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Time Series Forecasting of Ship Departure Health Inspections for Strengthening Quarantine Surveillance Using the ARIMA Model

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ABSTRACT

ARIMA (Autoregressive Integrated Moving Average) is a time series analysis method used to evaluate data based on temporal patterns. The number of ship departure inspections conducted by the Probolinggo Class I Health Quarantine Center has shown fluctuations over time. These inspections are part of disease prevention efforts as regulated in the Indonesian Minister of Health Regulation No. 10 of 2023 concerning the Organization and Work Procedures of the Quarantine Technical Implementation Unit. This study aims to forecast the number of ship departure inspections at the Probolinggo Class I Health Quarantine Center. This research employed a non-reactive design using secondary data from 2020 to 2023, sourced from the Health Quarantine Information System (SINKARKES). The ARIMA (2,0,2) model provided the best fit, with good accuracy (MSE 685,277; MAPE 7.311). Forecasting results show an upward trend in ship departure inspections throughout 2024. This increase is highly relevant for public health, as stronger inspection activity supports quarantine surveillance, helps detect potential disease risks early, and improves preparedness against cross-border health threats.

INTRODUCTION

The ship departure inspection process for the issuance of Port Health Quarantine Clearance (PHQC) is a crucial component in safeguarding maritime public health. PHQC is an official document issued by the Health Quarantine Center (Balai Kekarantinaan Kesehatan/BKK) and serves as a primary requirement for ships to proceed with their journey after being declared free from the risk of communicable diseases. This process is particularly important because ships traveling through international and domestic waters can act as vectors for disease transmission, thereby posing a threat to port communities and beyond (Nainggolan *et al.*, 2024)(Nasir, Noreen and Shah, 2023).

Globally, the importance of quarantine measures at ports has been reinforced by the International Health Regulation, which emphasize the role of points of entry (airports, ports, and ground crossings) in preventing the international spread of diseases (World Health

Organization (WHO), 2005). Maritime health security remains a critical challenge, as ships may facilitate cross-border transmission of pathogens, including those causing emerging and re-emerging infectious diseases (Tatem, Rogers and Hay, 2006)(Baker *et al.*, 2022). Strengthening surveillance and preparedness at ports is therefore central to global epidemic prevention and control strategies.

Despite this global recognition, research on port health quarantine has largely focused on descriptive analyses of surveillance activities and outbreak responses, with relatively limited attention to forecasting approaches. Forecasting is essential for anticipating inspection demand, optimizing resources, and ensuring that adequate infrastructure and personnel are available to meet future public health challenges (Song, 2025). This creates a knowledge gap: while studies have examined port health measures for disease surveillance, little is known about the use of statistical models such as ARIMA to project inspection demand and strengthen operational preparedness.

This study seeks to address this gap by evaluating the applicability of the Autoregressive Integrated Moving Average (ARIMA) model in forecasting ship departure health inspections. The objective is not only to support evidence-based planning at the local level, but also to demonstrate how time series forecasting can contribute to broader efforts in maritime health security and public health preparedness in line with international frameworks such as the IHR (2005).

METHODS

The Probolinggo Class I Health Quarantine Center is a Technical Implementation Unit under the Directorate General of Disease Prevention and Control, Ministry of Health of the Republic of Indonesia. Its working areas include several ports and airports, namely: the Probolinggo Main Office, Pasuruan Work Area, Paiton Work Area, Panarukan Work Area, Tanjungwangi Work Area, and Abdurachman Saleh Airport in Malang (Kemenkes RI, 2024). In accordance with its main duties and functions as regulated by the Minister of Health Regulation No. 10 of 2023, the Probolinggo Class I Health Quarantine Center provides health quarantine services for ship departures, including inspection of crew health, verification of ship documentation, and ship sanitation (Kemenkes RI, 2023).

