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Development and usability assessment of an integrated digital surveillance system for dengue control in Bali, Indonesia

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ABSTRACT

Background and purpose: Dengue infection remains a major public health issue in Bali, Indonesia, where high mobility and tourism increase the risk of transmission. Existing manual surveillance systems are often slow, fragmented, and resource-intensive. A digital, integrated approach is needed to improve early detection, reporting, and community participation in dengue control. This study aimed to design, develop, and assess the usability of an integrated digital surveillance system for dengue control in Bali, Indonesia.

Methods: The application, named SILIRA, was developed using the Rapid Application Development (RAD) approach and validated by experts in health information systems, vector control, and health promotion media. Usability was assessed through the Post-Study System Usability Questionnaire (PSSUQ), administered to 120 respondents (100 community users and 20 health workers). The evaluation focused on system usefulness, information quality, interface quality, and overall satisfaction

Results: SILIRA integrates hospital-based and community-based reporting, epidemiological investigation, entomological surveillance, and digital education. Usability testing showed favourable mean scores among community vs. health workers were 3.83 vs. 4.14 (system usefulness), 3.74 vs. 4.01 (information quality), and 4.18 vs. 4.25 (interface quality), with overall satisfaction of 4.08 vs. 4.30. System usage data showed that the education menu was the most frequently accessed feature (88%), followed by the dengue control (82%) and dengue information (75%) menus. A preliminary feasibility assessment suggested that SILIRA was compatible with existing reporting procedures and could be implemented within the existing health system.

Conclusion: The SILIRA prototype demonstrates strong usability and feasibility as an integrated digital surveillance system for dengue control. By combining rapid case reporting, larva density monitoring, and digital education. SILIRA has the potential to support dengue surveillance and control by facilitating integrated reporting, spatial monitoring, and community engagement.

Keywords: *Dengue, Public Health Surveillance, Mobile Health, SILIRA, Vector Control*

INTRODUCTION

Dengue fever is one of the most significant mosquito-borne viral diseases worldwide, with an estimated 390 million infections annually, of which 96 million manifests clinically. Approximately 129 countries are at risk, and 70% of cases occur in Asia. The high burden of dengue presents ongoing challenges for global health security, particularly in regions with dense populations and high mobility.[1]

Indonesia remains a dengue-endemic country with recurrent outbreaks. In 2020, 108,303 cases were reported with 747 deaths, while in 2021, 73,518 cases and 705 deaths were recorded. Despite national control efforts, the incidence and mortality remain concerning. Bali, as a major international tourism hub, faces heightened risks. Transmission not only threatens local residents but also travellers, raising the potential for international spread.[2- 3] This dual risk underscores the importance of strengthening surveillance and control systems in the province.[4]

The dengue surveillance system implemented so far uses manual procedures that require repeated reporting from the surveillance officer to the *puskesmas* and the city health office several times. This requires time, effort and money, so reports and follow-ups could be faster. The manual reporting system also generates paper waste that accumulates and takes up space. In the digital transformation era, innovation is needed for surveillance systems.

Several studies have utilized a digital approach to conduct surveillance. The digital approach can be helpful in efficiency and increase work productivity. Reporting systems are quickly dispatched to places so decisions can be made. Several digital applications have been developed, such as dengue detection via cell phones[5], Mhealth for dengue reporting and mapping[6], dengue surveillance with Epihack[7], geospatial smartphones[8].

During the COVID-19 pandemic, strict health protocols and difficulty conducting door-to-door field visits. An innovative digital approach is needed to conduct epidemiological and dengue entomology surveillance. Through a digital system, data collection can be done online. The public can access educational videos and case reports online. Therefore, an integrated digital surveillance system for dengue control is needed.

The SILIRA application offers an integrated approach by combining dengue case reporting, environmental larval surveillance, epidemiological investigation, community-based reporting, health education, and spatial mapping within a single digital platform. This integration is intended to facilitate rapid data transmission and support timely identification of dengue risk areas. Unlike routine manual surveillance, which is often fragmented and delayed, this digital platform enables faster, more comprehensive, and community-engaged monitoring. Early identification of dengue-prone areas may support more timely and targeted interventions and improve the allocation of surveillance resources. Therefore, this study aims to design and develop an integrated digital surveillance system for dengue control that is adaptive, efficient, and sustainable. The development of such a system is urgently needed to overcome the limitations of conventional manual reporting and to strengthen Bali's preparedness in protecting both local populations and international travellers from dengue threats.

