International Journal of Automation and Digital Transformation
Vol 2 Issue 1 (2023)
Pages (43 –66)

Available at www.emiratesscholar.com


# Smart Mobility Solutions through Bike Sharing System Design: A Case Study of Jerash Archaeological Site

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**Abstract**

Intelligent transport systems, or ITS, are gaining significance in transportation planning due to its capacity to enhance traffic flow, reduce environmental impact. This paper offers a case study of the Jerash Archaeological Site in Jordan's to planning and implementation of an ITS-enabled smart bike-sharing system. This system intends to assist tourists with a sustainable and environmentally friendly mode of transportation to the destination while also minimizing traffic congestion and air pollution. Smart bikes, wireless connectivity, and cloud-based data processing are combined in this technology to offer real-time information on bike availability, usage, and maintenance requirements. The article focuses into detail about the system's framework, which covers both software and hardware components, as well as the execution and user experience. User feedback, performance, and environmental impact were used to evaluate the system in future. The results indicate that the ITS-enabled smart bike-sharing system has the potential to provide a sustainable and efficient transportation solution for visitors to the Jerash Archaeological Site while also reducing traffic congestion and air pollution. The paper discusses the potential for scaling the system to other tourist destinations in Jordan and beyond.

*Keywords:* Intelligent Transportation Systems (ITS), Jerash archaeological site, smart bike sharing system, sustainable transportation, wireless communication, sustainable tourism, cultural heritage preservation, Internet of Things (IoT), Smart Transportation

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## 1. Introduction

Cities worldwide are creating more sustainable public transportation systems to address issues such as traffic congestion, emissions, accident rates, and carbon dioxide emissions; sustainable transportation systems have gained significant attention, particularly in cities and tourist sites worldwide [1], [2]. Intelligent Transportation Systems (ITS) have become integral to modern transportation networks, providing innovative technologies and approaches to enhance efficiency, safety, and sustainability [2]. ITS leverages sensors, communication devices, and data analytics to improve traffic flow, reduce congestion, and minimize environmental impact [3], [4]. One approach that has garnered popularity is the implementation of ITS-enabled smart bike-sharing systems, which provide a convenient and eco-friendly method for visitors to explore an area. Generally, smart bike-sharing systems involve bike stations equipped with electronic locking mechanisms and a mobile application that allows users to locate and rent bikes. These systems can be integrated with intelligent transportation systems (ITS) that utilize advanced technologies such as GPS, wireless communication, and sensing to manage traffic flow and improve transportation efficiency.

Sustainable smart bike design is critical to sustainable transportation planning, providing secure and convenient bicycle station facilities [5]. The design of bike-station facilities can significantly encourage more people to use bicycles for commuting, recreation, and other purposes, reducing traffic congestion and emissions while promoting healthier lifestyles [6], [7]. ITS can be used in sustainable bike design to optimize station capacity and promote sustainable transportation modes such as shared mobility services [2]. Location, capacity, security, accessibility, and sustainability must be considered when planning and designing bike facilities [3], [6]. Smart Effective bike station design can have numerous benefits, including reducing traffic congestion, improving air quality, promoting physical activity, and enhancing the overall livability of urban areas [8]; [9]; [10]. Thus, bike-station design is essential to sustainable transportation planning, providing a viable alternative and helping to create more resilient and sustainable communities. Bike-sharing systems have become a sustainable and convenient transportation option for users in urban areas worldwide [10]. Designing effective smart bike-sharing systems requires careful consideration of multiple factors, including location, capacity, security, accessibility, and sustainability [3].

These systems typically involve a network of stations or hubs where users can pick up and drop off bicycles, accessed through a mobile application or a smart card, and charged based on the duration of use [4]. Advanced technologies like smart locks, bike-sharing systems, and real-time information about station availability can enhance the efficiency and safety of transportation systems for cyclists [8]. ITS can also include using data analytics and modeling to improve the planning and design of bike station facilities, taking factors such as demand, location, and accessibility into account [11]. smart Bike-sharing systems can offer numerous benefits, including reducing traffic congestion, promoting physical activity, enhancing air quality, and improving the overall livability of urban areas [10]; [12]. Integrating ITS with heritage preservation practices can provide a platform for the sustainable management of heritage sites, preserving their cultural value while accommodating modern transportation needs [2]. Therefore, integrating ITS and sustainable smart bike design has become essential for traffic management in cities and tourist destinations, promoting sustainability, safety, and visitor experience [9]. The advantages of implementing a smart bike-sharing system for sustainable transportation are many; they can generate revenue for a site through bike rental fees and associated services [6]. The combination of sustainable smart Bike design and intelligent transportation systems (ITS) provides a comprehensive solution for traffic and station management, particularly in urban areas and tourist destinations [2]. Implementing sustainable smart Bike design and intelligent transportation systems (ITS) can help reduce traffic congestion, minimize carbon footprint, and enhance the visitor experience, thereby minimizing the need for expensive and harmful to the environment smart Bike infrastructure [9]. The Jerash Archaeological Site in Jordan is a historical site where Intelligent Transportation Systems (ITS) can be implemented to improve the visitor experience while preserving its cultural heritage. Integrating various technologies, including mobile applications, smart signs, and location-based services, can provide visitors with real-time information and guidance while minimizing the impact of transportation on the site's physical and cultural integrity [6], [7]. Implementing designated smart Bike areas and a bike-sharing program outside the site in the visitor center can provide visitors with alternative modes of transportation; a digital way-finding system can assist visitors in navigating the site, providing digital maps and information about the site to enhance their experience [14]. Integrating sustainable smart Bike design and ITS can transform traffic and smart Bike sharing system management, improving safety and minimizing envi-

