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Development of Performance Monitoring Dashboard for Product Packaging Manufacturer by using Waterfall Methodology

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Abstract. *Implementation of a robust and advanced management information system can enhance the organizational efficiency by streamlining data management, improving decision-making processes, optimizing resource allocation, and facilitating seamless communication across all departments. PT. MPM wanted to increase organizational efficiency but discovered that the organization currently lacks an appropriate system for measuring and monitoring the performance of its core processes. In this research, a business intelligence (BI) solution was used to address the issue by developing a BI dashboard, i.e., sales performance dashboard and production performance dashboard. The waterfall approach was used as the development framework and Google Data Studio was utilized for developing the dashboard itself. The BI Dashboard offered clear and understandable information, pertinent and accurate data, as well as an interactive user interface, so the implemented system aided the business in making decisions or developing a business strategy. The BI Dashboard was evaluated through alpha and beta testing, and the users were satisfied with the BI Dashboard with an average score of 82%.*

Keywords: *waterfall, google data studio, dashboard, business intelligence, management information system*

I. INTRODUCTION

Business intelligence (BI), a kind of contemporary information technology, enables businesses to collect, organize, and analyze data in both structured and unstructured forms (Lin et al., 2009; Nyblom et al., 2012). Thus, the field of information technology is generally interested in all aspects of the development, deployment, implementation, usage, and impact of information technology in businesses and society (Boell & Cecez-Kecmanovic, 2015). What matters in an information system is how technology is applied and used to enable the fulfillment of an information system that satisfies the information demands and requirements of different stakeholders in respect to certain objectives and practices (Lee, 2010).

In the face of ongoing alterations and intricacies within the business landscape, companies are compelled to expedite their decision-making processes due to the evolving circumstances brought about by various pressures. These decision-related endeavors demand substantial quantities of pertinent data, information, expertise, and sagacity. Moreover, all procedures within this framework must be executed with efficiency and proficiency, often necessitating computerized assistance (Turban et al., 2008).

BI can be defined as an umbrella term that spans people, processes and applications/tools to organize information, enable access to it and analyze it to improve decisions and manage performance (Hostmann et al., 2009). BI's main objective is to gain and accumulate business knowledge and insights, to make better business decisions, to make business operations more effective, to improve business processes, to promote business performances and to enhance competitive advantages in the market (Lu, 2014).

Additionally, according to (Gilad & Gilad, 1988), BI can be referred to as the processes, organizational functions, and products. In other words, BI is an activity carried out by BI employees to produce BI products. Instead of pure programming, which requires substantial knowledge and skill, BI systems today offer built-

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in features for point-and-click data visualization and analysis. These so-called management user interfaces have boosted the number of users for BI systems and provided whole new information management paradigms, like self-service BI.

Meanwhile, the phrase "enterprise dashboard" is used by (Malik, 2005) to refer to a computer interface that displays several charts, reports, visual indicators, and alarm systems on a dynamic and pertinent platform. While (Orts, 2005) used the word "dashboard" to describe a tool used to regularly monitor an organization. Decision-makers may obtain data that can be used to actively steer business performance by seeing Key Performance Indicators (KPIs) in a single interface. A group of indicators known as key performance indicators (KPI) concentrate on the aspects of organizational performance that are most important to the success of an organization (Parmenter, 2015). There is a helpful acronym for summarizing the fundamental features of an organizational dashboard, i.e., IMPACT (Interactive, More data history, Personalized, Analytical, Collaborative, Trackability) and SMART (Synergetic, Monitor, Accurate, Responsive, Timely) (Malik, 2005). Operational dashboards, tactical dashboards, and strategic dashboards are the three categories into which dashboards may be categorized based on the level of management they provide (Eckerson, 2006; Few, 2006).

A great tool for producing attractive and understandable data visualizations is Google Data Studio (Snipes, 2018). As part of Google's premium Analytics360 package, Google Data Studio was introduced in May 2016 and is a user-friendly tool for presenting complicated data sets in an engaging and understandable way (Snipes, 2018).

PT. MPM is the case study for this research. It is one firm that is interested in using BI solutions to enhance its operational performance. They are a regional producer of packaging based in Indonesia, providing a wide range of products. An efficient and strong information system is crucial, and BI solutions may be used to do this.

Due to the lack of a suitable application and/or system for properly assessing and monitoring performance, the top management ends up making decisions ineffectively, which reduces its competitiveness in relation to rivals. Therefore, this research attempts to provide a BI dashboard to help businesses monitor and evaluate the performance of their critical operations effectively and efficiently. This research is crucial for BI solutions through the development of a BI Dashboard for the organization, particularly in the operations department.

