JOURNAL LA MULTIAPP

VOL. 06, ISSUE 06 (1365-1379), 2025
DOI: 10.37899/journallamultiapp.v6i6. 2504

Strengthening MSME Digital Transformation through Android-Based Geolocation Mapping: Implementation of Location-Based Services and the Haversine Formula

Herry S. Langi[1], Johan Pongoh[1], Deby C. Sendow[1], Yurike S. Lewan[1], Doostenreyk N. Kantohe[1]

[1]*Politeknik Negeri Manado, Indonesia*

**Corresponding Author: Herry S. Langi*
Email: johanpongoh1105@gmail.com

Article Info

Article history:
Received 29 July 2025
Received in revised form 30 August 2025
Accepted 5 October 2025

Keywords:
Geolocation
MSMEs
Android
Haversine Formula
Digital Transformation.

Abstract

Information and Communication Technology (ICT) plays a strategic role in reducing socio-economic disparities and accelerating inclusive development, especially in rural areas. In Indonesia, Micro, Small, and Medium Enterprises (MSMEs) are the dominant sector, absorbing over 96% of the workforce and contributing around 60% to the national Gross Domestic Product (GDP). However, many MSME actors particularly in remote regions such as North Sulawesi still face challenges in accessing digital markets due to limited technology adoption and lack of business location exposure. This study aims to develop an Android-based application that integrates geolocation services through the implementation of Location-Based Services (LBS) and the Haversine formula. LBS is used to detect users' real-time locations via GPS, while the Haversine formula calculates the precise distance between users and MSME locations. The application is designed to send automatic notifications when a user is within a 1000-meter radius of a registered MSME location. This research adopts a software engineering approach through the design of context diagrams, system flowcharts, and the implementation of the Haversine algorithm using the Dart programming language. Testing results show that the distance difference between the application and Google Maps ranges only from 1.5 to 2.9 meters, and the distance calculated by the application matches 100% with online Haversine calculators. These findings indicate that the system has high accuracy and is feasible to be applied as a solution to improve MSME visibility, enhance community digital literacy, and strengthen the local economy through e-commerce.

Introduction

The rapid advancement of Information and Communication Technology (ICT) has acted as a catalyst for change in various aspects of human life, including the transformation of the global economy (Prabakar et al., 2025; Abdurrahman, 2025; Mamanazarov et al., 2025). In Indonesia, the adoption of digital technology has given rise to a new phenomenon known as the digital economy. This digital economy not only changes consumer behavior patterns but also compels business actors to transform in order to remain competitive in an increasingly digital and competitive market. Within this context, Micro, Small, and Medium Enterprises (MSMEs) are central actors that must be systematically empowered to adapt and play a significant role in the national digital ecosystem (Hetharie et al., 2025; Hermansyah et al., 2025; Zidane et al., 2025).

ISSN: 2716-3865 (Print), 2721-1290 (Online)

MSMEs have a significant contribution to Indonesia's economic structure. Data shows that MSMEs contribute more than 60% to the national Gross Domestic Product (GDP) and absorb approximately 96% of the national workforce (Hisnul et al., 2022). However, this sector continues to face major challenges, particularly in utilizing digital technologies. Many MSMEs, especially those located in remote and rural areas such as North Sulawesi, have yet to integrate information technology into their business operations. Issues such as limited capital, low digital literacy, lack of promotional strategies, and the inability to map markets are major obstacles that isolate MSMEs from broader market opportunities (Lestari, 2020; Malik et al., 2025; Akinrinde et al., 2024).

The COVID-19 pandemic has further highlighted the urgency of digital transformation in the MSME sector (Judijanto et al., 2024; Petropoulou et al., 2024; Wu et al., 2024). The drastic shift in consumer behavior from traditional shopping to online transactions has pushed business actors to rapidly adopt digital technologies. MSMEs that are unprepared for digitalization are at risk of failing to survive in this new business ecosystem. Meanwhile, most MSMEs still operate at a local scale with minimal visibility. Business locations often hidden within densely populated neighborhoods and poor promotion contribute to the limited recognition of MSMEs by potential customers outside their immediate community. This presents a challenge in building a broader and more diverse customer base (Rodriguez et al., 2015; Bouschery et al., 2023; Sudirjo, 2023).

