SEMARAK ILMU PUBLISHING

Semarak International Journal of Electronic System Engineering

Journal homepage:
https://semarakilmu.my/index.php/sijese/index
ISSN: 3030-5519

Implementing a Dam Safety Information System for Emergency Response in Hydro Power

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ARTICLE INFO

Article history:
Received 19 March 2025
Received in revised form 11 April 2025
Accepted 18 June 2025
Available online 30 June 2025

Keywords:
Dam failure; information system; emergency plan; dam safety; disaster management

ABSTRACT

A dam is built for many purposes. The number of dams constructed worldwide keeps increasing. There are 104 dams in Malaysia, with 83 located in Peninsular Malaysia and 21 in Labuan, Sabah, and Sarawak. Out of the total number, 81 are classified as large dams. The remaining 23 are considered small dams. Sixteen were built for hydropower, eleven for irrigation and agriculture, five for flood mitigation and the rest for water supply or other industries. Instead of benefiting economic development, the probability of dam failure is also a concern to the community in the downstream area. In order to mitigate the risk, dam owners have developed their emergency response plan as a mitigation measure during dam emergencies. As standard practices, the dam owners had developed a dam safety emergency response plan in a printed document as a reference manual during an emergency. In order to ease access to these documents, a system was developed to compile all of these documents in one centralized system called Dam Break Information System (DBIS). A pilot project was conducted for TNB hydroelectric dam, namely Dam Break Information System (DBIS). This app was developed in 2011, known as DBIS 1.0 and was then enhanced to DBIS 2.0 in 2015. Then, in 2022, DBIS 2.0 was upgraded to DSIS (Dam Safety Information System), which Android devices can access. The main objective of the new version of the DSIS is to allow multiple authorized persons to access and update the related information as necessary. This paper revolves around developing Dam emergency information systems to create better communication and effective response systems by dam owners in managing the risk of dam emergencies.

1. Introduction

Dams are common structures built worldwide; 38,667 dams and associated catchments drain nearly 35% of the global land area (excluding Antarctica) and approximately 32% of all tropical land areas. On a continental scale, Asia has almost half of all dams (18,951 dams), Europe has 7.1% (2,760 dams), North America has 16.4% (6,359 dams), South America has 16.5% (6,394 dams), Africa has 9.2% (3,558 dams), and Oceania has 1.7%. (645). The African continent has the fewest dams per

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https://doi.org/10.37934/sijese.6.1.3847

country. In contrast, Asia has the highest density, primarily in China and India (9,215 and 6,785 large and medium-sized dams, respectively), as well as Brazil (5,366), the United States (4,602), and South Africa (1,431). These data are supported by [1,2]. A dam is a man-made structure that primarily stores and diverts water. The dams were also used to generate power and recreation [3]. Nevertheless, most dams had an important function for flood mitigation to reduce flooding downstream. The ability of the dam to store water to its maximum capacity, consequently, less water will flow downstream of the dam. On the other hand, dams reduce the frequency and extent of flooded areas [4]; in the mountainous regions of Styria, Austria, more than 100 dams were built for flood mitigation [5]. Dams are indeed beneficial to economic development; however, their failure can cause massive destruction to the people and the properties downstream [6]. According to a study by F. Lempérière [7], the dam failure rate is 0.3% or 0.4% for an average life of 50 years, equivalent to an average yearly probability of about 6 × 10-5. Malaysia has 104 dams across the country, with 83 dams in Peninsular Malaysia and 21 in East Malaysia. These dams serve various purposes and are owned by different organizations, primarily utilized for irrigation, water supply, hydropower and flood mitigation [8].