METHOD

Study Design

This study employed a system development design using the Rapid Application Development (RAD) approach. The process included system analysis, prototype design, expert validation, and usability evaluation. The study was conducted in Denpasar, Bali, Indonesia, during the COVID-19 pandemic.

Participants

Respondents in this study were selected using a convenience sampling technique. A total of 120 respondents participated, consisting of 100 community members and 20 health workers. The health worker group included *jumantik* (larva monitoring volunteers), hospital surveillance officers, *puskesmas* staff, and health office staff. Participants were selected purposely based on their involvement in dengue surveillance or community health activities, ownership of an Android smartphone, and willingness to provide informed consent.

System Development

Dengue Control Integrated Environmental Surveillance System **(***Sistem Informasi Lingkungan Terintegrasi Demam Berdarah Dengue*/SILIRA) was designed as an integrated digital platform for dengue surveillance. The RAD process comprised system analysis, database design, and interface development. Core features included hospital- and community-based case reporting, larval density reporting, epidemiological investigation, health education videos, quizzes, dengue information, and emergency contacts. Five experts with expertise in health informatics, dengue vector control, and health promotion independently assessed the prototype in terms of functionality, content accuracy, usability, language clarity, and interface design.

Evaluation and Data Collection

Usability was assessed using a 16-item version of the Post-Study System Usability Questionnaire (PSSUQ). Each item was rated on a five-point Likert scale. The instrument measured system usefulness (items 1–6), information quality (items 7–12), interface quality (items 13–15), and overall satisfaction. Before analysis, item-level responses were checked for completeness and domain scores were calculated by averaging the corresponding items.

Data Analysis

Descriptive statistics were used to summarize PSSUQ scores for each domain. Mean scores were calculated for community respondents and health workers and presented separately. Higher scores indicated more favourable user perceptions of the system.

Ethical Considerations

This study was approved by the Ethics Committee of the Faculty of Public Health, Universitas Indonesia (No. Ket-416/UN2.F10.D11/PPM.00.02/2021). All participants provided informed consent prior to

participation, and confidentiality of data was ensured throughout the study.

RESULT

System requirements and development

The dengue case reporting system has yet to be integrated, and it takes time for case reporting from the hospital to the epidemiological investigation carried out at the *puskesmas*. These delays may hinder timely decision-making and implementation of dengue control measures. The hospital reports dengue infection with patient identification data to the health office. The data is forwarded to the *puskesmas*. The *puskesmas* conduct an epidemiological investigation by sending surveillance officers. The results of the epidemiological investigation are made into an epidemiological surveillance report to obtain a decision to fumigate or not from the health department. *Jumantik* routinely reports entomological surveillance data (larvae density) to the *puskesmas*. The data is recapitulated and reported to the health office once a month.

Dengue Control Integrated Environmental Surveillance System Model (SILIRA)

Integrated digital environmental surveillance system (SILIRA), DHF case reports from hospitals, clinics, and health centres diagnosed with dengue haemorrhagic fever (Hospital-based surveillance) are reported directly to the city health office. Case reports can also come from community reports (Community-based surveillance). Reports from the community were confirmed again from reports received by the City Health Office.

Epidemiological surveillance: through the SILIRA application, epidemiological investigations can use a digital questionnaire with coordinates so that case houses can be mapped. Rapid data transmission data is entered into the servers of the *puskesmas* and the Denpasar City Health Office. The system analyses this data and displays it as percentages and case density maps. Data can also be accessed in online reporting and rapid data transmission by all stakeholders.

Entomological surveillance: through the SILIRA application, *jumantik* officers can collect online data about larva density with coordinates and pictures of containers. The data can be displayed in available through the digital platform after submission and map the density of larvae and percentages. Therefore, intervention can be carried out quickly in high-risk areas.