One potential solution to address these issues is the use of geolocation technology. The Global Positioning System (GPS), now widely available on nearly all smart devices, provides an opportunity to develop location-based applications that connect businesses and consumers based on geographic proximity. By digitally mapping MSME locations, consumers can quickly and accurately locate nearby businesses. This not only increases MSME exposure but also encourages local and regional economic collaboration through digital integration (Cahyani et al., 2023; Setiowati, 2025; Arner et al., 2022).

Based on this urgency, this research aims to develop an Android-based geolocation application that integrates Location-Based Services (LBS) and the Haversine formula. LBS is used to detect users' real-time locations through GPS technology, while the Haversine formula calculates the distance between users and MSME locations with high accuracy. The application will send automatic notifications when users are within a 1000-meter radius of the nearest MSME. This innovation is expected to serve not only as a practical solution to digitally introduce MSME locations but also as a tool to empower communities in building an inclusive, adaptive, and technology-based local economy (Panjaitan et al., 2025; Fridayani et al., 2024; Wibowo & Rahman, 2024).

Literatur Review

Micro, Small, and Medium Enterprises (MSMEs) serve as a fundamental pillar in Indonesia's economic structure (Irawan & Sukiyono, 2021; Lismayangingsih et al., 2024; Arifin et al., 2021). Their role goes beyond job creation; they are also drivers of the people’s economy, operating across both formal and informal sectors. Nevertheless, MSMEs often face significant obstacles in areas such as marketing, business management, and adapting to digital technologies. As Fauzan (2021) noted, limited promotional media is one of the key factors contributing to the low visibility of MSME products in broader markets. To address this issue, technology-based strategies are needed that can reach consumers more efficiently and in a more targeted manner.

Several previous studies have developed technology-driven approaches based on recommendation systems and artificial intelligence to support MSMEs. Dharma and Tanone (2018), for instance, developed an Android-based application using the Collaborative Filtering method to recommend products to users based on preferences gathered through a

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rating system . This approach is relevant in the context of service personalization, yet it does not address geospatial aspects or the physical location of business actors. Conversely, Rahmawati's (2019) research focused more on MSME actors' perceptions of the risks of using information technology, showing that there remains hesitation in adopting IT due to a lack of understanding and a sense of security. This highlights the importance of approaches that are not only technically functional but also accessible to lay users.

On another front, Suryani (2020) proposed a system dynamics model to improve MSMEs' market share and profitability through social media-based promotions [7]. This model successfully illustrates the non-linear relationships between internal and external variables that influence business performance. However, it also does not utilize location-based elements as the foundation for interaction between consumers and MSME actors. Magdalena (2021) proposed a classification model to assess MSME organizational maturity using data analysis algorithms to support business sustainability. Meanwhile, the study by Zeng et al. (2021) in China focused on developing a credit decision model based on mathematical approaches to reduce MSME financing risks. While these approaches enrich the range of digital solutions for MSMEs, most have yet to explore the potential of business location mapping through geolocation technology.

Imameza et al. (2022) emphasized the importance of user interface (UI/UX) design in developing MSME websites to make them more user-friendly and effective in reaching consumers. This study highlights the significance of user experience in technology adoption by MSME actors. Similarly, Erinda et al. (2022) developed the "Dagang Yuk Yuk" application, which covers the entire digital transaction process from login to product delivery. While the application incorporates online service features, it lacks an integrated location mapping system that would enable quicker interaction based on geographic proximity. Lestari et al. (2022) also emphasized the importance of user interest-based ranking algorithms in product recommendation systems, yet these have not addressed the spatial aspects or the local context of MSMEs.

Furthermore, the study by Hermawan et al. (2022) identified a relationship between MSME digital marketing and social media engagement rates, which serve as indicators of MSME interaction with consumers. However, this interaction remains virtual and does not consider the physical proximity between consumers and business operators. Therefore, this study adopts a different approach by offering a geolocation-based solution to directly connect MSME actors and consumers through a location-radius-based notification system. By integrating GPS, Location-Based Services (LBS), and the Haversine formula, the application developed in this research presents a novel approach to supporting MSME promotion and visibility at the local level.

Methods

The research method used in this study is a software engineering approach, with key stages including system design, implementation of distance calculation algorithms based on the Haversine formula, and comprehensive testing of the application's functions. This study focuses on the development of an Android application that utilizes Location-Based Services (LBS) technology to detect the user's position and the Haversine formula to calculate the distance between the user and MSME locations registered in the database. The research process is conducted in two main parts: system design and distance calculation implementation.

