Online Reverse Auction System at Universities Based on Business Intelligence

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Abstract. Procurement activities at Universitas Surabaya in Surabaya utilize an information system to obtain goods or services at the best price, meeting various requirements. However, this system is still inadequate to address issues such as the unorganized flow of procurement documents and the lack of system capability to compare budgets and actuals. This study used the waterfall method to develop a better system by implementing business intelligence. Trials and evaluations were conducted using data from the university's procurement unit. The results showed that the new system can maintain the order of procurement documents and demonstrate a good comparison between budgets and actuals. Therefore, it was concluded that this application can assist in monitoring the procurement process at the university.

1 Introduction

Effective procurement is crucial for organizations and can provide a competitive advantage through various strategies, potentially adding value to the organization [1]. Procurement plays a crucial role in the process of discovering, approving requirements, and purchasing goods, services, or projects through bidding or tenders, with the goal of obtaining the best price commensurate with several aspects such as quality, quantity, time, and location [2]. According to interviews with the procurement unit at Universitas Surabaya, the procurement process in that organization begins with the creation of a Request Letter, continues with the auction and the creation of a Purchase Order (PO), and ends with the receipt of goods and payment. In practice, this process can sometimes become problematic due to inadequate monitoring, resulting in several asset requests failing to materialize.

According to Kuc et al. [2], in an analysis of the procurement process at universities in Vietnam, the process was deemed too lengthy and resulted in stakeholders' needs not being optimally met. Furthermore, failures in cost control risk slowing down operational management. Therefore, Kuc developed recommendations focused on procuring learning equipment and facilities, finding appropriate ways to control finances, decentralizing and simplifying the purchasing process, and conducting a survey of the campus community regarding equipment needed for teaching and learning. Meanwhile, a study of procurement

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procedures at a University in Surakarta, identified anomalies that resulted in poor fixed asset management due to procurement not being in accordance with the original plan. Negligence contributed to inconsistencies in procurement, as the procurement team lacked an integrated monitoring system to oversee the procurement process [3].

Based on interviews with the procurement unit at Universitas Surabaya, the problems described above also occurred in its procurement process. This suggests the need for solutions to improve business processes within procurement. Monitoring and visualization of existing data can help organizations conduct current business process analysis, improve business process effectiveness, and manage procurement processes within sustainable supply chain management [4]. Therefore, creating an information system focused on monitoring an organization's asset procurement is an appropriate solution. With a computerized system for monitoring procurement activities, data and information exchange will be faster and more transparent due to digital data visualization [5]. Many of the lengthy processes that still involve traditional methods can also be delegated to the system. This application is expected to streamline procurement processes within the organization.

The purpose of this research is to develop a procurement flow monitoring application at university that can assist in monitoring the procurement business process flow. Furthermore, this application is expected to assist external stakeholders in monitoring transactions related to them, such as tender winners who can monitor purchase orders and ongoing invoices. Ultimately, it can assist the organization in obtaining information regarding its assets.

2 Research methodology

The research was conducted according to the stages of the system development life cycle, using the waterfall method.

2.1 Preparation

This activity consists of several activities, namely:
1) Conducting a literature review of various literature related to the topic.
2) Gathering information from several organizations regarding the needs and business processes in asset procurement. The methods used were interviews and direct observation.

2.2 Analysis

The analysis phase focuses on analysing the current situation using the information obtained in the preparation phase, followed by benchmarking against similar systems. From these activities, a system overview and requirements can be generated to provide solutions to the problems faced by the organization.

2.3 Design

Equipped with the output in the form of a system overview and requirements from the previous phase, the design phase creates an Entity Relationship Diagram (ERD) to design the model and data storage settings in the database, a Business Process Model and Notation (BPMN) to depict the system workflow, and a User Interface (UI) as an initial depiction of the system's appearance.

2.4 Implementation

The implementation phase is the phase where the results of the two previous stages are implemented, starting with the implementation of the SQL database and the implementation of the processes and system interfaces built using the Laravel framework, which includes all its features.

2.5 Testing and evaluation

In this phase, the completed system is tested using behavioural testing methods within the organization to determine whether the system is running properly and adequately in meeting needs, while minimizing program errors. The output from this testing can be used as an evaluation to make improvements to the system if necessary.

