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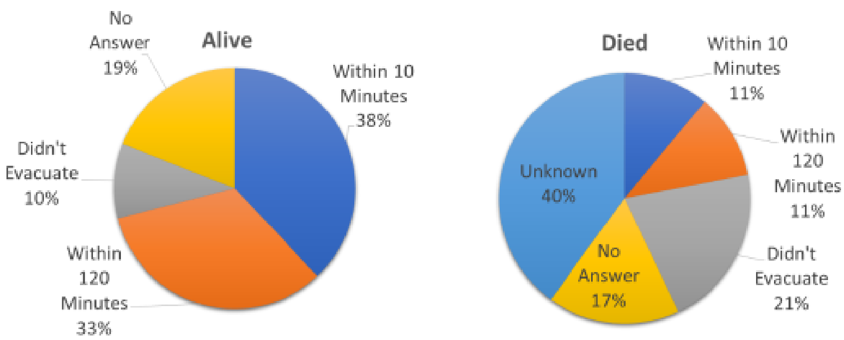
Abstract. In Japan, there are many flood and tsunami disasters caused by typhoons, heavy rains and earthquakes. In this case, the residents have an evacuation time to evacuate to shelters after evacuation alerts from a governmental office. However, the limited capacity of shelters and the delay in the rescue of support required people such as elderly and disabled people, the disaster can cause a serious damage. In order to prevent such a damage, we propose an evacuation support system that enables the information sharing of shelters' condition, the support required people and the support team. In this paper, we evaluated the effects of the evacuation support system by multi-agent simulation in a regional disaster. As a result of the simulation for a case study in a regional area with three evacuation shelters on Yahaba town in Iwate Prefecture, Japan, we confirmed that if we had enough evacuation time, the evacuation support system had an effect to increase the number of the evacuees.

Keywords: Evacuation support, Information sharing, Disaster response.

1 Introduction

In Japan, natural disasters happen frequently and the total damage amount is 18% in spite of Japanese small land of 0.25% in the world [1]. In the case of flood and tsunami disasters caused by typhoons, heavy rains and earthquakes, the residents have an evacuation time to evacuate to shelters after evacuation alerts from a governmental office. However, the limited capacity of shelters and the delay in the rescue of support required people such as elderly and disabled people, the disaster can cause a serious damage. So, in the case of a regional area disaster, a smooth evacuation is the most important.

The delay in evacuation of suffers has sometimes caused a large human damage. For example, Figure 1 (a) and (b) shows victims' evacuation start time on 2011 Great East Japan Earthquake [2]. The (a) and (b) show the ratio of alive people and that of died people respectively. Though 71% of the alive people evacuated within 120 minutes, the ratio of evacuated people in the die people was only 22 % people. It is difficult for many residents to predict the damage and they tend not to evacuate in the case of a disaster. Therefore, it is an important issue that government offices and supporters give residents a sense of evacuation in the case of a regional disaster. In addition, there are support required people who cannot evacuate alone at the time of a disaster such as elderly and disabled people. It is important that the supporters who support the evacuation of such people with sharing the information of the support required people, supporters and shelters' condition, and take evacuation action promptly.



(a) Alive people (b) Died people

Fig. 1. Victims' Evacuation Start Time on 2011 Great East Japan Earthquake

In order to solve above problems, we propose an evacuation support system that enables the information sharing of shelters' condition, the support required people and the support team.

In this paper, we survey the conventional researches on disaster evacuation simulation in chapter 2. Then, in chapter 3, we propose the evacuation support system. Then, in chapter 4, we show the evaluation on the proposed system by multi-agent simulation in a case study of Yahaba town in Iwate Prefecture, Japan. And we conclude the paper in chapter 5.

