



The Implementation of Industry 4.0 in Indonesian Museums

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Abstract. This research examines how far the industry 4.0 Initiative is implemented in Indonesian museums by observing both sides of museum management and museum visitor. This study is explorative and utilizes both qualitative and quantitative methods. Twenty-four Indonesian museums are interviewed. The research population for the survey is Indonesian people in general. The sampling technique used is convenience sampling and 290 respondents participated in the survey. The study takes place in Indonesia for five months. The current result shows that the implementation of Industry 4.0 Initiatives in Indonesian museums is not yet prevalent. Financing, technology, and human resources are the challenges mostly met by the museums. It is also known that museum visitors' needs for the industry 4.0 Initiative are high. Furthermore, the implementation of technology in Museum 4.0 has positive effects on visitor satisfaction, visitor revisit intention and visitor recommendations. It is suggested to survey with more diverse participants to understand better the visitor's needs in a larger area for further research. A survey for museums is also encouraged to test further the proposed framework based on the interviews.

Keywords: Industry 4.0 · Museum 4.0 · Museum Digitalization · Museum Visitor's Needs · Visitor Behaviour

1 Introduction

The tourism industry is one of the industries that experienced large growth in Indonesia before the Covid-19 pandemic [1]. It is also supported by the constant rise in the contribution from the tourism industry to the country's Gross Domestic Product (GDP) [2]. However, due to its potential as a natural and cultural tourist destination, Indonesia needs to develop its tourism industry further to ensure the arrival of both local and international tourists.

One of the most crucial tourist destinations is namely the museums [3]. According to the International Council of Museums (ICOM) Statute, a museum is "a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches, communicates, and exhibits the tangible and intangible heritage of humanity and its environment for education, study, and enjoyment," [4]. Therefore, as a museum aims to be of service to society, it is imperative that a museum needs to understand its visitors to better cater to their needs.

As time changes, the social-cultural aspect where a museum is situated also changes. Nowadays, society embraces the digital lifestyle as it eases many aspects of life. People also become more critical of what they consume and what they want from the service industries. Accordingly, a museum also has to start applying a digital mindset to keep up with its visitors. This effort to ‘digitalize museums’ can be seen as a simple step toward implementing a bigger industrial revolution called Industry 4.0 [5].

The Indonesian government has also already adopted the change toward digital, which can be found in a roadmap towards Industry 4.0 [6]. However, the implementation of Industry 4.0 is only widespread in the manufacturing industry, compared to the tourism industry, which has just started to implement the initiative. The Covid-19 pandemic, however, plays a part in jumpstarting digitalization more quickly than planned. This is due to the government regulations to combat Covid-19 which prohibit public places from opening freely. So, museums are forced to find a way to keep being connected to their visitors.

The Fourth Industrial Revolution or Industry 4.0 was a term first used in the 2011 Hannover Fair [7].

The initiative was born from the wide usage of the internet and technology development, which is integrated into a company’s operations. Industry 4.0 in a museum context, also called Museum 4.0, has a slightly different meaning. While Industry 4.0 refers to using the most sophisticated technology in a company, Museum 4.0 focuses on the approach used to fulfill museum visitors’ needs using technology [8]. The previous Museum 3.0 was oriented toward visitors and communications, and Museum 4.0 tries to further that connection. Museum visits are no longer limited to the physical aspect of a museum but already begin from pre-visit and last until post-visit activities. It also emphasizes a customized experience for each visitor [9].

Several museums have adopted the Museum 4.0 initiatives in Europe and North America. Research regarding the topic is also conducted regularly. On the other hand, some Indonesian museums just started their implementation of Industry 4.0 during the Covid-19 pandemic. The implementation is often in the form of a virtual tour held over video call applications, such as Zoom. Other museums collaborate with third-party, such as Google Arts and Culture, to digitize their collections, so people can visit the website and explore the museum’s collection archives [10].

In general, the implementation of Industry 4.0 has already begun in bigger museums, which are also tourist favorite destinations. The implementation is possible because their management is fully supported by these museums, mostly private institutions with sound financial backing or the central government. On the other hand, smaller museums opt not to implement the initiatives so soon for various reasons.

Some early research on Industry 4.0 in Indonesian museums has been conducted, for example, on overall conditions in Indonesia and on the application of particular technology in particular museums. Therefore, more comprehensive research regarding the current situation of Industry 4.0 implementation in Indonesian museums is needed to fully understand how far the museums have progressed and what challenges they face during the process. This is to help other museums that just initiated their Industry 4.0 implementation avoid future problems.

Consequently, this research aims to explore the implementation of Industry 4.0 in Indonesian museums by using several museums as case studies. The research will be conducted in mixed methods. The qualitative method is used to understand the implementation of Industry 4.0 from the museum's point of view, while the quantitative method is used to comprehend the visitors' views regarding this issue. Four research questions will guide this study:

1. How far is the implementation of Industry 4.0 in Indonesian museums?
2. What are the challenges the museums face during the implementation of Industry 4.0?
3. What are the needs of museum visitors regarding Industry 4.0 initiatives?
4. What can the museums expect from their visitor's behavior regarding Industry 4.0 initiatives?

The result of this study will produce a proposed framework that could benefit museums in mapping the challenges they would face in the process of implementing Industry 4.0. On the other hand, the study on visitors' views could help museums understand the expectations imposed on them. It will also contribute a new perspective in academic research on the Indonesian museum industry since the management perspective is rarely applied in such research.

