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Developing a Web-Based Virtual Tour for Smart Tourism Information in the Malioboro Area

Intan Anisa Sholikhah[1], Dwi Wahyuningrum[1*]
[1] Geomatics Engineering, Faculty of Mineral Technology, Universitas Pembangunan Nasional "Veteran" Yogyakarta, Indonesia
Email: 117200036@student.upnyk.ac.id[1], dwi.wahyuningrum@upnyk.ac.id[2]*
**Corresponding author*

Abstract. Malioboro is one of the most prominent urban tourism corridors in Yogyakarta, attracting a large number of domestic and international visitors. Despite its popularity, access to integrated digital information regarding essential public facilities remains limited, potentially reducing visitor convenience and mobility within the area. This study aims to develop a web-based virtual tour system that integrates spatial information on public facilities to support smart tourism services in the Malioboro area. The system was developed using the Multimedia Development Life Cycle (MDLC), which consists of six phases: concept development, design, material collection, system assembly, testing, and distribution. High-resolution 360° panoramic images and spatial data of public facilities were collected through field surveys and integrated into an interactive virtual tour platform equipped with a web-based map for spatial navigation. The developed system enables users to virtually explore the Malioboro area while accessing location-based information and navigation support through an immersive interface. Functional testing confirmed that all system features operated as intended, while a usability evaluation involving 50 respondents yielded a System Usability Scale (SUS) score of 84.75, indicating high usability and strong user acceptance. The findings demonstrate that integrating immersive virtual tour technology with interactive web map-based public facility information can support destination exploration while improving access to practical tourism information. This study highlights the potential of virtual tours to function not only as promotional media but also as interactive tourism information systems that support smart tourism implementation in urban destinations.

Keywords. Web Map, Virtual Tour, Smart Tourism, Multimedia, Malioboro

INTRODUCTION

Yogyakarta is widely recognized as one of Indonesia's major cultural, educational, and tourism centers. As the capital of the Special Region of Yogyakarta (DIY), the city attracts numerous domestic and international visitors due to its rich cultural heritage, traditional settlements, and distinctive culinary traditions (Hadi, 2024). The cultural identity of the region has been formally promoted through the regional branding "Jogja Istimewa," which functions as a strategic initiative by the local government to strengthen tourism development and regional identity (Pratama et al., 2024). This positioning has important implications for urban tourism management, heritage preservation, and the provision of public facilities that support increasing visitor mobility.

One of the most prominent tourism areas in the city is Malioboro, a historic urban corridor in the city center that serves as a focal point for tourism, commerce, and cultural interaction. The Government of the Special Region of Yogyakarta has implemented various revitalization programs in the Malioboro area to preserve its historical character while improving public spaces and pedestrian infrastructure.

Previous studies have examined Malioboro from different perspectives, including tourism potential, heritage architecture, and cultural preservation (Herliana, 2015; Septirina et al., 2016). More recent studies indicate that revitalization initiatives have contributed to increased tourist visitation and to the generation of economic benefits for local communities (Fajar et al., 2024). However, the increasing intensity of tourism activities in the corridor also increases demand for accessible, reliable information on public facilities that support visitor mobility and comfort.

In recent years, urban tourism development has increasingly aligned with the broader smart cities paradigm, which emphasizes the integration of digital technologies and data-driven systems to enhance visitor experiences and urban service delivery. The Yogyakarta City Government has initiated various information and communication technology programs to support smart tourism and urban innovation (Danendra et al., 2024). Studies on smart city implementation demonstrate that digital infrastructures—including sensor networks, surveillance systems, and spatial information platforms—can improve urban governance, mobility management, and public service delivery (Kashef et al., 2021; Pawłowski et al., 2020; Prateeppornnarong, 2025). Within this context, geospatial technologies such as WebGIS have become important tools for delivering location-based services and enabling interactive spatial information systems.

