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Analysis of Supporting and Hindering Factors for the Implementation of BIM and GIS Integration in IKN Projects

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ABSTRACT

The relocation of Indonesia's capital city from Jakarta to IKN (Capital City of the Archipelago) in Penajam Paser Utara is a monumental project covering an area of 2,876 hectares, which involves massive infrastructure development. To ensure the success of IKN development and development based on the principles in Law Number 3 of 2022 including equality, technological balance, resilience, sustainable development, livability, connectivity, and smart cities. BIM-GIS integration technology was key in managing the complexity of this project. With BIM-GIS integration, it supports digital transformation for more efficient and complete decision-making, including spatial variabels. This thesis aims to analyze the factors that influence the implementation of BIM-GIS integration technology in the early stages of IKN project development. Exploratory factor analysis methods are used to identify supporting factors that facilitate the successful implementation of BIM-GIS integration, as well as inhibiting factors that may hinder it. Questionnaires are used as a data collection tool from stakeholder respondents in IKN projects. Questionnaire data was analyzed using Exploratory Factor Analysis (EFA). The research results showed that there were 16 supporting factors with 4 component groups and 16 inhibiting factors with 6 component groups. Based on these results, strategic steps are proposed to contribute to the development of science and play a role in the successful relocation of Indonesia's capital city.

Introduction

The Nusantara Capital City (IKN) is a national megaproject that is being planned to move the capital of Indonesia from Jakarta to East Kalimantan (Bosch-Sijtsema, Isaksson, Lennartsson, & Linderoth, 2017). The IKN area has a land area coverage and the boundary is approximately 256,142 hectares depicted in the map in Figure 1. From the delineation map, information on the administration, water area, road network and other important information can be seen (Usmani, Hashem, Pillai, Saeed, & Abdullahi, 2020). The development of the IKN puts Indonesia in a more strategic position in world trade routes, investment flows, and technological innovation. The relocation of the state capital is based on several considerations such as equitable development and reducing the burden on Jakarta as one of the centers of national economic activity.

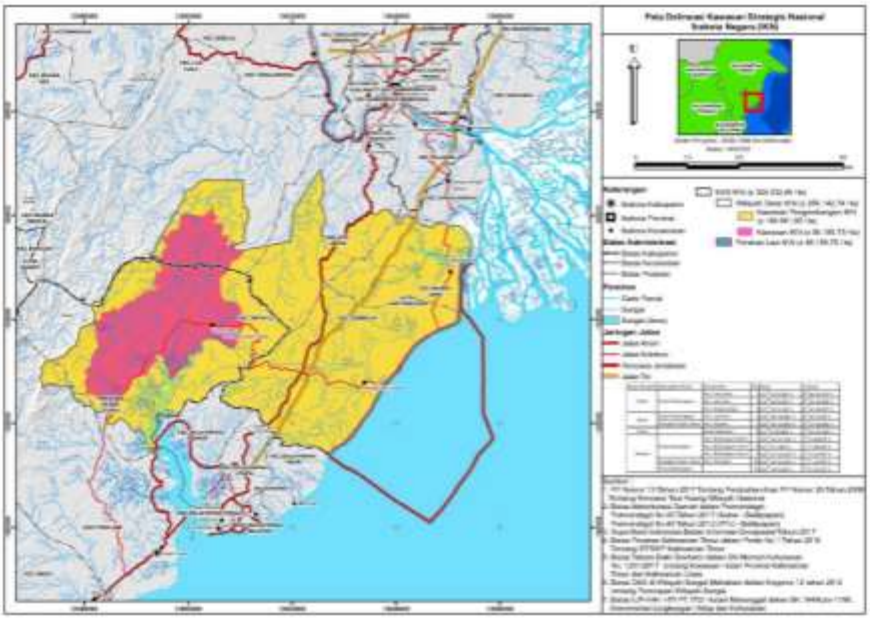

Figure 1
Map of the Delineation of the National Strategic Area of the National Capital City (Law of the Republic of Indonesia No. 3 of 2022)

The construction of the IKN project is included in the Indonesian National Strategic Project (PSN). Where IKN projects are part of projects prioritized by the government. The development of the IKN has a long period through several stages of development, starting from the early stages of 2022 and projected to be completed in 2045.