2 Literature Review

2.1 Industry 4.0

The first industrial revolution started when steam-powered machines were widely used during the late 18th century. Then it evolved into the second industrial revolution, which marked the start of mass-produced goods. The revolution was possible due to the usage of electricity during the early 20th century. The following industrial revolution started in the early 70s when Information Technology (IT) and electronic devices enabled manufacturing automatization. This phase of the industrial revolution continues to the present day. At the 2011 Hannover Fair, the fourth industrial revolution was acknowledged, and the term Industry 4.0 was introduced [7].

The new term was deemed necessary to describe the increasing use of the smart automatization process, which involves integrating several technologies beyond the physical and digital border. This merging between physical and digital interactions is known as Cyber-Physical System (CPS) [11].

Essentially, there is no definitive understanding concerning the technology considered as part of the Industry 4.0 initiative. On the one hand, there are some concepts and technology often associated with the Industry 4.0 initiative, namely CPS, Internet of Things (IoT), blockchain, 3D printing, sensor, advanced robotics, big data analytics, Artificial Intelligence (AI), cloud computing, augmented reality, and others [12–14]. On the other hand, some experts classify 'old' technology, such as Enterprise Resource Planning (ERP), Computer-Aided-Design (CAD), Computer-Aided-Manufacturing (CAM),

and Electronic Data Interchange (EDI), to be a part of Industry 4.0 as well [15]. Therefore, we can conclude that Industry 4.0 does not always refer to a new form of technology but a new approach inspired by existing technology development.

A smart factory is a well-known Industry 4.0 implementation in the manufacturing industry. It utilizes key characteristics of Industry 4.0, namely digitization, automation, virtualization, and real-time information sharing [16, 17]. As opposed to the manufacturing industry, the service industry started implementing Industry 4.0 a bit later, and it is still not widely adopted. For the most part, the implementation takes the form of servitization of the mechanism and process in the service industry. From a historical view, the service industry is also known to face difficulties in adopting new technology in a sustainable manner [18, 19].

Since service products involve customers' participation in the process, adapting the Industry 4.0 initiative does not automatically add to the product value. So, it is encouraged to use a humanistic approach in using the technology. Previous research regarding Industry 4.0 initiatives in the tourism industry includes topics such as theoretical framework [20, 21], smart tourism [22, 23], and different levels of technology adoption [24].

2.2 Museum

The word museum originated from the Ancient Greek word '*mouseion*,' which alludes to the temple to worship the Muses. It was a place for scholars to do their studies and resembled a library of archives. The modern concept of the word, however, appeared in 16th-century Europe [25]. The bourgeoisie often had a special room in their house called the Cabinet of Wonders. They used the room to store their ethnographic, minerals, natural history, religious relics, and art collections. The private collection turned public at the end of the 17th century when universities opened their museums to people.

The modern definition of a museum entails it as a nonprofit institution that conserves and communicates its collections to the public for education, study, and recreational purposes [4]. A museum can be classified based on different aspects. For example, based on the collections, they can be divided into a general museum or a specific museum. A museum can be privately owned or owned by the government at the central or regional level. Based on the collections they own, there can be ethnographic, historical, science, archaeological, natural history, or art museums, among others. The building of a museum can be a closed building or an open-air site [26].

2.3 Museum 4.0

The concept of Museum 4.0 departs from the history of the museum in the 16th century until the present day [27, 28]. The classification also focuses on how a museum transfers its knowledge to its visitors.

- a. Museum 1.0: marked by the Cabinet of Wonders. The collections were only open to the upper-class circle. Museum was still object-oriented and static.
- b. Museum 2.0: starts to be more interactive and attract visitors, museum collections can be touched or played with by visitors.

- c. Museum 3.0: adopts constructivism as a learning theory, is open-ended and visitor-oriented; public communication and nonformal education are encouraged.
- d. Museum 4.0: museum ‘without walls’, the museum manages pre-visit, visit, and post-visit aspects of the visitor experience. Visitations are customized according to visitors’ needs.

Other studies about museums in the modern world emphasize other aspects that are more important than adopting new technology. For example, personal stories that visitors can relate to the collections, the visitors’ participation in the curation of exhibits, and community building [8, 29]. Research about Museum 4.0 discusses issues such as case studies [30, 31] and technology applications in particular museums [32–35].

3 Research Methods

3.1 Research Design

This study can be categorized as basic research and is explorative in nature. It sets a foundation for further and detailed research regarding Industry 4.0 in Indonesian museums. It uses qualitative and quantitative methods (mixed methods) to describe the condition of Industry 4.0 from the perspective of Indonesian museum management and Indonesian museum visitors.

The qualitative method is used for the museum management part of the research because the number of museums that have implemented Industry 4.0 is only a few. So, the qualitative method can give us a deeper analysis of the subjects. The quantitative method is used for the visitor part of the research to give a general idea of what museum visitors demand of museums. Case studies will be used as an approach in the qualitative method. The result from these case studies will produce a proposed framework that will be used as a basis to create a survey in questionnaire form for the quantitative method.

3.2 Unit of Analysis

The unit of analysis for the qualitative method is Indonesian museums that have implemented Industry 4.0. A representative from each museum will act as an informant. They are either the head of said museum or someone responsible for the museum’s exhibition. Since no official data or research provides a directory of Indonesian museums which had applied Industry 4.0 initiatives, the museums are chosen based on a convenient manner. The screening criteria is that the museum must have a digital presence, such as an official website or social media accounts.

Twenty-four museums act as informants. The museums come from the government and private sectors, as well as have diverse collections with different scales. Most of the museums are located on Java Island, with a few on Sumatra, Kalimantan, and Bali islands.

Indonesian people as individuals will be the unit of analysis in the quantitative part of the research. There are no restrictive criteria to be a survey respondent, except for being Indonesian. Visiting experience to a museum is also not mandatory since this

study also wishes to understand the needs of those who have not visited a museum. The respondents are chosen conveniently. This study also attempts to have the respondents be as heterogeneous as possible.