This study employed a retrospective time-series design using secondary data. The study population consisted of all ship departure inspections recorded by the Probolinggo Class I Health Quarantine Center. The sample included the entire population, covering inspection records retrieved from monthly reports available on the Health Quarantine Information System (SINKARKES) website, spanning the period from January 2020 to December 2023 (https://sinkarkes.kemkes.go.id/). The dataset specifically represented the monthly number of ship departure inspections within the specified timeframe.

The secondary data used in this study were official records routinely collected and published by the Ministry of Health of the Republic of Indonesia through SINKARKES. As government administrative data, they are subject to standardized reporting protocols, verification by health quarantine officers, and routine audits, which support their validity and reliability for research purposes (Kemenkes RI, 2023).

Data analysis was conducted using the Autoregressive Integrated Moving Average (ARIMA) model with the assistance of the SPSS software package. The modeling process followed the Box–Jenkins methodology, consisting of the following steps (Wilson, 2016)(Hyndman, 2014).

1. Stationarity testing: The time series was assessed for stationarity in mean and variance using visual inspection, correlogram analysis, and augmented Dickey–Fuller tests. If the data were non-stationary, differencing and/or transformation were applied to achieve stationarity.
2. Model identification: Autocorrelation function (ACF) and partial autocorrelation function (PACF) plots were examined to identify potential AR and MA terms.
3. Parameter estimation: Competing ARIMA models were fitted and their parameters estimated.
4. Model selection: The best-fitting model was selected based on multiple criteria, including the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), Mean Square Error (MSE), and Mean Absolute Percentage Error (MAPE).
5. Diagnostic checking: Residuals from the selected model were tested for white noise using the Ljung–Box Q test and residual ACF plots.
6. Validation: Model performance was validated by comparing predicted values with observed data and assessing forecasting accuracy measures (MSE, MAPE).

This structured approach ensured that the chosen ARIMA model was statistically sound and reliable for forecasting ship departure inspections.

RESULTS

The results the number of ship departure inspections conducted by the Probolinggo Class I Health Quarantine Center has shown fluctuations over specific time periods. These inspections are carried out as part of disease prevention efforts, in accordance with the Regulation of the Minister of Health No. 10 of 2023 concerning the Organization and Work Procedures of Technical Implementation Units in the Field of Quarantine.

Below is the simulated data on the number of ship departure inspections conducted by the Probolinggo Class I Health Quarantine Center from 2020 to 2023.

Table 1. Data on the Number of Ship Departure Inspections at BKK Class I Probolinggo in 2020-2023

Moon	Number of Ship Departure Checks			
	2020	**2021**	**2022**	**2023**
January	9,127	8,161	7,336	6784
February	8,550	7,351	6,674	6532
March	8,627	7,986	6,738	6927
April	6,629	8,075	6,862	7110
May	6,099	6,906	7,404	7366
June	6,364	7,918	6,909	6908
July	6,805	6,553	7,331	6780
August	8,119	6,615	7,059	7150

September	7,956	7,070	7,196	6901
October	7,608	7,326	7,258	6980
November	7,538	7,074	7,133	6983
December	7,976	7,024	7,165	7365
Total	91,398	88,059	85,065	83,786

Source: Primary Data, 2024

The There are several stages involved in ARIMA modeling, including data stationarity, preliminary model identification, parameter estimation, diagnostic checking, selection of the best-fitting model, and forecasting results.

Data Stationarity

Stationarity refers to the condition in which data fluctuations remain relatively constant over time. If the mean and variance remain constant as time progresses, the data are considered stationary (Woodward, Gray and Elliott, 2020).

