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Research Article

Prototype Design of Metaverse-based Sustainable Smart Tourism Destinations Development: Design Science Research Methodology Approach

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ABSTRACT

This study aims to determine what user interface and prototype design should be in a metaverse-based sustainable smart tourism destination. A metaverse-based smart tourism destination is an approach that combines information and communication technology (ICT) to improve efficiency, quality, satisfaction, immersive experience, and sustainability of tourist experiences. The author uses the Design Science Research Methodology (DSRM) approach to build a prototype design artifact. DS (Design Science) is important in disciplines oriented toward creating successful artifacts. Several researchers have pioneered DS research in the Information Systems discipline over the past 15 years; therefore, DSRM is usually used as a reference by researchers in the Information Systems field. DSRM combines the principles, practices, and procedures needed to conduct research and fulfills three objectives: consistent with previous literature, providing a nominal process model for conducting DS research, and providing a mental model for presenting and evaluating DS research in IS. The DS process in this study focuses on design and development, demonstration, and evaluation. The author designs and develops the user interface, demonstrates it to end users, and then conducts testing or evaluation. The author tested the user interface and metaverse prototype to determine whether it was following the needs of users and stakeholders. Testing was carried out using interview techniques with experts/stakeholders using the AIKEN and ISO 25010 methods. Testing was also carried out using the black box method. End users tried the prototype directly and filled out a questionnaire the author had prepared using the GEQ (Game Experience Questionnaire) method. This study contributes to the discourse on smart tourist destinations based on the metaverse, which can add insight into smart destinations and increase satisfaction and immersive experiences. The evaluation results can be concluded that the experts agreed with the prototype, and the results of testing the prototype on the end-users showed that 90% expressed satisfaction in using/playing the metaverse prototype that had been built. This study presents a new basic pattern for developing sustainable smart tourist destinations based on the metaverse. This research is essential for stakeholders, including the government, destination managers, academics, and the community/tourists themselves, because it provides an overview of the user interface, and the prototype that was built can be a reference for all stakeholders in implementing sustainable smart tourist destinations based on metaverse.

Keywords: Smart Tourism Destinations; Metaverse; Sustainable; Prototype; DSRM.

INTRODUCTION

Tourism destinations need to take important and strategic steps to realize Sustainable Smart Tourism Destinations digitally by utilizing the latest ICT (Information and Communication Technology) to withstand the impact of the pandemic and remain competitive in the long term (Boes, Buhalis, and Inversini 2016a), (Altinay and Kozak 2021), (Woyo and Ukpabi 2022), (Esquivias et al. 2021), (Rodrigues et al. 2022).

Previous research findings stated that Smart Tourism is a social phenomenon believed to enhance tourist experiences through ICT (Hunter et al. 2015), (Koo et al. 2016). The main objective of Smart Tourism is to build new information infrastructure and business ecosystems, as well as to enhance the tourist experience by integrating mobile technology innovations into the tourism industry (Yoo et al. 2017). The perspective of scientists' states that Smart Tourism Destination (STD) or smart tourism destinations are necessary because they are believed to support sustainability goals by improving tourism efficiency in terms of automatable tourism business processes, creating new added value for tourists through technology, enhancing tourists' understanding of local culture, and reducing environmental damage by controlling the number of tourists through data and information management. (Ulrike Gretzel et al. 2015), (Yoo et al. 2017), (Hunter et al. 2015), (Negruşa et al. 2015), (Jovicic 2019), (Trunfio and Campana 2019).

Research related to Smart Tourism Destinations (STDs) and the technologies that support them has gained popularity and special attention over the past 10 years (Boes, Buhalis, and Inversini 2016a), (Shafiee et al. 2019), (Shafiee et al. 2022), (Woyo and Ukpabi 2022). STDs showcase various technologies applied to a tourist destination aimed at enhancing added value, both for the surrounding community in general and for tourists in particular (Boes, Buhalis, and Inversini 2016a), (Woyo and Ukpabi 2022), (Bulchand-Gidumal 2022). The research by Woyo and Ukpabi (2022) states that smart tourism destinations facilitate the engagement and integration of tourists with the environment, enhance the quality of the tourist experience, and improve the quality of life for residents around the destination. Shafiee et al., (2019) state that smart tourist destinations can be considered an integral part of the smart tourism ecosystem, which can drive new business models, interactive patterns, and even new types of tourism.

The main value of tourism itself is hedonic value & hedonic utility, which can be interpreted as the benefits of hedonistic values in terms of pleasure and joy. Therefore, according to Yoo et al. (2017) and Negruşa et al. (2015), the tourism industry has begun to introduce the concept of Sustainable Smart Tourism Destinations (SSTD) based on gamification, with the primary goal of changing tourist behavior to support sustainability principles and to enhance tourist experience satisfaction while in the tourist destination area.

In their paper, Negruşa et al. (2015) investigated the relationship between gamification and sustainability. The results of their research state that there is a synergy between gamification and sustainability, based on empirical evidence that both (gamification and sustainability) focus on emotional responses. The research findings of Negruşa et al. (2015) contribute to the benefits of gamification and sustainability in tourism, which consist of three (3) pillars of sustainability: economic, social, and environmental. The result is a complete component with gamification techniques' main implications for various stakeholders. This study positions the role of gamification for tourism within the broader context of sustainable development. Gamification contributes to the overall tourism experience in various ways. Gamification can act as an interface between tourists, destination management organizations, and local communities to promote more responsible and ethical tourist behavior.

Metaverse is a compound word derived from the combination of "meta" and "universe," referring to a three-dimensional virtual world where avatars, as players, engage in activities within it. This virtual world is based on everyday life where the real world and the virtual world coexist (Suanpang et al. 2022). The metaverse was first used in the science fiction novel Snow Crash by Neil Stevenson in 1992 and defines the metaverse as a world where the virtual and real worlds interact and create value through various social activities (Kim & Park, 2022). The Metaverse represents the idea of a hypothetical "parallel cyberspace" that embodies ways of living and working in a virtual city as an alternative to future smart cities (Allam et al., 2022). Metaverse, defined as a parallel virtual universe that uses ambient intelligence to enhance physical spaces, products, and services, emerges as a shared virtual space for value creation (M. Kim and Yoo 2024a; Koohang et al. 2023; D. Buhalis, Leung, and Lin 2023), (Buhalis & Karatay, 2022). The metaverse in tourism uses physical reality combined with MR Mix Reality (AR and VR) to unite all needs and stakeholders in a shared 3D virtual space and enhance physical spaces into MR spaces, transforming the internet into a parallel virtual universe (Buhalis & Karatay, 2022). The metaverse can completely transform travel by providing virtual experiences to tourists before they visit in person. This will take the concept of 'try before you buy' to the next level (Filimonau, Ashton, and Stankov 2022; Zaman et al. 2022). The Metaverse can inspire travelers to understand more about tourist destinations. 3D and VR experiences help prospective tourists understand the facilities and features available at the destination (Fan, Chen, and Huang 2022; Zhang et al. 2022).

The metaverse in tourism can provide people who may not be able to travel physically with a way to explore the world, either as a complement, as a substitute for direct visits, or as a way to prepare for upcoming trips (Fan, Chen, and Huang 2022; Zhang et al. 2022). Destinations can leverage the benefits of metaverse technology to create virtual

destination experiences for both tourists and potential tourists, providing a new way to interact with destinations without having to leave home (Fan, Chen, and Huang 2022; Zhang et al. 2022; U.-K. Lee 2022). Another study also stated that the metaverse cannot replace physical travel but can create a desire to travel (stimulate) (Baker, Nam, and Dutt 2023b; M. Kim and Yoo 2024b; Mihalic 2024).

Metaverse platforms provide users with sensations such as sight, hearing, touch, and smell. One of the positive impacts of a tourist destination having metaverse technology is the economic value that can open new avenues for revenue streams (Mihalic 2024; Kouroupi and Metaxas 2023; Su, Hsiao, and Fan 2023). The benefits of metaverse technology, according to Kounavis, Kasimati, and Zamani (2022), can enhance the experience of tourists during their stay at tourist destinations. Subsequently, there has been an increase in several studies exploring the value presented by the metaverse in the tourism sector. Studies report that the metaverse can enhance education/knowledge and interpretation, tailor information to specific tourist preferences, increase interactivity (Yung and Khoo-Lattimore 2017), and enhance the enjoyment/happiness, satisfaction, and engagement of tourists (Xu, Buhalis, and Weber 2017; Xu, Weber, and Buhalis 2013).

