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Yuko Murayama
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(Eds.)

Information Technology in Disaster Risk Reduction

Second IFIP TC 5 DCITDRR International Conference, ITDRR 2017
Sofia, Bulgaria, October 25–27, 2017
Revised Selected Papers

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Preface

The effects of disasters are very serious and it may take a very long time to recover from the destruction caused. Related damage can be severe and offering relief may lead to expenses in the billions of euros. There has been an increase in the occurrence of natural disasters in the past years and it is expected that their frequency will continue in the coming years.

Owing to the multidisciplinary nature of work in the field of disaster risk reduction, people from various backgrounds are included in this field of research and activity. Their backgrounds are likely to include industry, diverse geographical and global settings, not-for-profit organizations, agriculture, marine life, welfare, risk management, safety engineering and social networking services.

At present, at global and national levels, a wide range of scientific and applied research activity is conducted in the area of disaster risk reduction concerning individual types of disasters. Modern information and communication technologies (ICT) can facilitate significantly the decision-making processes from the point of view of disaster risk reduction.

Following the increasing number of disasters worldwide and the growing potential of both ICT and ICT expertise, at its General Assembly held during October 8–9, 2015 at the Daejeon Convention Center, Daejeon, South Korea, the IFIP established the Domain Committee on Information Technology in Disaster Risk Reduction in order to:

- Promote disaster risk reduction within the ICT community
- Provide an additional opportunity for IFIP members to work with other specialized bodies such as the UN, UNISDR, ICSU, ITU and ISCRAM
- Coordinate the efforts of member societies as well as different Technical Committees and Working Groups of IFIP in the disaster-related field

The disaster support offered by the Domain Committee is based on the following major pillars:

- Information acquisition and provision
- Shelter information management for local governments
- Disaster information systems
- State-of-the-art ICT (such as the Internet of Things, mobile computing, big data, and cloud computing)

IFIP's Domain Committee on Information Technology in Disaster Risk Reduction organized the Second IFIP Conference on Information Technology in Disaster Risk Reduction (ITDRR 2017), during October 25–27, 2017, at the University of National and World Economy, Sofia, Bulgaria.

ITDRR 2017 provided an international forum for researchers and practitioners to present their latest R&D findings and innovations. The conference was especially focused on various ICT aspects and the challenges of coping with disaster risk reduction. The main topics included: Natural Disasters, Big Data, Cloud Computing, Internet of Things, Mobile Computing, Emergency Management, Disaster Information Processing, Disaster Risk Assessment and Management.

ITDRR 2017 invited experts, researchers, academics and all others who were interested in disseminating their work to attend the conference. The conference established an academic environment that fostered the dialogue and exchange of ideas among different levels of academic, research, business, and public communities.

The Program Committee received 43 paper submissions, out of which 16 research papers were finally accepted. We are particularly grateful therefore to the members of the Program Committee, and the many reviewers of papers, for their dedication in helping to produce this volume.

October 2018

Yuko Murayama
Dimiter Velev
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Research on Disaster Communications

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Abstract. From our experience the Great East Japan Earthquake in March 2011 to help out the people in the affected area in terms of IT support such as internetworking and providing PCs, we came across an interesting issue concerning collaboration with people including supporters as well as the victims. We call this problem disaster communications. We also came to know the needs for disaster information processing as there was no such systems to manage shelters, goods distribution and volunteers. On the other hand such systems have been researched in the United States of America and Europe in terms of information processing for emergency management to a great extent. While we have had many natural disasters in Japan, only a very few of the researchers in computer science and information systems have been working on this issue. From this perspective, we try to identify the information required at disaster in this research. In particular, we explored the needs and seeds for disaster information processing in Iwate, Japan. We interviewed some supporters at Iwate in March 2011 such as local government officials, doctors and university administrators and found the situation awareness was required desperately in the beginning of the disaster. This paper reports our project of interviewing people who worked on disaster relief during the emergency response as well as our trial of a system for situation awareness based on the results from our interviews.

