Evaluation of Emergency Access Evacuation Routes Using Agent-Based Model Application

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ABSTRACT

One vital component in managing buildings, such as houses or buildings, is the implementation of safety measures against disaster risks. Artificial Intelligence (AI) technology can minimise fire risk in buildings. The integration of AI technology enables early detection, rapid response, and even realistic evacuation simulations to increase the efficiency of security systems and protect against disasters. This research aims to review a program based on Agent-Based Artificial Intelligence called AnyLogic to calculate the efficiency of emergency access evacuation routes. The research uses the journal review method as the primary approach. This method is part of systematic research on certain phenomena and collects data from related journal sources. This research concludes that AnyLogic optimises emergency access evacuation strategies in multiple contexts. AnyLogic has the advantage of determining the most efficient evacuation route, determining evacuation time, and being able to evaluate evacuation routes in certain buildings.

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1. INTRODUCTION

1.1. Research Background

One crucial aspect of managing structures like houses or buildings is the establishment of safety protocols to mitigate disaster risks. Disasters are a series of events that can happen at any time and can cause harm to humans, both material and non-material [1]. The importance of these security measures lies in protecting life and property with a holistic approach that includes prevention strategies and emergency response measures. Efforts to identify and overcome potential disasters are fundamental to designing effective security systems for these buildings. Artificial Intelligence (AI) technology can minimise the fire risk in buildings. The integration of AI technology enables early detection, rapid response, and even realistic evacuation simulations to increase the efficiency of security systems and protect against disasters. AI is

essential for modern disaster security system planning. It can quickly process and analyse vast amounts of data, understand and predict human behaviour, adapt to real-time changing conditions, and continuously improve evacuation strategies. By leveraging AI, disaster response systems can become more efficient, effective, and capable of saving more lives during emergencies.

The working process of AI involves collecting, merging, and sharing big data. Extensive data on the internet includes research, analysis, computing, and data storage required for a particular project. AI can create tools that significantly contribute to the longevity of architectural buildings. AI can increase efficiency in all building design and construction stages because it has high analytical and computational capabilities. AI can produce solutions to bring innovation to the world of architecture. Artificial intelligence directs architectural developments toward more sophisticated and practical solutions [2]. Fields included in AI include agent-based modelling, expert systems, natural language processing, speech recognition, robotics, and artificial neural networks.

In an era where technology is increasingly crucial in everyday life, the use of AI Agent Base in disaster simulation reflects the integration of advanced technology to ensure public safety and security. Through the continued development of this technology, the hope is that future buildings will be safer and have greater resilience to potential disaster threats. A concrete example of implementing AI Agent-Based is the AnyLogic program, which represents how artificial intelligence-based solutions can improve safety and sustainability in the disaster sector.

AnyLogic is modelling and simulation software developed by XJ Technologies. This tool adopts the latest complex system design methodology and uses the latest system design methods. Its main advantage lies in introducing the UML language into the model simulation domain, making it the only software that supports a wide range of modelling methods with a high level of development [3]. AnyLogic's ability to integrate factors into disaster evacuation simulations is a powerful tool for building designers and security experts. AnyLogic simulation provides an understanding of human behaviour in emergencies so that it is easy to overcome potential bottlenecks and the effectiveness of evacuation routes. AnyLogic is vital in developing realistic disaster evacuation simulations, significantly enhancing community safety efforts, and reducing disaster risks in various buildings. The software uses Agent-Based Artificial Intelligence (AI) to evaluate and improve the efficiency of emergency evacuation routes by modelling disaster scenarios, analysing human behaviour, and identifying bottlenecks. This research will help to improve safety, provide informed design decisions, and offer better insights into human behaviour during emergencies, ultimately contributing to more prepared structures and advanced disaster preparedness and response planning.

1.2. Problem Statement and Research Objectives

The problem statement in this research is "How can we review the use of Agent-Based AI to calculate the efficiency of emergency access to evacuation routes?" This research aims to review a program based on Agent-Based Artificial Intelligence called AnyLogic to calculate the efficiency of emergency evacuation routes.