II. RESEARCH METHOD

The waterfall methodology was chosen as the approach for this research. Each activity will be thoroughly described, along with a list of required tools. Dr. Winston W. Royce was the pioneer in introducing the waterfall methodology as the inaugural approach in the software development lifecycle (SDLC) (Powell-Morse, 2016).The waterfall methodology, according to (Sherman, 2014), uses a sequential or linear approach to software development. The project is broken up into tasks, with phases being the highest-level grouping. A proper waterfall approach requires phases to be finished in order and to have clear exit criteria, frequently a project stakeholder sign-off. In the waterfall methodology, a necessity exists for thorough definition and precise documentation, which serves to prevent misunderstandings and communication gaps (Calvello, 2021). The waterfall methodology adheres to a predetermined sequence of stages, which can result in the creation of anticipated timelines and guarantee the project's punctual completion (Van Der Merwe, 2017). The waterfall methodology may be a suitable option for intricate projects characterized by clearly outlined requirements and unchanging timelines (Van Der Merwe, 2017). (Utami et al., 2023) used waterfall methodology for developing Yogyakarta web-based food recipe application and based on the test results using a black box, the system created has functional features according to what is expected. SDLC waterfall methodology also used in development of project management system and it can support

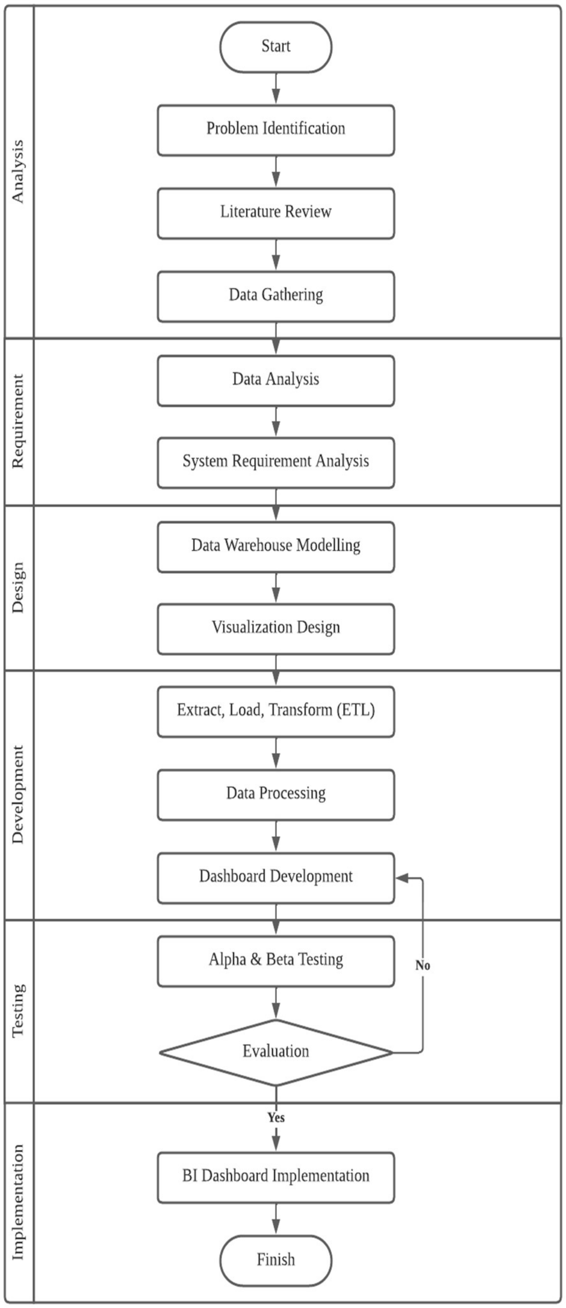

Figure 1. Research framework based on waterfall model

the company in handling project to be more productive and efficient (Hanief et al., 2020).

Figure 1 shows the research framework which adopt the waterfall methodology that consists of Analysis phase, Requirement phase, Design phase, Development phase, Testing phase, and Implementation phase. In this research, data were gathered using both primary and secondary sources. The main method of data collection is further divided into two groups, e.g., quantitative, and qualitative data, respectively. Primary data for this study was collected through focus group discussions, interviews, and observation. Information obtained by a person other than the original user is referred to as secondary data. After the data has been gathered and examined, a system requirements analysis is carried out. Determining the system requirements that must be made is the aim of system requirements analysis.

