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Integrated Identity Tag System for Biodiversity Collections in Indonesian Botanical Garden using QR Code

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Abstract

In the year 2023, Indonesia has more than 40 botanical gardens. The garden has an essential role as the last defence in terms of plant conservation in Indonesia. However, some problems are commonly faced in the daily management process of plant collections, especially in the inspection of plant collection activity. There are no proper records of inspection activity, wrong identification of plant collection identity, inefficient reporting system, and the lack of visualisation documentation are part of the issues. Considering the essential inspection activity of plant collection in terms of conservation in the botanical garden, the use of a QR code that is integrated into the information system of plant collection management could be an alternative to be implemented to solve the issues. The implementation of the QR code can help to identify plant collection identity, history of collection and reporting process. Every plant collection will have an identity card with a QR code. Inspection officers can access the plant collection data by scanning the QR code using a smartphone. Thus, wrong identification could be minimised, reporting process could be more efficient, and inspection activity could be recorded as a history of plant collection. In addition, basic information about plant collection can also be accessed by visitors to educate them about biodiversity and conservation.

Keywords: Biodiversity, Indonesian Botanical Garden, Information system, Scientific collection, QR code.

1 Introduction

As a tropical country, Indonesia is rich in biodiversity. Indonesia is home to more than 35.000 species of flora [1]. It makes Indonesia become a mega biodiversity country. Also, Indonesia is among the 10 biggest countries with flora diversity. However, based on the data, in 2013, 404 species need to be preserved because of the threatened category in IUCN [2]. Deforestation is a matter issue in Indonesia that contributes to making the situation worse. According to Gunawan, et al. [3], in Indonesia, only about 22,1 million hectares are conservation forest area. It is about 18% of the total forest area in Indonesia. Most of them are productions forest (approximately 64%). To address the issue, the existence of botanical gardens can be a solution.

The botanical garden is a conservation area for flora outside the habitat. The role of botanical gardens is essential to prevent the loss of biodiversity in Indonesia. It can be the last hope of flora conservation and the effort to eliminate the number of threatened species. Since 2011, Indonesia has had a presidential decree number 93 about botanical garden development. In 2023, more than 40 botanical gardens have been developed under the central government, local government, and university [4]. The development of information systems to help plant collection data management in Indonesian Botanical gardens also has been started in 2020 [5]. At the beginning of 2023, 10 botanical gardens in Indonesia already stored their plant collection data in the system. The data can be accessed by the public in makoyana.go.id. The authorized people can manage the plant collection data from the nursery until becoming a collection. The existence of the system in the Indonesian botanical garden is expected can solve some problems that are faced in the daily management of biodiversity conservation in Indonesian botanical gardens.

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A common problem that can obstruct the process of plant conservation in botanical gardens is identified in the collection routine check activity. Wrong identification of plant collection identity during the inspection process, there is no history record of inspection activity and inefficient process of reporting make the potential risk level in the plant conservation activity becoming high. First, the wrong identification can make the outcome of the routine check useless. All data that is reported will be invalid. Second, there is no historical activity record in the collection routine check, making the possibility to investigate the historical journey of the plant collection in the botanical gardens hard. The historical record can provide a vivid illustration of the plant collection lifeline. Furthermore, inefficient reporting processes also contribute to inefficient treatment of plant collection. According to Roychowdhury, et al. [6], the quality of a report relates to efficiency in an organization. For example, plant collection with pests or diseases needs a fast response treatment, it can be late when the reporting process takes a long time. To solve the issues, the implementation of a Quick Response (QR) code can be considered to help identification of plant collection identity in botanical gardens.

QR code is a simple technology that is often implemented in some industries nowadays. It is better than one-dimensional code to help the reading data process. QR code is also easy to use, easy to be implemented in some applications, and free [7]. The implementation of the QR code which is integrated with the plant collection data management information system of the Indonesian botanical gardens, is potential to be a solution to solve the issues about the collection routine check activity in botanical gardens. Some botanical gardens in Indonesia have implemented the QR code for name cards of plant collections such as Eka Karya Botanical Garden and Purwodadi Botanical Garden [8]. In addition, the implementation of QR codes for providing basic stories about aquatic plant collection has also been implemented in the Purwodadi Botanical Garden field[9]. However, the data that is used in the previous project is not integrated with the information system of plant collection data. Hence, the data that is provided is not dynamic data. To add value to the implementation of QR codes in Indonesian botanical gardens, the QR code should be integrated into the database system.

This research focuses on the implementation of the QR code that is integrated with the information system of plant collection data in the Indonesian botanical garden (Makoyana). The use of QR codes in this research is designed to solve the issues that are experienced in routine inspection of plant collection in Indonesian botanical gardens. A unique QR code is generated as a representative of a plant collection identity. The QR code that contains a web page link can help the visitor or officer to access the plant collection data in the database system. The authorized role can access the data in more detail to provide a report about the condition of plant collection.

