Original Article

USER ACCEPTANCE TESTING OF THE D-MOSS DENGUE PREDICTIVE MODEL AS AN EARLY WARNING SYSTEM IN MALAYSIA

Lim Mei Cheng[1], Nuur Hafizah **Md Iderus**[1], Sumarni **Mohd Ghazali**[1], Lonny Chen Rong Qi **Ahmad**[1], Nur'ain **Mohd Ghazali**[1], Mohamad Nadzmi **Md Nadzri**[1], Asrul Anuar **Zulkifli**[1], Mohd Kamarulariffin **Kamarudin**[1], Nur Ar Rabiah **Ahmad**[1], **Chew** Cheng Hoon[1], **Teh** Chien Huey[1], Nur Huda **Mohd Jaghfar**[1], Qistina **Ruslan**[1], Balvinder Singh **Gill**[1], **Chong** Zhuo Lin[2], **Wan** Ming Keong[3], **Tee** Kok Keng[4], Lokman Hakim **Sulaiman**[5,6], Sarbhan **Singh**[1]

1. Institute for Medical Research, National Institutes of Health, Ministry of Health Malaysia, Jalan Setia Murni U13/52, Seksyen U13, Setia Alam, 40170 Shah Alam, Selangor, Malaysia.
2. Disease Control Division, Ministry of Health Malaysia, Kompleks E, Pusat Pentadbiran Kerajaan Persekutuan, 62590 Wilayah Persekutuan Putrajaya, Malaysia.
3. Department of Medical Microbiology, Faculty of Medicine, Universiti Malaya, 50603 Kuala Lumpur, Wilayah Persekutuan Kuala Lumpur, Malaysia.
4. Department of Public Health and Community Medicine, School of Medicine, IMU University, No. 126, Jalan Jalil Perkasa 19, Bukit Jalil, 57000 Kuala Lumpur, Malaysia.
5. Centre for Environment and Population Health, Institute for Research, Development and Innovation, No. 126, Jalan Jalil Perkasa 19, Bukit Jalil, 57000 Kuala Lumpur, Malaysia.

Submission Date:
17th February 2025

Acceptance Date:
17th April 2025

Publication Date:
15th May 2025

***Corresponding author:**
Lim Mei Cheng
dr.limmeicheng@moh.gov.my
Tel: +603-33626922

DOI:
https://doi.org/10.63719/imrj.2025.11.01.006

ABSTRACT

Dengue remains a significant public health challenge in Malaysia with recurring outbreaks, highlighting the need for effective forecasting tools. This study aimed to evaluate user acceptance of the Dengue forecasting Model Satellite-based System (D-MOSS) in Malaysia, assessing its usability, strengths, challenges, and areas for improvement. A cross-sectional study was conducted among 32 stakeholders who were directly involved in using D-MOSS for dengue management. Data were collected during a national workshop using a structured survey adapted to the specific operational context of D-MOSS. Thematic analysis was employed to analyse open-ended responses using R for keyword-based categorisation and visualisation. Participants reported high comprehension of D-MOSS features, with a 100% understanding of the outbreak thresholds and forecast values. Common strengths included the system's forecasting capability (66%), impact on outbreak management (22%) and user-friendly interface (12%). Challenges highlighted included accuracy and credibility (54%), performance and technical issues (27%), and granularity and usability of data (19%). For improvements, 40% suggested greater customisation, such as smaller spatial resolution, 25% emphasised interface enhancements, 20% advocated for comparative analysis features, and 15% proposed integrating action planning tools. The system was perceived as a helpful tool for assisting proactive dengue management. D-MOSS demonstrated its user-friendliness and stakeholder adaptability, which support its application in dengue surveillance. Addressing identified challenges and enhancing system

features could strengthen its utility and integration, contributing to improved dengue surveillance and control efforts.

KEYWORDS: dengue, early warning systems, user acceptance testing, predictive model, public health surveillance

INTRODUCTION

Dengue fever remains a significant public health challenge globally, particularly in tropical and subtropical regions, where environmental conditions favour the proliferation of its primary vector, *Aedes aegypti*. An estimated 390 million dengue infections occur annually worldwide, with Southeast Asia bearing a significant portion of this burden (1). The economic ramifications are equally profound, with the global cost of dengue illness estimated at USD 8.9 billion annually (2). Malaysia, similar to many other nations in the region, continues to face a high incidence of dengue cases despite extensive control efforts, including vector control programs and public health campaigns (3). The unpredictable nature of dengue outbreaks, driven by climatic, demographic, and socioeconomic factors, underscores the need for innovative tools to improve outbreak prevention and management (4,5).

Predictive modelling has emerged as a critical component of public health surveillance, offering insights into disease trends and enabling proactive interventions. Early warning systems, such as the Dengue forecasting MOdel Satellite-based System (D-MOSS), leverage historical and real-time data to forecast dengue outbreak risks (6). These systems aim to transform dengue management from reactive to proactive preventive strategies, enabling public health authorities to allocate resources more efficiently and implement targeted interventions before outbreaks escalate (7). D-MOSS has been operational since 2019 in Vietnam and has demonstrated proven benefits in supporting budget planning and optimisation processes in dengue control measures, such as developing action plans and preparing chemicals and equipment needed to address dengue outbreaks (8). In Malaysia, D-MOSS has been piloted across several districts to assist in the control and management of dengue; however, to date, no study has evaluated its user acceptance testing (UAT) among public health officers involved in dengue control in Malaysia.

The success of any early warning system depends not only on the accuracy of its predictions but also on its usability, user acceptance, and integration into existing public health frameworks. Conducting UAT is a vital step before adopting any predictive systems into existing public health frameworks to enhance the applicability of such systems. By assessing user comprehension, system usability, and practical challenges, UAT provides critical feedback to refine system design and ensure alignment with the needs of diverse stakeholders (9,10). Evidence from the implementation of the Early Warning, Alert and Response System (EWARS) in Indonesia highlights the importance of evaluating usability, accessibility, and integration into existing public health frameworks during the early stages of adoption where it revealed several challenges that could have been mitigated through comprehensive user testing before full-scale implementation such as repeated data entry, technical issues affecting user-friendliness of the system and inconsistent training for public health centre staffs (11). These challenges underscore the importance of aligning system functionality with the operational realities of end users. This step is particularly crucial in resource-limited settings as it facilitates the development of robust and adaptable solutions that optimise usability and accessibility, ensuring readiness for full-scale implementation into national systems.