IKN will be built with the basic principles of regional development as a smart city to increase competitiveness regionally and internationally with the main pillars of digital transformation including the Internet of Things (IoT), artificial intelligence, robotics, big data, and other digital technologies. Where two of the principles of IKN are related to technology, namely connected, active, and easily accessible as well as convenience and efficiency through technology (Sardjono, Sudirwan, Priatna, & Putra, 2021).

Based on this description, IKN has a wide scope of work, interrelated periods between stages, complex project management spatial plans, and various other things. The construction of this project has complex challenges and high risks in its implementation.

In addition, the challenges of project implementation that are carried out massively and simultaneously will have project interface/interface problems as limitations and connections of various project phases, systems, tools, people, organizations, physical elements, and others (Mubaroq & Solikin, 2019). The definition of Interface Management (IM) according to (Callistus & Clinton, 2018) has two meanings, one of which is the management of communication, coordination, and responsibility across the general boundary between two interdependent organizations, stages, or physical entities. So it requires technology that synergizes with each other and collaboration is needed to maximize resources in the construction project development.

The availability of information on actual conditions and problems faced as well as other up-to-date information with easy access in real-time is a consideration in making decisions appropriately and quickly. According to (Wan Abdul Basir, Majid, Ujang, & Chong, 2018), BIM represents geometric and semantic information of buildings in detail, and the application of GIS is necessary to manage construction project information sources. GIS can complement BIM functions to develop a systematic platform for construction purposes. BIM-GIS integration is applied to data sharing, data integration, and data management.

The use of BIM and GIS integration technology in the IKN development process is one of the solutions to overcome problems and help a more comprehensive and complete decision-making process, including spatial variables. However, in the implementation of BIM and GIS integration with a large project area and projects that are carried out simultaneously, it is not known what factors are supporting and hindering integration.

Therefore, it is necessary to analyze factors that support and hinder the implementation of BIM and GIS integration using EFA (Explanatory Factor Analysis) from the results of the collection of questionnaire data of stakeholder respondents in IKN development projects so that the benefits of the use of technology can be maximized and help achieve the development goals of a quality, adaptive, innovative, inclusive, equitable, sustainable and dignified IKN through strategic proposals that can be applied in the implementation of BIM-GIS technology integration in IKN.

The use of Exploratory Factor Analysis (EFA) has been widely used in various fields, including in the field of project management, especially the use of BIM and GIS technology. Several studies with EFA analysis methods in the field of project management have been conducted in various countries. Generally, research is carried out within a limited project scope, besides that research in the implementation of BIM and GIS is carried out separately between BIM and GIS.

Research conducted by (Kamau & Mohamed, 2015) to determine the obstacles in the implementation of BIM in high-rise building projects due to their complexity and potential hazards using Exploratory Factor Analysis (EFA) and structural equation modeling (SEM). The results reveal six significant barriers: technical, integration, operational, creativity, privacy, and standardization. The practical implications suggest that organizations involved in the design, construction, and management of tall buildings need to overcome identified barriers to ensure the successful adaptation of BIM for risk management.

Another study aimed to improve the effectiveness of BIM adoption in Saudi Arabia. (Elsheikh, Alzamili, Al-Zayadi, & Alboo-Hassan, 2021) used normalization methods, Exploratory Factor Analysis (EFA), and fuzzy synthetic evaluation (FSE). The results of the EFA show five important points to increase BIM adoption, namely: developing programs to improve BIM competencies, developing programs to increase BIM awareness and understanding, developing programs to integrate BIM into educational and academic curricula, developing BIM-related contractual frameworks, and providing financial assistance to reduce BIM adoption costs.

The objectives of this study are:

1. Identify supporting factors and obstacles in the implementation process of BIM and GIS technology integration to overcome the challenges and complex problems of the development of the IKN mega project.
2. Analyze the supporting and inhibiting factors of BIM and GIS integration on the efficiency and effectiveness of the implementation of IKN development projects.
3. Formulate proposed strategic steps for the implementation of BIM and GIS integration in supporting the implementation of IKN development.

Method

This research can be classified as exploratory research that aims to find out the supporting and inhibiting factors in the implementation of BIM and GIS integration in the development of IKN. This research method uses a survey (distributing questionnaires), namely taking samples from the population using questionnaires as the main data collection tool to obtain facts.

