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Design of a Streptococcus suis Meningitis Epidemiological Surveillance Application to Improve Zoonotic Disease Prevention and Control in Bali Province, Indonesia

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ABSTRACT

Background: *Streptococcus suis* meningitis is an inflammation of the human central nervous system caused by the *Streptococcus suis* bacterium. The Health Department of Bali Province, Indonesia, reported a total of 7 cases of *Streptococcus suis* meningitis in Bali Province from January to April 2023, with 2 fatalities. The government has conducted an epidemiological investigation. However, the recording of epidemiological investigation data is still done manually, resulting in inaccurate and untimely data. This study aimed to develop a digital surveillance application for investigating Streptococcus suis meningitis based on Figma and Kobo Toolbox.
Subjects and Method: This was a design-based study using the Design Science Research Method (DSRM), conducted across all nine districts and cities in Bali Province. The target users were public health surveillance officers. A total of 130 respondents participated in the user acceptance evaluation. The application prototype was developed using Figma, and data collection forms were designed via Kobo Toolbox. The study evaluated application acceptance using the Technology Acceptance Model (TAM), which includes the following dependent variables: timeliness, information completeness, information accuracy, accessibility, usefulness, and ease of use. Data were analyzed descriptively.
Results: The results showed high user acceptance of the application, with mean percentages as follows: timeliness (85.8%), information completeness (86.8%), information accuracy (84.6%), accessibility (86.2%), usefulness (84.7%), and ease of use (81.9%).
Conclusion: The digital application for epidemiological surveillance of *Streptococcus suis* meningitis demonstrated good acceptance among users. Its implementation could improve the accuracy and efficiency of data collection, potentially enhancing the response time and decision-making in zoonotic disease control.

Keywords: application, streptococcus suis meningitis, epidemiological investigation, surveillance, technology acceptance model

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BACKGROUND

Streptococcus suis Meningitis is an inflammation of the human central nervous system caused by the bacterium *Streptococcus suis* (Hlebowicz, 2019). Streptococcus suis is a zoonotic bacterium, with pigs as the primary host. Transmission of *Streptococcus suis* meningitis from pigs to humans can occur through contact with animals or animal products contaminated with *Streptococcus suis* (Meurer et al., 2020).

Streptococcus suis Meningitis infection in humans has been reported in several countries, namely Western Europe, Northern Europe, Africa, South America, Australia, India, Japan, New Zealand, and several countries in Asia. About 90.2% of *Streptococcus suis* meningitis cases in humans occur on the Asian continent, 8.5% in Europe, and 1.3% in other countries (Hatrongjit et al., 2020). In Indonesia, especially in Bali Province, cases of meningitis caused by *Streptococcus suis* re-emerged in 2023. The Bali Provincial Health Service reported that from January to April 2023, there were 38 suspected cases of *Streptococcus suis* meningitis in Bali Province, with 7 confirmed positive cases and 2 deaths (Bali Provincial Health Office, 2023). Before 2023, confirmed cases of *Streptococcus suis* meningitis also occurred in Bali Province, with 48 cases in 2017, 8 cases in 2020, and 6 cases in 2021 (Bali Provincial Health Office, 2022).

In Indonesia, the pig farming industry is growing. The rapid increase in the industry and pig population also raises the risk of the spread of *Streptococcus suis* meningitis cases. In Bali Province, pigs are considered essential livestock for the community, as they are used to meet consumption needs and for religious rituals. This leads to a high pig population in the province. According to the Central Statistics Agency, the pig population in Bali Province was 398,291 in 2020 and increased to 449,859 in 2022 (BPS, 2023). As a province with a relatively high pig population, Bali also faces challenges in preventing and controlling diseases originating from pigs, including *Streptococcus suis* meningitis. The government has implemented various efforts to prevent and control *Streptococcus suis* meningitis, one of which is surveillance. Surveillance is a systematic and continuous observation activity concerning health problem (Handynata et al., 2022). In this activity, an epidemiological investigation is carried out to identify the causes, modes, and sources of transmission of *Streptococcus suis* meningitis.

