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The Asset Management and Tracking System for Technical and Vocational Education and Training (TVET) Institution Based on Ubiquitous Computing

Totok Sulistyo[1]*, Karmila Achmad[2], and Ida Bagus Irawan Purnama[3]

[1,2]Civil Engineering Department, Politeknik Negeri Balikpapan
Jln. Soekarno Hatta No. KM. 8, Kalimantan Timur 76129, Indonesia
[3]Electrical Engineering Department, Politeknik Negeri Bali
Kampus Bukit, Bali 80364, Indonesia
[1]totok.sulistyo@poltekba.ac.id; [2]karmila.achmad@poltekba.ac.id; [3]ida.purnama@pnb.ac.id

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Abstract **-** Generally, Technical and Vocational Education and Training (TVET) has numerous types of assets used for conducting various skill-based learning activities. The failure to properly manage the TVET assets can lead to inefficient operation and administration, such as difficulty in tracking the history of the asset, location, and users. The research solved the problems by developing and implementing asset management and tracking system based on ubiquitous cloud computing for movable and fixed assets. The research activities were conducted in Politeknik Negeri Balikpapan, one of ten state-owned TVET institutions in Indonesia. This system was accessed using a web and mobile application. Quick Response (QR) code was used for asset identification to make a mobile device read the code with their built-in camera. Meanwhile, the geolocation was attached to provide the spatial information of assets' whereabouts. Then, the research adopted the 5W1H question principle, so all aspects of asset management were collected and understood. The results show that the system helps TVET to keep track of their equipment and vital inventories in real-time. Moreover, the implementation of the system has a great impact administratively and ease in delivering instantaneous data and assets history for decision-making to internal and external asset auditors.

Keywords: asset management, tracking system, Technical and Vocational Education and Training (TVET) institution, ubiquitous computing

I. INTRODUCTION

Technical and Vocational Education and Training (TVET) has a significant contribution to economic development. It is a tool for a nation and region to reduce poverty and foster productivity (Pavlova, 2014). It takes developing skills, gaining underlying knowledge, and building practical experiences to prepare the competent workforce for entering the labour market. Considering the vital role of TVET institutions in national and regional economic development, they need to invest an enormous amount of money in their facilities, such as workshops, laboratories, and training instruments and equipment. Meanwhile, qualified graduates are highly demanded by teaching curriculum and users to have a good match for jobs in their early carrier (Korber & Oesch, 2019). Accordingly, providing learning facilities and teaching materials which keep up with the industry's needs is a must. It reflects reciprocal linkages between what is taught and trained in TVET and what is run in industrial work practices. However, the institution of TVET also needs to evaluate the rate of usage of all invested tools for training purposes, tools maintenance, and purchasing plans. The previous research on strategic assets management reveals that it is frequently found that the state's assets in Indonesia are idle or not used optimally (Hariyanto & Narsa, 2018). As known, the investment objectives on such state assets are for human resource development of the nations in a couple of decades. Therefore, it is urgent and important to manage those kinds of assets in reliable information systems to evaluate idle and

*Corresponding Author

usage time for the following asset policy and decision-making.

Relying on conventional administration or manually using a variety of spreadsheets to handle asset management functions in TVET will risk the investment. It can be costly, time-consuming, and unnecessarily intricate. It is not capable of overcoming the huge and complicated jobs, such as entering detailed assets identification, location, specification, circulation, queue, loss, and depreciation of thousand items. Moreover, tracking and reporting should also be performed where and when needed at any place and time. However, the inconsistencies of human administration can aggravate asset inventory and data. For example, when students of the Civil Engineering Department carelessly use the tool or the other items in the laboratory and the field, they can induce those items to malfunction or even break. When they work in the field, such as geomatic surveying and geotechnics in site measurement, a part of the instrument is sometimes lost.

For instruments and equipment used repetitively, they need maintenance or replacement periodically. Sometimes, a tool is misplaced or missing without being traced and knowing who is responsible for it. All those problems are frequently faced by TVET. They are hardly identified when conventional administration is solely conducted. Improper asset management practice has great financial risk, like spending more money on high-cost replacement and repairing the worsening tools, machines, and other infrastructure parts (Vanier, 2001).

Recently, some firms have applied the Internet of Things (IoT) based asset management system to manage their assets and track their asset data better (Man, Na, & Kit, 2015). In the healthcare industry, the asset management system is used for maintaining medical supplies and hospital-related equipment. Even in the oil and gas industries, which always hire high-tech instruments in the high-risk environment, they adopt the Integrated Asset Management (IAM) approach more than the conventional approach to optimize surface facilities (Sarvestani, Goodarzi, & Hadipour, 2019). Many other industries also rely on asset management and tracking systems, especially for maintaining their movable assets, such as retail, logistics, and transportation (Veiseh & Monfared, 2019). However, the problem of asset management and tracking in TVET has a unique nature different from those industries. In TVET, especially in Civil Engineering Department, equipment is mostly used concerning some job sheets and tutorials under a certain course and instructor. Students can only engage in the circulation of that equipment if they take that course. This trait makes the commonly available software and applications cannot fully fit on it.

Moreover, cloud computing has been growing in popularity in the recent decade. It enables parallel computing or access with different platforms and devices as long as an Internet connection is available. Parallel to the growth of computing, most people around the globe use mobile technology as part of their lifestyle. This technological trend has become ubiquitous computing (Choi, Park, & Jeong, 2013).

Moreover, What, Where, When, Who, Which, and How (5W1H) approach is usually used in the business field for asking a set of questions to identify the true nature of the problem (Ham, 2014). In the research, this approach is adopted to collect all necessary data on the assets so that all their contexts, including the circulation process, can be described precisely. Quick Response (QR) code is used in item identification instead of a barcode. It can easily make many mobile devices read the code with their built-in camera. Meanwhile, geolocation data that consists of latitude and longitude is attached to provide the spatial visibility of assets' whereabouts. The geolocation data is recorded by the built-in GPS of an Android smartphone and stored with asset ID in the cloud database. For example, when equipment is used outdoor for field measurement purposes, its location and movement can be detected and displayed on the map based on its coordinates. Once all the assets and transactions are recorded and put in the cloud, the queries can be submitted everywhere and every time. Then, the designing asset management system can be developed using an object-oriented approach by creating some classes like administrator class, student class, asset class, and others. Each class can be instantiated as an object at any time needed, so there is the interaction between objects, just like in the real world. Meanwhile, the designing and development system is conducted through the Unified Modeling Language (UML) and the Rational Unified Process (RUP) (Fauzan, Pamungkas, & Wibawa, 2019).

