

# A Review of AI and IoT Implementation in a Museum's Ecosystem: Benefits, Challenges, and a Novel Conceptual Model

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**Abstract**—The museums need to transform into modern museums by developing a digital ecosystem that integrates all elements in the museum to optimize organizational outcomes and impact people's welfare in the era of Society 5.0. This paper aims to conduct a review of the museum's digital ecosystem based on the implementation of artificial intelligence (AI) and internet of things (IoT). PRISMA methodology for literature review was adopted to search for the answers to the research questions, knowing digital technology trends, challenges, and benefits of a digital museum ecosystem development, and proposed a novel conceptual model of the museum ecosystem based on AI and IoT implementation. The dataset contained metadata from Scopus, Google Scholar, and IEEEExplore databases. Several stages were implemented in the literature review process so that it is known that AI and IoT technologies have never been separated in the development of digital museums since 2020, but there has yet to be research on the digital museum ecosystem model that integrates IoT and AI. The museum's digital ecosystem implementation benefits will improve museum resources and increase museum competitiveness. However, there will be challenges related to cybersecurity issues, data integration in multi-media formats, and interface designs to overcome user acceptance challenges of the technology constructed in the digital museum ecosystem. The proposed AI and IoT-based model also require an evaluation for implementation validation at the museum in future works.

**Keywords**—AI; IoT; digital museum; digital ecosystem

## I. INTRODUCTION

The COVID-19 pandemic that spread throughout the world has had a negative and positive impact. Various sectors of people's lives have transformed quickly to adjust to and overcome the problems during the COVID-19 pandemic. The community has adapted to new habits where community activities are based on Information and Communication Technology (ICT), which allows communication, community services, and business to be held without direct contact and is more efficient than conventional methods. One is in the Museum's public service sector for education, culture, and tourism. The traditional Museum has been transformed into a modern ICT-based museum by presenting interesting technology for visitors to add value to the Museum [1]. The digital Museum's performance during the pandemic was optimal compared to traditional museums. Digital museums provide a variety of applications to support exhibition spaces and services for visitors for educational purposes and museum tours.

However, more than a digital museum is needed to provide added value to museums and society, especially, toward Society 5.0. In that era, people demanded convenience in various public services supported by artificial intelligence-based ICT infrastructure that promised smart services to the public [2]. Stakeholder communities for museums will benefit more from the existence of a digital museum ecosystem.

The digital ecosystem is a concept of connectedness between human entities, technology, and organizational elements to provide added value in achieving organizational goals [3]. These entities are connected digitally to communicate and collaborate in the organization's business processes [4], [5]. Modern museums make it possible to develop digital ecosystems because they involve the community and various entities, which, if fully integrated with digital infrastructure, will provide added value in achieving museum tasks for education and tourism after the COVID-19 pandemic. Visitors with diverse backgrounds have different motivations and expectations, so they need an integrated system to exchange information effectively and efficiently to support the right and fast decision-making in supporting the performance of the Museum as a public service organization.

The digital museum ecosystem has been developed in previous research [6]. However, it is not yet known how developments, benefits, and challenges are faced, especially in the era of Society 5.0 where the application of artificial intelligence (AI) models and the Internet of Things (IoT) is a must. IoT offers ways to collaborate and more interconnection among people in an ecosystem [7] and AI delivers a smart way for living [8]. These questions will be answered in this study. This research conducts a literature review study on research on developing a digital museum ecosystem towards Society 5.0. This method makes it possible to carry out an analysis of the literature dataset regarding the digital ecosystem in a structured manner [9]. The research begins with formulating research questions, followed by applying the dataset inclusion and exclusion criteria until the final results are obtained to answer the research questions [10]. Based on the findings, a novel conceptual model of AI and IoT-based museum ecosystem is proposed and presented in this paper. The paper begins with the introduction in Section I discusses the research problem, gap, and related works Section II describes the research methodology, followed by the results and discussion in Section

IV. Finally, the conclusion is presented in Section V at the end of this paper.

## II. RESEARCH METHODOLOGY

The literature review is carried out to extract information systematically [11]. The literature review begins with developing a dataset containing documents related to the research. It is continued with filtering steps based on several criteria so that a dataset containing articles is produced and will be analyzed to get answers to research questions [11], [12]. To find out the current development of the digital museum ecosystem, three research questions are formulated to be answered in this study, *RQ1*, *RQ2*, *RQ3*, and *RQ4*, as follows:

*RQ1*: What is the trend of digital technology application at the museum?

