Simulation-Based Analysis of Evacuation Information Sharing Systems Using Geographical Data

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***Abstract*—In this study, we developed an agent-based model (ABM) to simulate and improve evacuation rates during flood disasters. Utilizing the "Evacuate Now Button", a previously proposed system for sharing real-time evacuation rates among residents, our experimental findings demonstrate a significant enhancement in evacuation behavior through this system. Simulations were conducted using geographical data from Nobeoka City, Miyazaki Prefecture, and Toyohashi City, Aichi Prefecture. Results showed that the "Evacuate Now Button" increased evacuation rates from a few percent to approximately 78% in Nobeoka City and 90% in Toyohashi City. We also investigated the effect of varying the range for calculating evacuation rates and the accuracy of the evacuation information shared with residents. It was found that larger calculation ranges led to higher final evacuation rates, while smaller ranges resulted in a quicker initial increase in evacuation behavior. These findings provide valuable insights for enhancing evacuation strategies and disaster preparedness in regions prone to floods.**

***Keywords*—Evacuation; flood disaster; evacuation rate; agent-based model; evacuate now button**

I. INTRODUCTION

Japan is a country frequently affected by natural disasters such as earthquakes, typhoons, and floods, making it crucial to strengthen disaster prevention measures. Past large-scale disasters have proven that prompt evacuation actions can save many lives. Despite the availability of evacuation warnings, many areas still report low evacuation rates. For instance, studies on Typhoons Faxai and Hagibis in 2019 reported that despite receiving evacuation information, many residents did not evacuate [1]. Various factors, such as insufficient understanding of evacuation advisories and delays in action, are thought to contribute to this low evacuation rate.

One of the reasons for the low evacuation rate is the lack of disaster awareness among residents and differences in how evacuation information is received. For example, it has been shown that personality traits significantly affect evacuation behavior, with individuals categorized as "cautious and proactive" more likely to take disaster information seriously and evacuate early, while those in the "careless and proactive" group are less likely to act upon the same information [2]. These differences in personality traits have a significant influence on how evacuation information is received and the subsequent actions taken, making them a critical factor in formulating disaster prevention strategies.

Additionally, research has been conducted on methodologies for accurately estimating evacuation rates during floods [3], providing valuable insights into modeling evacuation behavior. Other studies have analyzed evacuation behavior and its influencing factors during landslides, highlighting how the timing and method of information dissemination affect evacuation behavior [4]. In a case study of heavy rainfall in Gifu Prefecture, the impact of how evacuation information was provided on residents' evacuation decisions was analyzed [5]. Further, research has examined the influence of prior flood awareness on evacuation behavior, showing that pre-existing knowledge significantly promotes evacuation action [6].

In recent years, many studies have employed agent-based models (ABM) to simulate and deepen understanding of residents' evacuation behavior. For instance, the effects of flood warning lead times on evacuation behavior have been simulated using ABM, demonstrating the complexity of evacuation behavior and the importance of psychological and social factors [7]. Other studies have used ABM to analyze residents' behavior during floods, providing detailed insights into how individual evacuation actions are influenced by flood conditions [8]. These studies contribute to a deeper understanding of the diversity of evacuation behavior and the factors that influence it. Moreover, the effectiveness of mutual aid mechanisms within vulnerable communities has been analyzed using ABM, showing that mutual assistance contributes to improved evacuation behavior [9].

However, existing studies have not been able to sufficiently influence individual actions and decision-making, resulting in limited improvements in evacuation rates. Therefore, this study aims to utilize the new concept called the "Evacuate Now Button [10]" which we previously proposed. The system visually informs residents of evacuation statuses and fosters a sense of solidarity.

In this paper, we simulate evacuation behavior during disasters using an ABM and evaluate the effectiveness of new measures to improve evacuation rates. Specifically, based on survey results conducted in advance via the internet, the behavior of agents reflecting residents' personality traits and evacuation awareness will be modeled. This approach enables more accurate reproduction of the psychological and social factors influencing individuals' evacuation behavior.