The previous research on asset management information system development focuses on developing web-based and PC-based applications (Richard, 2017; Fauzan et al., 2019). Meanwhile, the research focuses on the development of asset management information systems based on web, mobile, and smart TV applications.

Based on the context mentioned earlier, there are three research aims. First, it is to help a TVET to identify its asset nature using the 5W1H approach and integrate them in the form of inventory data in the cloud server. Second, it develops and implements asset management and tracking systems based on ubiquitous cloud computing to improve TVET operation. Last is to inspect all problems faced during the system's deployment, followed by the proposed solution. These three goals are achieved by using the methodology described next. Then, the implementation of this system is expected to help the institution to manage their asset, keep their stationary and portable assets on track of inventories live online, and record them in a cloud database in their usage and transaction.

II. METHODS

The research is conducted in Politeknik Negeri Balikpapan, one of ten state-owned TVET institutions in Indonesia. The pilot project of the research addresses asset management and tracking problems in the Civil Engineering Department of Politeknik Negeri Balikpapan. Due to the numerous movable and fixed assets in this department, it needs to be managed and controlled correctly. It is also to fulfil the absence of an automated tracking system. The primary research method is designing, developing, and deploying web-based and Android-based applications. It also prioritizes the proposed TVET requirement, current business process, and expected usability. Here, user involvement is incorporated to open more opportunities to control the outcome.

The system implementation is resolved in eleven stages, as depicted in Figure 1. These eleven stages are the inter-related tasks that need to be carried out appropriately. The first stage reviews the related works in recent literature to get a suitable method, best practice techniques, and the latest technology for asset management and asset tracking. The second stage is data collection through interviews and Focus Group Discussion (FGD) of the involved users using the 5W1H approach and observing the current process business in handling all the assets administration and circulation. The third stage is data analysis. This stage is the effort to get an overview of the user's expectations

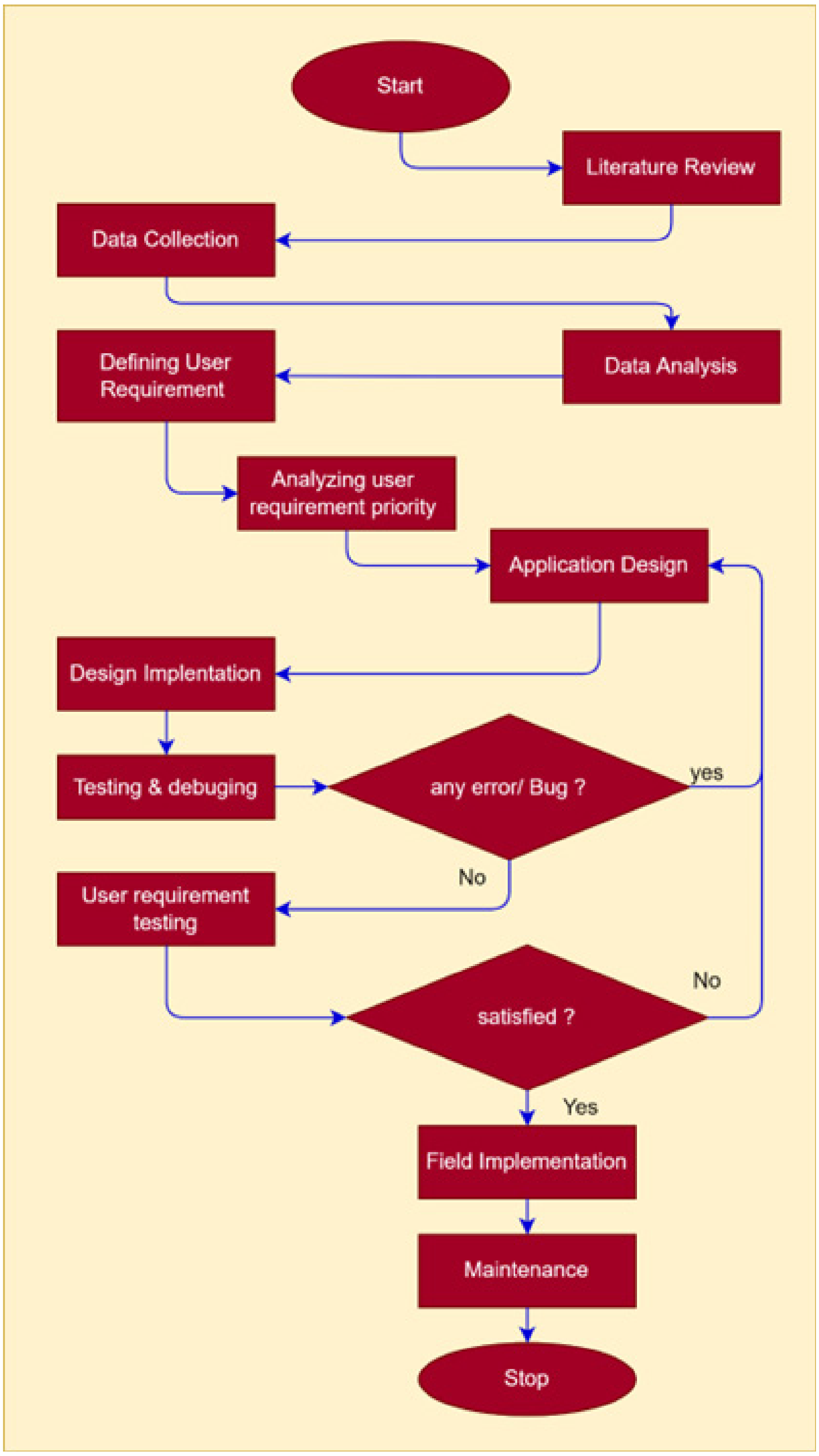

Figure 1 Development Procedure of Asset Management Application

and preferences regarding the usability of the system and application. The fourth stage defines the user requirements to precisely describe what the user can do or perform with the system and application. The fifth stage analyzes those requirement priorities to narrow the requirement based on the degree of importance and urgency and the available resource and time. The sixth stage consists of application design to meet the need for a user-friendly interface and efficient system, including algorithm and database design in MySQL that match the conceptual design and users' needs (Yuliana & Rahardjo, 2018).