Currently, epidemiological investigation and surveillance activities are still conducted manually using paper (paper-based) (Pascawati et al., 2022). Manual epidemiological investigation often causes several problems, such as delays in data reporting, data entry errors, and less accurate information analysis and presentation results, which reduce the quality of decision-making (Salim et al., 2021). A study on the malaria surveillance system in 2022 stated that manual data recording using paper media reduces time efficiency in data analysis (Heroza et al., 2022). Moreover, manual data collection can not accurately map disease occurrence coordinates, leading to inaccurate location mapping (Rifaldi et al., 2023).

The manual implementation of *Streptococcus suis* meningitis epidemiological investigation surveillance significantly affects the effectiveness and efficiency of disease prevention and control efforts. Delays in data collection and reporting result in delay-

ed disease control actions, such as treatment or care (Lim et al., 2019). The tracing of close contacts and other positive cases becomes hampered, which can increase the risk of further disease transmission. Delays in case tracking hinder the identification of disease transmission trends and patterns, making prevention and control efforts less than optimal (Aldosery et al., 2021).

In epidemic control, accurate and timely (real-time) information is crucial for faster and more informed decision-making (Rahmadewi, 2023). If the surveillance system is unable to detect diseases quickly and accurately, the risk of disease spread will increase, potentially leading to an outbreak. Based on the description above, it is necessary to develop a *Streptococcus suis* meningitis surveillance application that functions to collect, monitor and analyze disease data, as well as map the spread of *Streptococcus suis* meningitis based on epidemiological investigation results in Bali Province.

SUBJECTS AND METHOD

1. Study Design

This study used the Design Science Research Method (DSRM), focusing on the development of a digital epidemiological surveillance application for *Streptococcus suis* meningitis. The research was conducted over nine months, from July 2023 to March 2024, in Bali Province. A quantitative descriptive analysis was conducted to measure user acceptance of the developed application using the Technology Acceptance Model (TAM).

2. Population and Sample

Target population consisted of surveillance officers at public health centers, district/city health offices and the provincial health office in Bali Province. Total sampling technique was used, involving one officer from each of the 120 Puskesmas, nine district/city health offices and one provincial health office, resulting total of 130 subjects for assessing application acceptance.

3. Study Variables

This study did not include an independent variable. The dependent variables were application acceptance indicators based on the Technology Acceptance Model (TAM), including timeliness, information completeness, information accuracy, accessibility, usefulness and ease of use.

4. Operational Definition of Variables

The operational definitions of the dependent variables based on the Technology Acceptance Model (TAM) are as follows:

Timeliness: Refers to the application's ability to provide real time information that enables users to make accurate decisions based on up to date data.

Information Completeness: Refers to the application's ability to deliver comprehensive information required in the epidemiological investigation process, including descriptive epidemiological characteristics such as person, place, and time. This includes patient data, coordinates of incident locations, medical history, symptom data, contact history with family and neighbors, and risk factors.

Information Accuracy: Refers to the application's ability to provide accurate, reliable and error-free information to enhance the quality of data analysis results.

Accessibility: Refers to the application's ease of access by users and its availability across various devices or locations without being limited by time and place.

Usefulness (Perceived Usefulness): Refers to users' perception that the application can help improve productivity and work effectiveness.

Ease of Use (Perceived Ease of Use): Refers to users' perception that the application is effortless, easy to operate, easy to understand, and quick to adopt.

5. Study Instrument

The data were collected using a structured questionnaire adapted from the Technology Acceptance Model (TAM), which measured user perceptions across six indicators: timeliness, information completeness, information accuracy, accessibility, usefulness, and ease of use in the context of digital epidemiological surveillance.

6. Data Analysis

This research applied a mixed-methods approach by combining qualitative and quantitative descriptive analysis techniques. The qualitative descriptive analysis was specifically used to provide a comprehensive explanation of the system development process, which was carried out using the Design Science Research Method (DSRM) as the main methodological framework. This approach allowed the study to systematically describe each stage of application design, development, and implementation.

In addition, quantitative descriptive analysis was conducted to measure and evaluate the level of user acceptance of the application by applying the Technology Acceptance Model (TAM). The level of acceptance was determined by calculating an index percentage derived from respondents' responses. These percentage scores were then interpreted using the classification criteria proposed by Arikunto (1998). Based on this classification, user acceptance was grouped into four categories, namely Good, Fair, Poor, and Very Poor, according to the predefined percentage ranges. A detailed breakdown of these acceptance categories is provided in Table 1.