System Design

The research method used in this study is a software engineering approach, with key stages including system design, implementation of distance calculation algorithms based on the

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Haversine formula, and comprehensive testing of the application's functions. This study focuses on the development of an Android application that utilizes Location-Based Services (LBS) technology to detect the user's position and the Haversine formula to calculate the distance between the user and MSME locations registered in the database. The research process is conducted in two main parts: system design and distance calculation implementation.

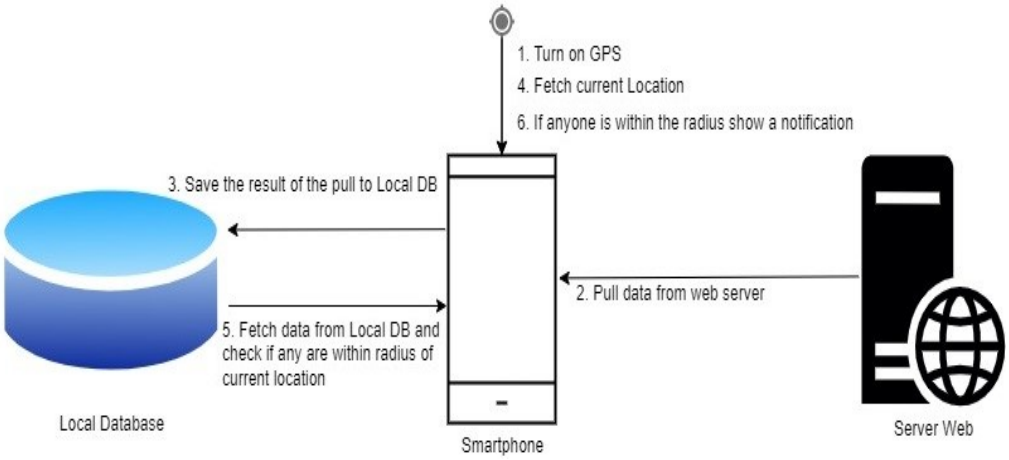

Figure 1. Context Diagram

These steps are explained in more detail in the flowchart shown in Figure 2. The application first retrieves data from the server and stores it in a local database. Then, the system obtains the user's location data from the GPS. If the system detects that the user's coordinates are within a 1000-meter radius of any registered MSME location, the application will display a notification. The notification will appear only once while the user remains within the radius; if the user exits and re-enters the radius, the notification will be shown again according to the updated status logic within the system.

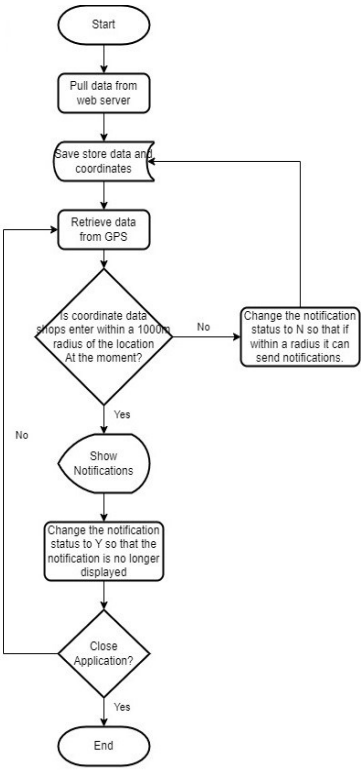

Figure 2. System Flowchart

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Distance Calculation Using the Haversine Formula

This section explains the use of the Haversine method to measure the distance between the user and the MSME location.

To calculate the distance between the user's position and the MSME location point, this study employs the Haversine formula, a well-known mathematical method used to determine the great-circle distance between two points on the Earth's surface based on latitude and longitude. The formula assumes that the Earth is a perfect sphere with an average radius of 6,371 km, and the locations of the two points on the spherical coordinate system (latitude and longitude) are denoted as lon1, lat1 and lon2, lat2 respectively [Azdy and Darnis, 2020).