Furthermore, this study will examine the effectiveness of the "Evacuate Now Button". This button is designed to encourage residents to take swift and appropriate evacuation actions during disasters, and its impact will be simulated using

ABM. The simulation will evaluate changes in evacuation rates with and without the button in order to clarify factors that contribute to the promotion of evacuation behavior.

The findings of this study are expected to provide important implications for future disaster prevention planning. In particular, understanding evacuation behavior based on residents' psychological factors and personality traits can improve the methods and content of evacuation information dissemination, as well as be applied to the design of education and training programs aimed at enhancing residents' evacuation awareness. This, in turn, is expected to contribute to the development of highly effective disaster prevention measures that help mitigate disaster damage.

The structure of this paper is as follows: Section II explains simulations using ABM as a foundational concept and introduces the proposed "Evacuate Now Button". Section III describes the specifications of the simulation program used in this study. Section IV presents the results of simulations using actual topographical maps and Section V discusses these results. The conclusion and the future work are presented in Sections VI and VII, respectively.

II. PRELIMINARIES

In this section, we provide an overview of the basic concept of the "Evacuate Now Button" and the ABM used in this study. This section aims to provide the foundational knowledge necessary for understanding the design of the simulations and the assumptions underlying the experiments, facilitating discussions in the following section.

A. *Evacuate Now Button* [10]

In a previous survey we conducted on residents regarding evacuation during heavy rains, 92% of respondents indicated that they were concerned about the evacuation status of others when deciding whether to evacuate. Based on this, we proposed a system called the "Evacuate Now Button". This is a physical button installed at the entrance of each residence, which residents press before evacuating. By pressing the button, the evacuation status of the residents is recorded and shared with emergency services, such as fire departments, to facilitate the rescue of those who have not evacuated in time. Additionally, the evacuation status is shared with residents, allowing them to gauge the evacuation progress in their area, which may encourage further evacuations. However, rather than sharing the evacuation status of individual households, the system provides aggregated evacuation rates for clusters of homes. This prevents the risk of burglary that could arise if specific households were known to have evacuated.

When sharing evacuation status with nearby homes, there is a possibility that residents will either evacuate in coordination with their neighbors or refrain from evacuating if no one else does. However, as mentioned earlier, 92% of survey respondents stated that they are concerned about the evacuation status of others, suggesting that the remaining 8% would decide to evacuate regardless of their neighbors' actions. Therefore, it is more likely that this 8% will begin evacuating based on information from local authorities or their own judgment, potentially prompting others to follow suit.

There are still many considerations for implementing this system, such as determining the appropriate cluster size for sharing evacuation rates. Therefore, in this study, we use ABM simulations to explore effective methods for utilizing the "Evacuate Now Button".

B. *Simulations Using ABM*

An ABM is a simulation method where autonomous entities, referred to as agents, interact with each other within a system. ABM is a powerful simulation technique that can be applied to a variety of real-world systems and is particularly useful for understanding and predicting complex collective behaviors.

1) Features and Advantages of ABM: The ABM provides several unique features that make it a powerful tool for simulating complex systems. By allowing individual agents to interact with each other and their environment, ABM can capture emergent behaviors that are not easily represented by other modeling techniques. The following are some of the key features and advantages of ABM [11]–[15].

- Reproduction of Individual Behavior

In ABM, agents act based on their unique attributes and behavioral rules, interacting with the environment to produce complex collective behaviors. This allows for a detailed reproduction of complex social phenomena, such as evacuation behavior and risk perception during disasters.

- Understanding System Dynamics

ABM is well-suited for understanding the overall behavior of a system that emerges from interactions among agents, known as "emergent phenomena". This is a significant advantage over other modeling methods. For example, by simulating residents' evacuation behavior and movement patterns during floods, ABM can be used to evaluate the effectiveness of disaster response measures.

- Scenario Comparison and Evaluation

ABM is useful for comparing agent behavior across different scenarios and is widely applied in evaluating policy effects and disaster response measures. For example, it allows analysis of how different evacuation routes or shelter locations impact residents' evacuation behavior.