2. RESEARCH METHODS

This research employs the journal review method as its primary approach, systematically collecting, reviewing, and compiling data from various relevant journal sources to present comprehensive information. By detailing, analysing, and drawing conclusions from the collected data, this method provides a strong foundation for an in-depth understanding of the researched phenomenon. It supports research sustainability through analytical and interpretive approaches. The research aims to explore the theoretical foundations and applications of Agent-Based Artificial Intelligence (AI), mainly focusing on AnyLogic's role in modelling emergency evacuation scenarios.

Key factors to be reviewed include AnyLogic's capabilities, previous case studies, and its effectiveness in disaster simulations. The research will assess human behaviour during emergencies, how AnyLogic models these behaviours, and identify potential bottlenecks in evacuation routes. Additionally, the study will synthesise findings to analyse the practical implications of AnyLogic in improving evacuation efficiency, supporting informed design decisions, and enhancing disaster preparedness and response planning. The research steps involve seeking theoretical bases, gathering literature on AnyLogic and disaster simulations, extracting essential insights, discussing findings, and drawing conclusions. This comprehensive review aims to provide a thorough understanding and meaningful conclusions about AnyLogic's role in emergency evacuation simulations.

This research contributes to the field by focusing on utilising AnyLogic, an Agent-Based Artificial Intelligence program, to assess the efficiency of emergency access evacuation routes. By employing a journal review method, the study delves into the capabilities of AnyLogic, analyses previous case studies, and evaluates its effectiveness in disaster simulations, offering valuable insights into optimising evacuation strategies. The novelty of this research lies in its detailed examination of how AnyLogic models human behaviour during emergencies, identifies potential bottlenecks in evacuation routes and aims to enhance evacuation efficiency, thereby providing a comprehensive understanding of the role of AI technology in improving safety measures in buildings during critical situations.

2.1 Theoretical Basis and Steps of AnyLogic Use

2.1.1 Disasters

As stipulated in Article 1 paragraph (1) of Law of the Republic of Indonesia Number 24 of 2007 concerning Disaster Management (UU PB), what is meant by disaster is an event or series of events that threatens and disrupts the life and livelihood of the community caused, by natural factors, and non-natural factors, as well as human factors, resulting in human casualties, environmental damage, property loss, and psychological impacts. Furthermore, Article 1 paragraph (2) of the PB Law explains that what is meant by natural disaster is a disaster caused by an event or series of events caused by nature, including earthquakes, tsunamis, volcanic eruptions, floods, droughts, hurricanes, and landslides [4].

2.1.2 Artificial Intelligence

Artificial Intelligence (AI) has the potential to become an inseparable part of people's daily lives. These changes impact personal experiences, changing how companies make decisions and interact with external stakeholders. AI technology can be integrated into various aspects of our routine. AI provides insightful solutions that simplify tasks and improve overall efficiency. The growing presence of AI in our lives represents a broader paradigm shift in society. Therefore, the increasing role of AI can change the routine and nature of decision-making processes.

Artificial intelligence (AI) is a branch of computer science that deals with developing computer systems and technologies capable of performing tasks that usually require human intelligence. AI aims to create programs or machines to learn, adapt, and perform tasks such as pattern recognition, natural language processing, decision-making, and problem-solving. AI can be used in various fields, including robotics, natural language processing, image recognition, and data analysis. The main goal of AI is to create systems that can think automatically and make intelligent decisions without human intervention [5].

Artificial intelligence (AI) is shaping a diverse landscape, from systems capable of interacting with humans to autonomous cars that enable driverless travel and even applications in the medical world to support clinical decision-making. It has significantly impacted various sectors, including health, automotive, and finance. AI is used for disease diagnosis, drug development, and patient data management in health matters. In the automotive sector, autonomous cars use AI technology to improve road safety and change how we travel. On the other hand, AI enables more sophisticated data analysis, better risk management, and more intelligent investment decision-making. Artificial intelligence continues to develop rapidly and plays a central role in changing our daily lives and various industries' operations.

2.1.3 AI Agent-Based

Agent-Based Modelling and Simulation (ABMS) is a multi-agent system concept applied to a simulation model's basic structure [6]. These agents have behaviours that can be described through simple rules, and they interact, influencing each other's behaviour. With the ability to represent any system element, ABMS enables in-depth analysis of the dynamics of interactions between agents, opening the door to a better understanding of the behaviour of complex systems. This approach provides a more adaptive and realistic way to model and simulate systems that involve many interactions and variability [7]. Simulation using ABMS is one of the most effective ways to predict people's behaviour in emergency conditions.