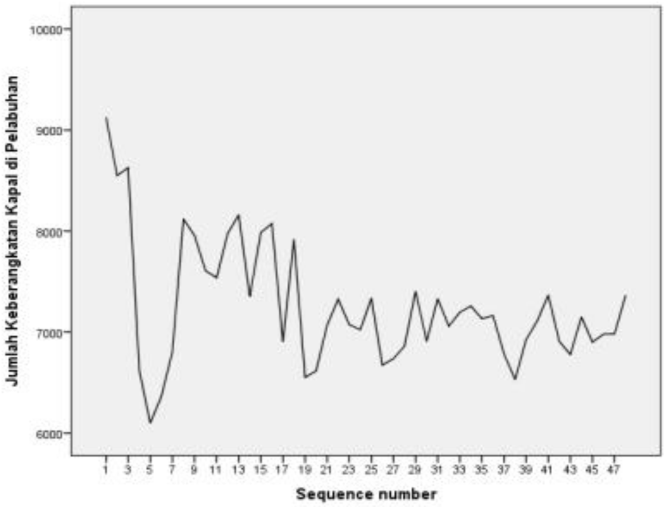


Figure 1. Data Plot of the Number of Ship Departure Inspections in BKK Class I Probolinggo Year 2020-2023

As shown in Figure 1, the data do not yet meet the criteria for stationarity in terms of mean and variance. This is indicated by the presence of fluctuating patterns over time. Therefore, transformation and differencing were applied.

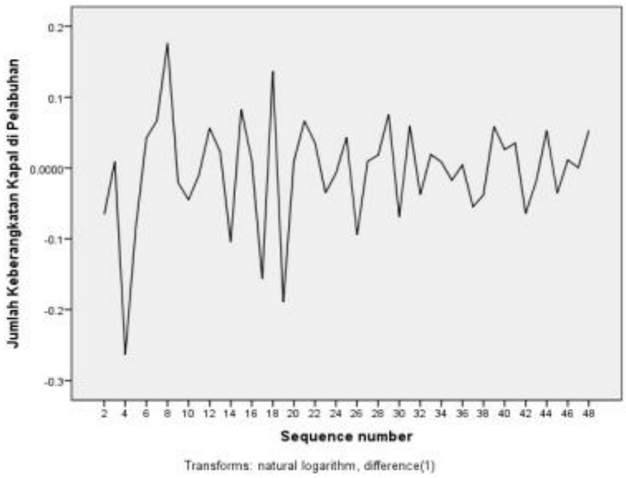


Figure 2. Data Plots after transformation and differentiating Number of Ship Departures at BKK Class I Probolinggo in 2020-2023

Figure 2 presents the data after undergoing transformation and differencing, showing that the series has achieved stationarity in both mean and variance.

Preliminary Model Identification

Once the data have achieved stationarity, the next step is to identify a preliminary ARIMA (p, d, q) model. The Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) plots are used to determine the values of p (autoregressive order) and q (moving average order), while the differencing results determine the order of d. In this study, the differencing process indicated an order of d = 2.