2) Practical Applications of ABM: ABM has been widely used for modeling human evacuation behavior in natural disasters, particularly in studies focusing on flood evacuation, where it has proven effective for detailed simulation of evacuation behavior [16]. In flood evacuation simulations, assigning agents with different attributes (such as age, gender, and socioeconomic factors influencing evacuation decisions) enables more realistic reproduction of evacuation behavior [17]. Specific applications of ABM include the development of models that help humanitarian organizations respond more effectively to flood evacuations by predicting evacuation dynamics and analyzing movement patterns to shelters [12].

Other studies have simulated pedestrian responses during emergency floods to evaluate how behavioral rules affect risk analysis, analyzing how pedestrians adjust their actions according to flood conditions using an agent-based approach [18], offering valuable insights for urban evacuation planning. Moreover, ABM has been used to model household decision-making regarding the adoption of flood mitigation measures, analyzing how individual choices impact regional flood risk and collective disaster prevention behavior [16]. ABM has also been applied to dynamic simulations of flood-human interactions, providing detailed analyses of residents' evacuation behavior and subsequent effects during floods. In urban settings, research has simulated pedestrian evacuation behavior during floods, providing data useful for emergency evacuation planning [15].

These simulations provide valuable information for optimizing emergency response measures during disasters. A comprehensive review of the application of ABM to flood risk analysis was conducted in reference [19], tracking trends in social dynamics and behavioral changes.

As demonstrated, ABM is highly effective for understanding and predicting evacuation behavior during floods.

III. SIMULATOR SPECIFICATIONS

In this study, we aim to examine the effective usage of the "Evacuate Now Button" by simulating residents' evacuation behavior using an ABM. First, the specifications of the simulation are described below.

A. *Overall Process*

This simulation is developed using Unity and C# scripts. While visual effects are not necessarily required for the simulation itself, Unity was chosen to facilitate the use of simulation videos for disaster awareness events and other purposes.

The program first loads a three-dimensional terrain model and places agents in locations corresponding to residential buildings. In this simulation, one agent represents one residence, including multi-unit buildings such as apartments, where one agent is assigned per building. For the terrain model, we utilize the 3D urban models developed under the PLATEAU project [20], promoted by Japan's Ministry of Land, Infrastructure, Transport and Tourism [21].

Agents, which represent residents, determine whether or not to begin evacuation based on evacuation information provided by local authorities and the evacuation status of surrounding residents. The simulation progresses according to Algorithm 1.

Algorithm 1 Overall Process

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1: Load the PLATEAU model.
2: Place agents in residential locations.
3: If the time for issuing a warning has been reached, issue it.
4: Agents decide whether to begin evacuation every $T_1$ seconds.
5: If Warning Level 5 has been issued, end the simulation.
6: Advance the simulation by one time step.
7: Return to Step 3.
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B. *Agent Evacuation Behavior*

Each agent determines whether to begin evacuation every T_1 seconds. The decision-making process is based on the results of the previously mentioned resident survey [10]. Agents are divided into one of two groups, Group I or Group II. Group I consists of agents that make their evacuation decisions without considering the evacuation rate of surrounding residents. In contrast, Group II includes agents that take into account the evacuation rate of their neighbors when deciding whether to evacuate.

For Group I agents, there is a possibility they will initiate evacuation when evacuation information is issued for their region. However, they do not always evacuate when conditions are met, but instead decide probabilistically with a certain probability P.

While some residents may evacuate before official evacuation information is issued, this study does not take such behavior into account. This is because excluding early evacuators does not positively contribute to the goal of improving the overall evacuation rate, which is the primary objective of this study. It is recognized, however, that the absence of early evacuators could negatively affect the overall evacuation rate.

At the start of the simulation, agents are randomly assigned to either Group I (approximately 8%) or Group II (approximately 92%). Additionally, Group II agents are further subdivided based on the extent to which they are influenced by the evacuation rates of others. Specifically, according to the survey results [10], agents are categorized into Group II(a) through Group II(e), as shown in Table I, which reflects the timing of evacuation initiation in relation to the surrounding evacuation rate.

