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Optimizing dengue surveillance with 'Tunggal Dara' android-based application: key findings for sustainable implementation

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Abstract

Purpose: This study evaluated the effectiveness of 'Tunggal Dara,' an Android-based system, in optimizing dengue surveillance in Semarang, Indonesia, using the Modified Consolidated Framework of Implementation Research (mCFIR). **Methods:** This explanatory mixed-method study utilized an online mCFIR questionnaire to measure performance and importance scores across five domains and two sub-domains. Perspectives of 46 epidemiologists and 167 community health workers (CHWs) were included. Focus group discussions, key-informant interviews with relevant stakeholders at the local-national level, field observations, and application log analysis were also conducted. Descriptive and thematic analyses were performed to provide insights into its fidelity, penetration, and sustainability. **Results:** In 2022, the weekly participation rate remained stable, ranging from 76.3-97.7% for village-level CHWs and 100% for epidemiologists, indicating strong program sustainability. However, cadres and epidemiologists rated performance support from the outer setting domain as the lowest, recognizing its potential impact when executed properly. Three major themes emerged as facilitators: solid community engagement, high users' demand and commitment, and collaboration opportunities. Four key barriers were discovered: integration and interoperability challenges, data input quality and standardization issues, variations in end-user characteristics, and limited involvement of local stakeholders. **Conclusion:** This study has the potential to contribute significantly to the field of dengue surveillance in Indonesia and beyond, providing valuable insights into the benefits and limitations of adopting digital innovations to combat this persistent public health threat.

Keywords: community participation; CFIR; dengue; digital surveillance; mobile health application

INTRODUCTION

Dengue fever is a prevalent mosquito-borne disease in tropical and subtropical countries, including Indonesia, where Semarang, the capital city of Central Java, is significantly affected due to its geographical location, climate, and urbanization [1–3]. Effective surveillance is crucial in combating dengue, as early detection and timely response are essential to prevent the virus spread and reduce disease severity [4].

Traditional surveillance methods, such as manual data collection and reporting, have limitations in terms of timeliness, accuracy, and coverage [5]. In recent years, digital innovations have revolutionized disease

surveillance, providing real-time data collection, analysis, interpretation, and dissemination, allowing for more effective and targeted interventions [4,6]. Several countries have successfully implemented digital dengue surveillance systems to enhance their disease response [7]. For example, adopting a cross-platform surveillance system in Northeast Brazil enabled better data collection and analysis, leading to more efficient resource allocation and vector control measures [8]. Similarly, the Philippines has implemented a pilot study using a mobile health dengue surveillance system called Mozzify, which has 3 primary functions: real-time dengue fever case reporting and mapping system, health communication, and behavior modification [9].

In alignment with the National Strategic Plan for Dengue Prevention and Control [2,10], Semarang City's government has also developed a dengue-integrated digital surveillance innovation called 'Tunggal Dara.' The initially web-based system was recently coupled with an Android version in 2020 to enhance accessibility for independent community entomological surveillance data reporting and for epidemiologists to submit the epidemiological investigation of confirmed dengue patients' data.

However, no such study has evaluated digital dengue surveillance systems in Indonesia, despite the country's high dengue burden and the potential benefits of digital innovations in disease surveillance. This paper aims to evaluate the effectiveness of the Android-based dengue surveillance system 'Tunggal Dara' in optimizing dengue surveillance in Semarang, Indonesia. Using the Modified Consolidated Framework of Implementation Research (mCFIR), the study assesses the barriers and facilitators of implementing the system [11]. This study also serves as pilot research to evaluate mobile health (mHealth) implementation in Indonesia using the mCFIR tool.

The research focused on three implementation outcomes: fidelity, penetration, and sustainability [12,13]. Fidelity refers to how closely the intervention aligns with the original plan, emphasizing the data's usage for dengue control and prevention program development. Penetration, or coverage, will be estimated by the number of users at different organizational hierarchy levels. Lastly, sustainability will be measured by assessing community perspectives and the motivation to continue using the intervention.