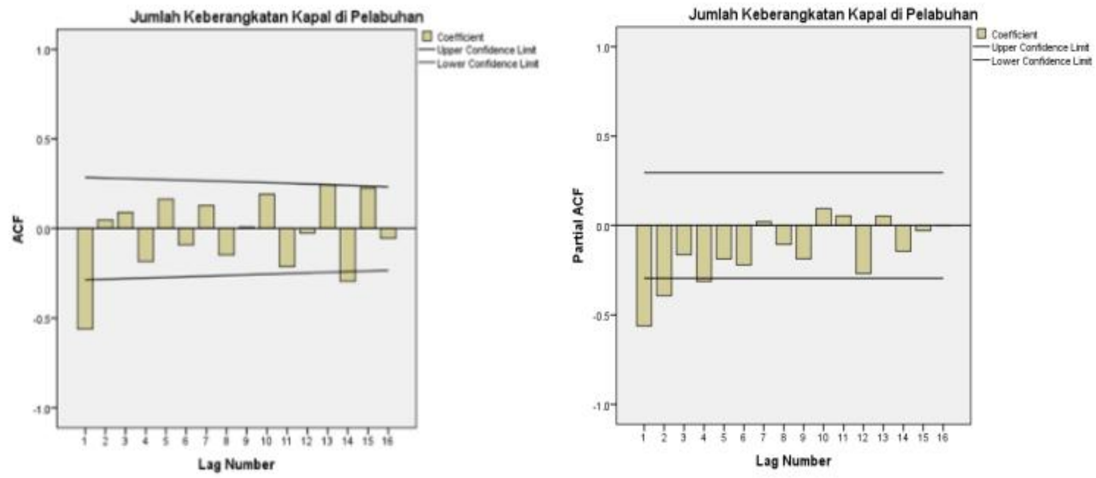


Figure 3. ACF and PACF Data Plot Number of Ship Departure Inspections at BKK Class I Probolinggo in 2020-2023

Figure 3 shows the ACF plot with cutoff lines observed at lag-1 and lag-14. In the ACF plot, lag-2 appears to be approaching significance. Meanwhile, the PACF plot indicates cutoff points at lag-1, lag-2, and lag-4, with a near-significant value at lag-3. These patterns in the ACF and PACF plots suggest the presence of both Autoregressive (AR) and Moving Average (MA) components.Based on these observations, the potential candidate models include ARIMA (1,2,0), ARIMA (1,2,1), ARIMA (1,2,2), ARIMA (2,0,2), ARIMA (2,2,1), and ARIMA (2,2,2).

Parameter Estimation

Each parameter within the proposed models must be evaluated for statistical significance through parameter estimation. The AR and MA coefficient values are determined based on their significance levels. A model is considered statistically significant if the p-value is less than the significance level α (Nurfadila and Ilham Aksan, 2020). This evaluation ensures the selection of the most appropriate model for forecasting.

Table 2. *p-Value* Data Parameters

Model	*p-Value*				Conclusion
	AR (1)	AR (2)	MA (1)	MA (2)	
(1,2,0)	0,000				Signifikan
(1,2,1),	0,295		0,250		Insignificant

(1,2,2)	0,954		0,767	0,872	Insignificant
(2,2,0	0,000	0,003			Signifikan
(2,2,1)	0,302	0,869	0,336		Insignificant
(2,2,2)	0,000	0,303	1	0,840	Insignificant

Source: Primary Data (Processed), 2024

Diagnostic Checking

A model is considered adequate for forecasting if it passes the diagnostic checking stage (Tasna Yunita, 2020). Diagnostic checking includes tests for white noise and normality. The purpose of the white noise test is to determine whether the model residuals behave randomly. If the residuals exhibit no specific pattern, it indicates that the mean is equal to zero and the variance is constant. The Ljung–Box Q statistic and the residuals are considered to represent white noise if the significance value is greater than α = 0.05.

Table 3. White *Noise Test* on Residual models

Arima Model	Sig. Value (Ljung-Box Q)
(1,2,0)	0,036
(2,0,2)	0,403

Source: Primary Data (Processed), 2024

Tabel 4. Kolmogorov Smirnov normality

Arima Model	Komogorov-Smirnov Sig. Value	Shapiro-Wilk Sig. Value
(1,2,0)	0,082	0,472
(2,0,2)	0,200	0,939

Source: Primary Data (Processed), 2024

As shown in table 3, the Ljung–Box Q significance value for the ARIMA (1,2,0) model is 0.036, while for the ARIMA (2,0,2) model, it is 0.403. Based on the white noise test results, the ARIMA (1,2,0) model does not meet the white noise criteria, whereas the ARIMA (2,0,2) model does—indicating that its residuals are random in nature.

Subsequently, a normality test was conducted to evaluate whether the residuals follow a normal distribution using the Kolmogorov–Smirnov test, as presented in Table 4 (Sigit & Setiyoargo, 2020). If the significance value is greater than α, the residuals are considered to be normally distributed (Sarjana, Masyarakat and Airlangga, 2023). Table 4 shows that the residuals of both ARIMA (1,2,0) and ARIMA (2,0,2) models meet the assumption of normal distribution.