2.6 Report preparation

In this final phase, the report is prepared simultaneously with the system development process. The report is based on the output from the application development, including the processes involved.

In addition, several theoretical foundations are explored to support the preparation of the research. These theoretical foundations include theories on procurement, data analytics and business intelligence, push notifications, and reverse auctions. These theories are obtained by reviewing various related literature.

3 Theoretical basis

This theoretical foundation section explains the various theories and components used as the basis for developing the system in this research. Each subsection within this section is explained in detail and references reputable scientific articles.

3.1 Procurement

Procurement is the activity of acquiring goods to meet organizational needs, placing purchasing at the core of interactions with suppliers. This activity is considered an important and crucial business process. Because of its crucial role in managing the purchasing cycle, good procurement cannot be based on low purchase prices, but rather on the value provided to the organization. Therefore, to reduce costs, improve supply chain performance, and achieve organizational goals, an effective and efficient procurement process is necessary.

Due to the frequent misperceptions between procurement and purchasing, Barros et al. [6] divide procurement implementation into two main stages. This is done to demonstrate that procurement has a broader scope than purchasing, while purchasing is part of the procurement process. The two main stages in procurement are defined as strategic procurement and operational procurement.

3.1.1 Sourcing

Known as strategic procurement, this stage focuses on providing the necessary resources before purchasing activities occur. Several business processes include specification formalization, supplier selection, and the contract process, as explained below:

1) Specification formalization, this process regulates purchasing requirements and establishes decisions regarding how to acquire goods, whether through manufacturing or purchasing. Determining the functionality and specifications of the goods to be purchased are the first necessary step.
2) Supplier selection, to procure goods, an organization needs to find and identify potential suppliers. Before selecting a supplier, certainty is needed regarding several factors, such as supplier criteria and qualifications, subcontracting methods, and payment methods.
3) Contract process, before a contract is approved, an agreement is required regarding its contents, such as delivery terms and prices, payment terms, and warranties.

3.1.2 Purchasing

After strategic procurement is underway, the next stage is known as purchasing or operational procurement. The core of this process is executing purchasing activities, which are divided into three processes: ordering, monitoring, and evaluation, as explained below:
1) Ordering, this process begins by confirming the previously agreed contract terms and all consequences. Only then can a purchase order be placed with the supplier.
2) Monitoring, once a purchase order is created, monitoring of the order is necessary. A series of activities that can be carried out include discussing any changes to specifications, delivery dates, and verifying product delivery as agreed.
3) Evaluation, making complaints, activating penalty clauses (if any), and processing documentation during interactions with suppliers are key activities in this process.

For-profit organizations such as corporations are not the only ones that carry out procurement; non-profit organizations in the education, health, and humanitarian sectors also require it. In the education sector, procurement is categorized as an integral part of the educational supply chain management system [7], which plays a crucial role in realizing long-term value by reducing short-term costs. From this statement, it can be seen that educational institutions such as universities and schools require a strategic procurement system to support the provision of various equipment and facilities to ensure a quality teaching and learning process and minimize excess costs.

Effective procurement implementation is considered crucial because it is related to the flow of funds. Therefore, when organizations develop business plans and asset management strategies, it is appropriate to integrate the procurement process into both. Furthermore, there are three essential principles that must be considered in procurement implementation, including:
1) Transparency, which emphasizes fairness and proper documentation in the procurement process [8].
2) Accountability to those who have provided funds by adhering to existing procedures and regulations throughout the procurement process.
3) Cost management by prioritizing efficiency and effectiveness. This principle is established to fulfil six procurement regulations: price compliance, timeliness, quantity accuracy, superior service quality, suitability of delivery destination, and the most economical source of origin.

3.2 Data analytics and business intelligence

Focused on generating useful conclusions, data analytics falls within the scientific field related to the analysis of raw data. With a very broad scope of use, this science can be applied both to help companies and organizations make better business decisions [9] and to assist science in validating or testing the validity of models or theories [10]. This activity generally

uses structured data, namely data that has been organized into variables and parameters and is usually obtained from internal system databases, as the object of processing. In its implementation, data analytics is supported by several instruments such as statistics, mathematical algorithms, simulations, and graphics as tools to visualize the obtained output. In the realm of Supply Chain Management (SCM), data analytics is grouped into three types: descriptive analytics, predictive analytics, and prescriptive analytics.