3.3 Data Collection Method

The qualitative part of this study was conducted first. This study acquired its data from interviews with museum representatives. Museums were chosen based on their digital presence on websites and social media. If there is an indication of the museum conducting a virtual tour during the Covid-19 pandemic, the museum was shortlisted. The sampling also uses the snowball technique, by utilizing the social network of the museum representatives to refer to other museums that also implement Industry 4.0 initiatives. The author then contacted the museum to agree to do interviews.

The interviews were conducted through written manners (e-mails and WhatsApp messages) and video call conferences. It was semi-structured with a guideline of several main questions, but the interviews expanded according to the interview flow (Appendix 1). There are 24 museums in total that participated in the research.

The result of the interviews produced a proposed theoretical framework that works as a basis for the quantitative part of the study. This proposed framework is used to construct the questionnaire used for the visitor survey. The questionnaire is also supported by similar previous research concerning museum visitor satisfaction, visitor revisit intention, and visitor recommendations.

The questionnaire consists of three parts: respondent demographics, the importance level of Industry 4.0 initiatives, and visitors' behavior (Appendix 2). Sex, age, place of residence, highest education, job, and income per month are gathered for the respondent information. The second part of the questionnaire asks the respondent how important particular Industry 4.0 technology is in a museum. Each technology is coded with TEK followed by a number. There are 11 items in the second part, with an additional question where respondents can fill in the blanks with other initiatives they think are needed. The last part asks respondents about their behavior towards museums with Industry 4.0 initiative. There are three behavior elements, namely Visitor Satisfaction (SAT) with four items, Visitor's Revisit Intention (INT) with four items, and Visitor Recommendation (REC) with three items.

A Likert scale is used for the second and third parts of the questionnaire. Scale 1 represents not at all important and strongly disagree, and scale 5 represents very important and strongly agree. The survey is descriptive in nature and has a single-stage and cross-sectional design. It was self-administered and held online through Google Forms. The technique for sampling is convenience sampling.

3.4 Data Analysis Method

The qualitative data analysis method used in this study is content analysis [36]. It starts with preparing the raw interview data by transcribing it, so it is ready to be analyzed. The main theme of each interview will be noted, described, and classified in the form of codes and categories. In the coding stage, the information will be grouped and labeled according to the research questions. The next step is finding the pattern within the

categories to finally be able to interpret the data in a logical manner. Finally, the result will be portrayed in a table.

The quantitative data is processed using Microsoft Excel and JASP 0.16.0.0 software tools. Some tests were run against the data, namely descriptive analytical methods, such as validity test using Confirmatory Factor Analysis (CFA), reliability test using Cronbach's Alpha, and normality tests with skewness and kurtosis. The result was also analyzed using Structural Equation Modeling (SEM) to test the relation between the elements.

4 Result and Discussion

4.1 Qualitative Data

Twenty-four museums participated in this study through interviews. Based on the management, there are six museums managed by the central government, four by the regional government, privately owned, one is owned by the police, one is owned by a state enterprise (BUMN), and one by a university. Based on their scope, 8 are national level, one is provincial, 14 is city level, and one is local. Based on collections, 2 are general museums, while 22 are specific museums. Based on the building, 12 are historical buildings, 11 are closed buildings, and 1 is an open-air site. The profile for each museum is provided in detail in Appendix 3.

Almost half of the museums (11 museums) started implementing Industry 4.0 after the Covid-19 pandemic, while 13 museums had started before Covid-19 happened. There are seven museums implementing Industry 4.0 in the administration and exhibition sections of the museum, while 17 of them only implement the initiatives in the exhibition sections.

There are many forms of Industry 4.0 implemented, but the most popular forms are social media accounts and virtual tours via Zoom, YouTube, or Instagram. The museums mainly (15 museums) work with a third party to develop the technical aspects of Industry 4.0, while nine museums only work within their internal team. Five museums do not involve external parties at all during the process, while 19 museums involve the community, professionals, and the general public in their implementation.

The challenges faced are mostly human resources, financial, and technical difficulties. Additional challenges faced, for example, are government regulations and resistance from either the internal or external side of the museum. They resolve the challenges with preventive or curative actions. Most museums (14 museums) have positive responses from their visitors regarding the usage of Industry 4.0 initiatives, whereas ten museums receive mixed reviews (positive and negative). Their future plan for Industry 4.0 is either developing innovations or maintaining the status quo. Appendix 4 contains the comprehensive results of the museum interviews.

From the interview results, we can propose a framework model (Fig. 1) of several factors that influence the implementation of Industry 4.0 in Indonesian museums. First, there are drivers, which can be either external or internal, that contribute positively to the implementation of Industry 4.0. External drivers are visitors' needs, technology development, and the Covid-19 pandemic. On the other hand, internal drivers are the progressive

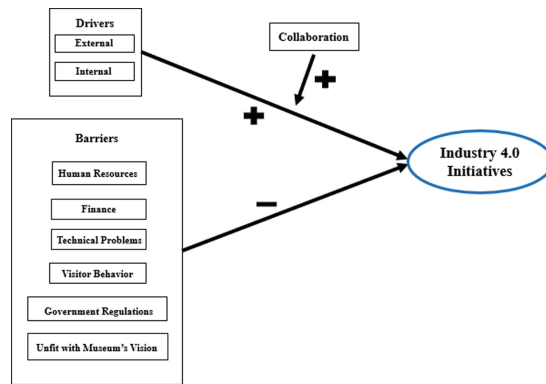


Fig. 1. Proposed model framework based on qualitative study

mindset of the museum and resource availability. These drivers are enhanced by collaboration with a third party. Most frequent collaborators are professionals, the community, society, and developers. In contrast, the implementation of Industry 4.0 can be slowed down by barriers. These barriers can come in the form of human resources problems, technical problems, financial, negative visitor behaviors, government regulations, and how the overall initiatives are unfit for the museum's vision.

