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Assessing Disaster Mitigation System Readiness in Building Construction Using Wireless Network Systems: An Exploratory Factor Analysis

Veonica Nanda Suwito[1]; Nusa Sebayang[2]; Lila Ayu Ratna Winanda[3]

[1,2,3] Program Studi Magister Teknik Sipil, Institut Teknologi Nasional Malang

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Abstract

The increasing frequency of natural disasters demands effective early warning and mitigation systems, especially in disaster-prone regions. This study explores the readiness to implement Wireless Network System (WNS)-based disaster mitigation in building construction through Exploratory Factor Analysis (EFA). A structured Likert-scale questionnaire was administered to 15 professionals involved in construction and disaster management in Trenggalek Regency, Indonesia. Principal Component Analysis (PCA) with Varimax rotation was used to identify the latent constructs behind system readiness perceptions. The analysis revealed a three-factor structure: Technological Readiness and Usage Attitude, Information Quality and System Interaction, and Perceived Usefulness. These dimensions explain the majority of variance in the dataset and highlight the key areas of concern in adopting WNS in real-world construction practices. The findings contribute to better system planning and policy development in the context of disaster-prone infrastructure.

Keywords: *Disaster Mitigation, Wireless Network System (WNS), Exploratory Factor Analysis (EFA), Principal Component Analysis (PCA), Construction Readiness.*

I. INTRODUCTION

Natural disasters such as earthquakes, landslides, and floods continue to pose a significant threat to public safety and infrastructure sustainability. In regions like Trenggalek Regency, Indonesia—an area categorized as highly prone to geological hazards—there is a growing need for the integration of technology into disaster mitigation systems. The construction sector, which plays a critical role in community resilience, must adopt systems that not only warn but also guide rapid responses during emergencies.

Wireless Network Systems (WNS) have gained significant attention as effective tools for enabling timely detection and communication during disaster scenarios. These systems utilize wireless sensors, microcontrollers, and communication modules (e.g., GSM or IoT) to detect and transmit environmental data. When integrated with public infrastructure, WNS can enhance responsiveness, reduce casualties, and minimize material losses. However, the deployment of such systems hinges not only on engineering specifications but also on the users' willingness and capacity to adopt the technology. Previous studies have evaluated the effectiveness of early warning systems, but limited research has examined the readiness factors associated with adopting WNS in construction settings, especially in semi-rural regions. Understanding stakeholders' perceptions is crucial, as these systems will be managed and operated by professionals in construction, disaster mitigation agencies, and local government.

This research addresses that gap through the application of Exploratory Factor Analysis (EFA), aiming to reveal the latent constructs underlying stakeholder readiness toward WNS adoption. By using Principal Component Analysis (PCA) and Varimax rotation, the research identifies key factors influencing system adoption. The results are expected to inform system developers, policymakers, and practitioners in planning, designing, and promoting effective disaster mitigation strategies using WNS.

II. LITERATURE REVIEW

➢ *Wireless Network System (WNS) in Disaster Mitigation*

Wireless Network Systems (WNS) represent a key innovation in early warning and mitigation strategies, particularly in areas prone to natural disasters. WNS enables real-time monitoring, automatic alert generation, and integration with mobile and web-based platforms. These systems often incorporate components such as wireless sensors, microcontrollers, GSM modules, and environmental detectors (Kaur et al., 2012), enabling seamless communication between infrastructure and stakeholders during emergency situations.

➢ *Technology Acceptance in Disaster Mitigation*

Assessing the readiness and acceptance of WNS requires a robust theoretical foundation. The Technology-Task Fit (TTF) theory suggests that system effectiveness depends on its alignment with users' tasks (Goodhue & Thompson, 1995). Perceived Usefulness (PU) and Perceived Ease of Use (PEOU), derived from the Technology Acceptance Model (TAM), are also considered critical in evaluating user acceptance (Davis, 1989). Several studies confirm that PU and PEOU influence attitudes toward technology adoption, especially in the public sector and emergency management (Haini et al., 2020).

➢ *System Quality and Information Quality*

System Quality (SQ) refers to the technical functionality, interface design, and response time of a system, while Information Quality (IQ) includes accuracy, relevance, and completeness of information (DeLone & McLean, 2003). In disaster mitigation systems, both SQ and IQ significantly affect decision-making and responsiveness. These dimensions are integrated into questionnaires to assess users' experiences and the system's operational reliability.