Digital educational videos are used to intervene in the community to increase their knowledge, attitudes and actions in carrying out vector control. The community is educated to eradicate mosquito breeding places at least once a week by draining the water containers in their homes. Field officers monitor the density of larvae once a month. The epidemiological and entomological surveillance data results are reported directly to the *puskesmas* and the Health Office. Surveillance reports are also reported to the Provincial Health Office and the Ministry of Health (Figure 1).

Web and mobile-based digital educational media are needed, which contain educational menus for dengue control. The use of social media continues to increase, and the public gets information through social media. Digital intervention is needed to improve people's attitudes towards dengue control through digital education by utilizing social media such as WhatsApp, Facebook, Youtube, Instagram, Tiktok and others. Users who

understand the benefits of education are willing to obtain the information. Educational videos are more interesting than giving brochures. Users can also freely access information without being bound by place and time. Therefore, the SILIRA application is equipped with learning videos on the educational menu which contains educational videos, video guides for using the application and an introduction to the SILIRA application. The SILIRA application model can be explained in the following figure 2.

The reporting system from the hospital uses the Hospital Early Alerting System menu. Reporting of dengue cases through the application is then forwarded to the city health office and *puskesmas.* The community can also report cases of dengue. The report is entered into the application system and followed up by the *puskesmas* surveillance team to ensure its accuracy. Reports on the density of larvae reported online by *jumantik* enter the system. The results of epidemiological investigation activities are reported in online reporting and rapid data transmission. They can be accessed by *puskesmas* and the health office so that decisions can be made immediately to take appropriate preventive measures. The SILIRA application can intervene through an educational menu that provides educational videos to make efforts to control dengue. Through an integrated system with *jumantik* officers, providing digital education and routine larvicide to the community can affect the density of larvae in the environment (Figure 3).

The SILIRA application is made according to the needs of each user of this application. Each user has a special menu to fill in according to their needs. The use of the menu is as follows:

1. *Jumantik* cadres use the SIJENTIK Menu, in this menu there is a larva density report menu. This menu reports the types of containers inside and outside the house, houses containing larvae, positive larvae containers. This data is then processed into house index, container index and Breteau Index numbers. Through this data, it is possible to know the risk of water containers and the density of larvae in an area.
2. The public can use the dengue education menu, to access brochures and educational videos about dengue prevention and control. The *Jumantik Mandiri* menu is a menu that can be filled in by users to report the density of larvae in their environment. The Independent Case Reporting Menu is a special menu that can be used by the community to report dengue cases in their environment. Through this menu, if there are reports of dengue cases that have not yet been submitted to the *puskesmas*, the community can report them and later be followed up by officers. DHF complaint menu, in this menu the public can make direct complaints via WhatsApp to the SILIRA admin if there are complaints related to DHF control.
3. *Puskesmas* surveillance officers can use the Epidemiological Investigation menu. This menu provides reporting on epidemiological investigation activities. Reports of dengue infection were followed up with observations in 20 houses where fever patients were recorded, and positive larvae were collected. The health office accesses the results of this report to decide on fumigation or not.
4. The hospital can use the hospital early warning system menu specifically for hospitals to report cases of dengue infection at the hospital. Through this menu, reports of dengue infection can be reported in an integrated manner by hospitals, health offices and *puskesmas.* Access to patient-level information was restricted to authorized users through individual accounts and password-protected access.

