Bike Rentals, Project

Neural Network Driven Demand Prediction

Presented by

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Introduction

WelcomeBike Bike Rentals, a bike rental company based in Beijing, has recently expanded its services to multiple locations across the United States. This report details our efforts to create a predictive neural network aimed at forecasting daily bike rentals at our Washington DC branch. Our main objective is to showcase how machine learning can help safeguard our business from the issues that have troubled numerous Chinese bike rental companies.

Our analytics team has partnered with WelcomeBike Bike Rentals to forecast bike rental demand in the Washington D.C. region. This collaboration has leveraged data spanning from January 1, 2011, to October 30, 2023, covering hourly and daily rental metrics under various environmental and temporal conditions. This report elucidates the derived insights and the implications for boosting the profitability of WelcomeBike Bike Rentals.

We utilized a sophisticated neural network model to predict rental volumes effectively. The model accounts for various inputs, such as date, hour, seasonality, weather conditions, and type of day (holiday or working day). Our predictive framework is robust, explaining 94 percent of the variations in rental numbers, demonstrating strong predictive accuracy for the Washington D.C. branch.

These insights not only enhance operational efficiency by aligning supply with anticipated demand but also strategically guide promotional activities to maximize user engagement and profitability.

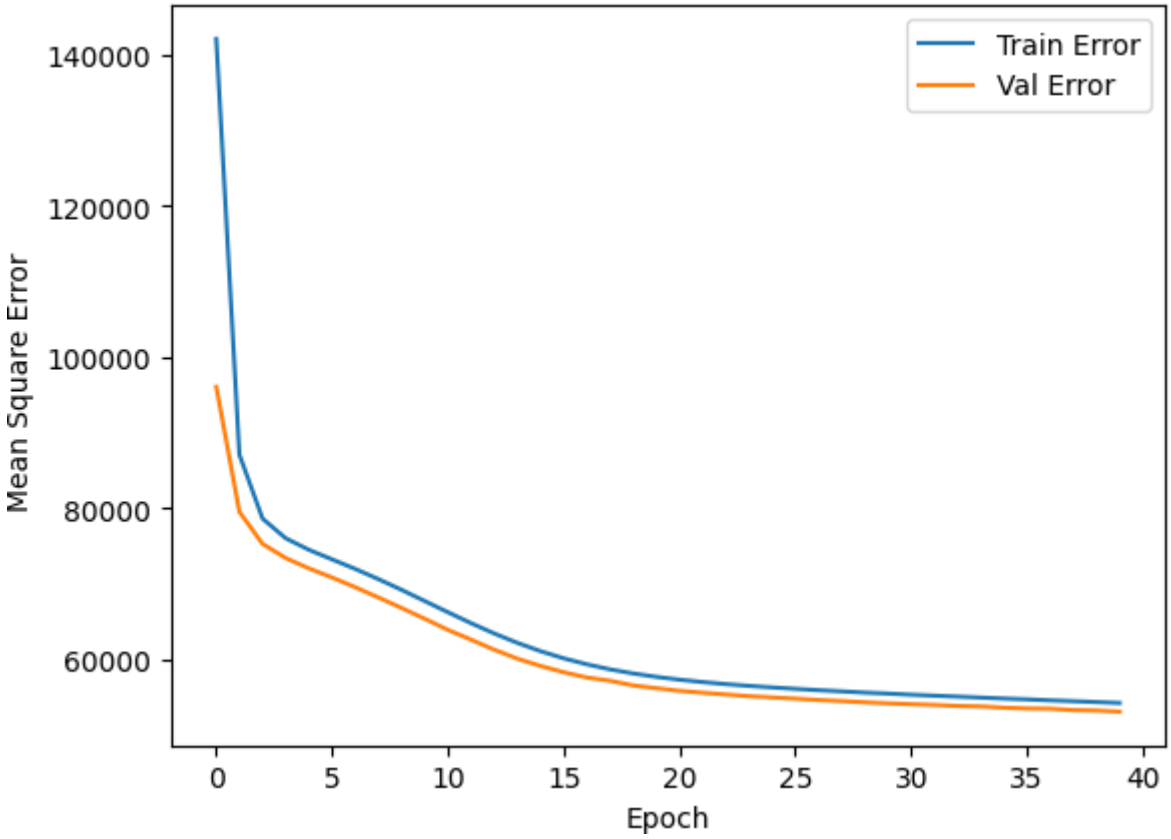
About our Model

Our predictive neural network has been meticulously designed to ensure precision and reliability. The architecture features an input layer with 128 neurons, specifically tailored to effectively process our comprehensive input data. To enhance the model's robustness, we've incorporated 2 hidden layers. Additionally, a carefully implemented dropout mechanism guards against overfitting, ensuring the model's applicability to real-world scenarios and future data. The architecture culminates in an output layer with one neuron dedicated to making accurate rental predictions. This comprehensive design highlights our commitment to leveraging advanced techniques and methodologies to deliver precise forecasts, thereby optimizing our bicycle rental services.