Several digital initiatives have already been implemented in Yogyakarta as part of the city's digital transformation agenda. These initiatives include village-based CCTV monitoring systems, web-based platforms supporting micro and small enterprises (UMKM), and WebGIS applications for spatial data visualization and public information dissemination (Alfiani et al., 2023; Azzahra, 2023; Novryaldy & Seitadi, 2018; Prabandari & Atmojo, 2022; Prabowo et al., 2024). In the tourism sector, immersive virtual tour technologies—particularly panoramic 360° panoramic visualization—have been increasingly adopted as innovative tools for destination promotion and remote exploration. Previous research consistently shows that immersive virtual tours can enhance visitor engagement, improve destination visibility, and support digital tourism marketing strategies (Chang et al., 2023; Liu & Roehl, 2025; Nautiyal & Polus, 2022; Okul & Şimşek, 2025; Palagiang & Sofiani, 2021; Sangmanee & Suwanwerakamtorn, 2024; Steidle et al., 2023; Zhang et al., 2024).

Despite these technological developments, the integration of immersive virtual tour technology with spatial information systems remains limited. Most existing virtual tour applications are primarily designed as promotional media that emphasize visual representation of destinations rather than as functional systems that provide practical spatial information to support visitor navigation. Previous studies also highlight the fragmentation of spatial information related to tourism-supporting infrastructure, including public toilets, transportation nodes, and parking facilities (da Silva et al., 2021; Pratama et al., 2024; Pradipto et al., 2014; Susetyarini & Masjhoer, 2018). In high-density tourism corridors such as Malioboro, the lack of integrated and easily accessible spatial information may reduce the effectiveness of smart tourism initiatives and limit tourists' ability to navigate urban environments efficiently.

These conditions highlight an important research gap in integrating immersive virtual tour environments with geospatial information systems to deliver comprehensive location-based information. While previous studies have demonstrated the effectiveness of immersive virtual tours for tourism promotion, limited research has explored their potential as interactive spatial information platforms that support visitor navigation and access to tourism-supporting infrastructure. Therefore, integrating immersive virtual tour environments with WebGIS-based spatial data within a single interactive platform represents a promising approach for enhancing information accessibility in urban tourism destinations.

To address this gap, this study proposes the development of a web-based immersive virtual tour platform that integrates 360° panoramic visualization with WebGIS-based spatial information on essential public facilities in the Malioboro tourism area. The proposed platform is designed to provide an immersive visual exploration experience while also delivering location-based information on key facilities, such as public toilets, Trans Jogja bus stops, and parking areas. The system was developed using the Multimedia Development Life Cycle (MDLC) approach, which enables systematic development of multimedia-based information systems.

The objective of this study is to design, develop, and evaluate a web-based virtual tour system that integrates immersive panoramic visualization with geospatial information on tourism-supporting infrastructure in the Malioboro area. This study contributes to the development of smart tourism applications in two ways. First, unlike conventional virtual tours that primarily focus on visual promotion, the proposed system integrates an interactive 360° environment with a WebGIS-based interactive map, enabling users to access both visual and spatial information through a single platform. Second, it demonstrates how location-based public facility information can be incorporated into a virtual tourism environment to enhance visitor navigation and accessibility. These findings provide practical insights for tourism managers and local governments seeking to leverage geospatial technologies to improve tourism information services.

METHODS

This study adopted the Multimedia Development Life Cycle (MDLC) as the development framework for developing the web-based immersive virtual tour system. MDLC was selected because it provides a structured methodology for developing multimedia applications that integrate visual media, interactive interfaces, and information systems. The MDLC framework consists of six stages: concept, design, material collection, assembly, testing, and distribution (Nurdiana & Suryadi, 2018). In this study, these stages, as illustrated in Figure 1 and Figure 2, guided the development of a virtual tour platform that integrates 360° panoramic visualization with spatial information on public facilities within the Malioboro tourism area.

The research began with a comprehensive review of theses, academic journals, and official websites to establish the theoretical foundation for the design of the web-based virtual tour. During the preparation phase, the required hardware and software were assembled. These tools included an Insta360 X3 camera, a tripod, and software applications such as Insta360 Studio 2023, 3DVista Virtual Tour, ArcGIS 10.5, Visual Studio Code, and Microsoft Excel for data management. Prior to data collection, a user needs assessment was conducted using a 10-question questionnaire distributed through Google Forms to obtain responses from a diverse group of participants. The results of this assessment were then used to guide the virtual tour design process.