➢ *Exploratory Factor Analysis (EFA), PCA, and Varimax Rotation*

Exploratory Factor Analysis (EFA) is a multivariate statistical technique used to identify the underlying factor structure of observed variables. It is suitable when the researcher does not assume a predefined structure but wants to explore how indicators naturally group together (Hair et al., 2010).

In this study, Principal Component Analysis (PCA) was used as the extraction method. PCA transforms correlated variables into a smaller set of uncorrelated principal components that explain the most variance in the data (Tabachnick et al., 2019).

After extraction, Varimax rotation—a type of orthogonal rotation—was applied to enhance the clarity and interpretability of the factor structure (Costello & Osborne, 2005).Varimax simplifies loading patterns so that each item loads highly on one factor only, thus improving conceptual clarity.

This study did not include KMO and Bartlett's tests, as the sample size was limited (n = 15), and the analysis focused directly on extracting interpretable factor structures with theoretical justification.

➢ *Instrument and Statistical Tools*

The questionnaire was developed using Likert scale items (1–5) and covered seven theoretical variables:

- Technology Task Fit (TTF)
- Information Quality (IQ)
- System Quality (SQ)
- Perceived Ease of Use (PEOU)
- Perceived Usefulness (PU)
- Attitude Toward Use (ATU)
- Actual Use (AU)

All questionnaire items were tested for validity using Pearson's correlation and for reliability using Cronbach's Alpha. Items with correlation values above 0.3 and alpha coefficients above 0.7 were considered acceptable and included in the EFA.

➢ *Minitab 19 Software*

Minitab 19 was used to conduct the entire Exploratory Factor Analysis process. Minitab offers a user-friendly interface and advanced tools for PCA, including scree plots, rotated component matrices, and summary statistics. It allowed for efficient dimensionality reduction without requiring additional plugins or scripting.

➢ *Instrument Validation: Validity and Reliability Tests*

Before conducting EFA, the instrument's psychometric quality was assessed through **validity** and **reliability** testing:

- **Validity** was measured using **Pearson's Product Moment correlation**, with item scores correlated to total variable scores.

The formula used is:

$$r = \frac{n\sum XY - (\sum X)(\sum Y)}{\sqrt{[n\sum X^2 - (\sum X)^2][n\sum Y^2 - (\sum Y)^2}}$$

Where:

XXX = individual item score

YYY = total score

nnn = number of respondents

A correlation value of **r > 0.3** was considered acceptable for construct validity (Hair et al., 2022).

- **Reliability** was assessed using **Cronbach's Alpha**, with the following formula:

$$a = \frac{k}{k-1}\left(1 - \frac{\sum \sigma_i{}^2}{\sigma_t^2}\right)$$

Where:

kkk = number of items
σi2\sigma_i^2σi2= variance of each item

σt2\sigma_t^2σt2= variance of the total scale

An alpha value of $\geq$ **0.7** indicates acceptable internal consistency.

Items that failed these tests were excluded prior to EFA, ensuring that only valid and reliable indicators contributed to the final factor structure.

➢ *Previous Empirical Studies*

Previous studies have implemented WNS for flood detection, earthquake alerts, and landslide early warning systems (Budianto et al., 2020). However, research on the acceptance and readiness for such systems in the Indonesian context—particularly in semi-rural areas like Trenggalek—remains scarce. This study fills the gap by using EFA to reveal the underlying structure of readiness perceptions and aligning it with theoretical dimensions from TAM and TTF models.

III. METHODOLOGY

➢ *Research Design*

This study employed a **quantitative descriptive design** using a survey method to investigate the readiness of stakeholders to implement Wireless Network Systems (WNS) for disaster mitigation in the construction sector. The primary statistical approach used was **Exploratory Factor Analysis (EFA)**, specifically utilizing **Principal Component Analysis (PCA)** with **Varimax rotation** to extract and interpret latent factors from the observed variables.

➢ *Instrumentation*

The research instrument was a structured questionnaire developed based on well-established theoretical models, including the Technology Acceptance Model (TAM), Technology-Task Fit (TTF), and the DeLone and McLean Information System Success Model. The questionnaire utilized a **5-point Likert scale** (1 = Strongly Disagree, 5 = Strongly Agree), covering seven key constructs:

- Technology Task Fit (TTF)
- Information Quality (IQ)
- System Quality (SQ)
- Perceived Ease of Use (PEOU)
- Perceived Usefulness (PU)
- Attitude Toward Use (ATU)
- Actual Use (AU)

After preliminary evaluation, 14 valid and reliable items were retained for factor analysis.