Working to process large amounts of data into smaller pieces, Descriptive Analytics (DA) is classified as the simplest type of data analytics. Given that important information can come from large amounts of data, even too large for humans to comprehend, this method provides a solution by simplifying the data into several pieces of information [11] that are not only smaller but also more useful. Essentially, the essence of DA application is to discover information about past events by utilizing analysis of current conditions.

According to Mujawar & Joshi (2015), more than 80% of business analytics, particularly social analytics, are estimated to be descriptive in nature. Descriptive means providing an overview of existing data. This analysis is generally conducted as a first step in examining a data set and is used when the data to be studied is quite large. There are two types of descriptive statistical analysis: univariate and bivariate:

3.2.1 Univariate

Providing an overview of the distribution of a single variable in a sample is the goal of this analysis. Visualizing this distribution can utilize graphs as an alternative to tables. For example, if you want to display nominal data without any order, you can use a pie chart, while if you want to display ordinal or discrete categorical data, a bar chart is an appropriate option.

3.2.2 Bivariate

In contrast to univariate analysis, this analysis involves the relationship between two variables, namely the "outcome variable" and the "explanatory variable," each of which has a different set of values. From the results of this comparison, an evaluation can be conducted regarding how the value of an outcome variable is influenced or explained by the value of an explanatory variable. There are two versions of this analysis: dependence analysis and interdependence analysis. Dependence analysis describes how the outcome variable changes when the explanatory variable changes, with the relationship between the two variables being asymmetrical. Interdependence analysis describes how the values of the two variables correlate with each other, with a symmetrical nature.

As data documenting the past increases, DA methods, which initially only statically described past conditions, can evolve to rely on fast algorithms for repeated evaluation, classification, and categorization [10]. Past data is identified and analysed for patterns, so that problems and opportunities can be identified. Techniques used in DA can vary, including data modelling, regression analysis, visualization, and online analytical processing (OLAP).

Business Intelligence (BI) is the result of data analytics processing. Therefore, data analytics can also be considered a service that is a crucial component in developing BI [12]. Through good use of DA, BI can transform into an intelligent system, which is able to assist in decision making. Business intelligence has also been proven to be able to be used for data processing and visualization in the tertiary sector [13].

3.3 Push notification

Notifications automatically sent to the target device from a server are called push notifications. This technology enables the delivery of information without a request from the recipient. If new information is sent, the user immediately receives a notification on their device. This simplifies the process of receiving information, as users do not need to periodically open the application to check for new information. Examples of push notification implementations can be seen in SMS notifications and email notifications.

Generally, each operating system has a dedicated Push Notification Service (PNS) for sending push notifications. However, the use of Hypertext Transfer Protocol (HTTP) is a common feature implemented by each operating system, such as Apple, Android, and Windows Phone, to manage the presentation of information within a network. The push notification mechanism utilizes PNS as a broker on the web or Android smartphone, as shown in Figure 1, with the following explanation:

1) First, the client must register with PNS.
2) To ensure that notifications are sent correctly and accurately, the broker issues a token to the registered client.
3) The token is sent to the server after being received by the client and stored in the database.
4) The broker receives the notification sent by the server.
5) The notification received from the server is sent to the client according to the token previously stored in the database.