2 Literature Review

QR code is a common technology that is familiarly used in the last decade. QR code is a two-dimensional image that can represent data. According to Deineko, et al. [10], a QR code can encode more than 4.000 characters. It is caused by the system of QR codes that is two-dimensional code. It saves the data not only in the horizontal pattern but also vertically. Since the QR code was developed in 1994 by Denso Wave, It has already been implemented not only in the industrial sector but also in the educational sector, tourism, health, and other sectors [11]. Although it only contains data or text without images or video, a QR code can be a bridge to access the visual or video data from a website or a database. QR code is appropriate to be implemented in any condition and situation. This code has an error tolerance that makes it able to be read in a certain level of damage or dust [12]. It is caused by the structure of the QR code that is designed from components that make it able to resist certain levels of failure. According to Yuan, et al. [13], the structure of a basic QR code consists of 5 components which are:

a. Finder pattern and alignment pattern
   These components are always located in a fixed position. The functions of this component are for helping to detect the orientation and location of the code.
b. Format information
   This component is useful to record the pattern of data masking and the level of error correction.

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c. Error correction block
   This component has a role to make the QR code can survive damage and noise. This component will send a message about the error correction data in order to be recovered at a tolerance level.
d. Data
   The encoded data is stored in this component. It consists of 8 modules.
e. Module
   This is a black-and-white component with a square shape. This is the smallest component in the code. The black square means 1 and the white square means 0.

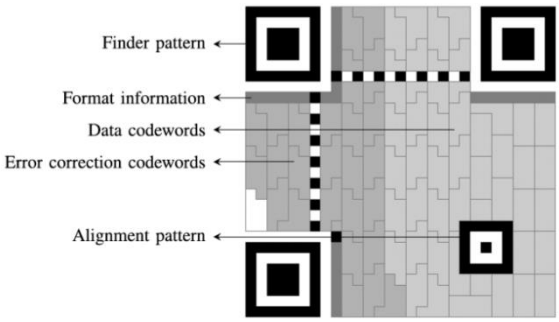

Figure 1. The Structure of QR Code

In biodiversity conservation, the implementation of QR codes has been implemented in many scenarios. A QR code is believed can be a solution to solve issues and address the needs in the work of biodiversity conservation. For instance, in the conservation of sea turtles in Huidong Sea Turtle National Nature Reserve, the QR code was utilised to mark the turtle that was released in the sea [14]. The purpose of this research is to improve rescue management and public participation. The QR code was printed on the body of the turtle with epoxy resin glue to provide. Information about the age, position and location of the turtles can be accessed by scanning the code. The current information about the location, time, and tools that are used to fish the turtle can be updated when people find the turtle. The system also can read the current position of the found turtle from the used device. Hence, when the turtle needs to be rescued, it can be identified and treated immediately.

The QR code was also used to label and collect specimen data in the research about Bioscience. According to Oteyo and Toili [15], the implementation of QR codes for specimen labelling, provides a convenient process for researchers in the data collection process of bioscience. The use of QR codes improves the efficiency of time and sources that are needed. In this research, the QR code will be scanned by users using their smartphones when they want to access the data collection form. All data is transformed into electronic format. Before using the QR code, the researcher should generate the code by converting the specimen identifier into the code. After that, in the experiment sites, specimen labels and the process of collection data can use the code. As a result, it becomes more paperless, costless, and timeless. This system also allows the researchers to manage their experiments.

In 2021, The botanical garden of the University of Teheran developed a system that is used to elevate the visitors' experiences when visiting the garden [16]. The system can be a guide for visitors to get knowledge about the local plants that are found in the garden. The QR code is considered becoming a trigger to access the main application in the system. The admin of the system should input the data that consists of names, descriptions, and the origin of the plant collection into the system. The QR code is generated and put on the plant. The visitor can access the plant data by scanning the QR code with the Android application that should be installed before. The data that is provided in the system is dynamic data. It can be changed or deleted by authorised users. This research also focuses on machine learning development. The machine learning module learns the image data and it can be used to identify the unmarked plants in the garden.

Auckland botanical garden in New Zealand worked together with Better Border Biosecurity (B3) to install QR codes in their areas to provide additional information about the pests and diseases related

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to biosecurity issues [17]. There were 12 checkpoints along the jogging track in the botanical garden that were displayed with the code. The purpose of this research is to educate visitors about biosecurity and to encourage them to be more aware of the prevention of pests and diseases that can harm the local flora. Hence, the visitors can actively help to stop the spread of pests and diseases in New Zealand. This research was conducted in 2019. The visitors of Auckland botanical garden can use their smartphones or tablet to get more knowledge about biosecurity by scanning the provided QR code.