➢ *Population and Sample*

The population consisted of stakeholders from Trenggalek Regency, including professionals in the construction industry, disaster management officials, and system operators.

- **Sampling technique**: Purposive non-probability sampling
- **Sample size**: 15 respondents
- **Inclusion criteria**: Individuals with experience in construction or disaster mitigation involving technological systems

➢ *Validity and Reliability*

Before conducting EFA, all items were tested for validity and reliability:

- **Validity** was assessed using **Pearson Product-Moment Correlation**, where items with r >0.30 were considered valid.
- **Reliability** was assessed using **Cronbach's Alpha**, and values above α=0.70\alpha = 0.70α=0.70 were considered acceptable.

Only items that passed both tests were included in the final factor analysis.

➢ *Data Analysis Procedure*

The factor analysis was conducted using **Minitab 19**. PCA was chosen as the extraction method, and **Varimax orthogonal rotation** was applied to clarify factor loading patterns. The decision to retain factors was based on:

- Eigenvalues > 1.0
- Scree plot inspection
- Factor loadings ≥ 0.50
- Conceptual alignment with theoretical constructs

KMO and Bartlett's tests were not applied in this study due to the small sample size.

➢ *Ethical Considerations*

All respondents participated voluntarily and anonymously. No personally identifiable information was collected. The study adhered to general ethical guidelines for academic research involving human participants.

IV. RESULTS AND DISCUSSION

➢ *Valid and Reliable Items*

Before performing factor analysis, all items were subjected to validity and reliability tests. The validity test used Pearson Product Moment correlation, with all items yielding r>0.3, indicating sufficient item-total correlation. Reliability was assessed using Cronbach's Alpha, with each construct exceeding the threshold of 0.70.

Table 1 summarizes the results of the validity and reliability analysis for the seven research variables:

Table 1 Results of Validity and Reliability Testing

Variable	Number of Items	R (Min-Max)	Cronbach's Alpha
Task Technology Fit (TTF)	14	0.523–0.901	0.871
Information Quality (IQ)	14	0.566–0.913	0.885
System Quality (SQ)	8	0.814–0.868	0.899
Perceived Ease Of Use (PEOU)	12	0.544–0.905	0.911
Perceived Usefulness (PU)	7	0.763-0.865	0.882
Attitudetoward Using (ATU)	8	0.764-0.934	0.889
Actual Use (AU)	14	0.557-0.706	0.878

- *Factor Extraction and Scree Plot*

Exploratory Factor Analysis (EFA) was conducted using PCA in Minitab 19. The Eigenvalue > 1.0 rule (Kaiser's criterion) and scree plot analysis were used to determine the number of retained factors. Based on the screen plot and eigenvalue values, three components were selected as they explained the most significant variance in the dataset.