2 Conventional Researches

Recently, the multi-agent model is widely used for traffic simulation or money flow simulation in the economical field. Muraki, Y. et al. proposed the multi-agent model for wide-area disaster-evacuation simulations with local factors considered [3]. They simulated the situations of Kobe city on the date of the Great Hanshin Awaji earthquake in Japan. The simulation results about the percentage of evacuees who arrived at refuges were in good agreement with the actual data when parameters for evacuation-start timing were adjusted. The earthquake sometimes brings a large damage by tsunami. Liu, Y. et al. also proposed the dynamic route decision model-based multi-agent evacuation simulation and described the case study of Nagata Ward, Kobe in Japan [4]. They were considering group evacuation, landmarks & evacuation signs, and familiarity with the local environment. They also developed a prototype of a multi-agent based evacuation simulation system for the case area of the Oike underground space of Kyoto, Japan and demonstrated the feasibility [5]. Uno, K. et al. developed a simulation system for the disaster evacuation based on multi-agent model using geographical information system (GIS) [6]. They used Dijkstra algorithm to obtain the shortest route to the refuge and showed the evacuation route to understand easily by using virtual reality technique. The system was applied to the evacuation analysis by the flood flow in urban area and was shown to be a useful tool to investigate the damage by natural disasters. Regarding to flood evacuation planning, Lim, H. et al. reviewed many recent studies in the view of behavioral science, risk analysis and transportation modeling [7].

Regarding emergency evacuation in the event of fire and smoke propagation disaster in a large building, Tissera, P. C. et al. proposed a hybrid structure model and simulated people's behavior by using Intelligent Agent model [8]. Gelenbe, E. et al. studied the large scale simulation for human evacuation and rescue in large scale physical infrastructures such as building, campuses, sports and entertainment venues and transportation hubs [9]. There, they surveyed recent research on the use of sensor networks, communications and computer systems to enhance the human outcome of emergency situations. Hawe, G. I. et al. used agent-based simulation to determine the allocation of resources for a two-site incident which minimizes the latest hospital arrival times for critically injured casualties [10].

Minamoto, T, et al. developed a tsunami evacuation simulation system based on Petri Net to find safety areas and to use for emergency evacuation drill [11]. The simulation results were useful to grasp the behavior of inhabitants and to find safety area in the case of tsunami disasters. But, those studies did not consider about the evacuation of vulnerable people who are unable to get away alone, such as elderly and handicapped people.

The Grate East Japan Earthquake, about 60 % of the victims of the tsunami was 65 years of age or older. Futagami T. et al. developed a scenario simulator that can be used as a target area where the tsunami is expected to see an animation action of sup-porters and vulnerable people to evacuate [12]. The system assumes the traffic inhibition and the evacuation behavior of supporters and vulnerable people by using the sys-tem.

Kawai Y. et al also developed a tsunami evacuation simulation system using a game engine and open data [13]. In the simulation system, they prepared multiple types of agent considering the walking speeds and disaster conditions and evacuation behaviors. As results of their simulation in Kamakura city in Japan, the high risk areas became clear.

However, above conventional studies did not mention about the evacuation support system and information sharing method in a disaster conditions. This paper proposes the evacuation support system and information sharing method in the event of a disaster and evaluates the effects using multi-agent simulation.

3 Concept of Evacuation Support System

In Japan, disaster vulnerable people who need evacuation support in the event of a disaster are called "Support Required Person" and they are registered and listed in each local government. The Support Required Person list should be managed and used in the local government, but it is not used even in the emergency case actually because of strong intension of personal information protection. Therefore, we propose to resister more than 3 supporters for each Support Required Person, and to support with 2 of the registered supporters in the event of a disaster. Next, we propose to register multiple disaster ICT volunteers in the area with an official evacuation site (shelter). Finally, we propose to use a behavior information sharing system among the evacuation supporters. The proposed system image is shown in Fig. 2.