METHODS

The study was conducted in Semarang City, Indonesia, from December 2022 to March 2023. Semarang City, the capital city of Central Java Province, has a unique topography, with a narrow lowland and hilly area ranging from 6.6 feet (2 meters) below sea level to 1,120 feet (340 meters) above sea level, with a slope of 0%–45% [14]. Administratively, the city is divided into 16 sub-districts, encompassing 177 villages, 1507 hamlets (RW), and 10434 neighborhood units (RT). The population density across these sub-districts varies from 1,176 to 12,067 persons/km^2, with an average of 4,441 [15]. These geographical and demographic characteristics challenge the implementation of dengue prevention and control programs.

An explanatory mixed-method design combined quantitative and qualitative data collection methods. For the quantitative aspect, the Modified Consolidated Framework of Implementation Research (mCFIR) tool was used to assess the performance and importance of five domains: intervention characteristics, outer setting, inner setting, end-users characteristics, and implementation process, along with two sub-domains: goal attainment scale and impact assessment (Table 1) [11]. The tool included Likert scale questions on a scale of 0 to 10 and a short survey, delivered via Google Form after receiving ethical approval from the Ethical Committee of Faculty Medicine, Public Health, and Nursing, Universitas Gadjah Mada (Ref. No: KE-FK-1351-EC-2022). Survey participants included 167 community health workers (CHWs/'Jumantik' cadres) and 46 epidemiologists selected from various city neighborhoods and primary health centers (PHCs). Descriptive analysis was conducted using IBM SPSS Statistics 25 and Microsoft Excel to analyze the data and select participants for follow-up focus group discussions (FGDs) sessions.

Nine participants from each user group, the CHWs and epidemiologists, were chosen based on their responses to the survey, ensuring the action of both positive and negative perceptions. The FGDs employed a semi-structured approach, utilizing questions aligned with the mCFIR domains and constructs. Additionally, key informant interviews were conducted with relevant stakeholders at local and national levels to gather qualitative insights. Representatives from the Semarang District Health Office (SDHO) and the Digital Transformation Office of the Indonesian Ministry of Health (DTO MoH) were purposively selected for in-depth interviews. Field observations and secondary data analysis from the application log were also conducted to support the primary data. Thematic analyses were performed using NVivo 12 Plus software to gain deeper insights into facilitators and barriers to the system implementation.

Table 1. Operational definitions of variables

Variable	Definition
Independent variables	
Intervention characteristics	The components and background of the intervention were assessed based on performance fidelity, adaptability, user-friendliness, comparative advantage, and affordability.
Outer setting	External factors affecting the intervention from outside the implementer team, including policies, other organizations, etc. Assessed based on stakeholder engagement, external support, and scale-up support.
Inner setting	Factors affecting the intervention from within the implementer team (SDHO, PHCs, and CHWs). Measured through the internal communication quality, acceptance, and organizational support.
End-user characteristics	Perspectives of epidemiologists and CHWs towards the application, including perception of benefit, training, and privacy. For the public, it also considers accessibility and language.
Implementation process	Implementation steps include intervention planning, stakeholder engagement, execution, and evaluation.
Goal attainment	Evaluate the achievement of implementation goals.
Impact assessment	Evaluates the achievement of key outcomes.
Dependent variables	
Performance	Evaluates the intervention's performance for each domain and construct.
Importance	Evaluate the importance of implementing the intervention for each domain and construct.

