

CHAPTER I

INTRODUCTION

1.1. Background

The waters of the Bali Strait are one of the strategic sea transportation routes that play an important role in supporting connectivity between regions and become the main lifeblood for the tourism sector and the national economy. In Indonesia, passenger mobility and logistics distribution across these waters has shown a significant increase in intensity in recent years. Based on data from the Central Statistics Agency (BPS), in 2025 crossing activities in the Bali Strait will be recorded to reach a very massive level of density with a total movement of more than 85 thousand ship trips and serving up to 9.2 million passengers per year. However, the distribution of the annual volume is uneven and often experiences a very extreme surge in operating expenses at certain momentum. In the peak period in April 2025, for example, the frequency of shipping in these waters was recorded to shoot sharply to exceed 13 thousand ship trips, with a volume of more than 1.7 million passengers in just one month [1]. This fact emphasizes the condition of the Bali Strait which has to endure very dense traffic concentration and constant movement of fleets in relatively narrow waters.

The traffic density in the narrow water space is a very crucial operational challenge when faced with the fluctuating and complex conditions of the Bali Strait. The funnel-like topography of the strait's waters not only limits the maneuverability of the fleet, but also triggers very strong and unpredictable movements of sea surface currents. This condition poses a persistent operational threat in the field, especially when the ferry is about to dock [2] at the dock. Based on research by Dewi et al. (2024), ships that enter the docking phase will move at very low speeds, so that the stability of their bow is very vulnerable to being pushed off the trajectory by the impact of cross-sea currents. This disturbance of current thrust often forces the skipper to cancel the landing maneuver and perform a return [3]. The inability to anticipate the dynamics of sea currents directly triggers an increase in the duration of maneuvers which leads to delays in operational schedules or delays [4]. Furthermore, in extreme current conditions, port authorities are often forced to take a policy of temporary closure of shipping lanes to avoid maritime navigation incidents.

The high level of difficulty in anticipating these conditions is basically rooted in the oceanographic characteristics of the Bali Strait which are very unique and complex. Geographically, these waters have a topography that resembles a narrow gap (choke point) that connects the waters of the Bali Sea on the north side with the waters of the Indian Ocean on the south side. This pinched position makes the Bali Strait one of the crossing routes for the flow of flows across Indonesia (Arlindo). When a mass of water in massive volume is pushed through this narrow gap, the speed of the current will naturally undergo significant amplification. Furthermore, the pattern of water movement in this region is the result of the interaction of various dynamic natural forces. The seasonally changing monsoon wind gusts provide pressure variability at sea level [5], while tidal cycles account for very massive daily oscillation fluctuations, [1]. This complex combination of narrow topography, monsoon circulation, and tidal interactions ultimately results in the movement of ocean currents in both the east-west (u_o) and north-south (v_o) velocity components that move randomly, fluctuates, and non-laterally [2]. Turbulence conditions filled with high temporal variability make modeling ocean currents in the Bali Strait very challenging.

To solve the complexity of ocean currents, previous research usually used mapping models based on physics formulas, one of which is the Princeton Ocean Model (POM). This model calculates the movement of water masses by including natural factors such as ocean depth and tides [6]. Although it is able to map the circulation of currents well, this model has a disadvantage because the process is too slow for the needs of ports that need fast-paced information. This conventional model requires very heavy computer performance and long simulation time, making it less suitable as a navigation early warning system [7]. In addition, the accuracy of these physics models often decreases drastically when it comes to predicting highly random and fickle short-term current movements in narrow waters [8]. These operational limitations are a strong reason why we need to switch to a modern data-driven approach that is much faster, resilient, and practical.

To overcome the slow pace of conventional models, ocean current prediction is now starting to shift to data-driven machine learning technology. Unlike classical models that rely on complex calculations of physics formulas, these artificial intelligence systems work purely by studying the current movement patterns from past data [9]. Through the training process using the historical data, this model is able to

predict the direction and speed of the current in real time without burdening the performance of the computer with heavy mathematical calculations [10]. The speed and practicality of deep learning technology is what makes it the most reasonable solution as a navigation warning system in waters as complex as the Bali Strait.

