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Conceptual Model of Architecture of 4-Layer Smart System for Emergency Response system of Negative Interaction of Human to Elephant

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A B S T R A C T

The interaction between elephants and humans in the era of smart systems requires a new approach to managing frequent conflicts. In this context, the development of an emergency response system based on smart system technology is very important, both for local communities and national park managers. This system is expected to utilize technology to improve the effectiveness of handling elephant emergencies. This study emphasizes the need to develop an emergency response system based on smart systems to improve the effectiveness of managing elephant-human interactions. Sustainable and participatory system development will be key to creating better solutions to these conflicts in the future.

INTRODUCTION

Background

Human population growth and land use changes [1], especially for agriculture, have led to the fragmentation of elephant habitats. This has pushed elephants into human settlements, leading to negative interactions between the two parties [2] [2]. [3] found that the intensity of these conflicts is influenced by ecological and socio-economic factors. Other studies by [4] [5] highlighted that habitat fragmentation exacerbates these interactions. These interactions can cause social and economic losses to local communities and increase elephant mortality due to human defensive actions or risky relocation efforts [6].

To reduce negative interactions between humans and elephants, an effective emergency response strategy needs to be designed [7]. The importance of an emergency response system is increasingly crucial in complex situations [8], such as disasters and human-wildlife conflicts. An efficient emergency response strategy is needed to minimize social and economic losses, as well as reduce the incidence of elephant mortality [6]. Implementing a rapid response in dealing with negative incidents can reduce further losses. Various emergency response efforts are carried out [7], [9][10] In the National Park, efforts are made to handle these negative interactions through the Elephant Response Unit (ERU) program [11]. Other handling approaches are through compensation [9] collaboratively and integrated with relevant stakeholders [2],, education and public awareness of elephant behavior, development of infrastructure such as fences to prevent conflict [6], increasing co-existence between humans and elephants [12], utilizing Internet of Things (IoT) technology to detect elephant movements non-invasively [13] [14]. Development of Emergency Response System [15] Use of Aversive Geofencing Devices [10], monitoring with an artificial intelligence approach [14], using robotics [8], provision of communication channels and emergency response systems [16], AI systems that analyze real-time data to respond to emergencies, To achieve more effective emergency response management, an approach is needed that harmonizes processes, people, and technology in an architectural perspective and conceptual model with an approach in the current era, namely a smart system according to its era [17]. This approach can be expected to be a sustainable solution and reduce negative interactions between humans and elephants in the smart system era so that it is developed into a smart organization [18] in the field of conservation [19]. So the research question for this study is how to design an emergency response architectural framework in the smart system era like today.

LITERATURE REVIEW

4-Layer Smart System Architecture

Smart System Architecture [8] , according to [20], is a reference framework for implementing a data governance system in an organization, including reference architecture, development methods, and maturity models [21]. This architecture is integrated with modern technologies such as the Internet of Things (IoT) and Cyber Physical System (CPS) [22] [23],, supporting digitalization and interoperability in industry 4.0 [14] [24] [25]. By managing information collaboratively, this architecture improves quality management [26] as well as the productivity and operational efficiency of the company [27], while [28] analyzes the characteristics of the reference architecture in the context of CPS.

The approach used in designing emergency response in this study is the 4-layer smart system architecture. The 4 Layer smart system architecture is a framework in our research group, which is a unified activity in the People, Process and Technology components that consist of clear Layer activities. The layer consists of four layers, namely: Instrumentation and Control Layer, Information System Layer, Business Intelligence Layer, and Gamification Layer. These layers are always related and deal with various fields in daily phenomena, for example: Education (Education 21), Transportation (Smart Transportation) [29] [30], Home Automation [31], SPBE , Defense and Security [32][33] [34], Smart Logistics, Blue Light Service, Next Generation Entertainment [35] [36] and others [37] [1]. Through the utilization of four modern technologies namely Internet of Things (IoT), HCI AR/VR [38] [39][40][41] [42], Artificial Intelligence (AI) and Big Data Platform. Smart System is always a combination of physical & local systems with virtual / cyber & global environments [31] so it is called Cyber-Physical System (CPS), Cyber-Physical System (CPS) is a combination of Internet-of-Things (IoT) & Robotics technology, Modeling-Simulation & Artificial Intelligence, Human-Content Interaction which is realized in the Big-Data platform. A modern application will consist of the following processes: a). How to obtain the required information either directly from the environment (IoT) or using humans as users (HCI); b). How to store, process and manage large amounts, diverse and unstructured data (Big-Data); c). How to get important meaning from the large amount of data and use it (AI, Data Mining, Machine Learning). The 4-Layer Smart System Architecture concept if depicted as below:

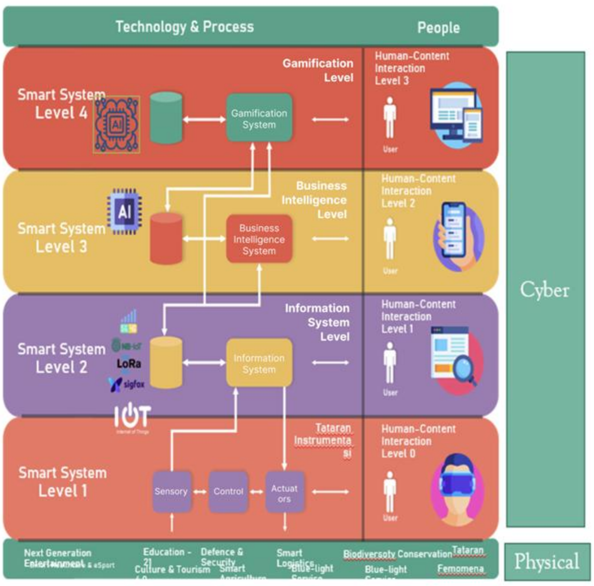


Figure 1. 4-Layer Smart System Architecture

The Layer 1 level is the first level of the Smart System in Organizations that relates to simple control sensors and actuators. For example, IoT technology, HCI Mobile, and Website. So it has special characteristics. First, it does not have a large database, only short-term memory. The system cannot store and access data continuously, but can only store temporary data needed to perform actions or make decisions. Second, the system has predefined and immutable algorithms. These algorithms are used to process the available data and information and make decisions or take actions in accordance with the goals or missions that have been set. Third, the system has the ability to interact with humans through displayed content. For example, this system can display the current short-term value or trend, as well as determine the appropriate reference value based on the available data and information. Level 1 smart systems are usually used to accomplish simple and limited tasks, such as managing manufacturing processes or controlling electrical systems. However, these systems have the disadvantage of not being able to store and access data continuously, so they cannot learn from previous experiences and adapt their behavior according to different situations.

Smart system level 2 is the third level of intelligent systems that have some special characteristics. First, the system has a large database that is both local and distributed, which is used as long-term memory. This means it can store and access data continuously, so it can learn from previous experiences and adapt its behavior according to different situations. Secondly, the system has predefined algorithms but has the ability to adapt to simpler or more complex algorithms using locally collected or distributed data. This allows the system to be more flexible in making decisions or performing actions according to different situations. Thirdly, the system has the ability to interact with humans through displayed content and can communicate with other systems in a distributed manner. For example, it can monitor and evaluate historical records and high-level statistics, and communicate with other systems to obtain necessary data and information.

Level 3 is the application level of the Business Intelligence system, which is when the information obtained from the application level of the information system is managed on a more massive scale to get a picture and insights that are richer, more diverse, and deeper than can be obtained at the scale of the information system application order so that it can help users to make more targeted decisions. This level usually involves processing massive amounts of data (Big Data), the use of mathematical models and more explicit modeling concepts (Modeling & Simulation), and the use of sophisticated Machine Learning algorithms. And related to humans as human-content interaction.

Layer 4 is the fourth level of intelligent systems that have some special characteristics. First, it has a large, global database, which stores comprehensive information and data structures and is a source of knowledge. This means it can store and access data continuously, so it can learn from previous experiences and adapt its behavior according to different situations. Secondly, the system has flexible algorithms with complex adaptability, which are designed to achieve goals by manipulating all levels and instruments below them. This allows the system to be more flexible in making decisions or taking actions according to different situations. Third, these systems have the ability to interact with humans through displayed content and can monitor and evaluate goals continuously. This level 4 intelligent system is usually used in strategies that require learning from previous experiences.