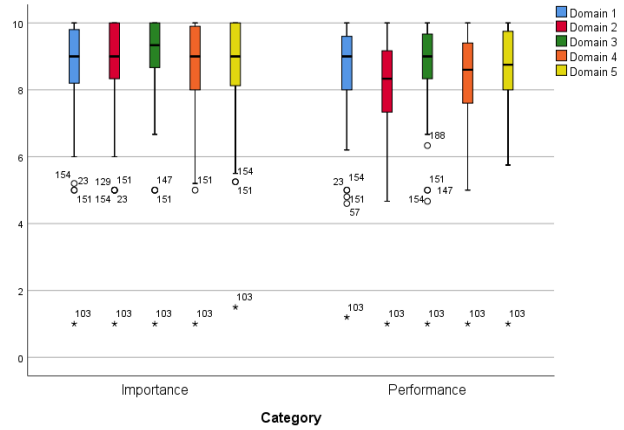
RESULTS

mCFIR Survey

Participants were identified based on several demographic data, including age, gender, and education, complemented with years working as CHWs or epidemiologists (before or after the mobile app development) and prior experience with the web version of 'Tunggal Dara.' CHWs mainly were aged 41-50 (44.3%), female (98.8%), and high school graduates (65.9%). The majority had been CHWs before the development of the Android app but had limited experience in accessing the web version of 'Tunggal Dara,' and only 28.7% had experience using the web platform. In contrast, epidemiologists were relatively younger, aged 21-30 (67.4%), predominantly female (89.1%), and held at least a bachelor's degree (91.3%). They had a balanced representation of those who joined before and after 2020, and they had experience in both web and mobile usage of 'Tunggal Dara.'

Box plots summarized performance and importance scores across domains from both user groups (Figure 1), guiding future development priorities. Additional insights into facilitators and barriers were obtained through two FGDs with each group, with feedback analyzed and categorized into implementation facilitators and barriers (Table 2).

a)



b)

NOTE:
Domain 1: Application characteristics; Domain 2: Outer setting;
Domain 3: Inner setting; Domain 4: End-user characteristics;
Domain 5: Implementation process
Median score cut-off:
5.0 - 6.67 Good; 6.68 - 8.34 Very good; 8.35 - 10.0 Excellent

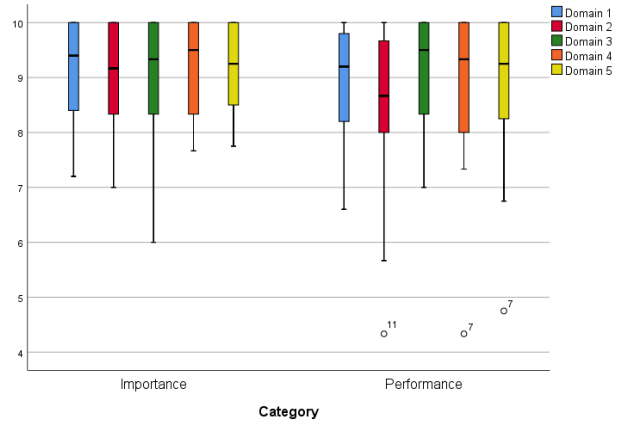


Figure 1. Box plots of mCFIR survey responses from the perspectives of a) CHWs and b) epidemiologists.

Epidemiologists rated all domains as excellent in performance and importance, with the outer setting domain having the lowest scores, indicating its lesser influence on the implementation's success. The CHWs considered the outer setting domain as the only non-excellent domain, recognizing its significant impact if executed properly, as it is regarded as the second most crucial domain after the inner setting. Further analysis of the constructs within the outer