Next, several visualization possibilities are established to provide the final BI dashboard representation that is needed. This visualization just has a static layout that shows several components of the finished design but is otherwise unusable. The operational manager approved the BI dashboard's final visual validation.

To improve the structure of the BI system, all gathered report data should also be converted to the same format. Google Sheets will be used to transform all the research's data. After all the data has been converted to Google Sheets format, the ETL (Extraction, Transformation, and Loading) process starts. In the ETL process, extraneous data is removed from the table structure (data cleansing), and the table structure is then divided into different components (data transformation). The data warehouse created in Google Sheets format will be uploaded into Google Data Studio once all data transformations have been finished.

A dashboard may now be made using the preceding procedure to display the data kept in the data warehouse. Additionally, the design must consider the parts that were identified and registered during the system requirements analysis stage, and the visualization design itself must refer to the design that the operations manager has approved. A sales performance dashboard and a production performance dashboard are created during this stage of dashboard development.

Following the successful completion of the construction of the BI dashboard, the system must undergo numerous types of testing to ensure the quality of the final product and user satisfaction. Alpha testing, in the form of user acceptability testing, is important to identify any issues and flaws that a system might have before the finished system is distributed to the users. Beta testing, which is carried out by a specific group of actual users of the program, is another type of acceptance testing. Since it is the highest degree of testing, it is carried out in a real or operational setting. The software is sent to a small number of outside participants or users for this type of testing, and they offer their opinions on the system's layout, usability, and overall quality. After Alpha and Beta testing, the assessment procedure will be carried out. If the evaluation step is unsuccessful, the procedure will restart at the development stage. If favorable, the corporation may fully employ the suggested BI dashboard to begin evaluating and tracking the performance of its main operations.

III. RESULT AND DISCUSSION

PT. MPM undertakes both mass production and customized job orders, spanning retail packaging, consumables, and shipping supplies. It typically receives sales forecasts in three formats – annual, quarterly, and monthly – from its clientele. When these projections reach the organization, the assigned staff engage in a comprehensive review and adjustment of prevailing production levels to optimize efficiency. This planning also involves a retrospective analysis of historical sales data, inventory availability, and insights from the production division manager. Every quarter, PT. MPM undertakes aggregate and material planning. Aggregate planning, a facility-wide strategy, is adopted to enhance resource allocation, considering various factors such as changes in customer orders. This approach contributes to the optimization of resource utilization despite fluctuations in specialized product demand. Its production system also operates as a form of specialized mass manufacturing. Multiple workstations are strategically positioned, and the assembly line cycles through each of them. Work at these stations follows a specialized workflow, with each station accountable for specific tasks.

Conceptual Model

To portray the conceptual model, a data flow diagram will be employed in this study. In this investigation, two data flow diagrams will be generated: data flow diagram (DFD) level 0 and DFD 1. Positioned at the highest level, DFD level 0