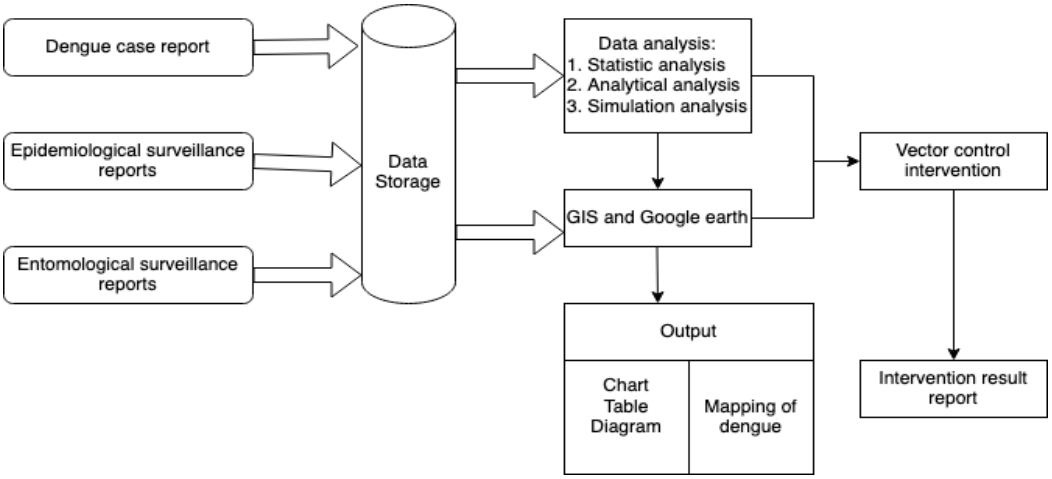

Figure 1. Reporting flow system with the SILIRA application

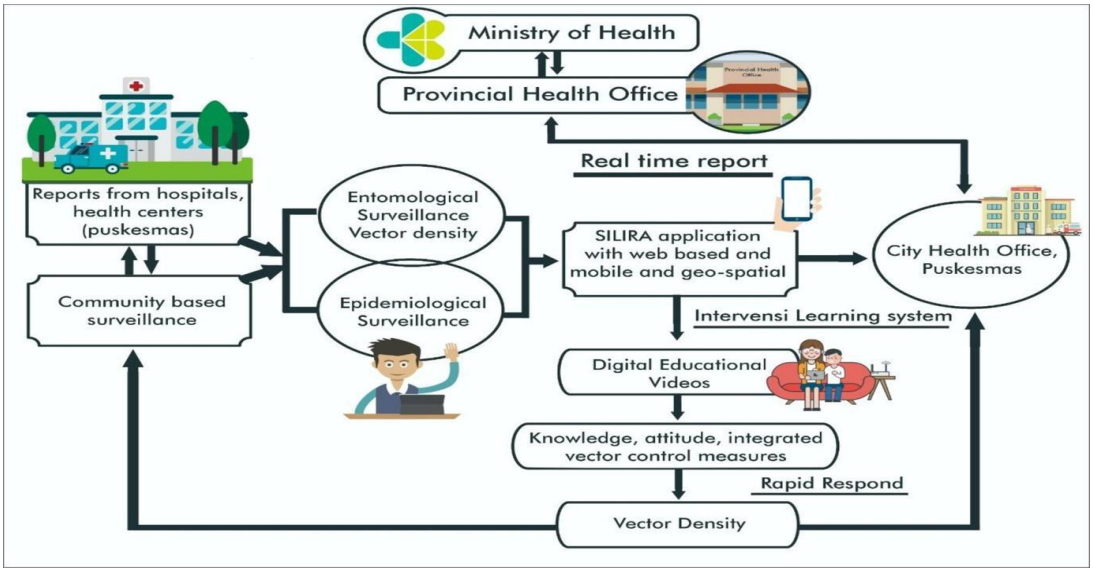

Figure 2. Model of an integrated dengue environmental surveillance system

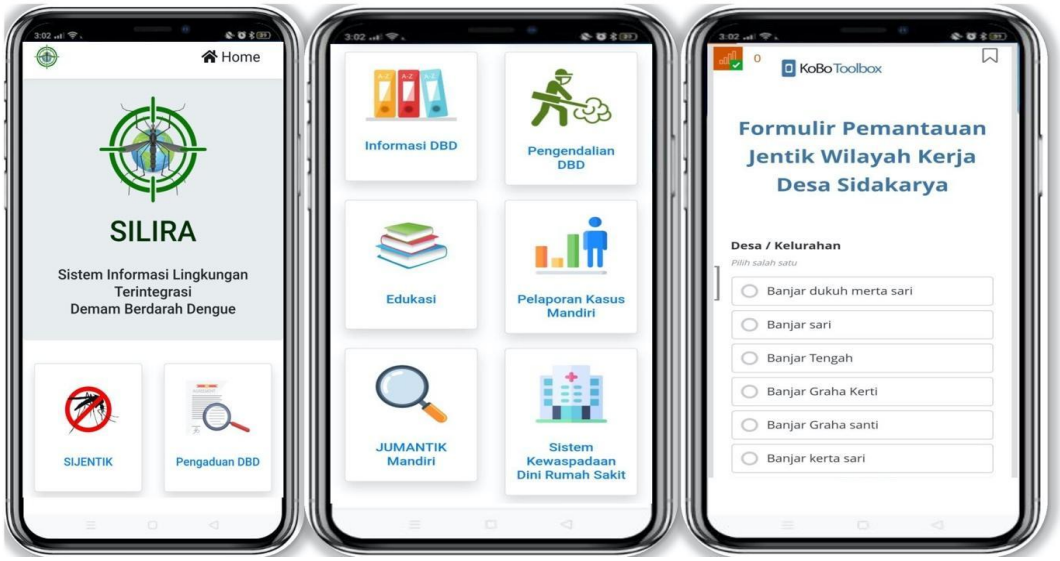

Figure 3. Silira application interface

SILIRA Application Assessment

The use of the mobile health application can assist in the surveillance process and online data reporting. An integrated environmental information system for dengue control (SILIRA) was created to assist epidemiological and entomological surveillance. This system is also integrated with educational media and data transmission from *jumantik* officers, the community, and hospitals to health centres and the health office. The resulting data are larva density, reporting of dengue cases and mapping of larva density and cases. This data can assist the city health office in mapping dengue-prone areas to make decisions.

Respondents who filled in the data used the SILIRA application, totalling 120, namely 100 community respondents and 20 health worker respondents. The usability test is carried out to evaluate the usability of the mobile application, which is in the development stage. The usability assessment measures the ease of learning the SILIRA application, the ease of using the application, the clarity of the layout, and the quality of the information.

In this study, the Post-Study System Usability Questionnaire (PSSUQ) was developed by IBM to evaluate the satisfaction of using the SILIRA application with a Likert scale of 5 with 16 question items grouped into four categories, namely question items number 1-6 about system usability, questions numbers 7–12 regarding information quality, question items 13-16 regarding interface quality, overall satisfaction.

System Usability

The assessment of the system's usefulness in the community has an average value of (3.83) and for health workers (4.14), which means that they agree that this system is helpful for users. The rating above points 3 means agreeing to the use of the system. Six items are assessed, namely the ease of using the system, namely the community (3.94), health workers (4.2), helping to complete tasks quickly (3.6) and (4.3). This system is effective in helping DHF case reporting (3.8) and (4.15), can complete tasks quickly (3.62) and (3.8), I feel comfortable using this system (3.45) and (4.05), easy to learn to use the system these (3.49) and (4.35).