Tenaga Nasional Berhad (TNB) is the power utility that owns 12 of Malaysia's dams, mainly used for hydropower generation. [9]. These dams are located sparsely in Perak, Kelantan, Terengganu, and Pahang, and these dams have independent emergency response plan to assist dam personnel during unexpected incidents. TNB had devised the idea of putting all ERP documents into a system where they could be accessed by authorized personnel to facilitate access to these documents. The main objective of the system development is to allow multiple authorized personnel to access and update information as necessary. Considering the idea, a simple system was developed using a basic information system (IS) application. An information system (IS) consists of interconnected components that collect, manipulate, store, and disseminate information while providing a feedback mechanism [10]. Information systems (IS) use various information technologies (IT) such as application software, databases, communication systems, the Internet, computers, mobile devices, and many other tools to perform specific tasks, interact with, and inform various actors in various organizational or social contexts [11]. Information technology has a broad interest in all areas related to the development, deployment, implementation, and effects of information technology in organizations and society [12–14]. The IS developed by TNB is known as Dam Safety Information System (DSIS). Figure 1 shows the development of ERP and the compilation of ERPS in the DSIS.

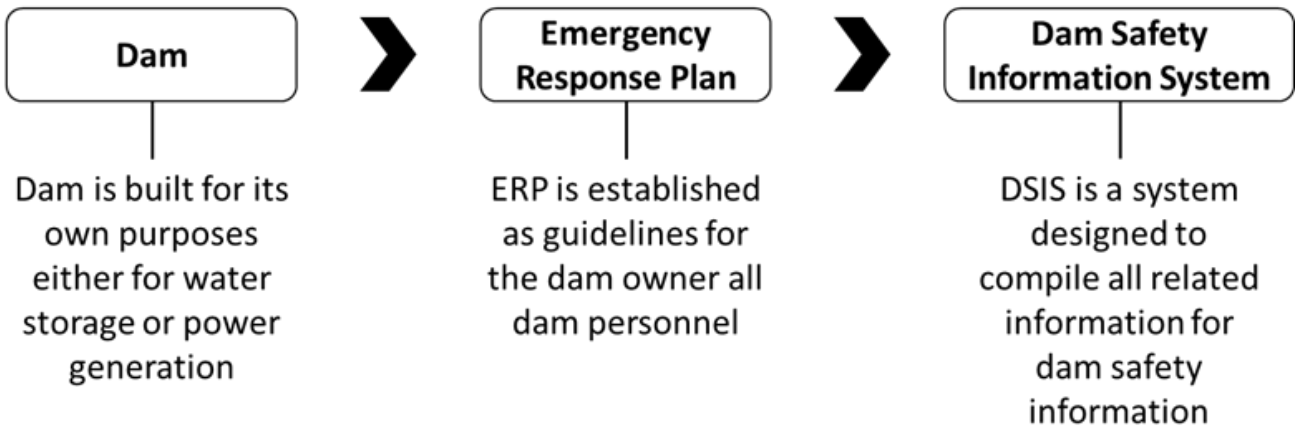

Fig. 1. The development of Dam ERP and DSIS

DSIS has undergone many enhancements since it was first established in 2011. This paper will discuss the development process and the outcome of the DSIS.

2. Emergency Response Plan

An emergency Response Plan (ERP) is developed for each dam to provide users with information and a manual on handling a situation if an incident occurs. The ERP outlines dam personnel's general responsibilities and duties in the event of an emergency [15]. Many dams worldwide have emergency response plans, such as the Mosul Dam Emergency Preparedness Plan, a joint project by USAID and UNDP [16]. Another example is the Dam Emergency Plan for Lake Cowichan Weir Dam, owned by Catalyst Paper Crofton Division [17]. The plan was prepared to comply with the Water Sustainability Act and Dam Safety Regulation and involves the dam owner and local, regional, and provincial response agencies. The purpose of the plan is to ensure that a system is available to communicate and direct emergency services and personnel to manage the risks to people on site, the local community, the environment, and assets in the event of a dam emergency and to ensure that adequate resources are kept in a state of readiness to provide a proper response of emergency control [15]. ERP documents developed by TNB serve the same purposes as the ERP created for the Mosul Dam and Lake Cowichan Weir Dam. The Dam Safety ERP (DSERP) manual is formulated to ensure a timely warning will be made to relevant authorities and the community in any emergency due to dam failure [18]. According to Muda *et al.,* [18], TNB has performed dam break studies for their hydropower dam to meet corporate duty since 2005. The study results have assisted TNB in creating a DSERP, an internal document that aids dam personnel in identifying, monitoring, and reacting to dam emergencies. The DSERP has been modified to include the standard operating procedures (SOP) of local, state, and federal government agencies through a collaborative training and engagement program between TNB and these agencies. TNB has opted to standardize the format of the DSERP, which encompasses public warning dissemination and evacuation of populations at risk by responder agencies. [18,19].