A modern application will consist of the following processes: a). How to obtain the required information either directly from the environment (IoT) or utilizing humans as users (HCI); b). How to store, process and manage large amounts, diverse and unstructured data (Big-Data); c). How to get important meaning from the large amount of data and use it (AI, Data Mining, Machine Learning). The *4-Layer Smart System* Architecture concept if depicted as below:

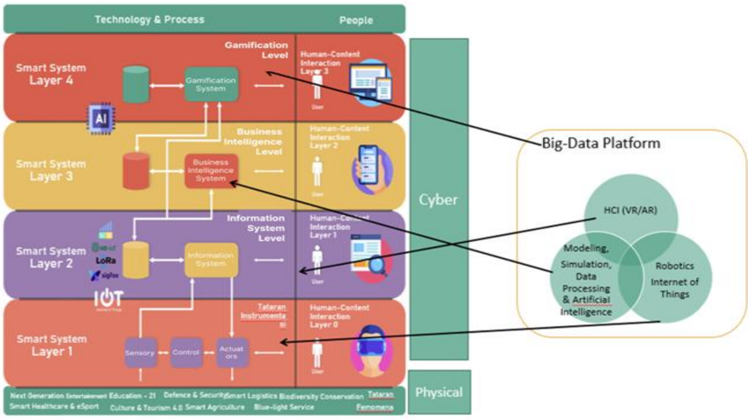


Figure 2. 4-Layer Smart System Architecture

The proposed solution in the 4-layer smart system architecture displays four explicit organizational layers: strategic, tactical, operational, and technical. Each of these layers is integrated with relevant technologies such as IoT, Big Data, HCI, AR/VR, and AI, which are explicitly defined to be implemented in each organizational layer [16]. The interaction between humans and technology and the processes in this approach are not yet fully comprehensive because they are not explained in detail in each layer. However, this figure shows that humans and AI work together as subjects in organizational activities. The system activity framework is illustrated as an activity triangle involving subjects (humans and AI), tools & artifacts, communities, rules/norms, division of labor, and goals. The interaction between layers is depicted with arrows indicating the flow of information and activities between the strategic, tactical, operational, and technical layers, indicating that these layers do not work in isolation but interact and coordinate dynamically. The synergy between humans and AI as subjects is emphasized, with both working together to achieve organizational goals and objectives. The Management By Objective (MBO) approach is applied in each layer to help direct activities and decision-making in each layer, ensuring that every action is aligned with organizational goals. This figure provides a comprehensive overview of a 4-layer intelligent system architecture that integrates state-of-the-art technologies with management concepts and organizational activities, creating an adaptive and flexible framework to support organizational operations and development.

Therefore, the 4-layer smart system architecture contains the following structure:

1. Explicit strategic, tactical, operational, and technical layer completeness aspects
2. All relevant technologies: IoT, Big Data, HCI, AR/VR, and AI
3. Explicit determination of technology (IoT, Big Data, HCI, AR/VR, and AI) that must be applied in each layer of the organization
4. Human interaction with technology and processes, people, the approach is not yet comprehensive and comprehensive
5. System Activity Framework in the activity network
6. Human and AI Synergy as Subjects
7. Management By Objective each layer
8. Dynamic interaction between layers

To integrate the two activity frameworks, a general and comprehensive smart system architecture perspective is needed, so that it can be a guideline for identifying elements and interactions with the environment by developing, implementing, adapting, evaluating, to maintaining and evolving systems that are integrated from the two activity frameworks [28]. In addition, the architecture requires an application whose main focus is architecture management, including the architecture life cycle and management principles.

METHODOLOGY:

In the context of research for the design and development of the 4-Layer Smart System architecture, the Methodology Reference is with Design Science Research Methodology (DSRM) which is a methodology for developing and evaluating research artifacts.

