# Boston University
# Electrical & Computer Engineering

## EC 463 Senior Design Project

# AI Trading Platform

By: Team 6

## 2nd Prototype Test Report

Adrian Pawlowski | ajp12@bu.edu
Gabriel Brown | gabrown@bu.edu
Yagiz Idlman | ykaan@bu.edu
Odilon Quevillon | odilon@bu.edu

# 1. Introduction

- Objective:
  Evaluate the performance of our trading platform by testing two new added components:
  - **NLP Model:** Assesses sentiment score accuracy using backtesting on TSLA, KO, and MSFT.
  - **Reinforcement Learning (RL) Model:** Analyzes trading decisions through actions, rewards, cumulative rewards, and realized profit.

- Scope:
  Backtesting for TSLA (high-volatility), MSFT (medium-volatility), and KO (low-volatility) using data from January 3, 2022, to February 19, 2025.

- Goals:
  - Verify that the NLP model achieves sentiment score accuracy > 50% for all stocks.
  - Confirm that the RL model meets the realized profit criteria:
    - TSLA: > $20 per share
    - KO: Between -$10 and $20 per share
    - MSFT: Between -$60 and $150 per share

# 2. Equipment and Setup

## Required Materials

- **XGBoost Model Scripts:** train_boost.py, xgboost_model_training_prototype.ipynb, xgboost_backtesting_prototype.ipynb
- **Data Processing:** Data_processing.py
- **Genetic Algorithm:** genetic_algorithm.py
- **NLP Model:** tsla_nlp_model_prototype_test.ipynb, ko_nlp_model_prototype_test.ipynb, msft_nlp_model_prototype_test.ipynb with corresponding CSV data files.
- **Reinforcement Learning Model:** Series of RL model scripts and backtesting notebooks for TSLA, KO, and MSFT.
- **Figma UI Project** (for reference)
- **Environment File:** Environment.yml

## Setup/Plan

- Local machine running an Anaconda environment with all required packages.
- Data sources: CSV files containing stock data and sentiment data.
- Backtesting period: January 3, 2022 – February 19, 2025.
- Evaluation based on the Lab Testing Plan and Measurable Criteria.

# 3. Methodology

## Testing Procedure

1. Initialize Environment:
   a. Start Anaconda with the pre-configured Environment.yml.
2. Run Backtests:
   a. NLP Model: Execute backtesting notebooks for TSLA, KO, and MSFT to obtain sentiment scores.
   b. Reinforcement Learning Model: Run RL model notebooks for each stock to generate trading actions, rewards, cumulative rewards, and realized profit.
3. Data Evaluation:
   a. Collect and analyze metrics from the outputs.
   b. Generate graphs to visually represent key performance indicators.
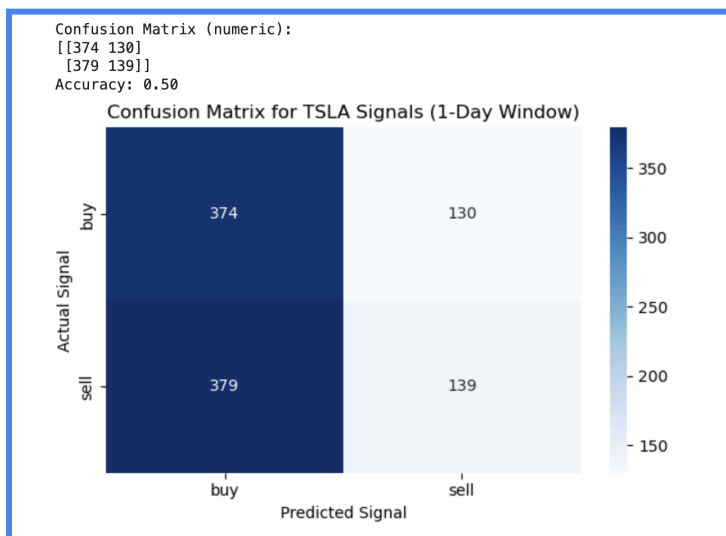
# 4. Measurable Criteria and Results