In Indonesia, the implementation of QR codes has also been widely used in the preservation of biodiversity. According to Wati, et al. [18], QR code technology was involved in the development of The Borneo Smart Forest information system. The code was used to monitor plant inventory and plant markers. The QR code was implemented together with the biodiversity data management system that can be accessed on the web. The research focuses on the *Dispterocarpaceae* family in Kalimantan's Forest. In this project, the trees were labelled with the QR code that contains information about the URL website. Visitors can scan the QR code that is integrated with the BSF information system to obtain information about the identity of the plant, the description of the plant, and the economic potency of the plant. It is believed that with the system, the visitor can be encouraged to learn more about the plant and support the sustainability and conservation in Kalimantan Forest.

Focusing on the Indonesian Botanical Garden, previous research and projects about the QR code have also been initiated to elevate the quality of services or improve biodiversity preservation. For instance, In Jompie Botanical Garden, which is under the supervision of the local government, research about the use of QR codes was conducted to improve the visitors' experience in the botanical garden [19]. Visitors can get new knowledge about the plant collection in Jompie Botanical Garden by accessing the QR code. Similar research was also conducted at Purwodadi Botanical Garden in 2020. To educate visitors about the aquatic collection in Purwodadi botanical garden, the QR code was provided as a module [9]. The module will be spread as an educational tool that consists of some components such as general information, observation routes, a list of species, and the function of plants. The satisfaction of users with the use of QR codes as a part of technology in botanical gardens was researched in 2021. According to Ginardi, et al. [20], in Purwodadi botanical garden, 49% of primary school visitors were very satisfied with the innovation and 44% were satisfied. In the secondary level, 88 % of visitors were satisfied and very satisfied. The number depicts that the implementation of the QR code to educate and encourage visitors in biodiversity conservation has a positive impact on the quality of services in the botanical garden.

According to the previous research that is elaborate above about the implementation of QR codes for biodiversity conservation around the world, this strategy is appropriate to be implemented to solve the issues in the Indonesian Botanical Garden. Most of the previous research has had a positive impact on biodiversity conservation activity and is able to educate the public and community. In some Indonesian botanical gardens, the technology can accommodate the needs of the organisation. Hence, it can be elevated to solve the issues at the national level of Indonesian botanical gardens.

3 Research Method

In this research, The Research and Development (R&D) Methodology is appropriate to be implemented. According to Gustiani [21], R&D methodology is a method that is suitable to conduct research in the development of products or services. In the R&D methodology, there are some variations of models that are proposed by experts. For instance, the ADDIE model that was suggested by Dick and Carey divided the method into four steps which are analysis, product design, validation, and final product [22]. Another model was proposed by Buchori and Setyawati in 2015. It suggested five stages: preliminary research, design, realization, test, and evaluation [21]. Although the R&D has many versions of models, according to Zakariah, et al. [23] it can be simplified into three main categories which are:

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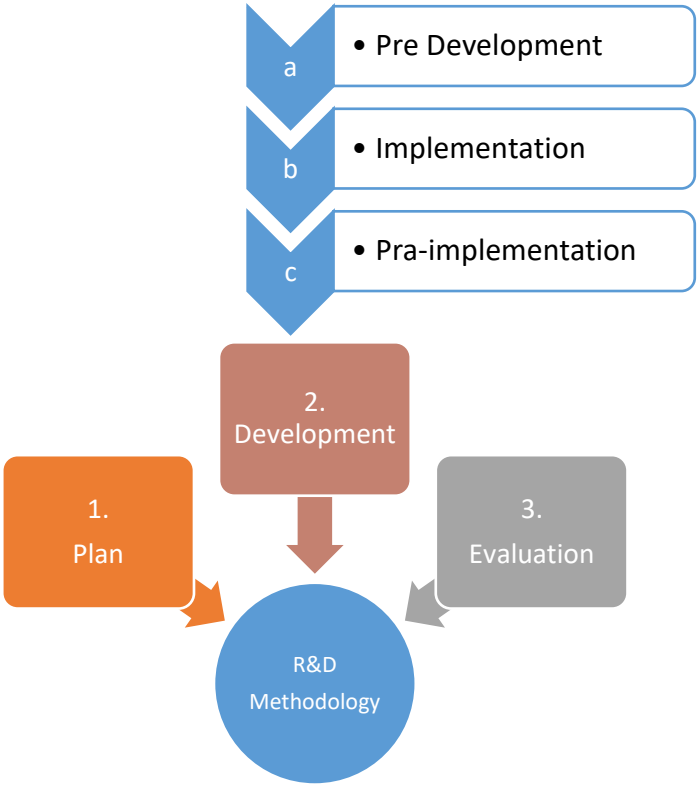