2.1 Access to Information for Dam Disaster

When a dam disaster occurs, quick access to accurate information is crucial for the safety and well-being of those affected. [20]. The need for immediate information is critical because it can help authorities and first responders promptly and effectively mitigate the disaster's impacts. No doubt, evacuation is the primary response to a dam disaster, and quick access to information can help authorities determine the best evacuation routes and notify people in the affected area [21]. This information can include the expected flood extent, areas likely to be impacted, and other relevant details that may help people prepare for evacuation. Besides, in the immediate aftermath of a dam disaster, first responders need accurate information to quickly and effectively respond to the situation. This includes information on the level of damage, the extent of the flood, and the location of people who may need assistance. Information is required to allocate resources appropriately. Quick access to information can also help authorities allocate resources effectively, including deploying personnel, equipment, and supplies to the affected areas to help those impacted by the disaster [22]. Accurate and timely information can help authorities make informed decisions about resource allocation. Communication among agencies, authorities, and communities is critical in the event of a dam disaster, and quick access to information can help authorities communicate with the public, emergency responders, and other stakeholders; this includes providing updates on the situation, notifying people of evacuation orders, and providing information on where to seek shelter or assistance. In conclusion, quick access to accurate information is important during dam emergency to ensure the safety and well-being of those affected.

3. Development of Dam Safety Information System (DSIS)

Dam safety information system (DSIS) is a software application developed to manage information related to dam safety. DSIS is designed to help dam personnel to monitor and analyze the documents related to the dam emergency response plan. DSIS is typically used by dam personnel as the stored digital information in the centralized system. Previously, all information regarding the flood hazard map, affected location, and population at risk (PAR) were documented in hard copy and soft copy, which are kept by respective dam personnel. The old document management system can hinge the flow during an emergency. It is time-consuming and inefficient to assist dam personnel during an emergency. Therefore, the system was developed to centralize documents and facilitate future system changes. The application system is formally known as Dam Break Information System (DBIS) and was developed using Visual Basic software in 2011. It was specifically designed for Cameron Highlands Hydro Scheme. Then, the application system was enhanced to DBIS 2.0 with additional information for Sg. Perak and Pergau hydroelectric schemes. In 2020, major changes to the application system were made. The system was redesigned and developed using Android Studio software and web-based documents and can be accessed via mobile apps and web browsers. The application system is known as Dam Safety Information System 2.0 (DSIS 2.0). Figure 2 illustrates the hydro dam information system development evolution, with DSIS 2.0 designed for secure, authorized access and modification. Users verify their identity via ID and password on the main page, ensuring data security. Information is stored on a local server, accessible through DSIS 2.0 applications in mobile and web browsers.