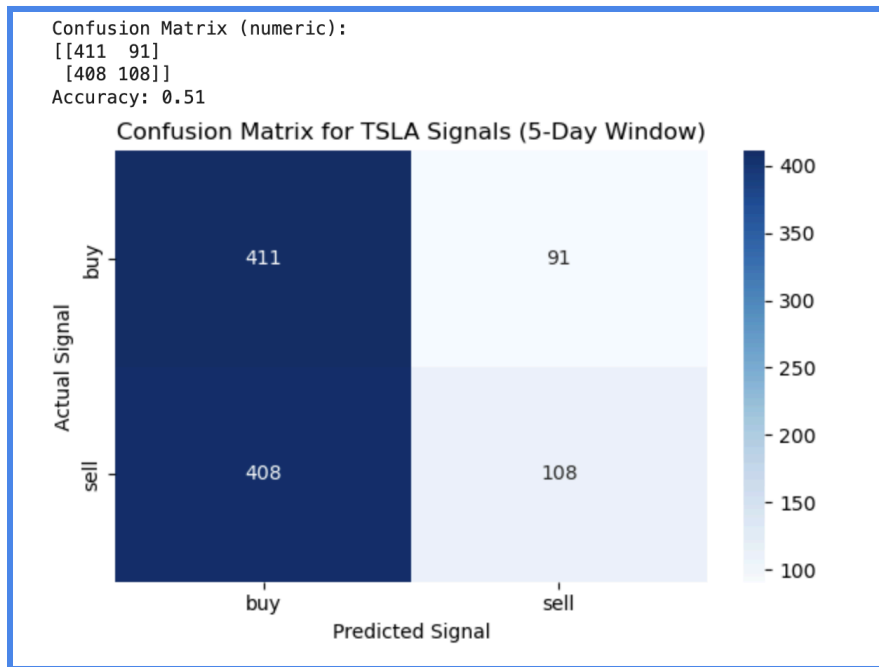## 4.1 NLP Model Results

Metrics Evaluated:
- **Accuracy:** Ensure sentiment score accuracy > 50% for TSLA, KO, and MSFT.
- **Confusion Matrix:** Analyze true vs. false predictions for sentiment classification.
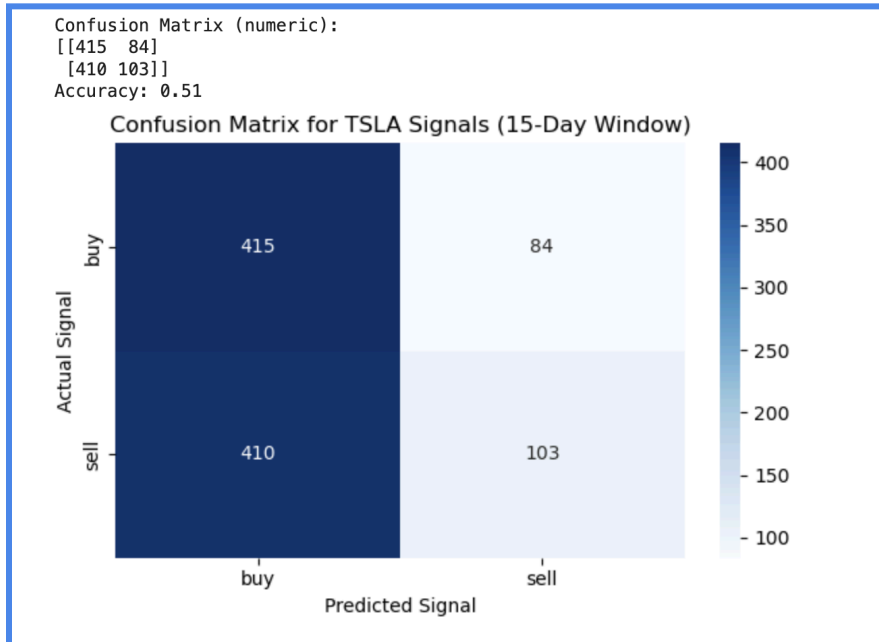
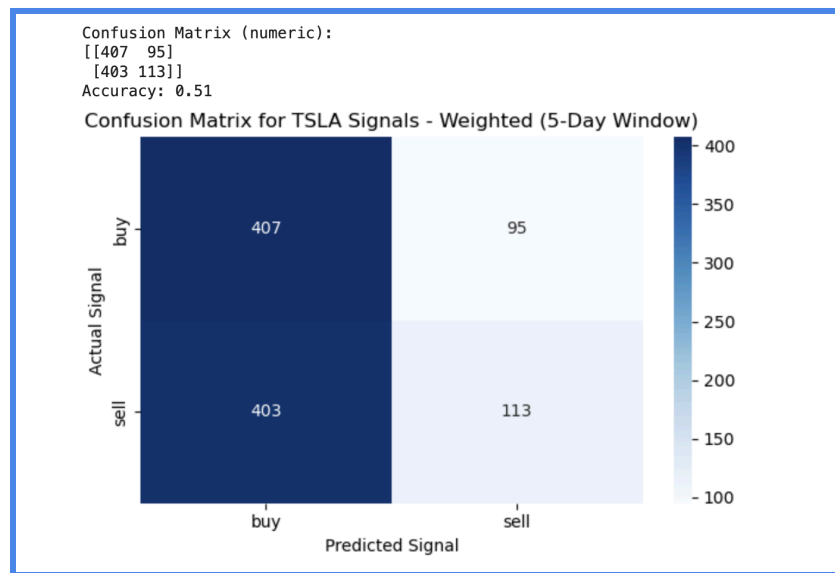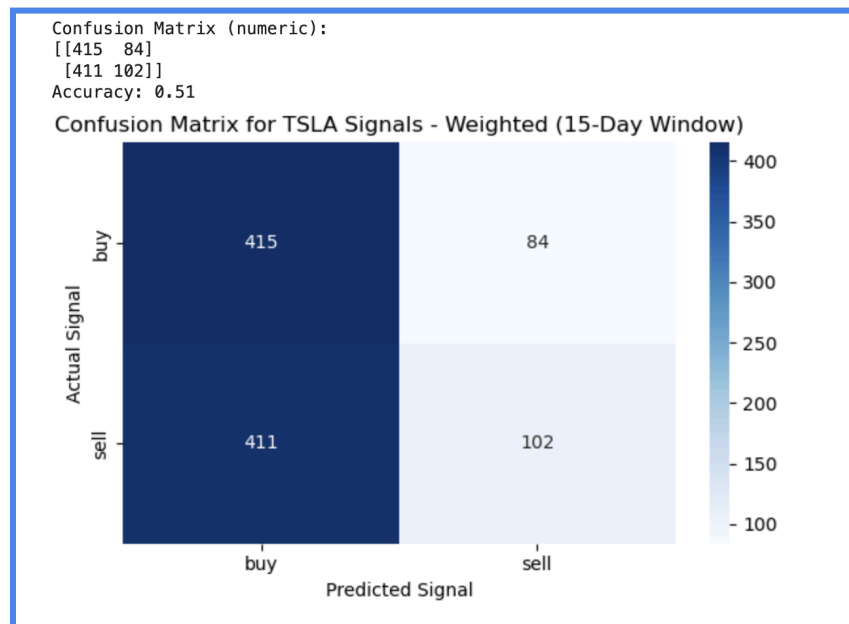### Tesla (TSLA)