Field observations were conducted throughout the Malioboro tourism area to identify tourist attractions and supporting public facilities. Spatial data on these facilities were collected through field surveys and georeferenced using coordinates obtained from Google Maps, which were subsequently verified through direct observation. To create the immersive virtual tour environment, 360° panoramic images were captured using an Insta360 X3 camera. A total of 47 panoramic locations were recorded across the study area. These locations were arranged in a zigzag pattern along both sides of the street to provide broader spatial coverage and capture multiple perspectives of the area. Each panoramic point represents a strategic location, including pedestrian intersections, commercial zones, and clusters of public facilities.

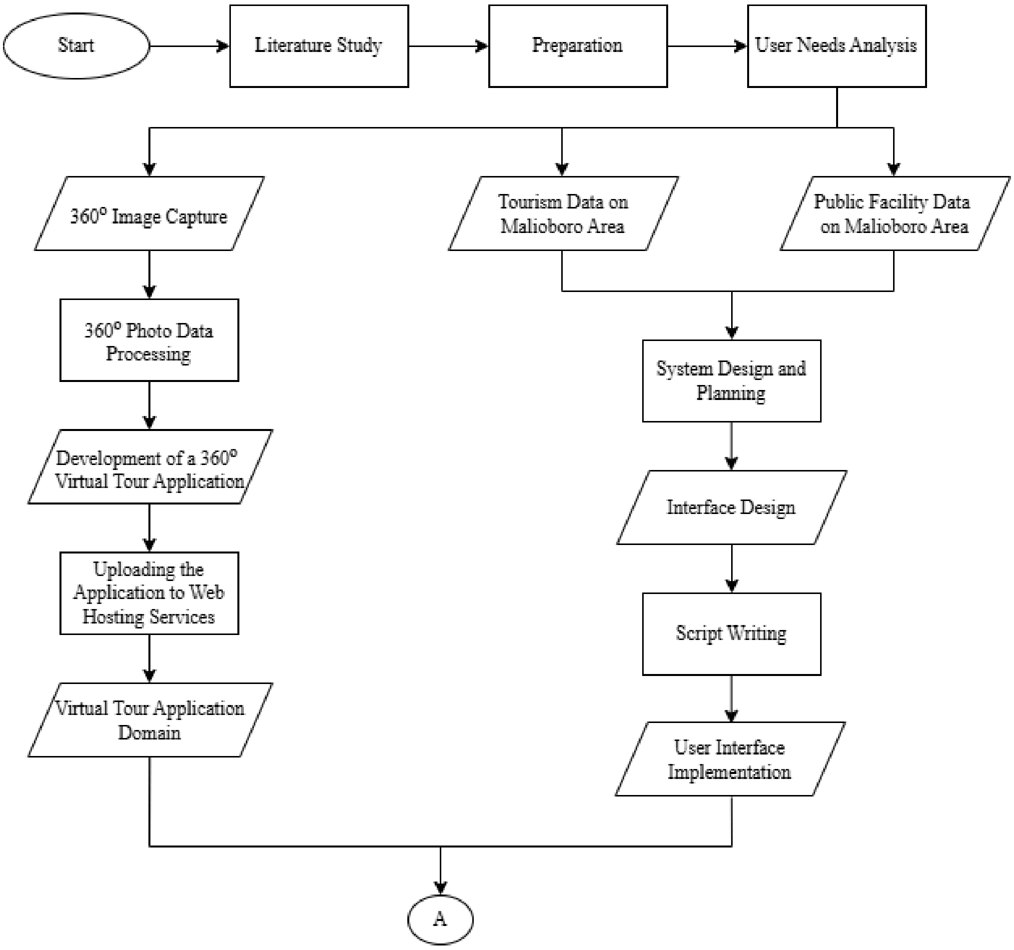

Figure 1 Research Flowchart (Part 1): Data collection and system development using the MDLC

The development of the virtual tour system followed the stages defined in the MDLC framework. Panoramic images were first processed using image-stitching software to produce high-resolution 360^0 visual content. The captured images were subsequently integrated into a virtual tour environment using 3DVista, where interactive components, including navigation hotspots, directional arrows, and information pop-ups, were incorporated to enhance user navigation and spatial understanding. The virtual tour environment was integrated into a web-based interface developed using HTML, CSS, and JavaScript. The website interface includes several sections: Home, History, Virtual Tour, Map, Gallery, and Contact. Additionally, an interactive spatial map was created using Leaflet.js to display the spatial distribution of tourism attractions and public facilities within the area. The completed system was deployed online and made accessible through a web browser.