TABLE I. RESULTS OF THE SURVEY ASKING AT WHAT EVACUATION RATE AMONG SURROUNDING RESIDENTS RESPONDENTS WOULD BEGIN TO EVACUATE

Evacuation Timing	**Respondent Percentage**	**Group**
10% evacuation rate	20%	II(a)
30% evacuation rate	31%	II(b)
50% evacuation rate	32%	II(c)
80% evacuation rate	12%	II(d)
100% evacuation rate	5%	II(e)

Agents in Group II(a) through Group II(e) also make their evacuation decisions probabilistically with a certain probability P, rather than always evacuating when conditions are met.

C. *Discount Rate for Evacuation Probability*

Agents consider evacuating when certain conditions are met, such as when the evacuation rate of surrounding residents exceeds a certain threshold. When this occurs, they decide whether to evacuate with probability P. However, based on real-world evacuation behavior, it can be assumed that if an agent does not evacuate the first time conditions are met, the barrier to evacuation increases in subsequent evaluations. To reflect this in the simulation, a discount rate is applied to the evacuation probability. Let the discount rate be denoted as α. The probability P_i that an agent evacuates during the i-th evaluation is given by Eq. (1), where $P_1 = P$:

$$P_i = \alpha \times P_{i-1} \quad (i > 2) \tag{1}$$

This formula models the decreasing likelihood of evacuation as agents delay their decision.

D. Start and End of the Simulation

The simulation begins when evacuation information equivalent to “Warning Level 3” is issued. Warning Level 3 corresponds to evacuation information for elderly and vulnerable residents. Prior to the 2021 revisions, it corresponded to “evacuation commencement,” which makes it an appropriate starting point for the simulation.

The simulation ends when evacuation information corresponding to “Warning Level 5” is issued. Warning Level 5 is defined as a situation where it is no longer possible to safely evacuate, and lives are at risk, meaning all evacuations should be completed before this level is issued.

The timing of each warning level’s issuance is determined based on real-world examples of past incidents.

Additionally, each agent is given a maximum delay of T_2 from the start of the simulation, after which they begin to act asynchronously.

IV. EXPERIMENTS

We verified the operation of the simulation program developed according to the specifications defined in Section III. The simulation was run under the conditions based on the heavy rain disaster that occurred in Nobeoka City, Miyazaki Prefecture in September 2022 [22] and the heavy rain disaster in Toyohashi City, Aichi Prefecture in June 2023 [23]. The conditions are outlined in Table II and the values of other parameters used in the simulation are shown in Table III.

Experiments are conducted using multiple random seed values, and the average values are calculated. Fig. 1 shows the state of the simulation in progress. The blue color represents the residences of agents who have not yet evacuated, and the red color represents the residences of agents who have started evacuating.

Fig. 1. The state during the simulation. The red dots represent the evacuated agents while the blue dots represent agents in their house.

In Section IV-A, we present the results of examining the impact of the range used to calculate the evacuation rate. Section IV-B discusses the results of examining the effect of the accuracy of the evacuation rate communicated to the agents. In Section IV-C, we present the results of evaluating the effectiveness of the “Evacuate Now Button”. The discussion of these results is provided in Section V.

A. Distance for Calculating Surrounding Evacuation Rate

Each agent is able to know the evacuation rate of residences within a radius L meters from their own residence, and they decide whether to evacuate based on this information. We first examined the optimal range for calculating the evacuation rate that agents can access. The results using the geographical data of Toyohashi City, Aichi Prefecture, and Nobeoka City, Miyazaki Prefecture, are shown in Fig. 2 and 3, respectively.

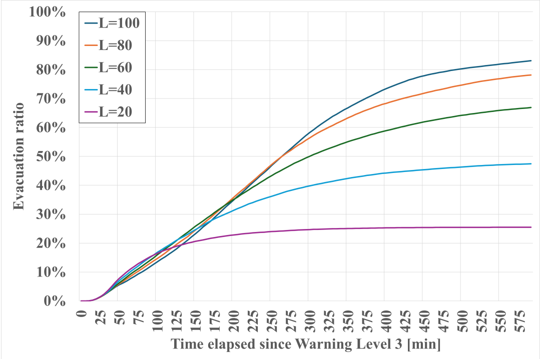

Fig. 2. Evacuation rate transition in the simulation with Toyohashi City’s data. Agents know accurate evacuation rate of their surroundings within a range of L meters.