A data-driven approach using deep learning has been widely applied to predict time series data in various fields. Al Haromainy et al. (2021) proved that repetitive neural network-based methods such as Echo State Network (ESN) are able to produce very small error values (MAPE 0.28%) in predicting multivariate time series data compared to conventional RNN methods [11]. In addition, the application of machine learning-based methods has also been successfully implemented in web-based monitoring and prediction systems, such as those carried out by Nurlaili et al. (2025) in predicting student payment delays using Binary Logistics Regression with an accuracy of 93.75% [12]. This further strengthens the belief that data-driven approaches are reliable for a wide range of complex prediction problems, including the prediction of sea level currents in the Bali Strait.

Of the various types of deep learning technologies that exist, ocean current prediction requires a special model that is smart to recognize the sequence of data from time to time (time-series). Therefore, this study chose to use the Bidirectional Long Short-Term Memory (BiLSTM) method. Unlike ordinary memory systems that only read data in one direction (from the past to the future), BiLSTM has the advantage of being able to read information from two directions at once, aka back and forth. This ability to read back and forth makes BiLSTM much more sensitive to seeing sudden changes in the direction of ocean currents due to tides or winds. Previous research has also proven that to guess complex and random ocean conditions, the guessing results from BiLSTM have proven to be more accurate and stable than models that only read one-way data [13]. Because of this greatness, the BiLSTM method was finally chosen in this study to predict how fast and where the sea currents in the waters of the Bali Strait will go.

1.2. Problem Formulation

Based on the description of the background that has been presented, several problem formulations are obtained that will be discussed and analyzed in this study, which are as follows:

1. How is the Bidirectional Long Short-Term Memory (BiLSTM) method implemented to predict the speed and direction of sea surface currents in the Bali Strait?
2. How to analyze the results of the Bidirectional Long Short-Term Memory (BiLSTM) method in predicting the speed and direction of sea surface currents in the Bali Strait based on the hyperparameter batch size and epoch trials?

1.3. Research Objectives

The purpose of the research with the title "Implementation Bidirectional Long Short-Term Memory (BiLSTM) To Predict the Speed and Direction of Sea Level Flow in the Bali Strait Shipping Lanes" is as follows:

1. To find out the best results in predicting the speed and direction of sea surface currents in the Bali Strait using the Bidirectional Long Short-Term Memory (BiLSTM) method.
2. To find out the results of the Bidirectional Long Short-Term Memory (BiLSTM) method in predicting the speed and direction of sea surface currents in the Bali Strait based on the hyperparameter test batch size and epoch.

1.4. Research Benefits

The expected benefits of the preparation of the research with the title "Implementation Bidirectional Long Short-Term Memory (BiLSTM) for Predicting the Speed and Direction of Sea Level Flows in the Bali Strait Shipping Lanes" are as follows:

1. It is hoped that this research will be able to be a supporting reference for future research related to the prediction of the speed and direction of sea surface currents using the Bidirectional Long Short-Term Memory (BiLSTM) method.
2. To expand the author's insights related to the Bidirectional Long Short-Term Memory (BiLSTM) method in terms of its advantages and usefulness in predicting the speed and direction of sea surface currents.
3. Provide better information and understanding of predicting sea level speed and currents in improving navigation safety. Accurate information about ocean current conditions can be used to plan safer and more efficient shipping routes, thereby reducing the risk of marine accidents.

1.5.Problem Limitations

In order to keep the discussion in the thesis research entitled "Implementation of Bidirectional Long Short-Term Memory (BiLSTM) to Predict the Speed and Direction of Sea Level Currents in the Bali Strait Shipping Lanes" remains directed and in accordance with the goals to be achieved, several limitations of the problem are set as follows:

1. The method used to predict sea surface currents is a machine learning method, namely Bidirectional Long Short-Term Memory (BiLSTM).
2. Hyperparameter tests using batch size and epoch.
3. The current data used comes from the Copernicus Marine Service website.

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