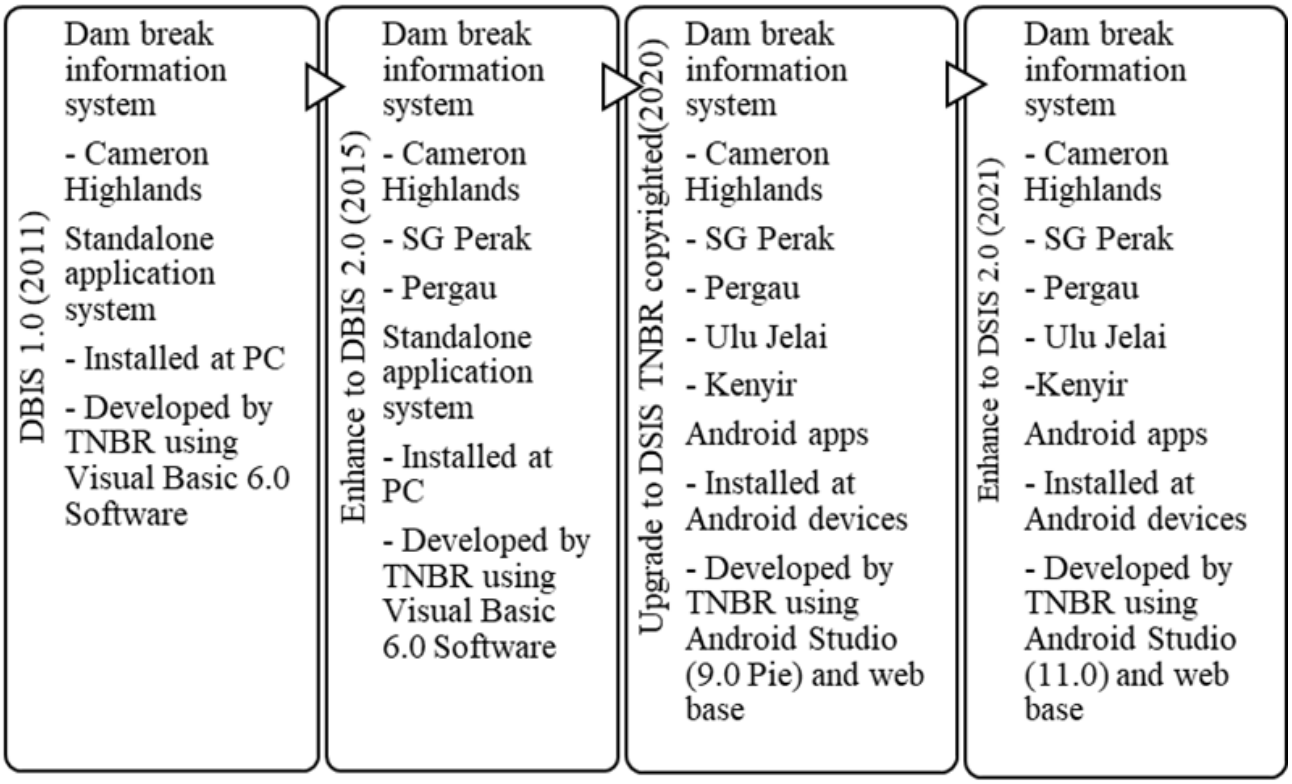

Fig. 2. TNB's Hydro Dam Information System

3.1 Development Process DSIS 2.0

The development of DSIS 2.0 requires a multidisciplinary approach that involves collaboration between dam safety experts, data management professionals, and software developers. By implementing a robust DSIS 2.0, stakeholders can make more informed decisions about dam safety and help prevent catastrophic impacts due to dam failures. Figure 3 shows the development process of DSIS 2.0.