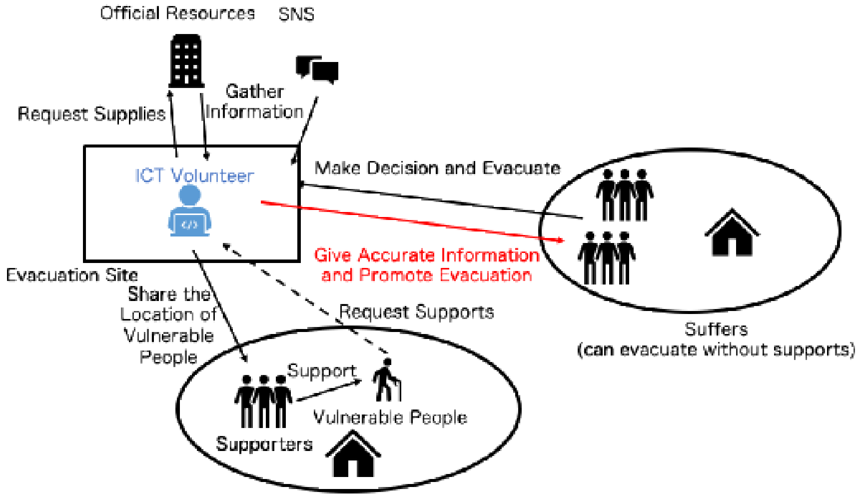


Fig. 2. Proposed system image

In the event of a disaster, the ICT volunteers gather at evacuation site (shelter) and register evacuation information and safety information for residents in the area by using a computer system. In addition, the information on the capacity of the shelter and the ratio of the number of evacuees is sent to all residents and evacuees via Social Network Service (SNS), etc. If the number of evacuees is worried to exceed to the capacity, the ICT volunteers recommend the other nearby and available evacuation site.

The supporters go to the registered Support Required Person. If two supporters have already arrived at the Support Required Person, they back to the evacuate site. This information can be confirmed by the supporter behavior information sharing system.

This proposed system is expected to solve the problem of changing the evacuation site because of the limited shelter capacity, the problem of late evacuation of the Support Required Person, and the problem of involving the supporters in the disaster. As we carried out a multi-agent simulation experiment to verify whether our proposed system has the expected effects, we describe it as a case study in the next chapter.

4 Evaluation

4.1 Case Study Field

In Japan, as there are many rains and typhoons, the river flood frequently occur from summer to autumn, and people often evacuate to shelters. We selected the Shirasawa area of Yahaba town in Iwate Prefecture which is a typical local area in Japan as the experimental field of the case study. Table 1 shows the condition of the Yahaba town and Shirasawa area, which is required data for the later described simulation.

Table 1. The condition of Yahaba town and Shirasawa area in 2018.

Items	Yahaba town	Shirasawa area
Population	27,340	626
Number of vulnerable people (Support Required People)	1,107 (4.05%)	25 (estimated)
Number of supporters (fire men)	308 (1.17 %)	7 (estimated)

Figure 3 shows the hazard and the population distribution map of the Shirasawa area, where the size is approximately 2km (from north to south) and 2.5 km (from east to west). This area has three official evacuation sites (shelters) of No.38, 39 and 49 which are designated by the local government. They are used as a public hall (No.38), a meeting place (No.39) and a junior high school (No.49) in a normal case. In the hazard map, the colors show the possibility of river flood, where yellow area is under 0.5 m of water and blue area shows under 2.0 m of water. This area has 14 districts and each population is opened by the government website. We estimated the number of vulnerable people (Support Required People) and supporters in each district by using the whole ratio (shown in Table 1) of those people presented by Yahaba town.

Table 2 shows the condition of the shelters. We calculated the capacity of evacuees by using the size of space and Sphere Standard (Humanitarian Charter and Minimum Standards in Humanitarian Response, 1998).

Table 2. Conditions of shelters.

Evacuation sites (Shelters)	Size of space	Capacity of evacuees
No.38 Hanayahaba public hall	300 m^2	85
No. 39 Morigaoka meeting place	80 m^2	22
No. 49 Yahaba junior high school	2,240 m^2	640

4.2 Evaluation Using Multi-agent Simulation

We simulated the behavior of evacuees when a disaster occurred in the above mentioned area by using multi-agent simulation. Table 3 shows the agent model. There are three types of agents, which are general evacuee, vulnerable person (Supporter Required Person) and Supporter. We assumed the simulation condition on the total number and moving speed for each agent type as Table 3. Ideally, it is desirable to rescue on vulnerable person by two or more people, but there is a possibility that the supporter may be a victim by late escape. For this reason, in this time simulation, we considered that one supporter could rescue one vulnerable person.

Figure 4 and Figure 5 show the behavior model of each agent for a general evacuee (Fig.4 (a)), a vulnerable person (Fig.4 (b)) and a supporter (Fig. 5), respectively. The purpose of the simulation is to evaluate the effect of the proposed Evacuation Support System with ICT volunteers. The ICT volunteers give the shelter information and supporters' behavior information for general evacuees and the supporters by using information sharing system and SNS in the event of a disaster.