This study aimed to evaluate user acceptance of D-MOSS in Malaysia, assessing its usability, strengths, challenges, and areas for improvement based on feedback from key users involved in dengue management. The findings of this study aim to inform enhancements to the D-MOSS system, ensuring its functionality and relevance while facilitating its seamless integration into public health practices. This approach supports national priorities for improving disease surveillance and prevention and aligns with global efforts to strengthen public health preparedness to address Malaysia's increasing dengue burden.

MATERIALS AND METHODS

Study design, setting and population

This study employed a cross-sectional design to evaluate the user acceptance of the D-MOSS dengue predictive model. The evaluation focused on understanding the usability, comprehensibility, and practicality of the system as an early warning tool for dengue outbreak management in Malaysia. The study was conducted among the key stakeholders from the Vector Control Division of the Ministry of Health Malaysia, state health departments and district health offices with direct involvement in using D-MOSS and can integrate predictive tools like D-MOSS within operational contexts for control and management of dengue. The stakeholders from the headquarters of the Ministry of Health and state health departments are responsible for dengue surveillance and forecasting using D-MOSS, while those at the district level serve as implementers who coordinate and execute dengue prevention and control activities locally in response to D-MOSS.

Sample size estimation and sampling method

The sample size was estimated based on a confidence level of 95%, a 5% margin of error, and an assumed user acceptance rate of 80%. Using Cochran's formula, a minimum sample size of 30 participants was required (12). The sampling frame included a total of 50 key stakeholders, with 25 public health officers (epidemiologists and medical officers) and 25 health inspectors and assistant health inspectors. The demographic characteristics of the participants are shown in Table 1. Universal sampling was employed, which resulted in a formal sample size of 32 participants who consented to participate in this study.

Table 1. Demographic characteristics of 50 key stakeholders

States	Headquarters	State Health Department	District Health Office
Ministry of Health	8		
Johor		2	2
Kedah		3	
Kelantan		3	
Melaka		1	2
Negeri Sembilan		2	1
Pahang		2	1
Perak		3	

Perlis	1	
Pulau Pinang	2	1
Sabah	2	2
Sarawak	1	2
Selangor	2	2
Terengganu	1	1
Wilayah Persekutuan (WP) Labuan	1	
WP Kuala Lumpur & Putrajaya	2	

Data collection

A structured survey was administered during a national workshop in January 2022. Prior to this workshop, participants received periodic formal training and resource materials on the use and application of the D-MOSS for dengue control management. The D-MOSS was subsequently piloted in their respective state health departments and district health offices. The national workshop was then convened to evaluate the user acceptance of D-MOSS, assessing its usability, strengths, challenges, and areas for improvement based on feedback from key users involved in dengue management.

Measures

The instrument used in this study was guided by the principles of the System Usability Scale (SUS) but adapted to the specific operational context of D-MOSS as shown in Table 2 (9). It comprised items organised into five domains: usability and comprehension, system strengths and challenges, accessibility and implementation, anticipated impact and integration, and user recommendations. These domains were selected based on relevant literature and structured to ensure comprehensive coverage of constructs relevant to evaluating D-MOSS (13,14,15).

Domain 1 relates to usability and understanding of the D-MOSS website. This domain has six items that assess participants' comprehension of the core functionalities and outputs of the D-MOSS system, including outbreak thresholds, exceedance probabilities, forecast values, and forecast periods. It also evaluates the ease of interpreting forecast data and integrating the outputs, such as graphs and tables, into practical applications like reporting. These questions aim to measure the clarity and accessibility of the system's interface and information.

Domain 2 relates to the D-MOSS system's strengths and challenges. This domain has two items that capture participants' perceptions of the D-MOSS system's strengths and limitations. Through open-ended questions, users share what they value most about the system and identify areas where the system falls short. These insights provide qualitative feedback essential for understanding user experiences and identifying opportunities for enhancement.

Domain 3 focuses on the accessibility and implementation of the D-MOSS system. This domain has three items on understanding how the D-MOSS system can be accessed and utilised in practice. It explores which stakeholders will access the system regularly, how the forecasts will be communicated to communities, and how the system can be integrated into existing dengue management processes

in Malaysia. These questions aim to assess the practicality and scalability of the system's implementation.

Domain 4 is related to the anticipated impact and integration of the D-MOSS system. This domain evaluates users' perspectives on how the D-MOSS system can contribute to dengue outbreak management. It focuses on the system's potential to assist in planning and executing proactive interventions, helping to shift from reactive to proactive preventive approaches in public health practices.

Domain 5 focuses on the improvement and recommendations of the D-MOSS system. This domain has two items, which gather user feedback on areas for system enhancement. Participants provide suggestions for improving the D-MOSS interface, functionality, and outputs. Additionally, this section explores whether the forecast system provides sufficient information and identifies any additional data or features users would find helpful. Responses were measured using a dichotomous question (e.g., "Yes" or "No") and open-ended feedback.