AI Agent Base technology enables the creation of highly realistic simulation models, predicting fire behaviour, smoke spread, and human response in emergencies. With precise data and advanced algorithms, AI Agent Base has the potential to change the way building designers think about and design security systems, resulting in safer buildings, minimising disaster risks, and improving occupant safety by providing deeper insights into disaster planning and evacuation strategies.

AI Agent Base simulation has tremendous potential to improve building security against disasters. AI's ability to test various evacuation scenarios enables early identification of potential risks, a proactive step in building safety planning. The results of these simulations allow building designers to design more resilient structures for disasters, install more intelligent and responsive warning systems, and organise more efficient evacuation routes. Building occupants can feel safer and more protected, while the risk of loss in disaster scenarios can be minimised. In this way, AI Agent Base technology has a crucial role in advancing efforts to improve the safety and sustainability of our environment.

Using AI Agent Base technology in emergency simulation opens opportunities for significant improvements in building security against potential disaster threats. Through the implementation of artificial intelligence (AI), early detection, forecasting the development of disaster impacts, and real-time monitoring can be carried out, ensuring efficient and safe evacuation routes. This technology allows training security personnel more realistically, creating a simulated experience close to actual conditions.

2.1.4 AnyLogic

AnyLogic is one platform that utilises the concept of Agent-Based Modeling (ABM) in simulation development. With the Agent-Based concept, active entities, known as agents, must be identified and their behaviour determined. They may be people, households, vehicles, appliances, products, companies, or whatever is relevant to the system. The connection between them is established, environment variables are established, and simulations are executed. The global dynamics of the system then arise from the interaction of many individual behaviours. The AnyLogic model enables analysts, engineers, and managers to gain deeper insights and optimise complex systems and processes across various industries.

In an emergency evacuation simulation using AnyLogic, everyone within the building can be represented as a unique agent. They can be set up to respond to disasters based on careful programming so that simulations can illustrate a variety of possible evacuation scenarios. Evacuation scenarios include the arrangement of evacuation routes, an understanding of the different levels of danger, and how individuals interact with each other during the evacuation process.

2.1.5 AnyLogic Usage Steps

The steps to use the Anylogic application are explained as follows. First, install AnyLogic from the official website and create a new project. Choose the type of project that fits the purpose, such as entity-based, agent-based, or dynamics-based simulation. Next, develop our model by importing graphical components corresponding to the modelling process, such as entities, processes, resources, and queues. Set the parameters, variables, and rules required for the model. Define initial scenarios and conditions. Once the model is complete, run simulations and analyse the results using graphs, reports, and statistics provided by AnyLogic. You can experiment with changing parameters and conditions to answer specific questions or identify the best solution. Then, the model will be documented, and an analysis will be performed to complete the simulation. There are three main stages in the modelling process when using AnyLogic for emergency evacuation simulation:

1. A physical model is built to match the layout of the actual simulated environment. AnyLogic has a scale that can be adapted to the user's needs, and AnyLogic's pedestrian displacement model has appropriate spatial markers to help draw graphics.
2. The flow of people's behaviour is regulated. The pedestrian module is adjusted to the corresponding spatial marker, and the module parameters are determined as needed.
3. The simulation parameters are set.

The parameters are set according to the situation of the people in the simulation object, such as the proportion of sex and age of the people, and the corresponding convenient speed is set according to different groups of people.

3. RESULTS AND DISCUSSION

Table 1 shows the literature researchers collected on using analogies in disaster evacuation. The data above shows that AnyLogic is crucial in optimising emergency evacuation strategies in various contexts, such as field stations, complex spatial environments, building plans, and crises such as gas leaks. AnyLogic is used as an efficient simulation tool to evaluate and improve evacuation plans, improve visitor safety, and

provide optimal solutions regarding evacuation time. AnyLogic has also proven effective in developing simulation models for mass evacuation strategies, predicting various situations, and improving evacuation efficiency at subway stations, cancer medical centres, and airports.