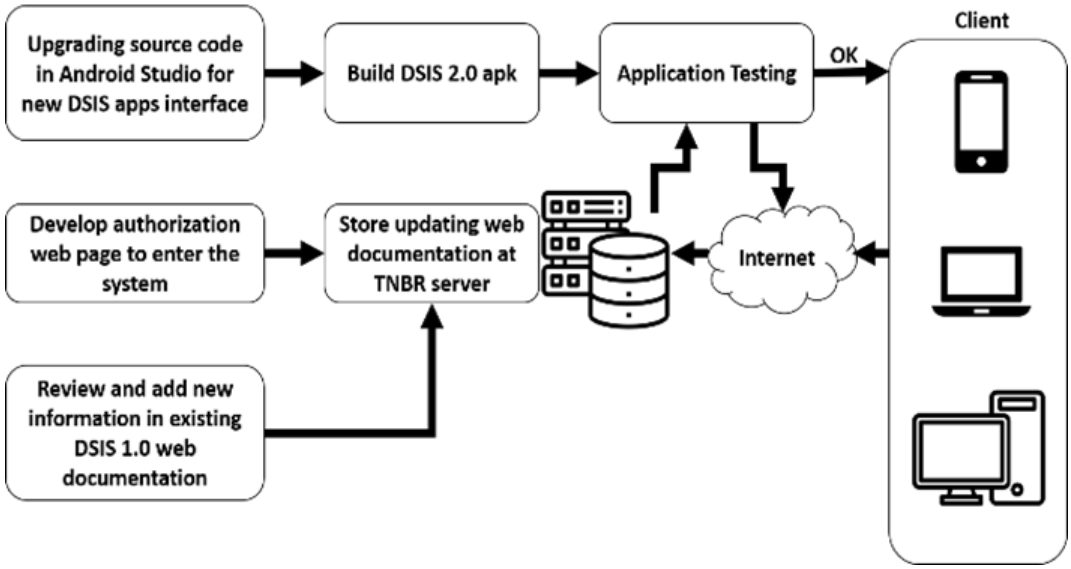

Fig. 3. Development Process of DSIS 2.0

DSIS 2.0 apps were redesigned and developed using Android Studio 4.1.2, as shown in Figure 4. The setting for the target Software Development Kit (SDK) version is 29, and the minimum version for the Android system is 9. The web View function is used to develop DSIS 2.0 to view applications using Android apps. WebView allows users to display web pages as part of their activity layout. It does not include any fully developed web browser features, such as navigation controls or the address bar. WebView only shows web pages hosted online.