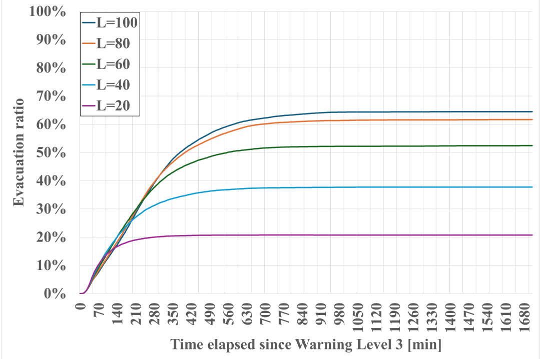

Fig. 3. Evacuation rate transition in the simulation with Nobeoka City’s data. Agents know accurate evacuation rate of their surroundings within a range of L meters.

In both Fig. 2 and 3, the horizontal axis represents the time elapsed since the issuance of Warning Level 3, and the vertical axis represents the evacuation rate. L is varied from 20 to 100 meters in increments of 20 meters. Agents are able to accurately know the evacuation rate of residences within a radius L meters from their own location.

B. Accuracy of Communicated Evacuation Rates

Agents can know the evacuation rate in the surrounding area and decide whether to evacuate based on this information. However, communicating a low evacuation rate may, in fact, hinder evacuation behavior. Therefore, a method of providing a more generalized evacuation rate, rather than a precise one, is proposed. For example, if the actual evacuation rate is between 10% and 30%, the agent would be informed that the evacuation rate is “up to 30%”. This would result in agents perceiving a higher evacuation rate than the actual one,

TABLE II. Warning Levels and Announcement Times During Heavy Rain Disasters in Nobeoka (2022), and Toyohashi (2023)

Warning Level	Issuance Time in Nobeoka	Issuance Time in Toyohashi
3	17:00, Sep. 17th, 2022	6:40, Jun. 2nd, 2023
4	8:00, Sep. 18th, 2022	14:40, Jun. 2nd, 2023
5	21:30, Sep. 18th, 2022	16:30, Jun. 2nd, 2023

TABLE III. Parameters Related to Agents' Evacuation Decisions

Parameter	Description	Value
T_1 [min]	Interval at which agents decide whether to evacuate	15 ± 50%
T_2 [min]	Delay time before agents begin actions	30 ± 50%
P	Probability of starting evacuation when conditions are met	0.5
α	Discount rate applied to P when evacuation is not initiated	0.8

potentially encouraging evacuation. However, if the range is too broad, the credibility of the information may decrease. Thus, we conducted experiments using two different patterns, Pattern 1 and Pattern 2, as shown in Table IV and Table V.

TABLE IV. Pattern 1 for the Evacuation Rate Communicated to Agents

Actual Evacuation Rate [%]	Evacuation Rate Shared with Agents [%]
0	0
$0 < r \leq 50$	50
$50 < r \leq 100$	100

TABLE V. Pattern 2 for the Evacuation Rate Communicated to Agents

Actual Evacuation Rate [%]	Evacuation Rate Shared with Agents [%]
0	0
$0 < r \leq 30$	30
$30 < r \leq 50$	50
$50 < r \leq 80$	80
$80 < r \leq 100$	100

Additionally, we define Pattern 3 as the case where the actual evacuation rate is communicated accurately to the agents. The results for Pattern 3 correspond to Fig. 2 and 3.

For each of these patterns, the agents' level of trust in the "Evacuate Now Button" was set according to the values shown in Table VI.

TABLE VI. The Values Representing the Agents' Level of Trust in the System for Each Communication Pattern

Pattern	Trust Level θ
1	0.3
2	0.75
3	1

When the trust level θ is applied, agents use the adjusted evacuation rate ρ', which is calculated from the evacuation rate ρ obtained through the "Evacuate Now Button" and a random number k ($0 \leq k < 1$), using the formula $\rho' = \rho \times (\theta + k(1-\theta))$. This adjusted evacuation rate ρ' is used as the current evacuation rate.