ronmental impacts [9]. The proposed transportation systems in Jerash Archaeological Site aim to improve the visitor experience, reduce traffic congestion, and enhance safety within the site. Intelligent Transportation Systems (ITS) have emerged as a promising solution for managing smart Bikes at archaeological sites. This study presents a case study of ITS-enabled sustainable smart Bike design at the Jerash archaeological site in Jordan. The proposed transportation systems can promote sustainability, safety, and visitor experience while minimizing the impact on the site's cultural heritage. In this context, exploring the design and implementation of an ITS-enabled smart bike-sharing system for sustainable transportation is essential. This article discusses at the various technologies and frameworks that could support the system, as well as the possible benefits and problems of implementing it. The goal is to provide insights into the development of sustainable transportation solutions while also inspiring additional research and innovation in this field. These findings could be replicated in other regional archaeological sites, providing a comprehensive solution for traffic and applying smart Bikes. Integrating Intelligent Transportation Systems (ITS) with heritage preservation practices can support the sustainable management of heritage sites by preserving their cultural value while accommodating modern transportation needs. Conducting a comparative analysis between the ITS-enabled smart bike-sharing system proposed for the Jerash Archaeological Site and existing transportation systems or bike-sharing programs would shed light on the advantages of the proposed system. By evaluating factors such as integration with existing infrastructure, user experience and convenience, sustainability and environmental impact, and performance and scalability, researchers can highlight the specific benefits of the ITS-enabled smart bike-sharing system. This analysis would provide a comprehensive understanding of how the proposed system outperforms other transportation options in terms of seamless integration, user-friendly features, sustainability practices, and adaptability to fluctuating visitor demand. By emphasizing the advantages of the proposed system over existing solutions, stakeholders make informed decisions and prioritize the implementation of the ITS-enabled smart bike-sharing system in archaeological sites and similar contexts.

### *1.1. Site description*

Jerash Archaeological Site is a well-preserved ancient Roman city located in Jordan, situated approximately 48 kilometers north of Amman. The site is one of the well-preserved Roman cities globally, covering an area of around 610,000 square meters and featuring a variety of well-preserved Structures (Figure1). The site also contains a collection of Ottoman-period Jordanian houses and several Byzantine-era Churches [15]. The Roman city of Jerash was founded in the first century AD, reaching its zenith during the third century AD [16]. Although it was established during the Hellenistic period and initially influenced by Greek culture, the city was extensively developed during the Roman period and became a significant center for trade and commerce, renowned for its impressive architecture and well-preserved columns, arches, and mosaics [17].

The city was abandoned in the seventh century, and its ruins were rediscovered in the nineteenth century. Today, the Jerash Archaeological Site is an exceptional cultural monument as well as one of the most important archaeological sites in the Middle East, attracting people from all over the world. The Jordanian Department of Antiquities has methodically conserved and repaired the UNESCO World Heritage Site of Jerash (Figure 2).The architecture of the site represents the city's Roman and Byzantine origins, with structures such as the Cardo Maximus and the Temple of Zeus displaying elaborate Roman and Byzantine architectural features such as columns, arches, and mosaics [13], [15]. The site also has well-preserved items like pottery, coinage, and jewelry, which provide insight into the daily life of the city's occupants during the ancient Roman and Byzantine periods [17].

*1.1.1.*

*Figure 2: Buffer zone the Jerash archaeological site (Anglin, 2012).*

• *Urban Heritage in Jerash Archaeological Site.* Jerash, also known as Gerasa, was founded by the Romans in the early second century BC and is one of the best-preserved ancient cities in the world. Jerash is a city in northern Jordan known for its uphill topography and suitable Mediterranean climate. The city landscape includes both the heritage part, consisting of ancient public buildings, and the modern city, built on the ancient inhabited area, with the two parts connected only by an ancient Roman bridge over Jerash River [18]. The historic part of Jerash covers an area of about 1.5 km x 1.0 km and is particularly valuable for its many splendid monuments and intact city layout. The existence of urban heritage within the frame of the modern city brings advantages for the local communities, particularly in terms of the tourism activities based on such heritage. However, the condition of the urban planning system in the modern part of the city, as connected

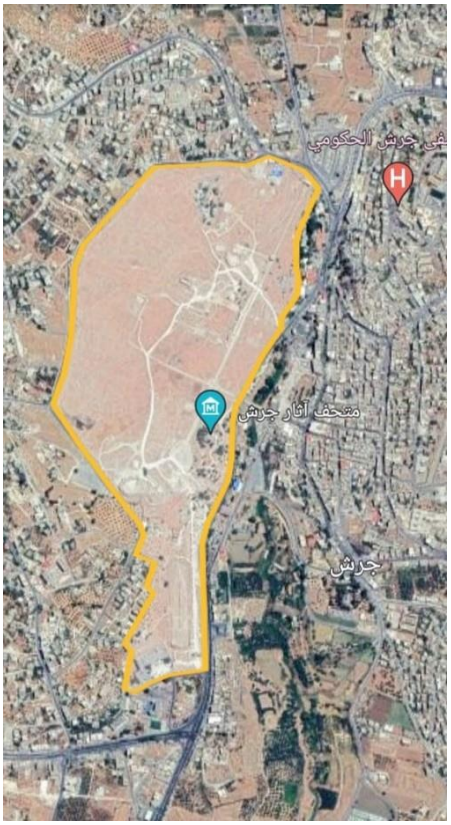


Figure 1:

with the ancient part, plays an important role in achieving a sustainable tourism industry in Jerash.

Improper systems may lead to major threats for the urban heritage and subsequently the source of tourism in the city, which may end with severe degradation and destruction of this heritage site over time [17]. These main concerns will be covered in coming sections to make a realistic assessment of the urban system in the modern Jerash city and its interaction with its archaeology, to provide important recommendations for the improvement of the current system. The urban morphology of Jerash is heavily influenced by the extensive archaeological site, which holds significant international importance. The site is situated across a wadi from the urban core, connected by a Roman bridge (the South Bridge) [13]. This archaeological site, the Roman Decapolis City of Gerasa, is the second largest tourist destination in Jordan and is under the jurisdiction of the Department of Antiquities. It encompasses the western half of the walled city, bordered by the Irbid Road, and extends southwards to include the Hippodrome and Hadrian's Gate [15], [18].

As the number of visitors to the Jerash archaeological site grows as shown in figure 5, innovative mobility solutions are required. Developing a smart bike transportation network is one such strategy that can help minimize in the streets, pollution in the air, and the number of parking required. Intelligent Transportation Systems (ITS) relate to the integration of information and communication technology in the transportation industry.

