REGIONAL DISASTER PREVENTION WITH CLOUD-BASED GIS MAPPING AND LOCATION-BASED GAMING: DISASTER PREVENTION GO!

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ABSTRACT

In this study, we aim to develop and discuss ideas for a location-based mobile game called "*Bosai-Go!* (Disaster Prevention Go!)" for regional disaster prevention. The application is designed to familiarize local residents of Japan with their nearby rivers through their daily life routines and motivate them to evacuate right before a disaster occurs. In this game, players are provided with local information maps through their mobile device and they score points whenever they visit specific sites such as monuments of disasters and evacuation shelters. We constructed cloud-based GIS base maps of local information and made them accessible on mobile devices. These maps were based on the "Midorikawa River Waterfront Area Map" provided by a local river office. The map was originally prepared for the appropriate local river management of the Midorikawa River. This was related to various themes which included the history, natural environment, and hazard risks concerning the river. We then invited optional ideas from university students for a location-based mobile gaming contingent on this base. The obtained ideas were evaluated for their expected effects on regional disaster prevention. The concerning issues regarding playing the game were also looked into. Finally, the possibilities and challenges toward the development of the mobile game were discussed.

Keywords: Disaster prevention, gaming, mobile GIS, river basin, river management

1. INTRODUCTION

In recent years, heavy rainfall has frequently occurred in Japan. However, even with this phenomenon, many residents still have delayed evacuation measures prior to the flooding or debris flow. As a result, many people lose their lives to natural disasters every year. The heavy rainfall often causes the river basin to overflow, thereby causing the flooding. Therefore, it is really important for local residents to regularly pay attention to their surrounding river basin. Despite the fact that many local governments release a variety of hazard maps (*e.g.*, flood, earthquake, sediment disaster, high tide, and tsunami) through the Internet and printed media in Japan, there are still many cases where residents cannot readily access such information and at times even experience difficulty understanding it. Even with disaster prevention information systems being improved and developed, many people still have difficulty in accessing unused systems on a daily basis in case of an emergency. As such, one of the main challenges of disaster prevention is the issue of how to involve people with low awareness of disaster prevention.

To solve such issues, we propose a solution involving a combination of cloud-based GIS mapping and location-based gaming. The Web-GIS, which is more commonly used than the cloud-based GIS, allows anyone to publish and access spatial data such as local disaster risk and disaster prevention information, create interactive maps, and communicate between people via Internet-based GIS (Abdalla and Esmail, 2018). On the other hand, the popularity of location-based games for smartphones, such as Pokémon GO, has motivated players of various generations to explore and understand their own respective communities.

In this study, we aim to develop ideas for a location-based mobile game called "*Bosai-Go!* (Disaster Prevention Go!)" and discuss the various possibilities and problems of using the application for regional disaster prevention. This game shall provide a variety of regional information maps including data on disaster risks around rivers. This will allow local residents to familiarize themselves with the nearby rivers and ultimately improve their evacuation motivation before any disaster may occur. Our approach contributes to community-based disaster risk management, which could lead to an overall sustainable reduction in disaster risks (Maskrey, 2011; Shaw, 2012).

2. BACKGROUND

2.1 Cloud-based GIS mapping

One of the ways to raise people's awareness of disaster risk is using participatory mapping. Traditional participatory mapping can evaluate the disaster risk in their immediate environment by overlapping the hazard, vulnerability, and risk on a map (Gaillard and Pangilinan, 2010). Considering that the integration of geospatial tools and datasets that allow for Internet access is useful in the various phases of a disaster, the cloud-based GIS provides some advantages of data access, distribution, and data capturing (Abdalla and Esmail, 2018; Asgary and Kari, 2017).

In terms of data access and distribution, a cloud-based GIS will make the access and distribution of data on disaster risk and disaster prevention information simpler through the use of any Internet connection. It is also important to share not only disaster risk and disaster prevention information, but also the pool of knowledge that local people accumulated from previous experiences; this can be done through the use of the Internet connection. Moreover, there is a need to provide open data which includes real-time information for disaster prevention in the event of a disaster (Koike et al., 2018).