Model Performance

Vanilla Model

We started with a basic “vanilla” model that only had one hidden layer and 40 epochs. Clearly there was a lot more work to be done as our R Squared was only 0.54 and our root mean squared error was 234.4. Below are our results from this model.

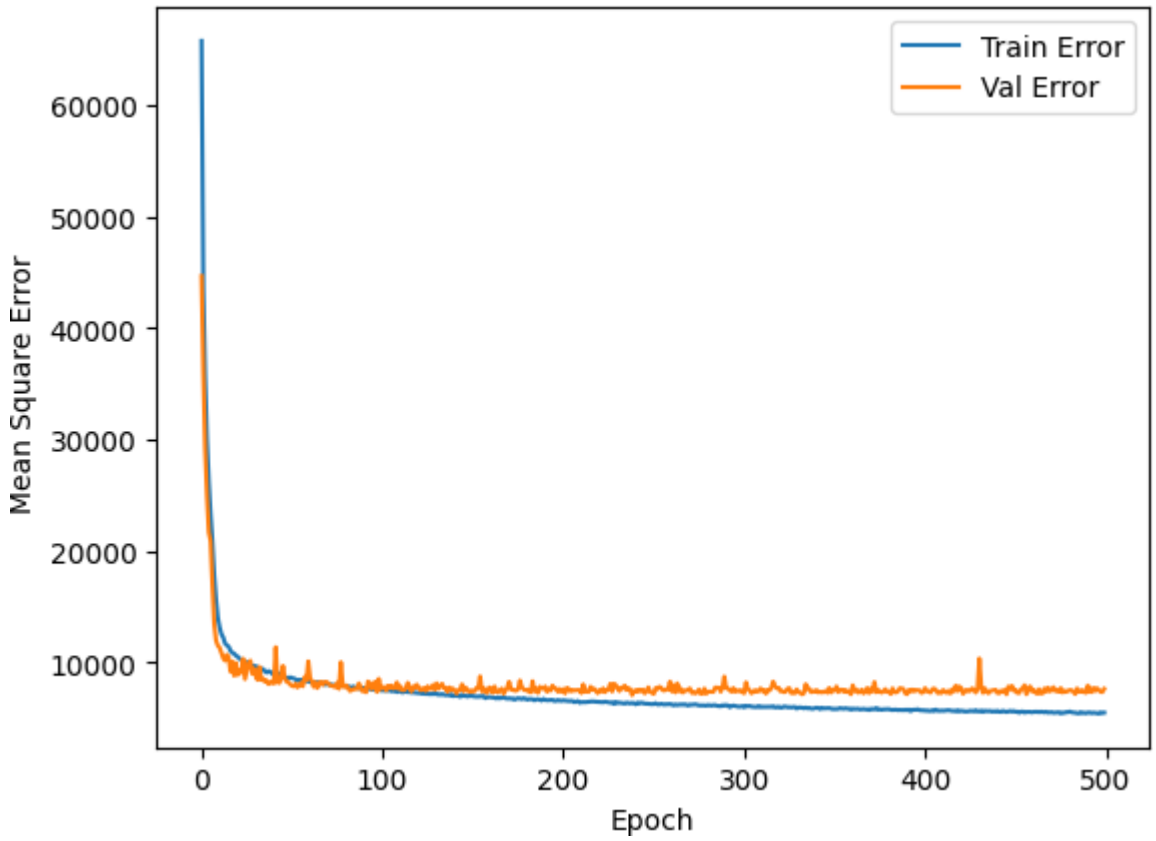


Root Mean Squared Error: 234.4

R Squared: 0.54

Model After Added Layers, Neurons and Epochs

Next, we added more layers, neurons and epochs. We added 2 more hidden layers and a dropout layer to prevent overfitting. We also added 460 epochs. These few changes made an insane amount of difference. As you can see, the mean squared error on the chart dropped from 60,000 all the way down to below 10,000. It also gave us a root mean squared error of 87.2 and an R Squared of 0.94.