Paliokas et al. (2020) identified three main reasons for using metaverse technology at tourist destinations, namely:

1) Personalization, for example, visitors have varying levels of knowledge with different ages, cultural backgrounds, and knowledge. With metaverse technology, they can adjust the learning pace to their own needs, interact with knowledge content on their own devices, and at their own interaction rhythm, which is a good example of adjusting the learning pace to personal needs and preferences. Additionally, visitors can follow their own navigation routes through information spaces and pay attention to the details of artifacts at the tourist destinations they prefer the most. Metaverse technology provides the opportunity to make such adjustments according to individual needs;

2) Motivation: the metaverse can maximize tourist motivation, especially for the younger generation who enjoy listening to stories, playing Virtual Reality (VR) games, and can easily master mobile devices. According to the constructivist approach, one of the approaches to metaverse technology itself is gamification-based. Gamification has become one of the models for metaverse applications in the modern era, so it can be understood that metaverse technology serves not only as a medium to enhance engagement and maintain tourists' attention but also as a way to reconstruct the meaning of artifacts through animated storytelling incorporated into VR scenarios. The stories told at tourist destinations are intended to enhance the emotions and fantasies of tourists to maximize their engagement and interest. In addition, certain game elements such as competition, challenges, conflict, control, and rewards for achieving goals can serve as "experience enhancers" for visitors and prevent visits to activities at destinations from being boring;

3) Learning Efficiency, making the perception of learning speed a criterion for the success of technology-based educational activities, we can accept that learning in a VR setting can help master skills and knowledge more quickly.

Based on the review of previous research studies the author presented above, the identified research gap is the lack of comprehensive studies integrating the concept of Sustainable Smart Tourism Destinations (SSTD) with the characteristics of metaverse technology. Thus, this research presents an opportunity to generate a novelty contribution from the perspective of information systems science, focusing on the research object in the smart tourism industry. This research produces a user interface design up to the information system application in the form of a metaverse application prototype on Nusameta, one of the metaverse application platforms available in Indonesia. The prototype application for the metaverse-based tourist destination was then tested with stakeholders and end users to gather feedback and determine whether the developed application meets user needs.

By creating a prototype of a sustainable smart tourism destination based on Metaverse technology, the author hopes to serve as a guide or reference for stakeholders to be implemented in all tourist destinations in Indonesia. Regarding the limited research time and to align with the government's 2020-2025 program, the author will focus on developing a sustainable smart tourism destination model, specifically for the 5 (five) Super Priority Tourism Destinations (DPSP). The five Super Priority Tourism Destinations (DPSP) are as follows: 1) Lake Toba, North Sumatra; 2) Borobudur, Central Java; 3) Mandalika, West Nusa Tenggara; 4) Labuan Bajo, East Nusa Tenggara; 5) Likupang, North Sulawesi.

However, within the specific scope of this research, Borobudur Temple was chosen as a pilot project to develop a metaverse prototype because Borobudur Temple is the closest to Jakarta, where the author resides, making it easily

accessible for field observations. In addition, Borobudur Temple has also been designated as one of the centers of world cultural civilization by UNESCO (United Nations Educational, Scientific and Cultural Organization).

LITERATURE REVIEW

The following sections discuss the related studies on metaverse development, smart tourism destinations, and sustainable tourism.

2.1. Metaverse Development

Metaverse is a compound word from the transcendence of meta and universe and refers to a three-dimensional virtual world where avatars engage in political, economic, social, and cultural activities (Aljumaie et al. 2023a). Metaverse is widely used as a virtual world based on everyday life where the real and the unreal coexist. The term "metaverse" was first used in the science fiction novel Snow Crash by Neil Stephenson in 1992 and refers to a world where the virtual and reality interact and create value through various social activities (Park & Kim, 2022).

Metaverse, defined as a parallel, virtual universe that uses ambient intelligence to enhance physical spaces, products, and services, emerges as a joint virtual space aimed at value creation (Dimitrios Buhalis and Karatay 2022).

The Metaverse in Tourism uses physical reality combined with Mixed Reality (AR and VR) to unite all needs and stakeholders in a shared 3D virtual space and enhance physical spaces into MR spaces, transforming the internet into a parallel virtual universe (Dimitrios Buhalis and Karatay 2022). The metaverse is a collaborative universe that combines human interaction with avatars and various products and services between the real world and the digital world without boundaries, where everything can happen simultaneously and in parallel (Aljumaie et al. 2023).

The Metaverse has great potential for society to interact, work, learn, and create. Of course, it is not only intended for 'gaming' or NFT (non-fungible tokens) exchanges alone (Suanpang et al. 2022; D. Buhalis, Leung, and Lin 2023). NFTs are digital assets that represent their original objects and cannot be used as a medium of exchange but can be traded like physical assets (Suanpang et al., 2022; D. Buhalis, Leung, and Lin 2023).

2.2. Smart Tourism Destinations

According to Boes et al (2016a), smart tourist destinations have several key components that are important and necessary for their implementation. The key components are People, ICT, and Leadership. From these three key components, Smartness Economic Actors are then produced, and from Smartness Economic Actors, Smart Innovations are subsequently generated, which consist of Smart Mobility, Smart Government, Smart Economy, Smart People, Smart Living, Smart Environment, and Smart Tourism Destination (STD). According to Boes, Buhalis, and Inversini (2016a), this STD consists of Smartness Attractions, Accessibility, Amenities, Available Packages, Activities, and Ancillary Services.

Shafiee et al (2021) developed a Smart Tourism Destinations (STD) model consisting of several main components: Stakeholders, Structure, Process, Technology, and Policies. In addition to the components, Shafiee et al. (2021) also mention the measurement in STD, which consists of several dimensions, namely environmental, economic, social, technical, and political. The author can conclude that this measurement is derived from the concept of the 3 pillars of sustainability (economic, environmental, and social) plus the technical and political dimensions. Here is the STD Model according to Shafiee et al (2021):

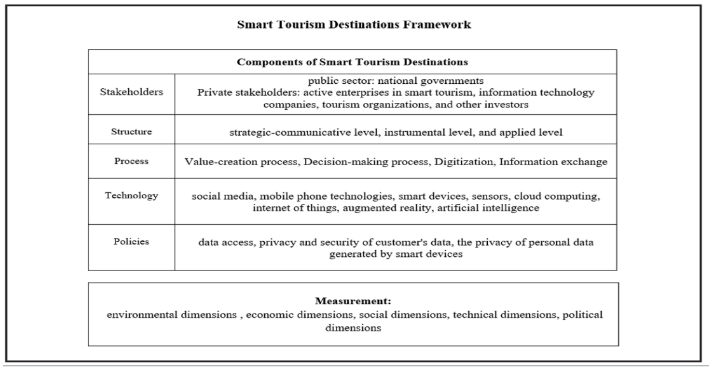

Figure 1. Smart Tourism Destinations Model (Shafiee et al., 2021)

2.3. Sustainable Smart Tourism Destinations

Minister of Tourism Regulation No. 14 of 2016 on Sustainable Tourism Destination Guidelines, there are 4 (four) main pillars in tourism development. These pillars also serve as criteria formulated by the Global Sustainable Tourism Council, which include: 1. Sustainable tourism destination management (Sustainability Management) 2. Economic utilization for the local community (Social-Economy) 3. Cultural preservation for the community and visitors (Culture) 4. Environmental conservation (Environment) The four pillars mentioned above have been clearly stated in the Indonesian Tourism Law, where the performance of tourism development is not only measured and evaluated based on its contribution to economic growth but also on its contribution to improving community welfare, reducing unemployment and poverty, preserving natural resources/environment, developing culture, and enhancing the nation's image and identity, with the hope of increasing tourist interest in visiting a tourist destination and also boosting repeat visits. In previous research, it was stated that sustainability in tourism has two sides (Yoo et al. 2017).

On one hand, the tourism industry is closely related to the development and growth of sustainability (Yoo et al. 2017). This aligns with the International Standard Organization (ISO) 21401: 2018, which explains the tourism industry and its related services, specifically the sustainability management system regarding accommodation requirements.

ISO 21401:2018 is in line with the SDGs (Sustainable Development Goals) set by the UN (United Nations) in 2015, specifically SDG number 11 on sustainable cities and communities ("ISO 21401:2018 - Tourism and Related Services — Sustainability Management System for Accommodation Establishments — Requirements" 2018).

In addition, there is another standard, ISO 21902:2021, regarding tourism and related services, specifically accessible tourism for all (requirements and recommendations). ISO 21902:2021 aligns with the Sustainable Development Goals (SDGs) number 8 on economic growth and decent work, then number 9 on industry, innovation, and infrastructure, as well as SDG number 10, which focuses on reducing inequality in various aspects (ISO 21902:2021 - Tourism and Related Services — Accessible Tourism for All — Requirements and Recommendations" 2021). The United Nations World Tourism Organization (UNWTO) defines sustainable tourism as a concept of tourism development and growth that fully considers the economic, social, and environmental impacts both currently and in the future (UNWTO 2022). Continued development and growth create economic benefits through the intangible value tourists perceive through experiences in nature tourism and cultural tourism, for example, as well as other types of tourism (Yoo et al. 2017). Economic value is also created through the empowerment of local communities, making them part of the workforce and contributing to the development of the tourism destination (Yoo et al. 2017; Negruşa et al. 2015). Thus, the potential to achieve sustainability for a destination can be realized by integrating the balance of the three pillars of sustainability: economic growth, environmental preservation, and positive social impact (Yoo et al. 2017; Negruşa et al. 2015). Economic growth can be achieved by empowering communities or residents by creating job opportunities in tourist destinations and surrounding areas (Negruşa et al. 2015; Perles Ribes and Ivars Baidal 2018; Yoo et al. 2017). Environmental preservation, for example, includes strict regulations regarding waste management in tourist areas, the separation of wet and dry waste, and the reduction of plastic use (Negruşa et al. 2015; Souza, Marques, and Veríssimo 2020; Ivars-Baidal et al. 2021). The positive social impact, for example, is the presence of acculturation and positive cultural adoption between residents and tourists (Negruşa et al. 2015; Ivars-Baidal et al. 2021).