This research follows a series of structured stages to achieve its goals. The research stage begins by compiling a background, which introduces the context of moving the capital of Indonesia to IKN (the capital city of the archipelago) and identifies supporting and inhibiting factors in the implementation of BIM-GIS integration technology in the development project. This background is the basis for formulating research objectives.

The next step is to conduct a careful literature study to identify previous studies that are relevant to the purpose of this research. In the literature study, various aspects related to BIM-GIS integration and major infrastructure projects, including the relocation of the capital city, are explored in depth. Variables related to supporting and inhibiting factors are then synthesized from the literature.

Population and Sample

A population is a complete group of elements, which is usually in the form of people, objects, transactions, or events that we are interested in studying or making the object of research (Kuncoro, 2009). This study takes the stakeholder population of construction service actors in the development of IKN. Meanwhile, samples are a small part of the population that is taken according to a certain procedure so that in the end it can represent the population.

The sampling technique uses purposive sampling. This technique is a sampling technique. The researcher selects construction service actors who are directly involved, especially projects in the IKN development area. According to the Central Statistics Agency (BPS), purposive sampling is a technique for determining samples by making certain considerations, provided that the selected sample represents the population. A group of subjects in this technique is based on certain characteristics/traits that are considered to be closely related to the characteristics/traits of the population.

According to Hair et al. (2010), in the factor analysis, there are provisions for determining the sample size, including:

1. The sample should have more observations than the variables;
2. The absolute sample size must be at least 50 observations.

The target respondents who are sampled in this study are stakeholders involved in the development of IKN starting from experts in the field of BIM and GIS, owners, consultants, and contractors as described in Table 1.

Table 1
Target list of Respondents

No	Prospective Respondents	Target
1.	BIM and GIS Expert	PUPR construction experts; Independent experts
2.	Owner	Project leaders and teams involved in BIM-GIS implementation
3.	Konsultan	Supervisory consultants involved in BIM-GIS implementation
4.	Contractor	Head office, Division Manager, Project Manager, Site Manager, and teams involved in BIM-GIS implementation

Research Data Collection Methods

The data collection used in this study is using primary data which is the answer from respondents including stakeholders in IKN projects to a questionnaire about factors that encourage and hinder the integration of BIM and GIS. The questionnaire consisted of several parts including a survey introduction containing an explanation of the research objectives, the background of the respondents, and the respondents' assessment of the research conducted related to the driving and inhibiting factors in the integration of BIM-GIS.

Formulation of Research Variables

In the literature study described in sub-chapter 2.6.1 Variable Synthesis, there are 19 factors in the driving factors for the implementation of BIM-GIS integration (Table 2.1) and 21 factors inhibiting the implementation of BIM-GIS integration in the IKN Project (Table 2.2). From each of these factors, factors relevant to research case studies, and projects in IKN, through FGD (Focus Discussion Group) with experts and parties who have a role in the implementation of BIM-GIS integration. The results of the FGD were obtained in the driving factors that there was no change or it was considered that all factors from the variable synthesis could be used in the study, which still amounted to 19 factors, while in the inhibiting factors, there were 3 factors that were eliminated, namely the factor of lack of data in the development of BIM-GIS integration, compatibility, and interoperability problems, and the lack of demand for BIM-GIS. Of these three factors, according to the results of the FGD, it is not necessary to include them in the research variables because they are considered to have run in general and smoothly in the IKN project environment.

Data Collection

The sample/respondents in this study include direct users of BIM and GIS integration (users, experts) as well as decision-makers (managers, top management). The sampling technique in this study uses Non-Probability Sampling, with the Purposive sampling method. This approach is carried out because not everyone (only certain people in the company) masters and uses BIM in their duties. So respondents who filled out the questionnaire were involved in the implementation of BIM and GIS integration activities.

The collection of questionnaire surveys is distributed to respondents through an online platform after obtaining permission and approval to conduct research from related companies or projects. The selection of online media is used with consideration so that respondent data facilitates data collection and collects enough data to be processed and reflects the conditions of the implementation of BIM and GIS technology integration in ongoing IKN projects.

Results and Discussion

Survey Results

From the results of the pre-survey that determined the variables/factors used in the research, both supporting and inhibiting factors, data was then collected through the distribution of questionnaires to respondents.