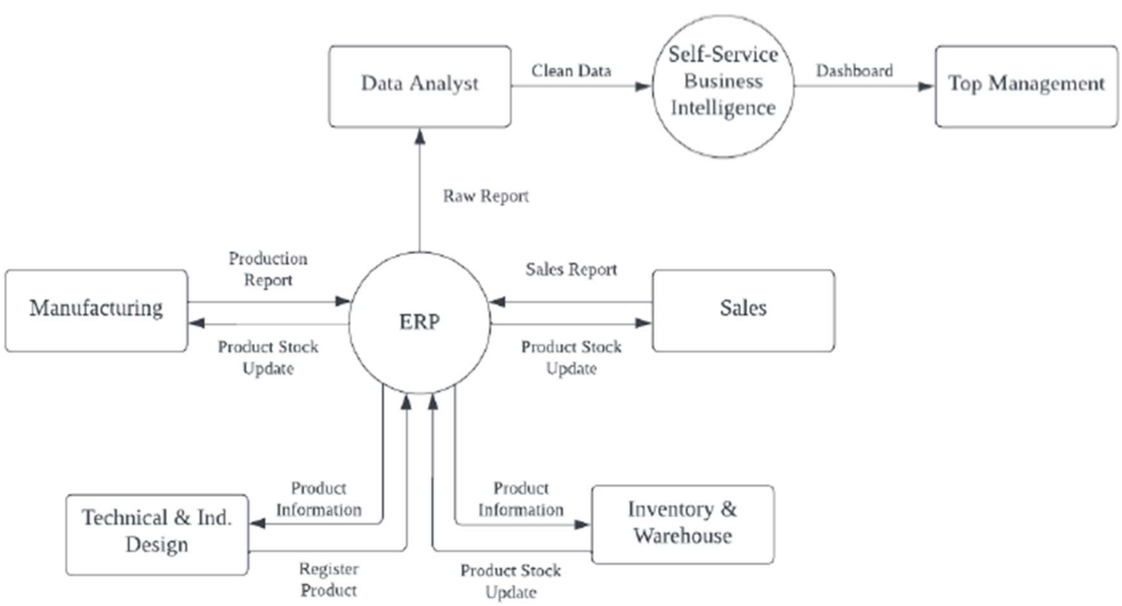

Figure 2. DFD Level 0

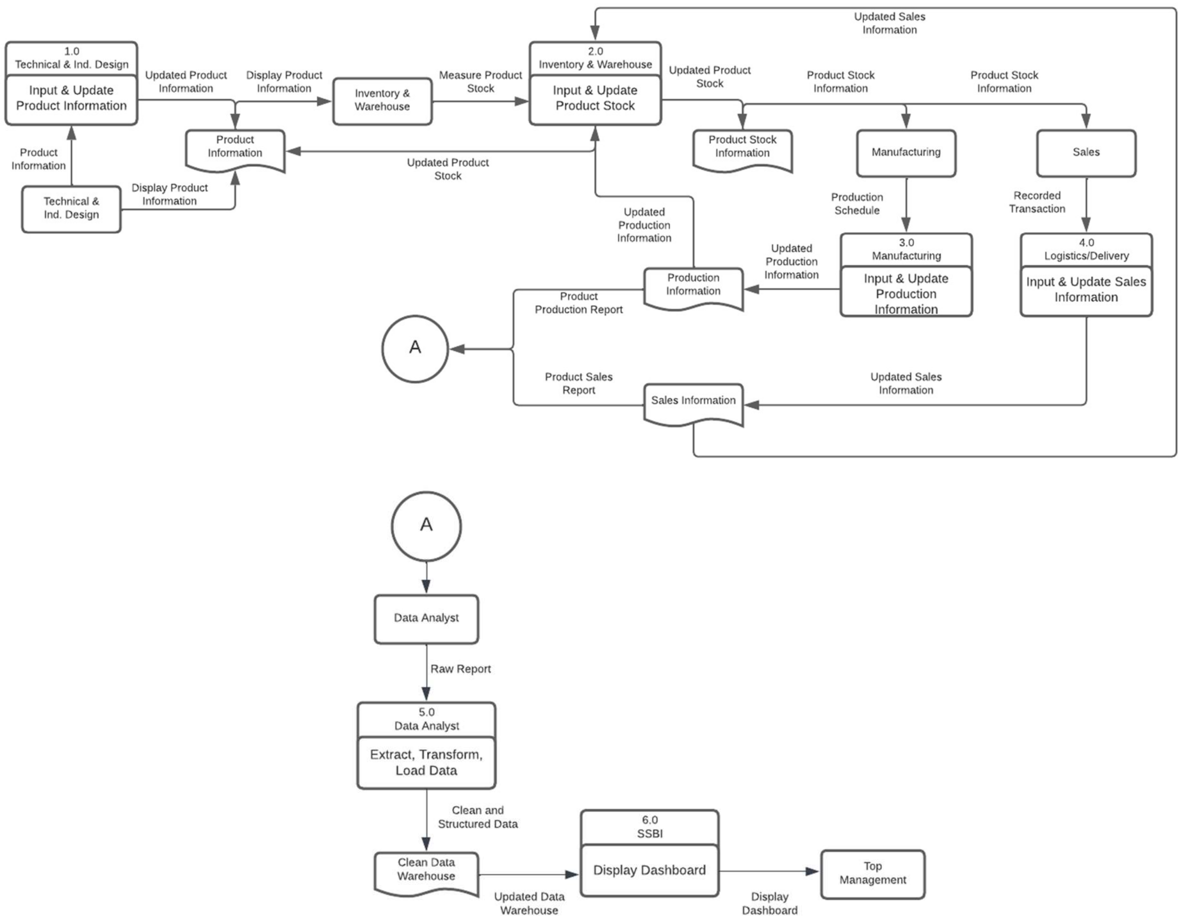

Figure 3. DFD Level 1

encompasses fundamental operations and serves as an input interface for external entities. The illustration in Figure 2 represents the context diagram. It offers an overarching view of the upcoming BI diagram, along with insights into the system's user access privileges. The envisioned conceptual model of the management information system encompasses six key entities: Technical & Industrial Design, Inventory & Warehouse, Sales, Manufacturing, Data Analyst, and Top Management.