Regarding data collection, crowdsourcing involving the efficient collection of geospatial information by an undefined network of people to solve a complex problem using mobile applications has become popular in recent years (Brovelli et al., 2016; Chatzimilioudis et al., 2012). Given that traditional media is dominated by one-way communication, a cloud-based participatory GIS has benefits of generating a shared understanding of hazardous phenomena and improving communication through "citizen science" (Hicks et al., 2019).

2.2 Location-based gaming

There is an increasing number of cases where gaming is being incorporated into local disaster drills and education. Game-based learning can be used effectively as a new communication medium to encourage the active participation of community members (Yamori, 2012). In fact, many studies have shown that playing games can be very effective in disaster education due to the players' increased motivation for disaster preparedness and increased levels of engagement (Noda et al., 2012; Thai et al., 2020).

In this context, serious games are often used as an educational tool for the prevention not only of floods but also of a variety of natural disasters (Solinska-Nowak et al., 2018). Simulation games such as evacuation games (Lovreglio et al., 2018; Suzuki and Moriyama, 2014) are also very popular; these games are becoming more advanced by combining new technologies such as virtual reality (Lovreglio et al., 2018). As Toyoda (2020) explained, it has been theorized that such simulations and games have the benefit of enhancing community resilience in coping and creating an adaptive capacity.

However, conventional disaster prevention games tend to raise awareness of community disaster risk not in everyday life but only after the gaming event. In addition, there is a difficulty in accessing the games for a wide range of residents and these are often hard to play through their daily life routines. On the other hand, the advantages of location-based mobile games, as seen in Pokémon GO, are highlighted in many aspects. First, the gameplay has great potential to motivate the players to explore their community, encouraging them to access new locations and even see already familiar places from a new perspective (Kim et al., 2020; Koskinen et al., 2019). For example, in the case of Pokémon GO, the player physically walks, finds and collects creatures called Pokémon, done by navigating the world of games linked to the real world. The player's location is tracked by GPS using a mobile application installed on his device. By motivating players to move around in their neighborhood to succeed in the game, playing Pokémon GO allows players to explore and learn about their own communities that they were not previously aware of (Kim et al., 2020).

Second, this experience helps build a sense of belonging and a sense of place for players to be in the community. Apart from this, playing location-based mobile games also promotes conversation with strangers and strengthens social connections (Thibault, 2019; Vella et al., 2019). Potts and Yee (2019) also indicated that Pokémon GO can have a positive effect on the sense of place, increasing the level of use and involvement of the public space because the game encourages players to regularly participate and move around in public spaces.

Third, as location-based mobile games attract a wider range of players compared with ordinary digital games (Malik et al., 2019), the games are likely to be accessed by a population with previously less activity. In fact, according to Althoff et al. (2016), playing Pokémon GO increased the frequency of staying outdoors and walking, almost irrespective of the players' age or gender. Likewise, in Japan, Hino et al. (2019) found that the number of steps taken by middle-aged and elderly players increased after the release of Pokémon GO. Due to such characteristics of the location-based games for smartphones, there are possibilities of overcoming the disadvantages of the conventional disaster prevention games discussed above.

3. METHODS

First, a cloud-based GIS base map containing local information based on the "Midorikawa River Waterfront Area Map" is constructed for the Midorikawa River basin. The Midorikawa River is a first-class river that flows almost through the center of the Kumamoto Prefecture in Japan and its basin has many cultural properties and historical sites. However, this river has caused large floods in the past. As mentioned earlier, the map was originally prepared by the local river office for the appropriate local river management of the Midorikawa River. For these reasons, this was related to various themes which included the history, natural environment, and hazard risks concerning the river basin.

Thereafter, in order to gather ideas about what kind of games are useful for regional disaster prevention, we held an "ideathon" event with the theme of "disaster prevention and location-based gaming" based on the above mentioned cloud-based GIS map. An "ideathon" is a coined word which combines an idea and a marathon. This refers to an event where participants intensively present and discuss new ideas on a specific theme for problem-solving. Regarding the ideas presented here, we asked participants to evaluate, through a questionnaire survey, their understanding of the expected effects of and the potential concerns regarding playing the game on community disaster prevention.

Eventually, we will develop a disaster prevention game integrating a real-time mode and evacuation simulation mode, as shown in Figure 1. This shall use real-time information on sediment disaster forecast and river flood forecast during disasters. Considering the overviews, this study is deemed to be the preliminary step for the development of the normal exploring mode marked in Figure 1.