The interview results are then incorporated with the theory of visitor behaviors to understand further how this implementation affects the visitors. Industry 4.0 initiatives can be classified as facilities that contribute to visitor satisfaction. Visitor satisfaction then, in turn, influences how likely visitors will revisit a museum and recommend the visit to others. Therefore, some hypotheses are proposed to explain the relationship between these aspects based on previous research [37, 38]:

- H1: The implementation of Industry 4.0 has a positive influence on visitor satisfaction.
- H2: Visitor satisfaction has a positive influence on visitor's revisit intention.
- H3: Visitor satisfaction has a positive influence on visitor recommendation.

The proposed framework for this relationship between Industry 4.0 initiatives and visitor behavior is in Fig. 2.

4.2 Quantitative Data

There are 290 completed responses to the survey, but 1 is unusable. So, only 289 responses are utilized for analysis. The first part of the questionnaire assesses the respondent's profile. Among the respondents, 41,87% are male and 58,13% are female. The respondents' age ranges from below 19 years old (1,38%), 20–29 years old (44,64%), 30–39 years old (29,07%), 40–49 years old (4,50%), and over 50 years old (20,42%).

Most of the respondents live in the Jakarta Metropolitan Area, which consists of Jakarta, Bogor, Depok, Tangerang, and Bekasi (74,39%). The rest of them live in Sumatra (9%), Java (12,11%), Kalimantan (2,77%), Sulawesi (0,35%), and abroad (1,38%). Two

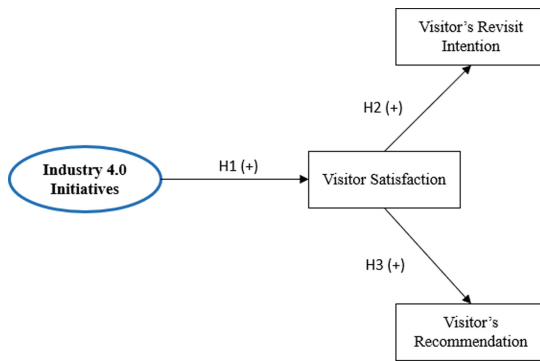


Fig. 2. Proposed quantitative model framework for the relationship between Industry 4.0 implementation and visitor behaviors

hundred and sixty-four respondents (91,35%) are college graduates, 24 are high school graduates (8,30%), and one did not finish elementary school (0,35%).

Based on the respondents’ jobs, the highest group are employees from the private sector (41,18%). Around 18,69% work as either civil employees or in a state-owned enterprise. Respondents who are entrepreneur or freelancer is about 14,19%, students are around 10,73%, and 0,35% is in the army/police (TNI/POLRI). Fourteen respondents are homemakers (4,84%), another 14 reported to be either not working or retired (4,84%), and 15 people reported their job as others (5,19%). In terms of the respondents’ monthly income, 17,65% has income below Rp2.500.000,00, 20,76% has Rp Rp2.500.001,00–Rp5.000.000,00, 21,80% reported between Rp5.000.001,00 and Rp7.500.000,00, 15,22% has Rp7.500.001,00–Rp10.000.000,00, and 24,57% reported has above Rp10.000.001,00.

The second part of the questionnaire appraises visitors’ needs for a particular technology. It is measured using the Likert scale of 1 to 5, but in the analysis stage, the data is converted to a scale of 3 to 5 to give better gradation in the result. The most important Industry 4.0 initiative according to respondents is interactive media (4,882), while the least important one is the museum dedicated app (4,512) (Fig. 3). Respondents were also allowed to add other initiatives they consider as important. Only 37 returned an answer and the most mentioned technology are CCTV and Artificial Intelligent with 5 answers each (Fig. 4).

The last part of the questionnaire discusses visitor behaviors with a focus on three aspects, namely Visitor Satisfaction (SAT), Visitor Revisit Intention (INT), and Visitor Recommendation (REC). The measurement instrument is evaluated to verify whether the items are inherently consistent. The Cronbach’s alpha value for each variable is above 0,700 (Appendix 5). Therefore, the instrument can be considered reliable [39].

The instrument is also tested for its validity. Confirmatory Factor Analysis (CFA) works as a validity test and the factor loadings for each variable are above >0.05 (Appendix 5). Therefore, the instrument can be considered valid [40].

Skewness and kurtosis for every variable are used for testing the normality distribution of the data. For each variable, the skewness values are between –0,500 and –1

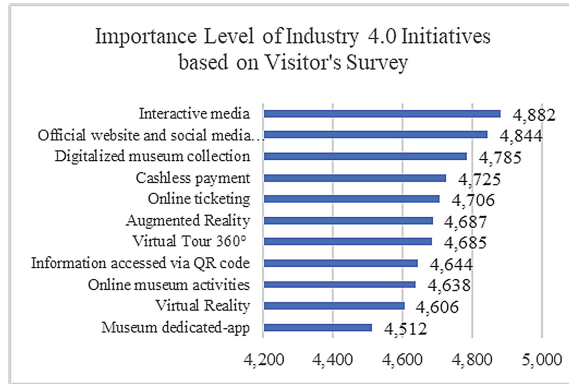


Fig. 3. Importance level of Industry 4.0 Initiatives based on visitor's survey. Source: Quantitative study result