AnyLogic can model the safest and optimal emergency evacuation plan, improve the efficiency of emergency evacuation, and evaluate the efficiency and safety of disaster evacuation routes. AnyLogic can model individual behaviour in fire evacuation situations and enrich understanding of evacuation dynamics in real situations. Factors affecting evacuation efficiency include the number of people, density, and movement speed. Potential improvements in the safety and accessibility of evacuation routes involve increasing the number of emergency exits, adding emergency stairs, and improving lighting quality.

Table 1. Literature about Agent-Based Artificial Intelligence AnyLogic.

Research, Year, City	Research Title	Research Title	Research Subject	Research Result
Niu et al. 2023. China	Emergency Evacuation Simulation Study Based on Improved YOLOv5s and AnyLogic	Quantitative research methods	Methods to improve the efficiency of emergency evacuation in field *stations* through target detection and simulation	AnyLogic can help emergency management in the field station *become more effective and efficient by simulating the emergency evacuation process at the* field station [8].
Haris et al. 2018. Pakistan	Modelling Safest and Optimal Emergency Evacuation Plan for Large-Scale Pedestrian Environments	Modelling and simulation approach	Modeling and simulation to design optimal and safe emergency evacuation plans for pedestrian environments	Anylogic is used as a simulation to develop a framework that allows space and pedestrian markups to design complex spatial environments and simulate pedestrians at scale, providing optimal solutions regarding evacuation time and crowd safety [9].
Matveev, et al. 2019. Russia	Simulation Model of Emergency Evacuation in Case of Fire in a Nightclub	Agent-based modelling approach – evacuation simulation	Nightclub visitors who had to be evacuated in a fire situation	AnyLogic, as a tool for creating building plan layouts and crowd movement simulations, can help evaluate and improve existing evacuation plans[10].
Avdeeva, et al. 2020. Russia	Simulation of the Evacuation Process at Various Economic Facilities Using the Anylogic Software Product	Experimental quantitative research methods – simulation.	The process of evacuating people from office space in emergencies	The use of AnyLogic dramatically facilitates the task of conducting many experiments, allows for obtaining adequate results, and predicts various situations that can reduce human losses and, in some situations, prevent many deaths [11].
Mahmood, et al. 2017.	Analysing Emergency Evacuation Strategies for Mass Gatherings using Crowd Simulation and Analysis Framework: Hajj Scenario	Simulation and analysis of agent base with case study approach	Microscopic crowding to identify optimal evacuation strategies in emergencies in Hajj scenarios.	AnyLogic can potentially develop simulation models for emergency evacuation strategies in crowds[12].
Feng, et al. 2020. China	Simulation and Optimization of Emergency Evacuation in Gold Museum Based on AnyLogic	Simulation and optimisation using AnyLogic software	Gold Museum	AnyLogic helps develop effective and efficient emergency evacuation plans to minimise the risk of accidents and ensure the safety of visitors[13].
Zhang et al. 2023. China	Application of Minecraft in the Study of Evacuation Dynamics	Quantitative research methods	Pedestrians were involved in evacuation experiments on the	AnyLogic is an efficient tool for simulating evacuation, traffic flow, manufacturing industrial