Here is an illustration of the three pillars in the concept of sustainable tourism destinations, plus one pillar based on the Minister of Tourism Regulation No. 14 of 2016 mentioned above, which is the pillar of sustainable tourism destination management (Sustainability Management). The author created the image below to illustrate the concept of a Sustainable Smart Tourism Destination.

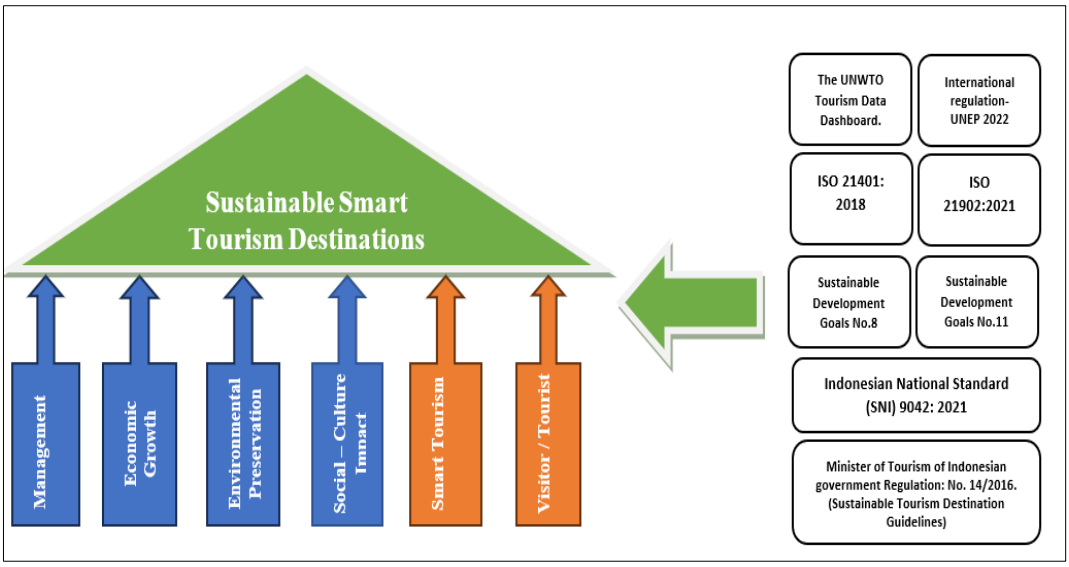

Figure 2. Sustainable Smart Tourism Destinations Model (Hiererra et al., 2024)

METHOD

3.1. Design Science Research Methodology (DSRM)

The research methodology used in this study is the Design Science Research Methodology (DSRM) model, which is very suitable for research in the information systems discipline [9]. DS (Design Science) is important in disciplines that are oriented toward the creation of successful artifacts [9].

Several researchers have pioneered DS research in the Information Systems discipline over the past 15 years. Therefore, DSRM is commonly referenced by researchers in information systems [9], [10], [11], [12].

DSRM incorporates the principles, practices, and procedures needed to conduct research and fulfills three goals: it is consistent with previous literature, provides a nominal process model for conducting DS research, and provides a mental model for presenting and evaluating DS research in IS [9], [10], [11], [12].

The DS process includes six steps: problem identification and motivation, solution goal definition, design and development, demonstration, evaluation, and communication.

3.2. Design Science Research Methodology (DSRM) Process Iteration Model

Here is a picture of the iteration process of the design science research methodology / DSRM:

Figure 3. DSRM Iteration Model

3.2.1. Identify the Problem & Motivate

At this stage, the author conducts open problems by looking for existing problems in the context of the scope of this research. The author reads various kinds of journals and proceedings from previous studies, reads popular news, learns from the websites of regulatory institutions related to existing problems, and makes direct observations of the field. So that the problems found in this research are:

1. Drastically reduced tourist visits due to the covid 19 pandemic
2. Significant reduction in destination's revenue
3. Destination wants to increase visitation and revisit rates
4. The destination wants to increase tourist satisfaction by utilizing the latest technology (such as VR /Metaverse)
5. Destinations want travelers to be able to have an immersive experience

3.2.2. Define the Objectives of a Solution

At this stage, the author formulates goals and solutions based on the problems found. In formulating goals and solutions, the author interviewed the Borobudur temple tourist destinations manager. The author also conducted initial FGDs with the Ministry of Tourism and Creative Economy representatives, namely the Director of Industry Management and Marketing Expert Staff. Based on the results of the initial interview, the following objectives and solutions were formulated:

1. Increase the level of tourist visits and return visits
2. Increase tourist satisfaction by applying immersive technology; this solution can be applied in all tourist destinations, especially in the five Super Priority Tourism Destinations, and Borobudur Temple as a pilot project
3. Support government program 2020-2025 (Sustainable Tourism, Experience Satisfaction, Technology Adoption)
4. Metaverse-based Immersive Experience

3.2.3. Design & Development

At this stage, the author determines the Research Question (RQ) and the completion steps to achieve the Research Objective (RO).

Designing and developing this metaverse prototype application refers to the Sprint method.

The design sprint method was chosen because it is a best practice often used to create game applications. Design Sprint is an approach to designing and testing, especially user interfaces and testing ideas with potential users. It has five phases: understand, diverge, decide, prototype, and validate.

In the understanding phase, information regarding user problems and needs is collected. This follows the initial iteration phase of the DSRM methodology that the author uses in this research. The diverge and decide phases aim to identify potential strategies to answer the needs and challenges found in the understanding phase. This is in line with the second and third iteration stages of the DSRM methodology.

In the decide phase, namely determining the design of the Borobudur mobile and VR (Virtual Reality) game application, the UML system modeling design or Unified Modelling Language is first used as a medium to convey the design as a use case diagram (UCD). Use case diagrams explain a general picture of the system where users are illustrated as actors who can have several activities. The authors designed the UCD for the Borobudur mobile and VR game application prototype.

After creating the use case diagram, the author designs the game architecture. Then, the author built a prototype for the Mobile platform and VR version with the Oculus Quest 2 tool. The authors designed a game based on mapping from the Metaverse-based Smart Sustainable Tourism Destination Model concept.

3.2.4. Demonstration – Use Artifacts to solve the problem

In making the artifact, the metaverse tourism application prototype, the author created a user interface screen design using Figma software. Based on previous research, Figma software was chosen because it is the best practice and is relatively easy, user-friendly, efficient, and effective. The author used Blender software to create avatar designs and three-dimensional asset environments and to build games using Unity software version 2022.3.11.f1 with the C# programming language.

3.2.5. Evaluation – Observe

At this stage, the author tested the prototype on respondents. The selected respondents were Gen Z because it suited the target sample and research objectives. Observations through this prototype test were carried out at the Binus Campus in Semarang, Jakarta, Alam Sutera, and Bekasi, as well as at Borobudur Temple.

After the respondents had played the prototype application, they were asked to complete the prepared questionnaire. The research questionnaire instrument uses the Game Experience Questionnaire (GEQ) formula.

Points 3, 4, and 5 can be concluded into a research framework that the author proposes, namely as follows:

Research Question 1 is How to Design Borobudur Temple Metaverse Application Prototype? consist of 5 steps namely as 1. Design & Develop Borobudur Temple Metaverse Application Prototype based on Agile Method (Feature Driven Development). 2. Preparing the User Persona & User Stories. 3. Preparing the User Experience Flow Chart, 4. Preparing the User Interface. 5. UX Deployment result to Metaverse Platform "NusaMeta".

To facilitate understand the RQ 1 research framework, the author created a diagram as follows:

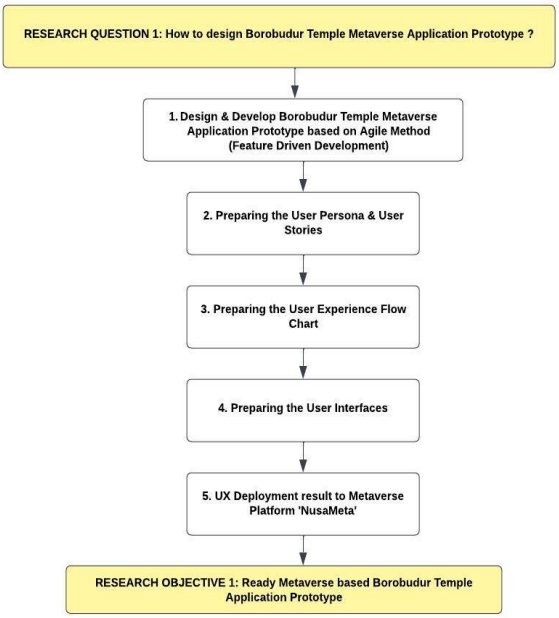

Fig. 1. Research Framework 1

Research Question 2 is How to evaluate Borobudur Temple Metaverse Application Prototype? consist of 4 steps namely as 1. Evaluate the app using ISO 25010. 2. Interview the Expert. 3. Get the Feedback Result. 4. Visualize the reulst using Radar Chart.

