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(Research) Article

Design and Development of a Product Data Traceability System Capable of Printing Web-Based Information Labels

Jamal Haiqal Bahanan[1], Prasaja Wikanta[2*], Fitriyanti Nakul[3]

1. Batam State Polytechnic; jamal@polibatam.ac.id
2. Batam State Polytechnic; antok@polibatam.ac.id
3. Batam State Polytechnic; fitriyantinakul@polibatam.ac.id

* Corresponding Author: Prasaja Wikanta

Abstract: The Printed Circuit Board (PCB) industry increasingly relies on automation and digitalization to improve efficiency and accuracy in production and distribution processes. One common practice is the use of labels containing product information in the form of barcodes or QR codes, which allow automatic data input and reduce the risk of human error compared to manual writing. However, in current practices, these labels are only attached to PCBs after they have been placed inside casings. This creates a significant limitation, as access to the label information requires disassembling the casing whenever product verification, tracking, or troubleshooting is needed. Such a process not only consumes additional time and resources but also increases the risk of damaging the product. To overcome this challenge, this study proposes the development of a traceability system designed to accurately monitor the location, identity, and status of PCBs throughout the distribution process. The system was implemented as a web-based application capable of generating and printing product information labels in the form of barcodes and QR codes. Each label functions as a unique identifier, ensuring that every PCB can be distinctly tracked from production to final product assembly. All data associated with the labels is automatically stored in a centralized database, providing real-time accessibility, simplifying information management, and enabling faster decision-making in the event of quality control issues. System evaluation was carried out through rigorous testing, which showed a 100% success rate in generating, storing, and retrieving product information without errors. The findings indicate that the proposed traceability system is both effective and efficient, and it offers a practical solution for industries seeking to enhance supply chain visibility, improve product accountability, and reduce operational inefficiencies in PCB distribution and lifecycle management.

Keywords: Printed Circuit Board (PCB), Traceability System, Barcode dan QR Code, Web-Based Application, Product Tracking.

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1. Introduction

The development of technology in today's computer-based digital era is considered to be growing rapidly, influencing the industrial sector. With the advent of information technology, information processing has become more effective. To simplify tasks that require fast and concise data processing and to meet the need for accurate information presentation, several companies require a system to cover all aspects of information used in a product to be traded. A system is a collection of elements consisting of data, work procedures that are interconnected, human resources, and technology—both hardware and software—that interact as a single unit to achieve a specific goal or objective (, 2017) .

Each product produced by Electronic Company ABC has a unique Serial Number as an identifier for each PCB used, which can be seen in the form of a Barcode Label or QR Code Label. The company typically has its own Label Printing Station that produces labels in bulk with sequential numbers in a format corresponding to each model currently in production, which are then affixed to each PCB to be assembled.

After all parts are assembled into a finished product, the condition of each PCB inside the unit is enclosed by the finished product's case, making the serial number on the PCB difficult to see.

The units produced are semi-finished products that will be shipped to customers to be turned into final goods before being sold to end users. Some customers require the serial number on the PCB for , program loading, and identification of the serial number of each PCB on the final goods. Therefore, it is necessary to duplicate the PCB serial number label, which will be affixed to the surface of the case and the box of the finished goods unit for easier viewing and to apply a barcode or QR code template on the label for more efficient data entry and reading.

In carrying out the label duplication process, the existing system generally still tracks and records the serial number data from each PCB, and designs and prints labels using an office-based application, namely Microsoft Excel, resulting in suboptimal performance. This also causes difficulties for the Engineering team in analyzing problems that require identification of each PCB used in the problematic unit because the data is stored offline on a separate PC. Therefore, an online data traceability system integrated directly with the printer is needed to facilitate data processing and direct label printing. In general, traceability can be defined as the ability to identify the origin of a product based on the information stored in each part of the supply chain (, 2013). Traceability is recognized as a determining factor in the quality of a designed software system (Garcia & Paiva, 2016) . The most popular online application is the web application. Web development involves several processes, as mentioned by (Wardhani, 2014) , who developed a health card information system as an alternative to digital management of posyandu (community health centers). Web applications generally use MySQL (Haviluddin & Rahmawati, 2016) , PHP (Ardhana & Kusuma, 2012) , and are displayed through HTML (Sovia & Febio, 2011) and Bootstrap. The prototype will use XAMPP (WIRDANA, n.d.) .

The implementation of a system does not only depend on its model and the features of the software and programming language used, but must also consider the appropriate model for its implementation so that its main objectives can be achieved (Nur, 2019). Therefore, in the design process, the author employs the Object-Oriented method with Unified Modeling Language (UML) modeling. UML itself is a highly reliable tool in the field of analysis and design of object-oriented information systems (Object-Oriented) (F. Setiawan & Yanuarti, 2016).

There are several studies on traceability, such as the research by Stacy-Ann A. Anuli & Daniel T. Fokum titled "Implementation of an Internal Food Traceability Application for Local Farmers in Jamaica" ( ) (Anuli & Fokum, 2016) , which explains how they track food distributed by local Jamaican farmers using QR codes and display the results on a system.