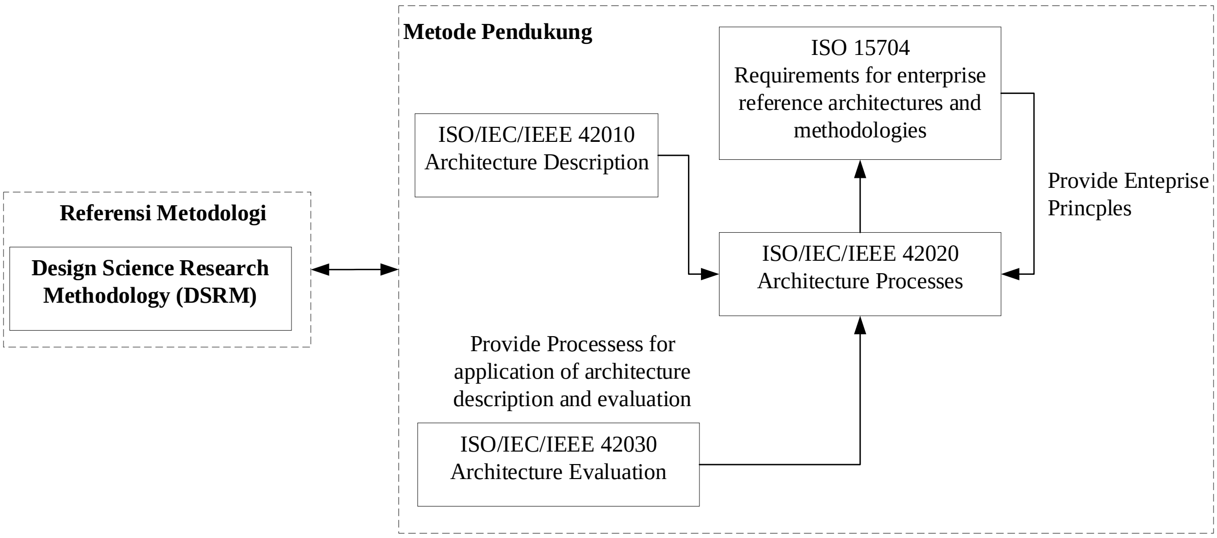


Figure xxx 4-Layer Smart System Architecture Design Research Flow

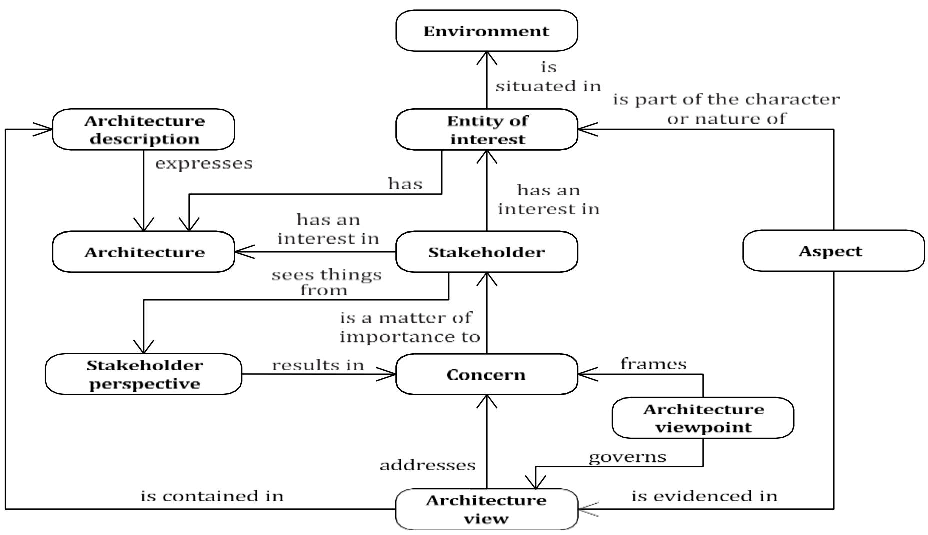
To support the DSRM methodology, supporting methods of several ISO standards are used to provide more specific guidance and frameworks in each stage of 4-Layer smart system architecture development. ISO standards used as supporting methods include:

1. ISO/IEEE/IEC 42010:2022 - provides guidance and frameworks for describing system architecture by identifying, documenting, and validating architectural elements.
2. ISO/IEEE/IEC 42020:2020 - provides structured guidance and frameworks for managing the entire architecture life cycle.
3. ISO 15704 provides guidance for developing an enterprise framework, identifying key elements, mapping relationships between elements, using appropriate models and notations.

The process of developing a 4-Layer smart system architecture using DSRM involves steps from problem identification to communication of results. This design ensures compliance with the following standards: a) ISO/IEC/IEEE 42010:2022 - Systems and software engineering — Architecture description used to develop architecture descriptions and blueprints covering four layers: strategic, tactical, operational, and technical, b) ISO/IEC/IEEE 42020:2019 - Software, systems and enterprise — Architecture processes for guidance on architecture governance, and c) ISO/IEC/IEEE 15704:2019 - Automation systems and integration — Requirements for enterprise-reference architectures and methodologies to ensure system integration and interoperability.

