



Lecture Notes in Mechanical Engineering

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Mohammad Osman Tokhi *Editors*

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Lecture Notes in Mechanical Engineering

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Preface

We are delighted to present the proceedings of the fourth edition of the 6th International Manufacturing Engineering Conference and the 7th Asia-Pacific Conference on Manufacturing System (iMEC-APCOMS 2024), hosted by Universiti Malaysia Pahang Al-Sultan Abdullah through its Faculty of Manufacturing and Mechatronic Engineering Technology. Held on September 11 and 12, 2024, the conference embraced the theme of “Sustainable Development Goals through Innovative Manufacturing Engineering.”

iMEC-APCOMS 2024 has attracted a remarkable 99 submissions, all of which underwent a rigorous single-blind review process. Based on the recommendations of our dedicated reviewers, 44 papers were selected for publication in Volume 1 of the conference proceedings. We are immensely grateful to all contributing authors whose research has added great value to this collection. Each paper in this volume was thoughtfully evaluated by our esteemed technical review committee, comprised of leading experts in manufacturing engineering.

The conference served as a vibrant forum for the exchange of pioneering ideas and insights, highlighted by keynote presentations from distinguished speakers, including Prof. Ir. Dr. Nik Mohd Zuki Nik Mohamed (Universiti Malaysia Pahang Al-Sultan Abdullah, Malaysia), Prof. Dr. Cucuk Nur Rosyidi (Universitas Sebelas Maret, Indonesia), and Prof. Dr. Ir. Anas Ma'ruf (Institut Teknologi Bandung, Indonesia).

In closing, we hope that readers find this volume insightful and enriching. Our sincere appreciation goes to Springer Lecture Notes of Mechanical Engineering for their invaluable support in bringing this publication to life. Additionally, we extend our heartfelt thanks to the conference organizers and the dedicated members of the Conference Committee, whose tireless efforts made iMEC-APCOMS 2024 a resounding success.

Pekan, Malaysia
Pekan, Malaysia
Surakarta, Indonesia
London, UK

Siti Nadiyah Mohd Saffe
Siti Zubaidah Ismail
Cucuk Nur Rosyidi
Mohammad Osman Tokhi

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The Support Vector Regression Method with the Grid Search Algorithm in Forecasting Sales of Milk Product



Nailah Khalishah Auliyaanisa, Rina Fitriana, and Elfira Febriani Harahap

Abstract The sale of dairy products has always been in the top five with the highest sales value from 2021 to early 2024, although the monthly sales value of the dairy product is quite fluctuating. There was a problem in predicting demand that was less accurate compared to actual demand in the market, which then had a significant impact on the company's operations. The analysis of the forecast of the sale of dairy products has become crucial with the aim of avoiding a shortage or surplus of supplies that could affect the performance of the warehouse and the quality of the service. The objective of the study is to model the sales experience in the first five months of 2024 using the Support Vector Regression (SVR) method, analyze the accuracy of predictions, and create a dashboard of prediction results using Power Business Intelligence (Power BI) software, and verify and validate the research that has been done. Based on calculations with SVR, the best kernel obtained is the Linear kernel with a Mean Absolute Percentage Error (MAPE) value on the training data of 1.749% which belongs to the category of highly accurate predictions and the value of the determination coefficient of 0.98, whereas for the data testing, the result of the Mean Absolute Percentage Error (MAPE) of 0.843%. which falls into the very accurate forecasting category and the determining coefficient value of 0.794 so it can be concluded that the predictive model capabilities used can be effectively applied to the prediction of the sale of dairy products.

Keywords Sales forecasting · Support vector regression · Grid search · Power business intelligence

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1 Introduction

Inventory management is a process where inventory items are stored in warehouses or other storage areas, in this process an item is received, tracked, audited, and managed to fulfill orders [1]. Inventory management is an activity that determines the level and composition of inventory, raw materials, and manufactured goods or products so that companies can control their production and sales processes effectively and efficiently [2]. Sales forecasting is an effort to reduce the chance of problems in actual conditions that will occur in the future based on previous estimates [3]. Sales forecasting has a role in decision-making in manufacturing and service companies. By forecasting sales, companies can predict uncertain events and mitigate risk [4]. Sales forecasting is very important for many companies because it determines production planning, inventory, and many other aspects of a company's existing operations. Therefore, companies are always looking for ways to get more accurate sales predictions [5].