Table 2. Questionnaire containing 14 items on the UAT

Domains	Item	Response
Usability and understanding of the D-MOSS website	Do you understand the outbreak threshold?	Yes/No
	Do you understand the exceedance probability?	Yes/No
	Are you able to interpret the forecast values?	Yes/No
	Are you able to interpret the forecast period?	Yes/No
	Is the information provided in the D-MOSS forecast page easy to understand?	Yes/No
	Will you be able to use the output data and graphs from D-MOSS in your reports?	Yes/No
System strengths and challenges	What do you like best about the D-MOSS website?	Open-ended
	What do you least like about the D-MOSS website?	Open-ended
Accessibility and Implementation	Who will be accessing the website on a regular basis?	Open-ended
	How will the D-MOSS forecasts reach the communities?	Open-ended
	How do you anticipate D-MOSS helping you manage dengue outbreak?	Open-ended

Anticipated Impact and integration	How can D-MOSS feed into the existing processes for the management of dengue outbreak in Malaysia?	Open-ended
Improvement and recommendations	Please provide some ideas as to how DMOSS website could be improved	Open-ended
	Does the forecast system provide sufficient information? If No, state what additional information you would like to receive.	Yes/No

The instrument was piloted among a group of public health professionals to determine the content and face validity of the items. Content validity was assessed by ensuring that critical dimensions on usability, operational fit, and perceived value of the system were adequately addressed. All items obtained an item-level content validity index (I-CVI) of 1.00 with a mean I-CVI of 1.00. Face validity was established through expert review by professionals in public health and forecasting systems. This process ensured that questionnaire items were clear, appropriate, and relevant to the target user group and the practical context in which the system would be used.

Statistical analysis

Quantitative data was analysed using descriptive statistics, including frequencies and percentages for categorical variables. Thematic analysis was conducted for qualitative feedback with a structured coding framework to identify recurring themes, leveraging R, a statistical computing software, for comprehensive data manipulation, analysis, and visualisation (16). Thematic analysis with a hybrid approach was employed in this study, incorporating both deductive and inductive approaches. The deductive component was guided by predefined study domains, which informed the initial coding framework. Feedback was categorised into predefined themes using keyword matching, employing functions such as mutate () and case when () for streamlined classification. The stringr package was used for efficient text analysis and keyword extraction. For unmatched responses, an inductive approach was employed whereby the responses were manually reviewed and reclassified to ensure thematic alignment and to identify emerging themes not captured by the initial framework. The frequency and percentage of each theme were calculated using count () and mutate (), providing quantitative insights into the thematic distribution. Results were visualised with ggplot2, generating clear and intuitive bar charts that effectively represented the data.

To enhance inter-coder reliability, the qualitative data analysis was done by two independent researchers. Consistency was assessed through a comparison of coding outputs, and any discrepancies were resolved through consensus. This involved a joint review of the context of original responses, followed by discussions to reach an agreement on the appropriate theme assignment. This integrated approach ensured methodological rigour and facilitated meaningful interpretation of both quantitative and qualitative findings.

RESULTS

Out of a total of 50 key users invited to participate in the study, 32 consented, yielding a response rate of 64%. All 32 participants completed the questionnaire, resulting in a 100% completion rate. Given the small sample size of only 32 participants in our study, demographic characteristics were anonymised to prevent information bias and protect confidentiality, as including such demographic details could potentially lead to the easy identification of the individual participants. The results of the UAT of the D-MOSS system are described below:

Domain 1. User understanding and usability

All participants (100%) demonstrated a clear understanding of the outbreak threshold and exceedance probability. All users were able to interpret the forecast values and forecast periods effectively, demonstrating a high level of user comprehension. With regards to usability**,** 94% of participants found the information on the D-MOSS forecast page easy to understand. Furthermore, 97% reported being able to utilise the output data and graphs in their reports, with only 3% expressing concerns about insufficient explanations (Figure 1).

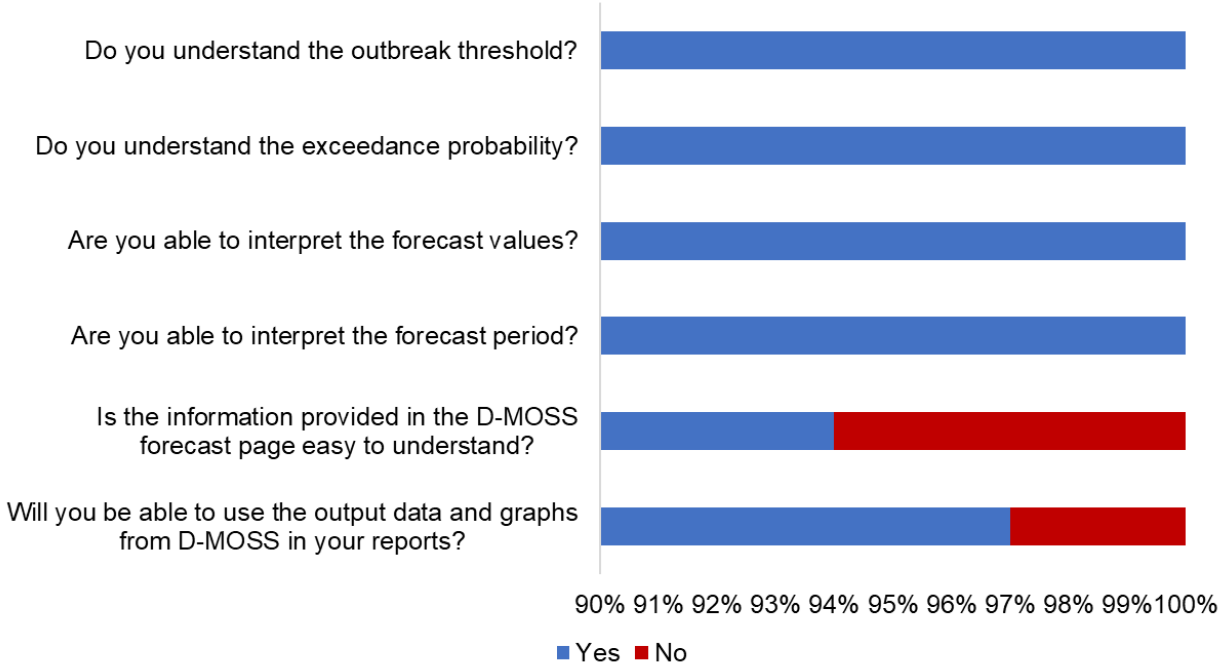


Figure 1. Responses on user understanding and usability of the D-MOSS system

Domain 2. System strengths and challenges

The common themes that appear on the strengths of the system include forecast capabilities (66%), impact on outbreak management (22%) and interface and accessibility (12%) (Figure 2). Participants identified the system's ability to forecast over extended periods as a significant strength, particularly highlighting its utility in strategic planning for dengue surveillance and control activities:

'Able to predict the probability of outbreak/increase of dengue cases.'