1-Day Window Results:

## 5-Day Window Results:

```
Confusion Matrix (numeric):
[[411  91]
 [408 108]]
Accuracy: 0.51
```

Confusion Matrix for TSLA Signals (5-Day Window)

|  | buy | sell |
|---|---|---|
| **buy** | 411 | 91 |
| **sell** | 408 | 108 |

Actual Signal / Predicted Signal

## 15-Day Window Results:

```
Confusion Matrix (numeric):
[[415  84]
 [410 103]]
Accuracy: 0.51
```

Confusion Matrix for TSLA Signals (15-Day Window)

|  | buy | sell |
|---|---|---|
| **buy** | 415 | 84 |
| **sell** | 410 | 103 |

Actual Signal / Predicted Signal

## 5-Day-Weighted Window Results:



```
Confusion Matrix (numeric):
[[407  95]
 [403 113]]
Accuracy: 0.51
```

Confusion Matrix for TSLA Signals - Weighted (5-Day Window)

## 15-Day-Weighted Window Results:



```
Confusion Matrix (numeric):
[[415  84]
 [411 102]]
Accuracy: 0.51
```
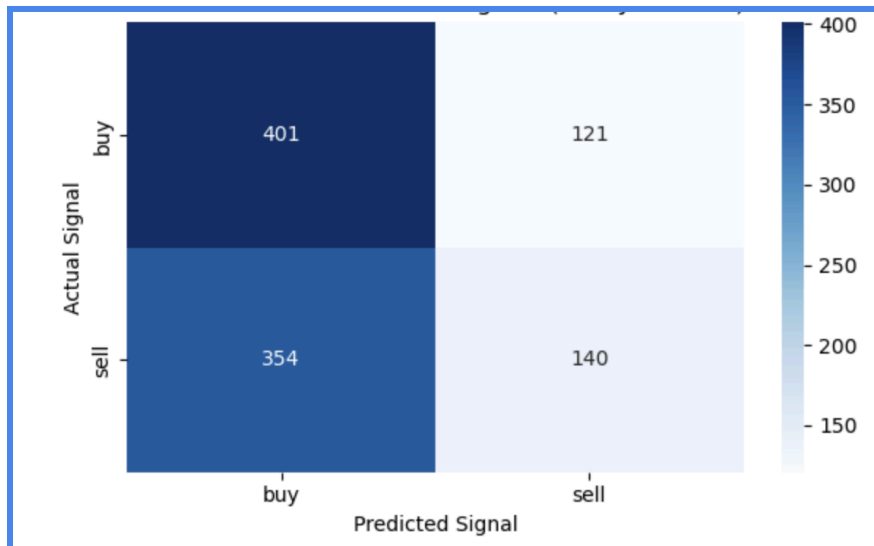
Confusion Matrix for TSLA Signals - Weighted (15-Day Window)