Several methods can be used to perform demand forecasting. One of them is to use the method of SVR. Based on research that has been conducted by [6], demand forecasting is carried out using the method of SVR by using sales data of 3 types of bread with data types time series. In research conducted by [7] demand forecasting was carried out on three types of onion seeds. In this study, calculations were carried out using the method Holt-Winters and SVR. It was found that the method used could provide an accurate estimate for all three types of leek seed varieties. Further on the research conducted by [8] forecasting water demand in urban areas and for individual consumption in the city of Milan. This research was conducted using a methodical approach SVR. Based on the results of data processing, it can be concluded that there is an increase in the accuracy of the forecasting value of water demand in the city of Milan. In addition, this method is also often used in forecasting types that have a non-linear distribution such as forecasting the number of confirmed cases of COVID-19 [9], support vector machines produce better results compared to both time series methods and artificial neural networks [10], in predicting the value of stock indices [11], forecast demand for long-sleeved shirts ARIMA (Autoregressive Integrated Moving Average) model [12], Prediction is using the Machine Learning methods, namely the SVR algorithm [13], and predicting currency exchange rates [14].

In addition, based on research that has previously been carried out comparing various forecasting methods, the SVR method is proven to have a better level of forecasting accuracy compared to other methods, as seen in research [15] which compares the SVR method with the ARIMA method. In [16] the research compares the performance of the SVR method and Artificial Neural Network (ANN). Inventory information system proposals are made to provide information on the availability of goods and spare parts that need maintenance [17]. This research compares the SVR method with the Artificial Neural Network (ANN) method method [18], in research [19] which compares forecasting using the Triple Exponential algorithm Smoothing (TES) with SVR method, and in study [20] which compared Simple Linear Regression method with SVR. The results of previous studies showed that

forecasting results using the SVR method had better accuracy than other methods. Besides that, the Support Vector Regression method is suitable for random data types or data with non-linear types [21]. Key findings reveal a correlation between defects and varying colors as identified by the Apriori algorithm [22].

The company currently faces issues with demand forecasting, resulting in inaccuracies compared to actual market demand. This leads to the company needing to supply additional products, as actual demand often exceeds forecasted values. These forecasting errors impact the company significantly, causing inventory shortages and excesses. This product shortage and excess stock mainly occurs in dairy products because demand is very high and has always been in the top five with the highest sales value and quite fluctuating. This study aims to improve demand forecasting using the Support Vector Regression (SVR) method, known for its suitability in short-to-medium-term forecasting and its proven accuracy. The goal is to model sales for the first five months of 2024 using the Support Vector Regression method, analyze forecasting accuracy, validate the results against actual sales, and create visual data dashboards with Power Business Intelligence (Power BI).

2 Literature Review

2.1 Support Vector Regression

Support Vector Regression (SVR) is the application of the method SVM used in regression cases. SVR methods can be applied to data Time Series, data that is not normally distributed and data that is not linear [9]. The purpose of using the SVR algorithm is to determine the dividing line called the best Hyperplane. The best hyperplane can be found by measuring the margin value with the hyperplane. The margin is the distance value of the hyperplane with the value of the support vector. Value Support vector is the closest data from the margin [6]. SVR function can be formulated in the following equation:

$$f(x) = \sum_{i=1}^I (a_i - a_i^*) K(x_i, x) + b \quad (1)$$

where:

- $a_i - a_i^*$ Multiplier Langrange
- $K(x_i, x)$ Kernel functions
- b Constant.

