



UNDERGRADUATE THESIS

PTBA STOCK PRICE PREDICTION USING BIDIRECTIONAL LONG SHORT-TERM MEMORY WITH WHALE OPTIMIZATION ALGORITHM

PRAMUDYA REKSHA KUMALA
NPM 22081010186

THESIS ADVISORS

Dr. Eng. Ir. Anggraini Puspita Sari, ST., MT.
Afina Lina Nurlaili, S.Kom., M.Kom.

**MINISTRY OF HIGHER EDUCATION, SCIENCE, AND TECHNOLOGY
UNIVERSITAS PEMBANGUNAN NASIONAL VETERAN JAWA TIMUR
FACULTY OF COMPUTER SCIENCE
INFORMATICS STUDY PROGRAM
SURABAYA
2026**

APPROVAL SHEET

PTBA STOCK PRICE PREDICTION USING BIDIRECTIONAL LONG SHORT-TERM MEMORY WITH WHALE OPTIMIZATION ALGORITHM

By:

PRAMUDYA REKSHA KUMALA

NPM. 22081010186

Has been defended before, and accepted by, the Board of Assessors of the Thesis Examination of the Informatics Study Program, Faculty of Computer Science, Universitas Pembangunan Nasional Veteran Jawa Timur, on July 19, 2026:

Approved,

Dr. Eng. Ir. Anggraini Puspita Sari, ST., MT (Advisor I)
NPT. 222198 60 816400

Afina Lina Nurlaili, S.Kom., M.Kom. (Advisor II)
NIP. 1993121 3202203 2 010

Dr. Intan Yuniar Purbasari, S.Kom. MSc. (Head Assessor)
NIP. 19800602 202521 2 029

Budi Mukhamad Mulyo, S.Kom., M.T. (Assessor I)
NIP. 19891118 202406 1 003

Acknowledge by,

Dean of the Faculty of Computer Science


Prof. Dr. Ir. Novirina Hendrasarie, MT.
NIP. 19681126 199403 2 001

APPROVAL SHEET

PTBA STOCK PRICE PREDICTION USING BIDIRECTIONAL LONG SHORT-TERM MEMORY WITH WHALE OPTIMIZATION ALGORITHM

By:
PRAMUDYA REKSHA KUMALA
NPM. 22081010186

Approved to proceed to the Thesis Examination

Approved by,
Coordinator of Informatics Study Program
Faculty of Computer Science



Dr. Intan Yuniar Purbasari, S.Kom. MSc.

NIP. 19800602 202521 2 029

STATEMENT OF ORIGINALITY

I am the undersigned:

Student Name	: Pramudya Reksha Kumala
NPM	: 22081010186
Degree Program	: Bachelor (S1)
Study Program	: Informatics
Faculty	: Faculty of Computer Science

Hereby declares that this undergraduate thesis contains no part of any other scientific work that has been submitted to obtain an academic degree at any higher education institution. Furthermore, it does not contain any work or opinions previously written or published by others, except for those which are explicitly cited in this thesis and listed completely in references.

And I declare that this scientific document is free from elements of plagiarism. If in the future indications of plagiarism are found in this Thesis, I am willing to accept sanctions in accordance with the applicable laws and regulations.

Thus, I made this statement without any coercion from anyone and to be used as it should.



Surabaya, July 19, 2026
Declarant,



PRAMUDYA REKSHA KUMALA
NPM. 22081010186

ABSTRACT

Student Name/NPM : Pramudya Reksha Kumala / 22081010186
Thesis Title : PTBA STOCK PRICE PREDICTION USING
BIDIRECTIONAL LONG SHORT-TERM
MEMORY WITH WHALE OPTIMIZATION
ALGORITHM
Supervisor : 1. Dr. Eng. Ir. Anggraini Puspita Sari, ST., MT.
2. Afina Lina Nurlaili, S.Kom., M.Kom.