ITS can provide services that improve the overall efficiency, safety, sustainability, and environmental friendliness of transportation systems by gathering data from sensors and equipment installed in cars and infrastructure [19]. As a result, by establishing a smart bike transportation network in Jerash, we can use ITS to create a more sustainable, efficient, and delightful experience for both visitors and locals.

## 2. Methodology

Smart Bike design involves the planning and implementation of facilities that provide secure, convenient, and accessible station for bicycles. Designing a sustainable smart Bike system and implementing intelligent transportation systems (ITS) at an archaeological site like Jerash, Jordan can be a challenging. By following this methodology, we can develop and implement a sustainable smart Bike and transportation system that meets vis-

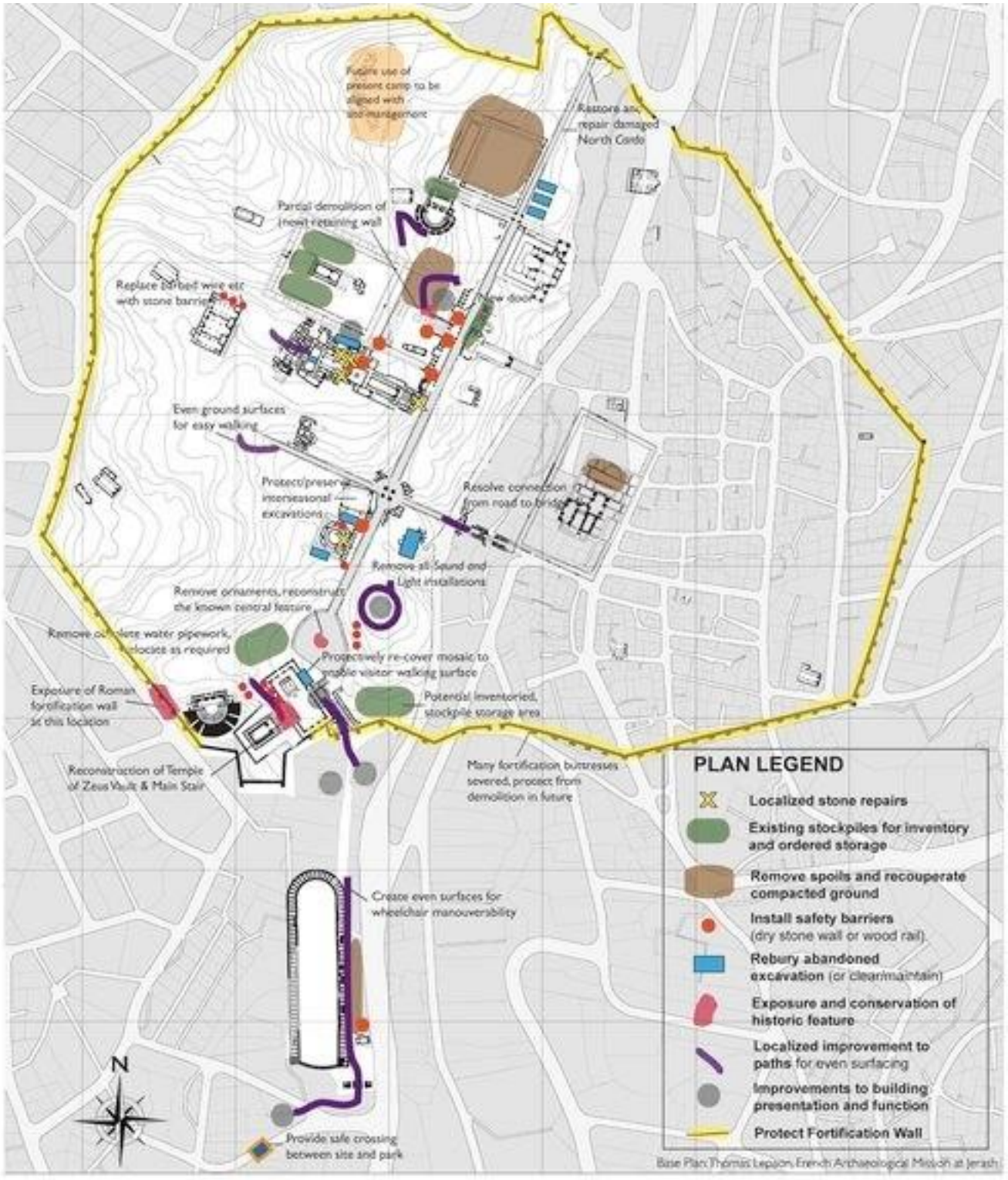


Figure 2:

Chart 1: Average number of visitors Jerash archaeological site (2017-2022)1

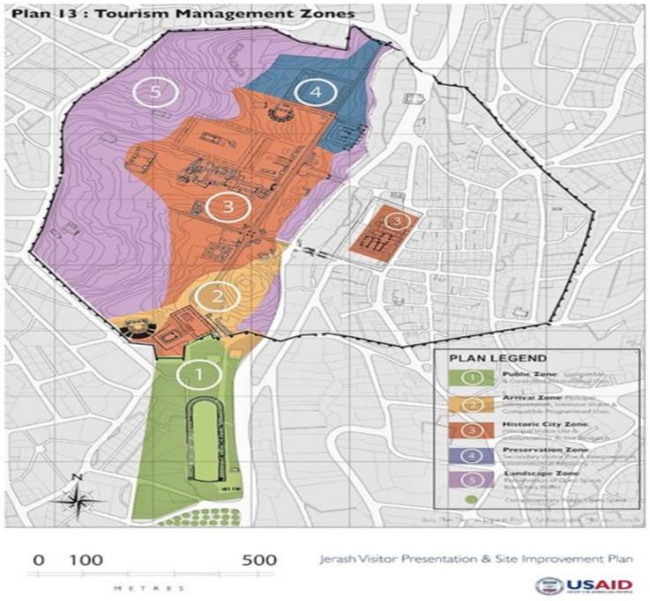


Figure 3: Mixed land use to the archaeological site.

itor needs while minimizing negative environmental impacts at historical and cultural sites. Here is a suggested methodology for this project:

1. Site Analysis: by conducting a comprehensive site analysis to determine the smart Bike station needs, this would involve analyzing visitor data, conducting surveys, and consulting with site management and local stakeholders, Visitor flow and existing transportation infrastructure. Smart Bike facilities should be located in areas that are easily accessible and visible, to encourage their use and deter theft. This analysis includes a study of the historical and cultural significance of the site, as well as the current and projected tourism levels.