2.2 *Kernel*

Support Vector Regression can be modified by transforming kernel functions. A kernel function is a function that maps data features from a low initial dimension to a higher dimension [10]. There are various types of kernels, namely linear, polynomial, Radial Basis Function (RBF), and sigmoid. Here is the formula for each kernel type [14]:

1. Kernel Linear

$$K(x, y) = x^T y + c \quad (2)$$

2. Kernel Polynomial

$$K(x, y) = (ax^T y + c)^d \quad (3)$$

3. Kernel Radial Basis Function

$$K(x, y) = \exp(-\gamma \|x - y\|^2) \quad (4)$$

4. Kernel Sigmoid

$$K(x, y) = \tanh(\gamma X * Y + c) \quad (5)$$

2.3 *Grid Search Algorithm*

To obtain an SVR model with optimal C , ϵ , and γ parameters, the grid search algorithm tries to combine parameters one by one and compare the smallest error values of each parameter [10]. GridSearchCV is a method for selecting combinations of models and hyperparameters that tests each combination and performs validation for each combination. This method automatically validates each combination of model and hyperparameter so as to save processing time [11]. Here are the inputs, processes, along with Output GridSearch algorithm.

Input: Time Series $\{x_i\}_{i=1}^n$, $x_i \in \mathbb{R}^d$

Output: Optimal Kernel Parameters

1. while validation error ≥ 0 do
2. Init, kernels; Lag k_x , k_y p // sample from grid
3. $X \rightarrow \left\{ \left[x_i^{(1)}, \dots, x_{i-p}^{(1)}, x_i^{(d)}, \dots, x_{i-p}^{(d)} \right] \right\}_{i=p+1}^{n-1}$ // AR format
4. $Y \leftarrow \left\{ [x_{i+1}] \right\}_{i=p+1}^{n-1}$ // one step ahead
5. $K(\mathcal{X}) \leftarrow X$, $K(Y) \leftarrow Y$ // matrices kernels
6. H , $A \leftarrow (K(\mathcal{X}), K(Y))$, // Eigen-Decomposition Equation.

2.4 Measurement of Forecasting Results

After getting the best parameter results, calculations are made on evaluation metrics, such as Mean Absolute Percentage Error (MAPE) and and R-squared (R^2). The MAPE equation can be formulated as follows [23]:

$$\text{MAPE} = \frac{1}{m} \sum \left| \frac{Y_i - X_i}{Y_i} \right| \quad (6)$$

where:

- Y_i Actual demand in period i
- X_i Forecasting demand in period i
- m Number of periods.

In addition, stiffened R-Squared calculations (R^2) as coefficient of determination. Values can indicate the goodness of the model R^2 [12]. The equation can be formulated as follows R^2 [24].

$$R^2 = 1 - \frac{\sum_{i=1}^m (X_i - Y_i)^2}{\sum_{i=1}^m (\bar{Y} - Y_i)^2} \quad (7)$$

where [12]:

- R^2 Regression line coefficient of determination
- X_i Value actual non-free modifiers on era i
- Y_i Value non-free modifier predictions on era i
- $\bar{Y}$ Nilah average non-free modifier.

3 Method

At the research stage which can be seen on Fig. 1, input data on dairy product sales from 2021 to 2023 was carried out. After that, data preprocessing is carried out, which consists of checking the missing data, dividing the data set into training data and testing data, determination of independent (X) and dependent (Y) variables, and normalizing data. Then data processing is carried out using the SVR method. In this process, the Gridsearch algorithm is used to determine the best parameter turning value on each kernel. The results of this forecasting will show MAPE and R-squared values for testing data and training data. Then demand forecasting is carried out for the next 5 months in the early 2024 using kernel types with the best MAPE and R-squared values. Then the forecasting results will be visualized on the dashboard using Power BI software.