In contrast to the DFD level 0, Figure 3 presents the DFD level 1, revealing the intricate procedures highlighted within the context diagram. It outlines the specific permissions granted to each user for different processes and system modules. DFD level 1 will encompass a total of six distinct processes, labeled from 1.0 to 6.0.

System Requirements

The analysis of sales performance examines diverse aspects of product sales, encompassing product categories, sales periods, revenues, and quantities sold, among others. On the other hand, the analysis of production performance evaluates multiple production key performance indicators (KPIs) such as Overall Equipment Effectiveness (OEE), Production Capacity, Product Ratio, Quality Ratio, and Time Ratio. Sales contribute data based on a compilation of sales endeavors, encompassing elements like Product Category, Product Name, Total Sales, Forecast Sales and/or Revenue, Sales Period, and Customer ID. Conversely, production supplies data concerning production-related tasks, encompassing Machine, Availability, Performance, Quality, OEE, Planned Production, Actual Production, Planned Production Time, Run Time, Stop Time, Product

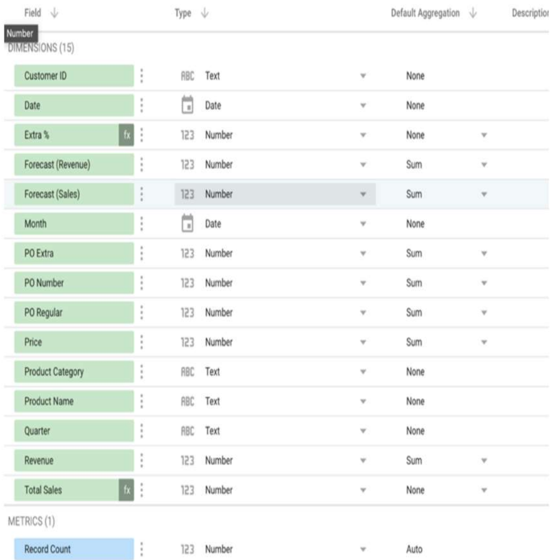

Figure 4. Sales Data Warehouse

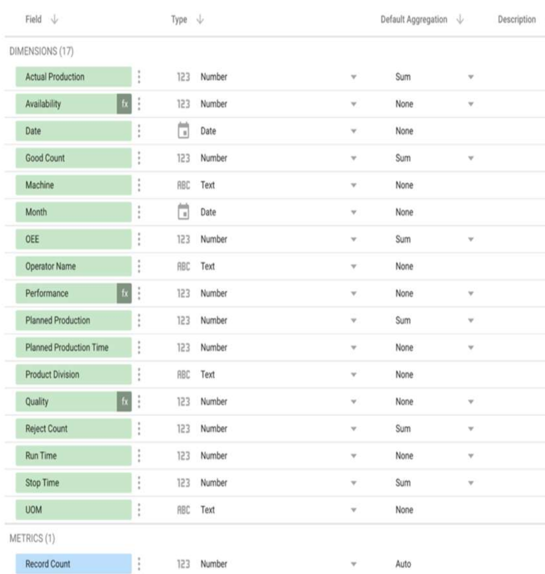

Figure 5. Production Data Warehouse

Division, and Production Period. Output data requirements are also produced by the sales and production performance analysis information systems.

Modeling a data warehouse constitutes a pivotal phase in the creation of a business intelligence (BI) dashboard, as it grants the developer the ability to depict the interconnections among data repositories. Figure 4 and Figure 5 present the sales data warehouse and production data warehouse, respectively.

ETL and Data Import

This research involved the creation of two distinct BI dashboards: the sales performance dashboard and the production performance dashboard. The proposed visualization design for both BI dashboards has already undergone validation by the upper management of PT. MPM.

Data will be amassed from diverse origins to formulate a warehouse database, which will subsequently undergo the ETL (extract, transform, and load) sequence. Once all necessary data is assembled, the primary phase entails converting this data into the Google Sheets format. For data that already resides in Google Sheets format, the ETL process will be initiated, involving the elimination of superfluous data (data cleaning). Solely data essential as per the system requirements will be retained, subsequently undergoing transformation. This transformation encompasses altering the data format of files, such as converting string-formatted date files into date formats, and similar adjustments. The sales table furnishes information based on combined sales operations. The production performance database table will be populated with data sourced from both the production report and the maintenance report prior to commencing the ETL process. The goal of this procedure is to produce a warehouse database that satisfies the system's needs.