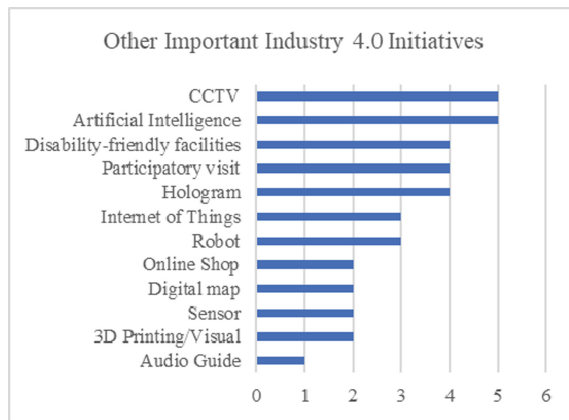


Fig. 4. Other Important Industry 4.0 Initiatives based on visitor's survey. Source: Quantitative study result

(Appendix 5). The data is then considered moderately skewed to the left [41]. On the other hand, the kurtosis of the data is between 0 and +1. Since the true normal is 0, the data can be considered non-normal, but not severely because it does not exceed the threshold of +3 [41].

An analysis using Structural Equation Modeling (SEM) is conducted to test the model fit for the proposed hypothesis model in Fig. 2. The analysis result shows that the value of chi-square is within the range of 2df (Appendix 5). One index fit (NFI) does not meet the minimum good fit value of 0,90. However, other fit measures such as CFI, TLI, NNFI, and GFI fall within the acceptable range [42]. The regression coefficient is also significant. As a result, the proposed model can be deemed acceptable. The path diagram depicting the relationships of variable TEK, SAT, INT, and REC are portrayed in Fig. 5.

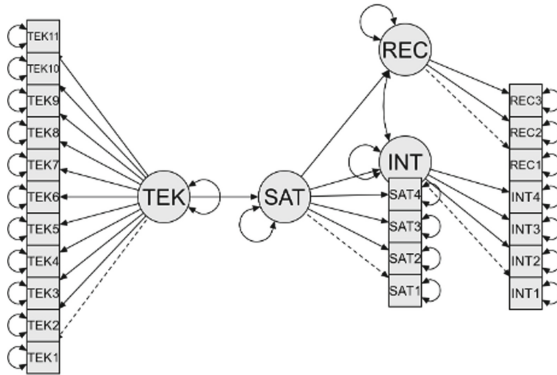


Fig. 5. Path diagram of the study. (Source: Quantitative study analysis using JASP)

4.3 Discussions

Industry 4.0 has been widely adopted by the manufacturing industry, whereas the service industry has just started to adopt the initiatives to keep on with the recent trends. With its Industry 4.0 roadmap, the Indonesian government hopes the initiatives will benefit them to compete in the global market. Consequently, as part of the service industry, museums have also begun implementing Industry 4.0 in their operations.

Based on the qualitative stage of this study, Indonesian museums are in different stages regarding their Industry 4.0 implementation. About half of the museums started implementing Industry 4.0 way before the Covid-19 pandemic. The other half just started initiating their implementation because the pandemic encouraged them to do so. Moreover, even among museums that had implemented Industry 4.0 before Covid-19, the implementation varies. Some museums have utilized sophisticated technology such as IoT, Cloud Computing, sensor, big data analytics, dedicated apps, and virtual and augmented reality. In contrast. Some museums can only manage by being active on their social media accounts and holding virtual tours over Zoom and YouTube.

The quantitative part of this study tells us that the respondents feel a relatively high need for Industry 4.0 technology. Some technologies are considered important for a museum to have, for example, interactive media, social media accounts, an official website, and digitized museum collections. Online ticketing and cashless payment are also valuable for a museum to have since both of them have become the norm nowadays in day-to-day transactions.

Since the proposed quantitative hypothesis model can be considered acceptable, it can be concluded that the hypothesis proposed in the previous section:

H1: The implementation of Industry 4.0 has a positive influence on visitor satisfaction is accepted.

H2: Visitor satisfaction has a positive influence on visitor's revisit intention is accepted.

H3: Visitor satisfaction has a positive influence on visitor recommendation is accepted.

Thus, the implementation of Industry 4.0 in museums can affect visitor satisfaction positively. The more satisfied the visitors are, the more likely they will revisit the museum and recommend the museum visit to others.

5 Conclusion

Based on the interviews with 13 government-owned museums and 11 private-owned museums, the implementation of Industry 4.0 Initiatives in Indonesia is not yet prevalent. Some have implemented on a bigger scale, while some have just started with modest means. Financing, technology, and human resources are the challenges mostly met by the museums.

The survey result shows that museum visitors' needs for the Industry 4.0 Initiative are relatively high. Furthermore, the implementation of Industry 4.0 technology has positive effects on visitor satisfaction. Visitor satisfaction will later affect visitors' revisit intention and visitor recommendation positively.

The result of this study helps contribute to the museum management study since a study to see how Indonesian museums progress in the context of Industry 4.0 has not been conducted. This study also helps museums recognize the importance of a formal visitor study to make better decisions regarding Industry 4.0. Other museums that just begin their Industry 4.0 implementation can also learn from the challenges other museums that have started the process before them had faced and how they resolved the challenges.

This study is limited in terms of how the museum informants and survey respondents are mainly from Jakarta and Java Island. For future research, it is suggested to interview more museums on other islands and do the visitor survey with more heterogeneous respondents and people who have visited museums with Industry 4.0 implemented. Moreover, quantitative research in the form of a survey of other museums based on the proposed model can also be done.

Appendix

Appendix 1: Interview Questions – Qualitative Stage

1. Introduction: name, museum, title, and responsibility in the museum
2. What do you know about Industry 4.0 in museums?
3. What Industry 4.0 initiatives are implemented in your museum?
4. When did the Industry 4.0 implementation in your museum start?
5. In which part of your museum is the Industry 4.0 initiatives implemented?
6. Why did your museum choose to implement that specific Industry 4.0 initiatives?
7. How was the process of the implementation?
8. Who was involved in the process?
9. What were the challenges faced by your museum during the process?
10. What did you do to solve the problems?
11. How is the response of your museum’s visitors regarding the implementation of Industry 4.0 initiatives?
12. What is your planning in the future regarding Industry 4.0?