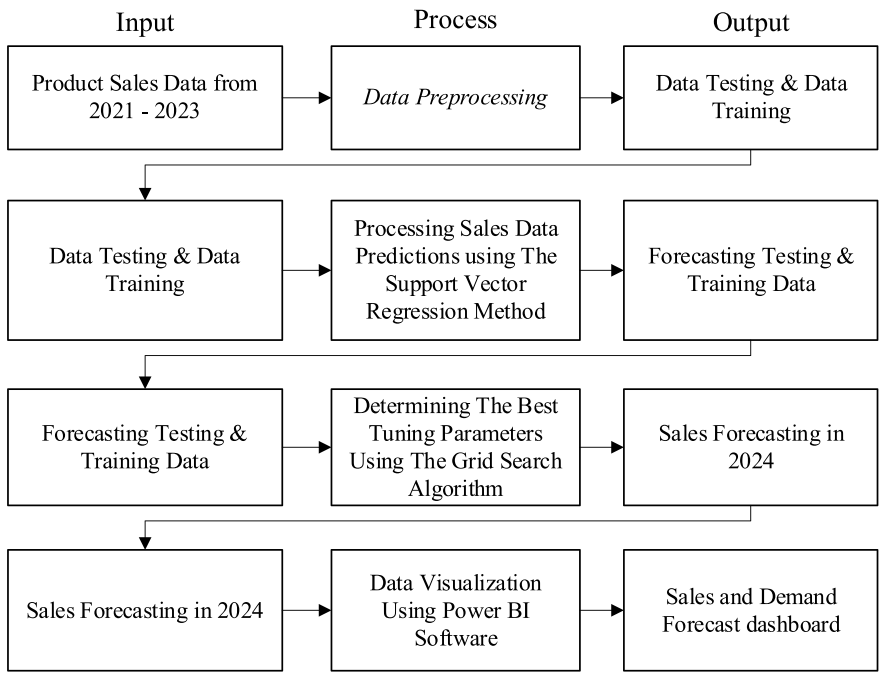


Fig. 1 Research method

4 Results and Discussion

The data processing process that will be carried out consists of conducting input and preprocessing stages of sales data, sharing training and testing data, modeling Support Vector Regression using the GridSearch algorithm to find the best parameters, evaluating accuracy with MAPE and R-Squared, and forecasting results for the next 5 months. Followed by designing dashboards using Power BI.

In data processing, Descriptive Analysis is carried out which aims to obtain an overview or characteristics of dairy product sales data. The results of the descriptive analysis of dairy product sales are presented in Table 1.

Based on the calculation results in Table 1, information can be obtained regarding descriptive analysis of the data. This provides a fairly representative picture of the distribution of data. Thus, the results of the above descriptive analysis can provide a deeper understanding of the characteristics and distribution of the total number of dairy product sales during the time period reviewed.

At the next stage, pre-processing data is done to convert the original data into a format suitable for use as input in prediction models. In addition, this process aims to improve the accuracy of analysis results and reduce the required computational time [12]. Pre-processing Data includes checking missing data, dividing data sets into training data (Training) and test data (Testing), determination of independent (X) and dependent (Y) variables, and normalizing data. In conducting model development using the method, the dataset will be separated into two parts, namely into data Training and Testing, where 80% of the dataset will be allocated to the Training, while 20% will be used for parts Testing. 80% of the total data is used as datasets Training, which includes sales data from January 2021 to April 2023, while the remaining 20% is used as a dataset Testing, which runs from May 2023 to December 2023.

Plot the results of data sharing Training and data Testing As can be seen in Fig. 2, this graph displays two lines representing two different sets of data. Data Training or 29 data for 29 months, shown in a blue line and for data Testing or test data as much as 8 data for 8 months, displayed in orange line. In the next stage, determination of research variables is carried out. This research is a research using Supervised Learning then used variables Input and Output [11]. The variable 'x' is used as the input variable used in forecasting. The value of variable 'x' is obtained from the data index and is transformed into a 2-dimensional matrix to fit the shape required in doing modeling, so it is made with the formula $[-1, 1]$, The variable 'y' is used as a variable output or the target to be predicted. After that, data normalization is carried out. In this study, a data normalization process was carried out using Library StandardScaler