Table 1. PSSUQ question average scoring items

No	Question Items	Community score (n=100)	Officer score (n=20)
1	Overall, I am satisfied with how easy it is to use this system.	3.94	4.2
2	It was simple to use this system.	3.6	4.3
3	I was able to complete the tasks and scenarios quickly using this system.	3.8	4.15
4	I felt comfortable using this system.	3.62	3.8
5	It was easy to learn to use this system.	3.45	4.05
6	I believe I could become productive quickly using this system.	3.49	4.35
7	The system gave error messages that clearly told me how to fix problems.	3.5	3.8
8	Whenever I made a mistake using the system, I could recover easily and quickly.	3.52	3.6
9	The information (such as online help, on-screen messages, and other documentation) provided with this system was clear.	3.35	3.9
10	It was easy to find the information I needed.	3.57	3.9
11	The information was effective in helping me complete the tasks and scenarios.	3.78	4.45
12	The organization of information on the system screens was clear.	3.6	4.45
13	The interface of this system was pleasant.	3.68	4.3
14	I liked using the interface of this system.	3.76	4.2
15	This system has all the functions and capabilities I expect it to have.	4.05	4.1
16	Overall, I am satisfied with this system.	3.97	4.25

Table 2. PSSUQ test results for community respondents and officers

Functional test	Average value	
	Community	Health workers
System usefulness	3.83	4.14
Information quality	3.74	4.01
Interface quality	4.18	4.25
Overall satisfaction	4.08	4.3

Information Quality

The assessment results of the quality of the information displayed on the SILIRA application get an average point for the community (3.74) and health workers (4.01). This score means that application users agree that the quality of the information displayed in the application gives satisfaction. The assessment items for the

quality of information consist of 6 questions, namely being productive, giving clear messages, being able to recover from errors quickly and providing information clearly, being easy to find the information needed, and effectively helping to complete tasks.