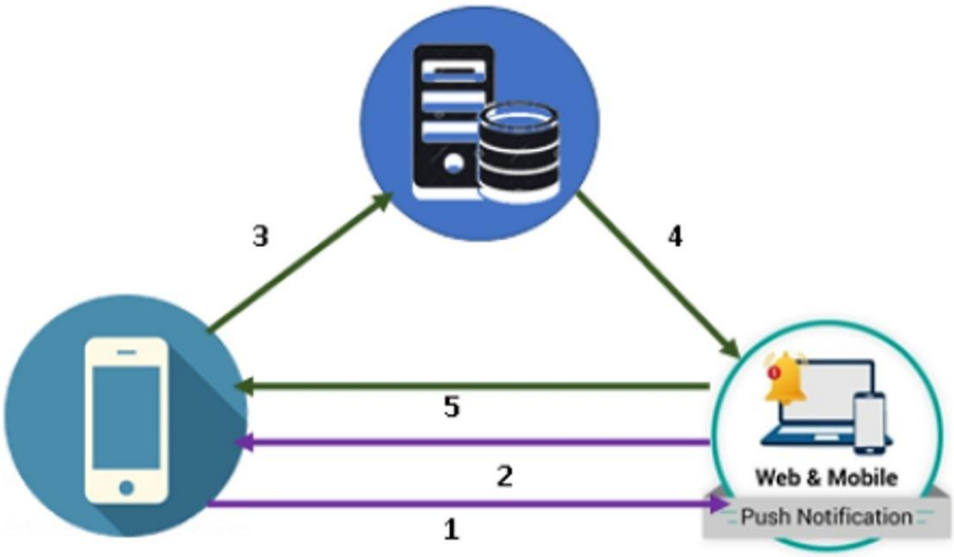

Fig. 1. Push notification mechanism [14].

3.4 Reverse auction

Along with forward auctions and double auctions, reverse auctions are classified as a type of auction, as illustrated in Figure 2. The figure shows that in a forward auction, the auction is conducted by a single seller selling to multiple buyers. In a reverse auction, however, the situation is reversed, with one buyer and multiple sellers. Combining the two previous auction types, a double auction involves multiple buyers and multiple sellers [15].

The reverse auction mechanism begins with a buyer announcing their need for goods or services, thus opening the way for vendors to compete to submit bids. Next, a winner is selected using specific evaluation rules. The convergence of multiple sellers for a single buyer in a reverse auction allows buyers the opportunity to obtain the lowest price offered by the sellers [15].

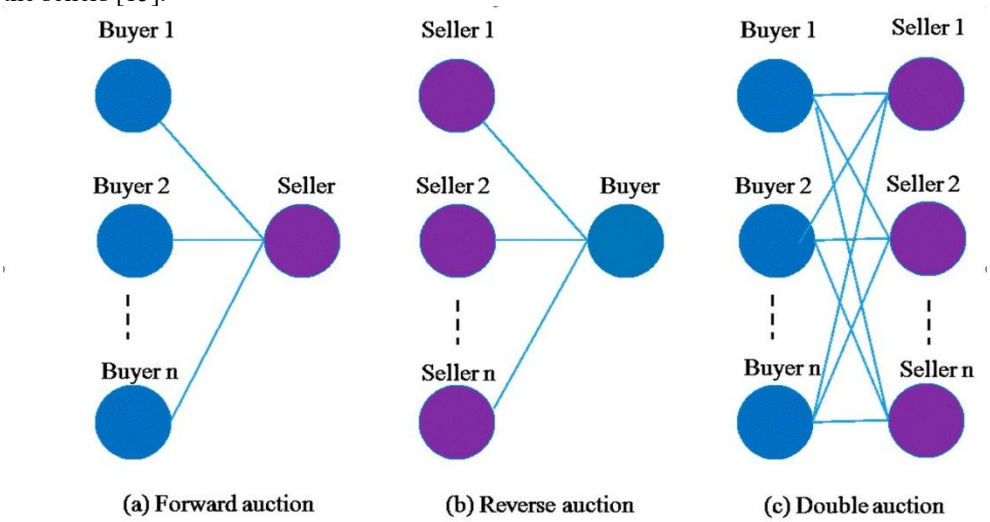

Fig. 2. Auction types [15].

There are several reverse auction implementation methods to choose from, including sealed, open, and semi-sealed bidding. In the sealed bidding method, each bidder cannot see the prices offered by their peers. Conversely, if the open bidding method is used, there is transparency in all price bids, allowing bidders to see the bids of all competitors. The final method, semi-sealed bidding, also does not allow bidders to see the prices submitted by competitors, but still provides access to their current ranking in the auction, based on a comparison of their bids with those of competitor.

4 Result and discussion

This section describes the data design and implementation, as well as the display implementation. The database design utilizes a MySQL-based ERD (Figure 3), while the main business process design is created using BPMN (Figure 4).

The application is implemented using XAMPP and phpMyAdmin, as well as the Laravel as MVC framework, using the PHP and JavaScript programming languages. The application's features include monitoring procurement activities as the primary focus, consisting of a dashboard for each role, sending emails as reminder notifications, data on goods requisitions and invoicing processes, auction and bid openings, procurement result reports, and other supporting master data such as goods data, user data, and requirements data. The application focuses on process monitoring in graphical form. The algorithm for creating the graphs can be seen in Algorithm 1.