2. Literature Review

A traceability system or product traceability has become an essential requirement in modern supply chains to ensure product quality, safety, and transparency. (Kurniawan & Budiyanto, 2021). Traceability enables the tracking of product data from raw materials, production processes, distribution, to consumers. With web-based system integration, traceability not only facilitates real-time data access but also supports operational efficiency (Saputra et al., 2022).

Product information labels that can be printed directly from a web-based system enable the presentation of important data such as production date, raw material origin, and product batch number. This technology is highly relevant for application in the food, pharmaceutical, and manufacturing sectors as it simplifies audit processes and quality monitoring (Sutrisno & Pratama, 2020).

Previous studies have shown that web-based traceability systems supported by relational databases and label printing technologies such as barcodes or QR codes can enhance consumer trust and product competitiveness in the market (A. Setiawan & Hidayat, 2019). The development framework for this system generally utilizes PHP/JavaScript programming languages and MySQL databases, along with automatic recording features and label printing capabilities (Rahmadani et al., 2023).

3. Proposed Method

3.1 Research stages

A flowchart explaining the sequence of stages in the implementation of this research can be seen in Figure 1. The system development process begins with a literature study. At this stage, information and knowledge are collected from various sources to support system development. After the literature study, the next step is to determine the system allocation. This stage forms the basis for continuing to the system and interface design process, where the visual design and structure of the system begin to be created.

The next stage is the Design Workshop phase, which consists of several core processes, namely: System Development followed by System Testing. If the system passes the test, the process continues to the next stage. However, if the system fails the test, a problem analysis process is conducted to identify the causes of failure, followed by a return to the system development stage for improvements. If the system has been successfully tested and declared passed, data is collected and analyzed further to obtain valid results. After the data is analyzed, the process continues with the report creation stage, which documents the entire process and results of the system development.

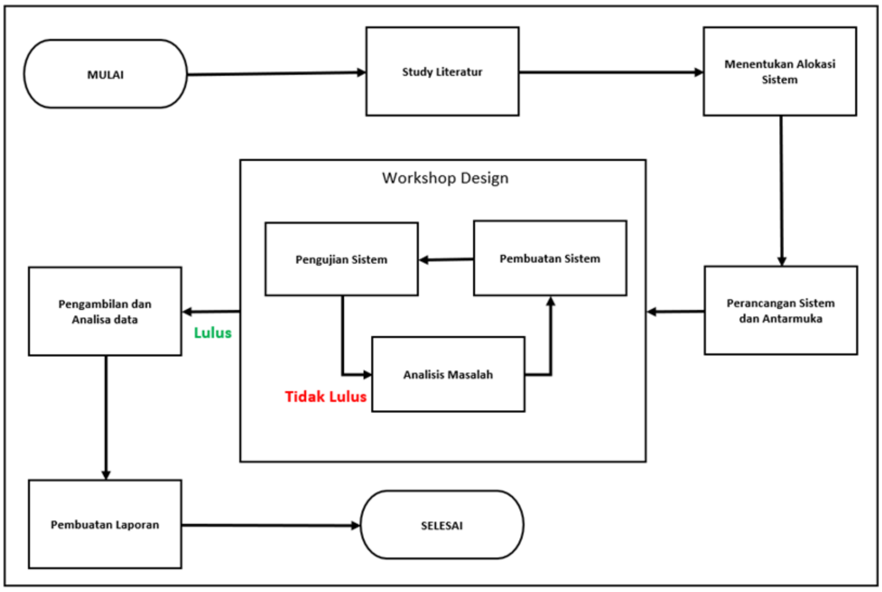

Figure 1. Research Flowchart

3.2 System Allocation

In a manufacturing company, a product goes through a lengthy production process before it becomes a product that is ready to be shipped to the customer who ordered it. This process includes SMT Process, Assembly Process, Inspection, and Packaging. The production process flow diagram in a manufacturing company engaged in electronics can be seen in Figure 2.