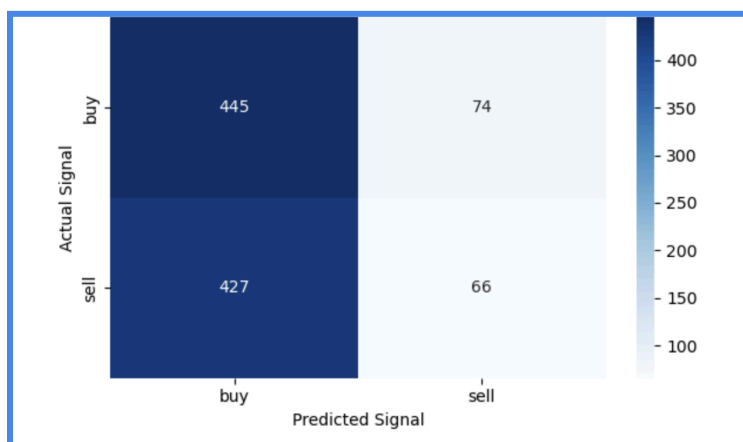# The Coca-Cola Company (KO)

## 1-Day Window Results:

```
Confusion Matrix (numeric):
[[401 121]
 [354 140]]
Accuracy: 0.53
```
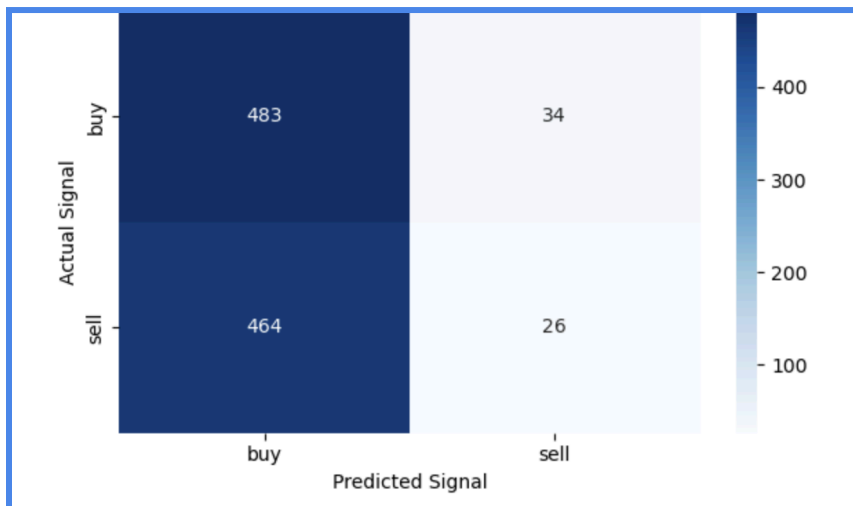


## 5-Day Window Results:

```
Confusion Matrix (numeric):
[[445  74]
 [427  66]]
Accuracy: 0.50
```
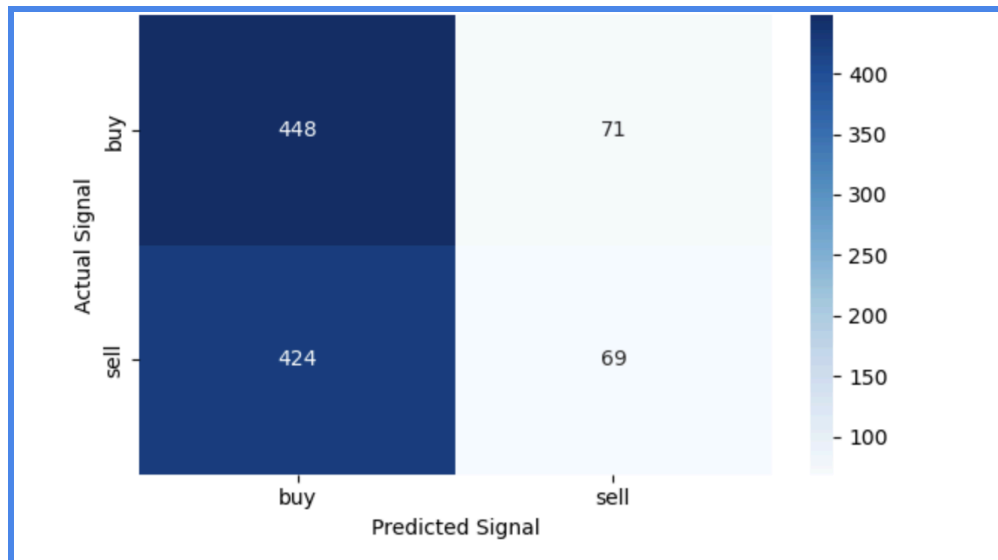
## 15-Day Window Results:

```
Confusion Matrix (numeric):
[[483  34]
 [464  26]]
Accuracy: 0.51
```
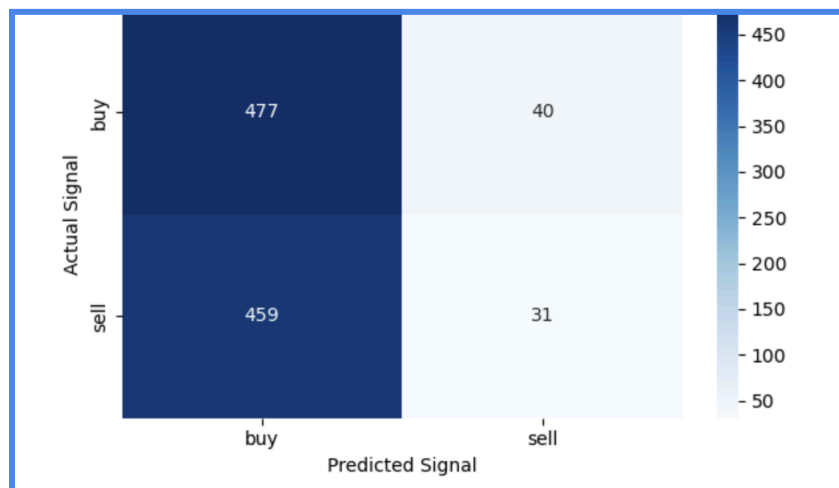