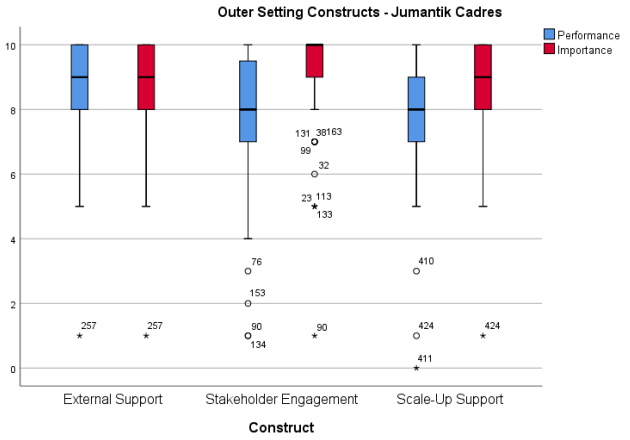
setting domain (Figure 2) shows that CHWs rated stakeholder engagement and scale-up support lower than external support. Epidemiologists considered all constructs to have similar medians, except for the importance of stakeholder engagement, which both user groups rated significant with a median score of 10. Therefore, it is evident that improvement in the outer setting involves enhancing the effectiveness of the intervention.

Table 2. Facilitators and barriers to 'Tunggal Dara' Android system implementation

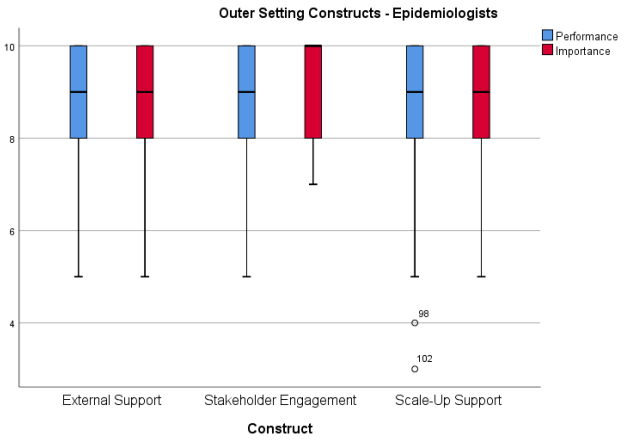
Categories	Theme	Open Code
Facilitators	1. Solid community engagement	• Effective communication and problem-solving discussion • Encourage independent learning
	2. High users' demand and commitment	• Perceived benefits • Strong users' commitment
	3. Collaboration opportunities	• Initial innovation idea and development • Continuous support and achievements
Barriers	1. Integration and interoperability challenges	• Repeated reporting • The use of FHIR-HL7 standard
	2. Data input quality & standardization issues	• CHWs' skills and honesty
	3. Variations in end-user characteristics	• User-friendliness for specific user types, e.g., elderly, technology illiterate, etc. • Phone compatibility issues • Low motivation • Conflicting responsibilities
	4. Limited involvement of local stakeholders	• Limited awareness and involvement of local stakeholders

Sub-domains' performance scores were generally excellent, except for the goal attainment scale from the CHWs' perspective (8.11±0.46), compared to epidemiologists (8.7±0.69). Similarly, the impact assessment score was lower from the CHWs' perspective (8.47±0.50) than the epidemiologists' (8.9±0.74). Both user groups agreed that using the mobile health surveillance system indirectly contributed to a decrease in dengue cases in Semarang City, with total dengue hemorrhagic fever cases decreasing from 320 in 2020 to 122 in 2021.

a)



b)



NOTE:
Domain 1: Application characteristics; Domain 2: Outer setting; Domain 3: Inner setting; Domain 4: End-user characteristics; Domain 5: Implementation process
Median score cut-off:
5.0 - 6.67 Good; 6.68 - 8.34 Very good; 8.35 - 10.0 Excellent

Figure 2. Box plots of outer setting constructs from the perspectives of a) CHWs and b) epidemiologists.

Implementation Fidelity

Report submissions' completeness and timeliness measured fidelity. Challenges arose within the CHW group, as some CHWs at the neighborhood unit level occasionally needed to remember to submit reports on time, leading to monitoring difficulties. Additionally, concerns were raised about the data input accuracy and standardization from the CHWs, as they consistently reported higher Larvae-Free Index (LFI) scores, leading to uncertainty about the accuracy of their measurements.

