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UML-Based Design of a GIS-Based E-Commerce Application for MSMEs

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Abstract
Purpose: This study aims to design a Geographic Information System (GIS)-based e-commerce application for Micro, Small, And Medium Enterprises (MSMEs) using the Unified Modeling Language (UML). The novelty of this study lies in the integration of UML modeling with GIS-based features to support spatial visualization in MSME e-commerce systems, which is limited in prior studies.
Methodology/approach: This research adopts a Research and Development (R&D) approach using the waterfall model, which was selected because of its suitability for structured system design with clearly defined requirements.
Results/Findings: The results demonstrate that UML modeling, including use case, activity, and class diagrams, successfully represents system functionality, user interactions, and data structures in a systematic and consistent manner. The completeness and consistency of the model were evaluated based on the alignment between system requirements and diagram representation. However, this study is limited to system design without full implementation and empirical testing.
Conclusions: This study introduces a GIS-based e-commerce design for MSMEs using UML modelling, a novel approach in integrating spatial features. The UML models effectively represent system functions and data. However, the study is limited by the lack of implementation and testing. Future research should focus on full implementation and empirical validation.
Limitations: This study has limitations in that comprehensive system implementation and testing have not been conducted.
Contributions: This research contributes conceptually and methodologically by providing a structured UML-based design model for GIS-integrated MSME e-commerce systems that can be used as a reference for future development and implementation.

Keywords: *E-commerce, Geographic Information System (GIS), UML, System Design, MSMEs*

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1. Introduction

MSMEs play a vital role in the country's economic growth, community empowerment, and job creation, providing a significant role and tangible impact in driving regional economic growth. Optimizing local MSMEs is a key strategy for maximizing national economic potential. Batam's leading local products include Malay culinary delights and souvenirs, handicrafts and batik, and a variety of other innovative products that are also being developed (Friadi, Windayanti, & Made, 2024). Efforts to expand the

marketing and increase the sales of local products are a key driver of MSME development, while strengthening Batam's identity as a region with diverse economic activity (Eravia, Magangka, Khattab, & Lahamid, 2025). However, this significant potential is often hampered by various obstacles, including limited market reach and a weak distribution network, resulting in intense price competition. The lack of geographic information system-based e-commerce applications is another obstacle to increasing the competitiveness of local products. (Yuniati & Supriadin, 2024). Global studies show that the main barriers to e-commerce adoption in MSMEs are often related to technological and infrastructure readiness (Indiani, Keshminder, Wiratama, & Amertha, 2025).

In addition, incomplete digital transformation can hamper the sustainable performance of MSMEs. (Kurniawati, Idris, Handayati, & Osman, 2021). The development of information and communication technology has triggered a shift in perspectives and patterns in conducting trade transactions, particularly through the use of web-based e-commerce applications. This system enables transactions to be carried out quickly, efficiently, and without the constraints of space and time. (Putra, Rahmadi, & Armin). Despite the growing adoption of e-commerce and GIS technologies, previous studies have largely focused on system implementation or general platform development without providing a structured modeling approach that integrates UML and GIS features specifically for MSMEs. Furthermore, there is limited research that explicitly demonstrates how UML can be used to represent spatial-based e-commerce systems in a systematic design framework.

In its development, a structured system design model is required to ensure that the resulting application has optimal functionality, reliability, and ease of use (Suroto & Friadi, 2023). At the system design stage, the features and processes in the system being built are described in detail (Narulita, Nugroho, & Abdillah, 2024). One of the methods that is widely applied in the system design process is the use of the Unified Modeling Language (UML), which functions as a visual modeling tool to systematically represent system requirements and processes. Compared to other modeling approaches, such as business process model and notation (BPMN), which primarily focus on business process workflows, UML provides a more comprehensive framework that covers both the structural and behavioral aspects of the system, including interactions between actors, system architecture, and data relationships.