Figure III. 2 Components of DSRM and ISO Integration Research

The scope of the current research is Conceptual model of an architecture description with a more specific scope of Architecture View and Viewpoint



Architecture View and Viewpoint Model

This model describes a systematic process in the preparation of architecture that focuses on the relationship between various elements such as stakeholders, concerns, viewpoints, and views. In this framework, the Entity of Interest (EoI) is the main entity that is the center of attention of the architecture, which is in an Environment or environment that influences the character and nature of the entity. Stakeholders are parties who have an interest in this entity, who have special concerns or interests, and who see it from a certain perspective. Their interests produce concerns, namely important issues or aspects that need to be considered in architectural design.

Furthermore, the Architecture Description is a document that expresses the architecture of the identified entity and contains various views that are relevant to stakeholder needs. The architecture itself is a structure or framework that explains how entities work and interact, seen through the Stakeholder Perspective which reflects the perspective of each stakeholder based on their concerns. To facilitate the interpretation of concerns by stakeholders, the Architecture Viewpoint is used as a framework or perspective that frames the concerns. Based on this viewpoint, an Architecture View is created, which is a representation of the architecture that is adjusted to answer the existing concerns. Finally, Aspect enriches the understanding of the characteristics or properties of relevant entities in the architecture, adding additional elements that support deeper interpretation. Through this structured relationship, the architecture can be designed effectively to meet the needs and expectations of stakeholders.

RESULTS AND DISCUSSION

1. Entity of Interest (EoI) Smart system for emergency response
   The 4-Layer Smart System architecture for human-elephant conflict mitigation focuses on a harmonious emergency response system between humans, processes, and technology in the human environment and elephant habitat. The Instrumentation and Control Layer monitors elephant movements in real-time using IoT to provide early warnings, while the Information System Layer stores historical data to analyze elephant movement patterns for better response. The Business Intelligence Layer uses Big Data and AI to support strategic decisions, such as elephant migration predictions, while the Gamification Layer involves intelligent strategies in managing more efficient systems and increasing awareness of conflict mitigation. This architecture, which is integrated with the Management By Objective (MBO) approach, aims to minimize human-elephant conflict through adaptive and effective responses, supporting habitat security and sustainability in the smart system era.

2. Environment elements of the Smart system for emergency response
   In the 4-Layer Smart System architecture for human-elephant conflict mitigation, the Environment element covers the area where the emergency response system operates, namely the natural environment of the elephant

habitat adjacent to human settlements. This environment has complex characteristics because it includes ecological, social, and geographical aspects that influence elephant behavior and interaction patterns with humans. The Environment element acts as an external factor that shapes the needs, responses, and adaptation strategies of the emergency response system architecture. Dynamic environmental conditions, such as changes in land use or seasons, affect elephant interactions with human settlement areas, so each layer in this system architecture needs to adapt to respond effectively to these changes. By understanding this environment, the architecture can provide more relevant and contextual responses to reduce conflict through monitoring, historical data storage, predictive analysis, and community participation in habitat conservation.

3. Stakeholder elements related to emergency response
   The Stakeholder elements in this architecture include parties who have direct or indirect interests in this emergency response system. Stakeholders include local communities, the National Park Office, local governments, conservation organizations, and environmental researchers. Local communities have an interest in maintaining security from elephant disturbances; governments are responsible for managing human-wildlife conflict effectively; conservation organizations aim to conserve elephant populations and their habitats; and environmental researchers seek data to understand elephant behavior patterns and the effectiveness of mitigation interventions. Each stakeholder views the EoI from a different perspective, reflecting their needs, expectations, and responsibilities to this system.