The results of the display implementation are shown in Figure 5, which is the admin dashboard. The home page displays information related to goods requisitions, including items that need to be processed, items that have been approved for funding, items that need to be confirmed by the unit, items that require an order note, items that are late in being sent by suppliers, and unpaid invoices to suppliers.

Figure 6 shows the dashboard for the procurement unit leader. On this page, unit leaders can monitor the number of goods request letters with process and confirmation status, total budget and expenses for the last few periods, total and accumulated expenses from procurement activities, accumulated expenses between units, and the number of orders based on item category. If one of the data is clicked, for example a goods request letter that has been confirmed by the unit is clicked, the system provides details of the procurement letter in request, as in Figure 7. Meanwhile, if the unit leader gives a confirmation status to a particular request letter, the system automatically sends a notification email to the related unit, as in Figure 8.

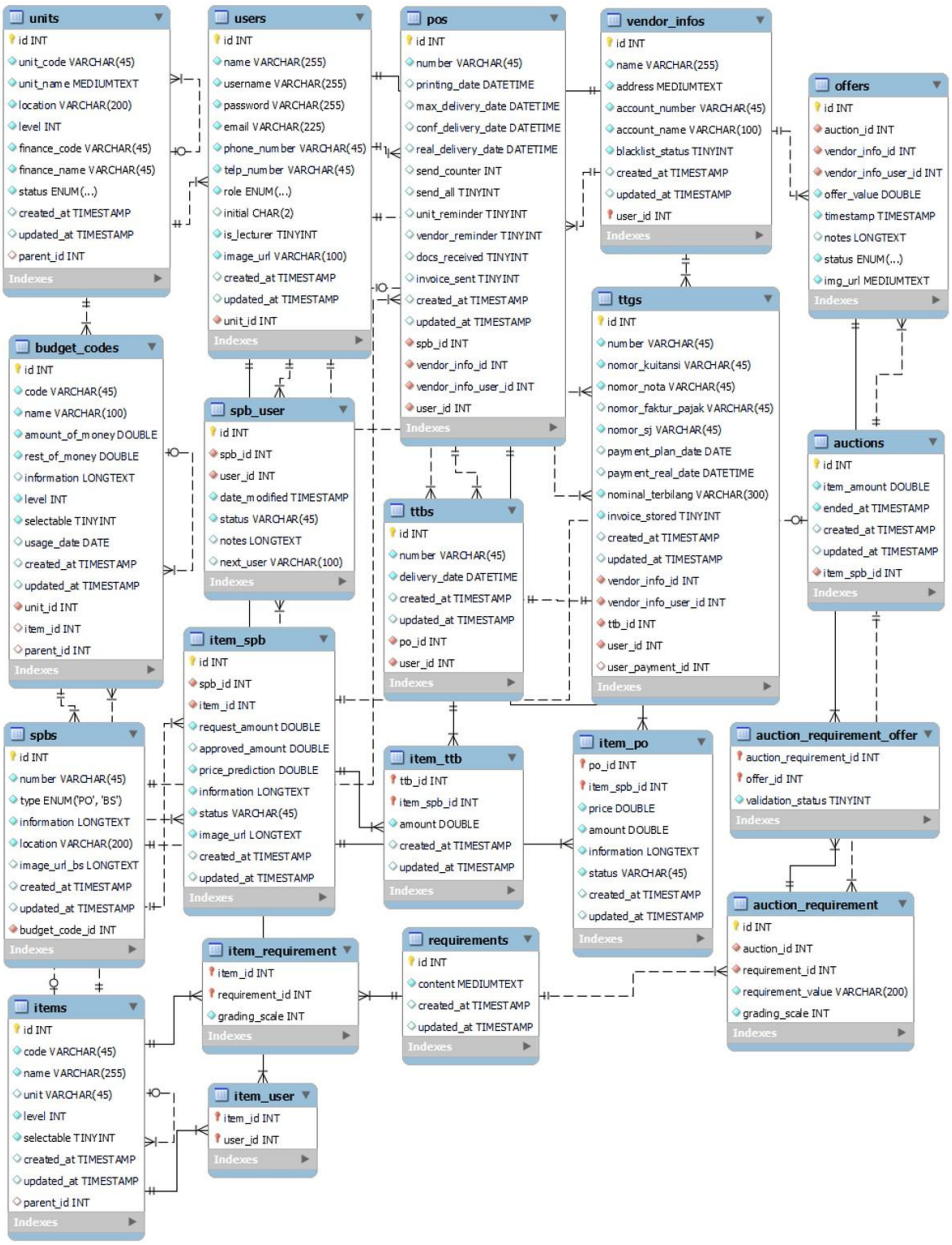

Fig. 3. Data design.