The stock price of PT Bukit Asam Tbk (PTBA) fluctuates due to global coal price movements and macroeconomic conditions, requiring an accurate prediction method to support investment decisions. Since PTBA's historical stock price data is a time series, a Bidirectional Long Short-Term Memory (BiLSTM) architecture was employed to capture its movement patterns. However, BiLSTM's performance is highly dependent on proper hyperparameter selection. Therefore, this study applies the Whale Optimization Algorithm (WOA) to search for the best hyperparameter combination, namely learning rate, hidden units, and dropout rate, using validation RMSE as the fitness function. The study uses 10 years of daily PTBA historical data (2016–2026), totaling 2,417 records obtained from Investing.com, using the Price, High, and Low features with an 80:10:10 data split ratio. The test results show that the BiLSTM model with a window size of 15, 2 hidden layers, and WOA with a population of 20 individuals and 40 iterations achieved an MAE of 29.59, RMSE of 49.72, and MAPE of 1.17%. These results outperform the LSTM model (MAPE 1.58%) and BiLSTM without optimization (MAPE 1.31%). These findings prove that WOA optimization significantly improves BiLSTM's prediction accuracy in forecasting PTBA stock prices.

Keywords : Stock price prediction, PTBA, BiLSTM, Whale Optimization Algorithm, Time Series

ACKNOWLEDGEMENTS

All praise and gratitude be to Allah SWT, the lord of the worlds, for His countless blessings, guidance, and mercy, which have enabled the author to complete this undergraduated thesis **“PTBA Stock Price Prediction Using Bidirectional Long Short-Term Memory with Whale Optimization Algorithm”**. May peace and blessings upon our Prophet Muhammad SAW, his family, his companions, and all those who follow his teaching until the end of time.

Through the pages of this undergraduated thesis, the author would like to express gratitude for the support, guidance, and motivation provided by various parties throughout the process of writing this thesis, which enabled the author to successfully complete it. Therefore, on this occasion, the author would like to express gratitude to:

1. Prof. Dr. Ir. Novirina Hendrasarie, M.T., as the Dean of the Faculty of Computer Science, Universitas Pembangunan Nasional "Veteran" Jawa Timur.
2. Dr. Intan Yuniar Purbasari, S.Kom., MSc., as the Head of the Informatics Study Program, Faculty of Computer Science, Universitas Pembangunan Nasional "Veteran" Jawa Timur.
3. Dr. Eng. Ir. Anggraini Puspita Sari, ST., MT., as the First Advisor, who tirelessly provided guidance, constructive feedback, and continuous motivation to the writer throughout the process of completing this thesis, enabling its successful completion.
4. Afina Lina Nurlaili, S.Kom., M.Kom., as the Second Advisor, who guided the writer with great care, offered meaningful feedback, and continually ensured a smooth and manageable process throughout the completion of this thesis.
5. Dr. Intan Yuniar Purbasari, S.Kom., MSc., as the Head Assessor, for the constructive criticism and valuable feedback provided on this research, which helped the writer refine and improve this thesis.
6. Budi Mukhamad Mulyo, S.Kom., M.T., as an Assessor, for the thorough and meticulous corrections and feedback provided, which helped the writer perfect this thesis to a higher standard.