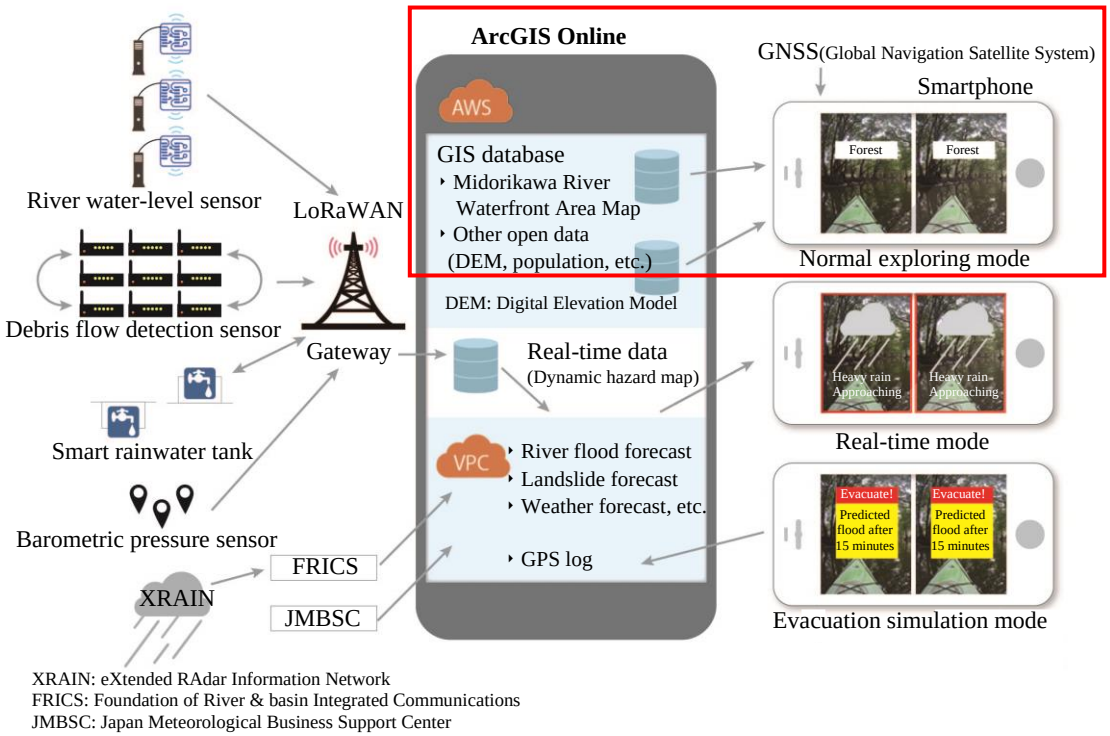


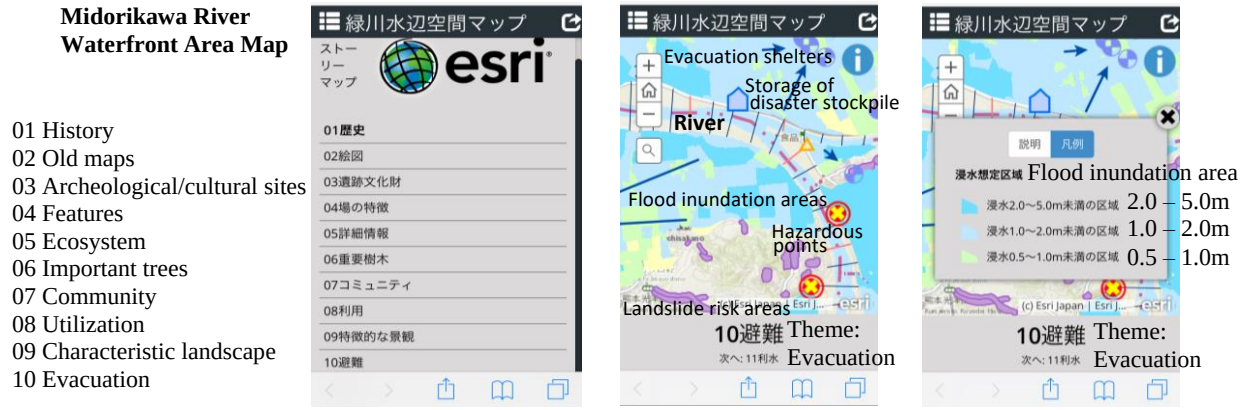
Figure 1. The overview of the application and the focus of this study (marked in red).