(Participant 2)

'Able to predict the chances of occurrence of dengue cases for 6 months in advance.'

(Participant 15)

On the impact on outbreak management**,** participants emphasised the system's role in facilitating outbreak prevention and noted that the graphical representation of mean values was particularly useful in assessing the likelihood of outbreaks:

'Maybe it can help to prevent outbreaks from occurring, and action can be taken as soon as possible.'

(Participant 26)

'The variability of the mean to determine the possibility of an outbreak based on values plotted in graphs is helpful.'

(Participant 17)

Additionally, participants appreciated the ease of accessing data and tables and found the user interface visually intuitive and user-friendly:

'Easy interface and produce a reliable forecast within a reasonable time frame.'

(Participant 23)

'System is straightforward and easy to understand.'

(Participant 29)

The common themes on the challenges of the system include accuracy and credibility (54%), performance and technical issues (27%), and granularity and usability of data (19%) (Figure 2). More specifically, with regard to accuracy and credibility, participants expressed concerns about the reliability of the forecasts, citing a lack of examples of successful implementation of similar systems in other countries:

'Accuracy of the forecast is questionable, no example of a country with a success story of using DMOSS.'

(Participant 8)

For the performance and technical issues, participants reported challenges with long loading times, non-responsive web design and intermittent connectivity issues when accessing the dashboard:

'The long time it takes to open the website.'

(Participant 1)

'Intermittent issue of connecting to the dashboard.'

(Participant 23)

In terms of granularity and usability of data**,** participants highlighted the lack of specific locality-level data as a drawback, along with the inability to compare forecasts with retrospective data as a limitation:

'Unable to pinpoint the locality of the outbreak.'

(Participant 22)

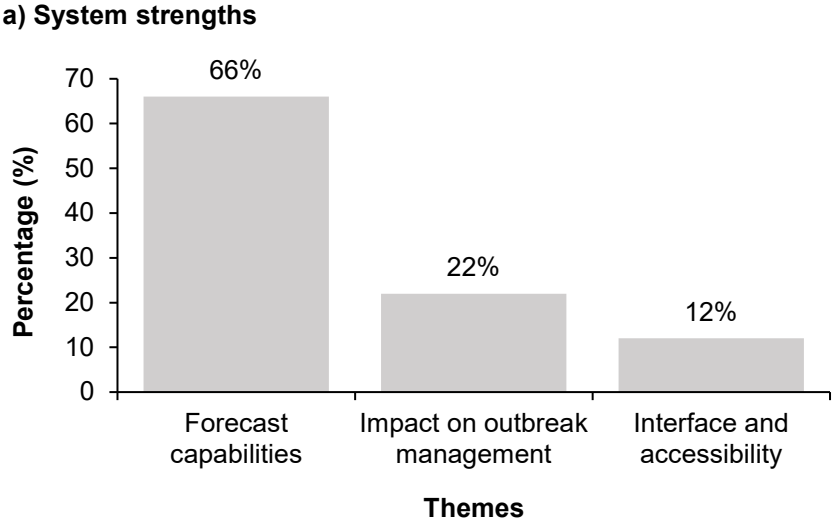
'I am unable to compare directly the forecast and reported value retrospectively.'

(Participant 6)

Additionally, frequent updates to the data were viewed as a challenge, particularly in aligning forecasts with weekly prevention measures:

'The data is still dynamic, with changes potentially occurring weekly and making it hard for me to adjust my prevention measurement every week.'

(Participant 15)



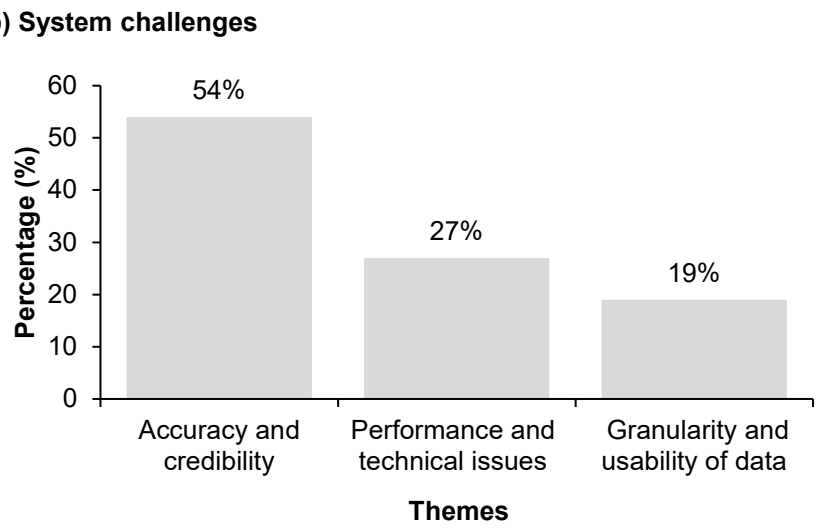


Figure 2. Thematic analysis of D-MOSS system strengths and challenges

Domain 3. Accessibility and implementation

The responses indicated that three primary user groups are anticipated to regularly access the D-MOSS website, namely Health Officers (50%), Liaison Officers (30%), and Technical Staff (20%) (Figure 3).

'National level, state and district officer who manages the vector-borne disease sector.'

(Participant 23)

'Health Inspector & epidemiology officer.'

(Participant 25)

'Liaison Officer at district and state level.'

(Participant 1)

'Technical health control officers.'

(Participant 3)

Respondents provided insights into several dissemination strategies for D-MOSS forecasts. Social media platforms such as Facebook, Instagram, and Twitter were frequently mentioned as key channels for sharing forecasts, accounting for 40% of the responses. In addition, 35% of respondents emphasised the importance of information sharing through existing networks and community engagement strategies. A further 25% of respondents underscored the use of early warning systems to directly communicate critical dengue forecasts (Figure 3).

'Formal (communities, meetings) and informal platforms, including social media.'

(Participant 16)

'Dengue alert through social media, local radio station and mobile public announcements.'