7. All Lecturers and Staff of the Informatics Study Program, Faculty of Computer Science, Universitas Pembangunan Nasional "Veteran" Jawa Timur, for the knowledge, guidance, and services provided throughout the author's academic journey.
8. The author's beloved mother, for her endless prayers, love, and countless sacrifices. And to the author's late father, who raised and guided the author with unconditional love; may Allah SWT bless him and grant him a place among the righteous. The author would also like to thank his grandmother and aunt for their constant prayers, care, and support throughout this journey.
9. Shandy Ilham and Arman Adrian, the author's closest friends since the very beginning of this journey. Thank you for always accompanying and helping the author through both good times and difficult ones, and for constantly being there even during the author's lowest points. Your companionship and unwavering support have meant more to the author than words can express throughout the completion of this thesis.
10. Gamar Ramadhani, Alief Listanto, Achmad Yusuf, Rafie Najwan, Rangga Agni, and Reyhan Fisena, the author's college friends who have accompanied the author since the very beginning of university life. Their presence has had a significant impact on the author throughout the college years, from countless shared activities to joyful moments that always managed to ease the burden amid the busyness of student life. May Allah SWT continuously grant ease and success to all of you, and may we all achieve success together in the future.
11. To all members of PlayerMusiman, especially Dian Lestari, Febiana Putri, Nindi Wulandari, Prasetyo Wicaksono, Agus Suryanto, Danaiswara, Abi Reo, Ayu Pitaloka, and Muhib Cendekia, well as the other members who cannot be mentioned individually, thank you for the companionship, support, and joy you have given the author. The author is also grateful for the motivation, feedback, and life lessons continuously given, which have helped the author to keep growing into a better person.
12. Lastly, the author would like to express gratitude to herself/himself, for having fought, endured, and never given up throughout every stage of writing this thesis, through moments of joy and hardship, fatigue and exhaustion that came

one after another. Thank you for remaining strong in facing every challenge, for continuing to try despite moments of doubt and weariness, and for never truly stopping despite the many obstacles encountered. This thesis is not merely a graduation requirement, but also tangible proof of the author's hard work, patience, and perseverance throughout the entire process. Thank you for holding on until finally reaching this point, and may this achievement be a good beginning for the steps ahead.

The author fully realizes that this thesis remains imperfect and inevitably carries certain limitations. In light of this, constructive criticism and suggestions from all parties are warmly welcomed to support its continued improvement. Despite these shortcomings, the author sincerely hopes that this thesis will bring meaningful benefit, both to its readers in general and to the author in particular.

Surabaya, July 19th 2026

A handwritten signature in black ink, consisting of a large, stylized capital 'P' followed by several fluid, connected strokes that trail off to the right.

Pramudya Reksha Kumala

TABLE OF CONTENTS

APPROVAL SHEET	i
APPROVAL SHEET	iii
STATEMENT OF ORIGINALITY	v
ABSTRACT	vii
ACKNOWLEDGEMENTS.....	ix
TABLE OF CONTENTS.....	xiii
LIST OF FIGURES	xvii
LIST OF TABLES	xxi
CHAPTER I INTRODUCTION.....	1
1.1 Background	1
1.2 Problem Formulation	3
1.3 Research Objectives	4
1.4 Research Benefits.....	4
1.4.1 Theoretical Benefits	4
1.4.2 Practical Benefits.....	4
1.5 Problem Limitations.....	5
CHAPTER II LITERATURE REVIEW.....	7
2.1 Previous Research	7
2.2 Stock.....	10
2.3 Stock Volatility	11
2.4 Prediction	12
2.5 Time Series.....	13
2.6 Min-Max Scaling	13
2.7 Recurrent Neural Network (RNN).....	15
2.8 Long Short-Term Memory (LSTM).....	16
2.8.1 Forget Gate.....	18
2.8.2 Input Gate.....	18
2.8.3 Candidate State.....	19
2.8.4 Cell State Update.....	19
2.8.5 Output Gate	20
2.8.6 Hidden State	21

2.9 Bidirectional Long Short-Term Memory (BiLSTM).....	21
2.10 Whale Optimization Algorithm (WOA)	23
2.10.1 Encircling Prey	24
2.10.2 Bubble-net Attacking Method (Exploitation Phase)	25
2.10.3 Search for Prey (Exploration Phase)	26
2.10.4 Exploration and Exploitation Mechanism.....	27
2.10.5 Implementation of WOA in Research.....	27
2.11 Evaluation Metrics	28
2.11.1 Mean Absolute Error (MAE)	28
2.11.2 Root Mean Squared Error (RMSE).....	29
2.11.3 Mean Absolute Percentage Error (MAPE).....	29
CHAPTER III RESEARCH METHODOLOGY	31
3.1 Needs Analysis.....	31
3.2 Data Collection.....	33
3.3 Data Pre-processing	34
3.3.1 Data Sorting.....	34
3.3.2 Data Cleansing and Conversion	35
3.3.3 Data Partition.....	36
3.3.4 Data Normalization	37
3.3.5 Sequential Formation	40
3.4 Model Design	41
3.4.1 BiLSTM Model Architecture	41
3.4.2 Hyperparameter Search Space	42
3.4.3 WOA-BiLSTM Integration Design.....	44
3.5 Model Training.....	45
3.5.1 BiLSTM Model Training with WOA Optimization	45
3.5.2 Training of BiLSTM models with Optimal Hyperparameters	50
3.6 Model Accuracy Measurement	55
3.6.1 Denormalization	55
3.6.2 Evaluation Metrics Value.....	56
3.6.3 Plotting Results	58
3.7 Testing Scenarios	59