Keywords: Disaster communications · Situation awareness · Information processing for emergency management

1 Introduction and Motivation

The Great East Japan Earthquake on March 11th, 2011 caused severe damage to the northern coast of the main island in Japan. 15894 people died, 2546 are missing and 6156 are injured [1]. Just after the disaster, industry in the Tokyo area wanted to provide PCs and printers to the affected areas but did not know who would like to have them. Academic and industrial groups of engineers wanted to provide internet connection services but again did not know where the services were most needed. With requests from such organizations and groups of people, we started our support as a coordinator of such requests and finding the needs for such services, with a few of us in a university in Iwate, Iwate Prefectural University ten days after the disaster [2].

Our activities included collecting local information on requirements for IT equipment and internetworking services in the affected area as well as arranging to receive,

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store and manage incoming IT equipment. We got the information on such needs by communicating with people in the various local government entities and with a volunteer center located in Tohno, Iwate, just a behind the affected area. We also set up a mailing list with those people and sent a daily reports on what we did. Most of our activities lasted for four and a half months from March to the end of July during the initial emergency response. By the end of July, most shelters were closed and the people moved to temporary housing constructed by local governments. Gradually we went back to our normal work.

Through our support activities we were aware of the needs for information systems to coordinate the needs from the affected area and the support coming from the outside that area. For instance, the information system for shelter management was required desperately after one month of the disaster, as the emergency response team at the Prefecture office would like to know the statistics of disaster weak o each shelter to provide medical support as well as collecting the accurate needs for goods for their timely distribution. We also came across an interesting issue concerning collaboration with supporters from heterogeneous backgrounds; we call this problem disaster communications and found that trust plays an important role [2].

We found the lack of research and development of such an information system for emergency in Japan, while the issue has been researched for long time in the other countries [3, 4]. We learned from the related work [3] that case studies were of great help to many researchers. Moreover, we learned that Hiltz and Plotnick started interviewing risk managers on the use of social media [5]. Consequently, we started interviewing officers, doctors and volunteers who worked for the earthquake and tsunami emergency response in Iwate [6].

Finally, we also introduce one of our work of information systems for emergency management. We have implemented some systems required to help out the affected area [7] and one of them was recovery watcher system to keep people being aware of what is happening in the affected area [8]. In our project, we implemented the system again with use of smart phones and found it applicable for other applications as well.

In this paper, we introduce our previous work on disaster communications including our experiences and interviews as well as the recovery watcher system. The paper organization is as follows. The next section reports IT support required at the disaster in Iwate Prefecture. Section 3 discussed the interviews and their results. Section 4 reports about some institute hit by tsunami. Section 5 presents our new recovery watcher. Section 6 gives some conclusions.

2 IT Support Required at the Disaster

We supported mainly four cities and two towns on the coast in Iwate prefecture during the initial four months after the disaster. The following supports were required:

1. Information acquisition and provision:
   - Safety information for search people,
   - Visualizing Lifeline information
   - Portal sites of disaster information

2. Networking for information infrastructure:
   - internetworking with communication links
   - IT environment with PCs and printers
3. Shelter information management
4. Volunteer Support

We describe more on the above requirements in the following subsections.

2.1 Information Acquisition and Provision

For safety information, initially we did not have any network connectivity in shelters. One of our graduates, working as a volunteer at the volunteer center, created an off-line system for people search. Another graduate in Tokyo created software for mobile phone access. The safety information was provided by local police; the information was also available on the Prefecture's home page.

For safety information, we had an interesting technology deployment in Japan for this disaster: the use of broadcast services. People in shelters appeared on TV with a piece of paper on which their names were written, saying where they were staying as well as any other comments such as whom they were seeking. Iwate Broadcast Company (IBC) converted such information on their TV and radio services into the digital form and provided them at their web site. The problem was that the IBC digital form was different from the one provided by the police. We merged those two types of information for the search system on the mobile phone.

For visualizing lifeline information, we mapped road conditions, transport, electricity, water supply and so on. For road conditions, the information was provided by use of GPS car navigation systems. The system was originally created by a car company [9]. Now the information was integrated into major web search systems.

We set up a portal site of disaster information. We provided all the above information and also information such as radioactivity levels, because in the beginning some people including the volunteers in the Volunteer Center (VC) did not know this because they were too busy every day to look at the news.

