the p-value (0.4171) is greater than the common significance level of 0.05, we fail to reject the null hypothesis. This means there is not enough evidence to conclude that there is a significant correlation between the usage lifetimes of TurboBM and BMClassic batteries.

Variance Test

- F-Test statistic: 1.3598 (This indicates the ratio of the sample variances -TurboBM variance to BMClassic variance)

- Null Hypothesis (H0): True ratio of variances is equal to 1

  Alternative Hypothesis (H1): True ratio of variances is not equal to 1

- P-value in F-test: 0.2665

- Since the p-value (0.2665) is greater than the common significance level of 0.05, we fail to reject the null hypothesis. This means there is not enough evidence to suggest that the variances of TurboBM and BMClassic batteries are different.

Mean Difference Test

- Mean Difference: 29.83 minutes

- T-test Statistic: 1.924

- P-value: 0.029

- Conclusion: Although there is a statistically significant difference between the mean usage lifetimes of TurboBM and BMClassic batteries, the mean difference of 29.83 minutes is not enough to conclude that the TurboBM batteries last at least 65 minutes longer than the BMClassic batteries.

Interpretation

The visual summary and correlation analysis indicate a weak relationship between the usage lifetimes of TurboBM and BMClassic batteries. The variance test shows that the variances are equal. The mean difference test suggests that the TurboBM battery does not have a significantly longer usage lifetime than the BMClassic battery by at least 65 minutes.

Task 3: Laboratory Data Analysis

Question

How do various factors affect the usage lifetime of TurboBM batteries under laboratory conditions?

Methods

- Exploratory Analysis: Explore the relationship between usage lifetime and temperature.

- Linear Model: Fit a linear model to the usage lifetime data.

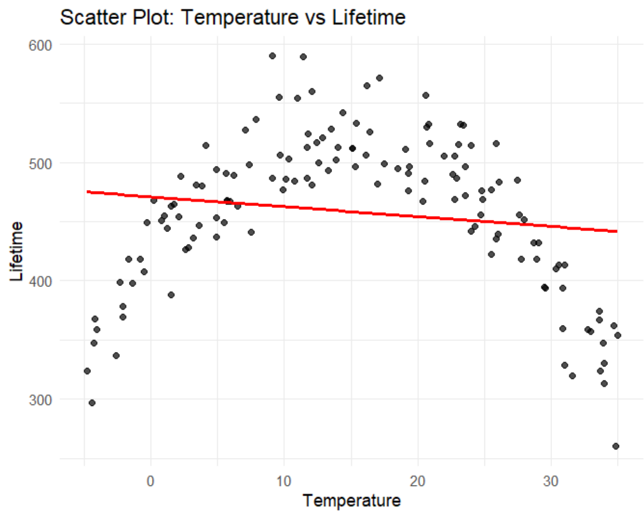
- Model Selection: Choose the most appropriate linear model.

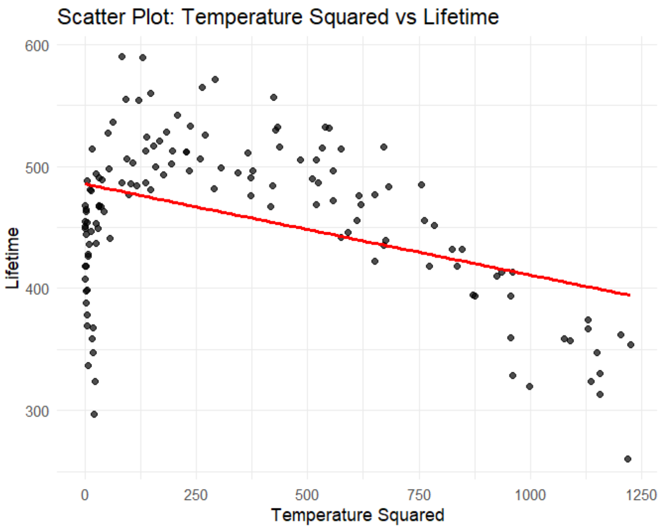
- Prediction Interval: Provide a 75% prediction interval for a specific case.