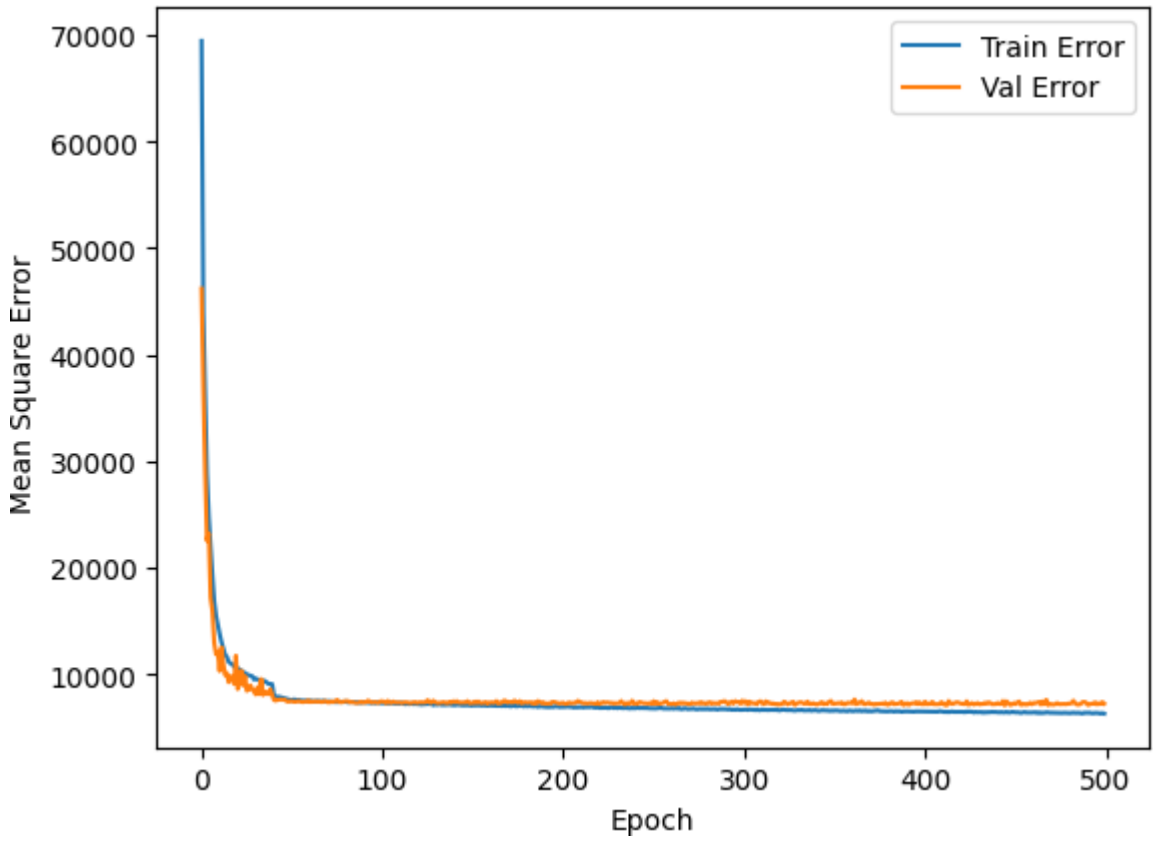


Root Mean Squared Error: 87.2

R Squared: 0.94

Final Model After Early Stopping and Learning Rate Reduction

The final thing we did to improve our model was add an early stopping feature that would attempt to stop our model at the lowest Mean Squared Error, and a learning rate reduction feature that would slowly reduce the learning rate over time helping the model to not make drastic changes late in the learning process. Although these changes didn't result in as drastic of an improvement as the last changes, it still improved. The lowered learning rate made the errors more consistent, and improved our R Squared by 0.01 and our Root Mean Squared Error by 5.5.