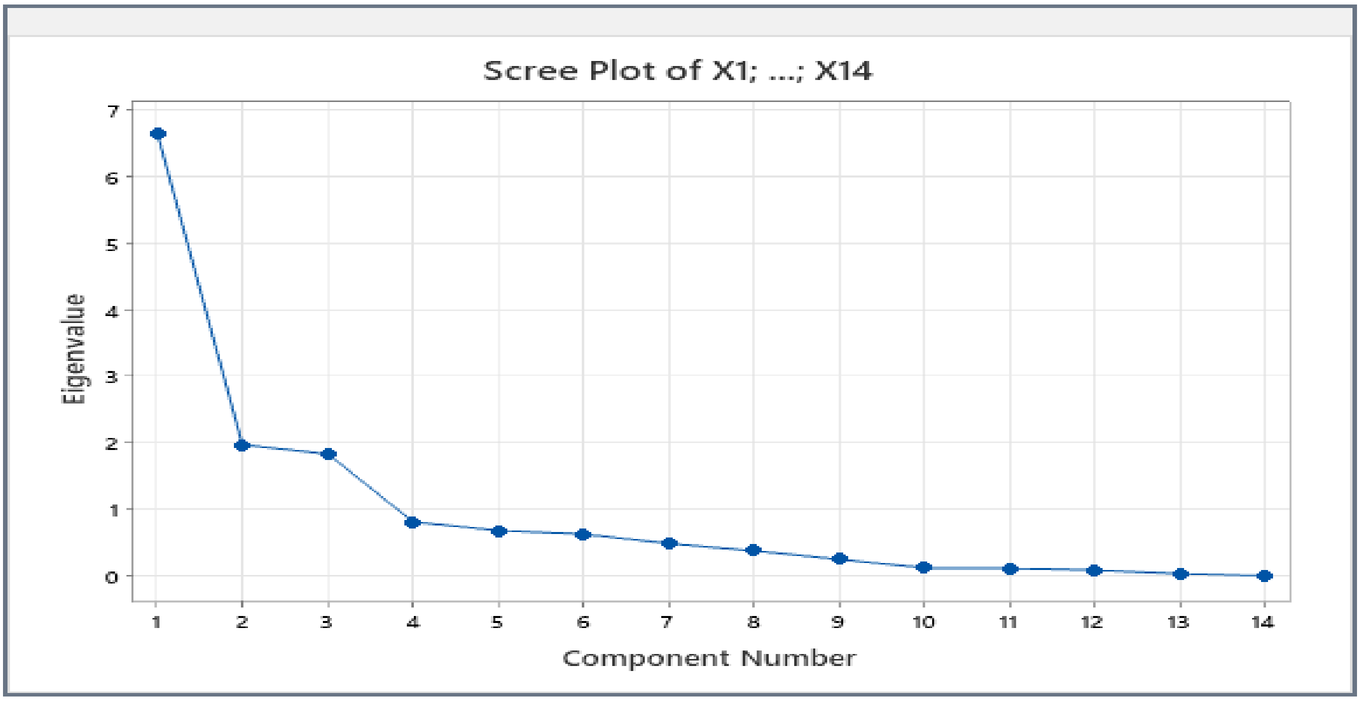

Fig 1 Scree Plot from Minitab

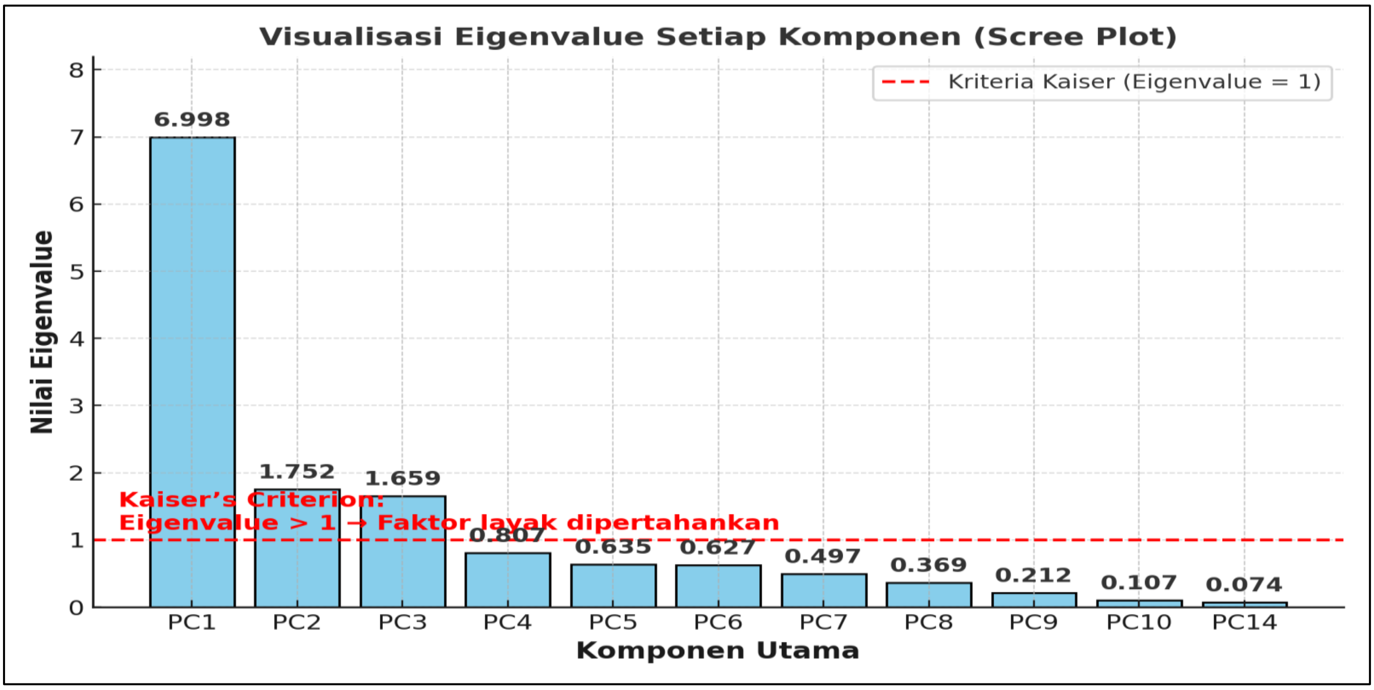

Fig 2 Eigenvalue of Each Component (Bar Version)