The research survey was conducted from February to March 2024 through a questionnaire filled out online. The number of questionnaires collected was 65 respondents. An explanation of the description and background of the respondent including the name of the company, type of project, job title, long time of knowledge of BIM and GIS technology, age, and recent education, is described in the next sub-chapter.

Respondent Description

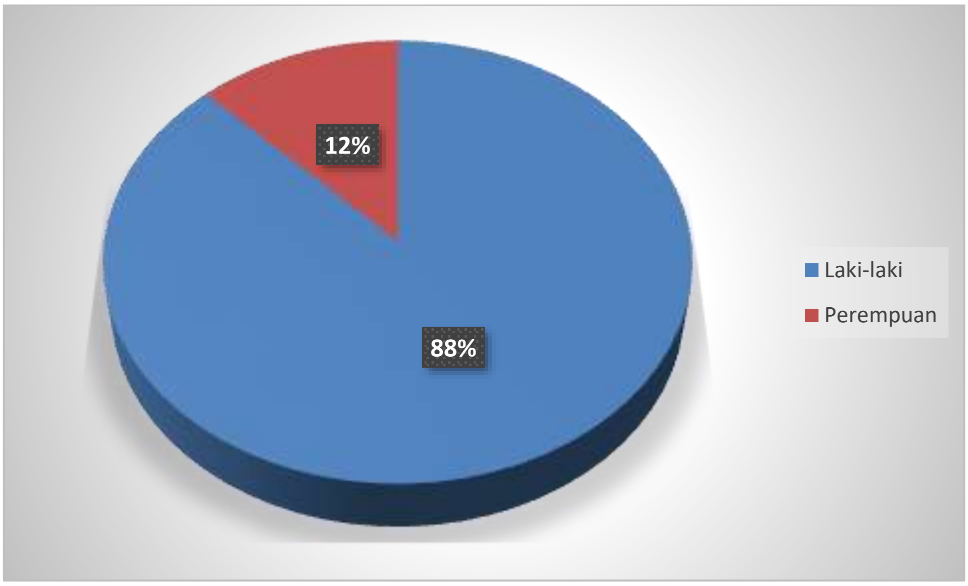

Figure 2 Respondents by gender

Respondents were selected based on experience in construction-related fields. The number of respondents obtained was 65 people, consisting of 57 men and 8 women. In other words, the respondents were 88 percent men and 12 percent women. The high percentage of men shows that the construction world is still dominated by men, so women's interest in construction services is still limited.

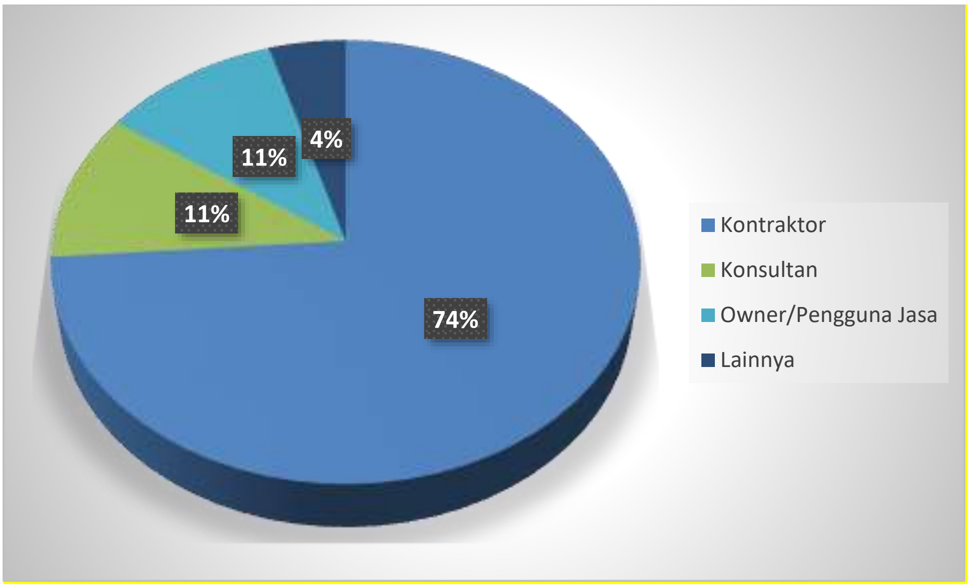

Figure 3 Respondents by stakeholder

When viewed from the stakeholders in Figure 4.2, contractors are the majority of respondents, namely 48 people or 74 percent, consultants and service owners/users as many as 7 people or 11 percent, and others as many as 3 people or 5 percent. From this data, it can be concluded that the distribution of respondents is not so evenly distributed. More details are presented in Table 2.