System evaluation was conducted through two approaches: functional testing and usability testing. Functional testing was performed using the black-box testing method to verify that all system features met the specified functional requirements. A total of 17 testing scenarios were designed, including navigation functionality, hotspot interaction, information display, and map visualization. Usability testing was conducted to evaluate user experience when interacting with the system. The evaluation employed the System Usability Scale (SUS), a widely used instrument for measuring the perceived usability of interactive systems. The questionnaire was distributed online to 50 respondents from the general public. Each item was rated using a five-point Likert scale. The SUS score was calculated using the standard scoring method, producing a score ranging from 0 to 100. The resulting score was then interpreted using the SUS grading scale to determine the overall usability level of the developed virtual tour system.

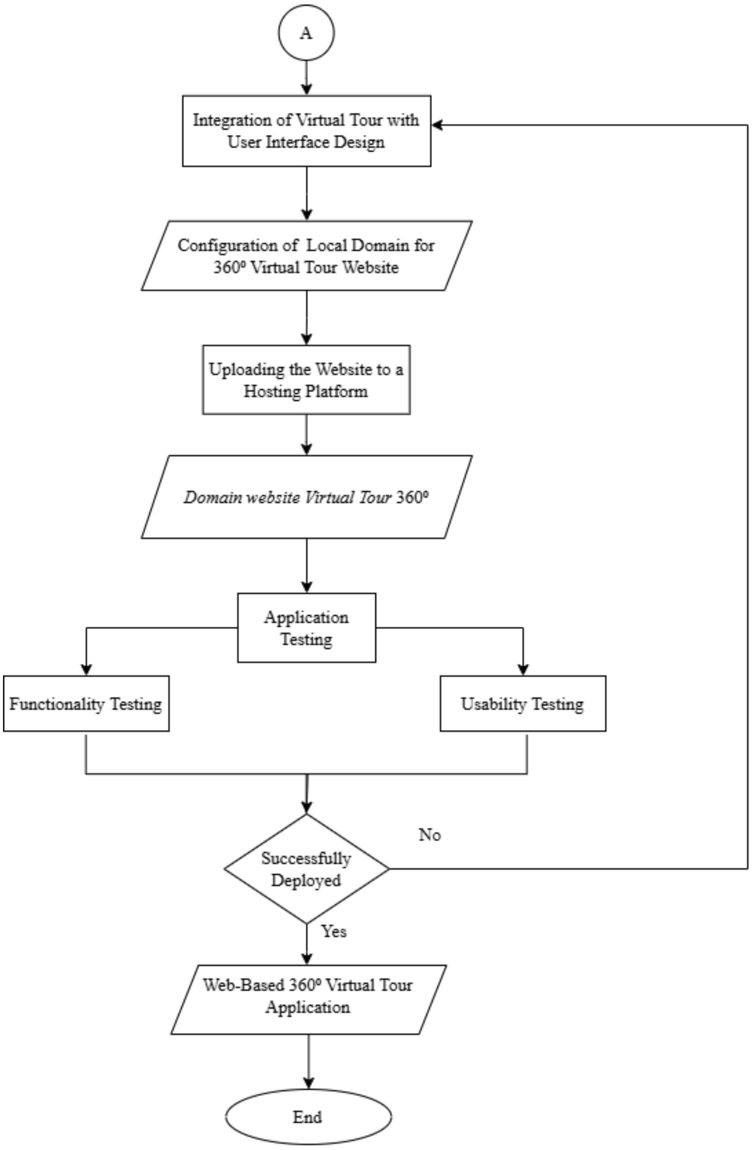

Figure 2 Research Flowchart (Part 2): Testing, distribution, and evaluation procedures

RESULTS AND DISCUSSION

1. Results of 360° Photographic Data Processing

The development of the Malioboro virtual tour system resulted in an interactive geovisualization platform that facilitates spatial exploration and enhances user understanding of the Malioboro area. The system was constructed using a dynamic model architecture that enables seamless transitions between spatial nodes while maintaining visual continuity throughout the virtual environment.