Table 1. Score Interpretation Criteria Based on TAM

Category	Score Range
Good	76 – 100 %
Fair	56 – 75 %
Poor	40 – 55 %
Very Poor	<40 %

7. Research Ethics

This study adhered to ethical research principles, including obtaining informed consent, maintaining confidentiality, and ensuring participant anonymity. The research ethical clearance approval letter was obtained from the Research Ethics Committee of the Faculty of Medicine, Udayana University, Denpasar, Indonesia, No. 2573-/UN14.2.2.VII.14/LT/2023, on November 30, 2023.

RESULTS

1. Design Process of Application

The process of designing an epidemiological investigation surveillance application for Streptococcus suis meningitis was carried out in five stages.

Figure 1. The Processes of Application Design

a. Ecosystem Creation

The ecosystem consisted of two core components:

1) Prototype Development (Figma)

The application prototype was designed using Figma on a web-based platform. A new design file was created using a frame

size of 375 × 667 pixels (iPhone 8 layout). The user interface included menu elements such as MSS Management Guidelines, MSS Case Data, MSS Investigation Forms, and MSS Case Distribution Map. These features were structured to ensure user-friendly navigation.

2) Form Development (Kobo Toolbox)
The epidemiological investigation form was constructed using Kobo Toolbox's builder. Questions were created to cover key investigation data: patient demographics, clinical symptoms, risk factors, and close contact history. Various question formats were applied, including numeric input, text, and GPS coordinates. Skip logic was configured to adapt question flows dynamically based on previous answers. The form was then deployed and made accessible via online and offline (multiple submission) mode to enable data entry in low connectivity environments.

b. User Interface Design
The visual design included the front page and main menu, featuring several components: MSS Management Guidelines, Epidemiology Investigation Guidelines, MSS Case Data, Pig Ownership Data, MSS Epidemiology Investigation Form, MSS Epidemiology Investigation Results and MSS Case Distribution Map. This study focused primarily on the MSS Epidemiology Investigation Form, which is linked to a digital form built on Kobo Toolbox.