The seventh stage is the design implementation by creating a user interface and writing code where the executable application is developed and written into the program. The eighth stage consists of testing and debugging, including code correction, to ensure that the executable application is free of errors and bugs. Then, the ninth stage has user requirement and acceptance testing to ensure that the candidate users are satisfied and willing to use the developed application. The next is the application deployment stage to ensure that the application is available for online use and downloading, including monitoring post-deployment such as crashes and an Android Application Not Responding (ANR). The last stage is maintenance and improvement of the application performance by reducing weaknesses and fixing emerging errors, such as crashes, ANR, and other bugs. So, it can support new required features and improve the application's performance and robustness.

The post-implementation stage is routine evaluation. This stage evaluates the post-implementation bug and the user's request in the system performance for developing a new feature intended for continuous system improvement. This stage can be done using the questionnaire method or FGD.

Next, the research uses the 5W1H approach to solve the problem. The aforementioned description method is based on best practices in application development. It has a development cycle that looks like a waterfall model, but it is a different model. It emphasizes the test of fixing bugs and meeting user satisfaction more than other states to carry out the development and implementation system of asset management. Somehow, the user requirement is vital to ensure the user's willingness to participate in new systems. The previous research method in the development of asset management has used the waterfall model in the sequential process of development and fishbone analysis to show the condition of the cause and impact contributions (Richard, 2017). There is also another research in asset management information systems using the Rational Unified Process (RUP) method in the application development (Fauzan et al., 2019).

The software development tools for the system implementation of application design consist of the text editor for PHP coding, MySQL database server, phpMyAdmin as MySQL Administration user interface, web browser (Chrome and Firefox), Android Studio for the development of an Android application, CPanel for web administration, QGIS for digital map management, and PHP QR Code Generator as the tool generating QR Code based on asset ID or user ID. Then, the web subdomain of this project is hosted in the Data Center of Politeknik Negeri Balikpapan. Meanwhile, the mobile or Android application is published in Google Play Store and available for downloading without charge.

III. RESULTS AND DISCUSSIONS

Prioritization of the user requirement is based on the classification of importance and urgency. The results of the classification of critical and urgent needs of applications from the users' needs and expectations are followed-up in the next stage. Three applications must be developed to enhance the asset inventory system in the Civil Engineering Department of Politeknik Negeri Balikpapan. The first application is web-based asset data management system. The application is intended to manage and operate assets circulation and monitor activity conducted by the administrator and department head. The second application is an Android application to facilitate administrators and students when working in the workshop or the field, so they are away from their desktops, PCs, or laptops. Hence, they can operate the application while doing other things simultaneously. The third application is the displaying system or billboard application dedicated to 51 inches LED screen to publish asset circulation information for the public.

The three application systems are connected and tied to the single database system so that the stored and displayed data come from the single source of the database server. The database server and the application server are two applications located in a single machine (hardware). The application server stores PHP files, JavaScript files, CSS files, and asset files. Meanwhile, the Android application resource files are stored in the Android client and packed as APK files or Android App Bundle (AAB) files. Inside APK and AAB files consist of code/DEX (Java & Kotlin), resources, assets, native library, and others. The download size is negligible because the mobile application is not for commercial and common uses, which are expected to get users as many as possible. The application is dedicated to internal use (administrators, operators, and students). An Android application can read the MySQL database if an available PHP file in the application server has a function to parse the MySQL table into JSON data. Then, it will be read and displayed in the Android application. An illustration of the entire application system, including the application server, application client, and database connection, is depicted in Figure 2.

The database of asset inventory management is built on the MySQL database server hosted in the institution's data center. The database is integrated into the Internal Quality Assurance System (IQAS).

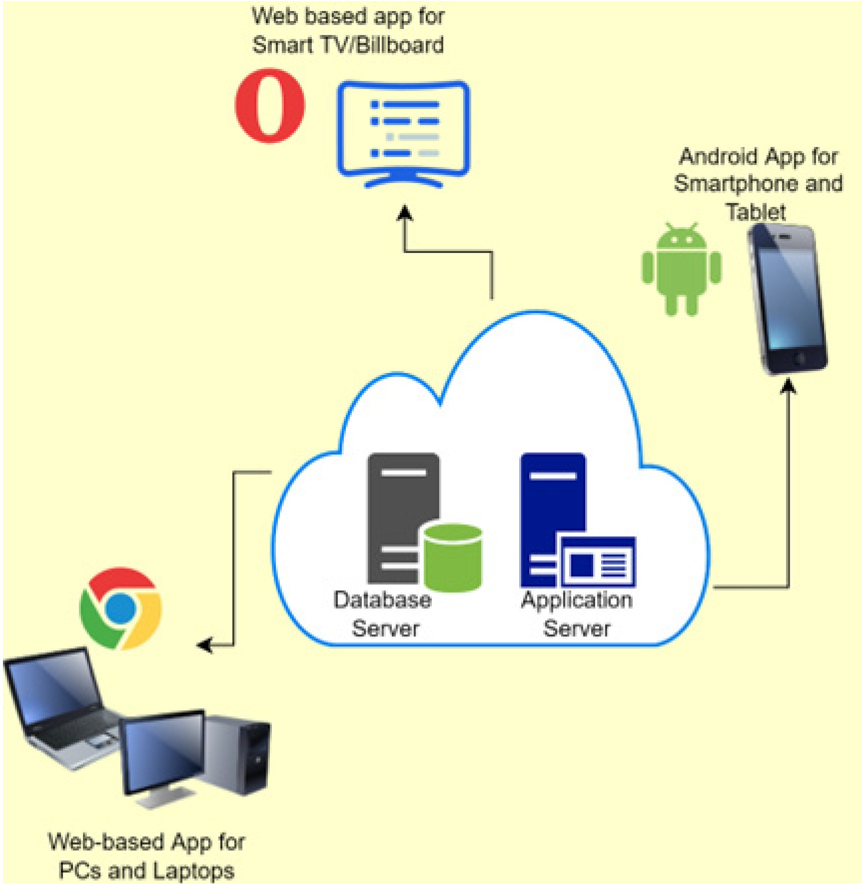

Figure 2 Integrated Database as the Data Source of Ubiquitous Computing of Asset Inventory