Table 1 Analysis descriptive

	Count	Mean	Std	Min	25%	50%	75%	Max
Total value	37	5885.16	1037.35	4134	4810	6234	6766	7215

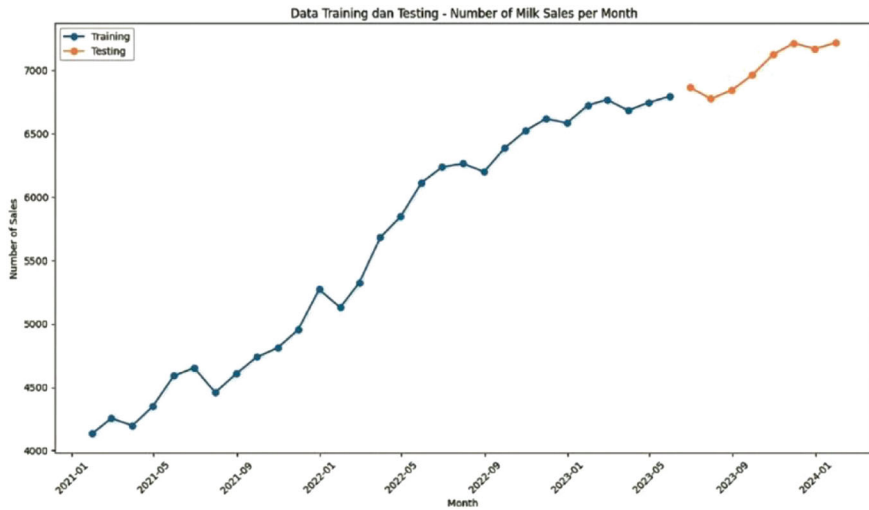


Fig. 2 Data training and testing

and MinMaxScaler. Preprocessing method known as StandardScaler done to prevent data from having too high a value compared to other values, which can lead to an unintended training process [25].

Once done Pre-processing the data, the next stage is to determine the best turning parameters. This stage is done to get optimal parameters on each kernel which will later be applied to the model Support Vector Regression [12]. In this study, the best parameters in the kernel function were obtained using an algorithm grid search. Algorithm Grid Search used by trying multiple parameter values over a specific range to build hyperplane [13]. There are various types of kernel, namely linear, polynomial, radial basis function (RBF), and sigmoid. The results of the evaluation of the best hyperplane parameters and MAPE values for each kernel type in the training data can be seen in Table 2.

Based on Table 2, it can be concluded that Based on the results of MAPE and R-squared as the determination coefficient, the Linear kernel type has a parameter value hyperplane best with the lowest MAPE is as high as 1.749% which belongs to the category of highly accurate forecasting and the value of the coefficient of determination as much as 0.98 which can be concluded that the ability of the forecasting model used is good [12, 26].

In the next stage, an evaluation of forecasting is carried out using testing data whose results can be seen in Table 3.

Based on Table 3, it can be concluded that Based on the results of MAPE and R-squared as the determination coefficient, the Linear kernel type has a parameter value hyperplane best with the lowest MAPE is as high as 0.843%. which belongs to the category of highly accurate forecasting and the value of the coefficient of determination amounting to 0.794 which can be concluded that the ability of the

Table 2 MAPE value and R-squared data training

No	Kernel type	Parameter	Best value	MAPE (%)	R-squared
1	Kernel linear	C (cost)	0.1	1.749	0.980
		ε (epsilon)	0.5		
2	Kernel polynomial	C (cost)	10	2.157	0.973
		ε (epsilon)	0.0001		
		d (degree)	2		
3	Kernel radial basis function	C (cost)	100	6.49	0.786
		ε (epsilon)	0.001		
		γ (gamma)	0.00001		
4	Kernel sigmoid	C (cost)	1	15.96	-0.022
		ε (gamma)	0.00001		