Similarly, epidemiologists needed help completing the epidemiological investigation form of confirmed dengue patients in time, mainly due to unavailable data during investigations, necessitating subsequent edits through the website. The timeliness of epidemiologists' submissions was also affected, with data from 2018 -2023 showing variations in average investigation time, with the lowest recorded in 2021, possibly attributed to the app's adoption during the COVID-19 pandemic and delays in hospital reports.

Table 3. Reported barriers in achieving implementation fidelity

1. *"Some users tend to forget to input data on time, resulting in the report submission together with the following week's reports, which can cause confusion to recap."* – CHW, female, 37 years old.
2. *"(LFI assessment results by) the CHWs always had almost perfect percentages, while epidemiologists' results were (usually) below 85. That's like honesty on the part of the CHWs (needs to be questioned), was it only inside the house that was checked, and the outside was not checked?"* – CHW, Female, 52 years old.
3. *"If the LFI is high but the number of cases remains high as well, it prompts self-evaluation. Is my larval control effective? Are my reports accurate? Thus, it needs to be consistently communicated with the community. So, I always say that results will not betray the process, having a good LFI, and there are no cases, that's truly excellent."* – Sub-coordinator of Prevention and Eradication of Infectious Diseases, Vectors, and Zoonoses, SDHO.
4. "*What usually becomes a constraint is when the patient hasn't returned home, so when we go there, we don't get information about their schools or other details that not everyone knows. There are also difficulties in finding the patient's house because even the neighbors don't know the patient's name. So, when filling out the form in the application, not all questions can be answered, and we can't save it. In the end, we just fill it in randomly, and if we get the data later, we can save it. Another challenge is that sometimes we can't edit the information. Once we input it in the Android app, we leave it as it is and we'll edit it later through the website.*" – Epidemiologist, female, 35 years old.

Penetration and Sustainability

Application usage was compulsory for the epidemiologists, whereas the number of surveillance reports submitted through the Android system by CHWs showed fluctuations (Figure 3). Some CHWs faced difficulties with the app and opted for manual report submission using a form to the higher administrative authorities. Consequently, the reporting percentage through the Android system was higher at the village and hamlet levels compared to the neighborhood unit level.

Despite these fluctuations, the community participation rate remained relatively stable, indicating favorable program sustainability. With the Android version's introduction, CHWs perceived numerous benefits, such as easier and faster report submission and real-time monitoring. However, some faced challenges in learning the new application, and a few had compatibility issues with their phones, preventing app installation. Despite these hurdles, overall feedback indicated a positive reception of the Android version among CHWs.

"Sometimes not everyone understands how to use the Android application, but there are several cadres who already understand how to use Tunggal Dara, so they can still help each other.." – CHW, Female, 37 years old.

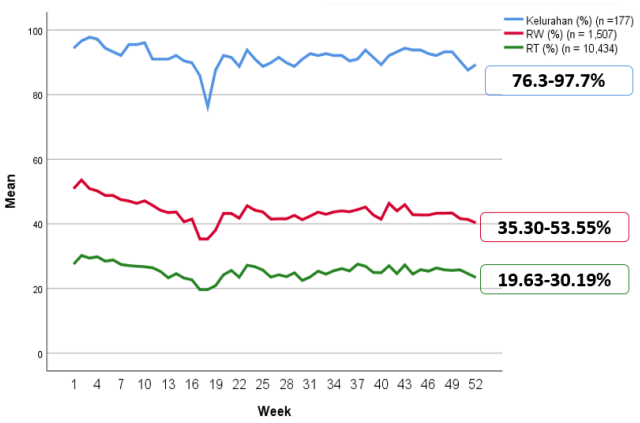


Figure 3. Weekly community participation rate based on the total report submitted through the Tunggal Dara app in 2022

The initial development of the 'Tunggal Dara' system received support from various Non-Governmental Organizations (NGOs), such as the Rockefeller Foundation, Mercy Corps, and Kalandara. However, the current maintenance funding comes from the Semarang city government's fund and several Corporate Social Responsibilities (CSRs). To enhance the system's capabilities, collaborative efforts with researchers, academicians, and other organizations were strengthened, focusing on improving the accuracy of the early prediction system and data analysis.