Figure 2. Research and Development Method

a. Plan
The plan is an essential part of the research or project. It is a rational and systematic process that determines the appropriate path or strategy that will be preferred to achieve the objectives of the research [24]. In this stage, some work should be done. First, gathering information about the current business process, related roles, and documents should be conducted. The appropriate method to gather the data and information in this research are using observation, interview, and literature study. Then, the gathered information should be reviewed and analyzed. The outcome of analyzing process is valuable to develop the research or project plan.

b. Development
In this stage, the project or research plan is executed. In this research, the database is prepared to accommodate the system's needs. At the same time, the information system is developed based on the current business process and the users' preferences. In the information technology project, the development stage is the main stage that is crucial to determine the quality of the outcome. The successful process of execution of the project plan contributes more to all processes in the project. According to Hanaizal and Mansoor [25], there are three main processes in the development stages:

1. Pre-development phase
In this phase, the outcome of the planning stage is transformed into a transition process. The first move in this phase is the project brief or project definition development. The initiative information from the previous stage is used to determine the objectives of the project, the scale of the project, time, and resources. Then, the first concept of the system should be made. The concept will be reviewed with the cost and time aspects. In the end, the initial design of the system will be ready to be executed.
2. Implementation phase

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The design of the system is executed on the site in this phase. The design will be transformed into a real model. In an IT Project, in this phase, most activities are generating a database, System code, and preparing the IT infrastructure.

3. Post-implementation phase
   According to Kerzner [26], the main focuses of the post-implementation phase are the maintenance period and the handover process. The tested system will be provided to the end user to obtain the final approval. The last, after tasks are completed, the system is in the user's hands.

c. Evaluation
   In the last stage of this method, the evaluation of the research or project is implemented. The evaluation is important to measure whether the system can address the users' needs. This stage is also useful for future research or project.

4 Results and Analysis

In this part, the results of the research are provided and elaborated following the flow of the adopted methodology in the research methodology. According to the preferred methodology above, there are three main segments that are also elaborated on in this part:

4.1 Plan

The outcome of this stage consists of stakeholder lists, requirements definition, current business processes, and a SWOT Analysis of the current business process.

a. Stakeholders list
   There are six groups of stakeholders that are identified in this research related to the routine inspection activity in the Indonesian Botanical Garden.

Table 1. Stakeholders list

No.	Stakeholders	Direct role in system	Interests
1.	Board office of BRIN	None	Monitoring scientific collection
2.	Researchers	None	Monitoring, updating, and obtaining scientific collection information.
3.	Registration unit	Registration	Data management and verification of updated report.
4.	Collection unit	Collection	Plant collection management and routine report oof plant collection
5.	Inspection team	Inspection	Updating and reporting data about current condition of plant collection
6.	Community or public or visitor	None	Obtaining a brief description about plant collection

b. Requirement definition
   The identified stakeholders are analysed to understand the stakeholders' needs and requirements for the new information system. As a result, it can be concluded that the stakeholders have different requirements based on their interests in the system.

Table 2. User requirements definition

No.	Stakeholders	Requirements
1.	Board office of BRIN	Realtime data monitoring of current condition of plants collection
2.	Researchers	Information about plant collection
3.	Registration unit	Efficient and effective data management

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4.	Collection unit	Efficient and effective plant collection management and treatment
5.	Inspection team	Appropriate data report and fast process of report
6.	Community or public or visitor	Information about plant collection

c. Current business processes

According to Lamine, et al. [27], great performance in an organisation has been influenced by the business process management that is implemented. Hence, it is mandatory to analyse the existing business process before developing the new system. In this research, there are three main roles that directly relate to the business process in the routine inspection of plant collection in the Indonesian Botanical Garden. In the Figure 3 below, inspection team reports the updated data to the collection unit. When the data needs to be changed, the collection unit reports to the registration unit to process the data.