The Haversine formula can be expressed as the following equation:

$$D = 2 \cdot \sin^{-1}\left(\sqrt{\sin\left(\frac{lat2 - lat1}{2}\right)^2 + \sin\left(\frac{lon2 - lon1}{2}\right)^2 \cdot \cos(lat1) \cdot \cos(lat2)}\right) \cdot \mu_E \qquad (1)$$

Explanation: 1) D = Great-circle distance between two points (in kilometers); 2) lat1, lon1 = Latitude and longitude of the first point (user); 3) lat2, lon2 = Latitude and longitude of the second point (MSME)

This formula is then implemented in the program code using the Dart programming language within the Flutter framework, which is a platform for Android application development. The code implementation is shown in Figure 3, illustrating the declaration of variables for conversion to radians, the distance calculation using functions such as pow, sin, cos, and asin, and the notification call function based on the calculation results.

lib > main.dart > _MyAppState

```
_hitungHaversine(
    String lokasi, double lt1, double lg1, double lt2, double lg2) {
  try {
    var lat1 = toRadian(lt1);
    var lng1 = toRadian(lg1);
    var lat2 = toRadian(lt2);
    var lng2 = toRadian(lg2);
    var dlong = lng2 - lng1;
    var dlat = lat2 - lat1;

    var res = pow(sin((dlat / 2)), 2) +
        cos(lat1) * cos(lat2) * pow(sin(dlong / 2), 2);
    res = 2 * asin(sqrt(res));
    double R = 6371;
    res = res * R;
    sendNotification('Jarak ke $lokasi ${roundDouble(res, 2) * 1000} meter');
  } on Exception catch (_) {
    Fluttertoast.showToast(
        msg: "Error exception",
        toastLength: Toast.LENGTH_LONG,
        gravity: ToastGravity.CENTER,
        timeInSecForIosWeb: 1,
        textColor: Colors.white,
        fontSize: 16.0);
  }
}
```

Figure 3. Program code implementation

The implementation of the Haversine algorithm was carried out using the Dart programming language within the Flutter framework. Dart was chosen for its compatibility with Android

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application development and its support for numerical data manipulation required in geospatial calculations. As shown in Figure 3, the variables lat1, lon1, lat2, and lon2 are converted into radians before being used in the formula. The calculation is performed using trigonometric operations such as sin, cos, pow, and asin, and then multiplied by the Earth's radius (R = 6371 km) to obtain the final result in kilometers.

This calculation process is then linked to the sendNotification function, where the final distance result is sent to the user in the form of a notification if the distance falls within a radius of ≤1000 meters. The implementation of this code demonstrates the alignment between geospatial mathematical theory and its real-world application in mobile software development.

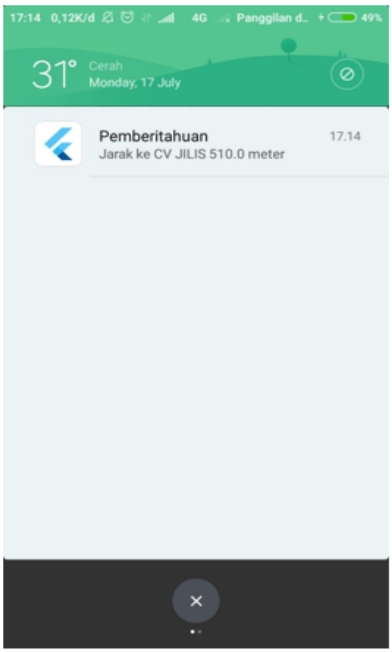
The choice of Dart as the primary programming language is also based on its runtime efficiency and the growing support of its community. Dart, developed by Google, is designed to build high-performance cross-platform applications with responsive user interface integration capabilities (Swatiga *et al.,* 2020). Using Dart enables the calculation process to be executed directly on the client side, without requiring additional server-side processing, thereby accelerating application performance and reducing users' data consumption.

Therefore, the use of the Haversine formula implemented in Dart allows for real-time and accurate geographic distance measurement and supports the creation of a geolocation system that is responsive to the user's position. This combination of mathematical methods and programming technology serves as a fundamental basis for developing Location-Based Services (LBS) applications aimed at promoting and automatically detecting MSME (Micro, Small, and Medium Enterprises) locations.

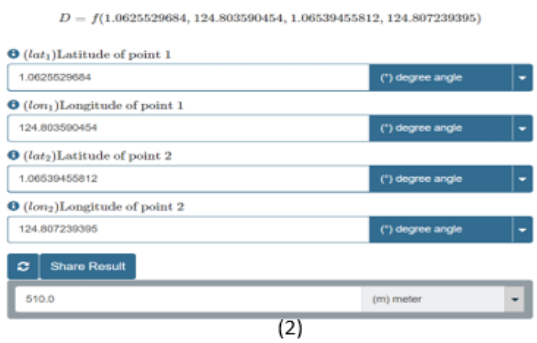
Results and Discussion

This section explains the results of the implementation of the geolocation-based application system, along with the analysis of the trials that have been conducted. The evaluation was carried out through a series of tests on the radius-based notification function, distance validation using the Haversine formula, and a comparison of the calculation results with Google Maps and online Haversine calculators.