4. PROTOTYPING CLOUD-BASED GIS MAPPING APPLICATION

In prototyping the game "*Bosai-Go!* (Disaster Prevention Go!)," the "Midorikawa River Waterfront Area Map" provided by the Kumamoto River and National Highway Office is transferred and published to the cloud GIS platform ESRI ArcGIS Online. This provides a portal environment for managing and sharing maps. The map is originally created as a base map for classifying regional blocks according to different characteristics in each region and setting the maintenance policy for each block. The themes are subdivided as shown in Figure 2(a). This is important because regional information need to be considered when implementing river improvement and maintenance for the community.

These maps are organized and integrated into a cloud-based GIS map application using the Web AppBuilder for ArcGIS. This enables us to build GIS mapping web applications without writing code. Figure 2(b)(c) illustrates the selected map of flood control and disaster prevention (*Evacuation*) on the mobile screen. As a result, the following points were confirmed to demonstrate the effectiveness of base maps for the game application:

1. To display the base maps on the mobile devices such as smartphones and tablets
2. To display the attribute information as a pop-up on the screen when a feature on the map is tapped
3. To monitor usage and restrict viewers by management functions
4. To identify the user's position and display it on the screen using the GPS on the device
5. To share and overlay other open data (*e.g.*, altitude and population)



(a) (b) (c)

Figure 2. Display on a mobile device: (a) thematic maps from "Midorikawa River Waterfront Area Map," (b) selected map of flood control and disaster prevention (*Evacuation*), (c) a pop-up window for point of interest.

5. IDEA DEVELOPMENT AND EVALUATION FOR LOCATION-BASED GAMING

5.1 Idea development through the ideathon

In order to collect ideas for the location-based mobile gaming that is useful for regional disaster prevention, we held an ideathon event for 56 Japanese university students from the Fukuoka Institute of Technology. This ideathon had the theme of "disaster prevention and location-based gaming," providing cloud-based GIS mapping application for smartphones constructed in the previous section. Similar to Pokémon GO, the basic idea of the game is that players are provided with local information maps in their mobile device and they score points whenever they visit specific sites such as monuments of disasters and certain evacuation shelters. We divided the participants into groups of 10 and encouraged them to suggest additional options to improve the game. These suggestions included game features and rules, mechanics, characters and stories, incentives to keep them going, and any other necessary data. The representative ideas presented are as follows:

1. Earn points when visiting specific sites (rivers, landmarks, evacuation shelters, etc.)
2. Earn points according to travel time and distance from evacuation shelters
3. Post actual sites (messages and photos of hazardous places, etc.) where the player goes on SNS (Social Networking Service)
4. Changed player's own character or the enemy according to the hazard level of the sites
5. Choose player's own character / change it depending on the area or game progress
6. Be able to use earned points at local stores
7. Simulate occurring disasters on the assumption of the real city and recovering the city

Next, we asked participants to evaluate ideas involving the expected effects and potential concerns when these ideas are loaded into the mobile game. The questionnaire survey included five possible expected effects and four potential concerns. Thereafter, the analysis also focused on the expected effects on those who have little interest in disaster prevention and those who have no game experience at all. Prior to the ideathon event, we asked participants how interested they were in disaster prevention and if they had experiences of location-based mobile games. Table 1 lists the characteristics of the respondents based on questions.

Table 1. Overview of respondents.

	Frequency and percentage (*N*=56)
Gender	Male: 47 (84%) / Female: 9 (16%)
Interest in disaster prevention before the ideathon	Low to middle: 12 (21%) / High: 44 (79%)
Experience of location-based mobile games	No: 27 (48%) / Yes: 29 (52%)