*RQ2*: What are the benefits of IoT and AI-based museum's ecosystem development?

*RQ3*: What are the challenges in IoT and AI-based museum's ecosystem development?

*RQ4*: What is the novel conceptual model of AI and IoT-based museum's ecosystem?

The methodology of the literature review process for finding this research question's answer adopted PRISMA [12]. Previous studies reviewed articles regarding existing models of museum digital ecosystems based on IoT and AI. The search was continued with article metadata in the developed database. The identification of new studies in databases was conducted using the following steps: database development, keywords for articles search, inclusion and exclusion criteria, and analysis of final search results. One thousand three articles were selected using the criteria in PRISMA, leaving ten articles reviewed in full text after inclusion and exclusion (Fig. 1). The study continued with searching for new studies on the IEEEExplore website using the same keyword on database search. The final articles were analyzed to find the answers to research questions”.

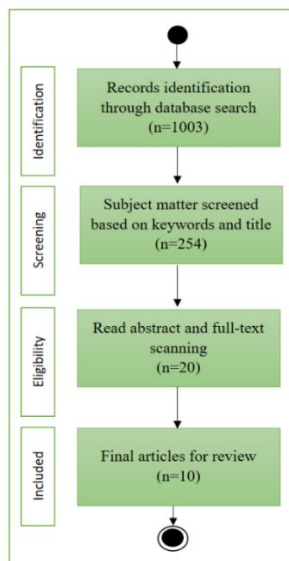


Fig. 1. Literature review methodology.

### A. Identification

The development of a database to build a literature dataset that will be reviewed systematically is carried out in the early stages of the research. Articles identification was conducted via metadata of Scopus and Google Scholar databases chosen to develop the dataset because Scopus contains up-to-date, reputable articles that guarantee the latest research on digital ecosystem museums. The Publish and Perish tools collected metadata from the Scopus and Google Scholar databases. The formed dataset is saved. RIS file format for analysis using the VosViewer tool. The article search period for the last five years, 2019-2023.

### B. Screening

Article searches in the Scopus and Google Scholar databases are heavily influenced by keywords to produce relevant articles with research problems. Keywords are repeatedly tried so that the best search results are obtained based on the articles found, namely with the keywords "Artificial Intelligence" OR "Internet of Things" Digital Ecosystem" OR "Digital Museum" OR "AI" or "IoT." With these keywords, a dataset was successfully formed from the Scopus and Google Scholar databases for the 2019-2023 period of 1003 articles.

### C. Eligibility

The initial search results are corrected to find the most relevant articles to be analyzed to extract information that effectively answers the research problem. The process of inclusion and exclusion of articles in the dataset was carried out by filtering based on keywords in the article's title so that there were only 255 articles in the dataset. Furthermore, the screening process was carried out based on the abstract and full text scanning to obtain the final results of 20 articles to be analyzed in full-text.

### D. Inclusion

The dataset analysis was carried out by mapping the bibliography in the dataset with the VosViewer tool [13] and continued with an analysis of 20 full-text articles to find answers to questions *RQ1*, *RQ2*, and *RQ3*. Bibliographical mapping will show the linkages between articles found based on keywords and some information related to the trend of digital research on the museum ecosystem toward Society 5.0. A full-text analysis is needed to find the challenges and benefits of developing digital museum ecosystems, especially during the COVID-19 pandemic in 2019-2023.