Trial of the MSME Location Notification System



(1)



(2)

(3)

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Figure 4. (1) Notification of CV Tulis, (2) Calculation Results of Haversine Formula CV Jilis, (3) Google Maps Measurement of CV Jilis

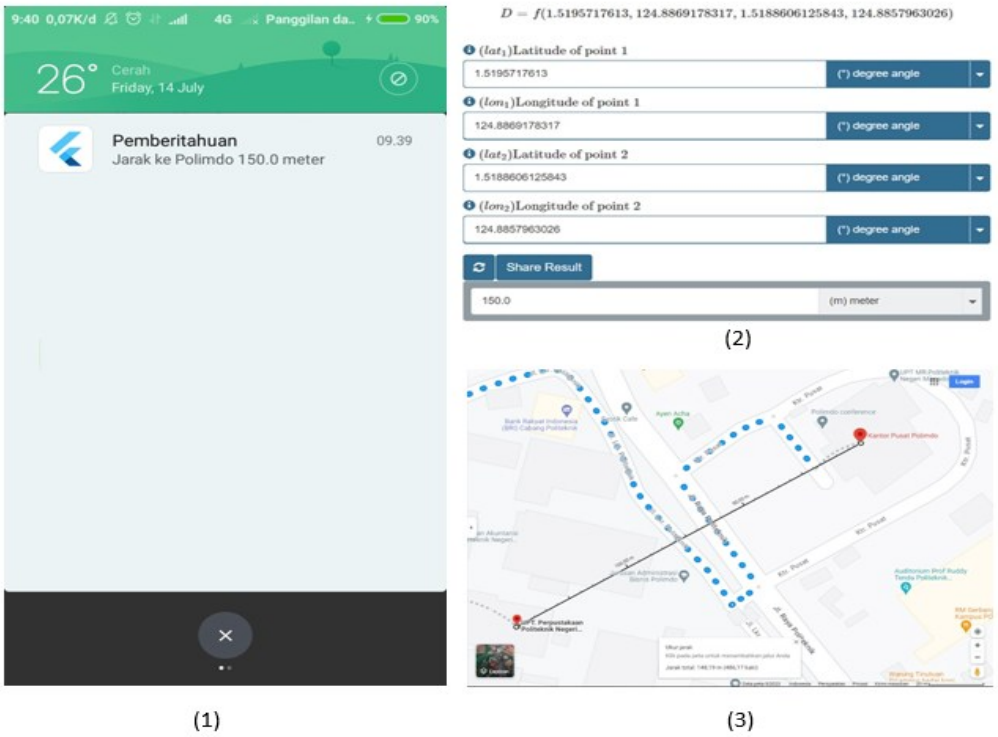

Figure 5. (1) Polimdo Notification, (2) Polimdo Haversine Formula Calculation Results, (3) Polimdo CV Google Maps Measurement