Appendix 2: Survey Questionnaire – Quantitative Stage

1. **Respondent profile:** sex, age, place of residence, highest education, job, monthly income.
2. **Visitor needs** (Likert scale from 1 (not at all important) to 5 (very important))
3. How important is this technology to be implemented in a museum?

Code	Industry 4.0 Initiatives
TEK1	Official website and social media accounts
TEK2	Online ticketing
TEK3	Cashless payment
TEK4	Interactive media
TEK5	Online museum activities
TEK6	<i>Virtual Tour 360°</i>
TEK7	<i>Virtual Reality</i>
TEK8	<i>Augmented Reality</i>
TEK9	Museum dedicated-app
TEK10	Information accessed via QR code
TEK11	Digitalized museum collection
	Other technology (fill in the blanks)

4. **Visitor behaviors** (Likert scale from 1 (strongly disagree) to 5 (strongly agree))

Behaviors	Code	Attribute
Visitor Satisfaction	SAT1	I feel visiting a museum that has implemented Industry 4.0 initiatives is the right choice to spend my free time.
	SAT2	I obtain useful knowledge when visiting a museum that has implemented Industry 4.0 initiatives.
	SAT3	I feel the visiting experience to a museum that has implemented Industry 4.0 initiatives exceeds my expectation.
	SAT4	I feel happier if I visit a museum that has implemented Industry 4.0 initiatives.
Visitor's Revisit Intention	INT1	I want to revisit a museum that has implemented Industry 4.0 initiatives.
	INT2	I am willing to make an effort to visit a museum that has implemented Industry 4.0 initiatives.
	INT3	I will choose a museum that has implemented Industry 4.0 initiatives when I want to visit a museum.
	INT4	I want to visit a museum that has implemented Industry 4.0 initiatives more often.
Visitor Recommendation	REC1	I will recommend visiting a museum that has implemented Industry 4.0 initiatives for other people.
	REC2	I will say positive things about visiting a museum that has implemented Industry 4.0 initiatives.
	REC3	I like to share my experience of visiting a museum that has implemented Industry 4.0 initiatives with other people.

Appendix 3: Museum Profile

Code	Management	Area Scope	Collection	Building
A	Central Government	National	General	Closed and historical building
B	Central Government	National	Specific (Art)	Historical building
C	Central Government	National	Specific (Art)	Closed building

(continued)

(continued)

Code	Management	Area Scope	Collection	Building
D	Central Government	National	Specific (History)	Historical building
E	Central Government	National	Specific (History)	Historical building
F	Central Government	National	Specific (History and Science)	Historical building
G	Regional Government	City	Specific (Art)	Historical building
H	Regional Government	City	Specific (Art)	Historical building
I	Regional Government	City	Specific (Art)	Historical building
J	Regional Government	Province	General	Historical building
K	Privately owned	City	Specific (Art)	Closed building
L	Privately owned	City	Specific (Art)	<i>Open-air site</i>
M	Privately owned	City	Specific (Art)	Closed building
N	Privately owned	City	Specific (History and Culture)	Closed building
O	Privately owned	City	Specific (Art)	Closed building
P	Privately owned	City	Specific (Industry)	Closed building
Q	Privately owned	City	Specific (Art)	Closed building
R	Privately owned	City	Specific (Science)	Closed building
S	Privately owned	City	Specific (Industry)	Historical building
T	Privately owned	City	Specific (History)	Historical building
U	Privately owned	City	Specific (Art)	Closed building
V	Police	National	Specific (Police)	Closed building
W	State-owned enterprise	National	Specific (Industry)	Historical building
X	University	Local	Specific (Science)	Closed building

Source: Qualitative study result

Appendix 4: The Implementation of Industry 4.0 in Indonesian Museums

Code	Start implementing Industry 4.0	Museum aspects where it is implemented	Forms of Industry 4.0 Implementation	Industry 4.0 Implementation Process	Party involved	Challenges faced	Actions taken	Visitors' response	Future planning
A	Before Covid-19	Administration and exhibition	Virtual guided tour, Virtual Tour 360, Collection digitalization, AR, Video Mapping, QR Code, Immersive Room, Integrated Marketing, Dedicated App, social media, Big Data Analytics	Curator works closely with exhibition team and technically executed by third-party (developer)	Hired specialist, Community, and general public	Technical difficulty, human resources	Increasing human resources competency and technology capacity	Positive	Making the museum disabled-friendly
B	Before Covid-19	Administration and exhibition	Virtual guided tour, Virtual Tour 360, social media, NFT, IoT, Big Data Analytics, Cybersecurity	Curator works closely with exhibition team and technically executed by third-party (developer)	Hired specialist and Community	Resistance from internal and external, technical difficulty	Curative actions	Positive and negative	Customized tour

(continued)

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Code	Start implementing Industry 4.0	Museum aspects where it is implemented	Forms of Industry 4.0 Implementation	Industry 4.0 Implementation Process	Party involved	Challenges faced	Actions taken	Visitors' response	Future planning
C	Before Covid-19	Administration and exhibition	Virtual guided tour, social media, Interactive Media, Collection digitalization, Cloud computing, QR Code, Cybersecurity	The internal team does all the work	Community	human resources, financial	Increasing human resources competency	Positive and negative	Maintaining status quo
D	Before Covid-19	Administration and exhibition	Virtual guided tour, Virtual Tour 360, AR, Video Mapping, Virtual Assistant, social media, Interactive Media, Dedicated App, Sensor, Big Data Analytics	Curator works closely with exhibition team and technically executed by third-party (developer)	Hired specialist	Government regulations, unsustainable technology, technical difficulty, financial	Trial and error	Positive	Doing more research on Industry 4.0