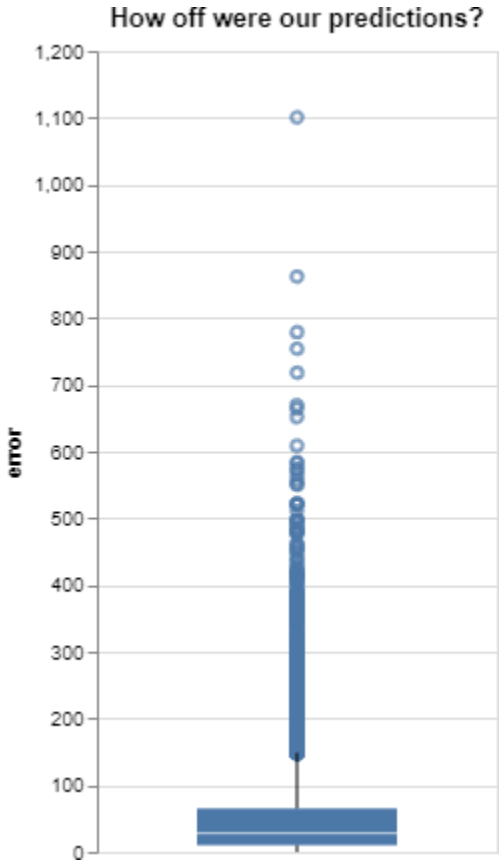


Root Mean Squared Error: 81.7

R Squared: 0.95

Closer Look

Here’s a closer look at our final results. We took the Root Mean Squared Error and made a boxplot out of our results. Although we do have some predictions that were significantly off, 75% of our results had a Root Mean Squared Error of 65 or lower.



Max: 1101

Q3: 65

Median: 28

Q1: 10

Min: 0

Trends

When should you sell more and less?

We will look into different metrics to see when your bike rentals have been high and when they have been low.

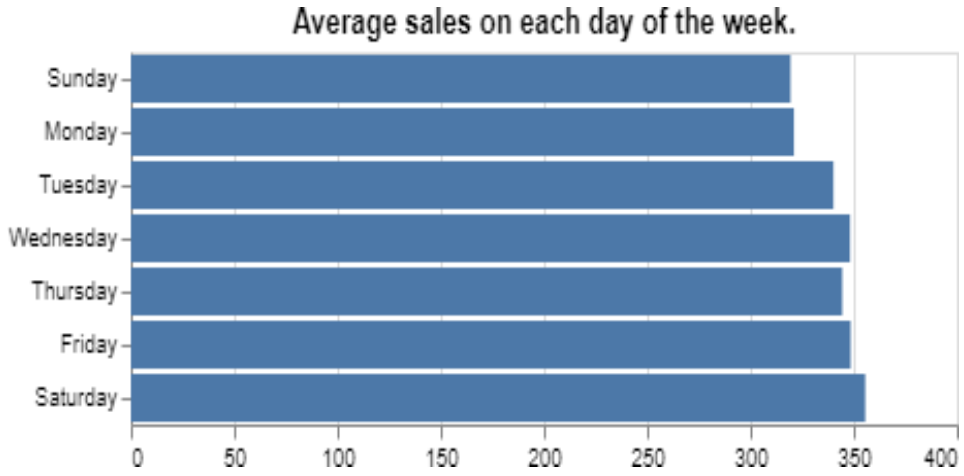


Figure 1

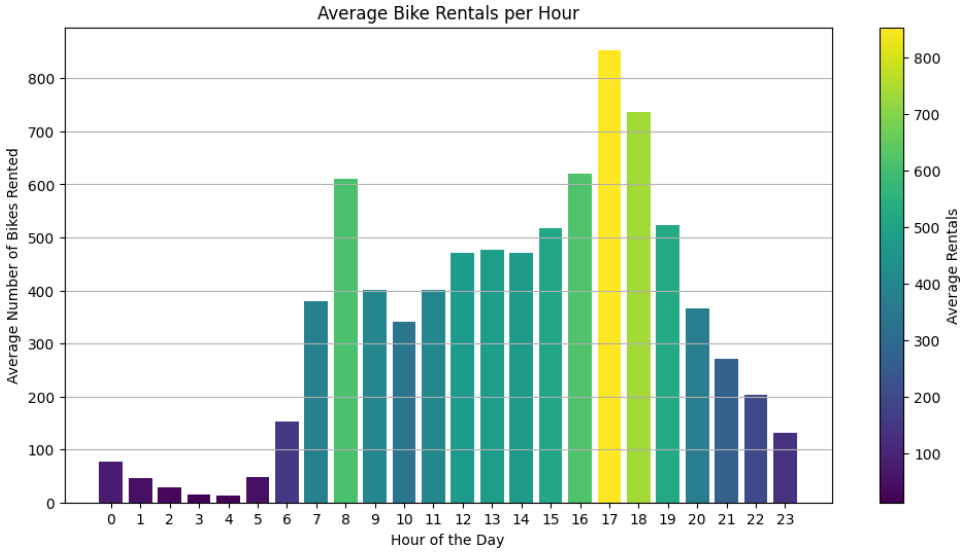


Figure 2

Figure 1 shows the average sales per day of the week, while Figure 2 shows the average sales per hour.