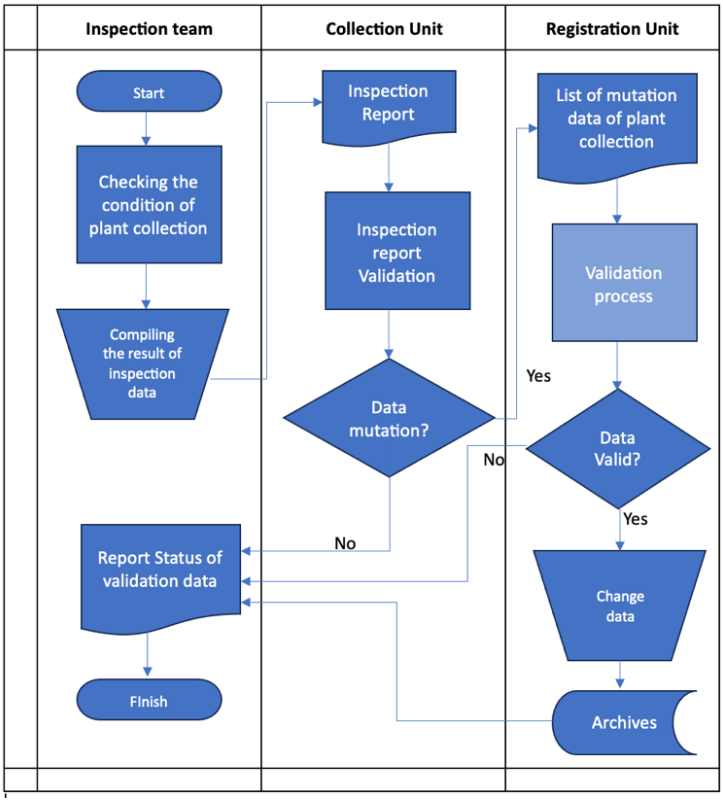

Figure 3. Flowchart of current business process

d. SWOT analysis of the current business process

SWOT Analysis is a common method to analyse the situation of the research object. A SWOT analysis is able to provide a systematic assessment and simplify the complexity of the research object analysis [28]. In this research, based on the SWOT analysis, the existing process business of routine inspection for plant collection management in the Indonesian Botanical Garden has some weaknesses such as there is no integrated system to identify the identity of plant collection and long-time report process. However, the opportunities as future potential lists were also identified such as the development of education tools for visitors based on the identity tag of plant collection and integrating routine inspection with the main system for plant collection management. These points can be novelty aspects of this research.

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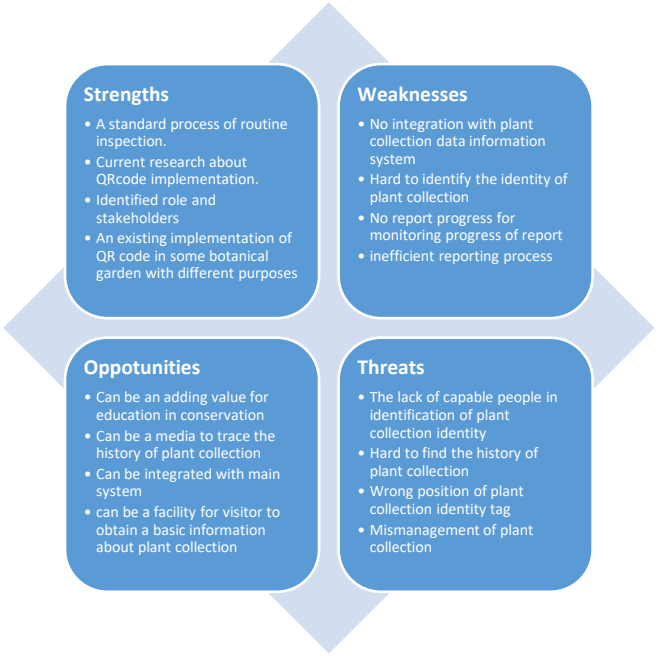

Figure 4. SWOT Analysis of current business process

According to Figure 4 above, the objectives of the future system can be developed with understanding the four aspects. The strength of current business process can be adopted such as the outcome of current research about QRcode implementation. The weaknesses are problems that should be solved with the future system. The new system should have functions to address the issues. Also, the opportunities can be considered to add values of the projects. For instance, the educational aspect can be facilitated in the new system.

4.2 Development

a. Pra-development phase
In this phase, there are some results that are established such as system architecture, Entity relationship diagram (ERD), and information access design. These outputs are needed in the implementation phase.

1. System architecture
This system is deployed in the cloud platform. The developed system consists of four components: plant collection database, internet, users' devices, and web server. In the Figure 5, the interaction between components can be seen. With the architecture, the users can access the system with their devices without installing the system first in their devices. It provides conveniences in accessing the process. In addition, the future updating process for maintenance purposes or functional updates can be done quickly with the implemented system architecture.

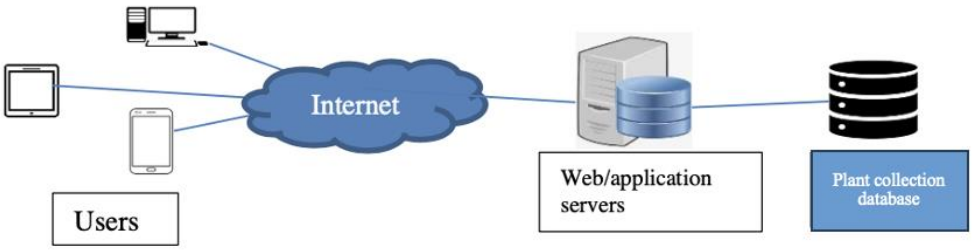

Figure 5. System architecture

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2. Entity Relationship Diagram

