Implementation of Grid Search Optimization Algorithm and Adaptive Response Rate Exponential Smoothing for Hyperparameter Tuning in Production Activity Determination

Federico Sanjaya[a], Jesslyn Alvina[b], Muhammad Amsar Putra[c], Delima Sitanggang[d]
[a,b,c,d]Universitas Prima Indonesia
Corresponding Author:
ricosanjaya73@gmail.com

ABSTRACT
This research aims to improve the accuracy of production planning at PT Bilah Baja Makmur Abadi by combining the Adaptive Response Rate Exponential Smoothing (ARRES) algorithm and Grid Search optimization. The main problems faced are unpredictable demand fluctuations, dead stock risks, and high operational costs due to imbalances between production and demand. The ARRES algorithm is used for demand forecasting with adaptive exponential weighting, while Grid Search optimizes the alpha and initial year parameters to improve prediction accuracy. This study uses a 5-year sales dataset (2017-2021) with model evaluation using Mean Absolute Percentage Error (MAPE). The results showed that the combination of Grid Search and ARRES optimization algorithms proved effective in helping predict production needs. This can be seen from the significant decrease in the average MAPE value, which is 7.07% using this combination method, compared to 8.18% in the ARRSES method. The lower MAPE value indicates that the Grid Search method is effective in optimizing the ARRSES model parameters. With relatively high prediction accuracy (MAPE < 10%), this method is able to cope with unexpected demand fluctuations.

Keywords : Production Planning, Adaptive Response Rate Exponential Smoothing (ARRES), Optimasi Pencarian Grid

INTRODUCTION

In the manufacturing industry, accurate production planning is one of the key factors in maintaining smooth operations and cost efficiency (Soeltanong & Sasongko, 2021). PT Bilah Baja Makmur Abadi is a company engaged in steel production and distribution, focusing on providing high-quality products for various industrial applications (Lutfi & Sasongko, 2022). The company faces the challenge of ensuring the number of products produced matches market demand. Over- or under-production activities can negatively impact the company's profitability, resulting in high storage costs and stock shortages that can result in lost sales opportunities (Maharani et al., 2024).

However, one of the problems often encountered is that demand fluctuations are difficult to predict. Sudden changes in demand or market trends that are not detected quickly can lead to an imbalance between production and demand (Venny & Asriati, 2022). This results in the waste of resources, such as raw materials and inefficient labor, as well as increased operational costs (Mustaghfirin et al., 2024). In addition, the inability to fulfill orders on time can reduce customer service and affect consumer confidence (Ratiwi et al., 2024). The next problem is related to the dead stock phenomenon, where products produced are not sold and accumulate in warehouses, which is also a problem. Deadstock ties up capital that could be used for other purposes, requires additional storage costs, and can hinder the movement of new goods that are more needed by the market, especially when the value of goods decreases due to changing trends (Saraswati et al., 2023).

To overcome this problem, applying the Adaptive Response Rate Exponential Smoothing (ARRES) algorithm can be an effective solution in production planning. The ARRES algorithm is a moving average or time series prediction algorithm that performs exponential downward weighting of older observations (Djami & Nanlohy, 2022). The Adaptive Response Rate Exponential Smoothing algorithm is similar to the Single Exponential Smoothing (SES) forecasting method. ARES has an advantage over the SES algorithm in that the smoothing parameter alpha can change automatically if there are changes in the data pattern (Romindo et al., 2023). In addition, to improve prediction accuracy, the ARRES algorithm is combined with the Grid Search algorithm to optimize by systematically exploring various possible combinations of parameter (Pramudhyta & Rohman, 2024). This study's optimized parameters are the alpha value and the initial year value. Algoritma Adaptive Response Rate Exponential Smoothing hampir sama dengan metode peramalan Single Exponential Smoothing (SES).