5.2 Evaluation of ideas: Expected effects

In order to develop an effective application for disaster prevention which can be used in the daily life, the perspectives of regional disaster prevention and gamification are all required. To begin with, Table 2 shows the percentage of participants who expected effects on five constructs related to regional disaster prevention and gamification when each idea is loaded into the game: (a) *increased awareness of disaster prevention and disaster risk*, (b) *increased interest in river basins and watersides*, (c) *better understanding own community*, (d) *simple enjoyment as a game*, and (e) *enhanced motivation to continue the game*. Based on the results, earning points when visiting specific sites is expected to contribute not only to the enjoyment of the player, but also shall provide an increased awareness of disaster and interest in watersides. This is despite the consideration of the most basic and simplest rules of location-based mobile games. Similarly, it has been found that exploring and finding a specific place such as evacuation shelters have potential to improve the player's understanding of his own community. Apart from this, the game also helps raise the player's awareness of disaster, which is partly supported by the findings from Pokémon GO (Kim et al., 2020; Koskinen et al., 2019). Integration to SNS is predicted to have the same effects though this may be hardly associated with the gamification. In particular, using such an interactive media, we will be also able to facilitate interactions between residents and river managers by sharing the river basin's situation, such as damage to dikes. This can be done through sharing photos as well as texts messages amongst these people.

The rest of the ideas put more emphasis on gamification compared with the other above mentioned ideas. In terms of gaming character, the attractive characters and the attachment with character play an important role in gameplay of users (Malik et al., 2019). Furthermore, Alha et al. (2019) found that progressing in the game is a key reason for continuing to play location-based games. Considering that participants indicate higher expectations to simple enjoyment as a game and enhanced motivation to continue the game, the results are in line with these previous studies. The last idea suggests that it is effective to incorporate a simulation experience as emphasized in conventional disaster prevention games (Lovreglio et al., 2018; Toyoda, 2020).

Table 2. Evaluation of ideas: Expected effects.

	(a) Increased awareness of disaster prevention and disaster risk	(b) Increased interest in river basins and watersides	(c) Better understanding own community	(d) Simple enjoyment as a game	(e) Enhanced motivation to continue the game
1.Earn points when visiting specific sites	63%	45%	48%	63%	29%
2.Earn points according from travel time and distance to evacuation shelters	54%	18%	54%	50%	39%
3.Post actual sites where the player goes on SNS	46%	34%	43%	23%	27%
4.Changed player's own character or the enemy according to the hazard level of the sites	50%	23%	34%	73%	34%
5.Choose player's own character / change it depending on the area or game progress	14%	5%	30%	80%	57%
6.Be able to use earned points at local stores	5%	9%	32%	45%	64%
7.Simulate occurring disasters on the assumption of the real city and improving the city	77%	48%	57%	63%	34%

Next, regarding expected effects related to regional disaster prevention (*increased awareness of disaster prevention and disaster risk* and *increased interest in river basins and watersides*), Figure 3 shows the results according to the interest of people in disaster prevention before the ideathon. Here, it was found that respondents with higher interest in disaster prevention tend to predict higher effects of gaming on regional

disaster prevention. However, there are limited statistically significant differences between the two groups through testing the difference between the ratios of the two groups. This suggests that a certain degree of effect can be expected even if the interest in disaster prevention is moderate or less.