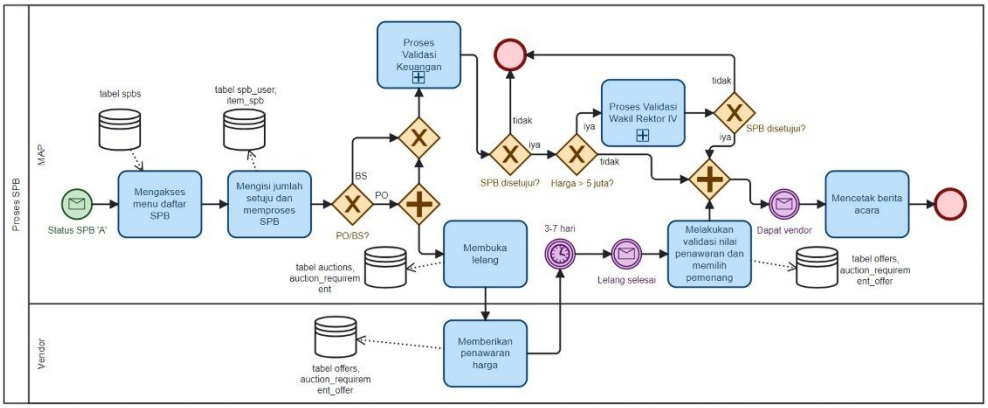

Fig. 4. Business process design.

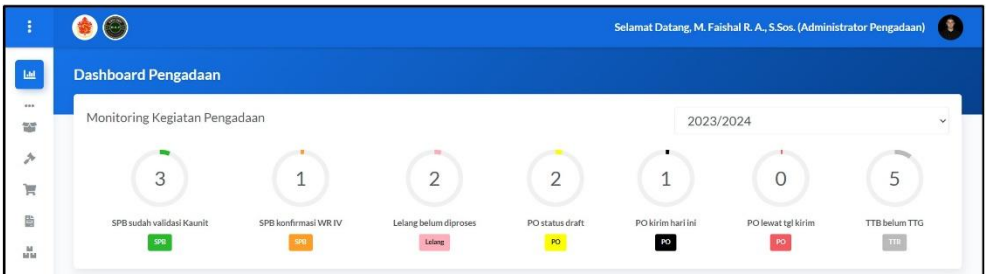

Fig. 5. Admin dashboard page.