3.8 Interface Design	63
CHAPTER IV RESULTS AND DISCUSSION	67
4.1 Data Collection.....	67
4.2 Data Pre-processing	68
4.2.1 Data Sequencing.....	68
4.2.2 Data Cleansing & Conversion.....	70
4.2.3 Data Partition.....	71
4.2.4 Data Normalization	74
4.2.5 Sequential Formation	77
4.3 Implementation of the BiLSTM Model	80
4.3.1 BiLSTM Architecture	80
4.4 Hyperparameter Optimization with WOA	82
4.4.1 Hyperparameter Search Space	82
4.4.2 Fitness Function	82
4.5 WOA-BiLSTM Model Training	86
4.6 Testing Scenarios	88
4.6.1 Feature Testing.....	88
4.6.2 Dataset Ratio Testing	100
4.6.3 Window Size Testing	112
4.6.4 Hidden Layer Number Testing.....	125
4.6.5 WOA Population Testing.....	136
4.6.6 WOA Iteration Testing.....	148
4.7 Model Evaluation	160
4.7.1 Model LSTM.....	160
4.7.2 Model BiLSTM.....	161
4.7.3 Recapitulation of Model Evaluation Results.....	162
4.8 Website Interface Implementation	163
CHAPTER V CONCLUSION	171
5.1 Conclusion.....	171
5.2 Suggestions	172
BIBLIOGRAPHY	175
APPENDIX.....	181

LIST OF FIGURES

Figure 2.1 RNN Architecture	15
Figure 2.2 LSTM Architecture.....	17
Figure 2.3 BiLSTM Architecture	22
Figure 2.4 Mechanism Bubble-net Feeding	23
Figure 3.1 Flow of research stages.....	31
Figure 3.2 Pre-Processing Stage Flow	34
Figure 3.3 BiLSTM Model Architecture	42
Figure 3.4 WOA-BiLSTM Integration Design Flow	45
Figure 3.5 Plotting Predicted and actual results.....	59
Figure 3.6 Interface Design Website.....	64
Figure 4.1 Daily Historical Data Snippets	68
Figure 4.2 Snapshot of Stock Daily Data After Sorting	69
Figure 4.3 Data Snippets Before Cleaning and Conversion	71
Figure 4.4 Data Snippets After Cleanup and Conversion	71
Figure 4.5 Dataset Distribution Details.....	73
Figure 4.6 Data Partition Distribution.....	74
Figure 4.7 Data Snippet Before Normalization.....	76
Figure 4.8 Data Snippet After Normalization	76
Figure 4.9 Comparison of Data Distribution Before and After Normalization	77
Figure 4.10 Results of sequential data formation.....	78
Figure 4.11 Sequence Data Visualization	79
Figure 4.12 BiLSTM Model Architecture	81
Figure 4.13 WOA Convergence Curve and Loss Model Training	88
Figure 4.14 WOA Convergence Curve 1 Features	89
Figure 4.15 WOA Optimization Results 1 Feature.....	90
Figure 4.16 Curve Loss Model 1 Training Features	90
Figure 4.17 Actual Price Comparison and Prediction 1 Feature.....	91
Figure 4.18 Evaluation Metrics 1 Features	92
Figure 4.19 WOA 3 Feature Convergence Curve.....	92
Figure 4.20 WOA Optimization Results 3 Features	93