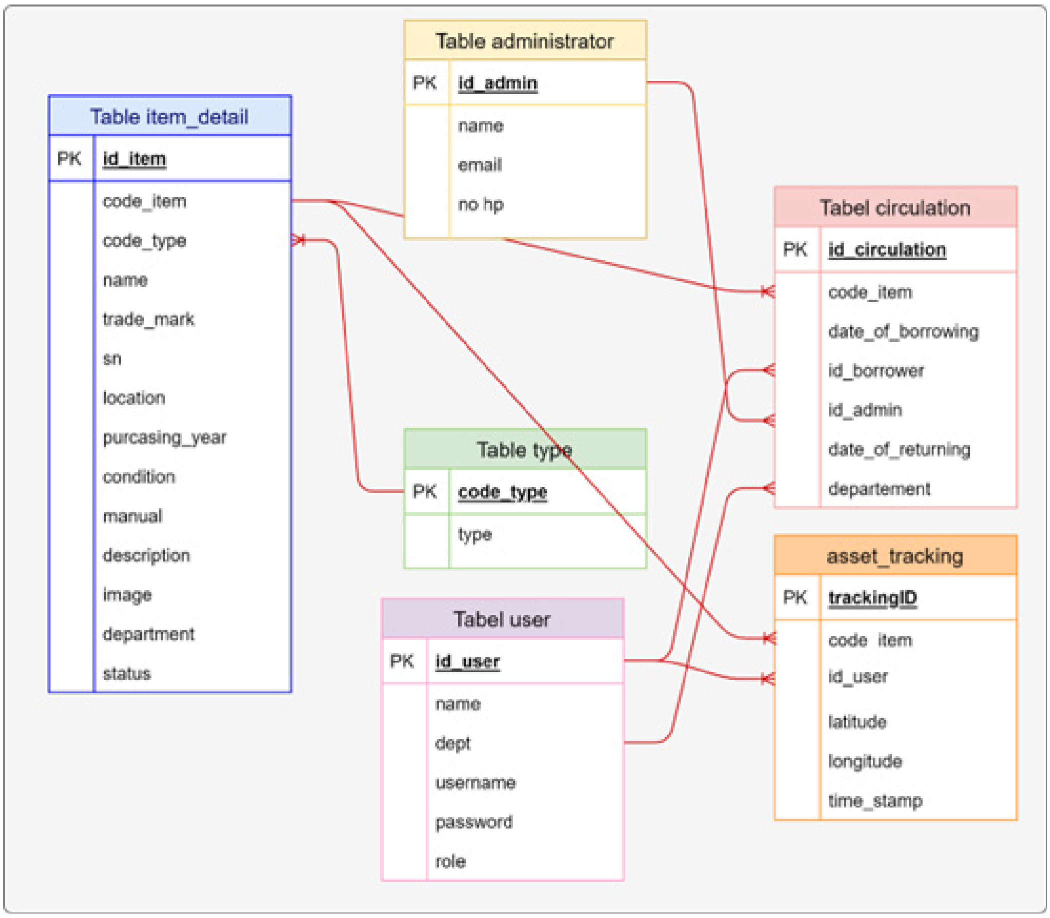

Figure 3 Entity Relation Database of Asset Inventory System

Therefore, the table of assets inventory is selected and portrayed separately from the main database focusing on the research aims. The structure and table relationship of the database of the asset management application can be depicted in Figure 3.

Web-based asset inventory application has three actors. It consists of the department head, administrator or operator, and visitor. The detailed feature and data accessibility can be seen in Figure 4. A visitor can only access the public home page. Meanwhile, the department head has access to home and asset data. Then, the administrator or operator must manage asset data, asset circulation, and student data.

Meanwhile, there are two actors for the Android application: admin and student. Admin users can access borrowing items by scanning the QR code of the item and student ID, returning the item by scanning the QR code of the item, scanning item QR code to display item specification, and displaying a list of the last twenty borrowers. Then, the student can show their QR code id dan display the last twenty borrowers. They can also scan the item's QR code to display its specification. Those described applications have been developed and published on Google Play and can be downloaded through the following link: https://play.google.com/store/apps/details?id=info.totok.asetpoltekba for administrator and https://play.google.com/store/apps/details?id=totok.sulistyo.assetmhs for students. The features of those Android applications are depicted in the use case diagram in Figure 5.

The overview of the Android application operation flow and the function of the administrator role in the asset inventory system is illustrated in Figure 6 (see Appendices). It consists of complete features. Starting with log in page, administrator can access several features on the Android application. There are asset information and managing circulation consisting of managing borrowing item, returning item, and viewing last twenty borrower.

The Android application for the student has a simpler function than for the administrator, as shown in Figure 7 (see Appendices). The Android application for the student has some functions. It can display QR codes of student ID, scan QR items to display asset information, and display the last twenty borrowers.

The Android application development is conducted using Java language in Android Studio. The development is conducted using PHP to connect the application to the MySQL database on the server-side. The database server and application server are hosted in the Data Center of Politeknik Negeri Balikpapan and can be accessed through https://spmi.poltekba.ac.id, and the asset catalogue also can be found at https://sipil.poltekba.ac.id.

Figure 8 (see Appendices) depicts the administrator's dashboard of asset data. Through this dashboard, the administrator can manage asset data, track asset history, and answer Frequently Ask Questions (FAQs) of the asset based on 5W1H, such as what kind of asset has been used, who uses it, when the asset is borrowed and used, and where the user operates the asset. The administrator can also generate a QR asset based on its id. Then, the administrator can export the selected QR code item to a DOC file and print it. The print layout is designed for item labelling purposes. Then, the printed QRs are attached to the asset that can be scanned using the developed Android application for circulation, identification, and asset introduction to the new student before they operate those assets. Using a certain scanning menu, the student can get assets specification information and their manuals.

The user interfaces for smart TV are designed using Cascading Style Sheets (CSS) and JavaScript to match smart TV screen resolution and give information at any time to anyone consisting of the administrative staff, student, lecturer, department head, and other external stakeholders. If there is a display screen with a different aspect ratio between horizontal and vertical, a little bit of adjustment in CSS is needed. The display of the smart TV app is depicted in Figure 9 (see Appendices).