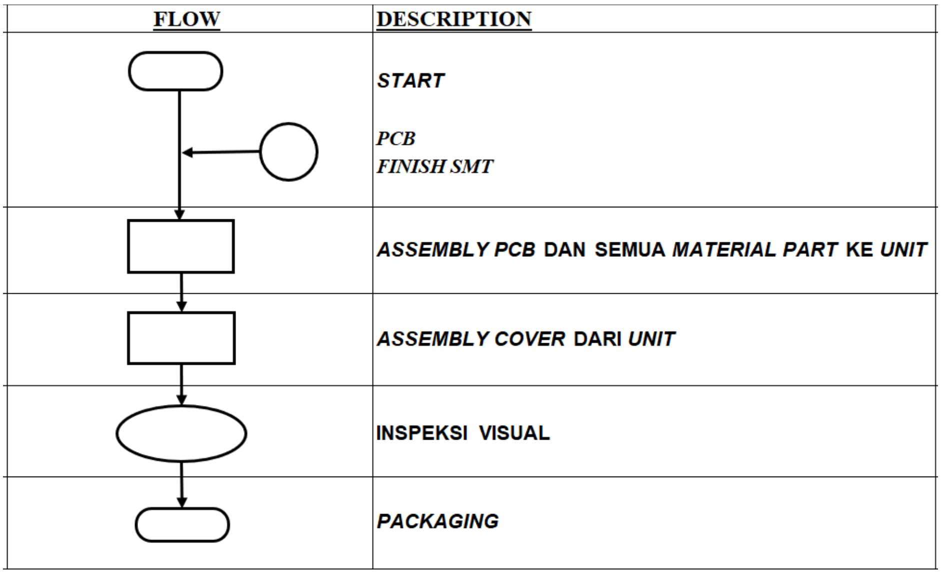

Figure 2. Production Process Flowchart

In this case, the author determines the system allocation based on the data collection requirements for each material part used in a production process and before the product is packaged, which allows the system to collect sufficient data to be presented to users. The System Allocation Flowchart for the production process can be seen in Figure 3.

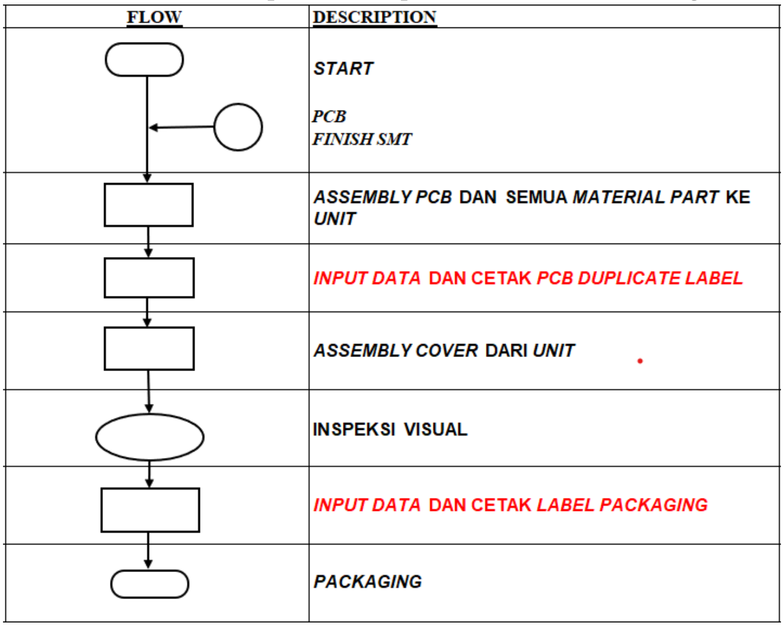

Figure 3. System Allocation Flowchart in the Production Process

3.3 Design

The author uses the UML (Unified Modeling Language) modeling method. In its modeling, the UML method uses several types of diagrams to produce a detailed and structured model, including Use Case Diagrams, Class Diagrams, Activity Diagrams, Sequence Diagrams, and User Interface Flow Diagrams.

A Use Case Diagram is a modeling technique aimed at describing the functions of each user or administrator within a system. The Use Case Diagram for the Traceability system can be seen in Figure 4.

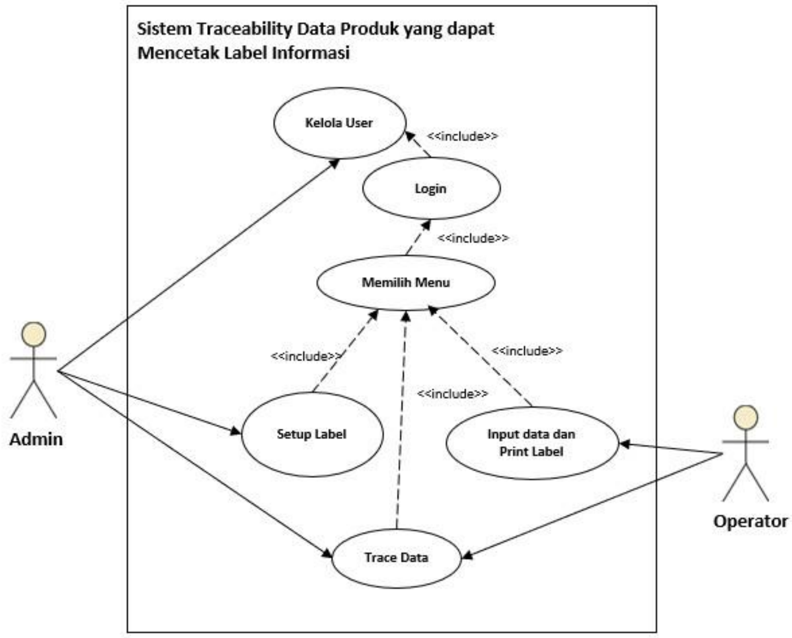

Figure 4. Use Case Diagram

A Class Diagram is used to depict the structure within system objects. This diagram shows the class objects that make up the system and the relationships between class objects (, 2016) . The Class Diagram for the Traceability system can be seen in Figure 5.