Table 2

Number and percentage of respondents based on stakeholders

Stakeholder	**Number of Respondents**	**Presented**
(1)	(2)	(3)
Contractor	48	74%
Konsultan	7	11%
Owner/Service User	7	11%
Other	3	5%

Results of Implementation Supporting Factors

After knowing the background of the respondents, then a factor analysis was carried out whose data was processed using SPSS. The first step in factor analysis is to conduct a validity test and reliability test of supporting factors in the implementation of BIM and GIS integration in the IKN project.

Validity Test of Supporting Factors

A validity test is a test used to determine the suitability or validity of a questionnaire to obtain data (Janna, 2021). The value r_tabel=r ((0.05; 63)) of 0.2441 with 65 samples. The results of the validity test are presented in Table 4.6. It can be seen in the table, the results of the validity test do not have a single variable that has a Pearson correlation (r_hitung) below r_tabel so there are no variables that need to be emulated.

Table 3
Validity Test Results of X Variables

Variable	r_{hitung}	r_{tabel}	Status	Variable	r_{hitung}	r_{tabel}	Status
(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
X1	0.571	**0.2441**	***Valid***	X10	0.56	**0.2441**	***Valid***
X2	0.526	**0.2441**	***Valid***	X11	0.687	**0.2441**	***Valid***
X3	0.601	**0.2441**	***Valid***	X12	0.609	**0.2441**	***Valid***
X4	0.468	**0.2441**	***Valid***	X13	0.614	**0.2441**	***Valid***
X5	0.605	**0.2441**	***Valid***	X14	0.539	**0.2441**	***Valid***
X6	0.709	**0.2441**	***Valid***	X15	0.570	**0.2441**	***Valid***
X7	0.668	**0.2441**	***Valid***	X16	0.602	**0.2441**	***Valid***
X8	0.726	**0.2441**	***Valid***	X17	0.565	**0.2441**	***Valid***
X9	0.765	**0.2441**	***Valid***				

Reliability Test

In addition to conducting validity tests, reliability tests are also carried out in the analysis stage of supporting factors. The reliability test is a test used to determine the level of consistency of the questionnaire used. The results of the previous validity test, 17 variables can be continued in the reliability test. The results of the reliability test calculation for the 17 variables are presented in the following table 4.

Table 4
Reliability Test Results of Supporting Factor Variables

Reliability Statistics		
Cronbach's Alpha	***Cronbach's Alpha Based on Standardized Items***	***N of Items***
(1)	(2)	(3)
0.919	0.921	17

From Table 4 above, it can be seen how many questionnaire questions/variables or N of Items are available. Where there are 17 N of Items with a Cronbach's Alpha value of 0.919. Because Cronbach's Alpha score > 0.60, it was concluded that the 17 questions in the questionnaire were consistent.

Analysis of Implementation Supporting Factors

After the validity test and reliability test were carried out, then the KMO and Bartlett's Test scores were calculated. The results of processing using SPSS software are presented in the following table 5.

Table 5
KMO dan Bartlett's Test Faktor Pendukung

KMO dan Bartlett's Test		
Kaiser-Mayer-Olkin Measure of Sampling Adequacy		0.826
Bartlett's Test of Sphericity	*Approx. Chi-Square*	755.606
	df	136
	Sig.	0.000

Based on the table above, it is known that the KMO MSA value is 0.826 and the Batlett's Test of Sphericity (Sig.) value is 0.000. According to (Kaiser & Rice, 1974), the KMO value is in the range of 0.80 ≤ KMO < 0.90 which can be categorized as the data used as good for factor analysis. Then Batlett's Test of Sphericity (Sig.) value of 0.000 < 0.05 shows that there is a significant correlation between the variables used, so factor analysis can be carried out.

Table 6
Hasil Uji Reliability

Reliability Statistics		
Cronbach's Alpha	***Cronbach's Alpha Based on Standardized Items***	***N of Items***
(1)	(2)	(3)
0.821	0.823	17

From Table 6 above, it can be seen how many questionnaire questions/variables or N of Items. Where there are 17 N of Items with a Cronbach's Alpha value of 0.821. Because Cronbach's Alpha score > 0.60, it was concluded that the 17 questions in the questionnaire were consistent.