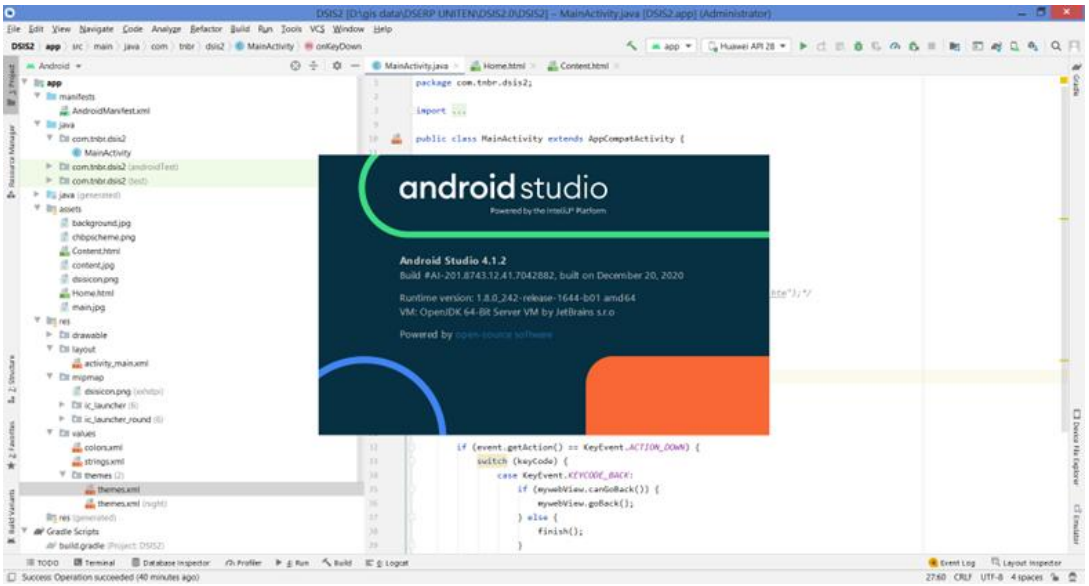

Fig. 4. Android 4.1.2 Software

The crucial part of Android apps development is the setting and coding using Java or Kotlin programming language to handle page navigation and link JavaScript from web page to client-side code. The code has been executed, and the output can be shown in Android Emulator. After all, DSIS2.0.apk was built, and the apps can be installed on any Android device which uses Android version 9.0 and above. Content Management System (CMS) WordPress is the platform used to develop the system, and it was designed to facilitate developers' use. Developers would not need to learn HTML, CSS, or other coding languages to develop the system. A content management system (CMS) is a software application used to create, manage, and publish digital content on websites, blogs, and online stores. CMS enables users to create and publish content without technical knowledge of web design or programming. A CMS typically consists of an easy-to-use editor for creating and editing content, a database to store the content, and a publishing engine that generates web pages. CMSs frequently include features such as version control, workflow management, and collaboration tools, which facilitate multiple users' contributions and management of content. Examples of CMSs include WordPress, Drupal, and Joomla, all of which are open-source and widely used for building websites. CMSs are also available for specific purposes like e-commerce, e-learning, or social networking. In the development process of DSIS 2.0, WordPress was used.

3.2 Migration of the System

System migration aims to adjust a system to meet evolving business needs, technological advancements, and other external factors that impact its functionality. The primary purpose of system migration is to ensure that a system can support the requirements of the organization and stakeholders, both presently and in the future. This process entails altering the software, hardware, or other system components to align with the new purpose. The need for system migration has been raised for several reasons, including better performance, scalability, security, and reliability and the need to reduce costs, improve efficiency, or meet new regulatory or compliance requirements. System migration allows organizations to keep their systems up-to-date and aligned with their business goals and objectives, enabling them to remain competitive and adaptable in a rapidly changing technological landscape. It also helps to improve the user experience, increase productivity, and reduce downtime, resulting in enhanced business value. System migration is typically done when there is a need to adapt to changing business requirements, technological advancements, or other external factors that affect the system's functionality.

3.3 Enhance Web-based Document to a New GUI

An appealing and user-friendly graphical user interface (GUI) is necessary for any website or web-based document. A well-designed GUI can enhance the user experience, making it easier for users to navigate and consume information. Hence, DSIS 2.0 was designed to meet the current technologies' criteria and trends. The first process of enhancing the system to a new GUI is by defining the purpose and goals of the new GUI. DSIS 2.0 was redesigned to improve the document's readability and simplify the navigation. The main goal was to create a visually appealing GUI and user-friendly system. The second process is to analyze the current document available in the system.

A review was done to assess elements that need to be removed or updated in the system. Target users and their preferences were also taken into consideration. The third process is to choose a design style to be implemented in the system. DSIS 2.0 was designed in a minimalist style to emphasize clarity and simplicity. The fourth process is to create a wireframe. A wireframe is a rough sketch of the new interface that shows where elements will be placed and how they will be organized.

The fifth process is to develop the new interface; with the initial wireframe and issues that had been resolved, the interface was developed. It involved creating new graphics and modifying some existing designs. In this process, it was determined that the new interface is responsive and works on other devices. The sixth process is to test and refine the interface. After developing the new interface, rigorous testing took place to validate its alignment with established goals. Multiple user tests involving real users provided valuable feedback for system enhancements. Utilizing this input, the interface underwent refinement, resulting in a visually appealing and user-friendly design for DSIS 2.0.

4. System Application

The end product of the enhancement process can be seen in the Figures below. After the installation in a device is finished, the DSIS 2.0 application icon will be created, as shown in Figure 5. It was designed so that the users could open the apps as usual by touching the icon. Some examples of DSIS 2.0 apps viewed via Android smartphones are shown in Figure 5.