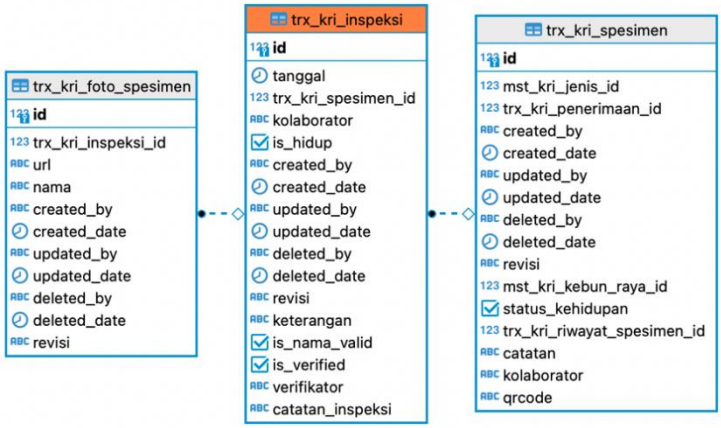

Figure 6. ERD Diagram

ERD diagram is designed based on the business process. Table specimens represent the plant collection databases. In the background process, the database consists of many tables such as users, exploration, nursery, and other related tables.

3. Information access design
The flow of how information is obtained is essential to get a vivid visualization of the information flow.

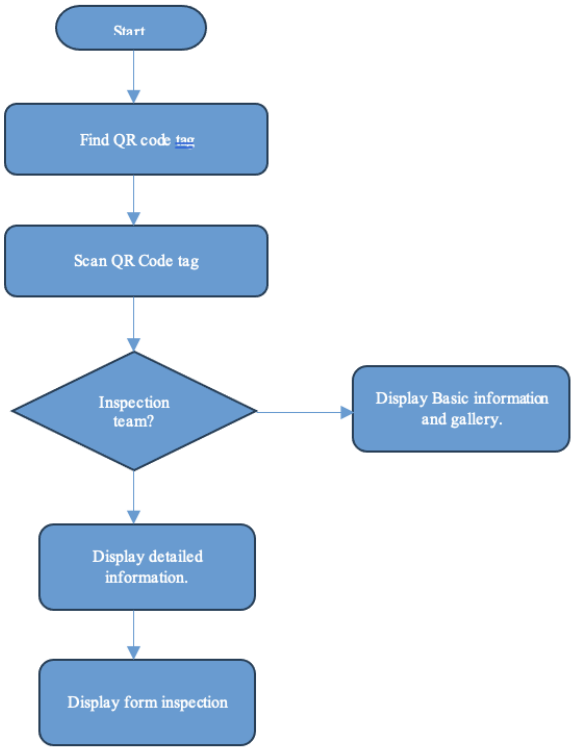

Figure 7. Diagram of Information access design

In the diagram of information access above (Figure 7), the first information for users can be obtained through scanning the QR code. The system will analyze the role of the users.

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The common users only can access the basic information about the plant collections. The inspection team can access the inspection form and detailed information.

b. Implementation

In this part, the system interface is generated to accommodate the business process and users' requirements.

1. Generating the QR code interface

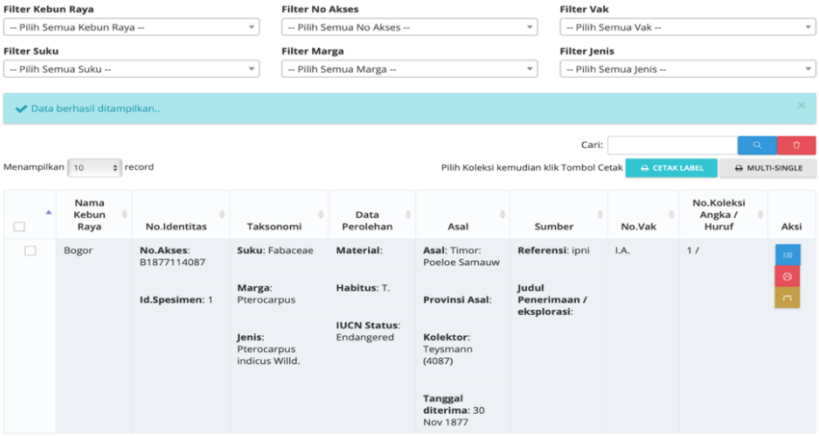

Figure 8. Generating QR code

According to Figure 8, the form of collection data includes some buttons such as the printing button, history button, and searching button. To print the QR code, the registration unit can access plant collection data and filter the data based on the needed field such as region or species. Then, the user can select the specimen and push the print button.