Research, Year, City	Research Title	Research Title	Research Subject	Research Result
	Under Fire Emergency Conditions		Minecraft platform during normal conditions and fire emergencies.	processes, logistical resources, and medical treatment [14].
Samah et al. 2022. Malaysia	An Assessment Algorithm for Indoor Evacuation Model	Simulation and clustering algorithms to assess indoor evacuation	Development of assessment algorithms for indoor evacuation models.	AnyLogic as a simulation software can show that the evacuation model developed can help building owners choose the most suitable evacuation model for their building [15].
Wu, et al. 2020. Taiwan	Constructing Constraint-Based Simulation System for Creating Emergency Evacuation Plans: A Case of an Outpatient Chemotherapy Area at a Cancer Medical Center	Development of constraint-based simulation systems in healthcare environments	Outpatient chemotherapy area at a cancer medical centre.	AnyLogic can simulate emergency evacuation conditions based on spatial constraints and activity in the outpatient chemotherapy area of a cancer medical centre [16].
Wang, Hui & Cui, Yue. 2020. China	Anylogic Simulation Research on Passenger Evacuation System of Urban Transportation Hub	Quantitative methods, simulation models, and analysis of their output.	Passenger evacuation system at urban transport stations, focusing on subway stations	AnyLogic is used to simulate a passenger evacuation system in subway stations to help improve the operational conditions of subway stations and optimise the layout of facilities [17].
Xu et al. 2020.	Emergency Evacuation Simulation and Optimization for a Complex Rail Transit Station: A Perspective of Promoting Transportation Safety	Emergency evacuation simulation and optimisation with AnyLogic simulation	Lianglukou high-speed rail transit station in Chongqing, China	AnyLogic is vital as a simulation platform for developing theoretical frameworks and conducting emergency evacuation simulations [18].
Wang et al. 2023. China	A Simulation-Based Optimization Method for Emergency Evacuation Induced by Gas Pipeline Leakage Risk	Optimization-based simulation method	Emergency evacuation scenarios resulting from gas pipeline leaks	AnyLogic is used to build a physical simulation environment and set parameters such as attributes and the number of evacuees in emergency evacuation due to the risk of gas pipeline leaks to improve evacuation efficiency [19].
Li, Zhu Huan & Zhang, Xi. 2014.	Simulation and Analysis Based on Emergency Evacuation Success Rate in Elevated Layer of Beijing South Railway Station	In-depth analysis method using evacuation simulation	Evacuation scenario on an elevated layer at Beijing Station	An emergency evacuation simulation model of the Beijing South Railway Station built using AnyLogic software showed an evacuation rate of 99.54-99.77% [20].
Chunhua, et al. 2023	Optimisation Analysis of Fire Characteristics and Emergency Evacuation Scheme of Small- and Medium-Sized High-Speed Railway Stations	Quantitative research methods	Small and medium-sized high-speed rail stations and passengers who are on board in evacuation emergencies	AnyLogic can improve efficiency by analysing passenger evacuation behaviour, fire characteristics, and emergency evacuation schemes in small and medium-sized high-speed rail stations [21].
Chen et al. 2019.	Effects of Exit Doors and Number of Passengers on Airport Evacuation Efficiency	Quantitative approach	Airport evacuation simulation using *agent-based*	AnyLogic models the airport evacuation process by changing passenger routes exits, and other variables [22].

Research, Year, City	Research Title	Research Title	Research Subject	Research Result
	Using Agent-Based Simulation			
Zhang. 2020.	Optimisation of Emergency Evacuation Strategy Based on Social Force Model	Computer simulation using *AnyLogic* software	Emergency evacuation simulation using social style model and *bottleneck evacuation model*	Evacuation simulations conducted using AnyLogic can produce recommendations for effective emergency evacuation strategies [23].

3.1 Advantages of Using Anylogic

AnyLogic can determine evacuation routes efficiently through agent-based simulation models. AnyLogic identifies the most optimal evacuation route in various emergencies at emergency sites. The main advantage of an agent-based AnyLogic lies in its ability to model individual behaviour, allowing everyone to have an agent who can make independent decisions about evacuation routes. AnyLogic libraries, such as Pedestrian, Agent-based, and Space Markup, provide powerful tools for building models of complex spatial environments. With the social style model, AnyLogic creates real-world behavioural simulations, enabling evaluation of the dynamics of individual interactions in evacuation and designing more efficient evacuation strategies in hotel emergencies.