Despite these efforts, challenges related to integration and interoperability surfaced when provincial and national governments implemented different surveillance systems, requiring repeated data input. The proposed solution by the DTO MoH to use the international standard FHIR-HL7 was not presently applicable.

"*We are still having trouble following the concept of FHIR, because the workshops on FHIR are not massive yet. FHIR uses full English, right, so for now it's still difficult to implement it in the real world. It would be better if there were FHIR experts in each region.*" – Sub-coordinator of Information and Control of Health Facilities SDHO.

DISCUSSION

Principal considerations and recommendations

The main backbone of community-level dengue prevention control measures relies on the involvement of CHWs, with women playing a primary role in community- and household-based prevention efforts (16). However, women often face challenges as they are already burdened with household and caregiving responsibilities, making their vector control work more difficult. This study's findings, which also revealed a majority of female CHWs, underscore the need for stakeholders to develop simple and less demanding health innovations to avoid increasing the workload of CHWs [8,17].

In addition to streamlining data reporting, it is crucial to provide comprehensive refreshment training for both users, encompassing application usage, proper LFI assessment, and epidemiological investigation techniques. This will help maintain good data quality and standards, as a lack of training can hinder risk assessment results and impede users' capabilities [7,18].

Expanding the coverage of cadres poses challenges, particularly in reaching certain groups, such as older people or those with limited time for app updates. Therefore, involving school-aged young adults, as demonstrated in The Philippines with positive impacts, could be considered to extend coverage [9].

The sustained success of the 'Tunggal Dara' system over nearly a decade can be attributed to the willingness of all stakeholders to adapt and evolve. To ensure long-term adaptability, the system's development should involve all users to gather their perspectives and create a more suitable and sustainable application [4].

Study implications and limitations

This study acknowledges the potential presence of interview bias and researcher bias resulting from the limitations of purposive sampling. To address these concerns and gain deeper insights, a future follow-up study is recommended, particularly after implementing the second version of the app. Given the rapid national transformation towards digitalization in healthcare, further research is essential to investigate the impact of such developments and assess the local preparedness within this context. The findings of this study have already contributed to practical applications, as the SDHO utilized them to update the 'Tunggal Dara' Android application to its second version, marking significant progress after two years of implementation.

CONCLUSION

In conclusion, this pilot study utilizing the mCFIR tool provides valuable insights into the implementation of 'Tunggal Dara,' an Android-based mHealth system for dengue surveillance in Semarang, Indonesia. The findings underscore the benefits of using an Android-based dengue information system in improving motivation and continuity of community-based dengue prevention control programs. They also highlight the importance of addressing the outer setting domain, particularly stakeholder engagement and scale-up support, to enhance the intervention's effectiveness. When implementing digital health innovations, consideration should be given to local context preparedness, including digital health literacy, data integration and interoperability, and data privacy.

This study has the potential to contribute significantly to the field of dengue surveillance in Indonesia and beyond, providing valuable insights into the benefits and limitations of adopting digital innovations to combat this persistent public health threat.

REFERENCES

1. Nonyong P, Ekalaksananan T, Phanthanawiboon S, Aromseree S, Phadungsombat J, Nakayama EE, et al. Dengue virus in humans and mosquitoes and their molecular characteristics in northeastern Thailand 2016-2018. PloS One. 2021;16(9):e0257460.
2. Kementerian Kesehatan Republik Indonesia. Strategi Nasional Penanggulangan Dengue 2021-2025 [Internet]. Kementerian Kesehatan Republik Indonesia; 2021 [cited 2023 Jun 2]. Available from: [Website]
3. Alfiyanti UN, Siwiendrayanti A. Analisis spasial dan temporal kejadian DBD di Kota Semarang tahun 2016-2019. Jurnal Kesehatan Lingkungan. 2021 Jan 2;18(1):39–48.
4. Pley C, Evans M, Lowe R, Montgomery H, Yacoub S. Digital and technological innovation in vector-borne disease surveillance to predict, detect, and control climate-driven outbreaks. Lancet Planetary Health. 2021 Oct;5(10):e739–45.