The 360° image processing stage involved the systematic acquisition of high-resolution panoramic photographs at 47 predetermined observation points distributed throughout the Malioboro tourism area. To improve spatial coverage, these observation points were arranged in a zigzag configuration along both sides of the corridor. This approach was adopted to minimize blind spots and visual occlusions that may occur when panoramic images are captured from only one side of the street. The resulting configuration provides overlapping visual perspectives between adjacent panoramic nodes, thereby maintaining visual continuity and supporting a more seamless navigation experience within the virtual environment. Furthermore, this arrangement facilitates the integration of points of interest (POIs) and public facility information with their corresponding panoramic locations, enhancing spatial context and improving the overall virtual exploration experience.

To ensure effective user interaction, the graphical user interface (GUI) components were implemented in accordance with the predefined system design framework. Key interface elements, including sidebar navigation, control icons, and pop-up information windows, were carefully positioned to facilitate efficient access to system functions without disrupting the immersive experience. Upon initiating the virtual tour, users can enable or disable background audio, as illustrated in Figure 3, providing a more personalized exploration experience.

Figure 3 The homepage interface of the web-based virtual tour system, showing the main interface and access to the 360° panoramic environment

As shown in Figure 4, the interface integrates a sidebar navigation panel that organizes the system functionality into three primary menus: Information, Layout, and Location. The Information menu provides operational guidance and an overview of the spatial zoning of the Malioboro area, enabling users to understand the structure of the virtual environment before exploration. The Layout menu presents a segmented representation of Jalan Malioboro divided into five spatial zones, allowing users to directly access selected panoramic nodes. Meanwhile, the Location menu integrates Google Maps to provide geographic references for the virtual locations represented in the system.

Figure 4 Expanded sidebar navigation panel organizing user controls into distinct information, layout, and location categories

Interactive hotspots play a central role in enabling spatial interaction within the virtual tour. Directional navigation icons allow users to transition between panoramic nodes, while information icons provide contextual descriptions of specific objects within the environment. Additional navigation controls support panoramic rotation and adjustable viewing perspectives, allowing users to explore the virtual environment in multiple directions. These interaction mechanisms improve spatial orientation and enhance the usability of the virtual tour platform.

Furthermore, as shown in Figure 5, each point of interest within the system is complemented by an informative pop-up interface that presents descriptive information about commercial establishments, historical landmarks, and public facilities located along the Malioboro area. By integrating immersive visualization with contextual information, the system enables users not only to observe the spatial environment but also to obtain relevant knowledge about the surrounding area. This integrative design supports a more engaging and informative virtual exploration experience for users.

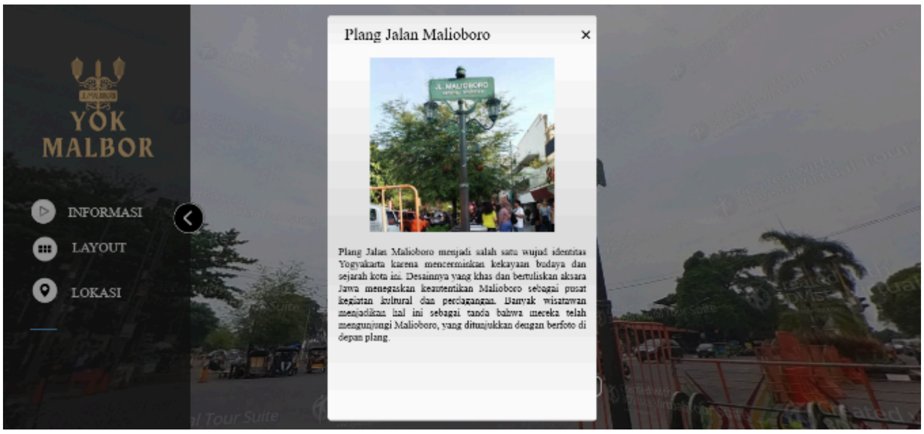

Figure 5 Information pop-up window displaying attributes data for a selected Point of Interest (POI).

2. System Design Outcomes

The development of the Malioboro virtual tour website resulted in an integrated web-based platform that supports interactive spatial exploration and facilitates access to tourism-related information. The system interface was designed using an earth-toned visual theme consisting of lavender purple, beige brown, and light blue. This color scheme was intentionally selected to create a calm and visually balanced interface while reflecting the cultural atmosphere associated with the Malioboro area tourism.