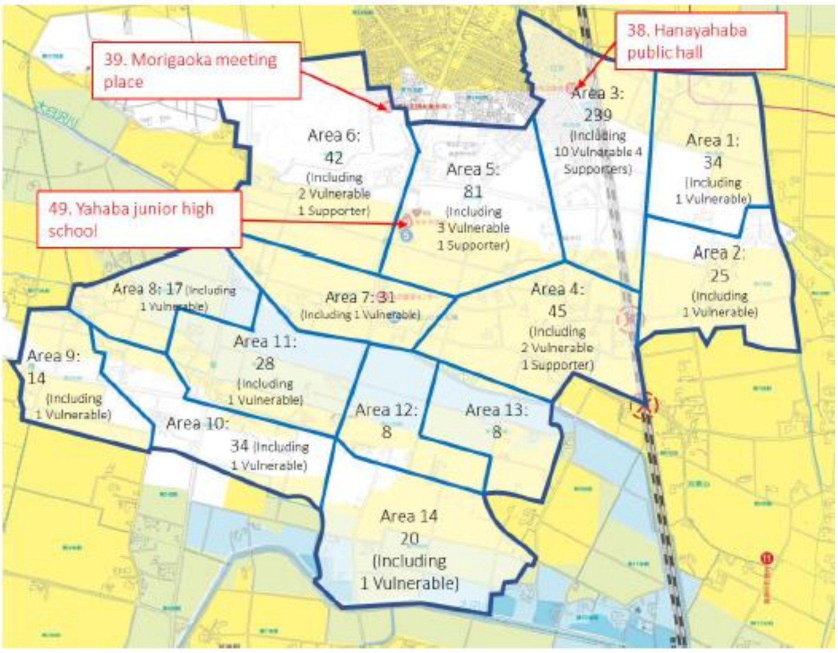


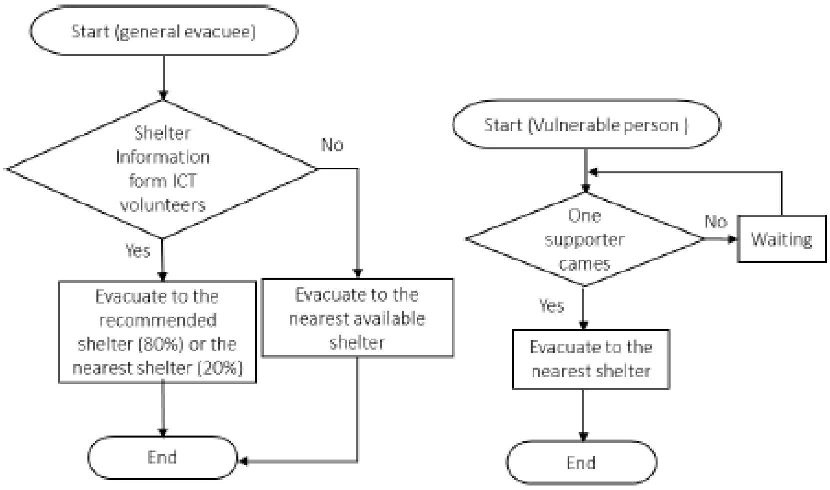
Fig. 3. Hazard and population distribution map around Shirasawa Area in Yahaba town.

Table 3. Agent model.

Agents	Total number	Moving speed
General evacuee	586	Random (From 1.8 km/h to 7.2 km/h)
Vulnerable person (Supporter Required Person)	25	0 km/h or 1.8 km/h (with one supporter)
Supporter	7	7.2 km/h

Figure 6 shows the number of evacuated people in the case of no ICT volunteers, where (a) is for general evacuees and (b) is for vulnerable people. One hour after the start of evacuation, all of general evacuees could finish the evacuation but 20 of vulnerable people could not evacuate (evacuated vulnerable people was only 5).

Figure 7 shows the same meaning figure with Fig. 6 in the case of with ICT volunteers. One hour after the start of evacuation, all of general evacuees could finish the evacuation and only 5 of vulnerable people could not evacuate (evacuated vulnerable people was 20). The number of evacuated vulnerable people (Support Required People) in-creased to be four times by the information form the ICT volunteers.