2.2 Networking for Information Infrastructure

For Networking for information infrastructure, we supported the engineers for internetworking by providing information where to set up the network with communication links. Accordingly, we provided an IT environment with PCs and printers in shelters and other sites such as city halls in which networks were set up. Networking was hard due to the size of Iwate Prefecture. For instance travel would take nearly three hours one way to the city located in the south of the prefecture. It took almost one day for network engineers to go there and set up networks.

We consulted the prefectural emergency response headquarters for which sites to be connected in the beginning and asked the network engineers to set up when communication links and electricity could be made available. We asked mainly medical doctors at the headquarters who wished to talk to the local doctors at shelters.

The engineers researched each site thoroughly by visiting and seeing what type of communication links should be set up such as a 3G link or a Satellite Communication link. Gradually, those network engineers knew the affected areas much better than we or engineers in the prefecture headquarter did. In the end, the field engineers were deciding where to set up networks independently by talking directly with the local government officers. Through our joint work the major shelters were connected onto the network and we provided around 200 PCs and 50 printers in total.

2.3 Shelter Information Management

Shelter information management was required from the beginning, however, we were asked to help with it one month later after the disaster. What happened was that goods and foods sent to Iwate prefecture were stored in the central warehouse near the prefectural office then they were delivered to shelters at the coast. However, the requirements from each shelter were not reported precisely enough and many shelters received some unnecessary goods. Initially, the requirements were collected manually and sent to the prefecture's emergency response headquarters by fax.

A management system with a good communication system was required desperately. We came across the people working on the Sahana system [10]. Sahana is an information sharing system for humanitarian assistance at disaster and was developed originally by programmers in Sri Lanka just after the 2004 Indian Ocean earthquake and tsunami. The system is based on a free and open software and has been used extensively at disaster such as the 2008 Chengdu-Sitzuan Earthquake in China and the 2010 Earthquake in Haiti [11]. Sahana has been introduced to the Japanese open source community in 2010 and some started with operating the system with a type of Sahana software called Sahana Eden which is based on Python [12].

We introduced Sahana to the prefecture's emergency response headquarter. After March 11th, 2011, Sahana Japan Team (SJT) [13] was set up and those industrial volunteers developed a new system for distribution for Iwate with the help from SJT [12].

The system was ready eventually, at the end of May, but it was late as most of the shelters were about to be closed by July and the residents were to move to temporary housing. It would have been more useful if the system had been provided much earlier in March or April. Nevertheless, the system was used experimentally in some cities [12]. The system was used to collect requests for daily accommodation as well as the statistics on the number of people from shelters, and commodities were distributed daily based on the requests.

2.4 Volunteer Support

We also provided information on shopping and other daily-life-related tasks for newcomers to the Volunteer Center. We were asked to set up a Volunteers' site for sharing information. In the VC, they were not capable or too busy to set up a server. Moreover, a physical system would have been hard for them to maintain.

We set up their site using a cloud service. We found it very practical. The cloud services are sustainable in that they do not suffer any damage such as blackout or physical damage to the server from local disaster. One does not have to worry about maintenance. Compared to physical servers, cloud services were much more flexible and easier to set up.

2.5 Findings from the Support Experience

From the above experiences we figured out what is needed for disaster information systems as follows:

1. Need a standard format
2. Open Source: e.g. Sahana
3. Need a well-known interface
4. Killer Application for Cloud Computing

As 1 above, we needed a standard format for the exchange of disaster-related information. In the Subsect. 2.1, we reported about the difference in the safety information formats between the one used by a broadcast company and the other by the police. If they had used the same format, it would have been a lot easier for us to put together the information from the both sources. Such standards were required in shelter management information, goods distribution and medical information. Information on donation could be standardized for traceability as well.

For 2 above, open source software would be usable at disaster because a global community of software developers would be of help. On the other hand, open source may need the local software engineers to deal with local language some times. That happened in Japan this time.

Sahana was not used immediately after the disaster in Japan presumably due to two reasons. One was a language problem. The great efforts were made by SJT to make the system workable in the Japanese language environment, but it was eventually available in April 2011, so that promotion for a use of the system was late. The other presumed reason would be the programing language. Python used in Sahana was not so popular in Japan. Sahana was needed to be adapted for the needs in Iwate and there were only a limited number of developers available who were able to do so. We may well need for a software engineers' community to work globally to exchange the information yet they can deal with local language problems.