Table 3 MAPE value and R-squared data training

No	Kernel type	Parameter	Best value	MAPE (%)	R-squared
1	Kernel linear	C (cost)	0.1	0.843	0.794
		ε (epsilon)	0.5		
2	Kernel polynomial	C (cost)	10	1..33	0.436
		ε (epsilon)	0.0001		
		d (degree)	2		
3	Kernel radial basis function	C (cost)	100	13.82	-37.76
		ε (epsilon)	0.001		
		γ (gamma)	0.00001		
4	Kernel sigmoid	C (cost)	1	17.87	-55.463
		ε (gamma)	0.00001		

forecasting model used is good [12, 26]. At the next stage, the forecasting results were plot using the kernel with the best parameter value previously obtained, namely by using the Linear Kernel with the best C parameter value of 0.1, the best ε value of 0.05. The plot of forecasting results can be seen in Fig. 3.

At the final stage of the dairy sales forecasting process, revalidation of the total actual sales value in 2024 sales is carried out. The following is a comparison between the forecasting value of sales and actual sales for February and March 2024 can be seen in Table 4.

Based on Table 4, It can be stated that the results of sales forecasting using the Support Vector Regression method are considered better in forecasting dairy product requests at PT XYZ because the average difference between actual sales and prediction value is only 30 cans of milk. In the last stage, data visualization is carried out using Power BI software. This is done to make it easier to read data and when

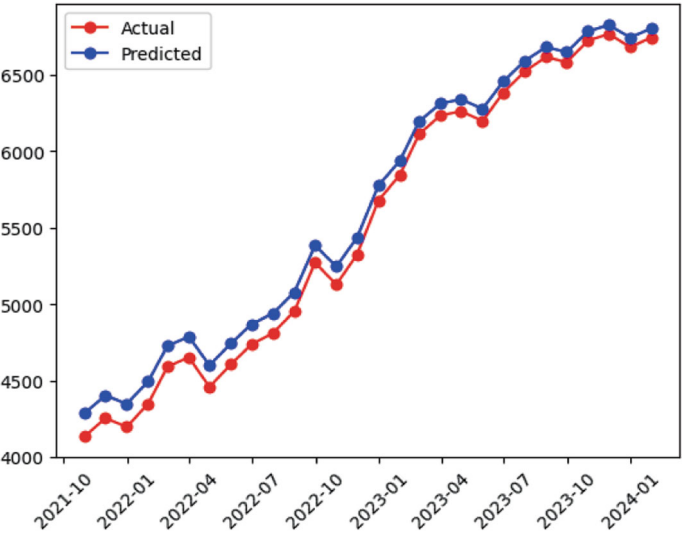


Fig. 3 Sales forecasting

Table 4 Predictions versus current milk sales 2024

Month	Prediction with support vector regression method	Actual sales
January	7256	7218
February	7298	7258
March	7339	7316
April	7378	7359

the Company wants to pre-order or order products to suppliers, it can immediately see on the existing dashboard.

Figure 4 is an overall visualization of the Demand Planning Dashboard containing information related to year, month, and product SKU numbers that allow users to select a specific time period to view sales data and sales forecasting. Data is presented in graphic and numeric formats, providing ease in reading and analyzing information.

4.1 Verification and Validation

4.1.1 Verification

As a form of verification, the company has conducted an evaluation that shows that the Support Vector Regression method provides better results than previous forecasting methods that have been used. This evaluation is based on a comparison of sales