(Participant 8)

'Alert the community to take some preventive measures through social media.'

(Participant 5)

The responses identified three primary ways in which D-MOSS is anticipated to support dengue management (Figure 3). The first is trend analysis, where 45% of respondents highlighted the value of analysing predictive trends to enhance understanding and preparedness for potential outbreaks:

'By looking at the trend of prediction with exceedance probability, we can conduct prevention earlier to avoid the outbreak.'

(Participant 1)

The second is geographical risk stratification, where 30% of respondents focused on the utility of D-MOSS in stratifying dengue risk geographically to optimise targeted interventions:

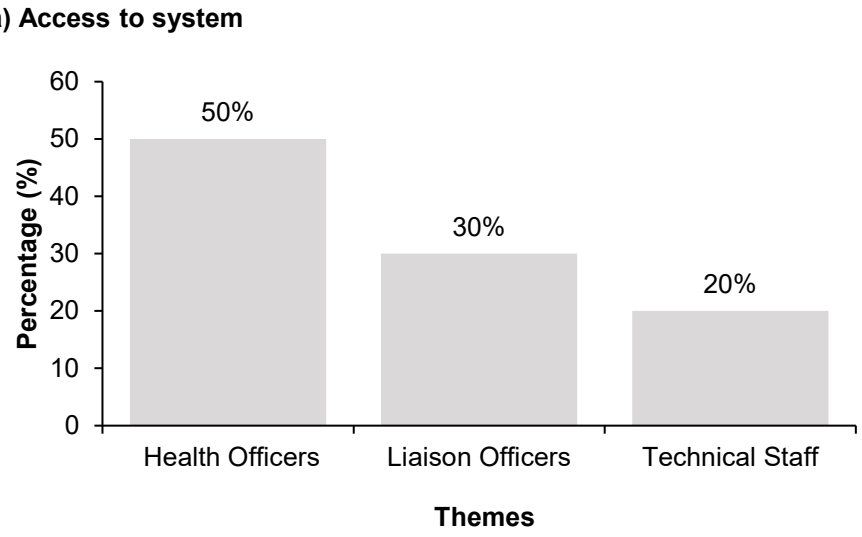
'Structured and focused plan for districts to plan out preventive measures.'

(Participant 6)

The third is preventive planning, where 25% of respondents recognised the role of D-MOSS in facilitating the planning and implementation of preventive activities:

'Can predict the occurrence of dengue cases 6 months in advance, which helps me to take preventive activities before the occurrence of dengue or outbreak of dengue.'

(Participant 15)



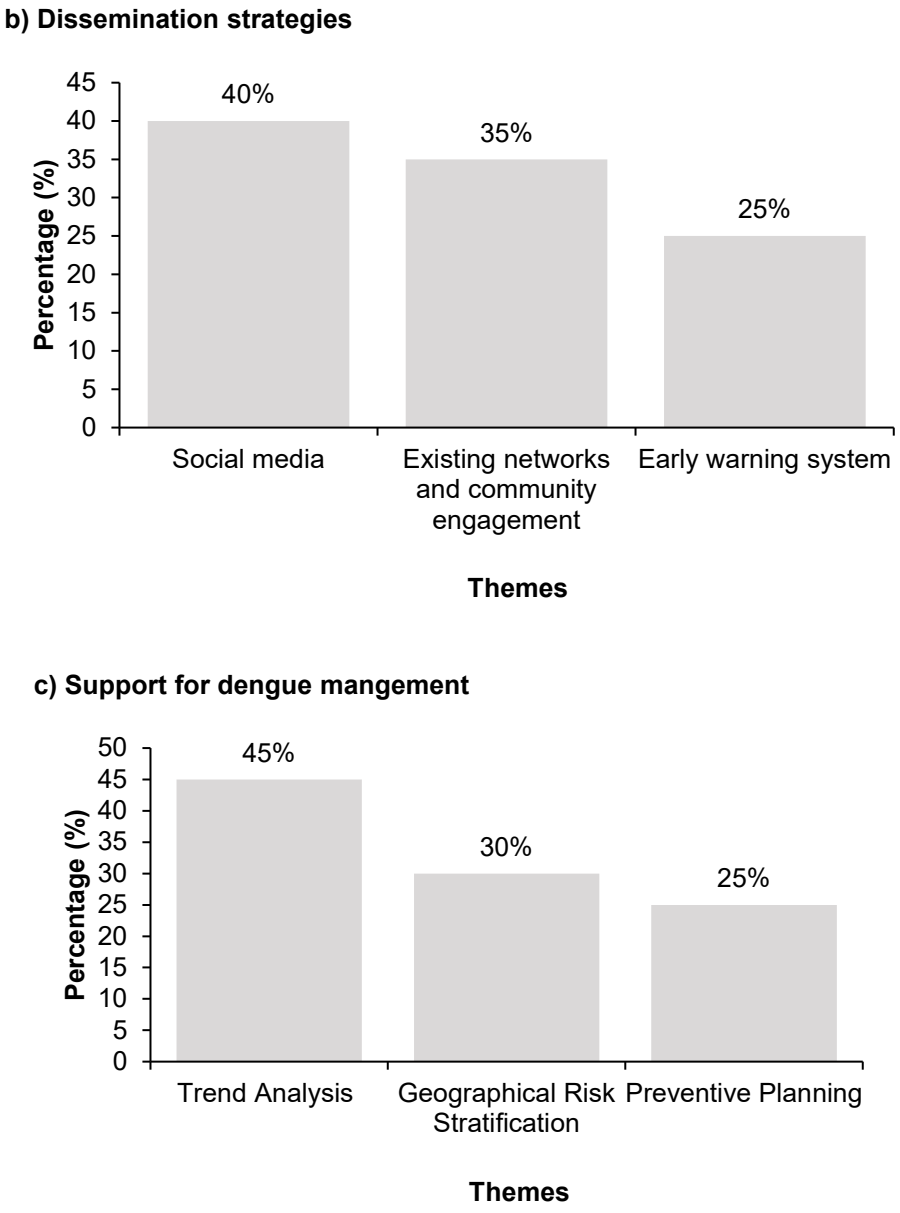


Figure 3. Thematic analysis of D-MOSS system accessibility and implementation

Domain 4. Anticipated impact and integration

Participants anticipated that the D-MOSS system would enable early preventive measures before outbreaks occur by using the threshold analysis to focus on predicted high-risk areas:

'Preventive measures can be planned & taken early to tackle the district that shows the higher exceedance probability*level for 3 consecutive weeks.'*

(Participant 5)

'Predictors of dengue fever outbreaks could provide timely information for health officials to implement preventative actions.'