Figure 4.21 Curve Loss Model 3 Training Features	93
Figure 4.22 Actual Price Comparison and 3 Features Prediction	94
Figure 4.23 Evaluation Metrics 3 Features	95
Figure 4.24 WOA Convergence Curve 5 Features	96
Figure 4.25 WOA Optimization Results 5 Features	96
Figure 4.26 Curve Loss Model 5 Training Features	97
Figure 4.27 Actual Price Comparison and 5 Features Prediction	98
Figure 4.28 5 Feature Evaluation Metrics.....	99
Figure 4.29 Convergence WOA 60:20:20	101
Figure 4.30 WOA Optimization Results 60:20:20.....	101
Figure 4.31 Curve Loss Model Training 60:20:20.....	102
Figure 4.32 Actual Price Comparison and Prediction 60:20:20	103
Figure 4.33 Evaluation Metrics 60:20:20.....	104
Figure 4.34 Convergence WOA 70:15:15	104
Figure 4.35 WOA Optimization Results 70:15:15.....	105
Figure 4.36 Curve Loss Model Training 70:15:15.....	106
Figure 4.37 Actual Price Comparison and Prediction 70:15:15	107
Figure 4.38 Evaluation Metrics 70:15:15.....	107
Figure 4.39 Convergence WOA 80:10:10	108
Figure 4.40 WOA 80:10:10 Optimization Results.....	109
Figure 4.41 Curve Loss Model Training 80:10:10.....	109
Figure 4.42 Actual Price Comparison and Prediction 80:10:10	110
Figure 4.43 Evaluation Metrics 80:10:10.....	111
Figure 4.44 Kurva Convergence WOA 15 Window size.....	113
Figure 4.45 WOA 15 Optimization Results Window size.....	114
Figure 4.46 Curve Loss Model 15 Training Window size.....	114
Figure 4.47 Actual Price Comparison and Prediction 15 Window size.....	115
Figure 4.48 Evaluation Metrics 15 Window size.....	116
Figure 4.49 Convergence WOA 30 Window size.....	117
Figure 4.50 WOA 30 Optimization Results Window size.....	117
Figure 4.51 Curve Loss Model 30 Training Window size.....	118
Figure 4.52 Actual Price Comparison and Prediction 30 Window size.....	119

Figure 4.53 Evaluation Metrics 30 Window size.....	120
Figure 4.54 Kurva Convergence WOA 60 Window size.....	121
Figure 4.55 WOA 60 Optimization Results Window size.....	121
Figure 4.56 Curve Loss Model 60 Training Window size.....	122
Figure 4.57 Comparison of Actual Prices and Predictions 60 Window size	123
Figure 4.58 Evaluation Metrics 60 Window size.....	123
Figure 4.59 Convergence WOA 2 Hidden Layer.....	125
Figure 4.60 WOA 2 Optimization Results Hidden Layer.....	126
Figure 4.61 Fuck Loss Training Model 2 Hidden Layer	126
Figure 4.62 Actual Price Comparison and Prediction 2 Hidden Layer.....	127
Figure 4.63 Evaluation Metrics 2 Hidden Layer.....	128
Figure 4.64 Convergence WOA 3 Hidden Layer.....	129
Figure 4.65 WOA Optimization Results 3 Hidden Layer.....	129
Figure 4.66 Curve Loss Model 3 Hidden Training Layer.....	130
Figure 4.67 Actual Price Comparison and Prediction 3 Hidden Layer.....	131
Figure 4.68 Evaluation Metrics 3 Hidden Layer.....	132
Figure 4.69 Convergence WOA 4 Hidden Layer.....	132
Figure 4.70 WOA Optimization Results 4 Hidden Layer.....	133
Figure 4.71 Curve Loss Model 4 Hidden Training Layer.....	134
Figure 4.72 Actual Price Comparison and Prediction 4 Hidden Layer.....	134
Figure 4.73 Evaluation Metrics 4 Hidden layer	135
Figure 4.74 WOA Convergence Curve of 20 Population	137
Figure 4.75 WOA Optimization Results 20 Population	138
Figure 4.76 Curve Loss 20 Population Model Training	138
Figure 4.77 Comparison of Actual Prices and Predictions of 20 Populations	139
Figure 4.78 Evaluation Metrics 20 Population	140
Figure 4.79 WOA Convergence Curve of 25 Population	140
Figure 4.80 WOA Optimization Results 25 Population	141
Figure 4.81 Curve Loss 25 Population Model Training	142
Figure 4.82 Actual Price Comparison and Prediction of 25 Populations	143
Figure 4.83 Population Evaluation Metrics	143
Figure 4.84 WOA Convergence Curve 30 Population.....	144