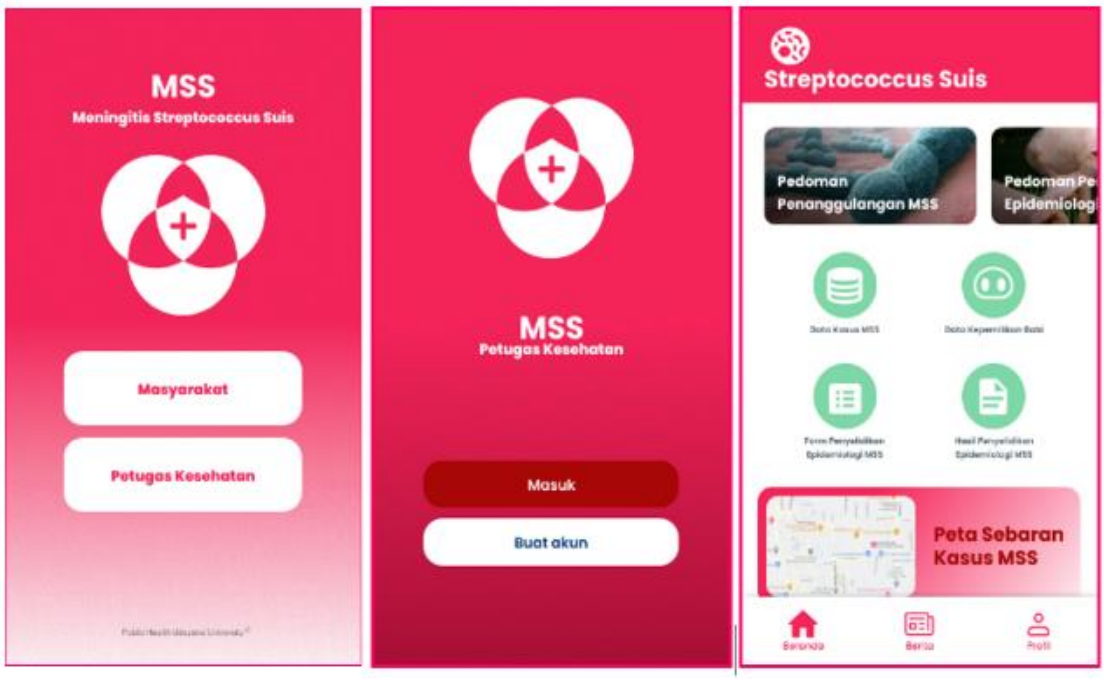

Figure 2. User Interface Design

Prototype of a meningitis epidemiological investigation surveillance application Streptococcus suis, designed using a data collection server with Enketo Webforms. The use of Enketo Webform in this application prototype is intended so that the data collection process can be carried out efficiently online or offline. This aims to avoid data being lost or not being saved due to poor signal coverage during the epidemiological investigation process in the field. By using Enketo Web form, data will be automatically

uploaded when an internet connection is available.

Data will be saved automatically on the server Amazon Web Services (AWS). Form data in the form of text, numbers, and location coordinates will be stored in the database and will not be deleted. In addition, stored data can also be accessed without deadlines and will not expire. Data from epidemiological investigations stored in Kobo Toolbox can be exported in the form of XLS, CSV, GeoJSON, SPSS Labels, GPS Coordinates (KML), Media Attachments (ZIP), XLS (Legacy) and CSV (Legacy).

The user acceptance of the Streptococcus suis meningitis epidemiological surveillance application was evaluated using the Technology Acceptance Model (TAM) questionnaire. This questionnaire comprised six dimensions: timeliness, information completeness, information accuracy, accessibility, usefulness, and ease of use. The characteristics of the surveillance officer respondents who assessed the application are presented below.

Table 2. Characteristics of Respondents

Characteristics	Category	Frequency	Percentage
Gender	Man	68	52.3 %
	Woman	62	47.7 %
Age	20–30 years old	28	21.5 %
	31-40 years old	30	23.1 %
	41-50 years old	53	40.8 %
	50-60 years old	19	14.6 %
Education	SMA/SMK/equivalent	3	2.3 %
	College	127	97.7 %
Institution	Health Center	120	92.3 %
	District/City Health Office	9	6.9 %
	Provincial Health Office	1	0.8 %

Table 2 indicates that the majority of respondents were male (52.3%), aged between 41 and 50 years (40.8%), and had attained tertiary education (97.7%). In terms of institutional distribution, respondents represented all relevant health institutions, including community health centers, district/city health offices, and the provincial health office, with most respondents coming from community health centers (92.3%).

Table 3. Results of Data Analysis on Application Acceptance Rate

Aspect	No	Score	Score Max	Percentage
Timeliness	A1	554	650	85.2 %
	A2	561	650	86.3 %
Information Completeness	A3	564	650	86.8 %
Information Accuracy	A4	550	650	84.6 %
Accessibility	A5	560	650	86.2 %
	A6	559	650	86.0 %
	A7	552	650	84.9 %
	A8	548	650	84.3 %
Usefulness	A9	545	650	83.8 %
	A10	549	650	84.5 %
	A11	554	650	85.2 %
	A12	544	650	83.7 %
	A13	554	650	85.2 %

Aspect	No	Score	Score Max	Percentage
Ease of Use	A14	537	650	82.6 %
	A15	534	650	82.2 %
	A16	548	650	84.3 %
	A17	545	650	83.8 %
	A18	532	650	81.8 %
	A19	518	650	79.7 %
	A20	532	650	81.8 %
	A21	514	650	79.1 %

Table 3 presents the percentage scores for each attribute within the six TAM dimensions. All attributes under timeliness, information completeness, information accuracy, accessibility, and usefulness scored above 80%, which falls under the "good" category. However, two attributes within the ease of use dimension, A19 (79.7%) and A21 (79.15%), scored slightly below 80%, though still categorized as "good".