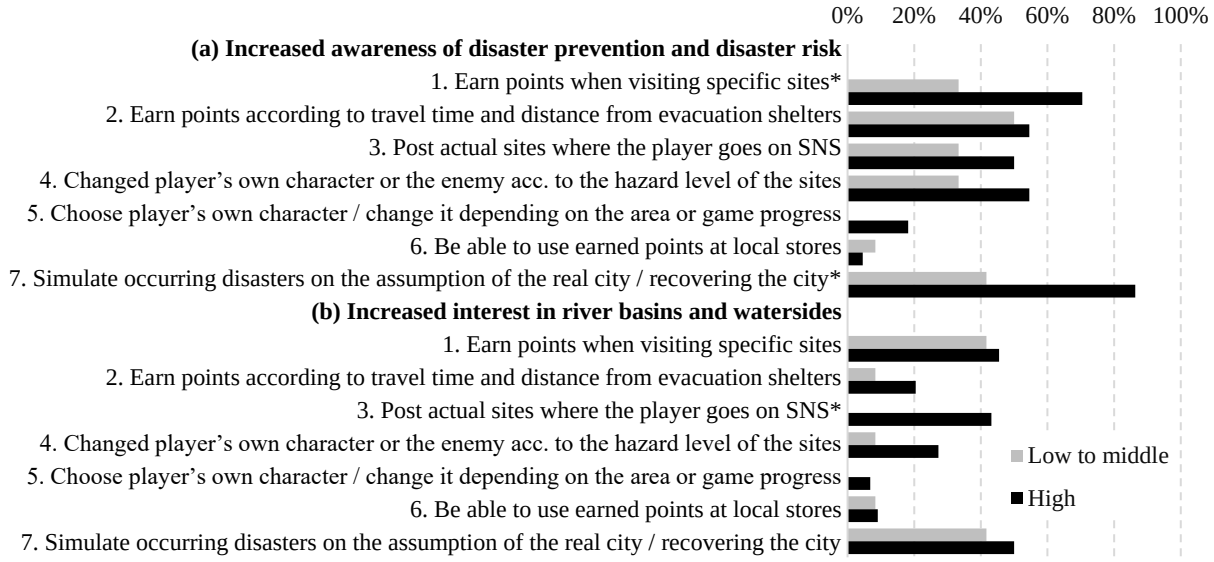


Figure 3. Expected effects of the presented ideas according to the interest in disaster prevention before the ideathon (*indication of a 5% level of significant difference).

Moving onto the expected effects related to gamification (*simple enjoyment as a game* and *enhanced motivation to continue the game*), Figure 4 shows the results according to the experience of location-based mobile games. There are no significant differences between the two groups in all constructs except the idea related to gaming character. This indicated that even people without gaming experience will be able to continue enjoying the game. Given that the effect of the character on game continuity is significantly higher for inexperienced gamers, special care must be taken to develop gaming character. This shall be crucial in order to maintain the player's motivation to use applications.

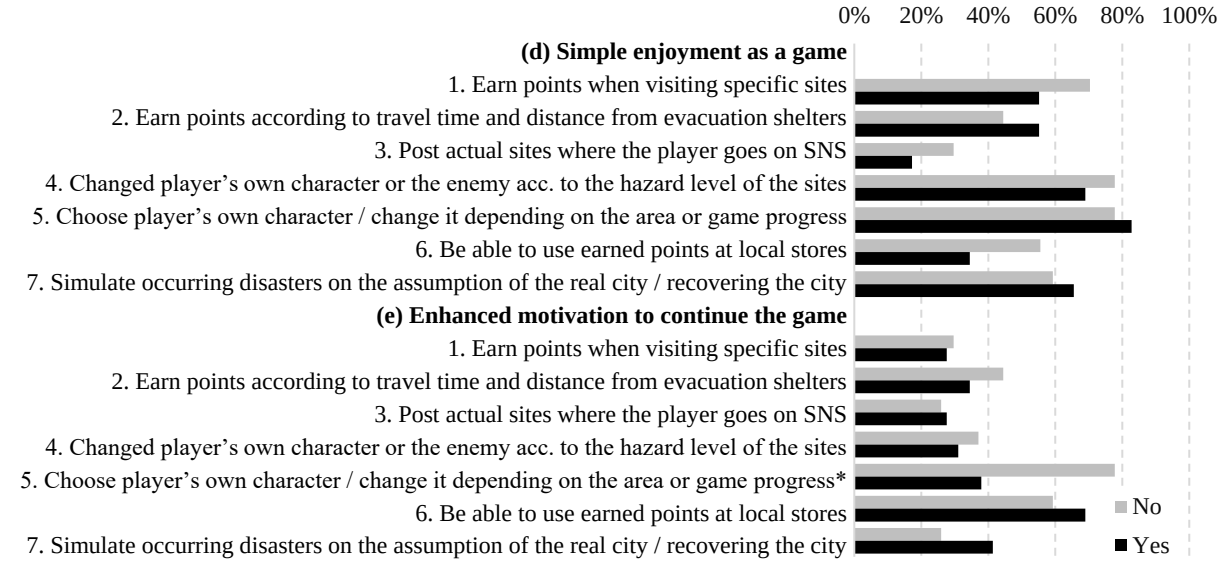


Figure 4. Expected effects of the presented ideas according to the experience of location-based mobile games (*indication of a 5% level of significant difference).