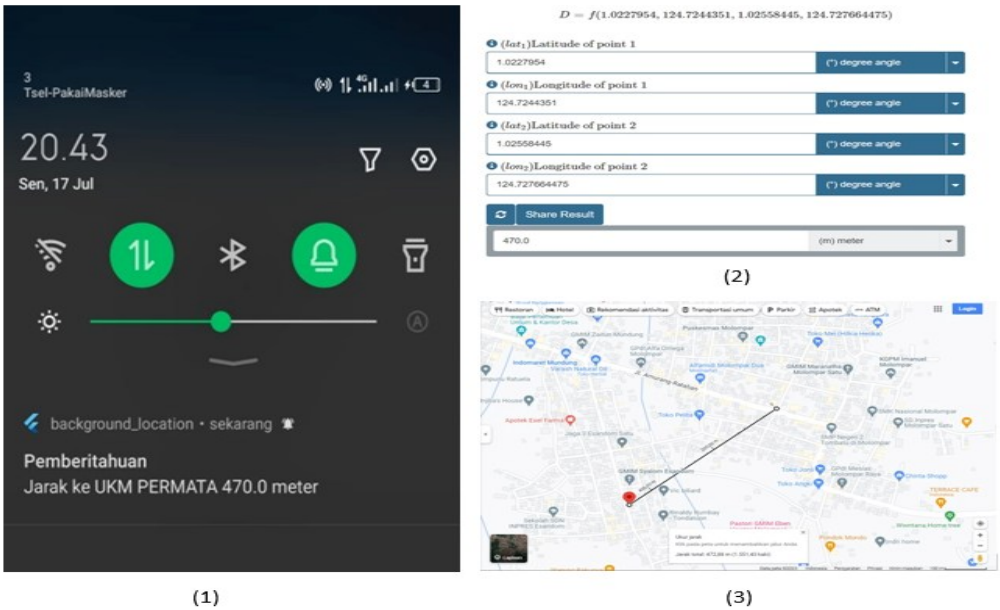

Figure 6. (1) Permata UKM Notification, (2) Results of the Harversine Formula Calculation of Permata UKM, (3) Google Maps Measurement of Permata UKM

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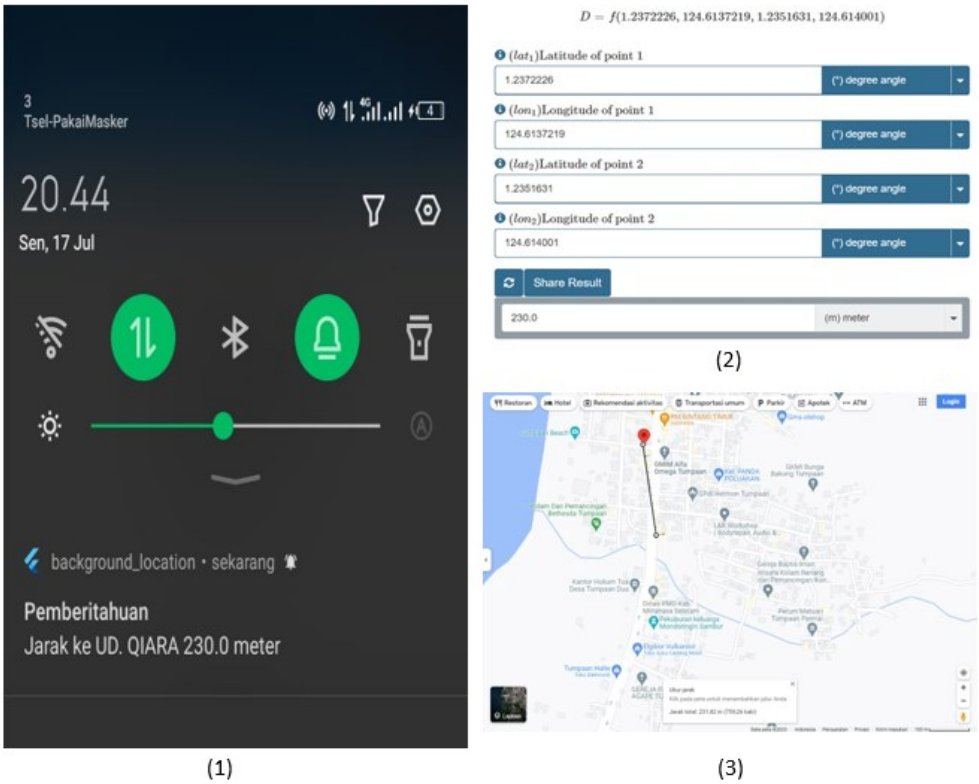

Figure 7. (1) UD Qiara Notification, (2) Harversine Formula Calculation Results for UD Qiara Notification, (3) Google Maps Measurement of UD Qiara Notification