Interface Quality

Assessment of the interface quality gets an average score of the community (4.18) and health workers (4.25). This score shows that the quality of the interface displayed gives satisfaction because the score is above 3. The assessment item consists of 3 questions: clear information on the system screen, fun interface, and people like using the system. The application system that has been made is to the user's expectations with the appearance of menus that are by what is needed.

Overall Satisfaction

Overall, the average rating of the SILIRA application is 4.08 and 4.3. This score shows that overall, the SILIRA application has been satisfactory for the users of this application. The overall assessment is the average value of the three variables: system usefulness, information quality, and interface quality. An assessment that meets point three means that the application user has been satisfied.

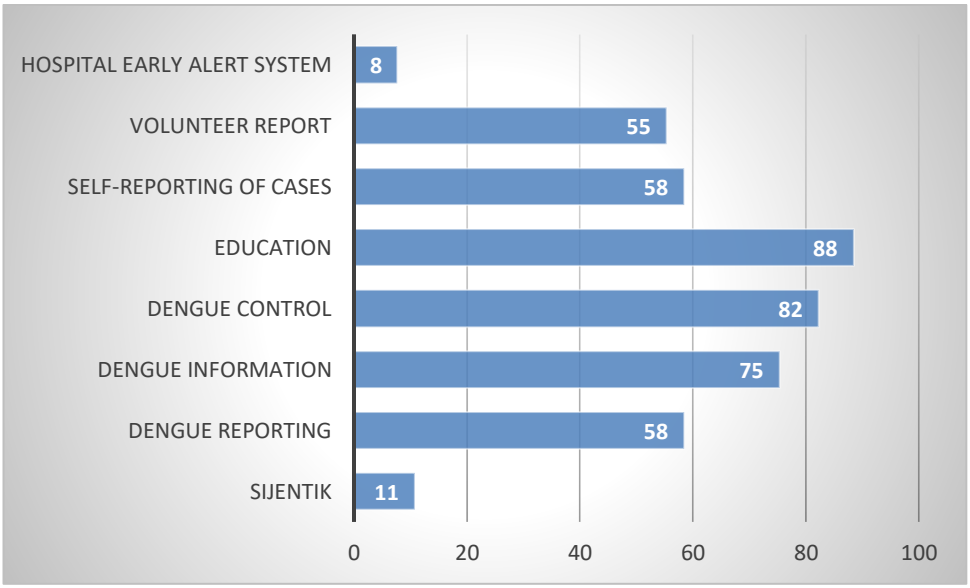

Figure 4. Distribution of Percentage of menus on SILIRA liked by users

System usage data showed that the education menu was the most frequently accessed feature (88%), followed by the dengue control (82%) and dengue information (75%) menus (Figure 4). The education menu was the most frequently used feature, which may reflect the predominance of community users among the study participants and their need for accessible information on dengue prevention and control. This menu provides educational videos on dengue control, how to use the SILIRA application and dengue control brochures. This menu also provides quizzes with prizes for answering questions above a score of 70.

Furthermore, in the independent case reporting menu (58%), residents can report cases independently then the data will be clarified by the *puskesmas* surveillance officer. The independent *jumantik* menu (55%) on this menu residents can report the results of the density of larvae in their household independently. Dengue complaints menu (58%) provides a telephone number and WhatsApp, which can contact officers directly if there are complaints. The *Sijentik* menu (11%) is a special menu used by *jumantik* to report the results of surveillance of larva density and epidemiological investigations on dengue infection. The hospital early warning system menu (8%) is specially provided to hospital surveillance officers to report case data (Figure 4).