## 5-Day-Weighted Window Results:

```
Confusion Matrix (numeric):
[[448  71]
 [424  69]]
Accuracy: 0.51
```

15-Day-Weighted Window Results:

```
Confusion Matrix (numeric):
[[477  40]
 [459  31]]
Accuracy: 0.50
```
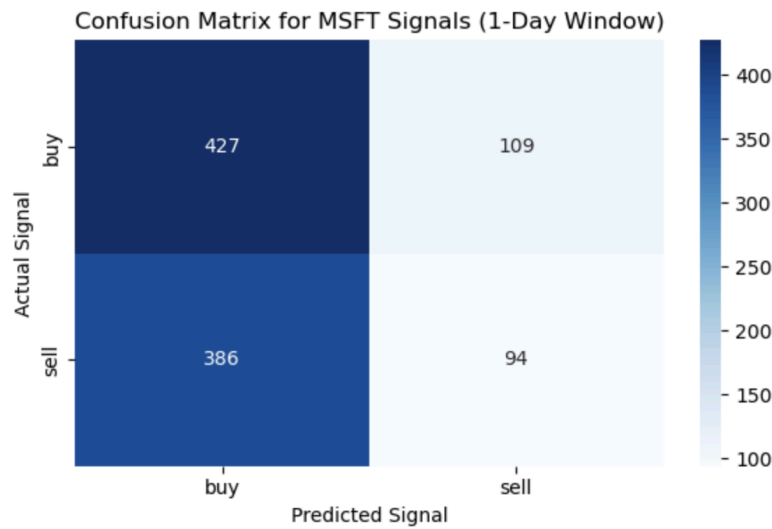


## Microsoft  (MSFT)

1-Day Window Results:

```
Confusion Matrix (numeric):
[[427 109]
 [386  94]]
Accuracy: 0.51
```

Confusion Matrix for MSFT Signals (1-Day Window)



## 5-Day Window Results:

```
Confusion Matrix (numeric):
[[463  72]
 [421  56]]
Accuracy: 0.51
```

Confusion Matrix for MSFT Signals (5-Day Window)

## 15-Day Window Results:

```
Confusion Matrix (numeric):
[[465  68]
 [416  58]]
Accuracy: 0.52
```

Confusion Matrix for MSFT Signals (15-Day Window)

| Actual Signal | buy | sell |
|---|---|---|
| buy | 465 | 68 |
| sell | 416 | 58 |

Predicted Signal

## 5-Day-Weighted Window Results:

```
Confusion Matrix (numeric):
[[460  75]
 [412  65]]
Accuracy: 0.52
```

Confusion Matrix for MSFT Signals - Weighted (5-Day Window)

| Actual Signal | buy | sell |
|---|---|---|
| buy | 460 | 75 |
| sell | 412 | 65 |

Predicted Signal

15-Day-Weighted Window Results:

```
Confusion Matrix (numeric):
[[466  67]
 [416  58]]
Accuracy: 0.52
```

Confusion Matrix for MSFT Signals - Weighted (15-Day Window)