(Participant 18)

The system was expected to complement existing dengue prevention programs, ultimately contributing to the reduction of manpower in dengue control and management:

'Integration into our readily available surveillance system will help reduce manpower.'

(Participant 23)

In addition, participants also suggested that the D-MOSS system should function as an early warning system integrated with existing platforms like "*Sistem Pengurusan Wabak Denggi*" (SPWD):

'Complement the SPWD.'

(Participant 22)

Domain 5. Improvements and recommendations

The majority (81%) of the users expressed that the D-MOSS forecast system provides sufficient information. However, those who disagreed (19%) expressed their wish for forecasts at a smaller spatial resolution, such as sub-district levels. Key themes for improvement and recommendations included customisation options (40%), interface enhancements (25%), comparative features (20%), and action planning integration (15%) (Figure 4). Specifically, regarding customisation options**,** participants recommended enabling forecasts for smaller geographical scales, such as sub-districts:

'It is better if the prediction can zoom into each district's locality.'

(Participant 18)

'Classify to a smaller unit- locality.'

(Participant 12)

Regarding interface enhancements, participants highlighted the need for faster loading times, improved user interface design and better navigation through the dropdown menu:

'Improve regarding the data storage/Random Access Memory (RAM).'

(Participant 17)

'Drop down for state and shorter period.'

(Participant 19)

To address comparative features, participants suggested adding graphs and tables to compare current forecasts with historical data:

'A graph of the comparison of predicted and forecasted cases.'

(Participant 6)

Lastly, for action planning integration, participants proposed incorporating tools within the system to plan and track intervention actions directly:

'Add a function to save forecast data according to date, planned action and details of action taken.'
(Participant 22)

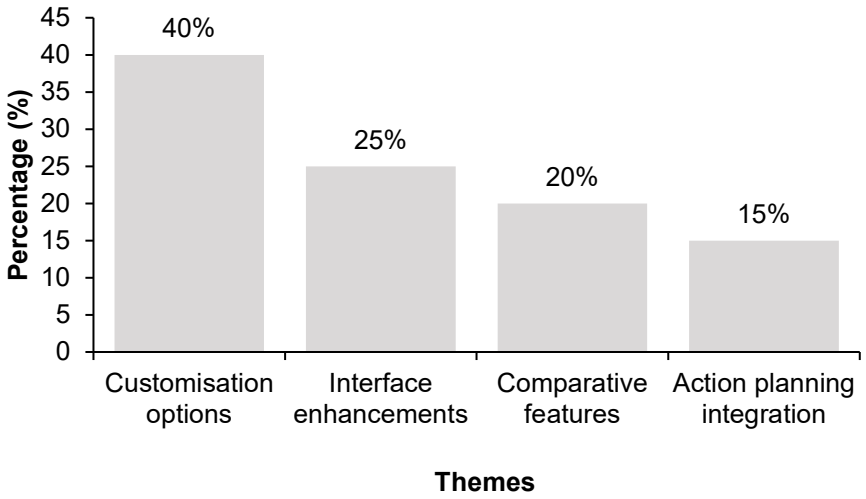


Figure 4. Thematic analysis of D-MOSS system improvements and recommendations

DISCUSSION

This study provides valuable insights into the user acceptability of the D-MOSS dengue predictive model as an early warning system for Malaysia and serves as a crucial step toward understanding D-MOSS applicability and alignment with Malaysia's public health needs. The study findings highlight the system's notable strengths, including high usability, comprehensibility, and strategic forecasting capabilities, while also identifying areas for refinement to further enhance its functionality and integration into public health workflows.

The high level of user comprehension observed in this study underscores the intuitive design of D-MOSS and its effectiveness in conveying complex information. All participants reported a clear understanding of key outputs, such as outbreak thresholds, exceedance probabilities, and forecast periods, demonstrating the system's ability to present predictive data comprehensively. Furthermore, the majority of the participants found the forecast page straightforward and user-friendly, enabling them to incorporate its outputs into their reports. These results align with best practices in predictive modelling, where accessibility and ease of interpretation are essential for public health applications (17,18). The user-friendly design of the D-MOSS system distinguishes it from many predictive systems that often require specialised training to interpret outputs effectively (19,20). However, while the study underscores the system's utility, continuous training and user engagement will be crucial to ensure constant refinement for sustained adoption and confidence among end-users.

Additionally, the encouraging feedback from stakeholders on the anticipated impact and practical applications of D-MOSS highlighted its potential to revolutionise dengue outbreak management by providing early warnings that enable proactive interventions. Participants emphasised its ability to shift the focus from reactive to proactive prevention measures to reduce the overall disease burden. This positive reception of its potential impact is supported by successful real-world applications of D-MOSS in Vietnam and EWARS in 17 countries (8, 21). Furthermore, suggestions to integrate D-MOSS with existing systems like SPWD and expand its role in policymaking would further enhance its functionality and operational relevance across different administrative levels. These suggestions, combined with lessons learned from the successful adoption of predictive systems in other countries, will potentially enhance the impact of D-MOSS implementation in Malaysia.