Analysis of Implementation Factors

After the validity test and reliability test were carried out, the KMO and Bartlett's Test values were then calculated to determine the feasibility of the variables. The results of processing using SPSS software are presented in the following table 7.

Table 7
KMO and Bartlett's Test Inhibitory Factors

KMO dan Bartlett's Test		
Kaiser-Mayer-Olkin Measure of Sampling Adequacy		0.634
Bartlett's Test of Sphericity	*Approx. Chi-Square*	413.799
	df	136
	Say.	0.000

Based on the table above, it is known that the KMO MSA value is 0.634 and the Batlett's Test of Sphericity (Sig.) value is 0.000. According to (Kaiser & Rice, 1974), the KMO value is in the range of 0.60 ≤ KMO < 0.70 which indicates that the data used is not enough for factor analysis, but it can still be continued to the next analysis. Then the value of Batlett's Test of Sphericity (Sig.) 0.000 < 0.05 shows that there is a significant correlation between the variables used, so factor analysis can be carried out.

Analysis of Supporting and Inhibiting Factors

From the results of the analysis of the supporting and inhibiting factors for the implementation of BIM and GIS Integration in the IKN Project, to facilitate the understanding of each of these factors, the following factors were grouped:

Table 8
Supporting Factor Groups

Code	Variable	Component	Factor
(1)	(2)	(3)	(4)
X4	The use of BIM-GIS models in the teaching process of various subjects.	1	BIM-GIS integration in reducing design risks and improving project quality.
X6	Improve project quality.		
X7	Simplify design understanding.		
X8	Clarify the scope of work.		
X16	*Clash detection*.		
X17	Synergy with stakeholders.		
X1	BIM-GIS synergy with *Lean Construction* and LPS.	2	BIM-GIS integration in synergy with other technologies and methods.
X2	BIM-GIS integration with IoT devices.		
X3	BIM-GIS-based plugin.		
X5	BIM-GIS Integration with *Extended Reality*.		
X9	The design process time and its changes.	3	BIM-GIS integration in the planning and monitoring stage of the construction process, including time and cost.
X10	Reduce construction costs.		
X11	Construction planning and *monitoring*.		
X13	Construction implementation time.		
X12	Better control and cost estimation.	4	BIM-GIS integration as *budget controlling* in

X15	Accelerate the construction process.		accelerating the construction process.

As for the inhibiting factors, the table is as follows.

Tabel 9
Kelompok Faktor Penghambat

Code	**Variable**	**Component**	**Factor**
(1)	(2)	(3)	(4)
Y7	No industry standard is used as a guideline for BIM-GIS integration.	1	There are no industry standards, a lack of regulations, and the need both internally and externally to implement BIM-GIS integration.
Y8	Lack of regulations or laws governing the adoption of BIM-GIS		
Y11	Not implementing because there is no request from clients/service users.		
Y12	It does not require the implementation of BIM-GIS.		
Y5	High investment in *software*, *hardware,* and training	2	Organizational support in equipment and training investment as well as the receipt of benefits and intellectual property.
Y14	Large file extensions and sizes		
Y15	Contract and intellectual property changes for BIM-GIS implementation		
Y16	Organizational support in the use of BIM-GIS.		
Y9	Shortage of BIM-GIS experts.	3	The need for human resources and the difficulty of the integration process.
Y10	Training and development.		
Y13	The difficulty is that the BIM-GIS process is not fully used.		

Y17	Collaboration between teams.	4	Collaboration and measurement of benefits received.
Y18	Difficulty measuring the benefits of BIM-GIS.		
Y4	There is no support or motivation for the adoption of BIM-GIS.	5	Support between teams and integration equipment capabilities.
Y6	Lack of ability to operate *software* and computers.		
Y2	Lack of individual knowledge and awareness of BIM-GIS	6	Individual knowledge and awareness of BIM-GIS

Qualitative Analysis of Inhibiting Factors

Furthermore, a qualitative analysis of supporting factors in the implementation of BIM and GIS integration in the IKN project that has been formed is carried out. There are 6 supporting factors (Nelson & Tamtana, 2019).