The results of the experiments conducted using the geographical data of Toyohashi City, Aichi Prefecture for Pattern 1 and Pattern 2 are shown in Fig. 4 and 5, respectively. Similarly, the results using the geographical data of Nobeoka City, Miyazaki Prefecture for Pattern 1 and Pattern 2 are shown in Fig. 6 and 7, respectively.

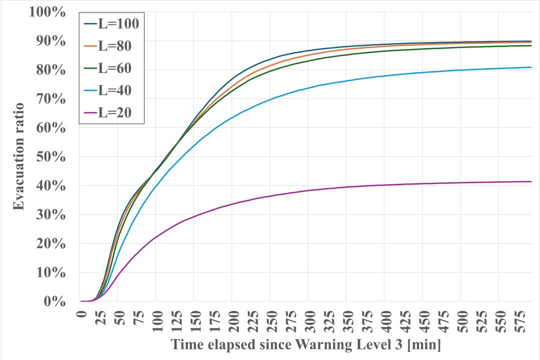

Fig. 4. Evacuation rate transition in the simulation with Toyohashi City's data. Agents can obtain the evacuation rate of their surroundings within a range of L meters, following the rule in Table IV.

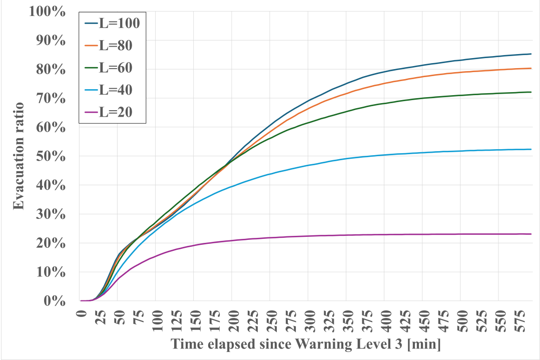

Fig. 5. Evacuation rate transition in the simulation with Toyohashi City's data. Agents can obtain the evacuation rate of their surroundings within a range of L meters, following the rule in Table V.

In Fig. 4 through 7, the horizontal axis represents the time elapsed since the issuance of Warning Level 3, while the vertical axis represents the evacuation rate. L is varied from 20 to 100 meters in increments of 20 meters.

C. *Effectiveness of the "Evacuate Now Button"*

Lastly, we investigated the effectiveness of the "Evacuate Now Button". As a comparison, we considered the case where the button is not used. In this scenario, agents are unable to know the evacuation rate of their surroundings. Instead, agents

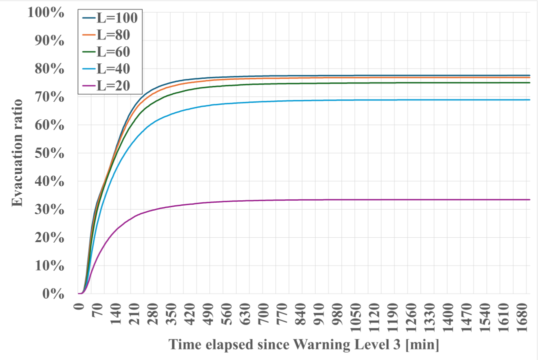

Fig. 6. Evacuation rate transition in the simulation with Nobeoka City's data. Agents can obtain the evacuation rate of their surroundings within a range of L meters, following the rule in Table IV.

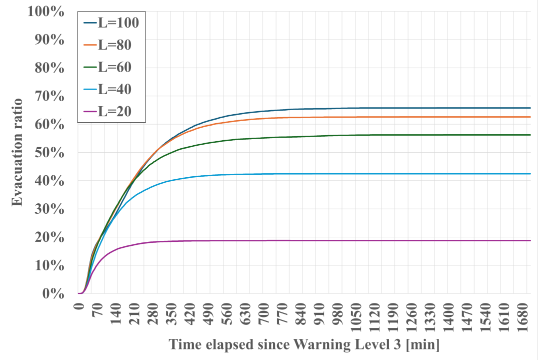

Fig. 7. Evacuation rate transition in the simulation with Nobeoka City's data. Agents can obtain the evacuation rate of their surroundings within a range of L meters, following the rule in Table V.

are assumed to observe the evacuation behavior of others within five minutes of them deciding to evacuate, and thus gain an understanding of the evacuation situation.