The novelty of this research lies in integrating the Adaptive Response Rate Exponential Smoothing (ARRES) algorithm with the Grid Search optimization technique, which has not been widely applied, especially in the context of the steel industry. This approach improves prediction accuracy through more effective parameter optimization to overcome unpredictable demand fluctuations. In contrast to previous research, such as the study of (Barus, 2022), which used the Exponential Smoothing method with parameter $\alpha = 0.5$ for sales forecasting and resulted in an error rate of 1.2%, this study carries a more complex and adaptive approach (Barus et al., 2022). The study of (Romindo et al., 2023) evaluated the performance of ARRES in product sales prediction with a MAPE value of 53.33%, which is quite accurate but without any parameter optimization (Romindo et al., 2023). Other studies, such as (Banat et al., 2024) and (Utami et al., 2024), compared various Exponential Smoothing methods for predicting production quantities, with Banat et al. finding the Single Exponential Smoothing method to be the best (Banat et al., 2024), and Utami et al. reporting the smallest MAPE value for Winters' Additive at 11.56% (Utami et al., 2024). On the other hand, (Medyanti et al., 2024) showed that Grid Search optimization in the Single Exponential Smoothing method was able to reduce the MAPE value from 10.172% to 5.783%, proving the effectiveness of parameter optimization in improving prediction accuracy (Medyanti et al., 2024). Recent research applying SES with Grid Search predicted the value of oil and gas exports. The test results show that the prediction results of the SES method with Grid Search optimization are more accurate, with a Mean Absolute Percentage Error (MAPE) of 5.783%, lower than the SES method without optimization (10.172%).

Implementing Grid Search in SES can produce predictions that reduce uncertainty's impact on oil and gas sector economic planning.

By combining ARRES which has adaptive capabilities in exponential weighting with Grid Search which systematically optimizes parameters, this research offers a more precise approach in the context of production planning. This integration is expected to be an innovative solution to the challenge of dynamic and unpredictable demand prediction in the steel industry.

METHODS

In this study, researchers used a quantitative type of research, which is research that involves collecting numerical data and statistical analysis to understand phenomena or answer research questions. This method is often used to measure the relationship between variables and identify patterns or trends in data (Ghodang & Hantono, 2020). The following is a flowchart of the stages of the research method in this study shown in Figure 1.

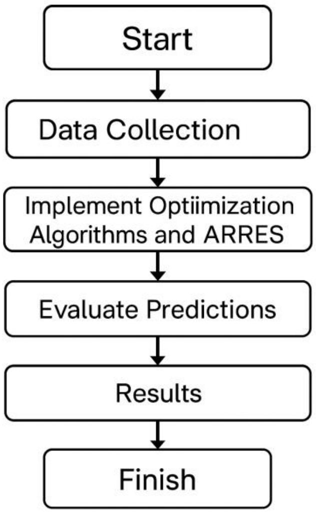

Figure 1. Stages of the Research Method

Based on the work procedure in Figure 2.1, this research uses a sales dataset from 2017 to 2021 consisting of 20,249 data. This dataset is uploaded to Google Drive to be analyzed using Google Colab. In the implementation stage, two optimization algorithms are used: Grid Search and Adaptive Response Rate Exponential Smoothing (ARRES). Grid Search was used to find the optimal parameter combination, focusing on alpha values between 0.1 and 0.9. Meanwhile, ARRES automatically adjusts the alpha parameter based on changes in the data pattern, suitable for time series with horizontal patterns. Model evaluation uses Mean Absolute Percentage Error (MAPE), which measures the prediction error.

Data Collection

The dataset used in this research is collected and taken from the sales data of PT Bilah Baja Makmur Abadi for 5 years, namely 2017 to 2021, totaling 20,249 data. Table 1 shows the dataset used in this study.

Table 1. Research Dataset

No.	Date	Product	Qty
1	1/1/2021	Concrete	63
2	1/1/2021	Pipe	66
3	1/1/2021	Wiremesh	46
4	1/1/2021	Wf	65
5	1/1/2021	Hnp	75
6	1/1/2021	Plate	97
7	1/1/2021	Wire	88
8	1/1/2021	Elbow	36
9	1/1/2021	Wiremesh	48
10	1/1/2021	Pipe	95
11	1/1/2021	Channel	35
12	1/1/2021	Ash	46
13	1/1/2021	Nipple	66
14	1/2/2021	Concrete	63
15	1/2/2021	Channel	43
16	1/2/2021	Plate	88
17	1/2/2021	Elbow	53
18	1/2/2021	Nipple	80
19	1/2/2021	Wire	78
...	...	...	...
20249	12/31/2017	Wire	126

The data that has been collected is entered into Google Drive so that it can be continued at the analysis stage using Google Colab.