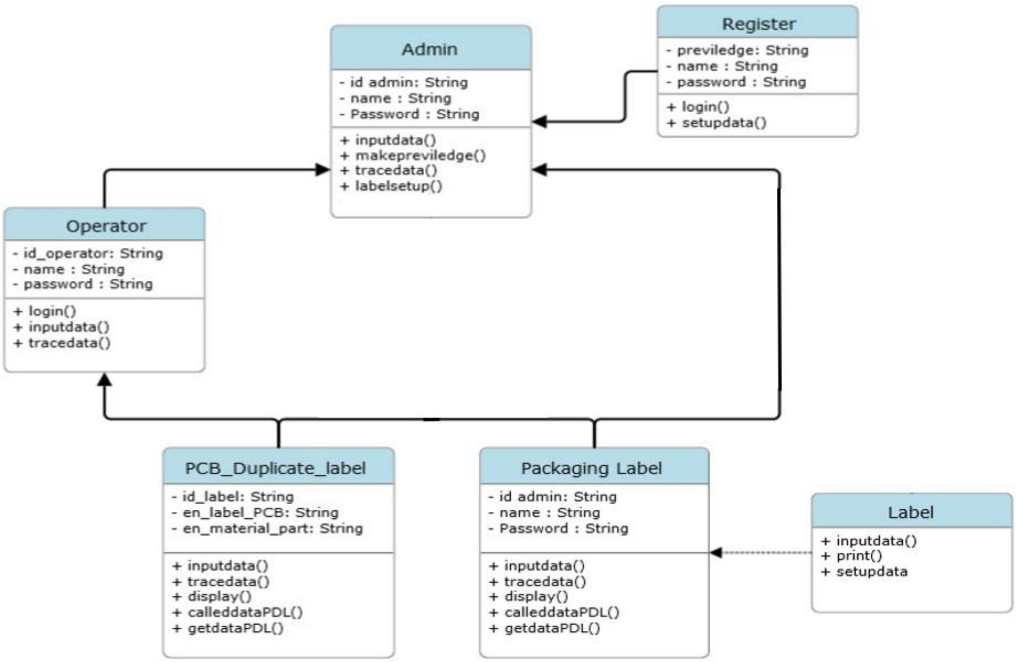

Figure 5. Class Diagram

A sequence diagram is used to illustrate the relationship between users and use cases. The Sequence Diagram in this Traceability system can be seen in Figure 6 for data input and Figure 7 for Trace data.