Asset data that consist of asset ID, age, and usage history, will help the asset manager or department head in maintenance and calibration measurement tools. It will also help the department in decision-making processes for purchasing for replacing broken assets or another contingency plan due to the age and usage history of the asset (Jung, Ray, & Salkuti, 2019). The location and usage time stored in the database can be utilized in monitoring assets and students or other users. It can also be used to trace back when and where a certain part of the tool or asset is lost or broken in the field during its usage using the map. The example is seen in Figure 10 (see Appendices). The tracking geolocation where the asset is used is recorded using the built-in GPS of the Android smartphone. Users must scan QR codes of the asset when they work outdoor for in-site measurements, such as geotechnics or geomatics jobs. The item code, user's ID (from user's session), and geographical latitude and longitude will be recorded in the asset tracking table of the asset database. Then, the location can be viewed on a QGIS map or Leaflet or Web GIS as an asset location layer. The weakness of this geolocation tracking is dependent on the user's willingness to scan QR codes in every sequential move of the asset as required to finish their jobs.

The implementation of the system starts from socialization with the users consisting of students, operator or administrator, workshop head, study program head, department head. This socialization includes training, distributing user manuals, and posting announcements. Then, user testing is conducted under the order of the department head, who has ordered the operator to start implementing the system while the operator keeps doing the old system. The difficulties and complaints of users are addressed by fixing bugs and adjusting to users' requests. After a couple of months, the operator and student are accustomed to the system and the operator shifts to the new system.