Table 4. Technology Acceptance Model (TAM) Results

Aspect	Average Percentage
Punctuality	85.8 %
Completeness of Information	86.8 %
Information Accuracy	84.6 %
Accessibility	86.2 %
Usage	84.7 %
Convenience	81.9 %

Table 4 summarizes the overall TAM evaluation results, indicating a high level of user acceptance and perceived success of the developed application. The mean percentage scores for each dimension were as follows: timeliness (85.8%), information completeness (86.8%), information accuracy (84.6%), accessibility (86.2%), usefulness (84.7%), and ease of use (81.9%).

3. Information Output

The information output generated from epidemiological investigation activities using the prototype of the *Streptococcus suis* meningitis surveillance application comprises descriptive analytical results that are systematically presented in the form of tables, graphs and spatial distribution maps. These outputs are generated automatically and displayed in real time immediately after data are entered by surveillance officers in the field, ensuring timely access to updated information for monitoring and evaluation purposes.

As the system is designed to operate on an open-access platform, authorized administrators at the community health center level, district/city health offices, and the Bali Provincial Health Office are required to log in to the Kobo Toolbox database using registered accounts to access and manage the data. This access structure supports multi-level data supervision and coordination across health institutions.

The tabular data available in the online database can be edited directly through the system interface and are equipped with an integrated validation feature. This feature allows administrators to classify and manage data based on verification status, including categories such as “Not Approved,” “Approved,” and “On Hold,” thereby facilitating data quality control. In addition to online editing, the tabular datasets can be

downloaded in XLS format, enabling further processing and in-depth analysis using Microsoft Excel or other statistical software.

Furthermore, the system automatically generates graphical outputs and frequency distribution tables for each survey question included in the epidemiological investigation. These visualizations can be customized into various chart formats, such as pie charts, area charts, polar area charts, and radar charts, allowing users to select the most appropriate visualization method to support data interpretation, reporting, and decision-making.