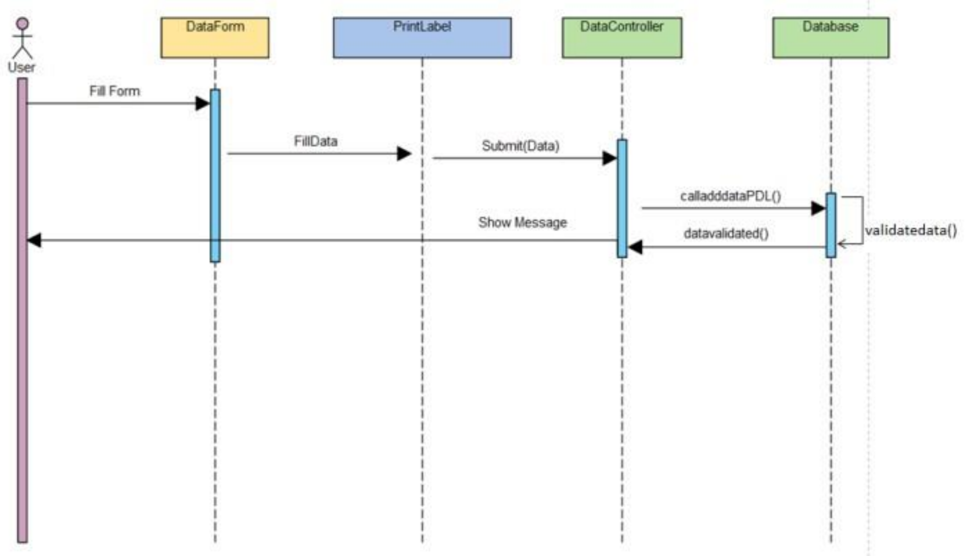

Figure 6. Sequence Diagram for Data Input

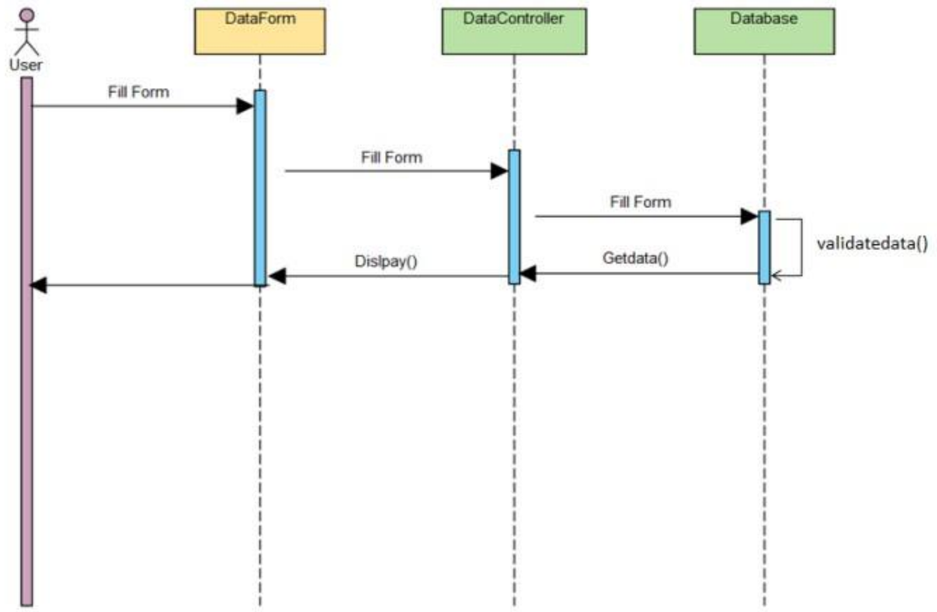

Figure 7. Sequence Diagram for Trace Data

Activity diagrams are used to illustrate the workflow between users and the system. The Activity Diagram for this Traceability system can be seen in Figure 8 for data input and Figure 9 for trace data.

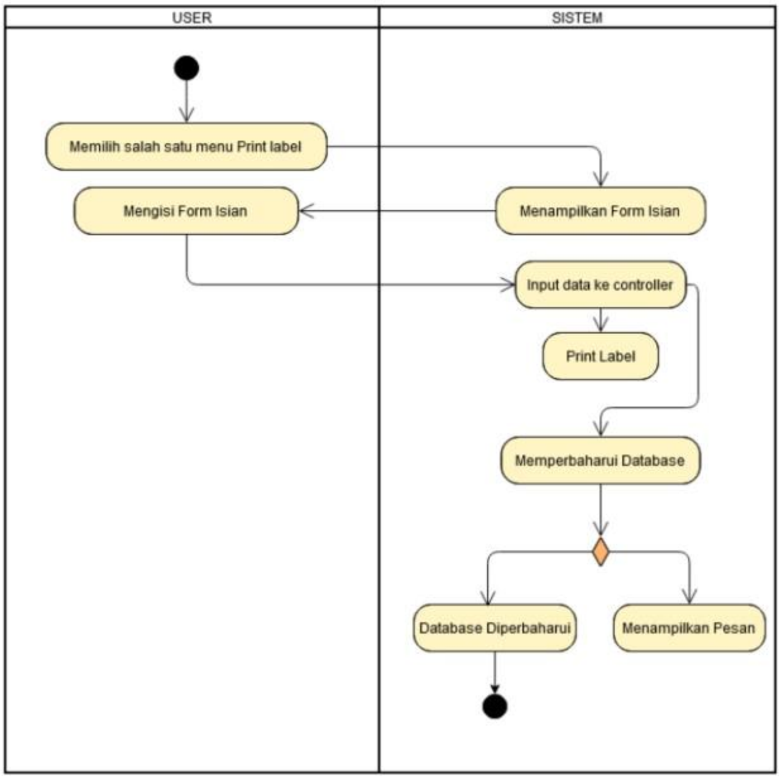

Figure 8. Activity Diagram for Input Data

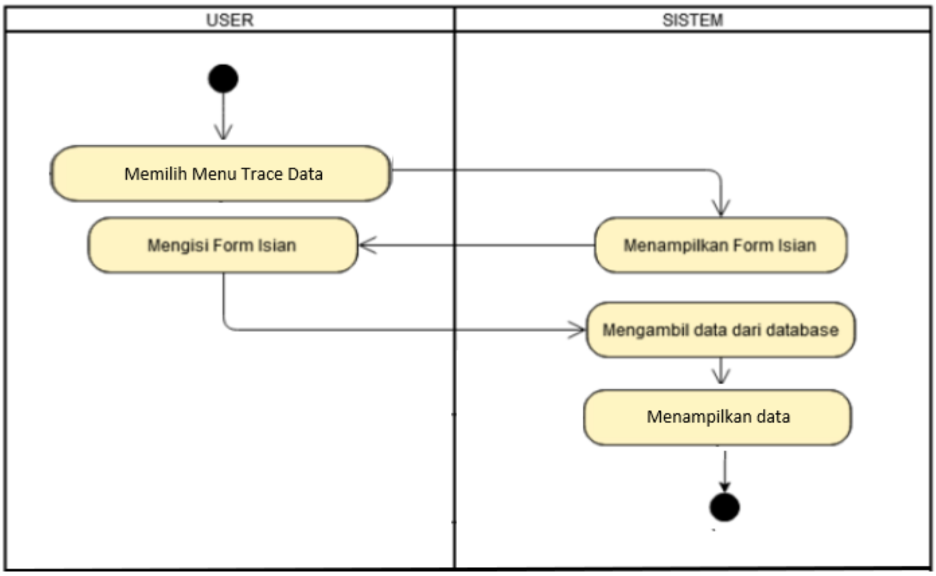

Figure 9. Trace Data Activity Diagram

UI Flow Diagram is one of the diagrams used to simplify the visualization of an interface in a system. The UI Flow Diagram explains the workflow between users and the interface, where each user has a different interface workflow depending on the privileges granted. The UI Flow Diagram in this Traceability System can be seen in Figure 10.