Implementasi *Algoritma Optimasi Grid Search* dan *ARRES*

At this stage, an analysis of the data that has been collected by implementing the Grid Search optimization algorithm and Adaptive Response Rate Exponential Smoothing to determine production activities at PT. Bilah Baja Makmur Abadi.

a. Algoritma Optimasi Grid Search.

   Grid Search optimization algorithm is a systematic search method to find the optimal combination of parameters in a model (Andi et al., 2023). In Grid Search, the range of values for each parameter is determined first, then a comprehensive search is conducted (Syahfitrri et al., 2024). Optimization is done using the Grid Search algorithm to determine the best or optimal alpha value for the model. The parameters used are alpha values with a range of 0.1 to 0.9, with the addition of 0.1 each grid (Medyanti et al., 2024).

b. Algoritma Adaptive Response Rate Exponential Smoothing (ARRES).
The Adaptive Response Rate Exponential smoothing (ARRES) method is a forecasting method similar to the Single Exponential Smoothing (SES) forecasting method. ARRES has an advantage over SES in that the smoothing parameter alpha will change automatically if there is a change in the data pattern. In its application, the calculation in ARRES does not need to determine the best alpha value because the alpha value constantly changes every time and is adjusted for changes in the data pattern. The characteristics of this method are that the data analyzed are time series and suitable for horizontally patterned data, and use different parameters for past data, where the parameters decrease exponentially from the most recent observation value to the oldest observation value The formula for ARRES is as follows (Supardi & Pahlevi, 2021)*:*

$$F_t = \alpha_{t-1} * A_{t-1} + (1 - \alpha_{t-1}) * F_{t-1} \quad (2.1)$$

Information:
F_t = Predicted or smoothed value for period t.
A_{t-1} = Actual value or observation data in the previous period (t-1)..
F_{t-1} = Smoothed predicted value in the previous period (t-1).
α_{t-1} = Adaptive smoothing factor determined in the previous period (t-1).

Grid Search serves to explore parameter combinations in a model to find the best configuration, such as optimizing the alpha value in Exponential Smoothing to improve the accuracy of production predictions based on historical data. Meanwhile, ARRES increases the flexibility of the forecasting model by automatically adjusting smoothing parameters to changes in data patterns, making it more responsive to trend or seasonal fluctuations. With the combination of both, optimization and forecasting become more effective, resulting in more accurate predictions and supporting more informed decision-making in production planning at PT. Bilah Baja Makmur Abadi.

Prediction Evaluation
Evaluation of the prediction model used in this study using the Mean Absolute Percentage Error (MAPE) method. Mean Absolute Percent Error is an error calculation method whose value is obtained by finding the percentage error of each prediction period and then dividing it by the amount of data in the time period used (Sebastian et al., 2024). The following is the equation for MAPE (Litha & Hasanuddin, 2020).

$$MAPE = \left(\frac{100}{N}\right) \sum A_t - \frac{F_t}{A_t} \quad (2.2)$$

Information:
N = Number of prediction periods involved
F_t = Prediction (forecast) in period-t
A_t = Actual data in period-t
The MAPE value that has been obtained from the calculation results can be analyzed whether a prediction has good performance. The following describes the performance of the MAPE value as listed in Table 2 below (Andi et al., 2021).

Table 2. Performance MAPE Value

MAPE Value	Prediction Accuracy
MAPE < 10%	High
10% < MAPE < 20%	Good
20% < MAPE < 50%	Reasonable
MAPE > 50%	Low

Result

The research results are in the form of a comprehensive discussion of the analysis that has been carried out, described in detail and linked to previous studies.

RESULTS AND DISCUSSION

In this study, the Grid Search and ARRES optimization algorithms were implemented to predict production needs at PT Bilah Baja Makmur. Training data is taken from product production data from 2017 to 2020. The algorithm implementation process is carried out with the Google Colab tool using the Python programming language as shown in Figure 2.