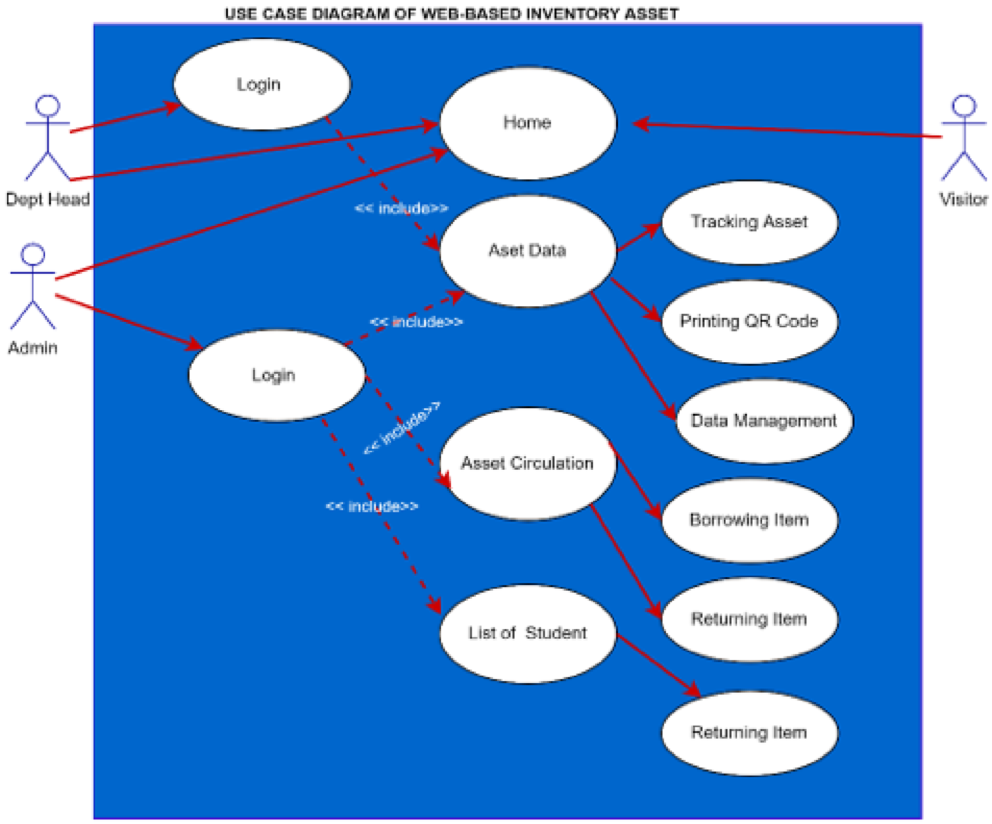

Figure 4 Use Case Diagram of Web-Based Inventory Application

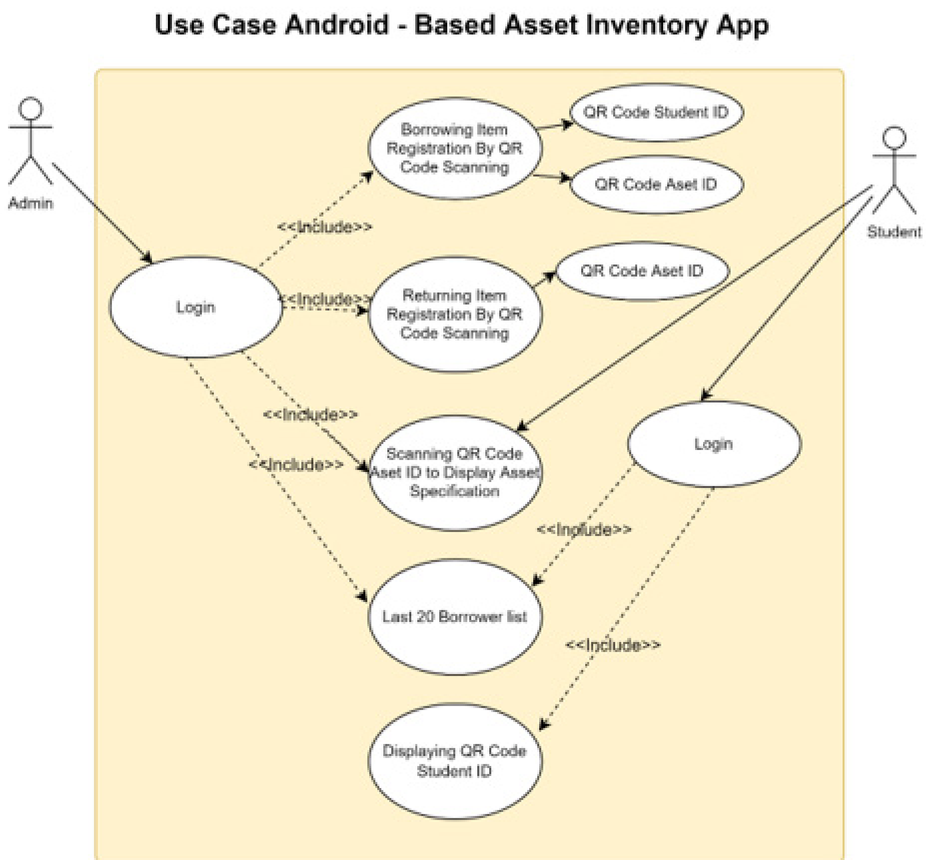

Figure 5 User Case Diagram of Android Application

The success of system implementation is evaluated using the FGD method. FGD is held in a virtual meeting that involves the department head, study program head, laboratory and workshop head, operators, and system developer. Based on this activity, there are several mentioned problems. Less electricity supply in the area sometimes can be solved by providing electricity backup using an electricity generator set. Then, Internet bandwidth is also a major challenge for the institution, as the growing number of students and staff causes the bandwidth allocation to get smaller. Solution of Internet bandwidth limitation and disconnection can use Internet connection backup from other Internet providers or mobile data more than just relying on a single Internet provider. This corrective action is handled by the computing and data center of the institution as requested by the department head.

Another hardship is the human resource issue. This issue is a common problem in implementing the new information system (Richard, 2017). The theory is proven by showing that the main hardship is the human resource readiness issue. The department staff's mindset and skills cannot be changed instantly. They are accustomed to managing asset circulation manually, and students must fill out the circulation form in the long run. They seem comfortable working with the old method more than adapting to new technology such as Information and Communication Technology (ICT). However, they must use new technology. The main hardship, such as human resource readiness issues, is handled by a series of efforts, like training, intense supervising from the department head, and proactive user support.

The common hardship is ICT literacy issues. It becomes a barrier to start using new technology in their daily job. Such hardship needs integrated solutions, like training, policy, regulation, incentives, and others. Moreover, skill and knowledge sets are not enough. Hence, regulation and policy are needed to adopt new habits and technology in routine jobs.

Based on observing the implementation of asset inventory systems in the Civil Engineering Department of Politeknik Negeri Balikpapan, continuous supervision and technical support (help desk) is also the primary success key to the new ICT implementation. ICT commitment is strongly needed to support the successful implementation of information systems as the part of asset management business process. The ICT literacy and skill of the staff are the manifestations of the ICT commitment to applying the sophistication of ICT in enhancing customer service (Saptadi, Sudirman, Samadhi, & Govindaraju, 2015). Finally, the application is gradually implemented in Civil Engineering Department to replace the conventional systems. Then, its implementation has a significant impact administratively, such as trackable asset whereabouts and ease of giving instantaneous data for decision-making for internal and external asset auditors.

IV. CONCLUSIONS

The development and implementation of the asset information system in TVET institutions such as the Civil Engineering Department of Politeknik Negeri Balikpapan is an imperative initiative that should be fostered in handling and managing the learning tools as an institution and state asset. The information system can give real-time, and the history of asset location provided by a built-in Android GPS and the Android application to the database server. The location data can help improve asset management, especially tracking the users and movable asset locations. The tracking data can easily track lost assets or part of assets. It even can find back when the asset or part of the asset is lost in the field during the utilization or operation of the asset. The cloud database implementation facilitates the operator to work more flexible to record every administrative asset transaction that will ease all interest parties to benefit from such data for any purposes.

The significant impact of implementing this asset management and tracking system is the improvement of asset databases by converting paper-based and spreadsheet data to less paper or even paperless cloud databases. The database accessibility can be retrieved faster anywhere and anytime than on paper and spreadsheet. It is instantaneously available when needed, such as in asset planning, decision-making needs, and asset audit, because the data can be displayed in any format on any platform.

There is a limitation in the research. The implementation of asset information system is limited in the small organization. It can be more complex and have bigger hardships and challenges when implemented in the bigger institution. Then, the mobile application is still limited in Android smartphones. The future research can be developed for other smartphones, such as iPhone and Windows smartphones.