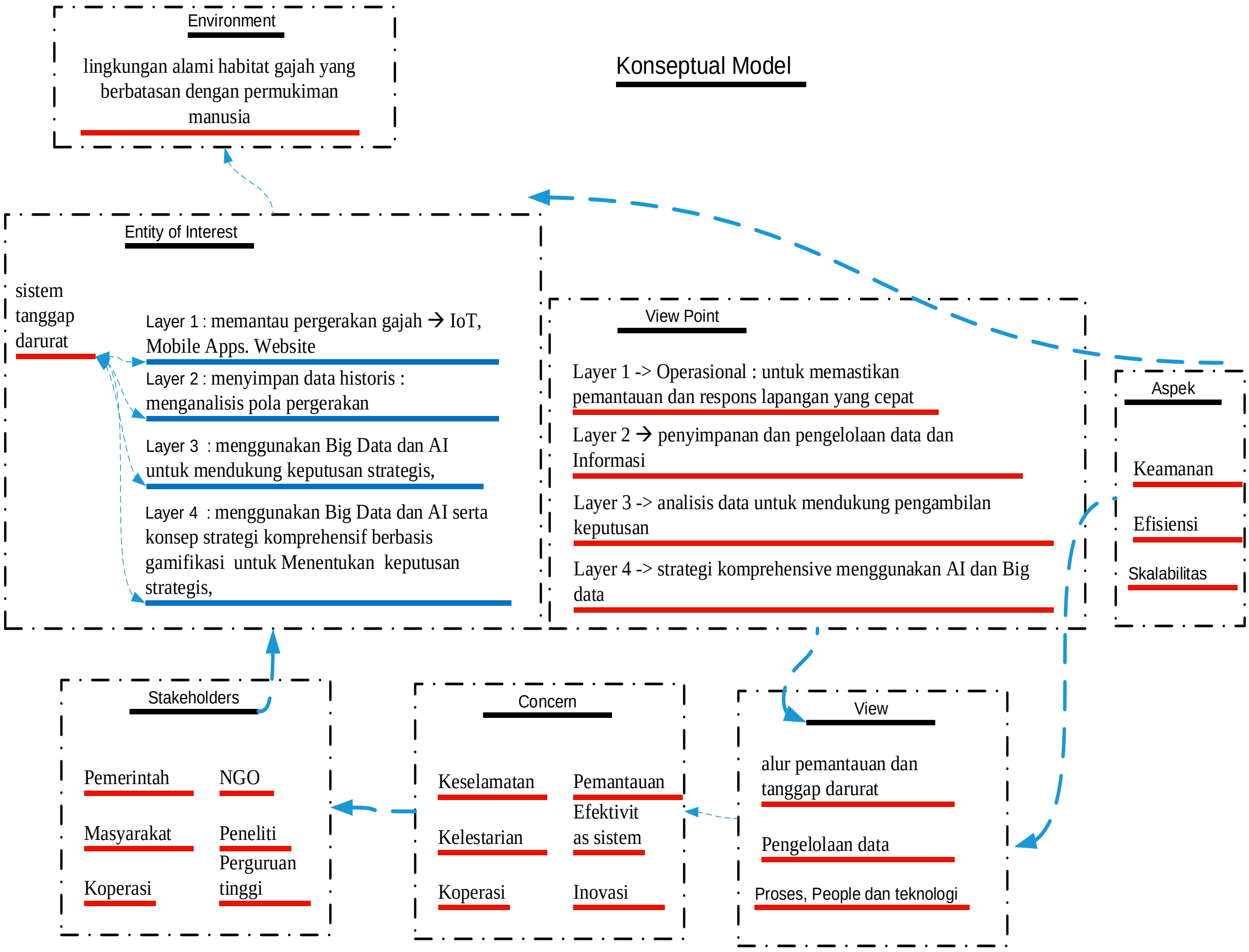
4. Architecture Viewpoint elements of the smart system related to emergency response
   In the 4-Layer Smart System architecture for human-elephant conflict mitigation, the Architecture Viewpoint element serves as a framework that frames and organizes the main issues (concerns) of various stakeholders, making it easier for stakeholders to interpret. This viewpoint groups stakeholder needs, expectations, and concerns into a specific form, such as community safety, elephant habitat sustainability, monitoring technology effectiveness, and data availability for analysis.
   Each layer in the 4-layer architecture can be viewed through various viewpoints that are appropriate to its specific role. For example, the Instrumentation and Control Layer can be viewed from an operational viewpoint to ensure rapid field monitoring and response. The Information System Layer requires a data storage and management viewpoint, the Business Intelligence Layer uses a data analysis viewpoint to support decision-making, and the Gamification Layer requires a viewpoint in a comprehensive strategy using AI and Big Data.
   This viewpoint serves as a guideline in creating a relevant architecture view, providing a structured way of viewing so that stakeholders can understand and evaluate the architecture in a context that suits their respective interests.