To facilitate understand the RQ 2 research framework, the author created a diagram as follows:

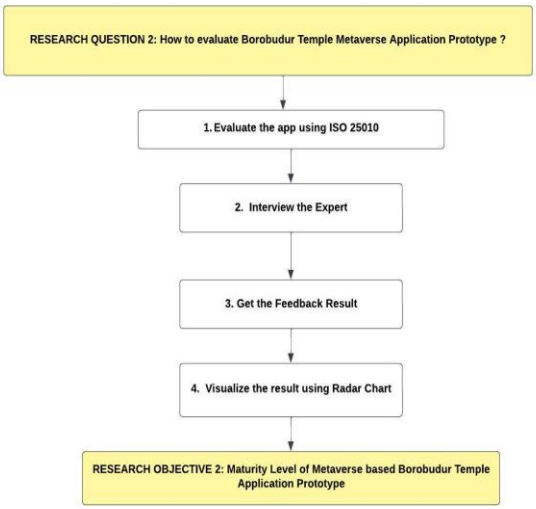

Fig. 2. Research Framework 2

Research Question 3 is How to evaluate Borobudur Temple Metaverse Application Prototype based on End User perspective? consist of 4 steps namely as 1. Evaluate the app using GEQ (Game Experience Questionnaire). 2. End

user tries the Application Prototype. 3. End user fills out the questionnaire. 4. Visualize the resulit using Diagram Chart. ssssTo facilitate understand the RQ 3 research framework, the author created a diagram as follows:

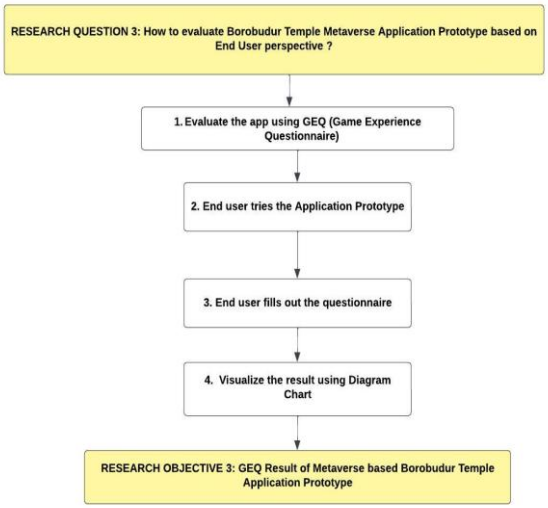

Fig. 3. Research Framework 3

3.2.6. Communication – Publication

At this stage, the author communicates the research results by publishing the results of this scientific work in a reputable and Scopus-indexed International Journal, and the author decides to submit and publish in this Metaverse Journal.

RESULTS AND DISCUSSION

The development of Borobudur Temple Metaverse Application Prototype was carried out in three Research Question following the research framework in Fig. 2, Fig. 3, and Fig. 4.

4.1. How to Answer Research Question 1

To answer Research Question 1, How to Design Borobudur Temple Metaverse Application Prototype that can achieve goals and be a solution to existing problems, following the research framework in Fig. 2.

4.1.1. Design & Develop Borobudur Temple Metaverse Application Protoype Based on Agile Method (Feature Driven Development)

The first step is to carry out design and development refers to the Agile Methodology, Feature Driven Development.

Agile Methodology emphasizes moderate planning, people-oriented collaboration, face-to-face communication, self-organization and management, and rapid development. This method can tolerate changing requirements and can effectively and quickly solve problems, increase output, and shorten the overall development time frame and increase speed and adaptability. [23], [24].

This research uses the agile method because of its ability to adapt and have high flexibility in the development process of this Borobudur Temple Metaverse Application. In addition, there is a Feature Driven Development which is one part of agile development, which is the core basis of the development process of Borobudur Temple Metaverse Application.

FDD (Feature Driven Development) is a practical model in the process of developing software in stages that is object-oriented and has five stages of activity, namely developing an overall model, building a features list, planning by feature, designing by feature, and building by feature.[25], [26]

The FGD method was chosen because the process of developing the Borobudur Temple Metaverse Application is oriented towards the details of the object that will be made into a metaverse-based, namely Borobudur temple tourism. By applying FDD, the author can focus on the object to be developed.

4.1.2. Preparing the User Persona & User Stories

The second step is preparing the User Persona and User Stories. User Persona is a fictional representation of the application user based on the application's needs and goals [27]. The author designed two user personas for the Borobudur mobile game & VR application, namely as follows:

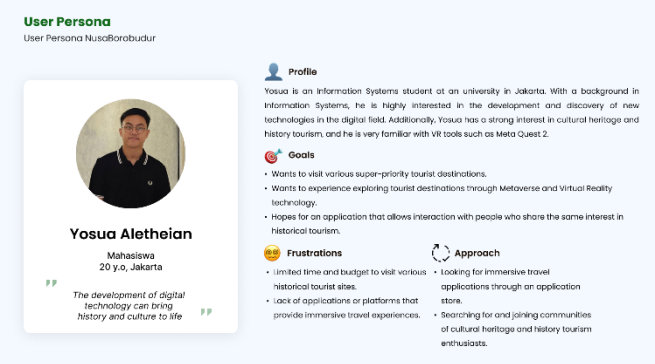

Fig. 4. Male User Persona

The user persona above consists of personal data of male potential users of the Metaverse based Borobudur Temple Application, profile, goals or things that users want to achieve when using the application, frustrations or things that prevent users from achieving their goals, and approaches as steps for users in achieving their goals.

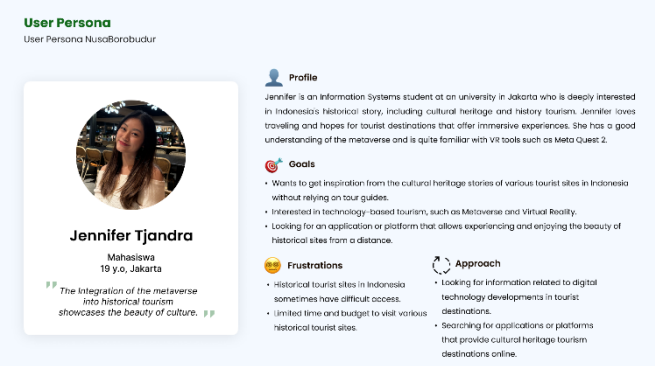

Fig. 5. Female User Persona

The user persona above consists of personal data of female potential users of the Metaverse based Borobudur Temple Application, profile, goals or things that users want to achieve when using the application, frustrations or things that prevent users from achieving their goals, and approaches as steps for users in achieving their goals.

User Stories are used to describe the features required and the goals the user wants to achieve[28]. The author designed five user stories for the Borobudur mobile game & VR application as follows:

1. As someone interested in cultural heritage, I want to explore cultural heritage and history tourism like Borobudur virtually so that I can learn about its history and experience the site without having to travel physically.
2. As a student, I want to learn how to sort waste from organic, inorganic, paper) so that I can find out the results of recycling the waste.
3. As a traveler, I want to explore super-priority tourism destinations through metaverse technology, so that I can find out about the destination before visiting it.
4. As a student, I want to see the reliefs in Borobudur virtually so that I can better understand the culture related with the site.

5. As a Gen Z, I want to play educational games about Borobudur so that I can learn about its history and culture in an interesting and fun way.

4.1.3. Preparing the User Experience Flow Chart

The third step is to prepare User Experience Flow Chart. User Experience Flow Chart is a diagram that shows the flow of activities carried out by users in the system, as well as the response to the activities carried out by users, namely that users can explore Borobudur Temple [29]:

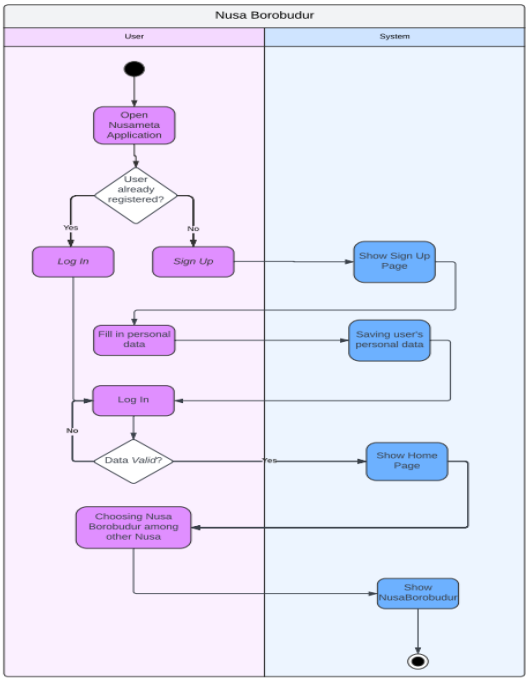

Fig. 6. NusaMeta to Nusa Borobudur User Experience Flow Chart

The diagram above explains the flow that the user goes through when the user enters the Nusameta application and selects Nusa Borobudur.