Results

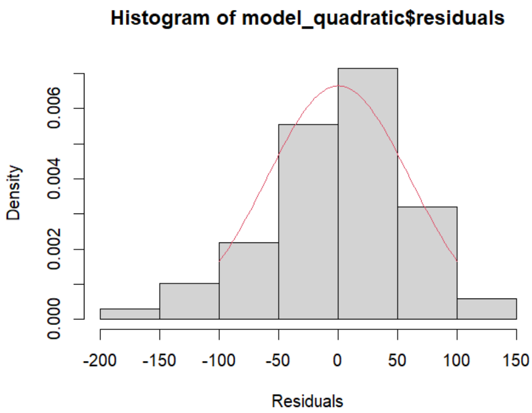
Exploratory Analysis:

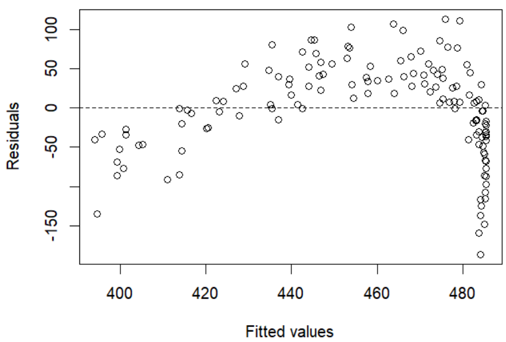
- Relationship between Temperature and Usage Lifetime: The data clearly has a non-linear relationship. When Temperature is squared, a linear relationship can be observed.





- We can fit a linear model for Lifetime against Temperature Squared and then plot the residuals to check the assumptions.





Linear Model: Lifetime= 485.4896-(0.0745·Temperature Squared)

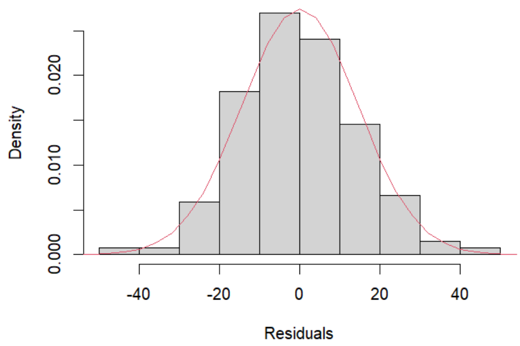
- The residuals appear to be approximately normal from the histogram plot. There is no trend in the plot of the residuals against fitted values, so the fitted model appears to be appropriate.

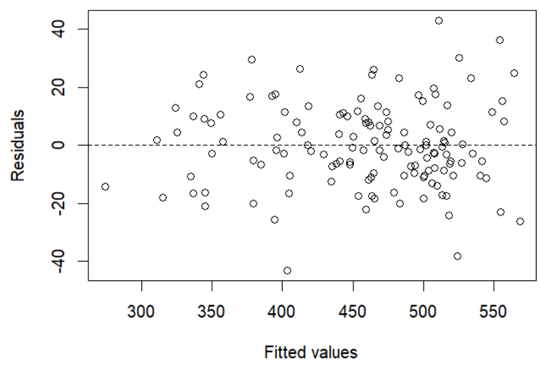
Fit Linear Model, Most Appropriate Linear Model, Comment on Model Fit

- Fit a linear model to the usage lifetime by using lm() function. Using stepwise selection based on AIC, the most appropriate model includes the predictors: DeviceB, DeviceC, Temperature, Recharge, Memory, and Temperature Squared.
- The best linear model fit is as follows:

$$Lifetime = 431.56574 + (24.51604 \cdot DeviceB) - (26.58340 \cdot DeviceC) + (15.33204 \cdot Temperature) - (0.23928 \cdot Recharge) + (0.02709 \cdot Memory) - (0.51227 \cdot Temperature\ Squared)$$

- AIC: 746.12





- The residuals appear to be approximately normal from the histogram plot. There is no trend in the plot of the residuals against fitted values, so the fitted model appears to be appropriate.