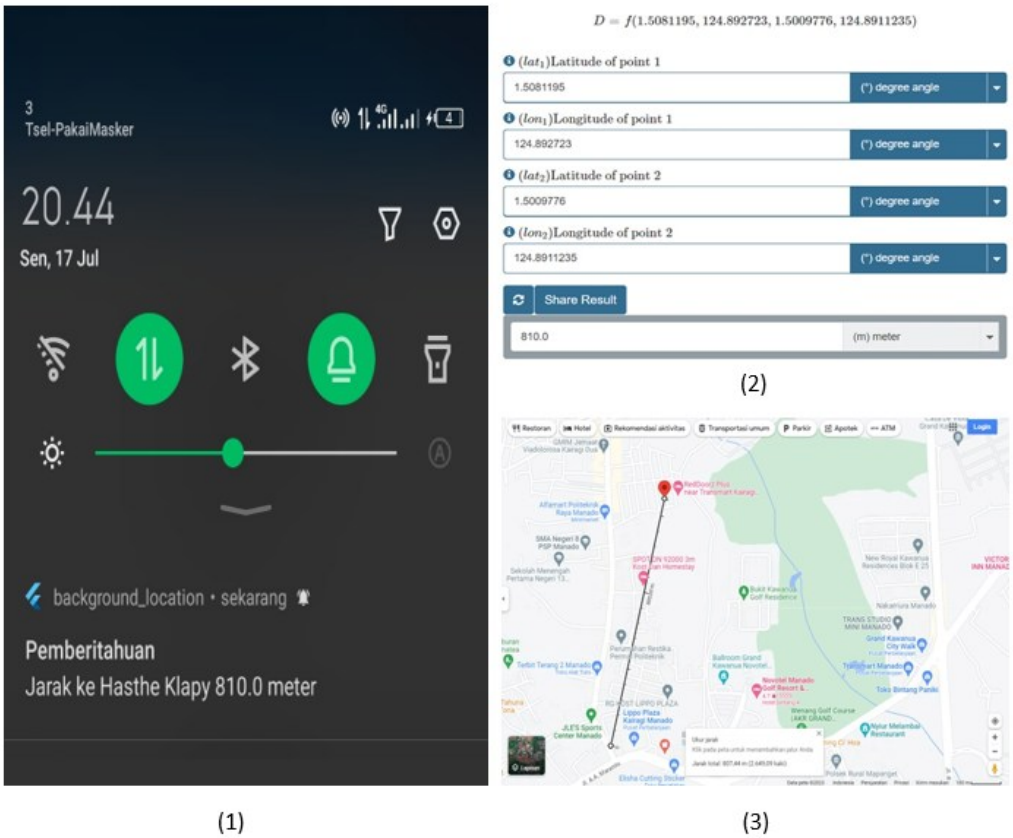

Figure 8.1) Has The Klapy Notification, (2) Haversine Formula Calculation Results Has The Klapy Notification, (3) Google Maps Measurement Has The Klapy Notification

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The initial testing was conducted by inputting several MSME locations across the city of Manado into the system's database. The application was then tested to detect the user's proximity to these MSME locations. When the user was within a 1000-meter radius, the system displayed a notification containing the MSME name and estimated distance. These notifications were visually presented through screenshots, as shown in Figures 4 to 8, each illustrating the notification results for CV JILIS, Polimdo, UKM Permata, UD Qiara, and Hasthe Klapy.

Each notification included the distance calculated using the Haversine formula within the application, as well as a manual calculation result from an online calculator (https://www.vcalc.com/wiki/vcalc/haversine-distance), and a distance measurement using Google Maps. The consistency of results between the application system and the online calculator confirms the accuracy of the implemented Haversine formula, while minor deviations observed when compared to Google Maps can be explained by the variation in route interpolation methods used by Google.

Distance Comparison Analysis

To provide a more objective overview, a comparative distance analysis was conducted, as presented in Table 1. Among the five MSMEs tested, the application produced results identical to those of the online Haversine calculator. Meanwhile, the differences in results compared to Google Maps ranged from approximately 1.5 to 2.9 meters. This deviation remains within an acceptable technical tolerance, considering that Google Maps utilizes dynamic mapping that accounts for road routes and terrain elevation, whereas the Haversine formula calculates the straight-line distance between two coordinate points on the Earth's surface.

Table 1. Comparative Analysis of Distance Calculation

MSMEs	Distance On App Notification (m)	Haversine (m) Calculator Calculation Results	Google Maps Distance Calculation Results (m)
CV Jilis	510	510	511.79
UKM Polimdo	150	150	148.19
UKM Permata	470	470	472.88
UD Qiara	230	230	231.42
Hasthe Klapy	810	810	807.44

These results strengthen the system's validity, demonstrating that the Haversine formula implemented in the application is capable of providing highly accurate distance estimates within the context of local user needs. This accuracy is crucial to ensuring that application users receive information that accurately reflects their actual geographic location.

System Functional Testing

In addition to distance testing, system functional testing was also conducted to evaluate how the application responds to various operational conditions. Testing was conducted using a black-box testing approach against common scenarios, including when GPS is active, when the user is within and outside the radius, and when an internet connection is available or not. The test results are shown in Table 2.