The results of the experiments using the geographical data of Toyohashi City, Aichi Prefecture, and Nobeoka City, Miyazaki Prefecture, are shown in Fig. 8 and 9, respectively.

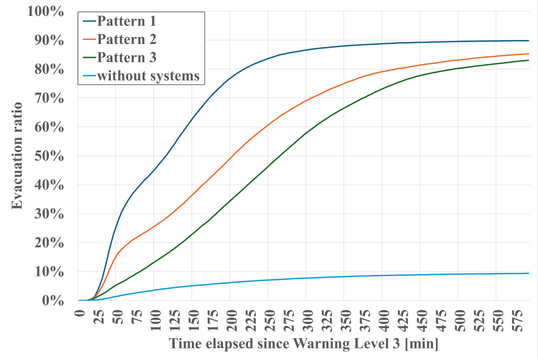

Fig. 8. Evacuation rate transition with / without the evacuation rate sharing system (Patterns 1-3) in the simulation with Toyohashi City's data. Agents with the system can obtain the evacuation rate of their surroundings within $L = 100$ meters. agents without the system can only observe those within a 40 meter range who have evacuated within the last 5 minutes.

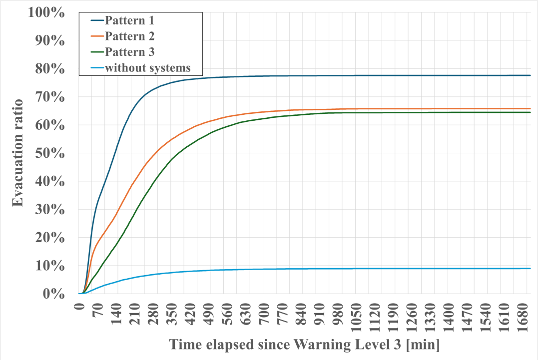

Fig. 9. Evacuation rate transition with / without the evacuation rate sharing system (Patterns 1-3) in the simulation with Nobeoka City's data. Agents with the system can obtain the evacuation rate of their surroundings within $L = 100$ meters. agents without the system can only observe those within a 40 meter range who have evacuated within the last 5 minutes.

In Fig. 8 and 9, the horizontal axis represents the time elapsed since the issuance of Warning Level 3, and the vertical axis represents the evacuation rate. For Pattern 1, Pattern 2, and Pattern 3, the range within which agents can know the evacuation rate was set to $L = 100$ meters, while agents without the evacuation information sharing systems can observe the evacuation behavior of others within a 40-meter radius.

V. DISCUSSION

This section discusses the experimental results presented in Section IV.

A. Distance for Calculating Surrounding Evacuation Rate

Fig. 2 and 3 show the results of varying the range L used to calculate the evacuation rate that agents can access. From these figures, we can observe that increasing L leads to a higher final evacuation rate. This is likely because, with a larger L, the probability of finding someone who has already begun evacuation increases within that range, which then influences other agents to evacuate. In other words, increasing L facilitates the spread of an "evacuation chain".

However, we also see that in the early stages, shortly after Warning Level 3 is issued, the evacuation rate increases more quickly when L is smaller. This is likely due to the smaller population size within a smaller range L, where the evacuation of just one agent has a larger impact on the overall evacuation rate for that group.

These results suggest that, when there is sufficient time after the issuance of Warning Level 3, increasing L could raise the evacuation rate. In other words, if the impact of the heavy rain can be predicted early and Warning Level 3 is issued at an appropriate time, a larger L is preferable. However, in situations where disasters occur shortly after the issuance of Warning Level 3, a smaller L might be more effective in increasing the evacuation rate more quickly.