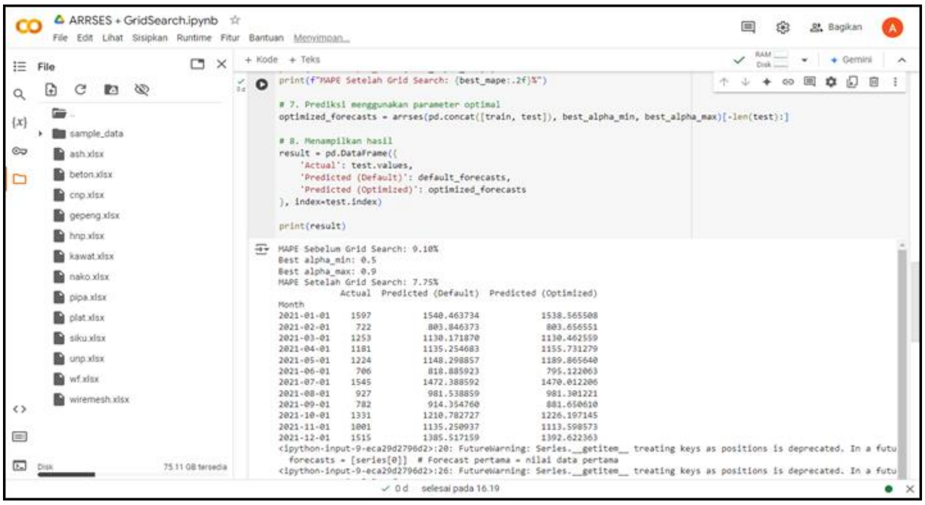

Figure 2. Implementation Results of Grid Search and ARRES Optimization Algorithms

Based on Figure 2, it can be seen that the results obtained are in the form of product production prediction results in 2021. These prediction results will be continued in the prediction evaluation process to determine the performance of the algorithm proposed in this study.

After the algorithm is implemented, the results of product production predictions will be compared with actual data. In this study, the testing data used is product sales data in 2021. Evaluate the prediction results using the Mean Absolute Percentage Error (MAPE) method to find the percentage error of each prediction period. These are the results of the algorithm prediction validation tested in this research on each product, among others:

a. Ash Product Production.
MAPE prediction of ash production so that the MAPE obtained with the ARRES algorithm is 9.10%, while the MAPE of the Grid Search and ARRES optimization algorithms is 7.75%.
b. Concrete Product Production.
MAPE prediction of concrete production so that the MAPE obtained with the ARRES algorithm is 7.20%, while the MAPE of the Grid Search and ARRES optimization algorithms is 6.00%.
c. Cnp Product Production.
MAPE prediction of cnp production so that the MAPE obtained with the ARRES algorithm is 7.64%, while the MAPE of the Grid Search and ARRES optimization algorithms is 6.12%.
d. Sprawl Product Production.
The MAPE of sprawl production prediction obtained with the ARRES algorithm is 8.88%, while the MAPE of the Grid Search and ARRES optimization algorithms is 7.67%.
e. Hnp Product Production.
MAPE prediction of hnp production so that the MAPE obtained with the ARRES algorithm is 11.40%, while the MAPE of the Grid Search and ARRES optimization algorithms is 11.03%.
f. Wire Product Production.
MAPE prediction of wire production so that the MAPE obtained with the ARRES algorithm is 9.63%, while the MAPE of the Grid Search and ARRES optimization algorithms is 8.06%.
g. Production of Nako Products.
MAPE prediction of brick production so that the MAPE obtained with the ARRES algorithm is 8.47%, while the Grid Search and ARRES optimization algorithms MAPE is 7.65%.
h. Pipe Product Production.
MAPE prediction of pipe production so that the MAPE obtained with the ARRES algorithm is 4.15%, while the MAPE of the Grid Search and ARRES optimization algorithms is 3.64%.
i. Plate Product Production.
MAPE prediction of plate production so that the MAPE obtained with the ARRES algorithm is 7.57%, while the MAPE of the Grid Search and ARRES optimization algorithms is 6.96%.
j. Elbow Product Production.
MAPE of elbow production prediction so that the MAPE obtained with the ARRES algorithm is 8.00%, while the MAPE of the Grid Search and ARRES optimization algorithms is 7.04%.

k. Unp Product Production.
MAPE prediction of unp production so that the MAPE obtained with the ARRES algorithm is 7.26%, while the MAPE of the Grid Search and ARRES optimization algorithms is 6.45%.

l. Wf Product Production.
MAPE prediction of wf production so that the MAPE obtained with the ARRES algorithm is 7.26%, while the MAPE of the Grid Search and ARRES optimization algorithms is 6.38%.

m. Wiremesh Product Production.
MAPE prediction of wiremesh production so that the MAPE obtained with the ARRES algorithm is 9.81%, while the MAPE of the Grid Search and ARRES optimization algorithms is 7.18%.