Prediction Interval:

- Prediction = 532.2305 minutes
- 75% Confidence Interval: (514.7405, 549.7205)

Interpretation

The exploratory analysis shows a non-linear relationship between temperature and usage lifetime. Temperature Squared and usage lifetime showed linearity. The linear model indicates that DeviceB, DeviceC, Temperature, Recharge, Memory, and Temperature Squared are significant predictors of usage lifetime. The selected model provides a reasonable fit, and the prediction interval for the specified case gives an expected usage lifetime estimate of 532.23 minutes with an upper bound of 549.72 and a lower bound of 514.74 for a 75% Confidence Interval.

Conclusion

The analysis of the TurboBM battery data provided by Batmobile has yielded several insightful findings across different tasks. Here, we summarize the most interesting results and reflect on the strengths and weaknesses of the analysis, as well as potential areas for further investigation.

Key Findings

Usage Data Analysis

- Manufacturer B: TurboBM batteries produced by manufacturer B have the highest mean usage lifetime of 418.0 minutes. The 98% confidence interval for the mean usage lifetime is between 387.59 and 448.51 minutes, indicating a high level of reliability in these batteries.
- Gamma Distribution for Manufacturer C: The usage lifetime data for TurboBM batteries from manufacturer C fits a gamma distribution well, with a Kolmogorov-Smirnov test p-value of 0.8318. This suggests that the gamma distribution is a reasonable model for this data.

Comparison Data Analysis

- Mean Usage Lifetime: TurboBM batteries have a mean usage lifetime of 390.76 minutes, compared to 360.93 minutes for BMClassic batteries. Although there is a statistically significant difference, the mean difference of 29.83 minutes is not sufficient to conclude that TurboBM batteries last at least 65 minutes longer than BMClassic batteries.
- Variance and Correlation: The variances of the usage lifetimes for TurboBM and BMClassic batteries are not significantly different (p-value = 0.2665). Additionally, there is a very weak positive correlation (correlation coefficient = 0.113) between the usage lifetimes of the two battery types, indicating that their performance is relatively independent of each other.

Laboratory Data Analysis

- Non-linear Relationship with Temperature: The relationship between temperature and usage lifetime is non-linear. A quadratic model, including temperature and its squared term, provides a better fit for the data.
- Predictive Model: The most appropriate linear model includes predictors such as DeviceB, DeviceC, Temperature, Recharge, Memory, and Temperature Squared. This model explains a significant portion of the variance in usage lifetime and provides a prediction interval for specific cases.

Strengths of the Analysis

- Comprehensive Approach: The analysis covers multiple aspects of the TurboBM battery performance, including exploratory data analysis, hypothesis testing, and model fitting.
- Statistical Rigor: The use of confidence intervals, distribution tests, and various statistical models ensures that the conclusions are based on robust statistical evidence.
- Predictive Modeling: The development of a predictive model for usage lifetime under laboratory conditions adds practical value, allowing for better planning and optimization of battery usage.

Weaknesses of the Analysis

- Limited Scope of Variables: The analysis primarily focuses on temperature and a few other variables. Other potential factors affecting battery performance, such as humidity, usage patterns, and charging cycles, were not considered.
- Assumptions in Models: The linear and quadratic models assume specific forms of relationships between variables, which may not capture all the complexities of real-world data.

Further Investigation

- Additional Variables: Future studies could include more variables, such as environmental conditions, user behavior, and battery age, to provide a more comprehensive understanding of factors affecting battery performance.
- Longitudinal Data: Collecting and analyzing longitudinal data could help in understanding how battery performance changes over time and under different usage conditions.
- Advanced Modeling Techniques: Exploring advanced modeling techniques, such as machine learning algorithms, could improve the accuracy and predictive power of the models.
- In conclusion, the analysis provides valuable insights into the performance of TurboBM batteries, highlighting their strengths and areas for improvement. By addressing the identified weaknesses and exploring further avenues of investigation, Batmobile can enhance the reliability and efficiency of their battery products.