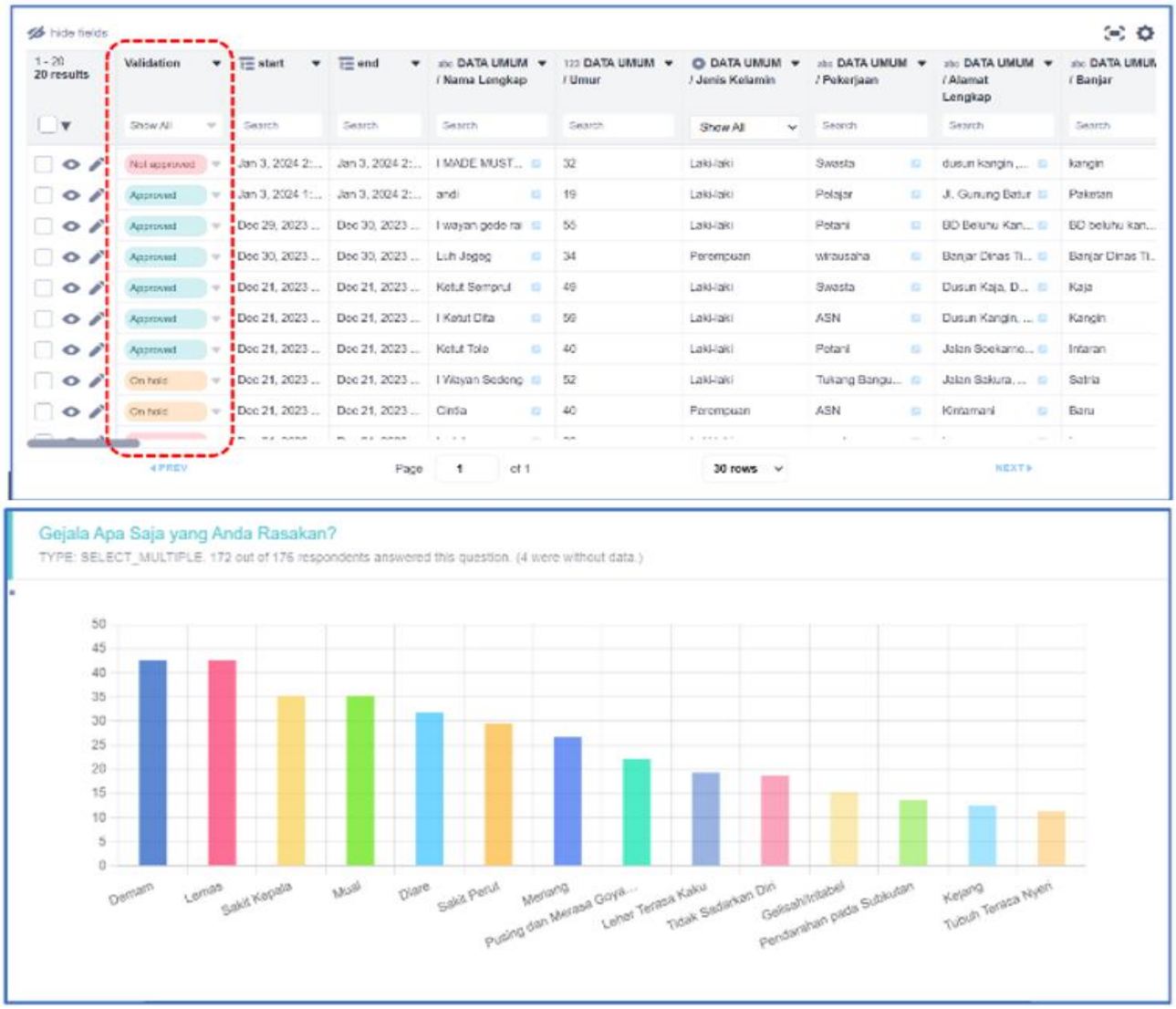

Figure 3. Graphical Outputs and Frequency Distribution Tables

Moreover, the application prototype provides mapping outputs based on the coordinates entered in the epidemiological investigation form. The distribution map can be displayed either as a point map or a heatmap, enabling accurate visualization of disease transmission locations. The full set of output tables, graphs, and distribution maps offers a comprehensive overview of the epidemiological data collected.