## III. RESULTS

The digital ecosystem is the concept of connectedness between elements in an organization with digital infrastructure to enable communication and collaboration in achieving goals and providing added value to the organization [4]. Elements contained in the digital ecosystem interact with each other to attentively produce information to support efficient decision-making by actors in the system related to digital technology, data, services, and organizational partnerships [14]. The main entity of the digital ecosystem is people, and the goal is to serve people [15]. The digital ecosystem within an organization [16] consists of a digital economy, digital infrastructure and adoption, and digital society, rights, and governance.

Information and communication technology infrastructure availability is central to forming a digital ecosystem within the organization [3], such as museums.

As a public service organization with roles for education, collection storage, and art, culture, and history tourism, the museum needs to form a digital museum ecosystem. The ecosystem enables visitors, service personnel, collections, exhibition rooms, museum facilities, and all entities and stakeholders in the museum to integrate, exchange information, and collaborate in carrying out museum roles. Additionally, with the digital museum ecosystem, it is possible to add value to society with the presence of ICT. The web-based digital ecosystem of museums has connected people in museums and collections [17]. However, more than a web-driven digital ecosystem for museums is needed for Society 5.0. In that era, people needed the support of digital technology to improve the quality of their lives and provide solutions to various life problems to present sustainable development in various aspects of life, including cultural heritage and museums [18]. IoT integration in digital ecosystem development is a promising solution for data communication and collaboration problems among people in an ecosystem [19], [20].

Meanwhile, AI optimizes data processing for an organization's competitive advantage [21]. IoT and AI impact the ecosystem model for improving its performance [22], [23]. The state of the art of the museum's digital ecosystem model, which integrates IoT and AI, needs to be explored for development. With a digital museum ecosystem, cultural preservation and resilience through museums can be maintained. It is effective in providing social impacts and has an economic impact on society.

### A. RQ1: Trend of Digital Technology Application at Museum

The RQ1 also tried to explore the related works of the digital museum ecosystem model proposed in this study. The finding may describe the gap between the existing model of the digital museum ecosystem. The dataset to be reviewed consists of bibliographies described statistically as in Table I. The average citation of 62.38 is relatively high because there is literature in a type of books cited > 1000. If the literature were removed from the dataset, the average number of citations would be 31.23. The distribution of literature with the number of citations > 1000 is described in Table II. The book was the most cited literature in this study, with citations double the journal articles' citation numbers.

Bibliographic mapping was carried out with the VosViewer tool, and the results of the overlay visualization are illustrated in Fig. 2. Based on the visualization of Fig. 2, which shows mapping based on keywords in the bibliography, it is known that there is no direct relationship between the four keywords "MUSEUM," "AI," "IoT," and "DIGITAL ECOSYSTEM."

The bibliography on the topic of the museum is quite a lot. However, those related to AI, IoT, and Digital Ecosystems have opportunities for further research. The trend of developing museums based on digital technology and artificial intelligence can be seen in publications starting to develop in 2020. For example, there are networks with the keywords "METAVERSE", "MACHINE LEARNING", and "DIGITAL

ECOSYSTEM" after 2020, which are marked by visualization in dominant yellow color. These keywords are also accompanied by the emergence of "COVID", which is connected with the keyword "MUSEUM". It can be concluded that the COVID-19 pandemic has forced the museum's digital implementation to adapt to a pandemic situation by developing museums based on AI and METAVERSE and leading to a digital ecosystem.