Another strength of D-MOSS, as highlighted by the participants, is its ability to provide long-term forecasts, which can facilitate strategic planning for dengue surveillance and control. Long-term forecasting enables public health officials to anticipate outbreaks weeks or months in advance, providing critical lead time for implementing preventive measures such as vector control activities, community awareness campaigns, and resource allocation. Studies have shown that early warning systems leveraging predictive models significantly improve outbreak preparedness and reduce disease burden by enabling proactive rather than reactive responses. In Vietnam, D-MOSS supported stakeholders in timely budget planning and approval by providing long-term forecasts up to six months in advance (8). This capability is critical for dengue control efforts, as delays in securing budget approval can lead to increased dengue transmission and a greater disease burden. In Mexico, the incorporation of the EWARS into the national platform for integrated epidemiological surveillance of dengue has proven to be highly beneficial (22). Evidence shows that districts that acted promptly to alarm signals generated by the prediction model 6-8 weeks in advance, when the probability of an outbreak surpassed the defined threshold, achieved considerable success in preventing outbreaks (22). This aligns with the findings of our study, where the majority of the participants highlighted the D-MOSS system's capacity to support district-level planning as a key strength, showcasing its potential to complement and strengthen existing public health frameworks.

Despite its strengths, several areas for improvement were identified. Performance issues, such as long loading times and intermittent connectivity, were highlighted as potential barriers to real-time usage, particularly in resource-limited settings. This finding is consistent with other studies, where technological inefficiencies have impacted the effectiveness of digital health tools (4,11,23). Addressing these issues will enhance the reliability and usability of D-MOSS as a decision-support system. A recurring theme in user feedback was the need for smaller geographical scale forecasts, such as localities or sub-districts, to enable more targeted interventions. Localised data is essential for vector-borne disease control, as it allows health officials to prioritise high-risk areas (24). Hence, enhancing the granularity of D-MOSS outputs will increase its relevance for field-level officers and improve its integration into operational decision-making. Participants also highlighted the challenge of interpreting frequent updates to forecast data, which complicated the alignment of prevention measures with predictions. While the dynamic nature of the system reflects real-time trends, providing clearer guidance or tools to support participants in managing these updates will be crucial for maintaining the system's practicality. Similar challenges have been observed in other dynamic forecasting systems, emphasising the importance of balancing real-time accuracy with user adaptability (25,26).

Participants provided valuable recommendations to optimise D-MOSS, including incorporating comparative graphs of current and historical data, enabling smaller geographical forecasts, and improving the interface for faster responsiveness. These enhancements align with user-centric design principles, emphasising the importance of iterative feedback in the development of digital health tools (2). Investing in these improvements will not only address current limitations but also strengthen user confidence and long-term engagement (5). These findings emphasise that UAT is not merely a technical exercise but an important foundational process to ensure that D-MOSS is practical, effective, and sustainable. Engaging end-users in the testing process enables the identification and resolution of potential barriers, while also uncovering the specific needs of end-users. This user-centred approach facilitates smoother integration of the system and strengthens its potential for long-term success in improving public health outcomes. By proactively addressing these challenges, incorporating user-driven insights, and developing a system tailored to the needs of end-users, D-MOSS can potentially become an even more impactful tool for public health management and outbreak prevention.

This study has several limitations. First, the relatively small sample size of 32 participants, while sufficient to meet our study objectives of gathering user-driven feedback for system refinement, may not fully capture the diversity of experiences, roles, or operational context of the broader user population. Therefore, the results should be interpreted with caution when generalising to other geographic regions, organisational settings, or user groups. Second, the absence of longitudinal follow-up restricts the assessment of long-term usability and the impact of D-MOSS. Nevertheless, the cross-sectional design for capturing user acceptance at a critical implementation phase provided timely and actionable feedback to guide system improvement.

CONCLUSION

The D-MOSS dengue predictive model demonstrates potential as an early warning tool for dengue management in Malaysia. Its strengths in usability, strategic forecasting, and user adaptability position it as an asset for public health planning. Addressing performance issues, enhancing granularity, and improving integration with existing frameworks are essential steps to enhance its impact. These findings contribute to the growing body of evidence supporting predictive modelling as a cornerstone of modern disease surveillance systems, providing a roadmap for scaling and refining D-MOSS to meet the needs of diverse stakeholders.

Author Contributions: All authors have read and agreed to the published version of the manuscript. Conceptualization: SS, BSG; Methodology: SS, BSG, MKK, LMC; Software: SS; Validation and Formal Analysis: SS, BSG, MKK, NHMI, SMG, LMC, NMG, MNMN, AAZ, NARA, CCH, LCRQA, KKT, CZL, WMK; Investigation: SS, BSG, LMC; Resources: SS, MKK, WMK; Data Curation: SS, NHMI, CZL; Writing - Original Draft Preparation: SS; Writing - Review & Editing: LMC, SS, SG, MKK, NHMI, SMG, LCRQA, NMG, MNMN, AAZ, NARA, TKK, CZL, WMK, LHS, TCH; Visualisation: LMC, SS, BSG, CZL, TCH, NHMJ, QR; Supervision: BSG, LHS; Project Administration: SS, BSG, LHS.

Funding: No financial support was received.

Ethics Statement: The study was registered with the National Medical Research Register (NMRR ID-23-01751-UO4 (IIR)) and obtained ethical approval from the Medical Research & Ethics Committee (MREC) reference no 23-01751-UO4 (1).

Informed Consent Statement: Not applicable.

Data Availability Statement: The datasets used and/or analysed during the current study are available upon request.

Acknowledgements: We would like to thank the Director General of Health Malaysia for his permission to publish this paper and the Director of the Institute for Medical Research for all the support given to this project.

Conflicts of Interest: The authors declared that they have no competing interests.

CITATION

Lim MC, Md Iderus NH, Mohd Ghazali S, Ahmad LCRQ, Mohd Ghazali N, Md Nadzri MN, et al. User acceptance testing of the D-MOSS dengue predictive model as an early warning system in Malaysia. International Medical Research Journal. 2025 May 1;11(1):59–76.
https://doi.org/10.63719/imrj.2025.11.01.006

REFERENCES

1. Bhatt S, Gething PW, Brady OJ, Messina JP, Farlow AW, Moyes CL, et al. The global distribution and burden of dengue. Nature. 2013;496(7446):504–7. doi: 10.1038/nature12060.

2. Shepard DS, Undurraga EA, Halasa YA, Stanaway JD. The global economic burden of dengue: a systematic analysis. Lancet Infect Dis.2016;16(8):935–41. doi: 10.1016/s1473-3099(16)00146-8.