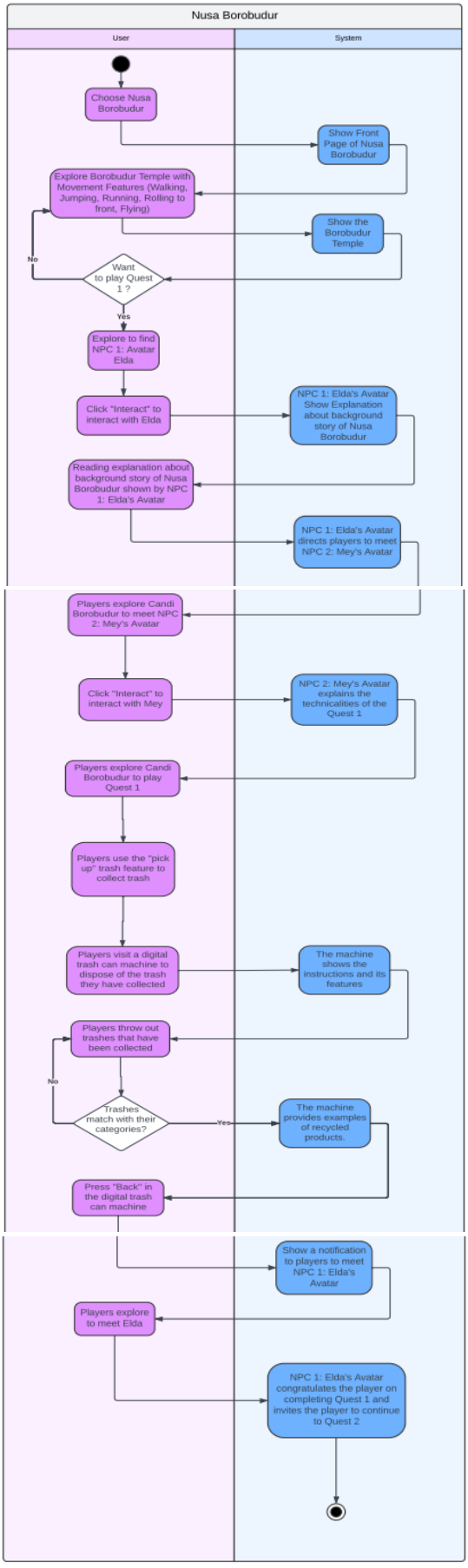

Fig. 7. Quest 1 User Experience Flow Chart

The diagram above explains the flow that players go through from entering Nusa Borobudur to completing quest 1. If players don't want to complete the quest, players can explore Nusa Borobudur.

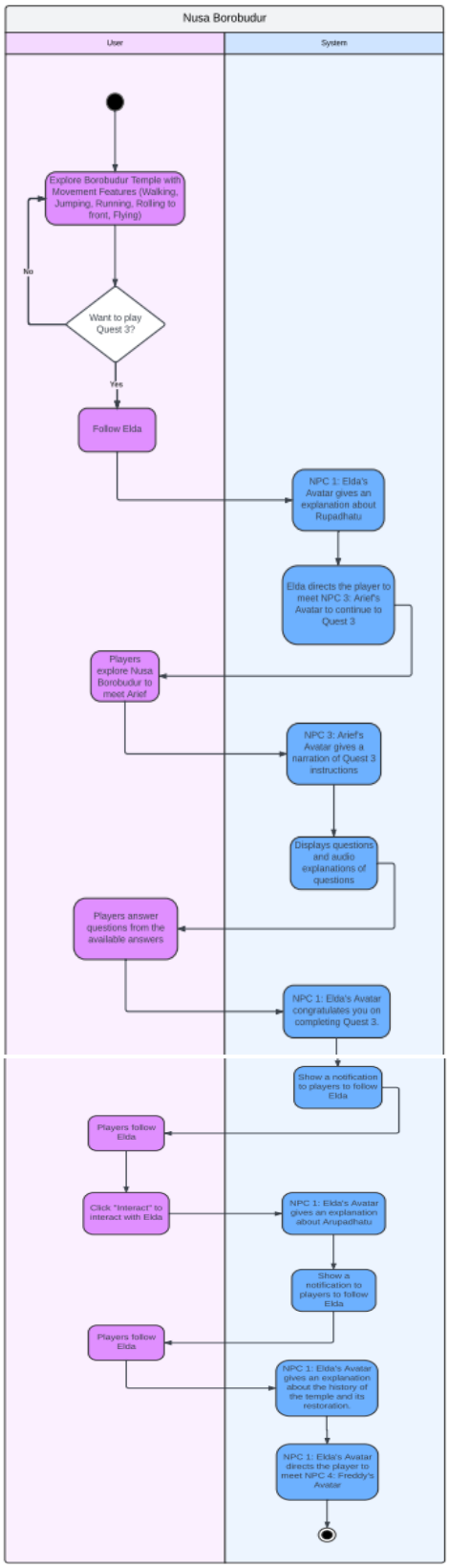

Fig. 8. Quest 2 User Experience Flow Chart

The diagram above explains the flow that players go through from finishing playing quest 1 to completing quest 2. If players don't want to complete the quest, players can explore Nusaborobudur.

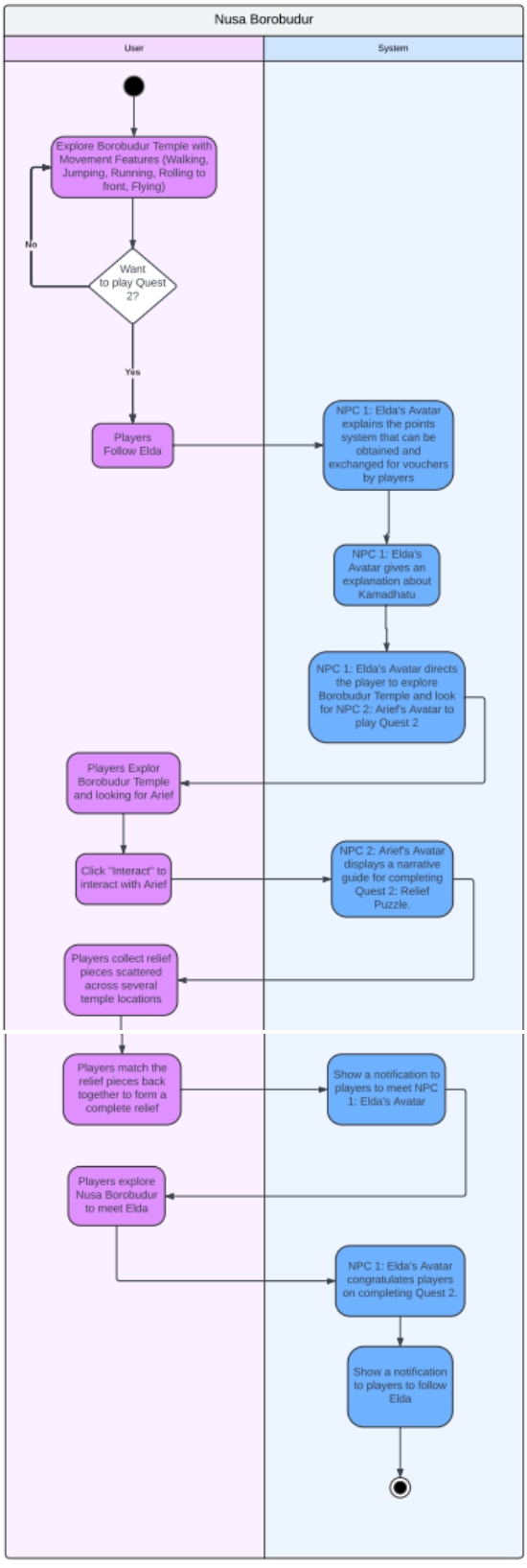

Fig. 9. Quest 3 User Experience Flow Chart

The diagram above explains the flow that players go through from finishing playing quest 2 to completing quest 3. If players don't want to complete the quest, players can explore Nusaborobudur.

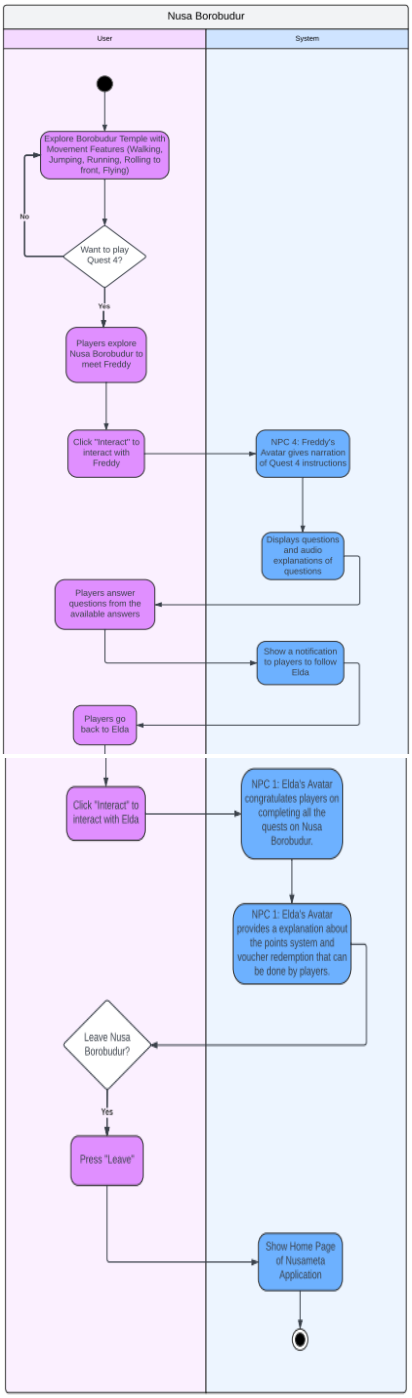

Fig. 10. Quest 4 User Experience Flow Chart

The diagram above explains the flow that players go through from finishing playing quest 3 to completing quest 4. If players don't want to complete the quest, players can explore Nusaborobudur. At the end of the quest journey, Nusa Borobudur will provide coins that can be converted to Indonesia Rupiah (Rp).