This makes UML more suitable for software system design that requires detailed representation from multiple perspectives. The application of UML in e-commerce application development can improve the clarity of requirements analysis, minimize implementation errors, and simplify the process of system development and maintenance, especially because the use of location-based technology (GIS) has been proven to improve logistics efficiency and strategic decision-making in market expansion (Agoo et al., 2024). Meanwhile, the integration of digital maps in e-commerce provides better visualization for customers regarding product origin and estimated delivery (Luo, Rose, & Awang, 2025). UML modeling can help application developers build information systems because it provides clear references regarding the functional modules that must be included and the parties who act as users in the system (Friadi, Yani, Zaid, & Sikumbang, 2023).

UML is widely used to model online sales systems in the MSME sector and general e-commerce platforms, focusing on transaction efficiency and data management. UML provides a visual modeling tool that makes it easier for system developers to express ideas and concepts in a standard and easy-to-understand graphical representation. As a standard visual modeling language, UML is widely used in software design and development processes to present, document, and organize systems in a structured and systematic manner (Kusnadi, Arkeman, Syamsu, & Wijaya, 2023). In addition, UML is equipped with a mechanism that makes it easy to share and communicate designs with other parties efficiently. This study aims to apply UML in the design of an MSME e-commerce application based on a geographic information system to facilitate efficient online shopping transactions and empower MSMEs, thereby contributing to local economic growth. Based on this gap, this study addresses the following research questions:

1. How can UML be effectively applied to design a GIS-based e-commerce system for MSMEs?
2. How does UML modeling represent system functionality, user interaction, and spatial integration in e-commerce systems?

3. What design structure can be proposed as a reference for future system development?

2. Literature Review

Advances in information technology and the development of the Internet and other computer networks have driven the development of e-commerce by offering various beneficial features, such as convenience, accessibility, broad market reach, geographic mapping, and electronic payments and logistics. Currently, e-commerce is supported by Geographic Information Systems (GIS) to capture, store, manipulate, analyze, manage, and present spatial data and facilitate decision-making (Shili, Hammedi, & Elkhodr, 2025). E-commerce supported by GIS will improve the user experience by providing more personalized recommendations based on user location, both for product delivery and product offerings. Logistics and distribution optimization can be used to improve delivery route efficiency and reduce costs. Support for mapping sales data and customer preferences on a geographic scale will enable the identification of new market opportunities and the development of more targeted marketing strategies.

UML is a standard language used to visualize, specify, construct, and document artifacts from software systems. UML provides a series of diagrams that assist in designing and understanding systems. Previous research has shown that UML is a modeling or design tool that can be utilized to support the process of describing and designing systems, especially in the development of object-oriented programming-based software (Narulita et al., 2024). UML has become a standard language that is widely applied in industrial environments to formulate system requirements, perform analysis and design, and represent architecture in object-oriented software development (Syamsuri, Auliah, Rukman, & Ruslan, 2026). This is because the current system development trend is not only focused on web functionality but also on integration with mobile services to increase the reach of public and commercial services (Pratama & Armin, 2024).

The existence of UML is motivated by the need for visual modeling that can establish specifications, describe structures, and build and document software systems in a clear and directed manner (Koc, Erdoğan, Barjakly, & Peker, 2021). UML has become a standard for visualizing, designing, building, and documenting software that helps developers explain and present the functionality of the system to be built to users or business developers (Bates, Vavricka, Carleton, Shao, & Pan, 2025). Therefore, the use of UML is highly recommended in modern software engineering to minimize ambiguity of system requirements between developers and stakeholders (Romeo, Raglianti, Nagy, & Lanza, 2025). This visual standardization also helps in detecting business flow logic errors from the early design stage (Siburian & Latifah, 2023).