Figure 4.85 WOA Optimization Results 30 Population	145
Figure 4.86 Curve Loss Model 30 Population Training	145
Figure 4.87 Actual Price Comparison and Prediction of 30 Population	146
Figure 4.88 Evaluation Metrics of 30 Population	147
Figure 4.89 WOA 30 Iterations Convergence Curve.....	149
Figure 4.90 WOA 30 Iteration Optimization Results	150
Figure 4.91 Curve Loss Model 30 Iteration Training	150
Figure 4.92 Actual Price Comparison and Prediction 30 Iterations.....	151
Figure 4.93 30 iteration evaluation metrics	152
Figure 4.94 WOA 40 Iteration Convergence Curve	153
Figure 4.95 WOA 40 Iteration Optimization Results	153
Figure 4.96 Curve Loss 40 Iteration Model Training	154
Figure 4.97 Actual Price Comparison and Prediction 40 Iterations.....	155
Figure 4.98 Evaluation Metrics 40 Iterations.....	155
Figure 4.99 WOA 50 Iteration Convergence Curve	156
Figure 4.100 WOA 50 Iteration Optimization Results	157
Figure 4.101 Curve Loss Model 50 Iteration Training	157
Figure 4.102 Actual Price Comparison and 50 Iterations Prediction.....	158
Figure 4.103 50 Iteration Evaluation Metrics	159
Figure 4.104 LSTM Evaluation Metrics	161
Figure 4.105 BiLSTM Evaluation Metrics	162
Figure 4.106 Dashboard Website	167
Figure 4. 107 Detailed Table of Actual Price Comparison and Prediction.....	168
Figure 4.108 Model Info Page	168
Figure 4.109 Specification Layer Models.....	169

LIST OF TABLES

Table 3.1 Hardware List.....	32
Table 3.2 Software List.....	33
Table 3.3 PTBA Stock Price	33
Table 3.4 PTBA Stock Price After Sorting.....	34
Table 3.5 Data Cleanup and Conversion Results.....	36
Table 3.6 Data Ratio Scenario Table	37
Table 3.7 Stock Price Data Before Normalization.....	38
Table 3.8 Stock Price Data After Normalization	39
Table 3.9 PTBA Stock Price Sequential Data.....	40
Table 3.10 Search Space Hyperparameter by WOA.....	43
Table 3.11 Examples of Population Initialization and Evaluation Fitness	46
Table 3.12 Development of the Best Solutions by Eteration	49
Table 3.13 Example of Model Prediction Results	54
Table 3.14 Example of Model Prediction Has Been Denormalized	56
Table 3.15 Prediction and Actual Price Comparison.....	57
Table 3.16 Testing Scenarios	59
Table 4.1 Feature Scenario Testing Comparison Results	99
Table 4.2 Dataset Ratio Scenario Test Results	112
Table 4.3 Scenario Testing Comparison Results Window size	124
Table 4.4 Hidden Test Comparison Results Layer	136
Table 4.5 Comparative Results of WOA Population Scenario Testing	148
Table 4.6 Comparative Results of WOA Iteration Scenario Testing.....	160
Table 4.7 Model Comparison.....	162