1. There are no industry standards, lack of regulations, and the need both internally and externally to implement BIM-GIS integration

BIM has become a mandatory standard in construction projects in several countries around the world, whereas GIS still has a limited role in the construction industry. In Indonesia itself, the lack of regulations or laws governing the adoption of BIM-GIS is an inseparable inhibiting factor. Supported by the absence of implementation because there is no demand from clients/service users, this means that in Indonesia itself there is no need for BIM-GIS implementation.

2. Organizational support in equipment and training investment as well as the receipt of benefits and intellectual property

The lack of organizational support for the use of BIM-GIS is the next inhibiting factor. In practice, high investment is required for software, hardware, and training. In addition, extensions and large file sizes are also a problem. Not only that, changes in contracts and intellectual property are also other factors for the implementation of BIM-GIS. In fact, according to Li et al. (2017), with its features, BIM has found many applications in creating design alternatives, detecting clashes early, controlling project costs and schedules, logistics management, monitoring progress, and asset maintenance and operation. In addition, according to Zhang et al. (2009), GIS can be used in area planning, infrastructure design, construction and maintenance, land surveying, and GIS-based simulation for spatial decision-making and optimization.

3. Human resource needs and difficulties in the integration process

According to (Pedó et al., 2023), the implementation of BIM and GIS integration still faces several challenges such as the complexity of creating applications due to the many steps required. The integration of BIM and GIS requires trained human resources who have a deep understanding of these two technologies. In addition, users also face challenges in understanding how to use the platform and its applications, so further training is needed to increase awareness and understanding of the technical use and available functions.

4. Collaboration and measurement of benefits received

Collaboration between teams that is not so good is also an inhibiting factor. In addition, there are difficulties in measuring the benefits of BIM-GIS by the stakeholders who implement it. According to ESRI (2022), the benefits of GIS can include improved communication and efficiency, as well as better management and decision-making. GIS technology integrates common operations of data, such as querying and statistical analysis, with the unique visualization and analysis capabilities of mapping (Zhu & Wu, 2022). This ability distinguishes GIS from other information system applications that are beneficial for explaining events, planning strategies, and predicting field conditions that occur and can be used to retrieve, store, analyze, and display spatial and non-spatial data (Rifai, 2022). Additionally, it's important to have clear metrics to measure the benefits received from these integrations, but it's often difficult to identify and measure the impact precisely.

5. Cross-team support and integration equipment capabilities

No support or motivation for BIM-GIS adoption is the next inhibiting factor. Continuity between the teams involved in the construction project and proper support for the integration equipment (both software and hardware) is essential for the success of BIM-GIS integration. The absence of adequate support can hinder the team's ability to collaborate and use equipment effectively.

6. Individual knowledge and awareness of BIM-GIS

Lack of individual knowledge and awareness of BIM-GIS is also a hindrance to implementation. Without a sufficient understanding of the benefits and potential of this integration, employees may be reluctant or unable to adopt this technology in their work. It is hoped that with this research, the understanding of BIM-GIS implementation can increase, especially in construction projects in IKN.

Understanding and overcoming these inhibiting factors is an important step in ensuring the successful implementation of BIM and GIS integration in construction projects, organizations can maximize the potential of this technology to improve project efficiency and quality, especially in projects in IKN that are carried out massively and simultaneously with different organizations.

Comparison of research results with literature studies

Some of the relevant studies that address the implementation of technology in BIM and GIS in the industry have some similarities with the results outlined in the previous subchapter.

The results show that the supporting factor in the implementation of BIM and GIS integration in the IKN Project is the BIM-GIS integration factor in reducing design risks and improving project quality. This is in line with the results of research from Sekarsari

(2019) and (Chan, Olawumi, & Ho, 2019) who stated that the implementation of BIM and GIS in construction projects can improve project quality with company and project performance discipline.

On the other hand, the research results also identify inhibiting factors in the implementation of BIM and GIS integration in the IKN Project, namely the lack of industry standards, lack of regulations, and needs both internally and externally. These inhibiting factors were also found in research conducted by (Bosch-Sijtsema, Isaksson, Lennartsson, & Linderoth, 2017), that the inhibiting factors were the lack of government support, company needs, and the absence of standards, guidelines, and policies in the implementation of BIM.