Tabel 2. System Testing Results (Blackbox Testing)

Scenario	Test Case	Expected output	Results obtained	Conclusion

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The system retrieves location data from the API when there is an internet connection.	Open Application	The system will display a notification that the data has been successfully retrieved.	The system will display a notification that the data has been successfully retrieved.	Valid
The system retrieves location data from the API when there is no internet connection.	Open Application	The system will display a notification that the data retrieval failed.	The system will display a notification that the data retrieval failed.	Valid
When within a radius of 1000 meters from the MSME location	Application running and GPS enabled	The system will display a notification that there is a nearby MSME location.	The system displays a notification that there is a nearby MSME location.	Valid
When you are still within a radius of 1000 meters from the MSME location and the notification has been displayed but the distance has changed	Application running and GPS enabled	While within a radius of 1000 meters, the application only displayed a notification once.	Notifications only appear once as long as you are within a radius of 1000 meters.	Valid
When you are more than a radius of 1000 meters and return to within a radius of 1000 meters from the MSME location	Application running and GPS enabled	The system will provide a notification after exceeding 1000 meters and returning to a radius of 1000 meters from the MSME location.	Notification appears after leaving a 1000 meter radius and returning within a 1000 meter radius.	Valid

All testing scenarios demonstrated that the system could operate stably and deliver output that aligns with real-world conditions in the field. This indicates that the integration of LBS services, GPS, and the Haversine algorithm within the Android application is capable of working synergistically and effectively.

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System Implications for MSME Mapping

The trial results not only confirm the system's accuracy in detecting user location but also highlight the significant potential of this application in supporting location-based promotional strategies. By displaying automatic notifications when users are near an MSME, the application can directly enhance the visibility of micro-enterprises. Additionally, this system opens opportunities for the development of supplementary features such as location-based product recommendations, MSME navigation route maps, and integration with digital payment platforms.

The implementation of a geolocation system in MSME mapping has a significant impact on facilitating the identification, classification, and grouping of micro, small, and medium enterprises in specific regions [16]. Through digital technology-based location tagging features, local governments and MSME-supporting agencies can obtain a more accurate visual overview of the spatial distribution of MSMEs categorized by business sector, production scale, or regional potential. This system directly addresses long-standing issues in MSME data collection, such as data duplication, manual recording, and limited survey coverage.

One of the main implications of using this system is the emergence of data-driven policymaking in MSME development (Munthe *et al.,* 2025). Location data integrated with business attributes such as revenue, product type, and support needs enables policymakers to designate priority empowerment zones, distribute capital assistance, and develop small industry clusters more efficiently. Such spatial information is also useful for financial institutions or investors to assess the feasibility and potential of a region for business expansion or location-based lending [18].

Furthermore, from the perspective of MSME actors, this system boosts business visibility and competitiveness, as their enterprises can be more easily discovered by consumers and business partners through interactive digital maps (Ariyanto, 2021). Previously hidden or unregistered MSMEs now have greater opportunities to access training, certification, or market access based on location. This supports the achievement of economic inclusion targets and helps reduce regional disparities.

However, the effectiveness of this system relies heavily on continuous data updates, active participation from MSME actors, and integration with other information systems managed by relevant ministries or agencies. Therefore, the development of the MSME geolocation system must be accompanied by digital education for business owners, simplification of data input workflows, and enhanced interoperability with national databases such as OSS (Online Single Submission) and the KUR (People's Business Credit) system. With such an approach, the MSME geolocation system can become the backbone of digital transformation in Indonesia's small and medium enterprise sector (Pamungkas et al., 2020).

Conclusion

This study successfully designed and implemented an Android-based application that utilizes Location-Based Services (LBS) technology and the Haversine formula to detect the presence of MSMEs (Micro, Small, and Medium Enterprises) around the user. The application automatically sends notifications when the user is within a 1000-meter radius of a registered MSME location. The use of the Haversine formula, implemented in the Dart programming language, demonstrated highly accurate distance calculations, showing 100% consistency with online calculators and a maximum deviation of 2.9 meters compared to Google Maps.

In addition, functional testing using the black box method showed that all application features performed well and remained stable under various usage conditions both with and without an internet connection, as well as when the user moved in and out of the MSME radius. The high

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accuracy and system stability indicate that the integration of geolocation technology in mobile applications can serve as a practical solution to enhance the visibility and competitiveness of MSMEs, particularly in regions with limited access to digital promotion.

Overall, this application not only fulfills the initial objectives of the study but also demonstrates significant potential for further development as part of a more comprehensive location-based MSME information system. The results of this research provide a tangible contribution to efforts toward local economic digitalization and the empowerment of MSMEs through technology-based solutions.

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