From an interaction design perspective, the website structure emphasizes navigational clarity and functional accessibility. The header section features the "Yok Malbor" logo in the top-left corner, serving as a visual identity and entry point for users. The navigation bar includes six primary menus—Home, History, Virtual Tour, Map, Gallery, and Contact—organized hierarchically to facilitate efficient user navigation throughout the platform.

The Home page as shows in Figure 6, serves as the primary entry point to the system and introduces the virtual exploration concept through a prominent title and a direct call-to-action button labeled "Start Tour." This button provides immediate access to the 360° virtual tour environment, reducing the number of steps required for users to initiate exploration. The homepage's graphical layout was developed in Canva and subsequently adapted to maintain visual consistency with the overall interface design.

The History page as illustrated in Figure 7, provides context on Jalan Malioboro, including its historical background and cultural significance. This section is structured using a tab-based interface that separates information content into distinct categories, enabling users to easily navigate between the area profile and its historical narrative.

Figure 6 Home page of the web-based virtual tour system

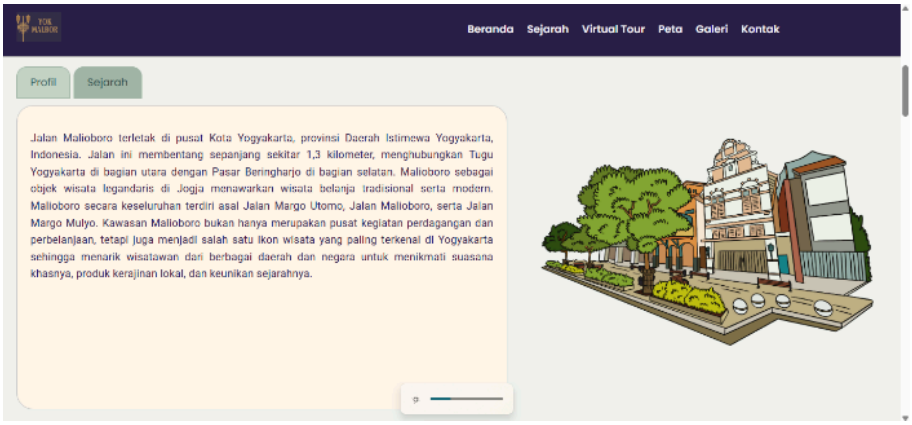

Figure 7 History page of the web-based virtual tour Malioboro Area

Figure 8 Virtual tour page providing access to the immersive 360° exploration environment

As illustrated in Figure 8, the Virtual Tour page serves as the transitional interface between the website and the immersive 360° panoramic environment. This page provides a brief introduction to the virtual tour application and includes a navigation button that directs users to the interactive panoramic viewer. The design of this page ensures that users can seamlessly transition from information browsing to immersive spatial exploration.

To complement the immersive virtual environment, the Map page,as shown in Figure 9, was developed as an interactive geographic interface utilizing Leaflet JS technology. The map enables users to explore the spatial distribution of tourist attractions and public facilities within the Malioboro area through standard cartographic interactions such as zooming and panning. In addition, category-based filtering options allow users to selectively display specific types of locations. When a map feature is selected, a pop-up window appears with an image, the location name, and a hyperlink to Google Maps, enabling further real-world navigation.

Figure 9 Interactive web map page displaying the spatial distribution of tourism attractions and public facilities

Figure 10 Gallery page of the web-based virtual tour system presenting photographic documentation of the Malioboro area

The Gallery page, as shown in Figure 10, provides a visual overview of several notable locations within the Malioboro area through a curated collection of images. Each image can be expanded via an interactive pop-up interface that displays the corresponding location name, enhancing user engagement and reinforcing the platform's information value.

Overall, the system design integrates aesthetic considerations, structured navigation, and interactive geospatial visualization components to deliver an accessible and engaging digital representation of the Malioboro tourism area. By combining web-based information services with immersive virtual tour technology, the platform extends conventional tourism information systems by enabling remote exploration alongside contextual information access.

3. Testing and Evaluation

A system evaluation was conducted to assess the functional performance and usability of the developed platform. Functional testing was conducted using the black-box testing method, focusing on validating that each system feature met the predefined functional requirements. The testing process involved 17 testing scenarios (Table 1), all of which were successfully executed, indicating that the implemented system functions performed as intended without operational errors.