Development of BI Dashboard

The outcome of this research will yield the sales performance dashboard and the production performance dashboard. It’s important to note that the data exhibited in the forthcoming dashboard are not authentic due to the company’s confidentiality. The sales performance dashboard, which is depicted in Figure 6, enables the company's senior management to assess sales performance and evaluate if it satisfies its KPIs. The user of a BI dashboard may examine the variation in addition to comparing the accuracy of the anticipated value to the actual value. The initial portion of the dashboard's design is seen in

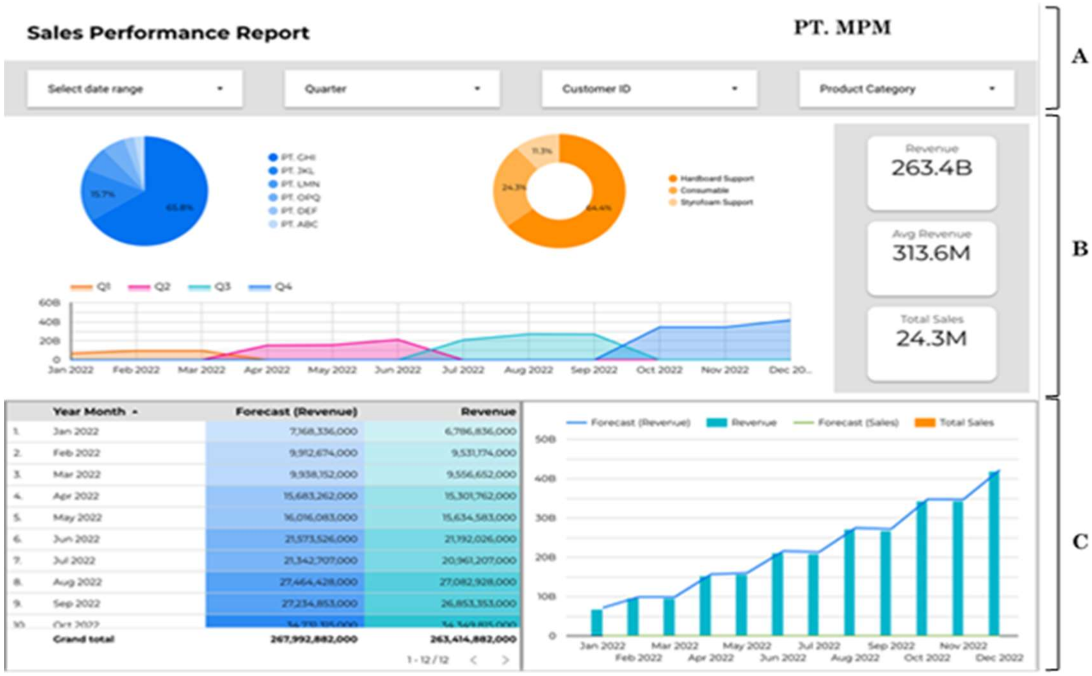

Figure 6. Sales Performance Dashboard

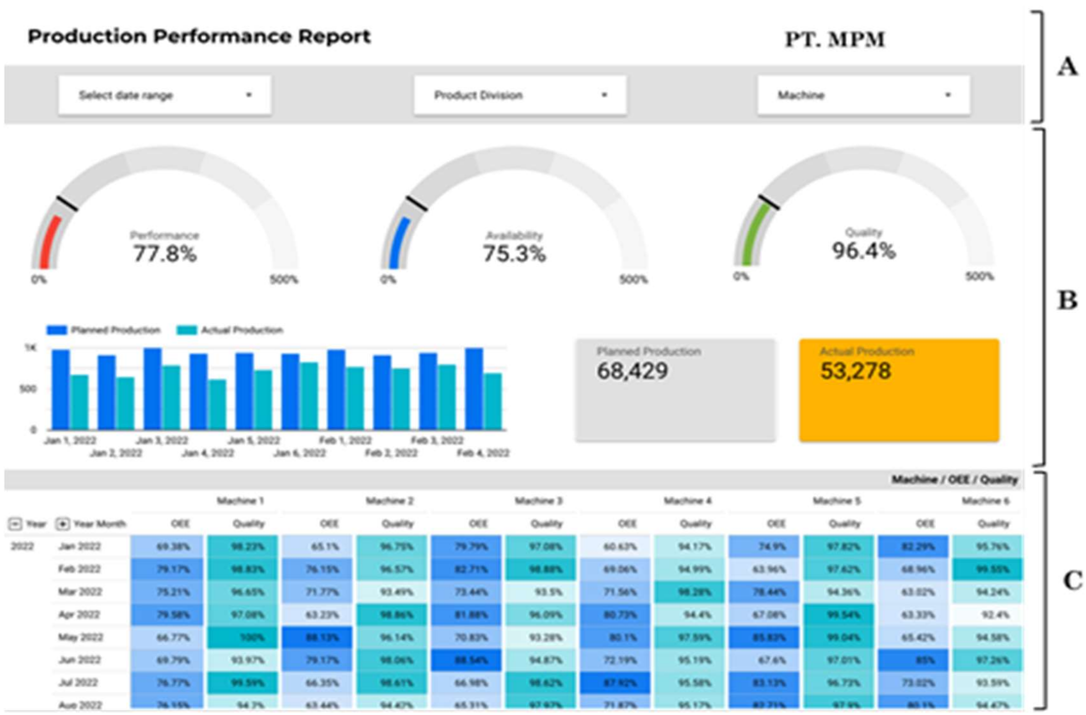

Figure 7. Production Performance Dashboard

Figure 6 section A. The control chart, from which the user may choose the required data depending on the date range, quarter, customer ID, and product category, is presented at the top of the dashboard, along with the name of the dashboard and the firm.

The second phase of the dashboard design is seen in Figure 6 section B. Two pie charts are included in this section where the user may learn more about how well the company's clients and goods are performing. The computation may consider both the volume of goods sold and the income made. The ultimate section of the sales performance dashboard, illustrated in Figure 6 Section C, entails a comparison between the company's projected and realized values. The table on the left adopts a heatmap format, with each cell's hue indicating its performance ranking; brighter colors signify lower rankings and vice versa. Conversely, the right side features a combo chart, permitting users to contrast more than two datasets simultaneously.

Figure 7 depicts the production performance dashboard, the secondary dashboard created. This dashboard furnishes the company's upper management with the capability to scrutinize the Overall Equipment Effectiveness (OEE) across each production line within the company. Beyond the OEE figure, users can delve into the analysis of machine-specific aspects. Moreover, the company's senior management can conduct an evaluation of the production department’s productivity by contrasting the projected production count against the actual production count.