5. Purnama S, Susanna D, Achmadi UF, Krianto T, Eryando T. Potential development of digital environmental surveillance system in dengue control: a qualitative study. Open Access Macedonian Journal of Medical Science. 2021 Dec 3;9(E):1443–53.
6. Kostkova P, Saigí-Rubió F, Eguia H, Borbolla D, Verschuuren M, Hamilton C, et al. Data and digital solutions to support surveillance strategies in the context of the COVID-19 pandemic. Frontiers in Digital Health. 2021 Aug 6;3:707902.
7. Carrillo MA, Kroeger A, Cardenas Sanchez R, Diaz Monsalve S, Runge-Ranzinger S. The use of mobile phones for the prevention and control of arboviral diseases: a scoping review. BMC Public Health. 2021 Dec;21(1):110.
8. Aldosery A, Musah A, Birjovanu G, Moreno G, Boscor A, Dutra L, et al. MEWAR: Development of a cross-platform mobile application and web dashboard system for real-time mosquito surveillance in Northeast Brazil. Frontiers in Public Health. 2021 Oct 27;9:754072.
9. Herbuela VRDM, Karita T, Carvajal TM, Ho HT, Lorena JMO, Regalado RA, et al. Early detection of dengue fever outbreaks using a surveillance app (mozzify): cross-sectional mixed methods usability study. JMIR Public Health and Surveillance. 2021 Mar 1;7(3):e19034.
10. WHO. Ending the burden of dengue infection: Indonesia launched the 2021-2025 National Strategic Plan for Dengue Control Programme [Internet]. 2021 [cited 2023 May 27]. Available from: [Website]
11. El Joueidi S, Bardosh K, Musoke R, Tilahun B, Abo Moslim M, Gourlay K, et al. Evaluation of the implementation process of the mobile health platform 'WelTel' in six sites in East Africa and Canada using the modified consolidated framework for implementation research (mCFIR). BMC Medical Informatics and Decision Making. 2021 Dec;21(1):293.
12. Lewis CC, Fischer S, Weiner BJ, Stanick C, Kim M, Martinez RG. Outcomes for implementation science: an enhanced systematic review of instruments using evidence-based rating criteria. Implementation Science. 2015 Dec;10(1):155.
13. Proctor E, Silmere H, Raghavan R, Hovmand P, Aarons G, Bunger A, et al. Outcomes for implementation research: conceptual distinctions, measurement challenges, and research agenda. Administration and Policy in Mental Health. 2011 Mar;38(2):65–76.
14. World Topographic Map. Semarang Topographic Map. 2023. Available from: [Website]
15. Badan Pusat Statistika. Population Density. 2023. Available from: [Website]
16. Mungall-Baldwin C. Women's participation in the prevention and control of dengue using environmental methods in the global south: a qualitative meta-synthesis. International Journal for Equity in Health. 2022 Sep 23;21(1):140.
17. Lwin MO, Sheldenkar A, Panchapakesan C, Ng JS, Lau J, Jayasundar K, et al. Epihack Sri Lanka: development of a mobile surveillance tool for dengue fever. BMC Medical Informatics and Decision Making. 2019;19(1):111.
18. Lwin MO, Jayasundar K, Sheldenkar A, Wijayamuni R, Wimalaratne P, Ernst KC, et al. Lessons from the implementation of Mo-Buzz, a mobile pandemic surveillance system for dengue. JMIR Public Health and Surveillance. 2017 Oct 2;3(4):e65.