We see that Sunday has the lowest number of sales with Monday also as low. The times with the least sales are at the beginning of the day from the 0-6th hour of the day and at the end of the day from the 20-23rd hour. So these are the times on Sunday and Monday you may consider bringing in the bikes for cleaning. Also, if you want a time mid-day, you could bring them in at the 10th hour of the day.

To provide more information on when sales are best, we made more visualizations to show this:

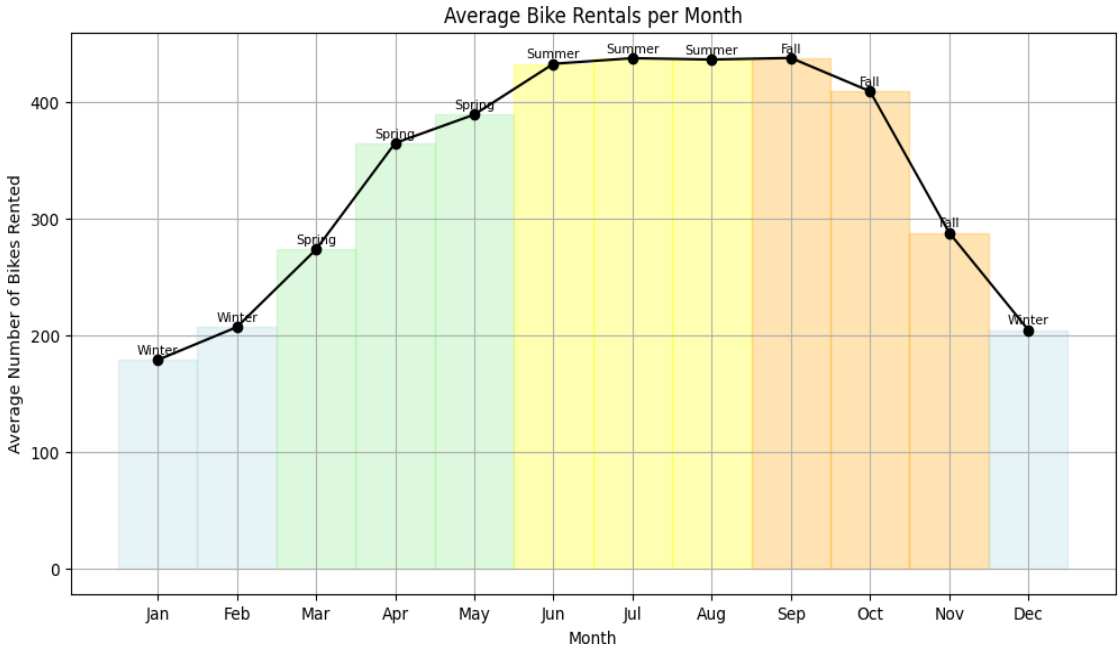


Figure 3

Figure 3 shows the average number of rented bikes for each month. From the graph, we see that during the summer season bikes are rented the most on average. However, September is the month with the highest number of bikes rented on average.

From these insights, you would want to invest most of your resources in selling during the summer season and invest less during the winter season.

Interesting Finds

Although COVID-19 didn't have much effect on the overall bike rentals, we did find some interesting trends in demand just before the time of the pandemic. As seen in figure 4 below.