# 4.2 Reinforcement Learning Model Results

Metrics Evaluated:
- **Actions & Rewards:** Overview of decision-making (buy, hold, sell) and corresponding rewards.
- **Cumulative Reward:** Overall performance of the trading strategy over time.
- Realized Profit:
  - TSLA: > $20 on one share
  - KO: Profit between -$10 and $20 on one share
  - MSFT: Profit between -$60 and $150 on one share

# Tesla (TSLA)

```
        Balance        Close
0   10000.000000   169.149994
1   10000.000000   168.539993
2   10000.000000   172.080002
3   10000.000000   167.979996
4    9997.200012   166.350006
5    9997.200012   166.520004
6    9997.200012   173.860001
7    9997.200012   176.889999
8    9997.200012   180.139999
9    9997.200012   188.869995
10   9997.200012   185.770004
11   9997.200012   182.899994
12  10004.780014   184.470001
13  10004.780014   193.169998
14  10004.780014   201.160004
```

TSLA RL Backtest (DQN) - Cumulative Reward
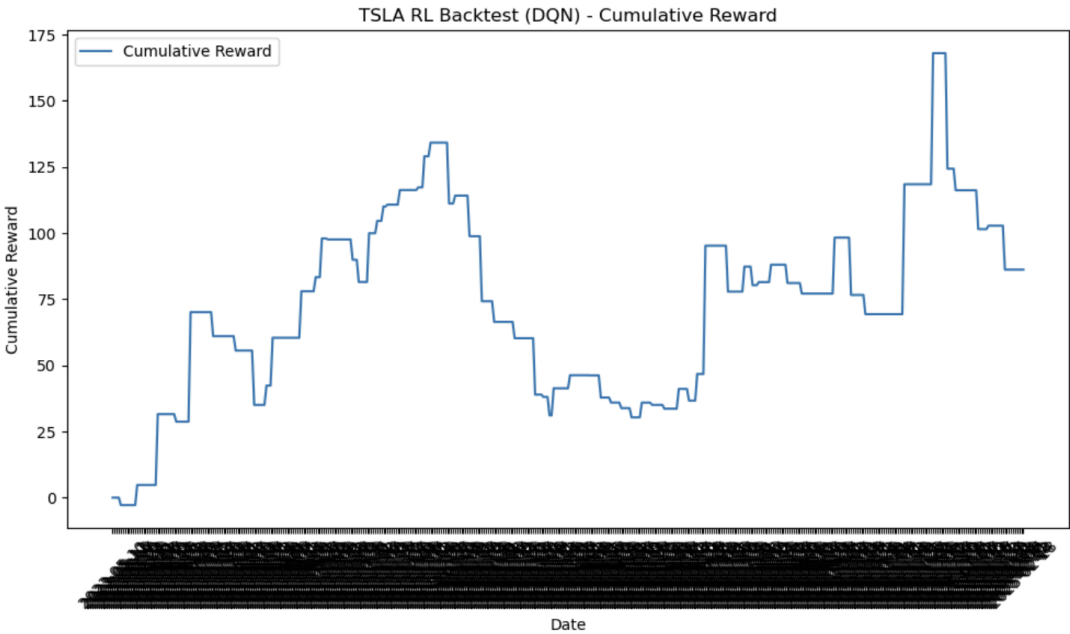


REALIZED PROFIT:
86.2000732421879

# The Coca-Cola Company (KO)

```
         Balance        Close
0    10000.000000    59.206909
1    10000.000000    59.391045
2    10000.000000    60.505028
3    10000.000000    60.725983
4    10000.000000    60.560272
5     9995.838673    56.343700
6     9995.838673    55.238914
7     9995.838673    56.141155
8     9995.838673    57.871979
9     9998.637444    58.939926
10    9998.637444    58.985958
11    9998.637444    59.197704
12    9998.637444    59.547562
13    9998.637444    58.350712
14    9998.637444    58.065308
```