In UML version 2.4, there are 14 types of diagrams grouped into two main categories. The first group is Structure Diagrams, which include class diagrams, object diagrams, package diagrams, deployment diagrams, component diagrams, and composite structure diagrams. The second group is Behavior Diagrams, which include Activity Diagrams, Sequence Diagrams, Communication Diagrams, Interaction Diagrams, Timing Diagrams, Behavior State Machines, Protocol State Machines, and Use Case Diagrams. Through UML, developers obtain standards for compiling system blueprints that can represent business process flows, class designs that can be implemented into certain programming languages, database designs, and various supporting components needed to build a user-friendly system (Salkiah & Putra, 2025).

Although previous studies have highlighted the role of UML in system modeling and the importance of GIS in enhancing e-commerce functionality, integrative studies that combine both approaches within a structured design framework are still lacking. Most studies focus either on system implementation or general conceptual discussions without demonstrating how UML diagrams can systematically represent GIS-based e-commerce systems (Putri, Asril, & Efendi, 2025). Therefore, this study addresses this gap by proposing a UML-based design that explicitly integrates spatial features into MSME e-commerce systems. The design and development of this application utilized UML modeling, UI/UX design, functional testing, black-box testing, and the System Usability Scale (SUS). However, this study focused solely on the application of UML, which included use case, activity, and class diagrams.

3. Research methodology

This study uses an R&D method with an experimental development approach, namely designing, developing, and evaluating application prototypes. Application development is carried out using the waterfall model, which includes the stages of requirements analysis, system design, application implementation, testing ranging from functional testing to black box testing, and the maintenance phase. Although agile methods are popular, the waterfall approach remains relevant for projects with clearly defined needs and those that require structured documentation (Pirmansyah, Saikin, Hamdi, & Fadli, 2025). The experimental approach in R&D ensures that the resulting prototypes have undergone functional validation before mass implementation (Afriansyah, Pratama, Fitriyani, Ramadhan, & Ventani, 2024).

The application of the waterfall model in this development process allows the creation of a system that is systematically structured, neatly documented, and has a strong basis for scientific accountability (Hendrowati, 2024). In the future, the collected transaction and stock data can be further analyzed using the clustering method to predict sales trends and stock requirements (Afriansyah et al., 2024). The waterfall system development model is one of the oldest and most widely used software development models. It was first introduced by Winston W. Royce in 1970. Although many new models have been developed, Waterfall remains relevant, especially for projects with clearly defined requirements and specifications from the outset.

The waterfall model was selected because the system requirements were clearly defined at the initial stage, allowing for a structured and sequential development process that is suitable for system design-oriented research. In this study, the waterfall model was adapted to support GIS-based e-commerce development by incorporating spatial data requirements in the analysis phase, integrating map-based features in the design phase, and ensuring compatibility with geographic data processing in the development stage. Each phase of the waterfall model produces specific UML artifacts; the requirement analysis phase results in a use case diagram, the system design phase generates both activity and class diagrams, and the development phase leads to the creation of a system prototype based on the UML design.

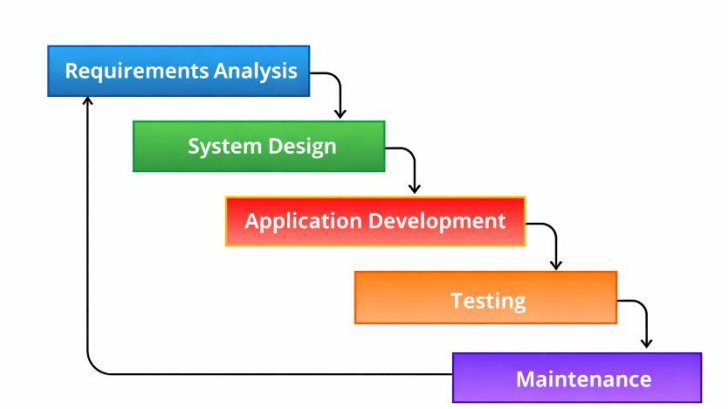

Figure 1. Waterfall system development model

As shown in Figure 1, the stages of the application development model are as follows:

a. Need analysis
   A needs analysis is conducted to identify and collect data through interviews and observations to understand user needs and ongoing business processes. This stage involves gathering and documenting requirements from users and stakeholders. In the context of geographic information system-based e-commerce, this might include the need for spatial data integration, interactive map features, and user location analysis.
b. System design
   The system design is compiled by referring to the results of the need analysis that have been obtained, and the system modeling process is then carried out using the Unified Modeling Language (UML) (Yas, ALazzawi, & Rahmatullah, 2023). Based on the identified needs, this

phase involves designing the system architecture, including the database design, user interface, and geographic information system elements. This design should include how geographic data will be integrated and displayed.

c. Application development
Application development is performed using programming languages and databases. The functions developed are designed in accordance with previously established system specifications and designs. At this stage, developers begin writing code based on the designs. For GIS-based e-commerce applications, this includes developing modules for spatial data processing and map API integration.

d. Testing
Testing is conducted to ensure that all developed features function according to established specifications and meet user needs. After application development is complete, the system is tested to ensure that all components function properly, both individually and in an integrated manner. The tested system is then deployed to a production environment. In geographic information system-based e-commerce, this means ensuring that all features function properly for end users. Because this study focuses on system design, empirical testing and user-based validation were not conducted. The evaluation was limited to design consistency and completeness.

e. Maintenance
After deployment, monitoring is performed, and any issues or damage that arise during application use are repaired. Subsequently, the system requires maintenance to correct bugs, enhance features, and ensure optimal performance.

Each stage in the waterfall model is closely related to the previous and subsequent stages. For example, errors in the requirements analysis stage can lead to an inappropriate system design, which in turn can lead to ineffective implementation. In the context of geographic information systems, it is crucial to ensure accurate and relevant geographic data from the requirements analysis stage, as this will influence the design and implementation of location-based features. Integration and testing play a crucial role in ensuring that all system components, including geographic information system modules, function harmoniously. Continuous maintenance processes are necessary to adapt the system to changing business and technology needs, including geographic data updates and e-commerce feature enhancements.

4. Result and Discussion

A geographic information system-based e-commerce application for MSMEs facilitates online buying and selling transactions and provides login, dashboard, profile settings, product management, shopping cart, checkout, transaction history, and stock management features. This is because a simple yet informative interface design is key to the success of e-commerce applications in attracting MSME users (Mandani, 2023). Ease of navigation within the system directly impacts user satisfaction and customer retention rates (Farhan & Usman, 2025). Users can also access the e-commerce application by first opening the login and registration pages. On these pages, users are required to fill in personal data, including their full name, username, and password, as credentials to access the system.

Once the registration process is complete, the system verifies the entered data and, if valid, creates a new account automatically. Subsequently, users can log in using the registered username and password and go through the validation process. The use of an integrated information system has proven to optimize sustainable MSME data management (Risdwiyanto, Sulaeman, & Rachman, 2023). In addition, the effectiveness of the e-commerce system is highly dependent on the readiness of business actors to manage digital platforms (Asmawati, Ahmad, Suwarni, Alita, & Hasrina, 2024). The application of UML in designing an MSME e-commerce application based on a GIS is shown in the following use case, activity, and class diagrams.

The use of UML in this study demonstrates its effectiveness in providing a structured representation of system functionality and interactions. Compared with unstructured design approaches, UML offers a clear visualization of user roles, system processes, and data relationships, thereby reducing ambiguity in system development. Furthermore, the integration of GIS features enhances the system by enabling

the spatial visualization of MSME locations, supporting more efficient logistics, and improving user decision-making. This indicates that the proposed design not only supports system clarity but also adds functional value through location-based services.

4.1 Use Case Diagram

A use case diagram describes the interactions between external actors and a system to achieve a specific goal. This diagram focuses on the system's functionality from the user's perspective. Use Case Diagram has the following main components: (1) Actors: entities that interact with the system (e.g., users or external systems), (2) Use Cases: representations of the functions or services provided by the system, (3) Relationships: consisting of associations, generalizations, and dependencies between actors and use cases, (4) Relationships: Use Case Diagrams help in identifying user needs and designing systems based on these interactions, becoming the basis for developing other diagrams such as Activity Diagrams and Class Diagrams.