(continued)

(continued)

Code	Start implementing Industry 4.0	Museum aspects where it is implemented	Forms of Industry 4.0 Implementation	Industry 4.0 Implementation Process	Party involved	Challenges faced	Actions taken	Visitors' response	Future planning
E	Before Covid-19	Exhibition	Virtual guided tour, Virtual Tour 360, social media	The internal team does all the work	Nobody	human resources	Increasing human resources competency	Positive	Increasing user-friendly features
F	Before Covid-19	Administration and exhibition	Virtual guided tour, Virtual Tour 360, AR, social media, Dedicated App, Digital Sign In, Digital info board, collection digitalization	The internal team does all the work and a third party provides the technology	General public	Resistance from internal	Increasing human resources competency	Positive	Improving museum and collection management
G	After Covid-19	Exhibition	Virtual guided tour, Collection digitalization, social media	By order of the Regional Bureau of Culture	Hired specialist	human resources, financial	Increasing human resources competency	Positive and negative	Maintaining status quo
H	After Covid-19	Exhibition	Virtual guided tour, Collection digitalization, social media	The curator works with supervision from the institute director	Community	human resources, government regulations, technical difficulty	Adapting to the current condition	Positive	Increasing human resources competency

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Code	Start implementing Industry 4.0	Museum aspects where it is implemented	Forms of Industry 4.0 Implementation	Industry 4.0 Implementation Process	Party involved	Challenges faced	Actions taken	Visitors' response	Future planning
I	After Covid-19	Exhibition	Virtual guided tour, Collection digitalization, social media, digital info board, Google Analytics	The internal team does all the work	Community	Government regulations, unsustainable technology, technical difficulty	Adapting technological usage to regulations	Positive and negative	AR, QR Code
J	After Covid-19	Exhibition	Virtual guided tour, social media	The internal team does all the work	Nobody	human resources, government regulations, financial	Recruiting new employees, holding a temporary exhibition	Positive	Collection digitalization, Virtual Tour 360, collaboration
K	After Covid-19	Exhibition	Virtual guided tour, social media	The internal team does all the work	Community	Financial, decreased income	Creating new virtual events	Positive	Maintaining status quo

(continued)

(continued)

Code	Start implementing Industry 4.0	Museum aspects where it is implemented	Forms of Industry 4.0 Implementation	Industry 4.0 Implementation Process	Party involved	Challenges faced	Actions taken	Visitors' response	Future planning
L	Before Covid-19	Administration and exhibition	A dedicated app, QR code, social media, Cloud Computing, Tablet Rental	The internal team does all the work	Community	human resources, financial, technical difficulty, problems with third-party, unfit with institution's goals	Changing QR code app-based to web-based	Positive and negative	Self-ticketing, centralized point of Sales
M	After Covid-19	Exhibition	Virtual guided tour, social media	The internal team works with third-party	Community and general public	Financial, no demand from visitors, human resources	-	Positive	Service integration

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Code	Start implementing Industry 4.0	Museum aspects where it is implemented	Forms of Industry 4.0 Implementation	Industry 4.0 Implementation Process	Party involved	Challenges faced	Actions taken	Visitors' response	Future planning
N	After Covid-19	Exhibition	Virtual guided tour, social media	The internal team works with third-party	Community	Museum location, creating content for digital visitors, difficult access to technology	Researching Industry 4.0	Positive	Virtual Tour 360, collection digitalization, collaboration
O	After Covid-19	Exhibition	Virtual guided tour, social media, Community engagement	The internal team works with third-party	Community and general public	Financial, human resources, no demand from visitor	Increasing human resources competency, focus on social media	Positive	Improving engagement
P	Before Covid-19	Exhibition	Virtual guided tour, social media, Interactive Media, Self-Ticketing, QR Code	The internal team works with third-party	Community and general public	Financial, technical difficulty, visitor behavior	Creating new programs	Positive and negative	More interactive programs, making collection prototype, collaboration

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Code	Start implementing Industry 4.0	Museum aspects where it is implemented	Forms of Industry 4.0 Implementation	Industry 4.0 Implementation Process	Party involved	Challenges faced	Actions taken	Visitors' response	Future planning
Q	Before Covid-19	Exhibition	Virtual guided tour, social media, Interactive Media, QR Code, Immersive	The internal team works with third-party	Nobody	human resources, technical difficulty, difficult access to technology, unfit with institution's goals, disturbing museum ecosystem	Balancing education and recreation	Positive	digitized visitor satisfaction survey, more QR Code, Virtual Reality, Augmented Reality
R	Before Covid-19	Exhibition	Virtual guided tour, social media, Interactive Media, sensor, immersive	The internal team works with third-party	Education Bureau and Community	Technical difficulty, unfit with institution's goals	Focus on visitor interaction	Positive and negative	Improving guide

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Code	Start implementing Industry 4.0	Museum aspects where it is implemented	Forms of Industry 4.0 Implementation	Industry 4.0 Implementation Process	Party involved	Challenges faced	Actions taken	Visitors' response	Future planning
S	After Covid-19	Exhibition	Virtual guided tour, social media, Interactive Media	The internal team works with third-party	Community and general public	human resources, financial, technical difficulty, government regulations, management problems, difficult access to technology, too few collections	Adapting to visitor's needs, Increasing human resources competency, collaboration	Positive and negative	Opening a new museum for recreation, collection digitalization, a new facility
T	After Covid-19	Exhibition	Virtual guided tour, social media	The internal team works with third-party	Hired specialist, Community, and general public	human resources, government regulations	Recruiting new employees, collaborating, creating new interactive programs	Positive	Collection digitalization index, making new contracts, creating a new building