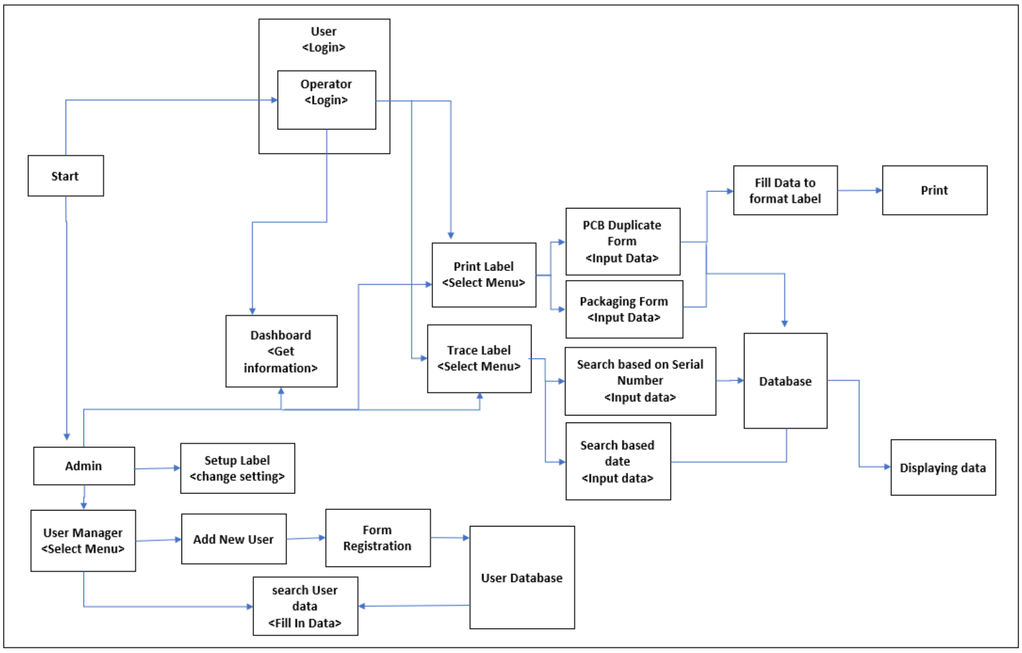

Figure 10. User Interface Flow Diagram

4. Results and Discussion

4.1 Login Form

Figure 11 shows the appearance of the Login Form. The Login Form functions as a security system that can sort the access granted to each user by the admin. At the top, there is a header displaying the words "Sign In" and below it is the title "Traceability System." Then, there are two forms for entering the username and password. At the bottom, there is a "Remember me" checkbox to facilitate users in logging in for subsequent sessions without needing to re-enter their username and password. At the very bottom, there is a Login button. The Login button is used after the user enters their username and password.

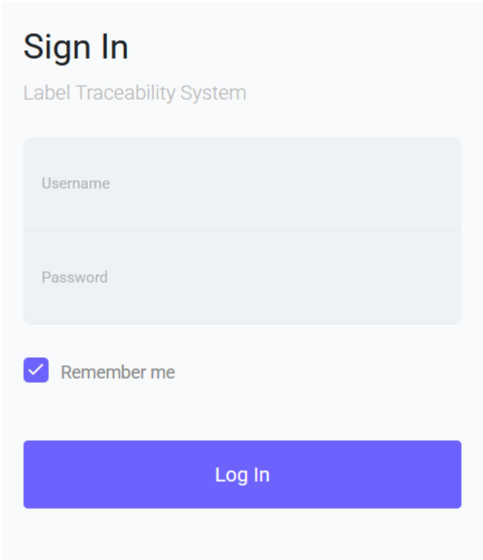

Figure 11. Login Form Display

4.2 Dashboard Page

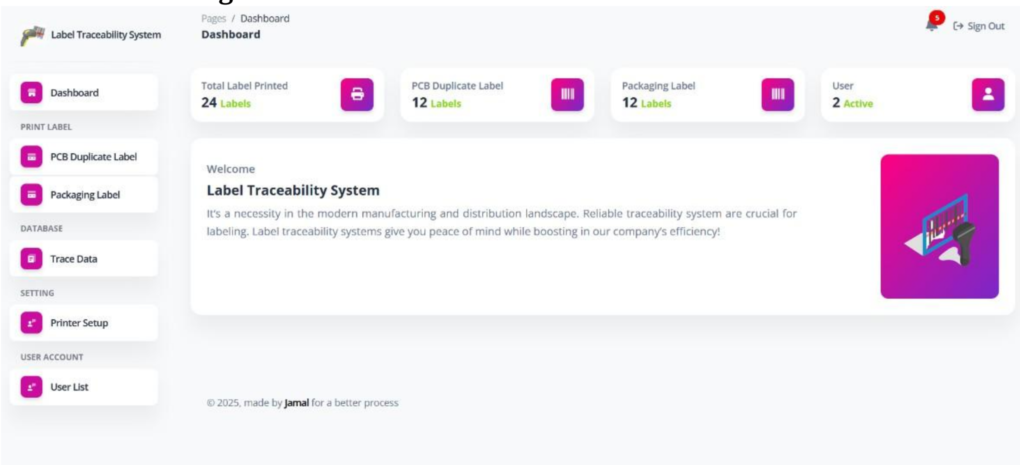

Figure 12. Dashboard Page Display

Figure 12 shows the Dashboard page. The Dashboard page is displayed after the user successfully logs in. This page displays information such as the total number of labels printed, the total number of duplicate PCB labels printed, the total number of packaging labels printed, and the total number of active users.