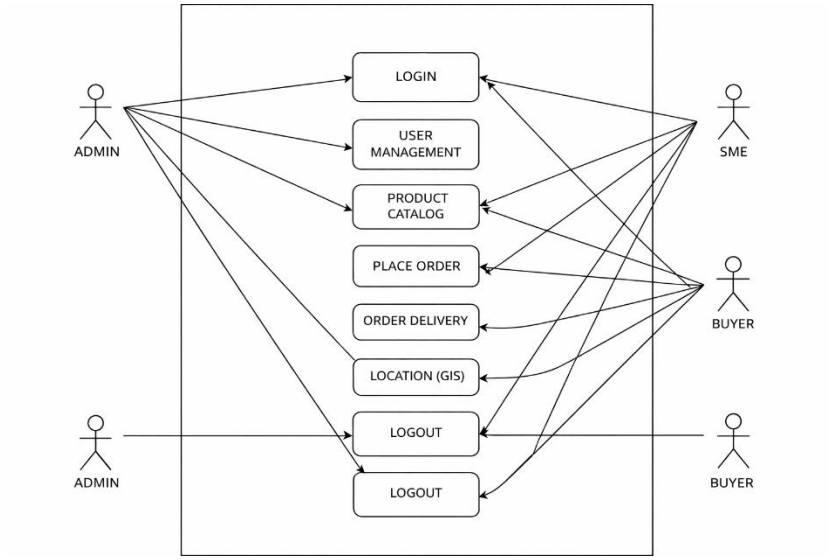

Figure 2. Use case diagram of MSME E-Commerce Application

As shown in Figure 2, in this use-case modeling, the system involves three actors: MSME staff, buyers, and application administrators. The diagram contains six use cases, covering login and logout processes, user account or profile management, product catalogue ues, product orders, product delivery, and MSME locations based on a Geographic Information System (GIS) (Güven Güney & Yüzer, 2025). The GIS functionality in this system enables users to view MSME locations on an interactive map, identify nearby products, and support location-based decision-making in purchasing and distribution.

4.2 Activity Diagram

An activity diagram depicts the workflow or activities of a system, showing the sequence of activities and the flow of control from one activity to another. Activity diagrams have main components such as (1) activity: step or task in the process; (2) transition: flow from one activity to another; (3) decision: decision-making point in the workflow; (4) swim lanes: dividing activities based on actors or responsibilities; and (5) relationship: activity diagram expands the use case by providing details about how the activities in the use case are carried out, including the decisions made. This helps in defining more detailed business processes and workflows.