5.3 Evaluation of ideas: Potential issues

On the contrary, there are also concerns about the ideas. Table 3 shows the percentage of participants' concerns on four constructs while playing the games. This is in relation to when each idea is loaded into the game: (f) *unintended use of location data*, (g) *leak of personal information*, (h) *spreading incorrect information*, and (i) *inducing dangerous and annoying behavior*. The first is privacy issue, which is likely to

be a concern when posting actual sites where the player goes on the SNS or uses earned points at local stores while these ideas are predicted to have great benefit in terms of increased awareness of disaster, enhanced motivation to continue the game, and even better river management, described in the previous section. It should be noted that the privacy issue is commonly pointed out not only in disaster prevention games but also in smartphone applications (Malik et al., 2019). Similarly, posting to SNS, while it is useful as a tool of participatory GIS, may raise doubts about the intentional spread of incorrect information.

Besides, as discussed in Pokémon GO (Alomar et al., 2019), while walking around and exploring neighborhoods in the mobile application, gameplay may induce dangerous and annoying behavior such as stepping into places that should not be entered into, or breaking street and traffic rules. The situation motivating players to attract attentions on SNS or enter more dangerous places is notably likely to lead to the above mentioned issues. When developing an application, it is necessary to take precautionary measures in advance to prevent users from having such anxiety.

Table 3. Evaluation of ideas: Potential issues.

	(f) Unintended use of location data	(g) Leak of personal information	(h) Spreading incorrect information	(i) Inducing dangerous and annoying behavior
1.Earn points when visiting specific sites	9%	13%	21%	50%
2.Earn points according from travel time and distance to evacuation shelters	11%	20%	11%	38%
3.Post actual sites where the player goes on SNS	27%	52%	45%	36%
4.Changed player's own character or the enemy according to the hazard level of the sites	13%	7%	9%	39%
5.Choose player's own character / change it depending on the area or game progress	9%	16%	7%	9%
6.Be able to use earned points at local stores	34%	23%	14%	16%
7.Simulate occurring disasters on the assumption of the real city and improving the city	13%	13%	20%	14%

6. CONCLUSIONS

To have local residents familiarize with their nearby rivers and community in daily life and improves motivation for evacuation before a disaster occurs, we aim to develop a prototype of a location-based game called "*Bosai-Go!* (Disaster Prevention Go!)." To this end, we presented a cloud-based GIS mapping system that provides regional information and invited ideas for location-based mobile games based on this base map provided by university students. The obtained ideas were evaluated for their expected effects and potential issues on regional disaster prevention. Finally, we discussed the availability and challenges towards the development of "*Bosai-Go!* (Disaster Prevention Go!)." This mobile application is expected to be useful for river management and regional revitalization through strengthening social relationships, as well as for overall enjoyment of the game.

Future tasks include implementing the ideas presented in this study into the game application. Based on these findings, we will give priority to ideas and consider countermeasures for the potential issues. Moreover, using this application, an on-site experiment will be conducted for local residents in the Midorikawa basin to verify the effects. At the same time, it is desirable to analyze the behavior data of players based on GPS log recordings.

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REFERENCES

Abdalla, R., and Esmail, M. (2018). *WebGIS for disaster management and emergency response*. Springer, Cham.

Alha, K., Koskinen, E., Paavilainen, J., and Hamari, J. (2019). Why do people play location-based augmented reality games: a study on Pokémon GO. *Computers in Human Behavior*, 93: 114-122.

Alomar, N., Alsaleh, M., and Alarifi, A. (2019). Behavioral consequences of Pokémon GO: the exaggerated picture. *Computers in Human Behavior*, 90: 223-245.

Althoff, T., White, R. W., and Horvitz, E. (2016). Influence of Pokémon Go on physical activity: study and implications. *Journal of medical Internet research*, 18(12): e315.

Asgary, A., and Kari, D. (2017). Communicating disaster risk reduction through web-map applications. In: Pirasteh, S., and Li, J. (eds.) *Global changes and natural disaster management: geo-information technologies*. Springer, Cham, pp. 91-99.

Brovelli, M. A., Minghini, M., and Zamboni, G. (2016). Public participation in GIS via mobile applications. *ISPRS Journal of Photogrammetry and Remote Sensing*, 114: 306-315.

Chatzimilioudis, G., Konstantinidis, A., Laoudias, C., and Zeinalipour-Yazti, D. (2012). Crowdsourcing with smart phones. *Internet Computing, IEEE*, 16(5): 36-44.