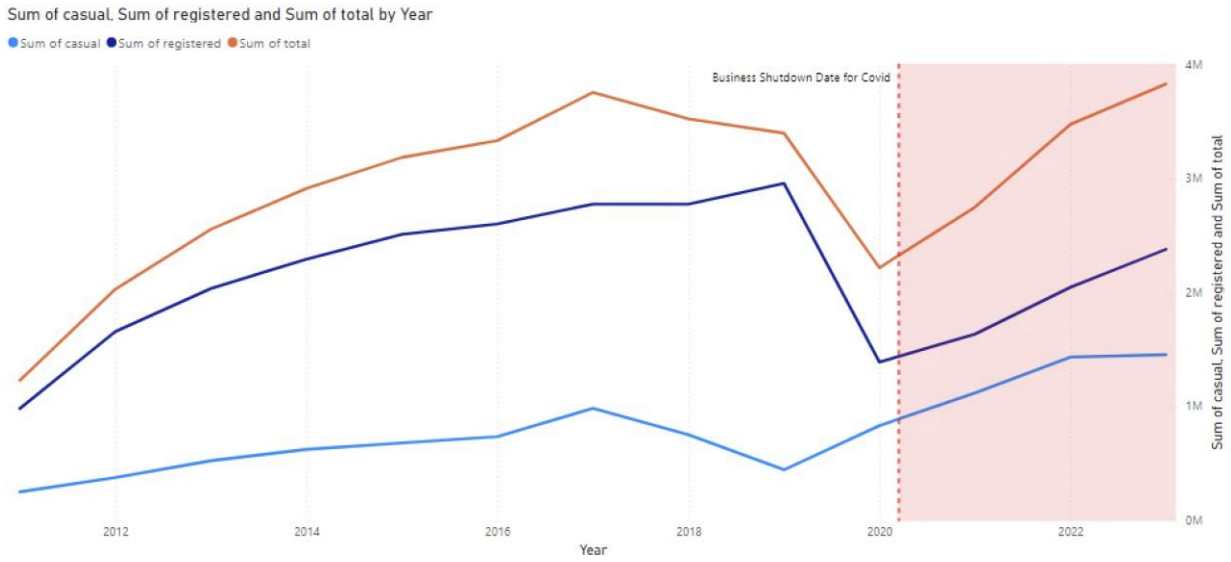


Figure 4

The drop in demand came before the pandemic (even as far back as 2017-2018) so other factors may have played into the significant drops seen above. A factor that could have played a role is the economic recession in early 2019, but it is likely the case that there are multiple other factors in play here. Looking into what may have happened during that time within the company and without will help to prevent these trends in the future. With this information, future neural networks can be trained to more accurately predict and account for these more unexpected shifts in demand resulting in increased profits and decreased expenditures for the company over what could be more crucial times.

Benefits of Using This Model

CEO ZAO wants to apply machine learning to avoid repeating his competitors' mistakes and finally make the company profitable, a point that has remained elusive and critical for investors. Here are the key benefits machine learning brings to WelcomeBike:

Accurate demand prediction means fewer bikes in stock, lower maintenance costs, and decreased wear and tear on idle bikes. Thus, it results in effective operations at an efficient level of inventory. Proper demand forecasting ensures the correct number of bikes is available, minimizing the loss of opportunity and increasing the chances that a customer may find bikes available when needed.

Further, by properly aligning customer demand with bike availability, the model increases customer satisfaction and repeat business. Therefore, it is effective in helping plan and allocate resources, for instance, in scheduling maintenance during low-demand times and marketing efforts when demand peaks. Most importantly, the model will form a data-driven basis for

making strategic decisions, allowing the company to respond proactively to the drift in market trends and demand shifts.

Conclusion

Our advanced neural network achieved a remarkable 95% accuracy in predicting daily bike rentals, empowering WelcomeBike to optimize inventory management, staffing, and marketing efforts. This data-driven approach has the potential to significantly improve operational efficiency and boost profitability. Now the Washington D.C. branch, with this model guiding the balance between supply and demand, presents a strategic opportunity for exceeding the profitability of even our Chinese and other branches. We recommend prioritizing the model's integration into existing systems to unlock its full potential and prove valuable for the future of WelcomeBike.

Plans Moving Forward

While our model achieved high accuracy, there's always room for improvement. Future work will involve incorporating additional data sources and exploring more advanced architectures to further enhance our predictive capabilities and address any remaining outliers.
This project demonstrates the power of machine learning in transforming WelcomeBike's operations. By continually refining the model and integrating it with real-time data, WelcomeBike can gain a significant competitive edge in the U.S. market.

Python Notebooks

Below are Github Gist links to the notebooks we used during this case study:

https://colab.research.google.com/drive/1K0feeXNQS1mPlyeByF9kIx95zBMtC8Wg?usp=sharing