Fig. 5. DSIS 2.0 Apps Icon in Android Platform

The login page for the DSIS 2.0 application system via a web browser can be seen in the Figure 6 and the hydro scheme viewed in Web Browser shown in Figure 7.

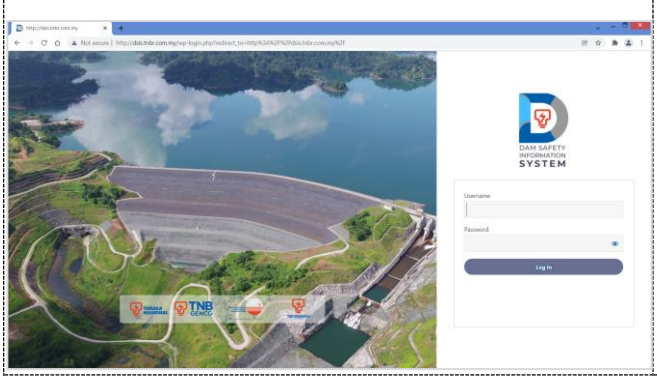

Fig. 6. DSIS 2.0 Application System Viewed in Web Browser (Login page)

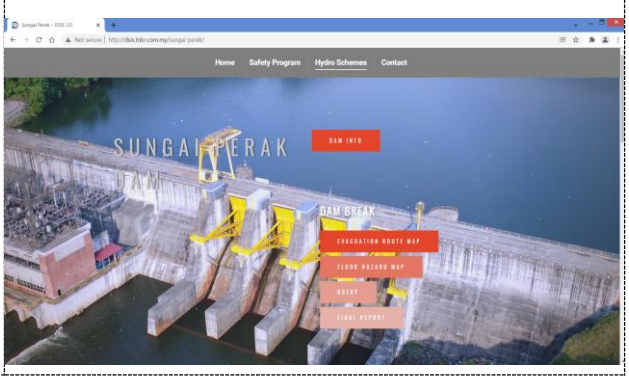

Fig. 7. Hydro scheme viewed in Web Browser

The application has undergone several tests to ensure that the system is stable and secured, as some information provided is confidential. DSIS 2.0 application is compatible only with Android smartphones. The DSIS 2.0 apps is developed for the Android platform only. However, for other alternatives, the system also can be accessed through various web browsers such as Internet Explorer, Chrome, Firefox and others. All devices can be used to open the system via the public network. The system is also equipped with a 2FA (Two-Factor Authentication) system. The 2FA ensures a secure environment in DSIS 2.0 as it stores valuable and crucial information. Two-factor authentication (2FA) is a security system that requires two separate, distinct forms of identification in order to access something. The first factor is a password, and the second commonly includes a text with a code sent to your smartphone or biometrics using your fingerprint, face, or retina. Figure 8 shows the 2FA implemented in DSIS 2.0.