2. Identify Goals: Develop a set of goals for the project that align with the site's historical and cultural significance, the needs of visitors, and sustainability principles in design the smart bike sharing system. This would include determining the number and location of bike stations, selecting appropriate bike models, and designing the mobile application and backend software.

This involves assessing the number of people who are likely to use a particular bike, to improving visitor experience.

3. Develop a Conceptual Design: This design includes the location and layout of smart Bike station, the routing of traffic and the placement of intelligent transportation systems (ITS) infrastructure such as sensors, and cameras. This may involve installing locking mechanisms or using surveillance cameras to monitor the area. Smart Bike facilities should be designed to be accessible to all users. This may include ensuring that the facilities are on level ground, that there is enough space for maneuvering, and that the smart bike station racks are at a suitable height. Smart Bike facilities should be developed with sustainability in mind, utilizing long-lasting and environmentally friendly materials. This could include designing with recycled materials.

4. Technology Selection: Selecting appropriate technologies for the system, GPS, wireless communication systems, sensing technologies, and dataset frameworks. This involve considering factors such as cost, reliability, and scalability.

5. Implementation Plan: Based on the results of the simulation and optimization, developing an implementation plan for the smart Bike and transportation system. This plan includes a timeline, budget, and resources required for implementation. It also considers any potential challenges or obstacles, such as cultural or environmental concerns.

## 3. Related Works and Structure of the Paper

The Internet of Things (IoT) has dramatically modified our courting with generation significantly, Integrating IoT, data-driven decision making, and user-centric design principles address the challenges faced by appling bike-sharing systems at the Jerash Archaeological Site. The Internet of Things (IoT) technology has been used in a variety of fields, including healthcare, public transportation,

and education [20].The researchers are currently growing interested in the integration of Internet of Things (IoT) technology into e-bike rentals due to its potential for improving bicycle utilization as well as reliability [21]. The objective of this literature review involves looking into the integrating of Internet of Things (IoT) technology into self-service smart bicycles, in addition to provide an overview of the most recent research on bike-sharing systems, including their benefits and limitations, components influencing their acceptance, and impact on mobility Using self-service smart bicycles are an imaginative mode of transportation that provides users with a convenient and ecologically responsible mode of transportation [22]. These bicycles typically have a locking mechanism that allows users to unlock and rent them using a smartphone app [23], [24]. Internet of Things (IoT) technology can enhance the functionality of self-service smart bicycles by providing real-time data on the location, condition, and usage [20], [21]. Previous research has utilized various methodologies, including data collection methods [21], analysis techniques [24], simulation models [23], and user surveys [20], to address these challenges.

Several studies on the integration of Internet of Things (IoT) technology into self-service smart bicycles have been done. [22] Showed a smart bicycle-sharing system that use Internet of Things (IoT) technology to provide clients with real-time bicycle availability and geographic data. Using sensors, GPS, wireless communications, or fiber, the system collects and transmits data to a centralized server. The authors performed a simulation have a look at to assess the overall performance of the proposed system and found that it can improve the efficiency and reliability of bicycle-sharing systems. In another study, [5] proposed a smart bicycle lock that uses Internet of Things (IoT) technology to provide users with a secure and convenient way to lock and unlock bicycles. The system uses Bluetooth Low Energy (BLE) technology to communicate with the user's smartphone and unlock the bicycle automatically when the user is in proximity. The authors conducted a user study to evaluate the usability and security of the system and found that it can provide users with a seamless and secure experience. [25] Proposed a smart bicycle system that integrates Internet of Things (IoT) technology to provide users with real-time data on the condition and performance of the bicycle. The system uses sensors and wireless communication to collect and transmit speed, distance, and battery-level data. The authors conducted a field study to evaluate the system's performance and found that it can provide users with valuable information on the condition and performance of the bicycle.

Bike-sharing systems offer a range of benefits, including improved access to transportation [4], reduced traffic congestion [11], and improved public health [6]. Studies [5], [26], [27] have shown that bike-sharing systems can increase the number of trips made by bicycle, reduce car use, and promote physical activity; bike-sharing systems have also improved access to public transportation. However, despite their benefits, bike-sharing systems face several challenges, including ensuring the availability and maintenance of bicycles [4], issues related to theft [5], vandalism [14], and user behavior [27], and concerns regarding safety and liability [27]. Several factors influence the adoption of bike-sharing systems, including individual, trip, and system characteristics. System characteristics such as the availability of bicycles, pricing, and ease of use are also important factors [12]. The adoption of bike-sharing systems has the potential to promote sustainable transportation and improve the overall transportation system. However, careful attention must be given to the design and implementation of such systems to ensure their success [7]. Safety and liability concerns have also been raised, particularly in areas with limited cycling infrastructure [23]. The integration of Internet of Things (IoT) technology into self-service smart bicycles has the potential to enhance the functionality and performance of bicycles. The studies reviewed in this literature review [15], [17], [20], [21], [23] demonstrate the various ways in which Internet of Things (IoT) technology can be incorporated into self-service smart bicycles to provide users with real-time data on the location, condition, and performance of the bicycles. Further research is needed to evaluate the effectiveness and usability of these systems in real-world settings and to identify potential challenges and limitations. The literature review highlights the challenges and opportunities in designing bike-sharing systems for archaeological sites. It emphasizes the importance of usability, scalability, integration, user experience, and sustainability. While previous studies have made progress, there are still gaps and areas for further research, including site-specific considerations, standardized evaluation frameworks, and the integration of emerging technologies. By addressing these research directions, bike-sharing systems can be tailored to meet the needs of archaeological sites, providing sustainable and user-friendly transportation options while preserving cultural heritage.