B. Accuracy of Communicated Evacuation Rates

In the simulations conducted using the geographical data from Toyohashi City, Aichi Prefecture, as shown in Fig. 4 and

5, the final evacuation rate is highest when $L = 100$, consistent with the results in Fig. 2. Comparing Pattern 1 and Pattern 2, we observe that Pattern 1 achieves a higher final evacuation rate for all values of L. However, as L increases, the difference between the final evacuation rates of Pattern 1 and Pattern 2 becomes smaller. This suggests that when L is small, Pattern 1 yields a higher effect, but as L increases, the difference between Pattern 1 and Pattern 2 diminishes.

In the simulations using the geographical data from Nobeoka City, Miyazaki Prefecture, as shown in Fig. 6 and 7, the results are similar to those in Fig. 4 and 5: Pattern 1 produces a higher final evacuation rate than Pattern 2, and the difference between the two patterns decreases as L increases. However, in the case of Nobeoka City, the final evacuation rate difference between Pattern 1 and Pattern 2 is approximately 10%, which is larger than the difference observed in Toyohashi City.

From Fig. 4 through 7, we conclude that Pattern 1 consistently results in higher early and final evacuation rates compared to Pattern 2. Therefore, Pattern 1 is the more favorable option.

C. Effectiveness of the "Evacuate Now Button"

Fig. 8 and 9 show that the scenario without the "Evacuate Now Button" yields the lowest evacuation rates, with a final rate of about 9%. In comparison, the actual evacuation rate during the heavy rain disaster in Toyohashi City, Aichi Prefecture, was approximately 0.068% [23], which may seem somewhat detached from the simulation result. However, it is important to consider that factors such as community relationships, the location and number of shelters, and resident demographics likely influence real-world evacuation decisions. Previous studies involving surveys across multiple regions have shown that the evacuation rate for storm and flood disasters is generally around a few percent [24], making the results of this simulation reasonable when considering the exclusion of regional characteristics beyond geography.

When the "Evacuate Now Button" is introduced, the effect varies depending on how the evacuation rate is communicated to the agents, but in all cases—Pattern 1 through Pattern 3—the evacuation rate is significantly higher compared to the scenario without the system. In particular, in the case of Pattern 1, the simulations show an evacuation rate of approximately 78% for Nobeoka City (Fig. 9) and approximately 90% for Toyohashi City (Fig. 8), indicating a remarkably high evacuation rate.

As the evacuation rate increases, the number of people who need to be rescued in an emergency decreases, reducing the burden on fire departments and other rescue teams, allowing them to allocate more resources to individual rescues.

D. Limitations

The limitations of this study include the following: First, the behavior of agents used in the simulation is modeled based on survey results, and thus may not fully replicate the actual behavior of residents. Additionally, social factors such as the calculation range of evacuation rates and relationships within the community have been simplified, which is another limitation. Considering these limitations, future research should aim to develop a model that incorporates more detailed regional characteristics and psychological factors of residents' behavior.

VII. CONCLUSION

In this study, we developed a simulation based on an ABM to improve evacuation rates during heavy rain disasters. We experimentally demonstrated how much the "Evacuate Now Button," our previously proposed evacuation rate sharing system, could enhance evacuation rates. Additionally, we investigated the optimal range for calculating evacuation rates and the level of accuracy in the shared evacuation rate that would best contribute to increasing the evacuation rate.

The results showed that using the "Evacuate Now Button" could raise the evacuation rate from a few percent to approximately 78% in the case of Nobeoka City, Miyazaki Prefecture, and to approximately 90% in the case of Toyohashi City, Aichi Prefecture. Furthermore, regarding the range for calculating evacuation rates, it was found that a larger range led to a higher final evacuation rate. However, we also discovered that a smaller range resulted in a quicker initial rise in the evacuation rate. Therefore, if the goal is to increase the evacuation rate early, a smaller range should be used, while if the goal is to maximize the final evacuation rate, a larger range is preferable.

VII. FUTURE WORK

The discussion concluded that the simulation results are reasonable when regional characteristics are excluded. However, as evacuation rates vary between regions, it is expected that developing a simulator that incorporates regional factors would further improve the accuracy of evacuation rate predictions. While incorporating factors such as shelter locations is relatively straightforward, integrating more complex aspects like relationships among residents would be challenging. Therefore, future research will need to explore methods for including such factors in the simulation program.

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