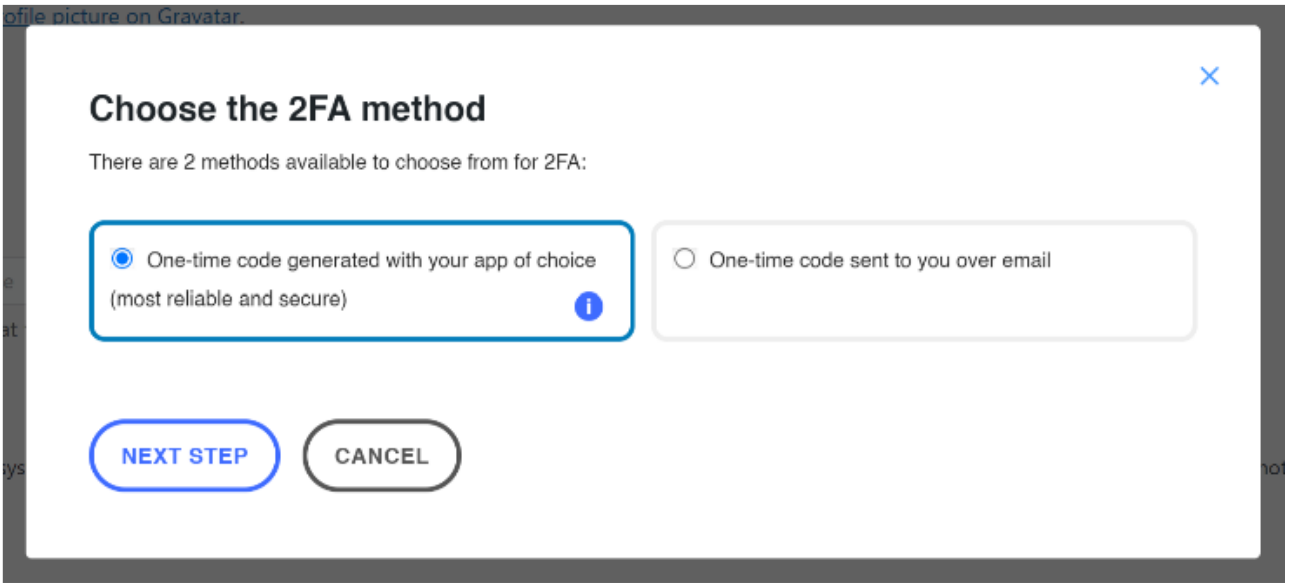

Fig. 8. 2FA Two Factor Authentication in DSIS 2.0

4.1 Application for Dam Disaster Management

DSIS can provide crucial information to emergency responders and other stakeholders during a dam disaster. For example, DSIS can help emergency responders quickly identify critical infrastructure, such as spillways and gates, that may need to be activated to reduce the risk of flooding downstream. DSIS 2.0 can also provide information on the water level where the emergency warning must be activated. It can help dam operators and agencies to make decisions regarding evacuation and other emergency actions. DSIS 2.0 can be a valuable tool for dam disaster management, providing critical information and data to support emergency response and ongoing dam safety management. In the event of a dam emergency, DSIS 2.0 can be used to provide crucial information to emergency responders, such as the flood hazard map, and the areas that are most affected. DSIS 2.0 would assist emergency responders in prioritizing efforts and optimizing resource allocation. DSIS 2.0 can facilitate data management, impact analysis, and handling of extensive data volumes. A DSIS 2.0 can ensure that all parties work effectively and efficiently by providing a centralized communication and information-sharing platform.

5. Conclusions

Dams are being constructed globally to meet increasing demands. They play a vital role in flood control, hydropower generation, and irrigation. There must be an emergency response plan for each dam built to aid dam personnel in an emergency. TNB, one of Malaysia's major dam owners, has developed a comprehensive Emergency Response Plan for hydro dams. The Dam Safety Information System was created to organize the ERP documents provided by TNB in one place that is accessible to authorized dam personnel. With the development of DSIS 2.0, all ERP documents from TNB's dams are now compiled strategically in the DSIS, allowing dam personnel to access them efficiently when needed. Since its start in 2011, the system has undergone several upgrades to keep up with the rapidly evolving technological landscape. Furthermore, the system can still be further enhanced for ease of use. A recommendation is to expand the system's availability to iOS users in addition to the current Android user base; currently, only Android users can access DSIS 2.0 apps. Another suggestion is to improve the system's security, as it contains sensitive and confidential information that requires strengthened security measures.

Acknowledgement

The authors are grateful to Tenaga Nasional Berhad, Malaysia, for funding the software development under the title of "Dam Safety Information System (DSIS 2.0)".

Disclaimers

While every effort has been made to ensure that the content of this paper is accurate, the authors make no representations or warranties in relation to the accuracy, completeness and suitability for any particular purposes. In no event will authors be liaising for any expenses, losses, damages and/or costs, including without limitation indirect or consequential damages, arising out of or in connection with the use of this paper.

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