The initial segment of the design is illustrated in Figure 7 section A. Positioned in the dashboard's header are both the dashboard's name and the company's name. This is followed by a control chart, facilitating user selection of specific desired data through certain options. The second element of the production performance dashboard is shown in Figure 7 section B. The gauge chart at the top of this section is used to illustrate the OEE (Overall Equipment Effectiveness) factors, which comprise product ratio (performance), time ratio (availability), and quality ratio (quality). The difference in output between planned and reality is then depicted in a bar chart. The anticipated production number and the actual production number for a certain time are summarized in the two scorecards to the right of this paragraph. The last element of the production performance dashboard is shown in Figure 7 section C. The company's top management may evaluate each machine's OEE (Overall Equipment Effectiveness). A heatmap is used to display the data in a pivot table. The color of each cell indicates its rank, the darker the hue, the higher the rank, and vice versa. The user may also choose the pivot table's display style using the expand-collapse function.

Testing and Evaluation

After the system is created, it must be tested; in this study, both alpha and beta testing are done. The alpha testing has multiple aims: to ascertain that all the system's features and functions work as intended, to see if the system satisfies the specifications outlined at the start of the development process, to determine whether the proposed system satisfies the system requirements and to evaluate the system's features and operations. The functioning of the system will be tested in a system environment by using the list of system functions. The results of the alpha testing are displayed on Table 1.

Table 1 shows that with all eight functions passing the alpha testing, the beta testing phase can be conducted. In the beta testing process, there were several PT. MPM stakeholders that participated. The user is supposed to use the system to find flaws or mistakes while using it, and then submit comments to the developer as a guide to enhance the proposed system. This beta testing will also be termed a UAT (User Acceptance Test). The researcher created a survey to gather feedback after the system's user testing. The five criteria that will be assessed are perceived satisfaction and usefulness, technical system quality, information quality, service quality, and perceived satisfaction.