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APPENDICES

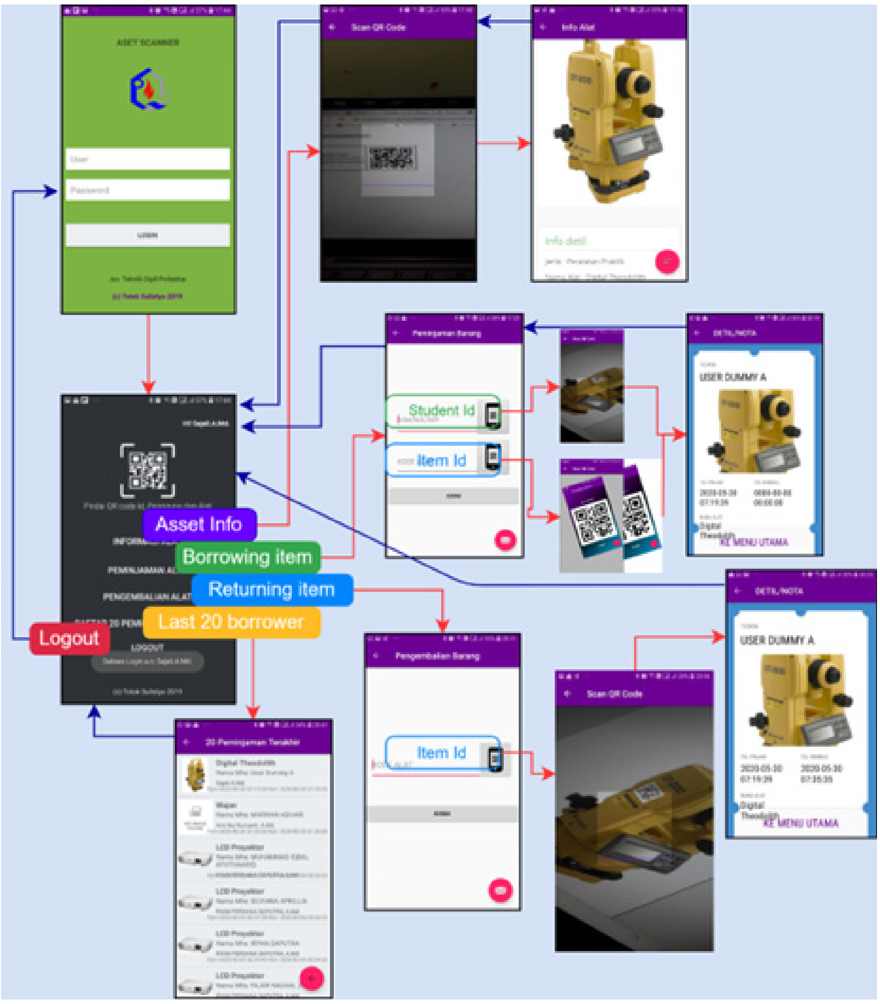

Figure 6 User Interface Workflow for the Administrator in Android Application

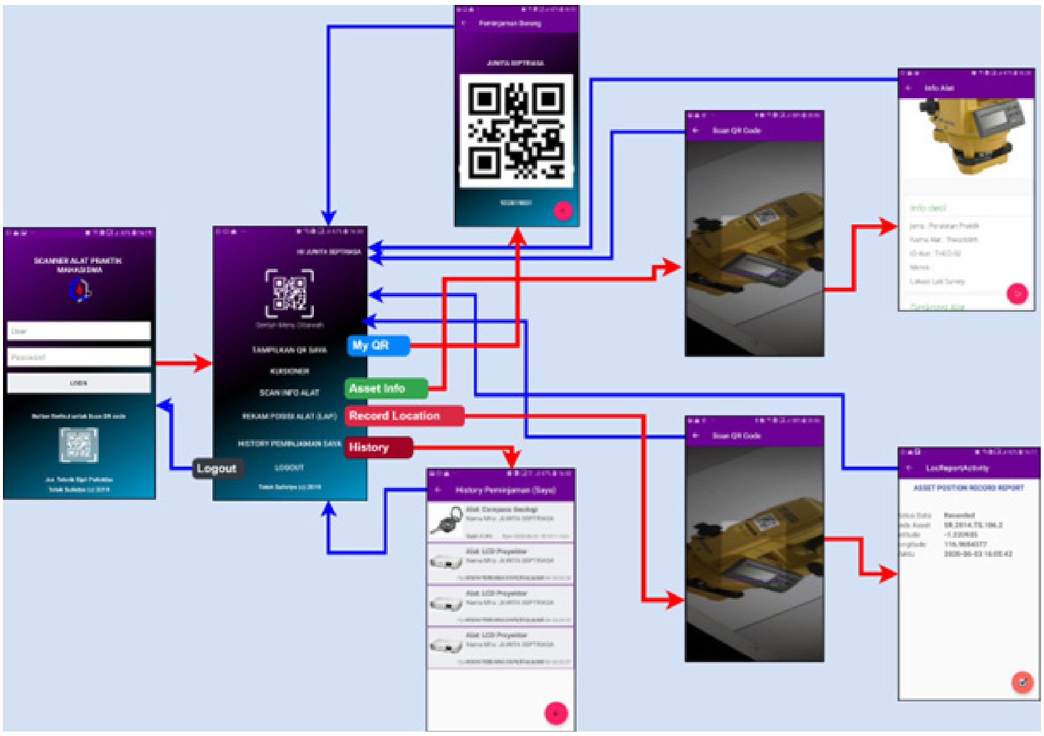

Figure 7 User Interface Workflow for the Student in Android Application

(a)

(b)

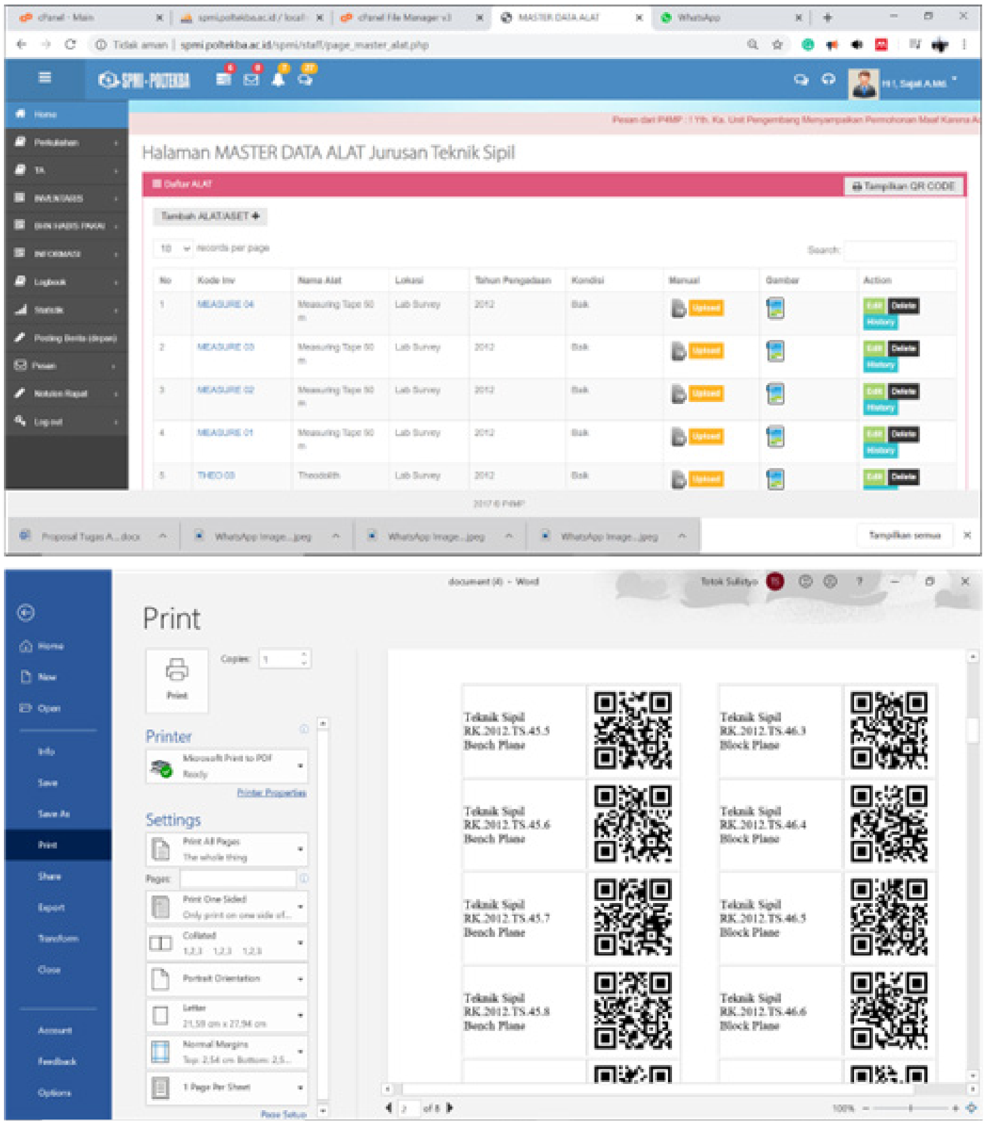

Figure 8 (A) Asset Data Dashboard and (B) Printing QR Item Layout from Asset Data