3. Ministry of Health Malaysia. Annual Dengue Surveillance Report [Internet]. 2024 [cited 2025 Jan 21]. Available from: https://www.moh.gov.my/index.php/database_stores/store_view/17.

4. Hii YL, Zhu H, Ng N, Ng LC, Rocklöv J. Forecast of dengue incidence using temperature and rainfall. PLoS Negl Trop Dis. 2012;6(11): e1908. doi: 10.1371/journal.pntd.0001908.

5. Murray NEA, Quam MB, Wilder-Smith A. Epidemiology of dengue: past, present, and future prospects. Clin Epidemiol. 2013;5(1):299–309. doi: 10.2147/CLEP.S34440.

6. D-MOSS. Dengue Forecasting Model Satellite-based System (D-MOSS) [Internet]. [cited 2025 Jan 20]. Available from: https://www.d-moss.org/.

7. World Health Organization. Comprehensive guidelines for prevention and control of dengue and dengue haemorrhagic fever. Revised and expanded edition [Internet]. Geneva: World Health Organization; 2011 [cited 2025 Jan 21]. Available from: https://iris.who.int/handle/10665/204894.

8. HR Wallingford. D-Moss: Dengue forecasting MOdel Satellite-based System for Vietnam Endline case study [Internet]. 2022 [cited 2025 Jan 21]. Available from: https://www.hrwallingford.com/projects/d-moss-dengue-forecasting-model-satellite-based-system.

9. Brooke J. SUS: A quick and dirty usability scale. In: Jordan PW, Thomas B, Weerdmeester B, McClelland IL, editors. Usability Evaluation in Industry. London: Taylor and Francis; 1996. p. 189–94.

10. Davis FD. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q. 1989;13(3):319–40.doi:10.2307/249008.

11. Hardhantyo M, Djasri H, Nursetyo AA, Yulianti A, Adipradipta BR, Hawley W, et al. Quality of national disease surveillance reporting before and during COVID-19: A mixed-method study in indonesia. International journal of environmental research and public health. 2022 ;19(5):2728. doi: 10.3390/ijerph19052728.

12. Cochran WG. Sampling Techniques. 3rd ed. New York: John Wiley & Sons; 1977.

13. Almasi S, Bahaadinbeigy K, Ahmadi H, Sohrabei S, Rabiei R. Usability evaluation of dashboards: A systematic literature review of tools. BioMed Research International. 2023;2023(1):9990933. doi: 10.1155/2023/9990933.

14. Maqbool B, Herold S. Potential effectiveness and efficiency issues in usability evaluation within digital health: A systematic literature review. Journal of Systems and Software. 2024; 208:111881. doi: 10.1016/j.jss.2023.111881.

15. Rizvi RF, Marquard JL, Hultman GM, Adam TJ, Harder KA, Melton GB. Usability evaluation of electronic health record system around clinical notes usage–an ethnographic study. Applied clinical informatics. 2017 ;8(4):1095-1105. doi: 10.4338/ACI-2017-04-RA-0067.

16. R Core Team. R: A Language and Environment for Statistical Computing R Foundation for Statistical Computing [Internet]. 2023 [cited 2025 Jan 21]. Available from: https://www.r-project.org/.

17. Gubler DJ. Epidemic dengue/dengue hemorrhagic fever as a public health, social and economic problem in the 21st century. Trends Microbiol. 2002;10(2):100–3. doi: 10.1016/s0966-842x (01)02288-0.

18. Wilder-Smith A, Gubler DJ. Geographic expansion of dengue: the impact of international travel. Med Clin North Am. 2008;92(6):1377–90. doi: 10.1016/j.mcna.2008.07.002.

19. World Health Organization. Operational guide: Early warning and response system (EWARS) for dengue outbreaks [Internet]. Geneva: World Health Organization; 2017 [cited 2025 Jan 21]. Available from: https://www.who.int/publications/i/item/9789241512053.

20. Brady OJ, Gething PW, Bhatt S, Messina JP, Brownstein JS, Hoen AG, et al. Refining the global spatial limits of dengue virus transmission by evidence-based consensus. PLoS Negl Trop Dis. 2012;6(8): e1760. doi: 10.1371/journal.pntd.0001760.

21. Schlesinger M, Prieto Alvarado FE, Borbón Ramos ME, Sewe MO, Merle CS, Kroeger A, et al. Enabling countries to manage outbreaks: statistical, operational, and contextual analysis of the early warning and response system (EWARS-csd) for dengue outbreaks. Frontiers in Public Health. 2024 Jan 19; 12:1323618. doi: 10.3389/fpubh.2024.1323618.

22. Sanchez Tejeda G, Benitez Valladares D, Correa Morales F, Toledo Cisneros J, Espinoza Tamarindo BE, Hussain-Alkhateeb L, et al. Early warning and response system for dengue outbreaks: Moving from research to operational implementation in Mexico. PLOS Global Public Health. 2023 20;3(9): e0001691. doi: 10.3389/fpubh.2024.1323618.

23. Chang W, Cheng J, Allaire J, Sievert C, Schloerke B, Xie Y, et al. Shiny: Web application framework for R. R Package version 1.7.1 [Internet]. 2021 [cited 2025 Jan 21]. Available from: https://cran.r-project.org/web/packages/shiny/index.html.

24. Horstick O, Runge-Ranzinger S, Nathan MB, Kroeger A. Dengue vector-control services: how do they work? A systematic literature review and country case studies. Trans R Soc Trop Med Hyg. 2010;104(6):379–86.doi: 10.1016/j.trstmh.2009.07.027.

25. Racloz V, Ramsey R, Tong S, Hu W. Surveillance of dengue fever virus: a review of epidemiological models and early warning systems. PLoS Negl Trop Dis. 2012;6(5): e1648. doi: 10.1371/journal.pntd.0001648.

26. Parikh R, Mathai A, Parikh S, Chandra Sekhar G, Thomas R. Understanding and using sensitivity, specificity and predictive values. Indian J Ophthalmol. 2008;56(1):45–50. doi: 10.4103/0301-4738.37595.