KO RL Backtest (DQN) - Cumulative Reward
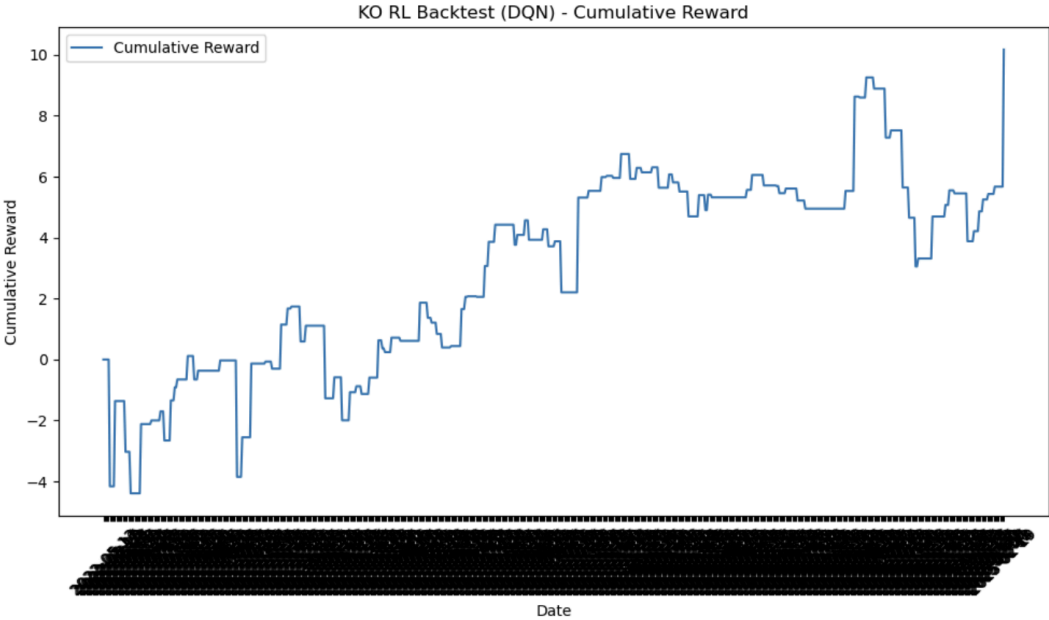
```
REALIZED PROFIT:
10.172584533691378
```

# Microsoft (MSFT)

```
        Balance        Close
0   10000.000000   280.634430
1   10000.000000   288.630585
2   10000.000000   291.675323
3   10000.000000   299.866119
4   10000.000000   302.512085
5   10000.000000   300.352478
6   10000.000000   304.924438
7   10001.371674   293.046997
8   10001.371674   297.609253
9   10001.371674   292.755157
10  10001.371674   296.266846
11  10001.371674   302.735718
12   9999.251068   294.146240
13   9999.251068   287.006073
14   9999.251068   286.967194
```

**MSFT RL Backtest (DQN) - Cumulative Reward**
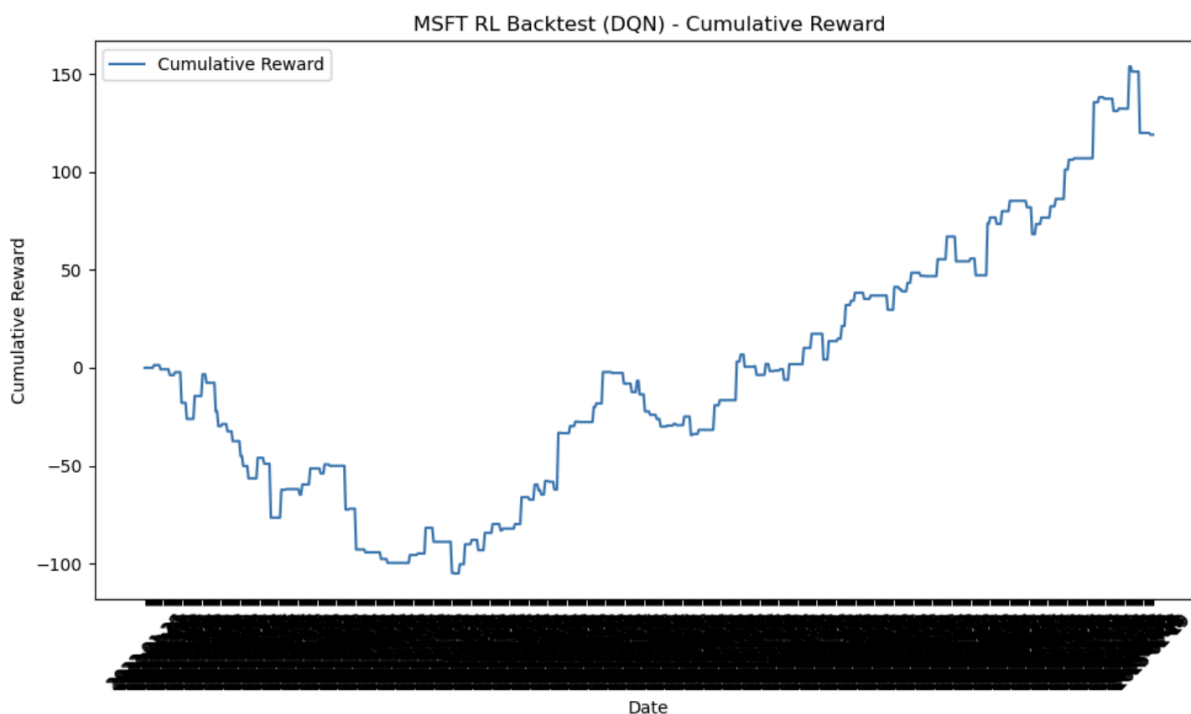


REALIZED PROFIT:
119.2009429931638

# 5. Discussion and Analysis

## 5.1 NLP Model vs. Reinforcement Learning Model

To evaluate the effectiveness of our trading model, we compared the performance of the NLP model and the Reinforcement Learning (RL) model based on accuracy and profitability. Each model was tested on TSLA (high volatility), KO (low volatility), and MSFT (medium volatility) over the backtesting period from January 3, 2022, to February 19, 2025.