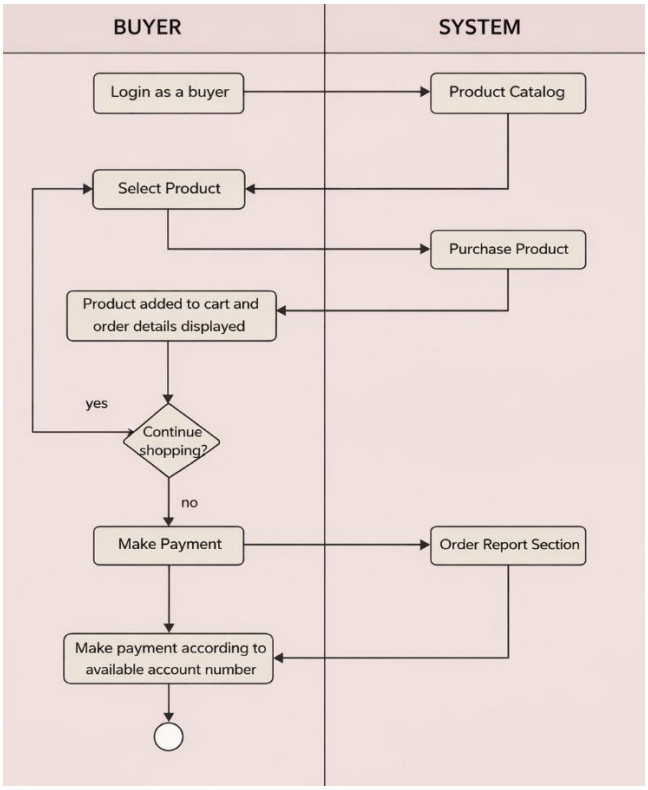

Figure 3. Activity diagram of MSME E-Commerce Application

As shown in Figure 3, the activity diagram displays the flow of activities in the MSME e-commerce application for the role of the buyer actor and their interaction with the MSME e-commerce application system (Aprilyani & Febriyanti, 2025). In addition to buyers, the activity workflow also involves MSME staff managing products and administrators overseeing system operations, ensuring a comprehensive representation of system processes across all actors. This diagram is divided into two main columns (swim lanes): buyers (left side) and systems (right side).

1. Login and access catalogue
   The process begins when a buyer logs into the application. After successfully logging in, the system responds by displaying a catalogue use of available products to allow buyers to explore various product options.
1. Product selection:
   The buyer selects the desired product from the displayed catalogue. After making their selection, they press the buy button, and the system automatically adds the product to their shopping cart and displays the order details to them.
2. Decision process
   In the next step, the buyer makes a decision about whether to continue shopping. If the buyer chooses to continue, the system redirects them to the product selection process to add additional items. However, if the buyer does not continue shopping, the process proceeds to the payment stage.
3. Payment and completion
   In the final stage, the buyer completes the payment process. The system receives the payment information and displays it in the order report. Subsequently, the buyer completes the payment by transferring funds to the account number provided and displayed by the system. The process ends with a small circle symbol at the bottom, signalling the end of the activity.

4.3 Class Diagram

A class diagram describes the structure of a system by showing classes, attributes, operations, and the relationships between those classes. The main components of a class diagram are as follows: (1) class, which is an entity with attributes and operations; (2) attribute, which is a property of a class; (3) operation, which is a function or method of a class; (4) relationship, which is an association, aggregation, composition, or generalization between classes; and (5) interrelationship class diagram

develops use cases by defining the system structure required to support the functionality identified in the use case diagram. It provides guidance for code development and data management. This structure improves system scalability and ensures data consistency across modules.