Table 1 Functional Testing Results

No.	Test Scenario	Success Criteria	*Observed Output*	Test Result
1	Accessing the virtual tour landing page	The system displays the virtual tour landing page	The virtual tour landing page is successfully displayed in the browser	Successful
2	Accessing the virtual tour page	The system displays the Jalan Malioboro sign area	The panorama of the Jalan Malioboro sign area is displayed	Successful
3	Accessing navigation buttons on the Jalan Malioboro virtual tour page	The panorama changes according to the selected navigation direction	The panorama transitions to the corresponding location based on the selected navigation control	Successful
4	Accessing the sidebar	The system can display and hide the sidebar	The sidebar appears and can be hidden when the control button is selected	Successful
5	Accessing the information menu on the virtual tour sidebar	The system displays the information tab of the Jalan Malioboro virtual tour	The information tab containing details about the Jalan Malioboro virtual tour is displayed	Successful
6	Accessing the layout menu on the virtual tour sidebar	The system displays the layout/panorama list of the Jalan Malioboro virtual tour	A list of panorama layouts from the Jalan Malioboro virtual tour is displayed	Successful
7	Accessing the location menu on the virtual tour sidebar	The system displays the location point of the Jalan Malioboro sign	The location point of the Jalan Malioboro sign appears on the interface	Successful
8	Accessing hotspot pop-up information windows in the Jalan Malioboro virtual tour	The system displays location information of the Jalan Malioboro area	A pop-up window appears containing information about the selected location in the Jalan Malioboro area	Successful
9	Accessing the website homepage	The system displays the homepage	The homepage of the website is successfully displayed	Successful
10	Selecting the history menu	The system displays the history page	The page containing historical information about Jalan Malioboro is displayed	Successful
11	Selecting the virtual tour menu	The system displays the virtual tour page	The virtual tour interface is successfully displayed	Successful
12	Selecting the map menu	The system displays the map page	The interactive map page is displayed on the website	Successful
13	Selecting the tourism and public facilities checkbox sub-menu on Jalan Malioboro	The system displays tourism spots and public facilities located on Jalan Malioboro	Markers representing tourism locations and public facilities appear on the map	Successful
14	Selecting a specific public facility location point	The system displays information related to the selected public facility	A pop-up window displaying information about the selected public facility appears	Successful
15	Selecting the gallery menu	The system displays the gallery page	The gallery page containing photo collections is displayed	Successful
16	Selecting a photo in the gallery	The system displays the selected photo in full size along with the photo name information	The selected photo is displayed in full size along with its title	Successful
17	Selecting the contact menu	The system displays the contact page	The contact page containing contact information is successfully displayed	Successful

To evaluate the user interaction quality, a usability assessment was conducted through a questionnaire-based survey following the Nielsen Attributes of Usability (NAU) framework. This framework examines five primary usability dimensions: learnability, efficiency, memorability, error, and satisfaction. Each dimension was represented by several evaluation statements, measured on a five-point Likert scale from Strongly Disagree to Strongly Agree. The usability questionnaire items are presented in Table 2.

Table 2 Usability Testing Questions

Category	Question
Learnability	I find this system easy to use.
	I believe other users will quickly understand how to use this system.
	I need to get familiar with the system before I can use it effectively.
Efficiency	I find the system's features function as expected.
Memorability	I intend to use this system again in the future.
Error	I find that many aspects of the system are inconsistent.
	I find the system confusing.
	I experience no significant obstacles when using this system.
Satisfaction	I require assistance from others or a technician to use this system.

A total of 50 respondents participated in the usability evaluation. This sample size satisfies the recommendation proposed by Nielsen, which suggests that at least 20 participants are sufficient for reliable quantitative usability evaluation. Therefore, the number of respondents involved in this study was considered adequate to represent user perceptions of the system.

To quantify usability, the System Usability Scale (SUS) was used as the primary evaluation metric. The SUS scoring procedure involves calculating contribution scores for each item, ranging from 0 to 4. For odd-numbered questions, the contribution score is obtained by subtracting one from the Likert scale value, whereas for even-numbered questions the contribution is calculated by subtracting the scale value from five. The total contribution score is then multiplied by 2.5 to produce a final SUS score ranging from 0 to 100 (Ependi et al., 2019).