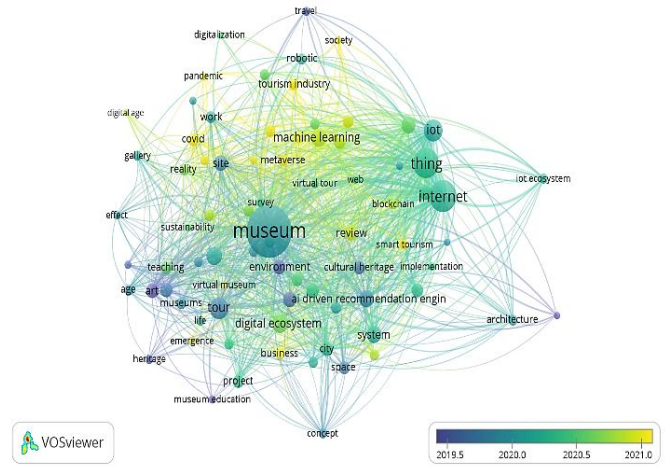


Fig. 2. Overlay visualization of bibliographic mapping.

TABLE I. DATASET STATISTICS IN THIS RESEARCH

Information	Results
Document	1033
Citation	62.38
Authors	2417
Multi-authored Documents	657
Single-authored Documents	345
Authors per Document	2.41
Co-Authors	1.41

TABLE II. SUBSET OF DATASET WITH CITATIONS >1000

Literature Type	Frequency	Citations
Journal Articles	5	11227
Book	6	31013
Citation	1	1011

The process was continued with selection, inclusion, and execution, and twenty documents were obtained for overall review. After conducting a literature review of 20 articles in full text, it is known that ten articles contain the development of digital technology to construct digital ecosystems that are applied in the museum domains with IoT and AI content. The digital technology development trend can be seen per year, as illustrated in Table III. The development of a digital museum ecosystem model has been carried out in previous research that is only based on digital technology with AI content. Meanwhile, a digital museum ecosystem model integrating IoT and AI has yet to be developed. The trend of developing digital technology in museums and tourism is described in Fig. 3. The development of digital technology for museum applications began to integrate

AI models in 2019, which were integrated with IoT. The development of AI technology in museums from 2020 to 2022 is relatively high. A pandemic situation requires a solution to the problem of limiting distance and interaction with exhibitions, collections, and visitors. AI and IoT are present as solutions that provide convenience and automation for museum management during a pandemic [24]. This condition has triggered the rapid development of the digital ecosystem at museums based on AI and IoT content since 2020. These results answer research question *RQ1*.

TABLE III. THE TREND OF MUSEUM DIGITAL ECOSYSTEM DEVELOPMENT

References	IoT	AI	Digital Ecosystem Model
[25], [26]	-	✓	NA
[27]	✓	✓	NA
[6]	✓	-	Available
[28], [18]	✓	-	NA
[29], [30]	✓	✓	NA
[25], [26]	-	✓	NA

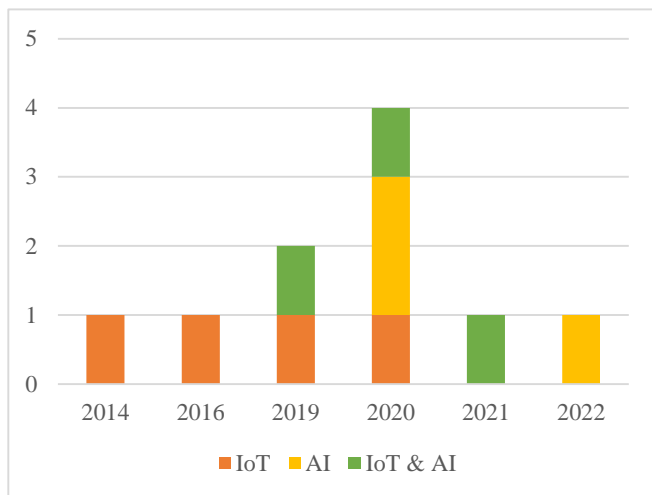


Fig. 3. The trend of IoT and AI implementation in museum.