Taking these findings into account, the study proposes strategic measures that can be implemented to overcome these barriers and maximize their supporting factors. The successful implementation of the integration of BIM and GIS will bring an increase in the success of the development of projects in the IKN area.

Proposed strategic steps for the implementation of BIM and GIS integration

The proposed strategic steps that can be taken in the implementation of BIM and GIS integration in the IKN project are as follows:

1. Analysis of strategic needs and objectives. This step relates to supporting factors, especially in terms of identifying the potential benefits of BIM and GIS integration in reducing design risk, improving project quality, and controlling project time and cost. By understanding the strategic needs and objectives, the project can prioritize the use of BIM and GIS integration to achieve the desired results.
2. Team building and collaboration between organizations. Bottlenecks related to organizational support and collaboration between teams can also be overcome with this step. Through the establishment of cross-disciplinary teams and inter-organizational collaboration, projects can ensure strong support from all stakeholders and facilitate effective cooperation.
3. Development of integration standards and guidelines. In overcoming the inhibiting factors related to the lack of industry standards and regulations, this step is crucial. By developing BIM and GIS integration standards and guidelines, the project can ensure that all parties involved have clear guidance on the implementation and use of these integrations.
4. Investments in equipment and training. Inhibitory factors related to human resource needs and investments in equipment and training can be overcome through this step. By making adequate investments in BIM and GIS equipment and providing comprehensive training for the team, the project can ensure that the human resources involved have the necessary skills and knowledge to implement this integration.
5. Pilot projects and periodic evaluations. This step relates to the inhibiting factors related to the need for support in equipment and training investments as well as the receipt of benefits and intellectual property. Through careful implementation pilots and evaluations, projects can test the effectiveness of the proposed solution and identify measurable benefits from BIM and GIS integration.

6. Risk management and performance measurement. Through this step, the project can overcome the inhibiting factors related to risk management and performance measurement. By identifying and managing the risks associated with the implementation of BIM and GIS integration and establishing clear performance metrics, projects can minimize risks and ensure the achievement of desired outcomes.
7. Continuous monitoring and adjustment. Finally, this step relates to continuous monitoring and adjustment, which is essential to address all the supporting factors and inhibitions that have been identified. By monitoring the progress of the implementation and making continuous adjustments based on the results of monitoring and feedback, the project can ensure the long-term success of BIM and GIS integration.

The proposal of strategic steps for the implementation of BIM and GIS integration in IKN projects is a solid foundation to achieve success. Taking into account the identified supporting factors and inhibitors, these measures are designed to address emerging challenges and maximize the potential of this integration. In implementing these steps, collaboration between teams, organizational support, investment in equipment and training, and continuous monitoring will be key to ensuring a successful implementation. Thus, the implementation of interrelated projects both by design and spatially can reap the maximum benefits of BIM and GIS integration, improve operational efficiency, reduce risk, and achieve the overall desired results.

Conclusion

Initial identification of inhibiting factors and supporting factors for the implementation of BIM and GIS integration in IKN projects, resulting in 16 (sixteen) supporting factors and 16 (sixteen) inhibiting factors. The factor analysis also produced findings, that of the 16 supporting factors for the implementation of BIM and GIS integration in IKN projects, 4 (four) factors can be determined, namely: a) BIM-GIS integration in reducing design risks and improving project quality; b) Integration of BIM-GIS in synergy with other technologies and methods; c) BIM-GIS integration in the planning and monitoring stage of the construction process, including time and cost; d) BIM-GIS integration as budget controlling in accelerating the construction process. For the inhibiting factors, this study produces findings that of the 16 factors that hinder the implementation of BIM and GIS integration in IKN projects, it can be grouped into 6 (six) factors, namely a) the absence of industry standards, lack of regulations, the need both internally and externally to implement BIM-GIS integration; b) Organizational support in investment in equipment and training as well as the receipt of benefits and intellectual property; c) Human resource needs and difficulties in the integration process; d) Collaboration and measurement of benefits received; e) Inter-team support and integration equipment capabilities; f) Individual knowledge and awareness of BIM-GIS.

Proposed strategic steps in the implementation of BIM and GIS integration in IKN projects require collaboration between teams, strong organizational support, investment in equipment and training, and continuous monitoring. These measures are expected to address the challenges that arise and ensure the success of this integration so that the project can achieve high operational efficiency, reduce risks, and achieve the desired results.

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