5. Elements of the smart system architecture view related to emergency response
   The architecture view is a representation of the elements in the architecture that are arranged to meet the needs of specific stakeholders in mitigating human-elephant conflict. In this context, the functional view shows the flow of monitoring and emergency response supported by technology such as IoT to monitor elephant movements and provide real-time notifications. The information view describes how data is collected, managed, and analyzed at various layers, such as big data management at Layer 2 and advanced analytics at Layer 3. The technology view details the role of technology, from IoT sensors at the base layer to the use of AI and Big Data to support strategic decisions. The operational view describes the workflow of each layer in supporting rapid response, while the security view ensures data protection to prevent unauthorized access. Finally, the business view shows the relationship between this architecture and the business objectives of conservation, namely minimizing conflict, supporting coexistence, and reducing economic losses to communities. The combination of these views creates an adaptive and flexible framework for conservation and conflict mitigation in the era of smart systems.

6. Smart system aspect elements related to emergency response
   Aspect elements in architecture refer to various qualities or characteristics of an entity that are part of the basic nature of the entity. These aspects include factors that can influence or shape the way of looking at the architecture, or Architecture Viewpoint. For example, in an emergency response system for human-elephant conflict, aspects include qualities such as security, efficiency, scalability, and sustainability. Security is an important aspect to protect data and ensure safety in the operation of the system, while efficiency is needed so that the system can respond to incidents quickly and effectively. Scalability ensures that the system can handle increasing needs over time, and sustainability ensures that the solution implemented can last in the long term. Each of these aspects becomes a framework that guides the perspective and design decisions in developing an architecture that suits the needs of stakeholders.

7. Smart system concern elements related to emergency response
   In the emergency response system architecture for human-elephant conflict, the main concerns or concerns come from various needs and expectations of stakeholders, such as local communities, governments, conservation organizations, and environmental researchers. For the community, the main concern lies in their safety from the threat of elephants, which requires an early warning system with a fast response. On the other hand, conservation organizations and researchers are more focused on preserving elephant habitat, requiring monitoring systems that can track elephant movements without disrupting the ecosystem and that can provide critical data for

analysis. Governments and conservation organizations are concerned about the effectiveness of technologies, such as IoT sensors and AI, which must perform optimally in diverse conditions and provide accurate real-time data, while maintaining the security of that data. In addition, all parties hope that these systems can support long-term coexistence between humans and elephants, where both the protection of elephant habitat and the safety of communities can be maintained. Efficiency and speed in responding to emergencies are also priorities, as any immediate threats need to be addressed quickly. Finally, attention to scalability and adaptability is essential, given the dynamics of the environment and changes in land use patterns. All of these concerns form the basis for the architecture viewpoint, which ensures that the architecture can effectively meet these needs.



CONCLUSION

This study concludes that the application of the 4-Layer Smart System architecture to the emergency response system for human-elephant conflict mitigation offers a comprehensive and adaptive solution that can reduce negative interactions between humans and elephants. This architecture consists of four main layers: Instrumentation and Control Layer, Information System Layer, Business Intelligence Layer, and Gamification Layer, which are interrelated in integrating the People, Process, and Technology components.

This approach enables the emergency response system to operate effectively through real-time monitoring, data storage and analysis, and community participation enabled through gamification. By adopting technologies such as IoT, Big Data, and AI, this architecture supports data-driven decision making that is adaptive and responsive to changing environmental conditions. The Management By Objective (MBO) approach also helps ensure that each layer in this architecture runs according to its purpose to create a harmonious coexistence between humans and elephants.

RECOMMENDATIONS

1. Deeper Implementation of Technology: It is recommended to deepen the use of IoT, AI, and Big Data technologies at each layer of the architecture. For example, AI technology can be further used in elephant behavior prediction and response automation, while Big Data can enrich the analysis of human-elephant interaction patterns.
2. System Activity Approach: The system activity approach in the 4-Layer Smart System architecture needs to be considered in order to create stronger synergy between humans, technology, and processes. Here are some suggestions for developing a more comprehensive system activity approach
3. Continuous Evaluation and Improvement: Given the dynamic nature of human-elephant conflict, this architecture needs to be periodically evaluated to ensure its effectiveness and adjusted to changes in the environment or socio-economic needs.
4. Utilization of Management By Objective Approach at Each Layer: Each layer of the architecture should be operated with the guidance of Management By Objective (MBO), so that actions at each layer are aligned with the objectives of mitigating human-elephant conflict and supporting the conservation mission.
5. Development of an Integrated Conceptual Model: It is recommended to develop a more comprehensive conceptual model that integrates the architecture framework and life cycle management principles. This will serve as a guide for the design, implementation, evaluation, and maintenance of the architecture in the long term.

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