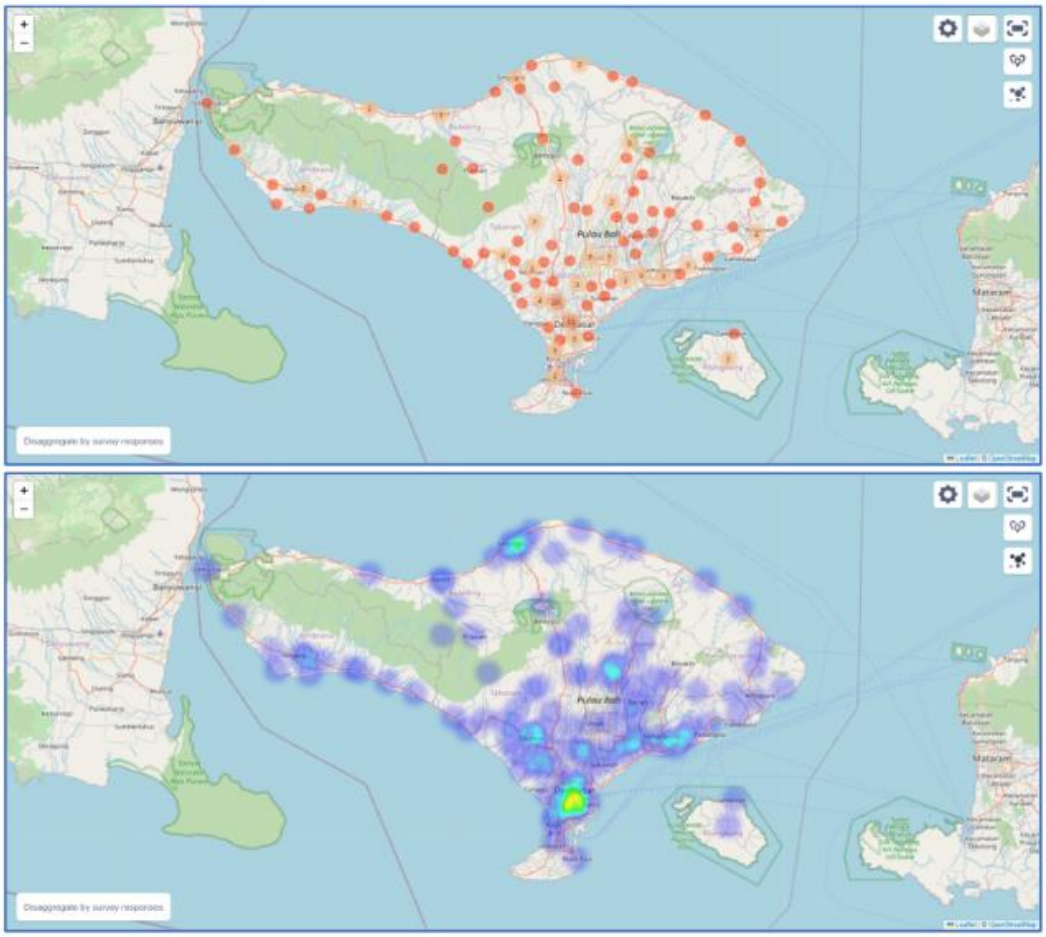

Figure 4. Application Output in the Form of Point Map or Heat Map

The first map shows the point distribution resulting from user-inputted simulated data during the system evaluation process. The second map presents the same dataset in a heat map format to demonstrate how the system visualizes data density. These outputs were generated solely to assess the system's mapping functionality and do not represent actual Streptococcus suis meningitis cases.

DISCUSSION

Prototype of the *Streptococcus suis* Meningitis Surveillance Application

The development of a prototype for the *Streptococcus suis* meningitis epidemiology investigation surveillance application was carried out by designing a prototype interface using Figma and creating an epidemiological investigation form using Kobo Toolbox. Figma is a web-based tool used for planning user interfaces or application prototypes through various vector graphic editors (Kurniawan et al., 2023). Meanwhile, Kobo Toolbox is an online application used for creating digital forms or survey instruments for data collection (Wahyuni et al., 2023).

The developed Epidemiology Investigation Form includes several mandatory questions covering general data, medical history, symptoms, contact history, and risk factors. This ensures that surveillance officers can not skip required questions. The "mandatory response" feature in Kobo Toolbox enforces these requirements to prevent

missing data during the reporting of epidemiological investigation results (Kobo Inc, 2023). A study conducted in the United States on Neonatal Abstinence Syndrome (NAS) surveillance in 2019 found that implementing mandatory responses effectively reduced missing data in surveillance questionnaires (Jilani et al., 2019).

Additionally, the form is designed so that each question must be answered with a predefined response type. For example, name fields must be completed with text, while age fields must be numerical. This reduces data entry errors. Kobo Toolbox provides response type validation to ensure form fillers input appropriate data for each question (Kobo Inc., 2023). These features help minimize data entry errors and missing data, which are common in manual epidemiological investigations.

The application also allows the recording of geographic location points where data is collected. Surveillance officers can automatically record investigation locations, aiding in accurate mapping of disease spread and close contact locations. Accurate case mapping is crucial for identifying sources of transmission and monitoring high-risk areas (Subrata et al., 2022).

All investigation data input into the system is stored in real time. The inputted data is automatically processed into tables, charts, and distribution maps. This real-time processing reduces the workload of surveillance officers and expedites the delivery of information (Hidayat, 2020). Digital-based investigation processes ensure timely data collection and reporting, enabling faster outbreak response (Aldosery et al., 2021).

External data from the *Streptococcus* suis investigation is stored in the Kobo Toolbox database and can be exported in various formats, including XLS, CSV, GeoJSON, SPSS labels, KML, and ZIP (Kobo Inc, 2023). This facilitates quick access for reporting. Research by Da Silva and Rodrigues Silva (2020) found that Kobo Toolbox increased work efficiency and productivity by up to 75% (Silva and Silva, 2020).

Kobo Toolbox forms used in the investigation process are accessible both online and offline. In online mode, data is sent directly to the server. In offline mode, data is temporarily stored on the device and automatically uploaded once an internet connection is available (Lakshminarasimhappa, 2021). This offline functionality is beneficial in rural areas with poor internet connectivity, where manual paper forms risk data loss and reduce efficiency (Rifaldi et al., 2023). Thus, dual-mode data collection improves surveillance effectiveness (Subrata et al., 2022).