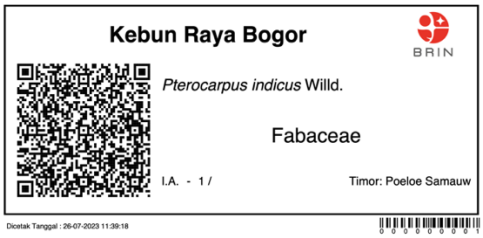

Figure 9. Identity tag with QR code

The identity tag that includes the QR code in Figure 9 above, contains some basic information such as the name of the plant collection, the origin of the plant, the name of the botanical garden, and the location of the plant collection in the botanical garden area.

2. Public page

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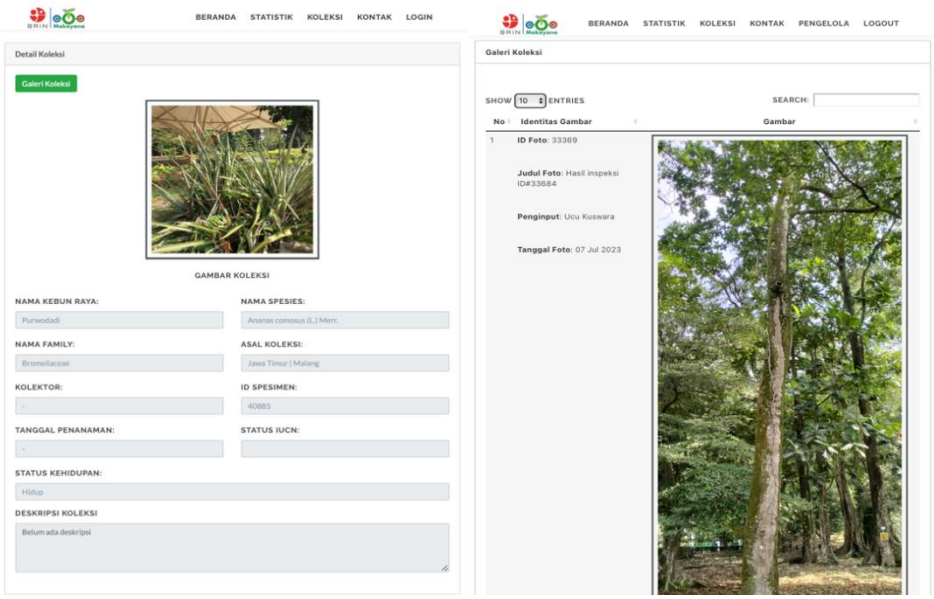

Figure 10. Public page

After scanning the QR code, the link that is contained in the QR code guides the user to access the public page. On this public page, which is shown in Figure 10 above, basic information about plant collection can be seen by users. The information consists of the current picture of the plant, the species name, the family name, the origin of the specimen, and the life status. Users also can access the gallery page to learn about the picture history of the plant collection.

3. Inspection page

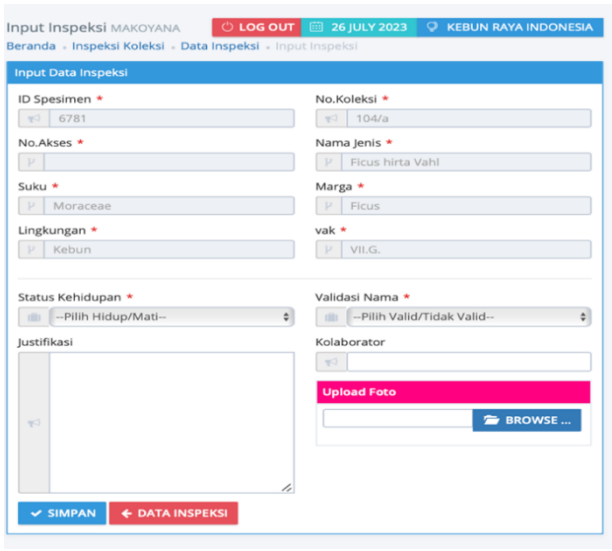

Figure 11. Inspection page

The inspection page in Figure 11 above is the restricted page that is only accessed by authorised users. On this page, users can update the current condition of the plant collection, report the living status, report the wrong identity identification, and update the current image of the plant collection.

4. Inspection data page

All reports from inspection activities using the QR code facility can be accessed on this page. In Figure 12 below, on the inspection data page, users can monitor the progress of

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inspection activities and trace the history of inspection activities. The data can be traced by location or access number.