Model Selection

The best model is selected based on the Mean Square Error (MSE) and Mean Absolute Percentage Error (MAPE) values. Lower MSE and MAPE values indicate better forecasting performance(Diningestu and Mahmudah, 2024). Therefore, the model with the smallest error values is considered the most appropriate for predicting the number of ship departure inspections.

Table 5. MSE and MAPE values of the Arima Model

Arima Model	MSE	MAPE
(1,2,0)	734.340	7.537
(2,0,2)	685.277	7.311

Source: Primary Data (Processed), 2024

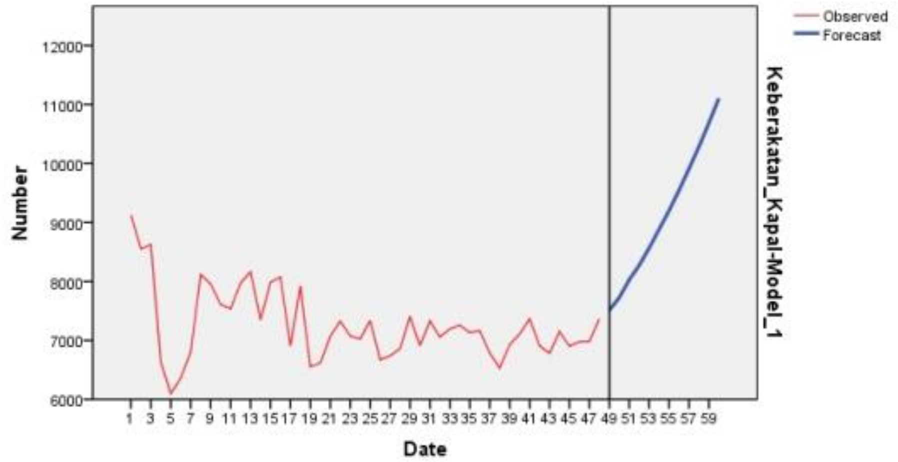
Table 5 shows that the MSE value for the ARIMA (1,2,0) model is 734,340, while for the ARIMA (2,0,2) model it is 685,277. Meanwhile, the MAPE value for the ARIMA (1,2,0) model is 7.537, and for the ARIMA (2,0,2) model it is 7.311. Based on these results, it can be concluded that the ARIMA (2,0,2) model yields the lowest MSE and MAPE values and is therefore selected as the best-fitting model.The ARIMA (2,0,2) model equation is expressed as follows:

$$Xt = \phi_1 Xt_{-1} + \phi_2 Xt_{-2} + at - \theta_1 at_{-1} - \theta_2 at_{-2}$$

$$Xt = -0.809Xt_{-1} - 0.431Xt_{-2} + at - \theta_1 at_{-1}$$

Forecasting Results for Ship Departures at Probolinggo Port

The forecasted number of ship departures at Probolinggo Port for the year 2024 is presented in Figure 4, which displays the ARIMA (2,0,2) prediction plot.



Forecast

Model		49	50	51	52	53	54	55	56	57	58	59	60
Jumlah Keberangkatan Kapal di Pelabuhan - Model_1	Forecast	7514	7728	8030	8273	8566	8884	9201	9548	9912	10290	10689	11105
	UCL	8870	9838	11062	12516	14031	15702	17491	19378	21379	23477	25671	27960
	LCL	6157	5618	4997	4029	3101	2067	911	-281	-1555	-2898	-4293	-5750

For each model, forecasts start after the last non-missing in the range of the requested estimation period, and end at the last period for which non-missing values of all the predictors are available or at the end date of the requested forecast period, whichever is earlier.

Figure 4. Shows the plot of the ARIMA prediction result (2,0,2)

Figure 4 displays the ARIMA (2,0,2) forecast plot, showing that the number of ship departure inspections at Probolinggo Port is projected to increase steadily throughout 2024. In January, the number of inspections is forecasted at 7,514, rising to 11,105 inspections by December 2024.