The following outlines a summary of the conclusions of the MAPE test results shown in Table 3 and Figure 3.

Table 3. MAPE Testing Results of All Product Production

No.	Product Name	MAPE ARSSES	MAPE *Grid Search* + ARSSES
1	Ash	9.10	7.75
2	Concrete	7.20	6.00
3	Cnp	7.64	6.12
4	Flat Bar	8.88	7.67
5	Hnp	11.40	11.03
6	Wire	9.63	8.06
7	Nipple	8.47	7.65
8	Pipe	4.15	3.64
9	Plate	7.57	6.96
10	Elbow	9.10	7.04
11	Channel	7.26	6.45
12	Wf	9.16	6.38
13	Wiremesh	9.81	7.18
	Average	**8.18**	**7.07**

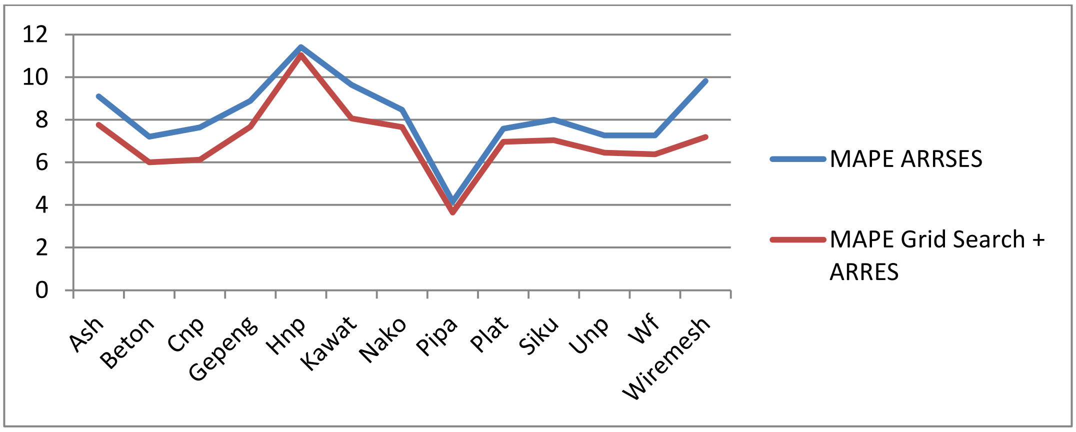

Figure 3. Graph of MAPE Testing Results for All Product Production

Based on Table 16 and Figure 3, it can be seen that the average MAPE value of the ARRES method of 8.18% was successfully reduced to 7.07% through the application of Grid Search + ARRES. This decrease in MAPE shows that the combination algorithm is able to produce more accurate predictions. In addition, if it is related to Table 2.2, namely the interpretation of the MAPE value, the results show that the combination of the Grid Search + ARRES optimization method has a high level of prediction accuracy.

In addition, the results of this study prove that integrating Grid Search with ARRES can help companies cope with unexpected demand fluctuations by predicting production needs more precisely. The increased accuracy allows for production planning that is more responsive to changes in market demand, thus assisting companies in adjusting production levels to actual needs.

CONCLUSION

Based on the research conducted, the combination of Grid Search and ARRES algorithms proved effective in predicting production needs at PT Bilah Baja Makmur Abadi. This method managed to significantly reduce the average MAPE value from 8.18% (ARRES alone) to 7.07%, indicating that Grid Search optimization is able to improve the accuracy of ARRES model parameters. With a high level of accuracy (MAPE < 10%), this method can cope with unexpected demand fluctuations. In addition, more accurate predictions from the combination of these algorithms can reduce the risk of dead stock and improve the company's operational efficiency. Future research is expected to improve forecasting accuracy by using datasets with longer periods. In addition, the integration of methods such as Bayesian Optimization or Genetic Algorithm can further optimize the results. The development of a web-based system also allows the application of this method on a wider industrial scale.

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