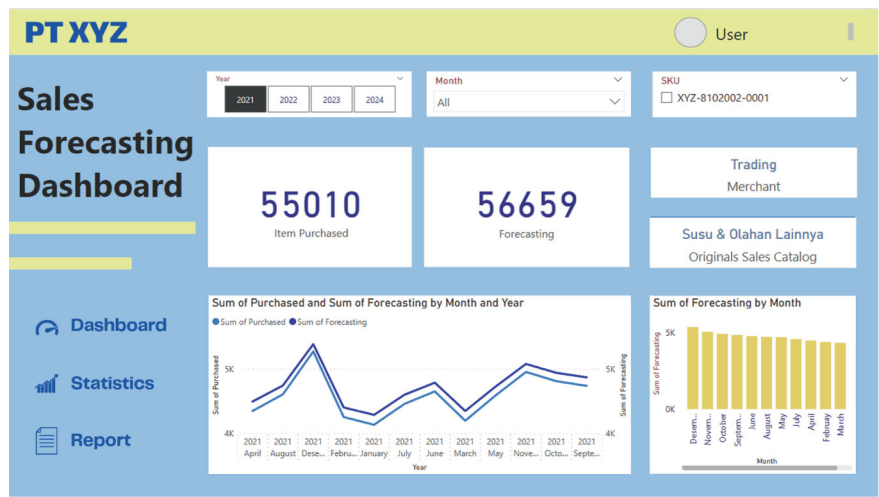


Fig. 4 Visualization of the entire dashboard

forecasting results between the current method, forecasting results with the Support Vector Regression method, and acute sales value in February and March 2024. Based on the calculation of the difference between forecasting values and actual sales, it can be concluded that the Support Vector Regression method gives much better results. This is proven by the calculation of the difference between prediction and actual sales using the Support Vector Regression method, there is only an average sales difference of 30 cans.

4.1.2 Validation

After validation, the company concluded that SVR is better at forecasting than previously used methods. In-depth evaluation shows predictions that are more accurate and closer to actual values, with a much smaller margin. The company recognized the potential of SVR in improving forecasting accuracy and planned custom dashboards with Power BI for data visualization, although its implementation took time as it involved coordination with technology teams and related departments.

4.2 The Role of Business Intelligence Systems

Business Intelligence Systems have an important role in two main aspects, namely updating forecasting methods and creating dashboards or databases. In the case of forecasting method updates, the system can enable more efficient inventory planning by accurately identifying demand trends, thereby reducing the costs and risks

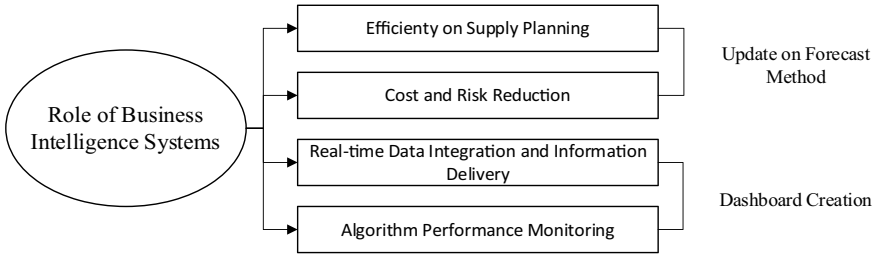


Fig. 5 The role of business intelligence systems

associated with improper inventory. In addition, in terms of creating dashboards or databases, this system can integrate data from various sources to provide real-time information, as well as monitor the performance of forecasting algorithms to ensure an optimal level of forecasting accuracy. Business Intelligence systems play a role in optimizing smarter planning and decision-making strategies for companies [27]. The role of business intelligence systems can be seen in Fig. 5.

5 Conclusion

Based on the results of forecasting using the Support Vector Regression method, it was obtained that the Support Vector Regression model with the Linear Kernel with the best C parameter value was 0.1 and the best ϵ value was 0.5, is the model with best forecasting accuracy value with the lowest MAPE in experiments on training data which is 1.749% and the value of R-Squared is 0.98 that is included in the category of very accurate forecasting. For testing data, MAPE results are obtained of 0.843% and the value of the R-squared is 0.794 which can be concluded that the ability of the forecasting model used is good. Based on the results of verification and revalidation of the actual sales value of milk products in sales in 2024, there is only a difference of 30 cans of milk. This is considered much better than the forecasting results used by the company currently. It can be concluded that the Support Vector Regression method more accurate forecasting results than the method currently used by the company. The company also plans to develop a special dashboard that uses the Power BI platform. Data visualization is carried out using Power BI software that can visualize sales forecasting data, total sales data, and information about merchants and product categories. Equipped with year and month filter options that make it easy to read detailed data.

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