4.1.4. Preparing the User Interface

The fourth step is to prepare the user interface. The authors created four Quests in the prototype, with 1 (one) level for each Quest. The first quest is about environmental preservation, visualized in a game application; the user will clean the courtyard around Borobudur temple by collecting scattered rubbish. Then, after finishing collecting the rubbish, the user can put it into the available rubbish box, which must match the rubbish category (organic, plastic, and paper/cardboard). The correct answer will get points/coins, which will later be accumulated until the final Quest.

From the coins collected, users can redeem points to get shopping vouchers as a stimulus for shopping at souvenir/merchandise shops located near the exit gate of Borobudur temple. Here is a design of the first Quest screen:

1. *User Interface Design 1st Quest*

Fig. 11. Main Menu

Fig. 11 above is a picture of the main menu of the Metaverse based Borobudur Temple Application which contains the application title and two buttons, the first is "explore" to enter the main features of the application, and "exit" to exit the application.

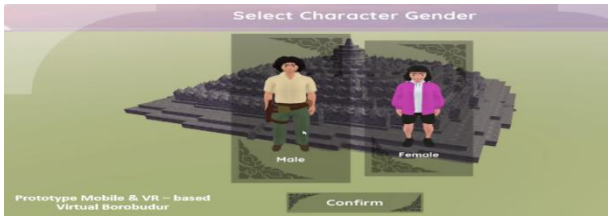

Fig. 12. Choosing Avatar

Fig. 12 above is a display for selecting an avatar where users can select the avatar they want before starting to play.

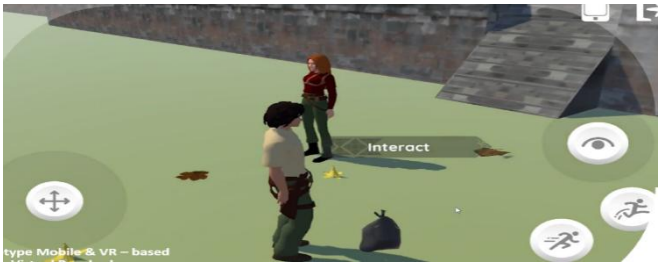

Fig. 13. Start Playing 1st Quest.

Fig. 13 above shows the display for starting the first quest, namely Litter Picking.

Fig. 14. Collecting Scattered Waste

Fig. 14 above is a display of the results of the waste that has been collected by players which must be thrown into the digital trash bin.

Fig. 15. Dispose of Waste According to category

Fig. 15 above is a display of throwing previously collected waste into a digital trash bin.

2. *User Interface Design 2nd Quest*

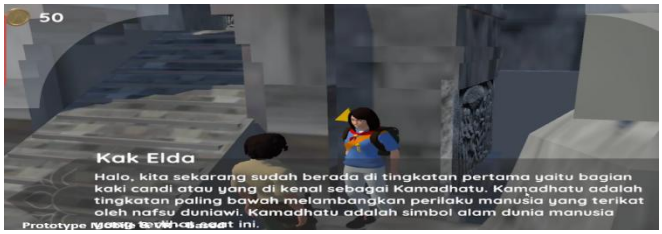

Fig. 16. UI Kamadhatu Area

Fig. 16 above is a view of the Kamadhatu area where the NPC explains about the area.

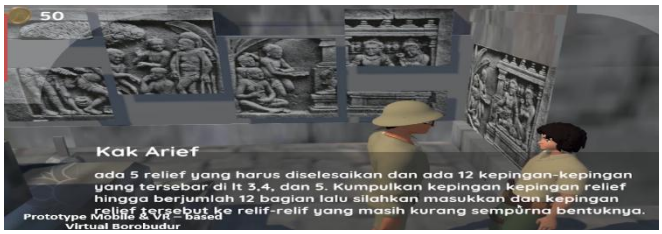

Fig. 17. Kamadhatu Area and Start Relief Puzzle Game

Fig. 17 is a view of the Kamadhatu Area where the NPC explains the game's technicalities and starts 2nd quest.

Fig. 18. UI Matching the Relief Puzzle Game

Fig. 18 above is a display where the user must match the relief puzzle pieces to complete the 2nd quest.

Fig. 19. UI Relief Puzzle Game Completed

Fig. 19 above is a display where the user successfully completes the 2nd quest Relief Puzzle Game.

3. *User Interface Design 3rd Quest*

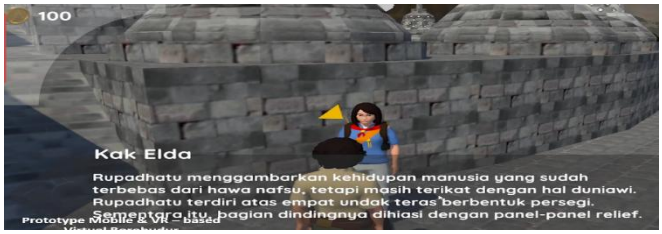

Fig. 20. UI Arupadhatu Area

Fig. 20 is a view of the Arupadhatu area where the NPC explains about the area.

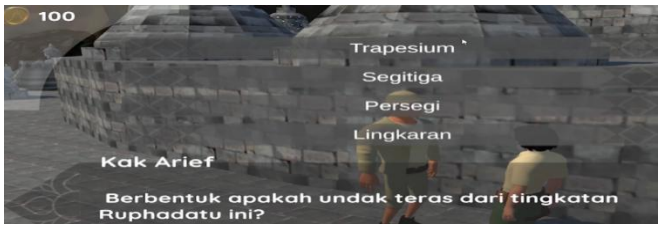

Fig. 21. UI Rupadhatu Area Answering Questions

Fig. 21 above is a view of the Rupadhatu Area and players must answer several questions to complete the 3rd quest.

4. User Interface Design 4th Quest

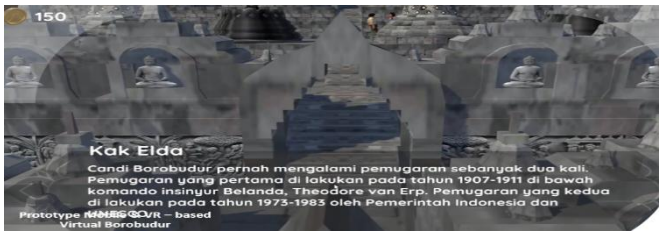

Fig. 22. UI Cut Scene Overall Borobudur Temple Area

Fig. 22 above is a cut scene overall Borobudur Temple Area before players start to play the 4th quest.

Fig. 23. UI Arupadhatu Area Answering Questions

Fig. 23 above is a view of the Arupadhatu Area and players must answer several questions to complete the 4th quest.

4.2. How to Answer Research Question 2

To answer Research Question 2, How to evaluate Borobudur Temple Metaverse Application Prototype that can achieve goals and be a solution to existing problems, following the research framework in Fig. 3.

4.2.1. Evaluate the App using ISO 25010

ISO 25010 is a quality model that is the basis of a software product quality evaluation system that has 9 characteristics, namely Functional Suitability, Performance Efficiency, Compatibility, Interaction Capability, Reliability, Security, Maintainability, Flexibility, Safety.[30]

4.2.2. Interview the Expert

The author selected 7 characteristics from 9 existing characteristics and selected 17 sub-characteristics from 39 sub-characteristics. The selection was based on the needs of the application prototype built by the author.

4.2.3. Get the Feedback Result

The author provides statement indicators that have been provided by ISO 25010 to 5 expert sources using a Likert scale of 1 - 4. Scale 1 Strongly disagree, 2. Disagree, 3. Agree, 4. Strongly Agree. The results of feedback from the experts will be displayed on the radar chart below.

4.2.4. Visualize the Result Using Radar Chart

The author also created a spider diagram (radar chart) to determine the maturity level of the application prototype that the author built and developed.

It can be seen in the image below that almost all the main characteristics have a metric value above three; Compatibility and Security characteristics have a value of 4.0, Performance Efficiency 3.8, Functional Suitability 3.7, Reliability and Interaction Capability have a value of 3.6 and Flexibility has a metric value of 3.5.