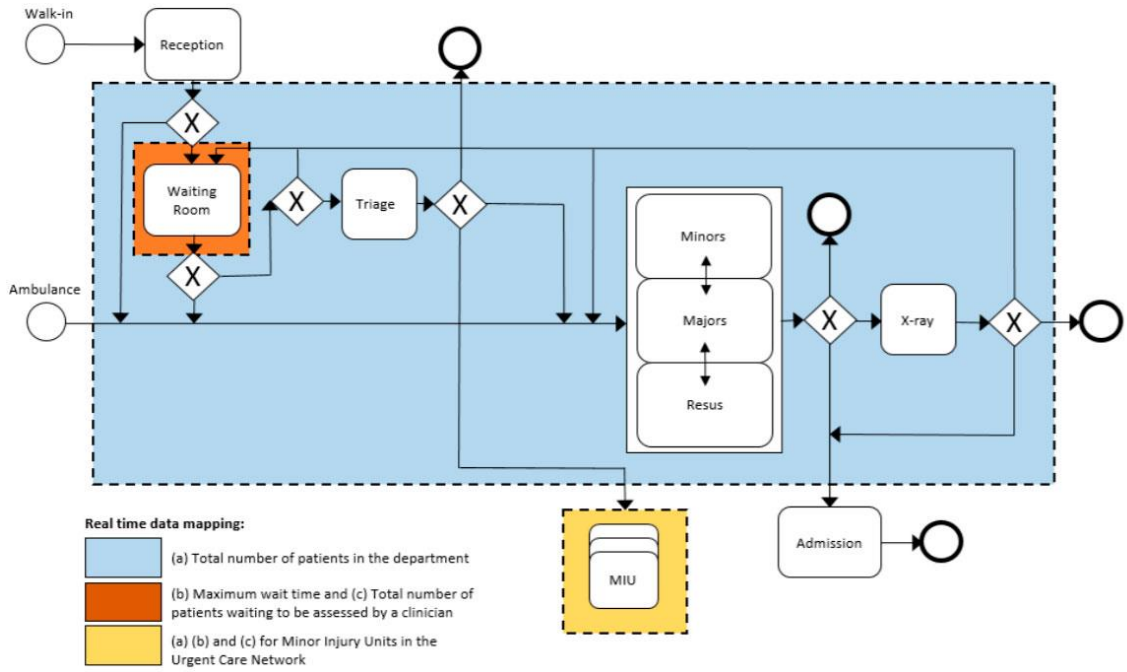

Figure 1. Real-time data mapping by AnyLogic [24]

AnyLogic could determine individual behaviour in simulations and monitor them to analyse the time taken by each agent to reach evacuation routes and safe points. In the analysis results, the presence and location of firefighting equipment, emergency stairs, and the placement of evacuation signs significantly affect the evacuation time. This data is critical to analysing the efficiency of evacuation routes and identifying areas where congestion points are likely. Leveraging advanced modelling and analysis features, AnyLogic provides an in-depth understanding of evacuation dynamics, enabling breakthrough improvements to improve emergency response and safety. For example, AnyLogic helps researchers create simulation models that visualise workflows in the Emergency Department (ED) and map real-time data components into these models. Thus, AnyLogic can assist in understanding ED operational processes and how real-time data interacts with these processes, as demonstrated in the process flow diagram (Figure 1) mentioned in the diagram.

AnyLogic uses analysis and simulation to evaluate the safety of evacuation routes by considering factors such as overcrowding and physical constraints, such as locked or blocked doors. The evaluation results show potential improvements in ensuring that evacuation routes are always accessible and safe to use. By utilising AnyLogic software, managers can build accurate simulation models to develop effective and efficient emergency evacuation plans to minimise the risk of accidents and ensure user safety. AnyLogic analysis or similar simulation tools are an essential foundation for improving the efficiency of evacuation points in future disaster planning. By collecting and analysing geographic and demographic data and simulating various disaster scenarios, we can identify optimal evacuation point locations, design efficient evacuation routes, and prepare communities with better training and understanding of evacuation procedures. The results of this analysis become the basis for better planning and improved safety when facing disaster situations.

4. CONCLUSION

Based on the analysis, AnyLogic optimises emergency evacuation strategies in various contexts. Anylogic has the advantage of determining the most efficient evacuation route, determining evacuation time, and being able to evaluate evacuation routes in certain buildings. With the combination of these features, AnyLogic becomes an efficient tool in disaster planning and safety. The application of AnyLogic provides optimal solutions for evacuation times, improves visitor safety, and is effective in various facilities, such as subway stations, cancer medical centres, and airports.

Facility managers and evacuation system designers need to deeply understand the capabilities and features of AnyLogic to maximise its use in future disaster planning. Intensive training on using AnyLogic in various evacuation scenarios can provide the expertise needed to design more effective and responsive evacuation plans. In addition, close collaboration between AnyLogic users, software developers, and security experts can result in continuous updates to the software to continuously adapt to the evolving security and disaster systems needs. The research has not only shed light on the potential of AnyLogic in optimising emergency evacuation strategies. Still, it has also emphasised the importance of leveraging AI technology to enhance building safety measures and improve disaster response planning.

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