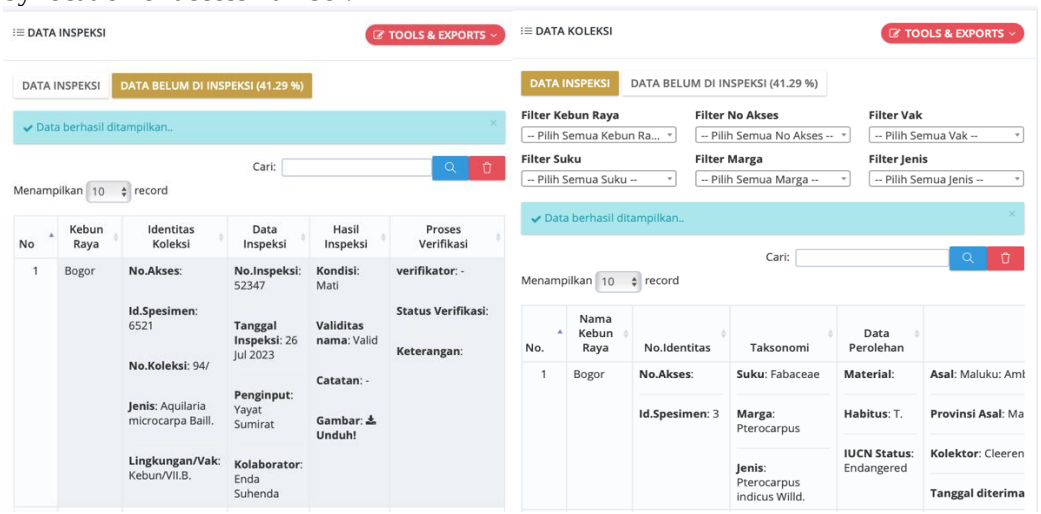

Figure 12. Inspection data page

c. Post-implementation

Before implementing the new system, system testing is needed to assess the success rate of the developed system. The system will be assessed by the user from five botanical gardens under the National Research and Innovation Agency of Indonesia (BRIN).

Table 3. User interface testing

Participant	Generate QR Code page	Basic information	Gallery page	Inspection page	Inspection data page
Purwodadi Botanical Garden	V	V	V	V	V
Bogor Botanical Garden	V	V	V	V	V
Cibodas Botanical Garden	V	V	V	V	V
Eka Karya Botanical Garden	V	V	V	V	V
Cibinong Botanical Garden	V	V	V	V	V
Success rate	100%	100%	100%	100%	100%

Based on the user interface testing in Table 3 that involves users from five botanical gardens, the new system can provide the services for the users. It can be seen from the success rate that is 100%. The success rate does not mean that the system is useful for users. It depicts the ability of the system to provide the pages that are requested by users.

4.3 Evaluation

After the system is implemented, the evaluation phase can be conducted by assessing the ability of the new system to address the users' requirements. The result of the evaluation phase can be useful for future development and research. It can be concluded that the system adds the capacity of the main system and improve the quality of plant collection data management. In this project, the outcome of users' requirements evaluation can be seen in Table 4. From the evaluation, the system can address the stakeholders' requirements. The

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system can provide real-time data and can be used to monitor the condition of plant collection. Also, the reporting process can be more effective and efficient with the system.

Table 4. Evaluation of users' requirement

No.	Stakeholders	Requirements	Evaluation
1.	Board office of BRIN	Realtime data monitoring of current condition of plants collection	The data that is provided from routine inspection can be monitored from the Makoyana information system.
2.	Researchers	Information about plant collection	The system is able to provide a basic information about plant collection with QR code scan process.
3.	Registration unit	Efficient and effective data management	The process of data management relates to the inspection process can be monitored from inspection data.
4.	Collection unit	Efficient and effective plant collection management and treatment	The plant collection can be treated based on the history of plant collection that can be seen from inspection history.
5.	Inspection team	Appropriate data report and fast process of report	Reporting process is efficient and effective.
6.	Community or public or visitor	Information about plant collection	The system is able to provide a basic information about plant collection with QR code scan process.

5 Conclusion

To conclude, based on the implementation of the system and the evaluation process, it can be claimed that the issues that are experienced by the Indonesian Botanical Garden about the routine inspection of plant collection, can be solved by the new system. The implementation of a QR code that is integrated with the plant collection data information system (Makoyana) is a solution to identify the identity of plant collection in the Indonesian Botanical Garden. First, it can decrease the possibility of mistakes in the routine inspection report. The accuracy of the data that is generated can be validated by the system. Also, it can improve the efficient time of reporting process. The role of users can be clearly seen in the system. Hence, the routine inspection of plant collection can be conducted efficiently and effectively. As a result, the quality of data that is generated from the inspection activity enriches the plant collection data that is useful to monitor the plant collection condition in real-time mode. In addition, the new system provides basic information for visitors to the Indonesian Botanical Garden. It can be a tool to educate them about the flora that is collected in the Indonesian Botanical Garden. It also can encourage them to be more active in flora conservation. The easy way to obtain the information by scanning the QR code with the smartphone is part of an improvement in the quality of the organisation to provide the best treatment for the public and the community. The QR code implementation is also a commitment of the organisation to support the Indonesian government program in the digitalisation transformation and open information for the public.

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