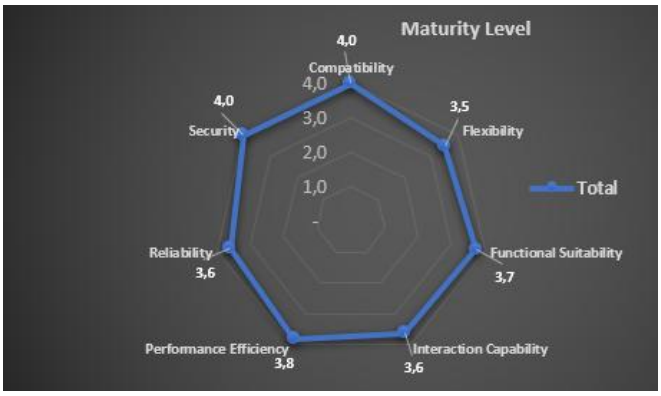

Fig. 24. Radar Chart – ISO 25010 Characteristics Maturity Level

Below is a detailed radar chart for each sub-characteristic:

Radar Chart - Sub Characteristics Maturity Level

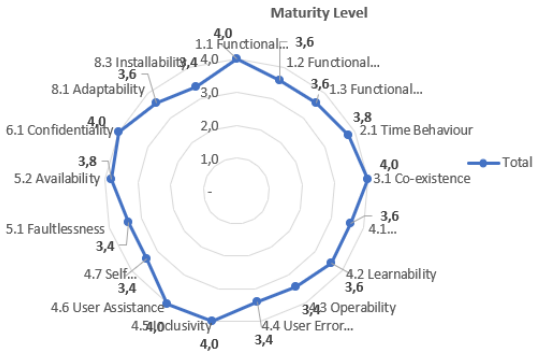

Fig. 25. Radar Chart - Sub Characteristics Maturity Level

The author concludes based on the data of the figures above, the results of the application prototype test using ISO 25010, namely the seven characteristics have a metric value above 3.5, meaning that on this scale it shows that the average respondent answered closer to "Strongly Agree" and "Agree" regarding the functional suitability and usability of the software. This indicates a high level of satisfaction with the software's ability to meet user needs in terms of functionality. This software shows high functional suitability, with most users agreeing or strongly agreeing that the software meets their needs. It covers the required functions comprehensively, users consistently receive correct results from the software, and the functions provided by the software are very appropriate to achieve user tasks and goals.

4.3. How to Answer Research Question 3

To answer the Research question 3, how to evaluate Borobudur Temple Metaverse Application Prototype based on End User Perspective, following the research framework in Fig. 4.

4.3.1. Evaluate the App Using GEQ (Game Experience Questionnaire)

The first step is to evaluate the application using GEQ (Game Experience Questionnaire). The Game Experience Questionnaire is an evaluation tool that specifically measures user experience in playing games. It has a modular structure and consists of four modules, namely The Core Questionnaire, In-Game GEQ, The Social Presence Module, dan The Post-game Module. [31]

The author prepared a GEQ questionnaire that was distributed to end users after they tried the application prototype.

4.3.2. End User Tries the Application Prototype

The number of end users who tried the application prototype was 346 people, which was specifically for end users who had a gen z demographic with an age range of 14 - 28 years. In this phase, 68% of respondents who tried the prototype and filled out the questionnaire were those aged 18-23 years, 29% of respondents were aged 12-17 years, and 3% were over 28 years.

4.3.3. End User Fills The Questionnaire

The author distributed the questionnaire after the end user tried the prototype of the Borobudur Temple Metaverse Application. Based on the data results, it was obtained that 247 people or 71% had visited and 99 people or 29% had never visited Borobudur Temple.

4.3.4. Visualize the Result Using Chart Diagram

Based on the results of the responses from the questionnaire that was filled out by end users, several data were found which are displayed in the chart diagram below.

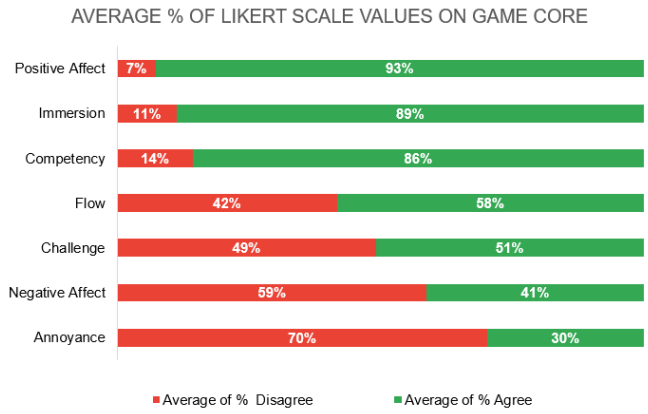

Fig. 26. Likert Scale Value % Chart on Game Core Module with Agree and Disagree Values

Based on the visual chart above, from 33 statements filled by 346 respondents then the average percentage of the Likert scale value was made in the core game module, it can be interpreted that from 346 respondents who had filled out the game experience questionnaire, namely the 'Positive Affect' category, 93% or 322 people agreed to feel a positive affect and 7% or 24 people who disagreed felt a positive affect. Then in the 'Immersion' category, there were 89% or 308 people who agreed to feel an immersive experience and 11% or 38 people who disagreed to feel an immersive experience. In the 'Competency' category, there were 86% or 298 people who agreed to feel competent and 14% or 49 people who disagreed to feel competent. In the 'Flow' category, there were 58% or 201 people who agreed to feel flowing in playing and 42% or 145 people who disagreed to feel flowing in playing. In the 'Challenge' category, there are 51% or 177 people who agree that they feel challenged in playing and 49% or 169 people who disagree that they feel challenged in playing. In the 'Negative Affect' category, there are 41% or 141 people who agree that they feel negatively affected in playing and 59% or 205 people who disagree that they feel negatively affected in playing. In the 'Annoyance' category, there are 30% or 104 people who agree that they feel annoyed in playing and 70% or 242 people who disagree that they feel annoyed in playing.

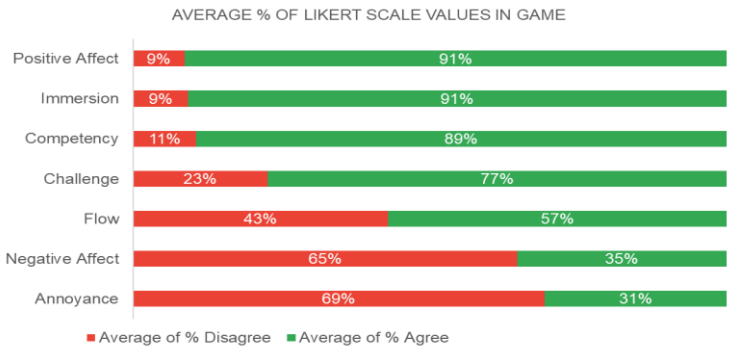

Fig. 27. Likert Scale % Value Chart In Game with Agree and Disagree Values

Based on the visual chart above, from 14 statements filled by 346 respondents then made an average % of the Likert scale value in the game, it can be interpreted that from 346 respondents who have filled out the game experience questionnaire, namely the 'Positive Affect' category, 91% or 314 people agreed to feel a positive affect and 9% or 31 people who chose not to agree felt a positive affect then in the 'Immersion' category there were 91% or 314 people who agreed to feel an immersive experience and 9% or 31 people who agreed to feel an immersive experience. Furthermore, in the 'Competency' category, 89% or 307 people agreed to feel competent and 11% or 38 people who disagreed felt competent. In the category of 'Challenge', 77% or 266 people agreed to feel challenged and 23% or 79 people disagreed to feel challenged, then in the category of 'Flow', 57% or 197 people agreed to feel flowing in playing and 43% or 148 people disagreed to feel flowing in playing. In the category of 'Negative Affect', 35% or 121 people agreed to feel negatively affected and 65% or 224 people disagreed to be negatively affected. In the category of 'Annoyance', 31% or 107 people agreed to feel annoyed and 69% or 238 people disagreed to feel annoyed.

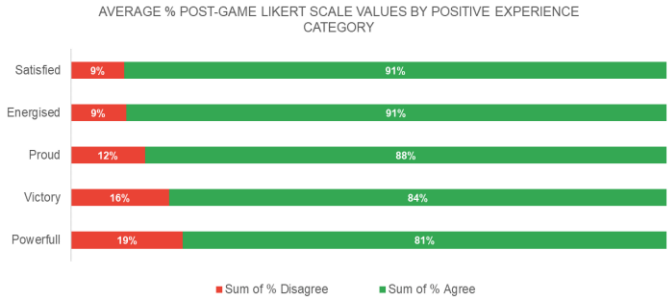

Fig. 28. Post-Game Likert Scale % Value Chart by Positive Experience Category

Based on the visual chart above, it can be interpreted that out of 346 respondents who have filled out the post-game experience questionnaire that produced an average % post-game Likert scale value based on positive experiences found in the 'Satisfied' category, there were 91% or 315 people who agreed to feel satisfied and 9% or 31 people who disagreed to feel satisfied. In the 'Energised' category, there were 91% or 315 people who agreed to feel energized and 9% or 31 people who disagreed to feel energized. In the 'Proud' category, there were 88% or 304 people who agreed to feel proud in playing and 12% or 42 people who disagreed to feel proud in playing. In the 'Victory' category, there were 84% or 291 people who agreed to feel victory in playing and 16% or 55 people who disagreed to feel victory in playing. In the 'Powerful' category, there are 81% or 280 people who agree that they feel powerful when playing and 19% or 66 people who disagree that they feel powerful when playing.