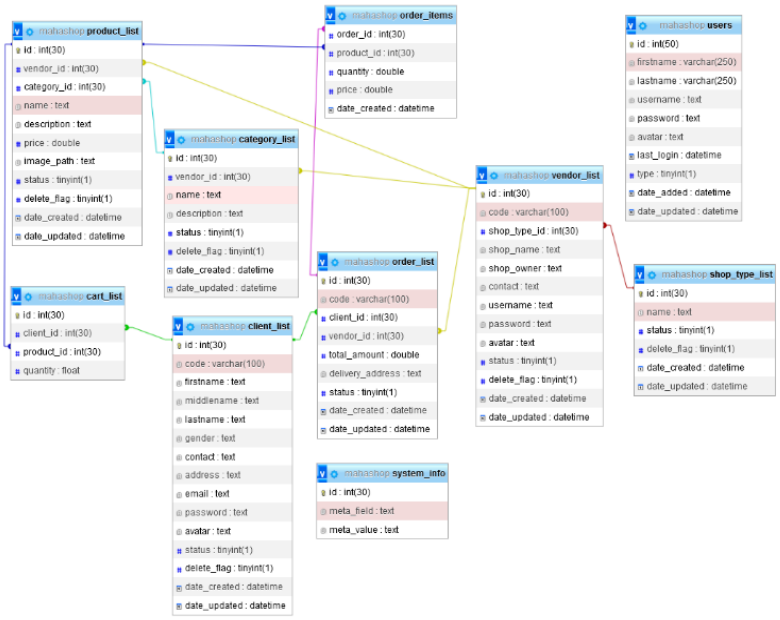

Figure 4. Class diagram of MSME E-Commerce application

As shown in Figure 4, the class diagram of an MSME e-commerce application is a map that shows how information is stored and connected to each other within the application (Agus, Harlinda, & Asis, 2024). The relationships between classes include associations between users and orders, aggregation between vendors and products, and multiplicity relationships indicating one-to-many interactions, such as one vendor having multiple products. Additionally, GIS-related attributes, such as location coordinates (latitude and longitude), are incorporated into vendor or product classes to support spatial functionality. This structure improves system scalability and ensures data consistency across modules. Here is an explanation of the main parts in easy-to-understand language:

1. User identity
   This system divides the involved parties into two main groups: users and the client list. The former group comprises data for administrators or Admins, who are responsible for managing and administering the overall operation of the application. The latter group comprises complete buyer data, including name, gender, shipping address, and login details such as email and password, which are used to access the system (Sari, Maharani, & Chamid, 2026).
2. Store and product Information
   To enable MSMEs to conduct sales activities, the system stores several important pieces of data. The vendor list lists shops or MSMEs registered with the application and records information such as shop name, owner's name, and type of business. The product list lists the products offered, with each product accompanied by a name, description, price, and photo to attract buyers. Furthermore, the category list is used to group products into specific categories, such as food, clothing, or crafts, making it easier for buyers to find the items they want.
3. Shopping process
   This section is the core of transaction activity within the application. The cart list serves as a temporary storage area for products that buyers have selected but not yet paid for. When a buyer clicks the "Buy" button, the cart data is transferred to the order list, which records the total price to be paid and the order status. Furthermore, the order items list records the details of the products purchased in a single transaction, including the quantity of each item.
4. System Support
   In addition, System Info stores basic application settings, such as application names and other technical information that supports overall system operations.

5. Conclusions

5.1. Conclusion

The application of Unified Modeling Language (UML) in designing a Geographic Information System (GIS)-based e-commerce application can effectively support stakeholders involved in the information system development process. UML provides a comprehensive and structured representation of system functionality, user interactions, and data relationships, ensuring that the system design aligns with user needs. The developed model includes use case, activity, and class diagrams, which collectively offer a clear blueprint for system development.

This study demonstrates that UML can be effectively integrated with GIS concepts to enhance the design of spatial-based e-commerce systems for MSMEs. Theoretically, this research contributes to the development of system modeling by combining UML and GIS approaches. Practically, it provides a structured design framework that can serve as a reference for developers and researchers in building GIS-based e-commerce applications. Additionally, this study highlights the importance of data security and user privacy and emphasizes the need to implement strong security mechanisms, such as data encryption and secure authentication, in future system developments.

5.2. Research Limitations

This study is limited to the system design stage and does not include full system implementation or empirical validation through user testing. Consequently, the effectiveness of the proposed system in real-world scenarios has not been measured. Furthermore, the evaluation is limited to the consistency and completeness of UML modeling without assessing system usability or performance.

5.3. Suggestions and Directions for Future Research

Future research should focus on implementing the proposed UML design by developing a functional system prototype. Further studies should include usability testing, such as the System Usability Scale (SUS), and performance evaluation to assess system effectiveness in real MSME environments. In addition, future research may explore the integration of advanced technologies, such as data analytics, machine learning for sales prediction, and enhanced GIS features, to improve system functionality and decision-making support.

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Author Contributions

JF contributed to the conceptualization of the study, system design, and manuscript drafting. AS was responsible for methodology development, data collection, and UML modeling. TMH contributed to the data analysis, validation, and interpretation of the results. DPY supervised the research process, provided critical revisions, and approved the final version of the manuscript. All authors have read and agreed to the published version of the manuscript.

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