### B. *RQ2: Benefits of the Museum's Ecosystem Development*

The visitors come to the museum with various motivations, including learning and entertainment. The monotonous presentation of museum showrooms requires a practical touch of technology to enhance the learning experience [31], [32] and the visitor's knowledge, especially students, as dominant visitors [33]. Museum digital transformation is more than just digitizing the museum. It requires designing a digital ecosystem model that benefits society and museum organizations, as described in Table IV. Integrating IoT technology and AI models in an ecosystem will provide added value for all the museum's people. Impact on museum resources, thereby creating the competitive advantages of the museum [29].

The optimization of museum services for people related to its role in education and tourism will be achieved through a digital ecosystem based on IoT and AI integration models. By utilizing digital technology, museums can optimize their performance during the pandemic, which limits museum visits [34]. Its efficiency can be achieved through AI and IoT

implementation [30]. These findings answer the research question *RQ2*.

TABLE IV. BENEFITS OF THE AI AND IOT-BASED MUSEUM'S DIGITAL ECOSYSTEM TRANSFORMATION

Benefits	References
Visitor engagement: Visitors interact and connect actively with the content of the exhibit.	[26][29] [6] [27]
A new business process: Enabling a new process in museum management.	[18] [29] [6][35] [27]
Competitive advantage: Enabling a museum to outperform its competitors.	[29] [35]
Resource improvement: Enhanced quality and efficiency of the available museum resources.	[18][6] [35] [30][25] [36]
Service improvement: Enhancing service quantity, quality, and efficiency of the museum.	[18] [6] [35][30] [36]
Visitor satisfaction: Fulfilment and positive experience after interacting with museum resources or services.	[18] [29] [27]
Learning enhancement: Improvement of learning experience to foster a better understanding of the museum.	[29] [6] [26] [27]

### C. *RQ3: Challenges of the Museum's Ecosystem Development*

There are challenges to be faced in developing the digital museum ecosystem. These challenges are described in Table V. Museum visitors who come from various backgrounds with low ability to use digital technology, especially those aged >30, face a challenge in accepting digital museum technology [37], [38]. The issue of cyber security and integration of data stored in various formats due to the implementation of IoT and various multimedia-based technologies is attractive to museum visitors [39][40]. It has become an obstacle that needs to be addressed, preceded by research in designing an effective digital ecosystem model for the museum domain. Interface design that is easily understood by various backgrounds of people's profiles.

TABLE V. BENEFITS OF THE AI AND IOT-BASED MUSEUM'S DIGITAL ECOSYSTEM DEVELOPMENT

Challenges	References
Technology acceptance: Accepting new technologies, reluctance to use the technologies at the museum because of lack of knowledge or refusing to use the technology.	[35] [27][26]
Cyber security and ethical concerns: Protecting the museum system and data from unauthorized access, disruption, or theft, is also behavior that has moral conflict concerning the privacy or well-being of the museum ecosystem.	[35] [30]
Feasible models and interfaces: Designing models and user interfaces suitable for different museums.	[18] [30][27]
Infrastructure improvement: A lot of cost for hardware improvement that supports the museum's digital ecosystem development.	[27] [36]
Data integration: The multimedia format creates a multi-data format that needs to be integrated into a museum's digital ecosystem.	[36][26]

Challenges also arise in the museum ecosystem for the implementation of digital technology by internal museum actors. Staff with inadequate knowledge of digital technology are an obstacle in carrying out the process of digitizing museum



collections. There is a lack of awareness of the benefits of digital transformation to increase competitiveness and optimize the role of museums compared to relying on physical museum collections as the main strength. This requires increased understanding from museum staff. High motivation from staff will accelerate the museum's digital transformation process, and the usage of digital technology to support the museum's role in education and tourism is also a challenge in developing the digital museum ecosystem [41]. These findings answer the research question RQ3.

#### D. RQ4: The Proposed AI and IoT-Based Museum Ecosystem Conceptual Model

In the museum digital ecosystem, the three main elements (people, services, and collection & facilities) collaborate and communicate to conduct the museum's roles by applying digital technology for optimizing the museum's organizational goals achievement. A proposed digital museum model is discussed in this study based on the literature review results presented as the answer of RQ4. Integrating IoT and AI in museum ecosystem models is expected to be effective in providing added value benefits for museum elements, especially visitors. Fig. 4 illustrates the proposed AI and IoT-based museum ecosystem model.