➢ *Rotated Component Matrix*

To enhance interpretability, **Varimax rotation** was applied. The rotated solution revealed three clear factors with loading values ≥ 0.5. The summary of interpretation is presented in the following table:

Table 2 Summary of Factor Interpretation Based on Rotated Component Matrix

Factor	**Main Indicators (Loading ≥ 0.5)**	**Original Variable**	**Interpretation**
Factor 1: Technological Readiness & Task Alignment	X13 (0.905), X2 (0.748), X7 (0.557), X3 (0.525)	Task Technology Fit (TTF)	Shows system compatibility with task requirements in the disaster mitigation context
Factor 2: System Information Quality	X8 (0.801), X11 (0.949)	Information Quality (IQ)	Reflects system reliability, accuracy, and completeness of information
Factor 3: Perceived Usefulness	X14 (0.840), X1 (0.557), X10 (0.731)	Perceived Usefulness (PU)	Indicates perceived benefits of the system in supporting mitigation tasks

Varimax rotation was applied to improve interpretability. The rotated component matrix revealed clean loading patterns, with each item strongly loading on one factor only. The final factor structure was as follows:

- *Factor 1: Technological Readiness and Usage Attitude*

Includes items related to Technology Task Fit (TTF), Perceived Ease of Use (PEOU), and Attitude Toward Use (ATU). This factor reflects stakeholders' confidence in the alignment between WNS technology and their tasks, as well as their willingness to adopt and use it.

- *Factor 2: Information and System Quality*

Combines items from Information Quality (IQ) and System Quality (SQ), including perceptions about the reliability, accuracy, and clarity of system performance.

- *Factor 3: Perceived Usefulness*

Captures how respondents perceive the effectiveness of WNS in enhancing disaster mitigation outcomes. Items from PU and AU were included, representing both perceived value and actual system usage potential.

This structure simplifies the original seven variables into three coherent dimensions that represent the conceptual readiness for WNS implementation.

➢ *Theoretical Links and Implications*

To clarify the theoretical foundation and contributions of each factor, Table 3 presents the linkage between extracted factors, original constructs, and their theoretical frameworks:

Table 3 Factor–Theory Linkage and Theoretical Implications

No	Research Factor	Original Variable	Supporting Theory	Theoretical Implication
1	Technological Readiness & Task Alignment	TTF	Task-Technology Fit (Goodhue & Thompson, 1995)	Highlights the importance of system-task compatibility in adoption
2	System Information Quality	IQ	Information System Success Model (DeLone & McLean, 2003)	Emphasizes the role of quality information in system acceptance
3	Perceived Usefulness	PU	Technology Acceptance Model (Davis, 1989)	Underlines perceived benefits as a foundation of system readiness

V. CONCLUSION

This study aimed to explore the readiness of implementing Wireless Network System (WNS)-based disaster mitigation in construction projects using Exploratory Factor Analysis (EFA). Based on data from 15 respondents, three latent factors were extracted using Principal Component Analysis (PCA) with Varimax rotation. These factors—Technological Readiness and Task Alignment, System Information Quality, and Perceived Usefulness—explained the majority of variance and reflect core components of system adoption in disaster-prone regions.

The findings provide empirical support for the integration of TTF, TAM, and IS Success Models into the assessment of technological readiness. The results also demonstrate that the successful adoption of WNS in disaster mitigation depends not only on technical features but also on users' perceptions regarding system compatibility, information accuracy, and perceived benefits.

➢ *From a Practical Perspective, Stakeholders in Disaster Management and Infrastructure Development Should Prioritize:*

- Ensuring that technological solutions align with end-user workflows and responsibilities;
- Improving the quality and reliability of system information;
- Promoting awareness of the usefulness and impact of WNS in improving disaster response.

The study also reinforces the feasibility of applying EFA for system readiness assessment in small-sample contexts, provided that instrument validity and reliability are well established.

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