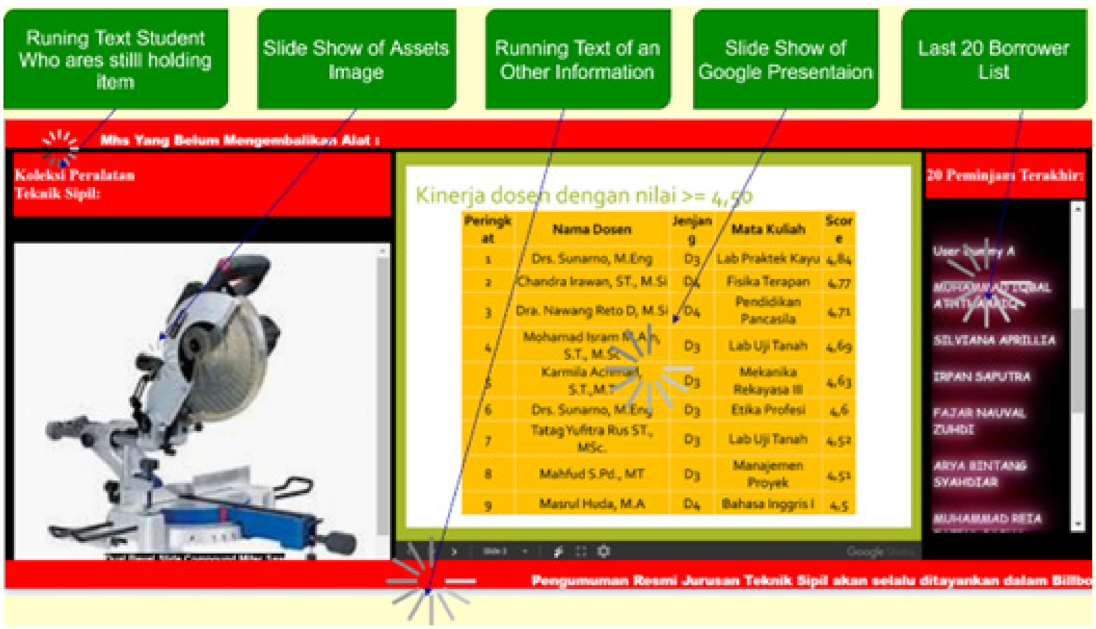

Figure 9 The Display of the Smart TV Application

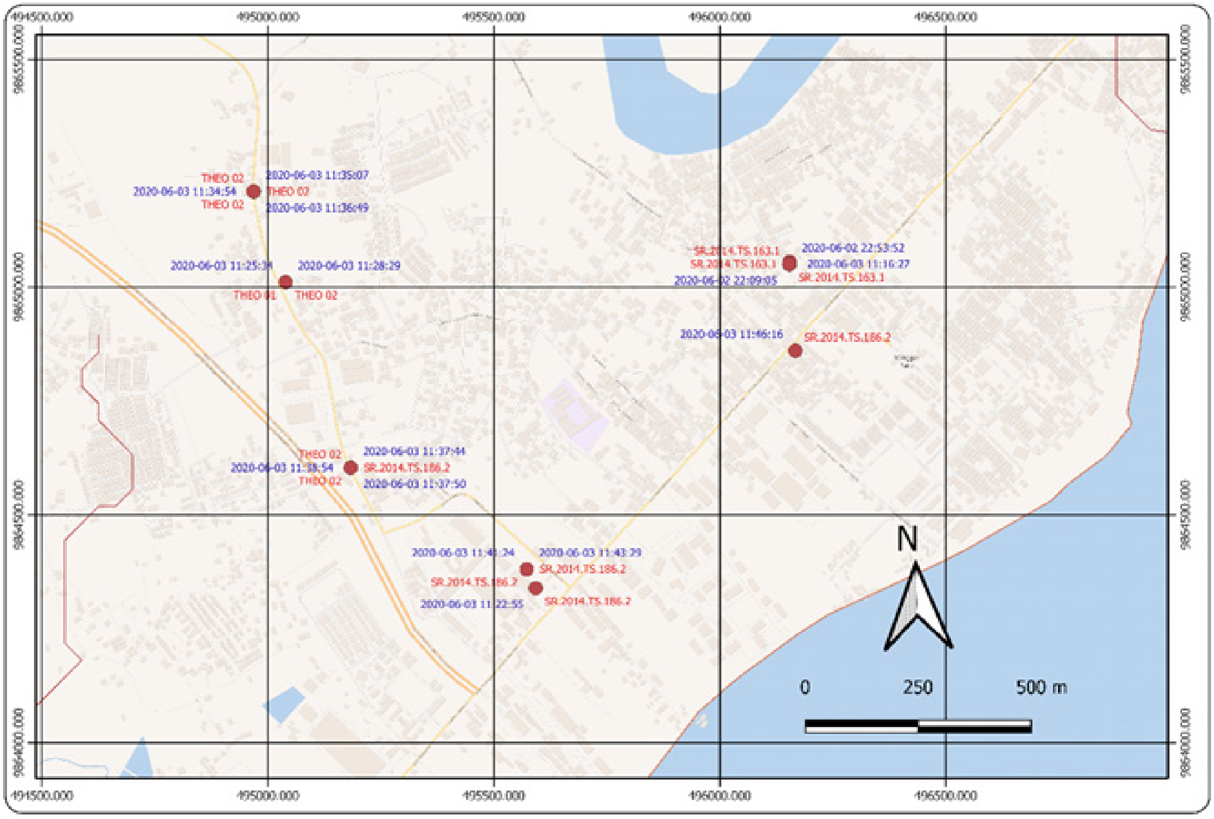

Figure 10 The Location of Used Assets Tracked on the Map