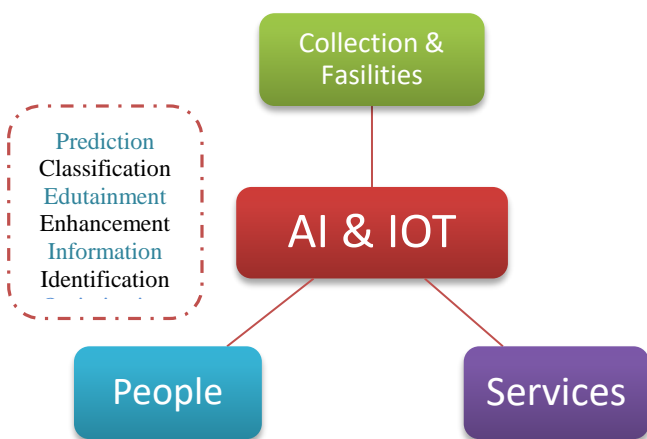


Fig. 4. The proposed AI and IoT-based museum ecosystem conceptual model.

*a) Prediction:* estimating museum visits to prevent overcrowding, especially during a pandemic which required distance among elements in the museum such as visitors and collections. Predictions try to find out which collections or exhibitions that most interesting, and estimate the resources and facilities [32], [42] needed for the operation and management of the museum.

*b) Identification:* determining the characteristics of objects due to manage and increase the museum experience. Object identification involves various processes, including computer vision for analyzing visual data, such as images or videos of museum objects as well as object recognition [43] effectively identifying objects presented to visitors to enhance experiences at museums.

*c) Classification:* Task classification is grouping objects or collections based on collection characteristics to determine

effective and efficient handling [44] which impacts the quality and curiosity of the collection. For example, the accurate automated classification of damage types to a museum painting or archive collection will help determine quick and appropriate actions to handle problems based on the type of damage to the collection.

*d) Information:* AI-based applications in museums enhance information delivery. This feature has not been included in the previous model proposed at the beginning of this study [42]. By using technologies like machine learning and natural language processing, museums can offer personalized experiences, where visitors receive tailored content based on their preferences. AI can do automated tasks like cataloging the collection, and creating real-time updates to exhibits. It also enables seamless information retrieval through smart search systems and multilingual support, making museums more accessible [45]. AI able to analyze data to optimize exhibits and improve accessibility for diverse audiences. These advancements make information more organized, accessible, and interactive, enriching the overall museum experience and management.

*e) Enhancement:* The implementation of AI at the museum effectively adds value for exhibitions and collections that present different non-traditional new experiences for visitors that impact revisit intention. Digital interactive technology integrated 3D and augmented reality technology in the exhibition presenting virtual and informative collections that are impossible in traditional museums. Especially for the Gen-Z who live in the digital era and are used to all the convenience features and technological sophistication, AI and IoT implementation are necessary for museum visit enhancement. The traditional museums that seem old-fashioned and unattractive without digital technology as an additional tool for visitors and museum management.

*f) Edutainment:* The museum provides interactive digital technology delivered to the visitor to attract their interest and interactive experiences by using digital technology, such as Augmented reality and virtual reality games integrating AI for smart apps giving added value to increase satisfaction and interest to revisit the museum [31]. The AI-based applications are effective in delivering entertainment at the museum and improving visitors' learning experiences and performance.