## 4. Data Analysis and Findings

- **Smart bike systems**

The Internet of Things (IoT) has impacted how we converse with technology. Internet of Things (IoT) technology has been applied to various domains, including transportation, healthcare, education, and many others [20]. In recent years, the integration of Internet of Things (IoT) technology into bicycles has been gaining attention due to its potential to enhance the functionality and performance of bicycles [21]. This literature review aims to explore integrating Internet of Things (IoT) technology into self-service smart bicycles and propose an analysis of current bike-sharing system studies, including their benefits and challenges, factors influencing their adoption, and their impact on transportation behavior. Self-service smart bicycles are an innovative mode of transportation that provides users with a convenient and eco-friendly way to get around [22]. These bicycles typically have a locking mechanism that allows users to unlock and rent them using a smartphone app [21], [22]. Internet of Things (IoT) technology can enhance the functionality of self-service smart bicycles by providing real-time data on the location, condition, and usage [18], [19].

Several studies have explored the integration of Internet of Things (IoT) technology into self-service smart bicycles. [26] Proposed a smart bicycle-sharing system incorporating IoT technology to provide users with real-time information on the availability and location of bicycles. The system uses sensors, GPS, and wireless communication to collect and transmit data to a centralized server. The authors conducted a simulation study to evaluate the performance of the proposed system and found that it can improve the efficiency and reliability of bicycle-sharing systems. In another study, [5] proposed a smart bicycle lock that uses Internet of Things (IoT) technology to provide users with a secure and convenient way to lock and unlock bicycles. The system uses Global Positioning System (GPS) technology to communicate with the user's smartphone and unlock the bicycle automatically when the user is in proximity. We conducted a user study to evaluate the usability and security of the system and found that it can provide users with a seamless and secure experience. [25] Proposed a smart bicycle system that integrates Internet of Things (IoT) technology to provide users with real-time data on the condition and performance of the bicycle. The system uses sensors and wireless communication to collect and transmit speed, distance, and battery-level data. The authors conducted a field study to evaluate the system's performance and found that it can provide users with valuable information on the condition and performance of the bicycle.

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- **Site analysis**

Before designing the bike-sharing system, it is important to thoroughly analyze the archaeological site, considering factors such as the site's size, terrain, visitor flow, and existing transportation infrastructure. By Wireless communication in the operation and management of smart bike-sharing systems, Jerash Archaeological Site will include a wireless communication system to enable real-time data transmission between the smart bikes, the central server, and the users' smartphones [20]. The smart bikes will be equipped with GPS and cellular modules that transmit data on the location, condition, and usage of the bikes to the central server [21]. The server uses cloud-based data analysis to process the data and provide real-time information on bike availability and usage to the users' smartphones [7]. The use of wireless communication in the smart bike-sharing system at Jerash Ar-

chaeological Site has several advantages. Firstly, it enables real-time monitoring of bike availability and usage, which helps optimize bike distribution across the site and ensures that users can easily find and rent bikes. Secondly, it enables remote monitoring of bike maintenance needs, such as battery level and tire pressure; it contributes to the bike's motorcycles constantly being in good functioning order and ready to use. Thirdly, it enables efficient communication between the users and the system, which helps to enhance the user experience and encourage more people to use the system. However, several difficulties are connected to wireless communication in the smart bike-sharing system at Jerash Archaeological Site. One challenge is the potential for signal interference or loss of connectivity, which could disrupt the system's operation and cause inconvenience for users. Another challenge is adequate network coverage and bandwidth to ensure reliable and fast data transmission between the bikes and the central server. a sufficient technical setup for the Jerash Archaeological Site include a robust internet infrastructure with high-speed connectivity, encompassing wired and wireless options like fiber optic cables, Wi-Fi, and cellular networks. This infrastructure ensures seamless data transmission and communication among different components of the system. Adequate network coverage is essential throughout the site, achieved through strategically placed access points or cellular towers. Data processing involves collecting information from various sources such as GPS sensors on bikes and sensors at bike stations. This data encompasses bike locations, availability, occupancy, and other relevant metrics. Collected data is typically stored in a centralized database or cloud-based storage system, allowing for efficient management, retrieval, and analysis. The choice of database technology depends on factors like scalability, reliability, and security requirements. Advanced data processing techniques like data mining, machine learning algorithms, or statistical analysis can be employed to gain insights into user behavior, optimize bike allocation, predict demand patterns, and enhance system performance.Communication protocols play a vital role in the functioning of the bike-sharing system. Bike-to-station communication can employ protocols such as Bluetooth, Zigbee, or RFID for tasks like bike locking/unlocking and real-time status updates, including bike availability information. Station-to-management system communication relies on standard protocols like HTTP or MQTT to transmit data related to bike availability, occupancy, maintenance requests, and system updates. User interface communication occurs through mobile applications or web interfaces, ensuring secure transactions and protecting user data using protocols like HTTPS.

- **Target users**

The target users of the bike-sharing system at Jerash Archaeological Site may vary based on several factors, such as age, physical ability, and travel patterns. The Jerash Archaeological Site is a popular tourist destination, and the bike-sharing system may attract individuals of varying ages. Younger visitors are more inclined to use the bike-sharing system to explore the site, while older visitors may prefer to take advantage of the system's convenience and ease of use. The bike-sharing system also targeted individuals with varying physical abilities. The system may appeal to visitors who need help walking or can walk long distances but still want to explore the site. The availability of electric bikes or bikes with adjustable seats may make the system more accessible to individuals with physical limitations. Visitors who plan to spend an extended period at the site may benefit from the system's availability, as they can rent bikes for more extended periods and explore the site at their own pace. Visitors who prefer to travel independently and at their own pace find bike-sharing more appealing than guided tours.

- **Bike models**

The choice of Electric bikes model (figure 6) for the Jerash Archaeological Site is based on the site's terrain and the users' needs; Electric bikes are a great option for visitors who want to explore the site but may need the physical ability to ride traditional bikes. They are equipped with a battery-powered motor that assists when pedaling, making it easier to climb hills and cover longer distances.