DISCUSSION

Compared to similar digital dengue surveillance systems in other countries, SILIRA demonstrates comparable functionality with added integration for both community participation and health system reporting. For instance, systems in Singapore and Brazil focus heavily on hospital-based case reporting and geographic mapping of dengue cases but offer limited direct community engagement for entomological surveillance.[9-11] In contrast, SILIRA incorporates independent community reporting of larva density, strengthening participatory vector control, which has been shown to enhance early detection and intervention effectiveness.

Studies in Thailand[12,13] and India[14,15] have highlighted the importance of combining digital case reporting with community education to reduce dengue transmission. SILIRA aligns with this approach by integrating audiovisual educational content that has been demonstrated to improve knowledge, perceptions, and preventive behaviors. This combination of real-time surveillance, community participation, and targeted health education positions SILIRA as a potentially scalable model for dengue-endemic, high-tourism regions globally, particularly where mobility and population density complicate traditional vector control efforts.

The SILIRA application is an integrated environmental information system for dengue control. Through this application, users can report the density of larvae in their environment and dengue infection. *Jumantik* officers can also use this digital application to collect data on larva density. Epidemiological surveillance activities of dengue infection can also be reported in online reporting and rapid data transmission. Hospital early warning system reporting can also be reported in this application. Users of this application can use the SILIRA application according to their needs.

Application trials are carried out in stages to meet the needs of each user who uses the application. The system's weaknesses have been tried to be fixed, namely difficulties in accessing, heavy and loading systems, and user confidentiality. They added special menus such as independent case reporting and dengue complaints according to input from respondents. The SILIRA application system is made as light and easy as possible so that users can easily access it.

Based on the results of this study shows that currently (37%) people access more information through social media than through television (23%). During the COVID-19 pandemic, access to social media has increased, and there are potential advantages and disadvantages for public health.[16-18] The COVID-19 pandemic has caused regulations to maintain social distancing so that health promotion officers have difficulty providing information from door to door.[19,20] Limited surveillance activities are carried out to prevent the transmission of COVID-19. Therefore, an approach with a digital information system is needed to monitor case data, larva

density and education to the public.

The epidemiological surveillance menu, *puskesmas* surveillance officers can use this menu to collect DHF case data in their area. *Jumantik* officers can use the *Sijentik* menu to collect data integrated with data from the *puskesmas* and the health office. The data is processed into a map of dengue-prone areas to become a dengue early warning system. Hospitals report dengue cases using the hospital's early warning system menu. The health office and *puskesmas* can directly access reports that are input. Thus, epidemiological investigation activities can be carried out immediately. Communities can also report the density of larvae independently through the independent *Jumantik* menu. This system is part of the community's participation in conducting entomological surveillance.

Educational menu for interventions for the community related to increasing knowledge, perceptions and actions in controlling dengue. Application users can access videos about dengue control, explanations about the SILIRA application and dengue control brochures online. The development of the SILIRA educational video menu has also been carried out in several stages, starting from collecting data on information about dengue that the community needs. Designing videos and expert consultations. Assessment of the quality of educational videos and conducting trials on respondents. This educational video helps provide information to carry out dengue control efforts and intervene in the community's knowledge and perceptions of dengue control.

Health behavior intervention through health education with interesting audiovisual. Some characteristics of health education intervention media with images, narration, audio, entertainment and education. In the long run, effectiveness depended on perceived user acceptance and perceived information needs.[21] Studies in Indonesia using educational audiovisual video media in groups effectively increase knowledge, perceptions and actions to control dengue.[22,23] Other studies state that using video learning media effectively and efficiently increases health workers' knowledge of dengue control.[24] Studies in India also show that audio-visual-based public health education effectively increases knowledge in dengue control.[25]

CONCLUSION

SILIRA application enables digital transformation in the health sector, especially in handling infectious diseases like dengue. Its ability to provide real-time information, involve various data components, and facilitate fast and efficient reporting can be a strong foundation for increasing the effectiveness of surveillance and response to dengue cases. Thus, further development and implementation of the SILIRA Application in the field can positively contribute to efforts to prevent and control dengue disease and increase digital transformation in public health management.

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this manuscript.

AUTHOR CONTRIBUTION

SGP designed and conducted the study, analyzed the data, wrote the first draft of the manuscript and edited the manuscript. DS, TE and UFA were involved in the study design and the research concept, provided feedback and edited the manuscript.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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