CONCLUSION

The author compiled a questionnaire referring to the GEQ framework, namely the Game Experience Questionnaire. There are 3 modules, namely the core module, the in-game module and the post-game module. The author also added statements related to the addition of knowledge and tourist satisfaction in accordance with the objectives of this study as many as 10 questions. The complete and clear research results for each statement category and also each indicator, the author presents in chapter 4 of the results and discussion of the research.

The author designed a use case diagram and system architecture for the design of the Borobudur temple metaverse application prototype. After that, the author also designed the user interface and user experience and compiled the

game flow in the form of a GDD (Game Design Document), consisting of 4 quests with each quest must be played by each user and users can explore the Borobudur virtual game by climbing and going around the entire Borobudur temple.

The results of this study can be a starting point for better further research. The suggestions for this research are that the research model that has been formed can continue to be developed by adding other research components, developing an application prototype so that it can be accessed on Android and iOS, and adding variations of games and levels of difficulty.

The author can offer suggestions for how stakeholders can better utilize the metaverse as an engaging and instructive medium to promote cultural heritage and history tourism, grow industry audiences to work with the government to further integrate the metaverse for the advancement of beneficial technology for all, and inspire community members to embrace and learn about the advancements in metaverse technology.

REFERENCES

[1] L. T. T. Tran, "Metaverse-driven sustainable tourism: a horizon 2050 paper," *Tourism Review*, no. January, 2024, doi: 10.1108/tr-12-2023-0857.

[2] G. Fazio, S. Fricano, S. Iannolino, and C. Pirrone, "Metaverse and tourism development: issues and opportunities in stakeholders' perception," *Information Technology and Tourism*, vol. 25, no. 4, pp. 507–528, 2023, doi: 10.1007/s40558-023-00268-7.

[3] J. R. Rameshwar and G. S. King, "Caribbean Metaverse Development: A Literature Review Perspective," *Journal of Metaverse*, vol. 2, no. 2, pp. 83–99, 2022, doi: 10.57019/jmv.1120470.

[4] E. C. Ciliberti, M. Fiore, and M. Mongiello, "Development of a Metaverse Platform for Tourism Promotion in Apulia," *Proceedings - 2023 IEEE International Conference on Metaverse Computing, Networking and Applications, MetaCom 2023*, pp. 680–681, 2023, doi: 10.1109/MetaCom57706.2023.00123.

[5] M. Martins, R. J. C. Guerra, L. Santos, and L. Lopes, "The exploration of the metaverse by destination management organisations towards sustainability," *Impact of Industry 4.0 on Sustainable Tourism: Perspectives, Challenges and Future*, pp. 105–117, 2023, doi: 10.1108/978-1-80455-157-820231007.

[6] S. Basheer, S. Walia, S. Farooq, M. A. Shah, and F. A. Mir, *Exploring the metaverse: The future of tourism through ai and virtual reality*. 2023. doi: 10.4018/978-1-6684-8898-0.ch012.

[7] X. Hui, S. H. Raza, S. W. Khan, U. Zaman, and E. C. Ogadimma, "Exploring Regenerative Tourism Using Media Richness Theory: Emerging Role of Immersive Journalism, Metaverse-Based Promotion, Eco-Literacy, and Pro-Environmental Behavior," *Sustainability (Switzerland)*, vol. 15, no. 6, 2023, doi: 10.3390/su15065046.

[8] C. Koo, J. Kwon, N. Chung, and J. Kim, "Metaverse tourism: conceptual framework and research propositions," *Current Issues in Tourism*, 2022, doi: 10.1080/13683500.2022.2122781.

[9] K. Peffers, T. Tuunanen, M. A. Rothenberger, and S. Chatterjee, "A design science research methodology for information systems research," *Journal of Management Information Systems*, vol. 24, no. 3, pp. 45–77, Dec. 2007, doi: 10.2753/MIS0742-1222240302.

[10] A. R. Hevner, S. T. March, J. Park, and S. Ram, "Design science in information systems research," *MIS Q*, vol. 28, no. 1, pp. 75–105, 2004, doi: 10.2307/25148625.

[11] S. T. March and V. C. Storey, "Design science in the information systems discipline: An introduction to the special issue on design science research," *MIS Q*, vol. 32, no. 4, pp. 725–730, 2008, doi: 10.2307/25148869.

[12] S. T. March and G. F. Smith, "Design and natural science research on information technology," *Decis Support Syst*, vol. 15, no. 4, pp. 251–266, Dec. 1995, doi: 10.1016/0167-9236(94)00041-2.

[13] M. N. Islam, N. I. Khan, T. T. Inan, and I. H. Sarker, "Designing User Interfaces for Illiterate and Semi-Literate Users: A Systematic Review and Future Research Agenda," *Sage Open*, vol. 13, no. 2, pp. 1–14, 2023, doi: 10.1177/21582440231172741.

[14] H. N. Meirieta, A. P. Nugroho, L. Sutiarso, and M. A. F. Falah, "Application of User Interface and User Experience for Smart Greenhouse Mobile Application Design," *IOP Conf Ser Earth Environ Sci*, vol. 1290, no. 1, 2024, doi: 10.1088/1755-1315/1290/1/012011.

[15] A. Darejeh and D. Singh, "A review on user interface design principles to increase software usability for users with less computer literacy," *Journal of Computer Science*, vol. 9, no. 11, pp. 1443–1450, 2013, doi: 10.3844/jcssp.2013.1443.1450.

[16] E. Karapanos, J. Zimmerman, J. Forlizzi, and J.-B. Martens, "User experience over time: an initial framework," in *Proceedings of the SIGCHI conference on human factors in computing systems*, 2009, pp. 729–738.
[17] R. Gupta and S. K. Pal, "Introduction to metaverse: Technology landscape, applications, and challenges," *Introduction to Metaverse: Technology Landscape, Applications, and Challenges*, pp. 1–166, 2023, doi: 10.1007/978-981-99-7397-2.
[18] H. Wang *et al.*, "A Survey on the Metaverse: The State-of-the-Art, Technologies, Applications, and Challenges," *IEEE Internet Things J*, vol. 10, no. 16, pp. 14671–14688, 2023, doi: 10.1109/JIOT.2023.3278329.
[19] O. Hashash, C. Chaccour, W. Saad, T. Yu, K. Sakaguchi, and M. Debbah, "The Seven Worlds and Experiences of the Wireless Metaverse: Challenges and Opportunities," pp. 1–7, 2023, [Online]. Available: http://arxiv.org/abs/2304.10282
[20] W. T. Lee and C. H. Chen, "Agile Software Development and Reuse Approach with Scrum and Software Product Line Engineering," *Electronics (Switzerland)*, vol. 12, no. 15, 2023, doi: 10.3390/electronics12153291.
[21] P. Teixeira, C. Eusébio, and L. Teixeira, "How to Develop Information Systems to Improve Accessible Tourism: Proposal of a Roadmap to Support the Development of Accessible Solutions," *Computers*, vol. 13, no. 3, 2024, doi: 10.3390/computers13030069.
[22] J. Vogel and R. Telesko, "Derivation of an agile method construction set to optimize the software development process," *Journal of Cases on Information Technology*, vol. 22, no. 3, pp. 19–34, 2020, doi: 10.4018/JCIT.2020070102.
[23] S. Sharma and N. Hasteer, "A comprehensive study on state of Scrum development," *Proceeding - IEEE International Conference on Computing, Communication and Automation, ICCCA 2016*, pp. 867–872, 2017, doi: 10.1109/CCAA.2016.7813837.
[24] L. Husain, T. Finlay, A. Husain, J. Wherton, G. Hughes, and T. Greenhalgh, "Developing user personas to capture intersecting dimensions of disadvantage in older patients who are marginalised: a qualitative study," *British Journal of General Practice*, vol. 74, no. 741, pp. e250–e257, 2024, doi: 10.3399/BJGP.2023.0412.
[25] E. Trisnawati, I. K. Raharjana, Taufik, A. H. Basori, N. A. Alghanmi, and A. B. F. Mansur, "Analyzing Variances in User Story Characteristics: A Comparative Study of Stakeholders with Diverse Domain and Technical Knowledge in Software Requirements Elicitation," *Journal of Information Systems Engineering and Business Intelligence*, vol. 10, no. 1, pp. 110–125, 2024, doi: 10.20473/jisebi.10.1.110-125.
[26] A. Trystan, O. Matiushchenko, O. Potapov, Y. Tertyshnik, and V. Kuznetsov, "Improving the Method for Assessing the Capabilities of Scientific Units in the Armed Forces of Ukraine," *Eastern-European Journal of Enterprise Technologies*, vol. 2, no. 4–128, pp. 23–37, 2024, doi: 10.15587/1729-4061.2024.300650.
[27] R. G. Luciano, R. G. Nabong, and M. B. Manuel, "Innovative solutions: Design and implementation of an advanced national service training program (NSTP) portal for state universities and colleges in the Philippines," *International Journal of Advanced and Applied Sciences*, vol. 11, no. 7, pp. 115–123, 2024, doi: 10.21833/ijaas.2024.07.013.
[28] W. A. IJsselsteijn, Y. A. W. de Kort, and K. Poels, "The Game Experience Questionnaire," no. 2013, 2013.