The SUS score was calculated using the formulation shown in Equation (1).

$$SUS = \{(S_1-1) + (5-S_2) + (S_3-1) + (5-S_4) + (S_5-1) + (5-S_6) + (S_7-1) + (5- S_8) + (S_9-1) + (5-S_{10})\} * 2.5 \quad (1)$$

In Equation (1), S_1 to S_{10} represent the individual responses to the ten SUS questionnaire items measured using a five-point Likert scale. The calculated contribution scores from all items are summed and subsequently multiplied by 2.5 to obtain the final SUS score, as shown in Figure 11 bellow.

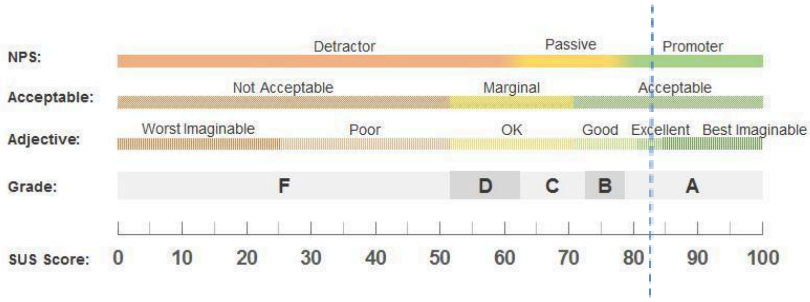

Figure 11 Interpretation of SUS Scores from Four Perspectives
Source: Muqoddas et al. (2020)

Usability testing results from 50 respondents yielded an average System Usability Scale (SUS) score of 84.75. Based on the SUS evaluation chart presented in Figure 11, the developed system falls within the “Acceptable” usability range, corresponding to a Grade Scale of B and an adjective rating of “Excellent”. These findings indicate that the system satisfies usability requirements and can be effectively operated by users. The high usability score may be influenced by the integration of immersive panoramic visualization, public facility information, and interactive map-based navigation within a single platform. Unlike conventional tourism information services that often require users to switch between multiple applications, the developed system enables users to explore the Malioboro area visually while simultaneously accessing location-based information and navigation support. This integration may reduce the effort required to obtain tourism-related information and contribute to a more intuitive user experience. In addition, the use of interconnected panoramic nodes, interactive facility markers, and contextual information windows allows users to obtain both visual and spatial information through a unified interface, which may have contributed to the high usability score obtained in this study.

Limitations and Future Work

Although the developed system demonstrated high usability and positive user acceptance, several limitations should be acknowledged. The current platform was developed specifically for the Malioboro tourism area and evaluated through functionality testing and a System Usability Scale (SUS)-based usability assessment. Therefore, further validation is required to examine its applicability in different tourism destinations and usage contexts.

In addition, while the platform is accessible through both desktop and mobile devices, the presentation of 360° panoramic content may be less convenient on smartphones due to the limited screen size. This constraint can affect the visibility of interface elements and the ease of exploring panoramic scenes. Furthermore, because the system relies on web-based panoramic imagery, users accessing the platform through mobile networks with limited bandwidth may experience longer loading times, reduced image quality, or delays during scene transitions. These conditions may affect the smoothness and immersion of the virtual tour experience, particularly when the system is used on-site by tourists.

Future research should focus on optimizing the user interface and interaction design for mobile devices, as well as improving system performance under varying mobile network conditions to enhance the accessibility and usability of the platform for on-site tourists.

CONCLUSIONS

This study successfully developed an interactive web-based virtual tour platform for the Jalan Malioboro area. The system architecture was implemented using HTML, JavaScript, and CSS to build the user interface, while Leaflet.js was used to support interactive map visualization. The developed platform demonstrated reliable performance based on both functional and usability evaluations. Functional testing was conducted using the black-box testing method, and all predefined success criteria across 17 testing scenarios were met. Usability evaluation was performed using the System Usability Scale framework, encompassing five dimensions: learnability, efficiency, memorability, error management, and satisfaction. Responses obtained from 50 participants yielded an average SUS score of 84.75. According to the standard SUS interpretation scale, this score falls within the “Acceptable” usability range and corresponds to an adjective rating of “Excellent.” These results indicate that the developed platform meets established usability standards and provides an effective and user-friendly medium for virtual exploration of the Jalan Malioboro area. Furthermore, the system demonstrates the potential of integrating virtual tour environments with web-based geospatial technologies to enhance digital tourism experiences and improve accessibility to spatial information.

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