User Acceptance of the *Streptococcus suis* Meningitis Surveillance Application

The results of the user acceptance test for the application design using the TAM demonstrate that the majority of surveillance officers involved as respondents provided a positive assessment of the *Streptococcus suis* meningitis epidemiological investigation surveillance application. In the timeliness aspect, the developed application achieved a score of 85.8%, categorized as good. This indicates that most respondents agreed that the application accelerated the processes of data collection, analysis, and reporting in epidemiological investigations. The automatic analysis of inputted data eliminates the need for manual recapitulation by surveillance officers. Timeliness in epidemiological data collection and reporting is crucial to accelerating the identification of cases or close contacts (Rifaldi et al., 2023)

Regarding the completeness of information aspect, the application achieved a score of 86.8%, also categorized as good.

This suggests that most respondents agreed the application improved the completeness and uniformity of *Streptococcus suis* meningitis epidemiological investigation data. Aspects of completeness include identity details, legibility, form completion, and response consistency (Yu et al., 2019). The Kobo Toolbox-based forms embedded in the application apply the mandatory response feature for required fields, which significantly reduces missing data and enhances data uniformity (Kobo Inc, 2023).

In terms of information accuracy, the application received a score of 84.6%, indicating a good category. This suggests that the majority of respondents believed the application yielded accurate data and minimized data entry errors. A study by Lakshminarasimhappa, 2021 (2021) confirmed that using Kobo Toolbox for digital form creation enhances data accuracy and reduces entry errors (Lakshminarasimhappa, 2021). This improvement is enabled by Kobo Toolbox's ability to restrict answer formats by question type, thus avoiding input mismatches (Kobo Inc, 2023). Moreover, the database includes a validation feature allowing officers to mark data as "Approved," "On Hold," or "Not Approved," which facilitates double-checking and improves data integrity.

For the accessibility aspect, the application scored 86.2%, categorized as good. This indicates that most respondents found the application easily accessible, with data presented in a practical, soft-copy format. Additionally, the integration of Enketo Webform allows access both online and offline (Kobo Inc, 2023). These findings align with a study by Augia and Dahlan (2020), which reported that 88.89% of respondents found Kobo Toolbox-based health applications easier to access and operate effectively, regardless of internet connectivity (Augia and Dahlan, 2020).

In the usefulness aspect, the application achieved a score of 84.7%, falling into the good category. This indicates that most respondents perceived the application as beneficial in enhancing work quality, increasing productivity, and improving the effectiveness and efficiency of surveillance tasks. These results align with research by Rifaldi et al. (2023), which found that Kobo Toolbox can improve surveillance officers' performance effectiveness by up to 76% (Rifaldi et al., 2023). This is due to the automatic data processing capabilities of the system, which convert raw inputs into tables, graphs, and distribution maps, thereby simplifying analysis. The features are also tailored to the specific needs of surveillance officers, supporting their data collection and analysis activities (Kusuma, 2020).

The final aspect assessed is convenience, where the application received a score of 81.9%, also categorized as good. This suggests that respondents found the application easy to operate, practical, user-friendly, and supportive in facilitating the reporting of epidemiological investigation results. A study by Augia and Dahlan (2020) similarly found that 82.22% of respondents agreed that Kobo Toolbox-based applications are easy to use and support efficient reporting for health workers, owing to their alignment with users' practical needs (Augia and Dahlan, 2020). Therefore, the findings of this study indicate that the *Streptococcus suis* meningitis epidemiological investigation surveillance application demonstrates strong potential to be further developed and implemented as a practical tool to support and enhance the work of surveillance officers in the field.

AUTHOR CONTRIBUTION

Putu Putri Agustini led the study design, application development, data collection,

analysis, and manuscript drafting. I Made Subrata supervise the research and provided critical review. I Gusti Ngurah Agung Surya Pratama developed the technical aspects of the application. I Dewa Agung Ayu Ari Shinta Dewi contributed to the literature review and manuscript editing. Ngakan Putu Anom Harjana advised on public health relevance. Sang Gede Purnama contributed to data interpretation. Romy Muhammad Dary Mufa supported discussion refinement and alignment with epidemiological standards.

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CONFLICT OF INTEREST

There are no conflicts of interest

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