(a) General evacuee (b) Vulnerable person

Fig. 4. Behavior model of a general evacuee and a vulnerable person

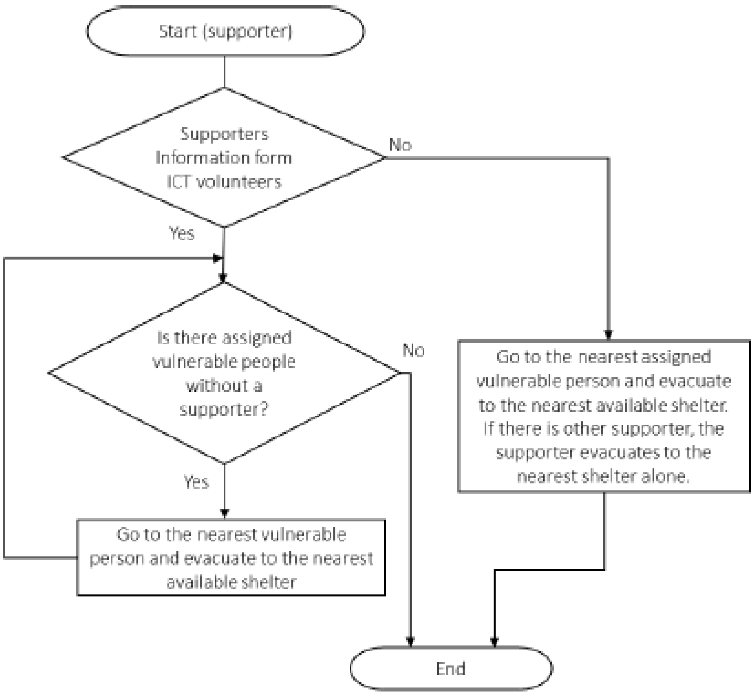
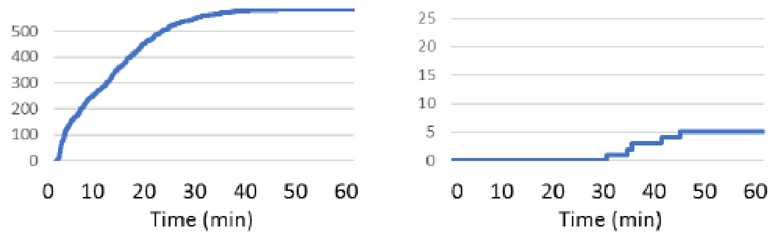


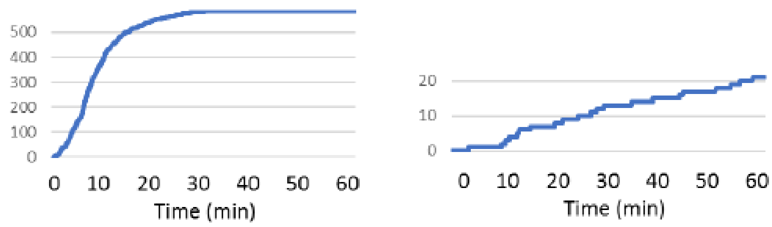
Fig. 5. Behavior model of a supporter.

Figure 8 shows the comparison of the number of evacuees in the case of with ICT Volunteers and that of no ICT Volunteers. Regarding (a) general evacuees, until the first 8 minutes, the number of evacuated people in no ICT volunteer is larger than that in with ICT volunteers. Though after 8 minutes, the number of evacuated people in with ICT volunteers increased than that in no ICT volunteers. This is because that freely evacuating people without ICT volunteers' information until the capacity of the shelter is filled would have better advantage than controlled evacuating by ICT volunteers. However, we could confirm that if we had longer time, it was more effective to evacuate by according to the information from ICT volunteers.



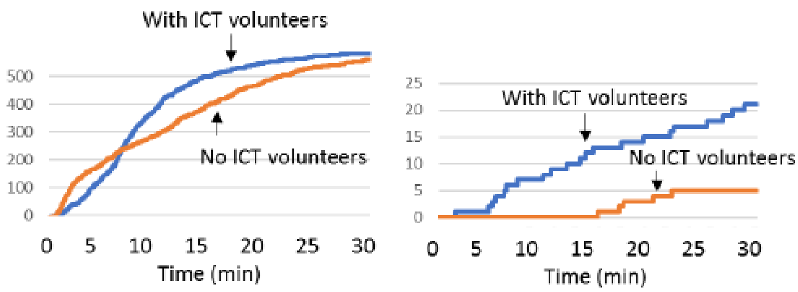
(a) General evacuees (b) Vulnerable people

Fig. 6. The number of evacuated people in the case of no ICT volunteers.