*g) Optimization:* AI and IoT-based applications in museums optimize various aspects of operations and visitor experience. By analyzing visitor behavior, it helps adjust exhibition and content in real-time to enhance engagement. It also optimizes visitor flow, using data to predict crowded areas and suggest alternative routes to reduce congestion. Additionally, AI systems manage energy use by adjusting lighting, and temperature systems based on visitor activity, improving sustainability and reducing costs. Personalized content delivery, such as tailored tours and recommendations based on visitor's profiles, improves the visitor's satisfaction, experience, and learning performance. On the operational side, AI automates routine tasks like inventory management and staff scheduling, improving efficiency and resource allocation. AI and IoT enable museums to streamline their operations,

enhance engagement, and create a more sustainable and efficient environment for museum elements.

#### IV. DISCUSSION

The proposed model integrates IoT and AI in museum ecosystem models that better than other existing models compared in Table III and discussed in *RQ1*. The models also identify the specific functionality of the museum ecosystem with AI and IoT integration than other models. It contains prediction, classification, education, edutainment, information, identification, and optimization to support the museum's role in education and tourism. The proposed model can be a case line for museum ecosystem development based on IoT and AI to support museum management with the benefits and challenges discussed in *RQ2* and *RQ3*. Further research is necessary for the proposed model validation.

The AI and IoT integration in the museum ecosystem model benefits society and museum organizations, as described in Table IV. It will provide added value for all the museum's elements and create competitive advantages. The strategic planning to overcome the challenges in developing the museum's digital ecosystem is also necessary for the museum's goals achievement and fully utilized by people in the museum ecosystem, especially in Society 5.0.

The proposed model in this study is based on the literature review and observations. The development evaluation of AI and IoT-based museum ecosystem models is required in future research to answer challenges and present valid new concepts, techniques, and innovations to provide a new atmosphere for museums suitable for Society 5.0. The presence of a digital museum ecosystem will not dismiss the existence of museums but will complement and improve performance after the COVID-19 pandemic.

The relationship between elements or entities in the museum's ecosystem connected through the digital technology that integrates AI and IoT will impact the preservation of the historical, cultural, and artistic values stored in museums. The new digital museum ecosystem model based on IoT and AI is expected to create innovation for modern museums. With IoT connectivity capabilities, the speed, and accuracy provided by AI models, developing the research implementation and evaluation stages is challenging for future work.

#### V. CONCLUSION

The digital transformation of museums was accelerated by the pandemic, which required the museums to find solutions to keep providing educational and tourism services for the public. Towards the era of Society 5.0, people need added value from museums regarding convenience, which impacts their well-being promised by implementing AI and IoT in museums. This study surveys by reviewing the literature dataset of bibliographies with Scopus and Google Scholar metadata sources of research topics about AI and IoT in museum apps. The dataset was processed with PRISMA methodology. The selected 20 documents were thoroughly reviewed. The research questions that will answered are, what are the benefits, challenges, and the novel conceptual model of museum's ecosystem based on literature review conducted in this study.

Bibliography mapping based on keywords relevant to the research topic was conducted using the VosViewer app. It was found that the development trend of digital museum technology started to be based on IoT and AI from 2019 to 2022, which was triggered by the COVID-19 pandemic. AI has become an integrated model in the development of digital museums since 2020 because of its ability to automate, making it easy for visitors and museum managers to deal with a pandemic. IoT integration in the museum's digital ecosystem development is a promising solution for data communication and collaboration problems among people as the main entity of the museum ecosystem. The background of the people involved in the museum, especially museum visitors, presents challenges in user acceptance to take advantage of digital technology in the museum ecosystem, which will have an impact on improving the quantity and quality of museum resources and lead to increasing museum competitiveness as the added value will be obtained, especially in the Society 5.0. However, the absence of a digital museum ecosystem model validation is an opportunity to develop a museum ecosystem based on the proposed model for model validation in future work. The proposed museum ecosystem contains three elements, people, services, and collection & facilities, which are designed to be integrated by AI & IoT-based technology. AI and IoT will facilitate the museum's role and present functionality for prediction, identification, classification, information, enhancement, edutainment, and optimization. AI and IoT implementation may improve museum performance and present added value to museum elements, especially visitors. Further research is necessary for the proposed model effectiveness validation.

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