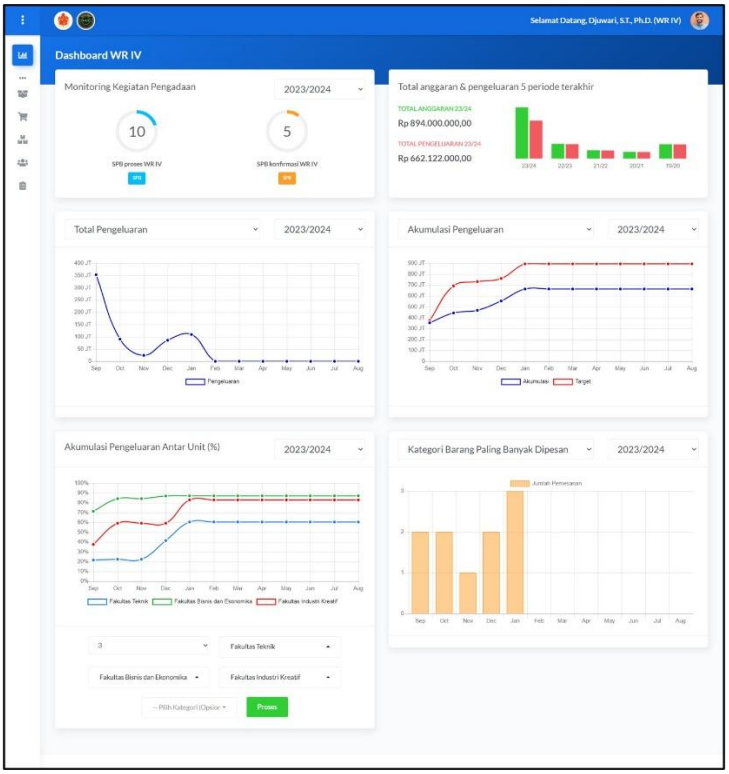

Fig. 6. Unit manager dashboard page.

Fig. 7. Data detail page.

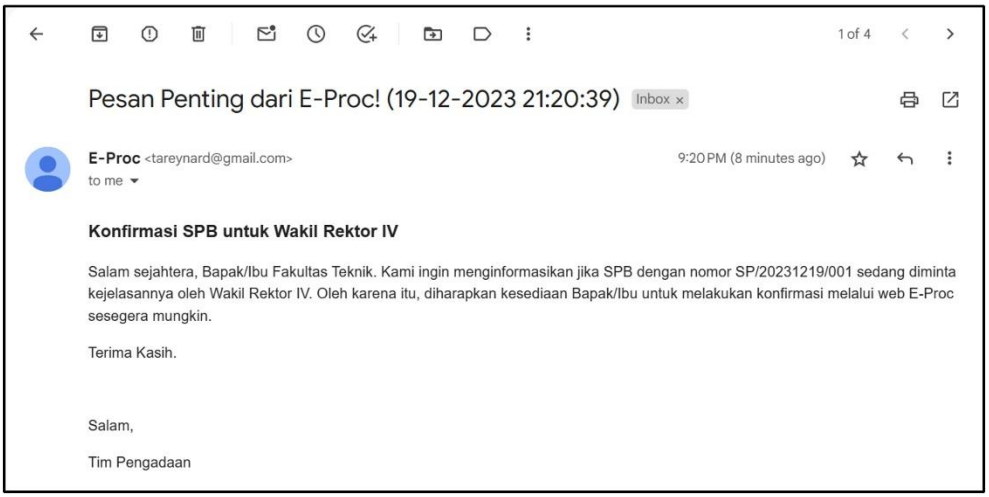

Fig. 8. Push notification via email.

Algorithm 1. Creating a budget realization graph.

1) Capture user-defined filters (item category, unit, year of occurrence).
2) Retrieve total budget data using planning time and total estimated planned value using the user-selected unit filter. The planning time falls within the year period entered by the user, and the item category matches the user's selection. The resulting data is grouped by transaction time (month). The source table for the data is SPB, User, Item.
3) Retrieve total realized value data using transaction time and total purchased value using the user-selected unit filter. The transaction time falls within the year period entered by the user, and the item category matches the user's selection. The resulting data is grouped by transaction time (month). The source table for the data is PO, Item, Category, User, SPB.
4) Create an array to store planned and realized value data for each month, while calculating the total budget and realization for the entire year. If the realization value is not available for a particular month (e.g., for the event year 2024, the realization for March is not yet available, as it is currently February), a marker is placed in the array indicating that there is no realization for that month.
5) Pass the array to the method in the JpGraph library to begin drawing the required graph.

Application testing was conducted with the involvement of the goods and services procurement unit of the research object. Consequently, the data obtained from the trial is primary data. The software evaluation method used qualitative techniques, namely by conducting a trial of application usage with potential users from the procurement unit while also conducting direct interviews. Through all application features demonstrated to users, responses were obtained that the application is suitable for solving problems encountered during the goods and services procurement process.

5 Conclusion

Developing a business intelligence application for monitoring procurement flows at Universitas Surabaya can assist in monitoring the business process flow within procurement. Test results, including verification and validation, demonstrate that the application meets its stated objectives, enabling monitoring of a series of procurement processes. The system's features include data analytics on the dashboard, email notifications and reminders, and visualization of crucial data, such as SPB and TTG statuses.

Future research could focus on using machine learning or predictive analysis to forecast procurement needs at the Universitas Surabaya. Integrating these artificial intelligence concepts could enhance the benefits and value of the applications developed.

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