Five PT. MPM stakeholders tested the proposed business BI dashboard. Users of the dashboard were selected from the operations, production, finance, and president and director of the business. A six-point Likert scale with a rating from strongly disagree (scale 1) to strongly agree (scale 6) is used to rate each statement in the questionnaire.

Based on the overview presented on Table 2, the mean score for beta testing of the proposed BI dashboard system tallies to 4.9 or 82 percent, signifying a satisfactory outcome. The most elevated score emerges from perceived

Table 1. The Alpha Testing Result

No	Function	Acceptance Requirement	Result	
			Accept	Reject
1	Login Session	The user can login into the system to view the intended dashboard without having trouble	Yes	
2	Update & Upload Data	The warehouse database can be updated and uploaded into the warehouse	Yes	
3	View Dashboard	When the user successfully enters the system, the system will provide user with a dashboard	Yes	
4	Analysis Feature	All the analysis features such as drill down analysis and optional metric can be used	Yes	
5	Edit Dashboard	The user can edit the dashboard, change layout, add, and remove elements	Yes	
6	Share Feature	The dashboard can be shared across platform and the report can be printed	Yes	
7	Dashboard Functionality	The dashboard can visualize the data that has been recorded in data warehouse	Yes	
8	Dashboard Objectives	The objective of the dashboard is to meet the system requirements listed by the top management	Yes	

Table 2. BI Dashboard Evaluation

Criteria	Indicator	Score	Total Score	Total Score %
Technical System Quality	System User Friendliness	5.2	5.1	84%
	Usefulness of features provided	5		
	BI Dashboard Availability	5		
Information Quality	Information Completeness	4.8	4.7	78%
	Information Accessibility	4.4		
	Information Clarity and Understandability	4.2		
	Information Relevancy	4.6		
	BI Dashboard Interface Quality	5.4		
Service Quality	Instruction Clarity	4.8	4.7	78%
	Quality of Service Provided	4.6		
	Responsiveness and Cooperation	4.6		
Perceived Satisfaction & Usefulness	BI Dashboard Performance Satisfaction	5.2	5.2	86%
	BI Dashboard assist user perceive information	5.2		
	BI Dashboard assist user in decision making process	5		
	BI Dashboard Usefulness	5.2		
	Average Score	**4.88**	**4.9**	**82%**

satisfaction and usefulness, amassing a total of 5.2 or 86 percent. This indicates users' gratification with the performance of the proposed BI dashboard, as the system facilitates their comprehension of company information, subsequently enabling informed business decisions and strategies.

Conversely, the aspects of information quality and service quality garnered the least ratings, both resulting in a cumulative score of 4.7 or 78 percent. Specifically, within information quality, data completeness and data relevancy attained scores of 4.8 and 4.6, respectively. However, information clarity and understandability achieved only a score of 4.2, implying some challenges in users comprehending the information displayed by the system. This challenge could be attributed to the need for users to adapt to the novel system, a process that is expected to become smoother as familiarity with the system increases.

Implementation

Both alpha and beta tests show that the system has successfully satisfied all the system's success criteria. Because of this, the proposed BI dashboard is currently at the implementation stage, where the firm may fully exploit the usage of the BI dashboard to gauge and keep an eye on the efficiency of its main operations.

IV. CONCLUSION

The sales performance dashboard and the production performance dashboard are two developed BI dashboards that are included in the current research. The waterfall methodology, which consists of six stages: analysis, requirement, design, development, testing, and implementation, was used for developing the BI dashboard. Google Data Studio was used as the dashboard development tool; as a result, it is a web-based dashboard that users can access from any computer with an internet connection. The proposed BI dashboard is approved and complies with system criteria. The technology may now be fully exploited and integrated into the business operations of the organization. Alpha and beta testing have also been conducted on the suggested BI dashboard system, and the dashboard system passed both. The technical system quality, the information quality, the service quality, and the perceived satisfaction and usefulness were the four criteria used in the design of beta testing questionnaire. The participants expressed satisfaction and agreement with the suggested BI dashboard, as evidenced by the average score of 4.9 or 82%.

Based on the evaluation of the research findings, several recommendations are made for the business, future research, and enhancements to the BI dashboard. Firstly, the organization may utilize the business intelligence dashboard in other divisions like finance, buying, and logistics. Secondly, the enterprise resource planning (ERP) system should be installed so that all departmental data may be connected into one system for the BI dashboard network to function successfully. The company can expand the use of the BI dashboard to other departments. In addition, it is recommended to the company that for the BI dashboard network to operate effectively, the ERP system needs to be implemented, so that all department data can be integrated into one system.

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