DISCUSSION

The Ship departure inspections conducted by the Health Quarantine Center are mandated by the Health Law No. 17 of 2023 as part of the clearance in and clearance out procedures, ensuring vessels obtain Port Health Quarantine Clearance (PHQC) before departure (Presiden RI, 2023). This regulation plays a crucial role in safeguarding the port environment and preventing the transmission of communicable diseases. The forecasting approach applied in this study provides an evidence-based perspective that can strengthen resource planning and operational readiness at the Probolinggo Class I Health Quarantine Center.

Nevertheless, the PHQC process faces multiple operational barriers. These include delays in updating ship health documents, disruptions in online submission through the SINKARKES system due to connectivity issues, and weather conditions that may hinder physical inspections (Nainggolan *et al.*, 2024). Addressing such barriers requires not only sufficient staffing but also enhanced digital infrastructure and contingency planning. Forecasting inspection demand offers an opportunity to anticipate these constraints and guide the allocation of resources more efficiently.

The 2023 performance report of the Probolinggo Class I Health Quarantine Center indicated that inspection fluctuations were associated with increased ferry operations on the Ketapang–Gilimanuk route, alongside a decline in merchant and cargo vessel traffic in other areas. Cross-sectoral collaboration and adequate human resources have contributed to inspection success; however, the upward trend forecasted by the ARIMA model highlights the need for scalable strategies to ensure sustainable performance.

From a broader public health perspective, ship departure inspections represent a frontline defense against the cross-border spread of infectious diseases. The International Health Regulations (IHR 2005) explicitly require countries to strengthen core capacities at points of entry, including seaports, as part of global epidemic preparedness. Thus, integrating forecasting models such as ARIMA into routine inspection planning not only supports compliance with national regulations but also aligns with global health security mandates.

Maritime traffic has long been identified as a pathway for infectious disease spread (Tatem, Rogers and Hay, 2006). During the COVID-19 pandemic, lapses in port health preparedness were shown to exacerbate transmission risks across countries (Zhang *et al.*, 2021). In this context, the present study contributes conceptually by demonstrating the practical value of time-series forecasting for strengthening quarantine surveillance. Unlike descriptive institutional reports, this study bridges operational realities with predictive analytics, offering a tool that can improve preparedness and resilience at the interface of national and global health systems.

In summary, the forecasted increase in ship departure inspections should be viewed as more than an administrative workload. It underscores the strategic need for capacity building, digital system enhancement, and stronger inter-agency coordination. Embedding predictive modeling into maritime health surveillance can enhance the role of health quarantine centers as sentinels of public health, preventing transboundary threats and supporting international commitments to health security.

CONCLUSION

During the period from 2020 to 2023, the number of ship departure inspections conducted by the Probolinggo Class I Health Quarantine Center exhibited monthly fluctuations, with the ARIMA (2,0,2) model identified as the best-fitting forecasting tool. The projections for 2024 suggest a steady monthly increase in inspection activities.

Beyond the technical results, these findings underscore the importance of strengthening port health preparedness in response to increasing maritime traffic. Forecasting models such as ARIMA can support evidence-based decision-making, enabling health authorities to anticipate workload fluctuations and allocate resources more effectively. From a public health perspective, reliable forecasting contributes to the early detection and prevention of cross-border disease transmission, aligning with the objectives of the International Health Regulations (IHR).

Practical recommendations derived from this study include:

1. Strengthening the capacity of health inspectors through continuous training and adequate resource allocation.
2. Developing data-driven forecasting systems to improve operational efficiency and enhance planning for inspection workloads.
3. Integrating forecasting results into cross-border health risk management strategies, ensuring that local port health measures contribute to regional and global health security.

This study provides empirical evidence for policymakers and port health authorities to enhance maritime surveillance systems, highlighting the role of predictive analytics in safeguarding public health at points of entry.

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