- **Bike-sharing plan**

Smart bike-sharing systems have tackled various issues associated with bike-sharing programs by implementing electronic unlocking and user identification features [22]as shown the steps in figure 7. Requiring users to input their credit card information before borrowing a bike enables bike-sharing companies to impose charges for any damage or theft, which is a strong deterrent , station-less bike-sharing system provides on-demand services via a mobile phone application (app) [22] As the buffer zone is covered by a wireless internet network. Adopting technological solutions has also enabled cities to offer a more efficient and effective bike-sharing service [19]. For instance, sensors installed in bike-sharing docking stations collect real-time data that can be used to plan and manage the service and customize it to meet users' needs better [18], [23]. Many smart bike-sharing services provide live maps showing bikes' availability at different loca-

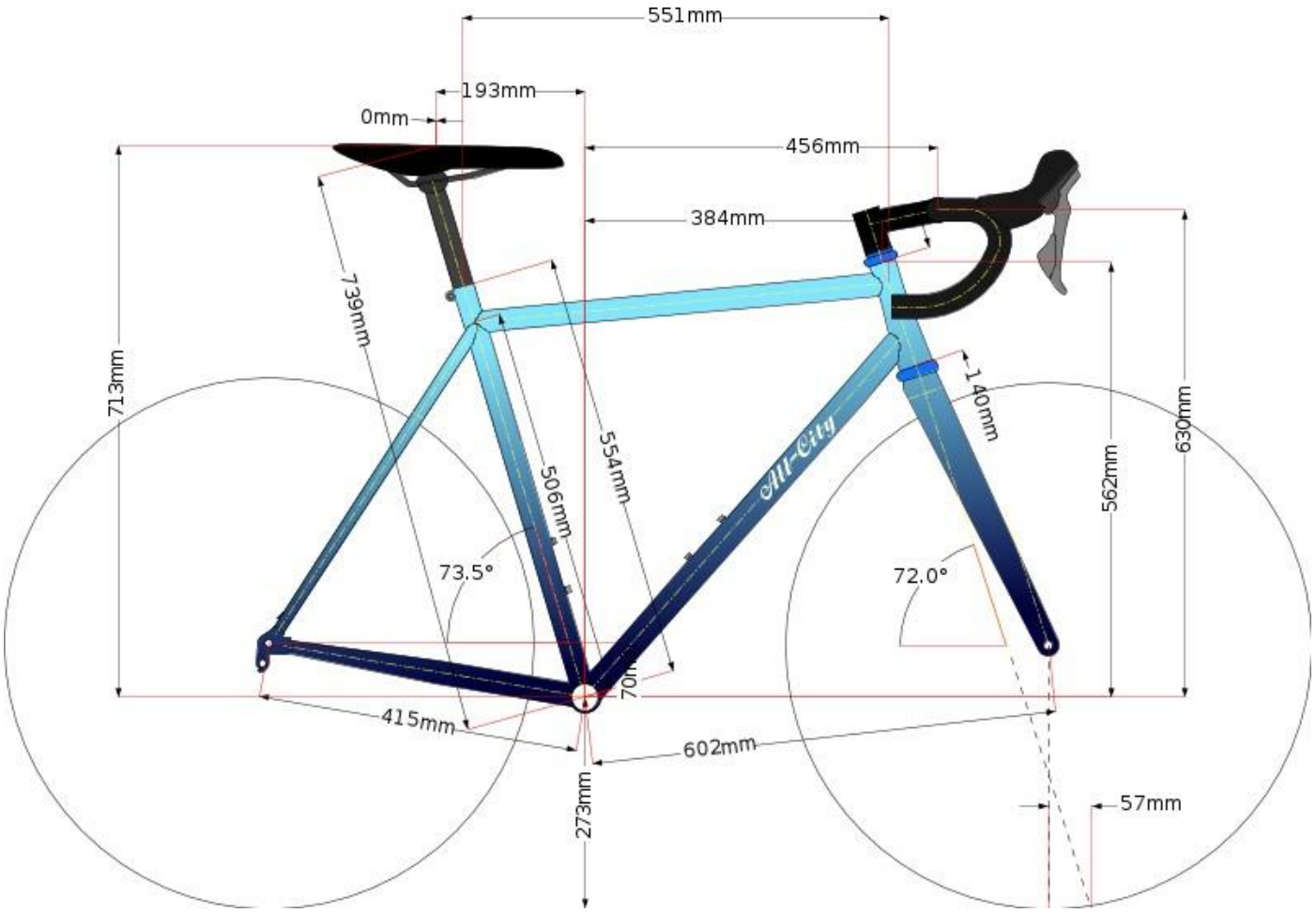


Figure 4: Electric bikes model (https://www.bikecad.ca)

tions, while research is underway to develop methods for remotely detecting broken bikes to facilitate swift repairs or replacements [24]. It's easy to find a Bike Share anywhere in their network using an app. download the app, and it tells you how many bikes [10], enables users to rent and return bikes using their smartphones require careful consideration of several factors.

Designing a successful Internet of Things (IoT) enabled a bike-sharing system that

These factors include equipping bikes with GPS systems for real-time tracking, developing a mobile the application that enables users to locate nearby bikes and manage their rentals, creating a payment system that allows for convenient payment through various means, equipping bikes with smart locks to eliminate the need for physical keys or combination locks, implementing a user verification process to ensure authorized usage, and implementing a user rating system for feedback and service improvement [17], [23]. By focusing on these factors, designers can create an efficient and sustainable bike-sharing system that reduces traffic congestion and carbon footprint in urban areas. An effective IoT-enabled bike-sharing system can improve the accessibility and convenience of bike rentals, encourage more sustainable modes of transportation, and enhance the overall transportation efficiency of a city. By considering the specific needs and context of the urban area, we can develop a system that meets the requirements of both users and the environment, providing a valuable service that contributes to the development of smart and sustainable cities.