4.3 PCB Duplicate Label Input Form

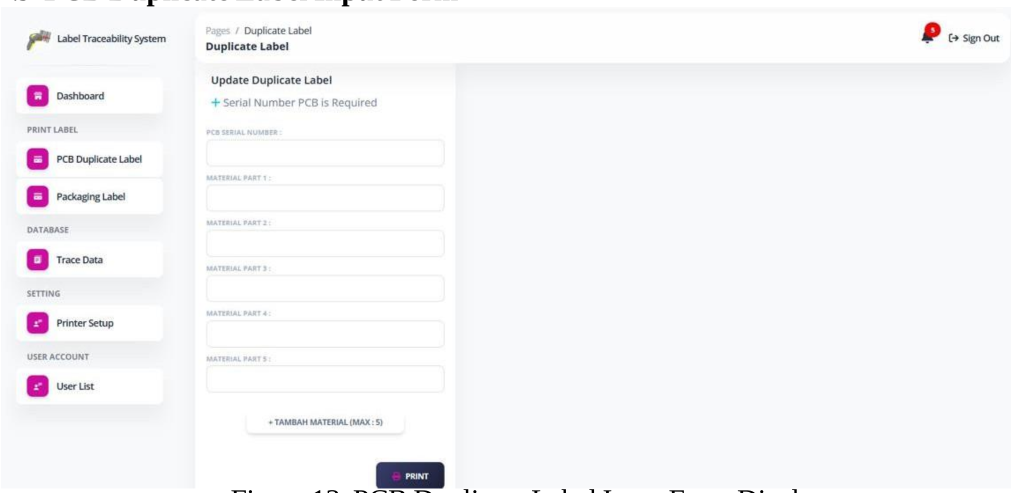

Figure 13. PCB Duplicate Label Input Form Display

Figure 13 shows the PCB Duplicate Label input form. The input form contains a text box for the PCB serial number, which must be filled in by the user as a data reference. The next text box can be filled with the material used by the user, corresponding to the number of materials used in a product (maximum 5 materials). At the bottom, there is a print button on each input form above, which serves as a command button to execute the data entered by the user.

4.4 Packaging Label Input Form

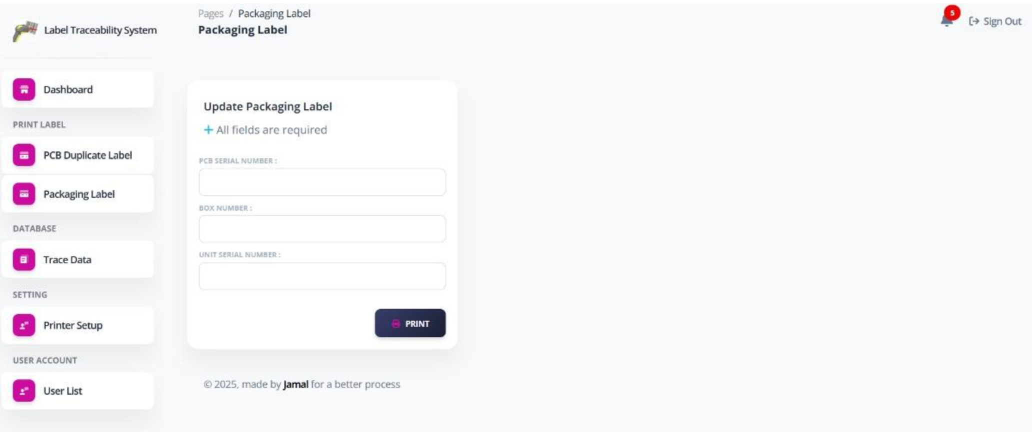

Figure 14. Display of the Packaging Label Input Form Page

Figure 14 shows the display of the input form for the Packaging Label. The input form contains a text box for the PCB serial number, which must be filled in by the user as a data reference to find data in the database. The next text box is filled with the unit serial number and box number used by the user. At the bottom, there is a print button on each input form that functions as a command button to execute the data.