(a) General evacuees (b) Vulnerable people

Fig. 7. The number of evacuated people in the case of the ICT volunteers existing.



(a) General evacuees (b) Vulnerable people

Fig. 8. The comparison of the number of evacuees in the case of with ICT volunteers and no ICT volunteers.

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References

1. Hilz, S. R., Van de Walle, B. and Turoff, M.: The domain of emergency management information, in Information systems for emergency management, Van de Walle, B.,Turoff, M. and Hiltz, S.R.eds pp.3-20 (2009). The original figure was produced by Guy Weets.
2. Weathernews Inc., Tsunami investigation of the Great East Japan Earthquake (2011), http://weathernews.com/ja/nc/press/2011/pdf/20110908_1.pdf (in Japanese).
3. Muraki, Y. and Kanoh, H. :Multiagent Model for Wide-Area Disaster-Evacuation Simulations with Local Factors Considered, Journal of Japanese Society for Artificial Intelligent, Vol.22, No.4F, pp.416-424 (2007) (in Japanese).
4. Liu, Y., Okada, N. and Takeuchi, Y. : Dynamic Route Decision Model-based Multi-agent Evacuation Simulation – Case Study of Nagata Ward, Kobe, Journal of Natural Disaster Science, Vol. 28, No.2, pp.91-98 (2008).
5. Lie, Y., Okada, N., Shen, D., and Li S.: Agent-based Flood Evacuation Simulation of Life-threatening Conditions Using Vitae System Model, Journal of Natural Disaster Science, Vol. 31, No.2, pp.69-78 (2009).
6. Uno, K. and Kashiyama, K. : Development of Simulation System for the Disaster Evacuation Based on Multi-Agent Model Using GIS, Tsinghua Science and Technology, ISSN 1007-0214 56/67, Vol. 13, No.S1, pp.348-353 (2008)
7. Lim, H., Lim, Ma. B. and Piantanakulchai, M.: A Review of Recent Studies on Flood Evacuation Planning, Journal of the Eastern Asia Society for Transportation Studies, Vol. 10, pp.143-162 (2013).
8. Tissera, P. C., Castro, A., Printista, A. M. and Luque, E. : Evacuation simulation supporting high level behavior-based agents, Elsevier, Proceeding of International Conference on Computational Science ICCS 2013, 18, pp.1495-1504 (2013).
9. Gelenbe, E. and Wu, F. J.: Large scale simulation for human evacuation and rescue, Elsevier, Computers and Mathematics with Applications, 64, pp.3869-3880 (2012).
10. Hawe, G. I., Coates, G., Wilson, D. T. and Crouch, R. S. : Agent-based simulation of emergency response to plan the allocation of resources for a hypothetical two-site major incident, Elsevier, Engineering Applications of Artificial Intelligence, 46, pp.336-345 (2015).
11. Minamoto, T., Nariyuki, Y., Fujiwara, Y. and Mikami, A.: Development of Tsunami Evacuation Simulation System and Its Application to Assessment of Area Refuge Safety, Journal of Japan Society of Civil Engineering, Vol. 65, No.1, pp.757-767(2009) (in Japanese).
12. Futagami, T., Akizuki, K., Matsuyama, Y. and Kunikata, Y.: Development of the Vulnerable People Supporting System for a Tsunami Refuge Area, Journal of Japan Society of Civil Engineering, Vol. 69, No.2, I_1-I_6 (2013) (in Japanese).
13. Kawai, Y. and Kaizu, Y.: Tsunami Evacuation Behavior and Identification of Damaged Agents, The 33rd Annual Conference of the Japanese Society for Artificial Intelligence, 4Rin 1-34, p.1-4 (2019).
14. Sasaki, J., Maejima, T., Li, S., Sato, Y., Hiyama, M. and Herrera-Viedma, E.: Life- Area Broadcasting System (LABS) for Normal and Emergency Cases by Using Easy Contents Management System and New Speaker Devices, 16th International Conference on Information Systems for Crisis Response and Management (ISCRAM 2019), pp.933-939 (2019).