| Model | Strengths | Weaknesses |
|-------|-----------|------------|
| **NLP Model** | Provides sentiment insights, and enhances predictive power. | Limited direct trading decisions, low accuracy, positively biased. |
| **RL Model** | Adapts dynamically and ensures profit optimization | Requires extensive training, may struggle in unpredictable market shifts |

## 5.2 NLP Accuracy Analysis

The NLP model's primary metric is sentiment score accuracy, ensuring it exceeds the 50% threshold. Looking at the NLP Model's results, we can see that our accuracy target has been reached. All three stocks tested (TSLA, KO, MSFT) with the NLP model outputted a 50% or higher accuracy, whether on a 1-day, 5-day, or 15-day window. This signifies that on any signal given by the NLP, our model will correctly decide to buy or sell at least 50% of the time. This level of accuracy provides an initial foundation for integrating sentiment analysis into our Reinforcement Learning Model, especially for high-volatility stocks where sentiment-driven price changes are significant.

## 5.3 Reinforcement Learning Realized Profit Analysis

Examining the performance of our Reinforcement Learning Model, we can confidently state that it performed exceptionally well. The cumulative realized profit across all tracked stocks totaled approximately $215. Breaking this down by stock:

- Tesla (TSLA): Generated a realized profit of $86.
- Coca-Cola (KO): Produced a realized profit of $10.
- Microsoft (MSFT): Achieved a realized profit of $119.

This confirms that the RL model met the expected profit criteria for each stock, proving its ability to make solid trading decisions. It handled different market conditions impressively—Tesla's high volatility led to big gains, Coca-Cola's lower volatility brought steady but smaller profits, and Microsoft, with its medium volatility, delivered solid returns. Overall, the RL strategy showed strong adaptability and efficiency.

## 5.4 Overall Percentage Gains

To assess the performance of our model in relation to the initial investment, we looked at the prices of Tesla, Coca-Cola, and Microsoft on January 3rd 2022. Assuming we initially bought one share of each stock, we calculated the percentage gain generated by our model with respect to this initial investment.

- **Tesla (TSLA):** On January 3rd, 2022, Tesla's closing price was $399.93. With a realized profit of $86, the percentage gain on Tesla is **21.53%**
- **Coca-Cola (KO):** On January 3rd, 2022, Coca-Cola's price was around $59.30. With a realized profit of $10, the percentage gain on Coca-Cola is **16.85%**
- **Microsoft (MSFT):** On January 3rd, 2022, Microsoft's closing price was $334.75. With a realized profit of $119, the percentage gain on Microsoft is **35.55%**

The total initial investment for one share of each stock was:
$399.93 (Tesla) + $59.30 (Coca-Cola) + $334.75 (Microsoft) = $793.98

The total realized profit across all three stocks is $215, so the overall percentage gain across all three stocks is approximately **27.1%** (very good).

## 5.5 Conclusion

In conclusion, both the NLP and Reinforcement Learning (RL) models have demonstrated valuable strengths and applications in stock trading. The NLP model is particularly effective at providing sentiment insights, which is crucial for high-volatility stocks like Tesla, where market sentiment plays a significant role in price movements. Its accuracy, consistently above 50%, shows that sentiment analysis could be a reliable tool for decision-making in trading. However, we are not necessarily satisfied with this metric and will experiment with other NLP models, such as OpenAI's API instead of solely relying on FinBERT, which has shown to be positively biased.

On the other hand, the RL model has shown remarkable profitability, with a total realized gain of **27.1%** across Tesla, Coca-Cola, and Microsoft. This performance surpasses the average hedge fund returns for the same period, emphasizing the RL model's ability to generate substantial returns and its adaptability to varying market conditions. While the RL model requires extensive training and may face challenges during unpredictable market shifts, its ability to adjust to different volatilities and optimize profits makes it an effective tool for long-term investment strategies. Also, this model is still a work in progress as the environment does not dynamically change the amount of shares it works with and it does not take short positions.

Together, these models provide complementary advantages. The NLP model offers valuable sentiment-driven insights, while the RL model optimizes trading decisions and profitability. Both models will play a crucial role in the development of our sophisticated trading platform that will adapt to diverse market environments and deliver strong returns.