4.5 Data Trace Page

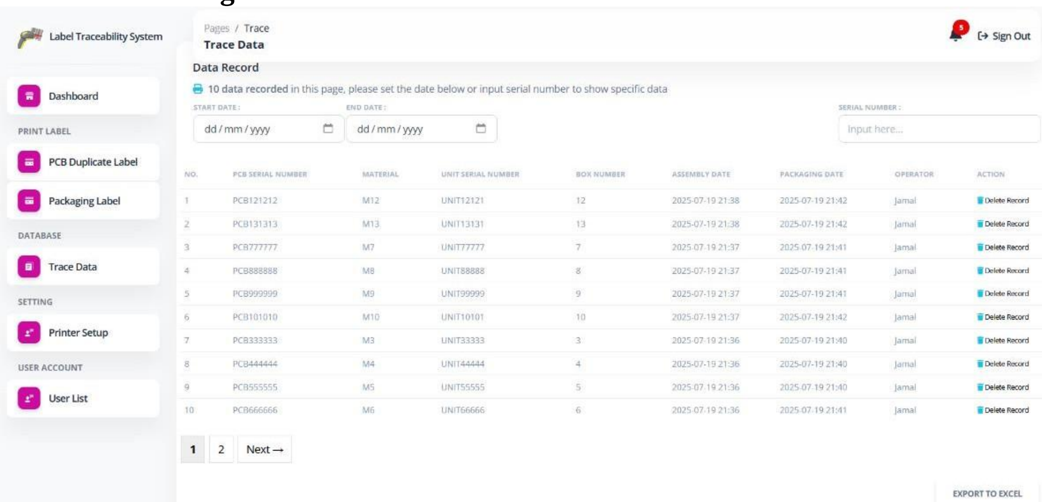

Figure 15. Trace Data Page Display

Figure 15 shows the Trace Data Page display. The Trace Data Page serves as a medium to display the results of data searches retrieved from the database. On this display, the user can choose whether to search for data based on the serial number or the date created, and the user can export the trace results to Excel format by pressing the "Export to Excel" button.

4.6 PCB Duplicate Label Print Results

Figure 16. PCB Duplicate Label Print Results

Figure 16 shows the print output for the PCB Duplicate Label. The label print output will align with the settings saved in the printer setup page.

4.7 Packaging Label Print Results

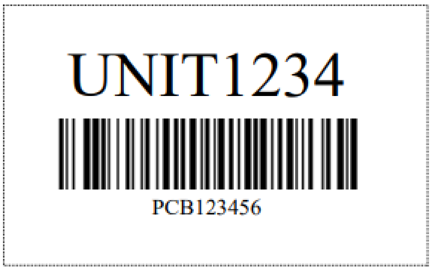

Figure 17. Packaging Label Print Results

Figure 17 shows the print output for the Packaging Label. The label print output will adjust to the settings saved in the printer setup page.

4.8 System Testing Results

System testing aims to ensure that the system functions properly. This testing uses the Black Box method. Black Box Testing is a functional test of a system performed by observing the execution results of a data- (Syaban, 2015) . Each data execution result has a weight score of one. The test results can be seen in Table 1.

Table 1. Testing Results

Page	Action	Expected Result	Result	Score
LOGIN	Enter *Username* and *Password*	*Form* can be filled in with *Username* and *Password*	Correct	1
	Click the *Login* button	*Login* function works properly	Correct	1
DASHBOARD	Press the *Dashboard* button	*The Dashboard* displays the required data from *the database*	As	1
USER LIST	Click the *User list* button	Displays user information	As	1
	Fill in the *User* Data and press the *Register* button	The system is capable of registering *users* and assigning *privileges* according to each *user's role.*	As per	1
PRINT PCB LABEL DUPLICATE	Enter the main label content, then click the *Print* button	The system is capable of *converting* duplicate labels into a print-ready PDF format with content matching the main label, and can save the data to *the database*	As per	1
PRINT PACKAGING LABEL	Type the main label content, press the Print button	The system is capable of converting duplicate labels into print-ready PDF format with content matching the main label, and can save data to the database	As per	1
TRACE DATA	Type the content you want to search for	The system can search for data and present data from the database	As	1

Page	Action	Expected Result	Result	Score
LABEL SETUP	Specify the search period	The system can search for data and present data from the database based on a specific time period	According	1
LABEL SETUP	Adjust the label position and perform a print test	The system can set up label positions properly and accurately	Correct	1
LOGOUT	Press the Logout button	The system returns to the Login Page	As	1

The analysis method used is descriptive analysis. According to Iyan Sopyan[13], descriptive analysis is a statistical method used to explain data by describing it so that conclusions can be drawn from a group of data. To measure the feasibility of the system, the calculation is as follows:

Feasibility Percentage = Test Score / Expected Score x 100%
= 11/11 × 100%
= 100%

According to (Masruri et al., 2016) , if the feasibility percentage has been obtained in a study, it can be concluded as quantitative data using a conversion table. The feasibility conversion table can be seen in Table 2. The black box testing results show that the system feasibility percentage reached 100%. Referring to Table 2, it can be seen that the percentage of feasibility falls within the "very good" criteria.

Table 2. Feasibility Conversion

Feasibility Percentage	Criteria
81% - 100	Very Good
61% - 80	Good
41% - 60	Fair
21% - 40	Poor
<20	Very Poor

5. Conclusions

From the results of the system testing using the black box method and analysis with descriptive analysis techniques, it can be concluded that the system operates as expected with excellent criteria for acceptability, namely 100%. The system can also store complete and accurate data from a product that has been sent to the customer, making it easier to trace the product's history (traceability). The system has successfully printed barcode and QR code information labels via the web.

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