Gaillard, J. C., and Pangilinan, M. L. C. J. D. (2010). Participatory mapping for raising disaster risk awareness among the youth. *Journal of Contingencies and Crisis Management*, 18(3): 175-179.

Hicks, A., Barclay, J., Chilvers, J., Armijos, M. T., Oven, K., Simmons, P., and Haklay, M. (2019). Global mapping of citizen science projects for disaster risk reduction. *Frontiers in Earth Science*, 7: 226.

Hino, K., Asami, Y., and Lee, J. S. (2019). Step counts of middle-aged and elderly adults for 10 months before and after the release of Pokémon GO in Yokohama, Japan. *Journal of medical Internet research*, 21(2): e10724.

Kim, J., Merrill Jr, K., and Song, H. (2020). Probing with Pokémon: feeling of presence and sense of community belonging. *The Social Science Journal*, 57(1): 72-84.

Koike, K., Iyobe, M., Ishida, T., Uchida, N., Sugita, K., and Shibata, Y. (2018). Proposal of an open data visualization system for disaster prevention and disaster reduction. In: Xhafa, F., Caballé, S., Barolli, L. (eds.) *Advances on P2P, Parallel, Grid, Cloud and Internet Computing*. Springer, Cham, pp. 517-527.

Koskinen, E., Leorke, D., Alha, K., and Paavilainen, J. (2019). Player experiences in location-based games: memorable moments with Pokémon GO. In: Geroimenko, V. (ed.) *Augmented reality games I: understanding the Pokémon GO phenomenon*. Springer, Cham, pp. 95-116.

Lovreglio, R., Gonzalez, V., Feng, Z., Amor, R., Spearpoint, M., Thomas, J., Trotter, M., and Sacks, R. (2018). Prototyping virtual reality serious games for building earthquake preparedness: the Auckland City Hospital case study. *Advanced Engineering Informatics*, 38: 670-682.

Malik, A., Hiekkanen, K., Hussain, Z., Hamari, J., and Johri, A. (2019). How players across gender and age experience Pokémon Go?. *Universal Access in the Information Society*.

Maskrey, A. (2011). Revisiting community-based disaster risk management. Environmental Hazards, 10(1): 42-52.

Noda, Y., Miki, K., Iwaka, K., Mitsuhara, H., Kozuki, Y., and Yano, Y. (2012). Real world edutainment based on branched game story and its application to earthquake disaster prevention learning. Proceedings of *IADIS Mobile Learning 2012*, 205-212.

Potts, R., and Yee, L. (2019). Pokémon Go-ing or staying: exploring the effect of age and gender on augmented reality game player experiences in public spaces. *Journal of Urban Design*, 24(6): 878-895.

Shaw, R. (2012). Overview of community-based disaster risk reduction. In: Shaw, R. (eds.) *Community-based disaster risk reduction*. Emerald Group Publishing Limited, pp. 3-17.

Solinska-Nowak, A., Magnuszewski, P., Curl, M., French, A., Keating, A., Mochizuki, J., Liu, W., Mechler, R., Kulakowska, M., and Jarzabek, L. (2018). An overview of serious games for disaster risk management–prospects and limitations for informing actions to arrest increasing risk. *International Journal of Disaster Risk Reduction*, 31: 1013-1029.

Suzuki, Y., and Moriyama, T. (2014). The visualization system for evacuation support using simulation games. Japan, Patent 5737683. (In Japanese)

Thibault, M. (2019). Towards a typology of urban gamification. Proceedings of *the 52nd Hawaii International Conference on System Sciences*.

Toyoda, Y. (2020). A framework of simulation and gaming for enhancing community resilience against large-scale earthquakes: application for achievements in Japan. *Simulation & Gaming*, 51(2): 180-211.

Tsai, M. H., Chang, Y. L., Shiau, J. S., and Wang, S. M. (2020). Exploring the effects of a serious game-based learning package for disaster prevention education: the case of Battle of Flooding Protection. *International Journal of Disaster Risk Reduction*, 43: 101393.

Vella, K., Johnson, D., Cheng, V. W. S., Davenport, T., Mitchell, J., Klarkowski, M., and Phillips, C. (2019). A sense of belonging: Pokemon GO and social connectedness. *Games and Culture*, 14(6): 583-603.

Yamori, K. (2012). Using games in community disaster prevention exercises. *Group Decision and Negotiation*, 21(4): 571-583.