- **Install bike stations**

They are installing bike stations in strategic locations throughout the Jerash Archaeological Site in the major attractions as transportation hubs and visitor centers. The station has enough space to accommodate the bikes and visitors, and it should be well-lit and secure, with adding


3. RETURN
Find the nearest station by using the mobile app to return your bike.
2. PICK UP
At the T-bike station, the customer simply picks up his reserved bike and pays for it using the digital mobile pass.
1. FIND & RESERVE
T-pass, a digital mobile pass, holds the required info of the user, as well as funds to facilitate checkout and authentication.
Bike availability can be checked using a mobile application to reserve a bike in advance.
CLICK
FIND
RESERVE
MOBILE APPLICATION

Figure 5:


Figure 6:

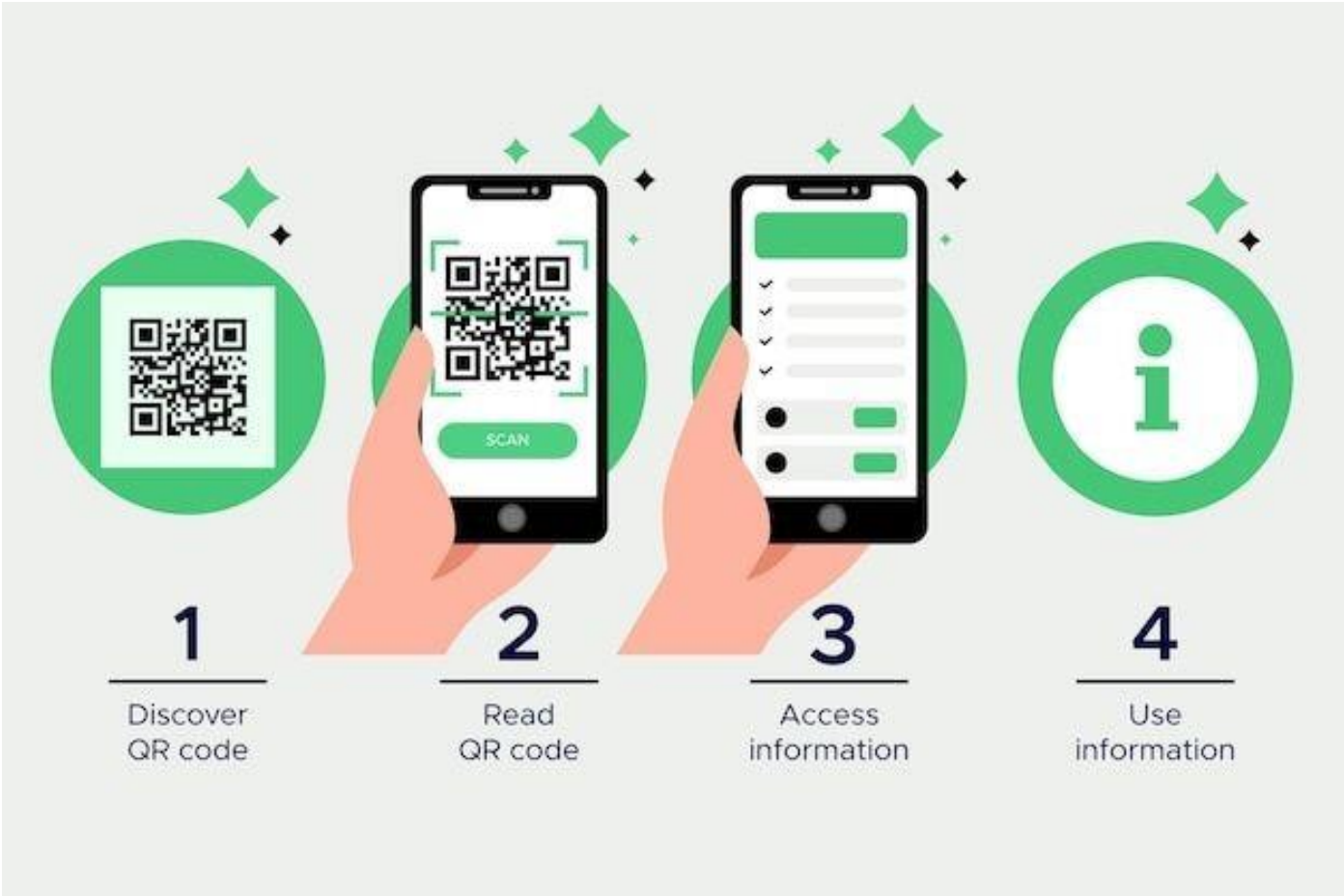


Figure 7:

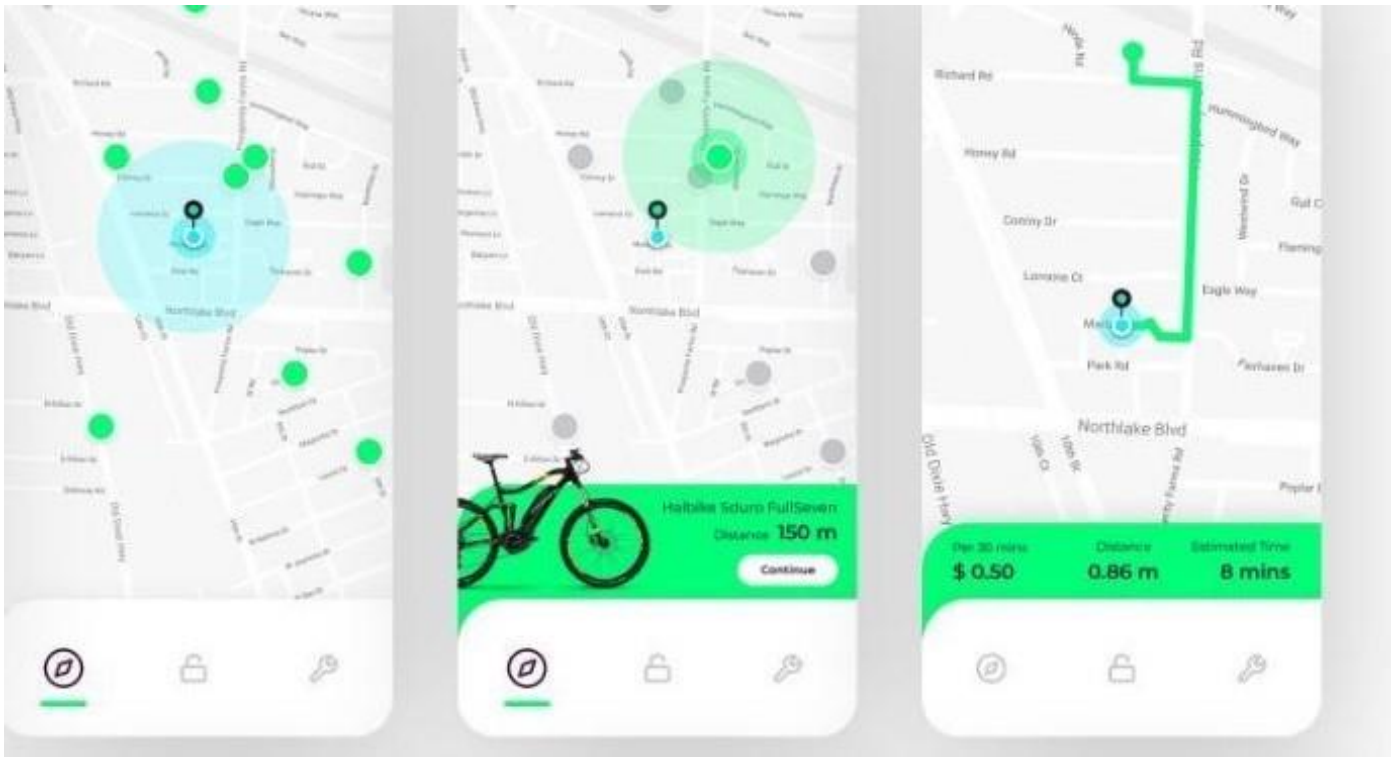


Figure 8:


Figure 9:

bike racks or a bike share system to make it easier for visitors to rent and return bikes. They are promoting the bike stations through signage, brochures, and other marketing materials, ensuring visitors know the stations' locations, hours of operation, and rental fees. Regularly maintain the bike stations to ensure they are clean, functional, and secure. Provide regular inspections and repairs to the bikes and the station infrastructure. The stations are securely anchored to the ground and are easily visible and accessible to visitors.

## 5. Result

The successful implementation of an ITS-enabled smart bike-sharing system at the Jerash Archaeological Site could bring several benefits, including improved sustainability, enhanced visitor experience, and increased data-driven insights for site management.

Implementing a smart bike-sharing system could provide visitors with a sustainable transportation option, reduce noise pollution and improve air quality, creating a more pleasant environment for visitors to enjoy. The smart bike system could enhance the visitor experience by providing convenient and accessible transportation, allowing them to explore the site conveniently. Visitors could easily rent a bike from a nearby station and explore the site without needing a guided tour or personal vehicle. The system could provide valuable data insights on visitor behavior and preferences, which could be used to improve site management and inform future sustainability initiatives. For example, data on popular bike routes and usage patterns could inform on-site maintenance and development decisions. In contrast, visitor feedback and complaints data could be used to enhance the overall tourist experience. The successful implementation of an ITS-enabled smart bike-sharing system at the Jerash Archaeological Site could lead to multiple positive outcomes, including improved sustainability and enhanced visitor experience; the system could provide visitors with a convenient and accessible transportation option, allowing them to explore the site at their own pace and convenience, and increased data-driven insights for site management. Implementing a smart bike-sharing system could provide visitors with a convenient and sustainable transportation option to explore the site. IoT technology could enable real-time monitoring and management of bike availability, usage, and maintenance, ensuring a consistent and reliable user experience. Bike stations could be monitored remotely, and any bike availability or maintenance issues could be quickly identified and addressed. IoT technology could enable real-time monitoring and management of bike availability, usage, and maintenance, ensuring a consistent and reliable user experience. The system could provide valuable data on visitor behavior and preferences, which could be used to improve site management and inform future sustainability initiatives.

## 6. Conclusion

Implementing sustainable smart bike-sharing systems and intelligent transportation systems at archaeological sites is crucial to minimizing negative environmental impacts and improving the visitor experience. Implementing a sustainable, innovative bike-sharing system, specifically an ITS-enabled smart bike-sharing system, at the Jerash Archaeological Site could bring numerous benefits. By providing a convenient and sustainable transportation option, the system could reduce the environmental impact of tourism while enhancing the visitor experience. IoT technology could enable real-time monitoring and management of bike availability, usage, and maintenance, ensuring a consistent and reliable user experience. Additionally, the system could provide valuable data insights on visitor behavior and preferences, which could be used to improve site management and inform future sustainability initiatives.

However, it is important to note that implementing sustainable smart bike-sharing system design and ITS at archaeological sites requires considering the site's historical and cultural significance, local community involvement, and the use of ITS technologies. Further research is needed to explore the applicability of these strategies to other archaeological sites and to address the challenges of maintaining cultural heritage sites in the context of tourism and sustainable development. The Jerash, Jordan case study demonstrates the potential of a sustainable smart bike-sharing system and ITS implementation to promote sustainable tourism and preserve cultural heritage sites for future generations. The study recommends using ITS in heritage management practices as an effective solution for promoting sustainability, safety, and visitor experience while preserving the cultural value of heritage sites. Stakeholder engagement and community participation are crucial for implementing and managing ITS in heritage sites. By integrating ITS with heritage preservation practices, heritage sites can be managed sustainably, ensuring their longevity and safeguarding cultural value for future generations. This study highlights the potential of ITS in enhancing the visitor experience and promoting sustainable tourism while preserving the cultural

heritage of heritage sites. to provide a comprehensive view of the system's applicability in different contexts, it is crucial to delve into the challenges and considerations for scalability, One important consideration is the infrastructure requirements for scaling the ITS-enabled smart bike-sharing system to other tourist destinations. This entails evaluating the availability of bike stations, parking facilities, and necessary connectivity infrastructure. Additionally, the adaptability of the system's technology to different environments and contexts should be assessed, taking into account factors like varying network connectivity, environmental conditions, and cultural considerations. Another critical aspect is stakeholder collaboration, as successful system expansion relies on effective coordination among local authorities, transportation agencies, and tourism organizations. Understanding the dynamics and collaboration mechanisms necessary for scalability is essential. Lastly, analyzing user behavior and demand patterns in different locations is crucial to optimize bike availability, distribution, and system performance. By addressing these scalability factors and challenges, future research will provide valuable insights into the system's applicability and contribute to the planning and implementation of the ITS-enabled smart bike-sharing system in various tourist destinations, both within and beyond Jordan.

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