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Code	Start implementing Industry 4.0	Museum aspects where it is implemented	Forms of Industry 4.0 Implementation	Industry 4.0 Implementation Process	Party involved	Challenges faced	Actions taken	Visitors' response	Future planning
U	After Covid-19	Exhibition	Virtual guided tour, social media, Self-ticketing, cashless payment, Collection digitalization	The internal team works with third-party	Nobody	Art copyrights are owned by artists	Showing collections in the public domain	Positive	Audio guide, Virtual Tour 360
V	Before Covid-19	Exhibition	Virtual guided tour, social media, Interactive Media, Virtual Tour 360, Cybersecurity, disabled-friendly	The internal team does all the work	Nobody	human resources, financial, unsustainable technology	Increasing human resources competency	Positive	Virtual tour revitalization

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Code	Start implementing Industry 4.0	Museum aspects where it is implemented	Forms of Industry 4.0 Implementation	Industry 4.0 Implementation Process	Party involved	Challenges faced	Actions taken	Visitors' response	Future planning
W	Before Covid-19	Exhibition	Virtual guided tour, social media, Interactive Media, Virtual Tour 360, Augmented Reality, Collection digitalization	The internal team works according to the company's goals and collaborates with third-party.	Hired specialist	Technical difficulty, unsustainable technology, deciding on suitable content, visitor behavior	Creating new contents	Positive and negative	Renewing Virtual Tour 360, maintaining the status quo
X	Before Covid-19	Administration and exhibition	Virtual guided tour, social media, Interactive Media, Cloud Computing	The internal team works according to the university's goals and collaborates with third-party	Hired specialist, Community, and general public	human resources, financial, technical difficulty, too few collections	Creating exhibitions suitable for the young audience	Positive and negative	Virtual Tour 360, Virtual Reality, Augmented Reality, QR Code, Self Ticketing, digitized visitor satisfaction survey, themed tour

Source: Qualitative study result

Appendix 5: Survey Result

5. Reliability test

Item	Cronbach's Alpha if item dropped	Cronbach's Alpha per variable
SAT1	0,828	0,835
SAT2	0,773	
SAT3	0,779	
SAT4	0,787	
INT1	0,859	0,880
INT2	0,854	
INT3	0,842	
INT4	0,826	
REC1	0,744	0,846
REC2	0,833	
REC3	0,774	

Source: Quantitative study result

6. Validity test with CFA

- **Model Fit - Chi-Square Test**

Model	χ^2	df	P
Baseline Model	2055,802	55	
Factor Model	133,127	41	<0.001

Source: Quantitative study result

- **Parameter Estimates - Factor Loadings**

Factor	Indicator	Symbol	Estimate	Std. Est. (all)
Visitor Satisfaction	SAT1	λ_{11}	0,484	0,655
	SAT2	λ_{12}	0,512	0,807
	SAT3	λ_{13}	0,544	0,749
	SAT4	λ_{14}	0,523	0,793

(continued)

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Factor	Indicator	Symbol	Estimate	Std. Est. (all)
Visitor Revisit Intention	INT1	λ_{21}	0,540	0,794
	INT2	λ_{22}	0,654	0,791
	INT3	λ_{23}	0,675	0,807
	INT4	λ_{24}	0,699	0,839
Visitor Recommendation	REC1	λ_{31}	0,606	0,849
	REC2	λ_{32}	0,498	0,730
	REC3	λ_{33}	0,583	0,838

Source: Quantitative study result

7. Descriptive statistics

	TEK	SAT	INT	REC
Valid	289	289	289	289
Missing	0	0	0	0
Mean	4.402	4.432	4.304	4.431
Std. Deviation	0.451	0.584	0.697	0.627
Skewness	-0.707	-0.893	-0.871	-0.981
Std. Error of Skewness	0.143	0.143	0.143	0.143
Kurtosis	0.370	0.376	0.251	0.631
Std. Error of Kurtosis	0.286	0.286	0.286	0.286
Minimum	2.727	2.000	2.000	2.000
Maximum	5.000	5.000	5.000	5.000

Source: Quantitative study result

8. SEM

• Model Fit

				Baseline Test			Difference Test		
	AIC	BIC	n	χ^2	df	ρ	$\Delta\chi^2$	Δdf	ρ
Model 1	7329,670	7586,320	289	454,547	205	<0.001	454,547	205	<0.001

Source: Quantitative study result

- **R-Squared**

	R ²
TEK1	0,191
TEK2	0,129
TEK3	0,137
TEK4	0,281
TEK5	0,278
TEK6	0,364
TEK7	0,359
TEK8	0,462
TEK9	0,325
TEK10	0,342
TEK11	0,239
SAT1	0,435
SAT2	0,649
SAT3	0,547
SAT4	0,618
INT1	0,636
INT2	0,625
INT3	0,648
INT4	0,700
REC1	0,722
REC2	0,535
REC3	0,700
SAT	0,435
INT	0,811
REC	0,679

Source: Quantitative study result

- **Additional Fit Measures**

Index/Metric	Value
Comparative Fit Index (CFI)	0,912
Tucker-Lewis Index (TLI)	0,901

(continued)

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Index/Metric	Value
Bentler-Bonett Non-normed Fit Index (NNFI)	0,901
Bentler-Bonett Normed Fit Index (NFI)	0,852
Goodness of Fit Index (GFI)	0,998
Root mean square error of approximation (RMSEA)	0,065
RMSEA ρ -value	0,001

Source: Quantitative study result

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