For 3 above, for any information system for emergency management, user interface is important and should be well-known. If one provides a new interface for the systems at disaster, the users have to learn how to use them firstly; that would be impossible when one needs to deal with things immediately.

For 4 above, most of the information at local governments were papers which were lost or contaminated with sea water physically. The information would be kept electronically and in a distributed manner for disaster so that the original information could be saved. From this perspective, cloud computing is ideal for the governmental information at local governments.

3 Interviews of the Relief Workers

Hiltz and Plotnick started interviewing risk managers on the use of social media [14]. Consequently, we interviewed thirteen people since December 2014; they were officers, doctors and volunteers who worked for the earthquake and tsunami emergency response in Iwate [6].

As some interviewees mentioned, many outsiders came and helped the disaster area. However, communications between relief workers and local workers were not so good. Misunderstandings happened easily when one was exhausted with short sleep while daily work and situations were not familiar. We identified the need for trust [2] in communications between relief workers at disaster.

Indeed, swift trust was required for those who need to collaborate with the outsiders. Swift trust is a novel issue in the research on trust and defined by Meyerson et al. [14] based on related work. According to Aggarwal [15], social diversity influences decision making in swift groups. For emergency response, governmental officers as well as doctors need to work together forming swift groups. We could apply findings from researches in swift trust.

Our findings include the followings:

- It is important in emergency response to collect information, to coordinate different sectors and entities and to make decisions without enough information.
- One needs to make decisions promptly and to proceed under unusual mental situations such as dealing with corpses.
- One needs to work together with people from heterogeneous perspectives and organizations.
- A trustworthy and reliable coordinator is required for a swift team of relief workers with different perspectives to deal with various issues.
- In hospitals, doctors need to deal not only with acutely-ill victims but also with the chronically ill patients. Coordination is needed between regular doctors and DMAT doctors.

We also interviewed one of the officers of the prefectural government again in March 2017, who moved to work for a local government in the affected area. He raised two more findings both related situation awareness:

- At the disaster in 2011, in the beginning, information was not enough for situation awareness.
- Before one talks to the local government officers in an affected area, we may well need to consider what situations the local government officers were involved; they might have been stressed by loss of family members and colleagues, as well as by too much work load with a limited number of officers.

The following issues need to be explored in future:

(a) Swift trust in disaster relief workers.
(b) How to deal with false information at emergency response.
(c) Information processing with or without network connections.
(d) Protection of information.

(e) Swift trust could be applicable for communications at emergency response to let people collaborate with one another.
(f) Situation awareness is important in various situations such as for rescue and emergency management as well as communications to the people in a disaster area.

We need those issues solved in future as well as keep interviewing to get more information on needs at disaster. One could protect information locally by use of USB stick memories as reported in the next section. Use of cloud computing would be ideal. The problem with cloud computing is that without communication links, it does not work. Indeed, communication links were gone at the disaster.

We also need to look into how one can handle false information when the situation is chaotic. We could apply some research results on how one can trust the information [16]. How one can deal with false information has been researched for SNS [17, 18].

4 An Office at Tsunami

Prior to our interview we heard informally what happened in the disaster area from one of the office workers at our university office, who was working for Iwate Fisheries Technical Center, a prefectural government organization, at the Great East Japan Earthquake and Tsunami [19].

Iwate Fisheries Technical Center was located by a bay in Kamaishi City, which is in the disaster area in Iwate Prefecture. The center conducts research and provides information and support for fisheries in Iwate. The center office was severely affected by the Tsunami. The ground floor of the center was flooded with seawater and computers and IT equipment were soaked in the water. As the research center had a system to produce distillated water, hard discs were washed with the water. Some of the disks' data were recovered successfully but others' were not. Among various methods to recover data, a traditional USB stick memory with a cap protected data almost perfectly. In our support project, we had many requests for data recovery from memory and PCs soaked with seawater. We shall need IT support for such hardware as well as distributed information management making use of cloud computing services.

At the Fisheries Center, they had many documents on paper. They were soaked with seawater but saved. After some time, they got too moldy and smelly to be used. The documents would need to be digitalized to be saved. Also, at the disaster area, there was popular voluntary work to wash and save personal photographs which were soaked with seawater. One could develop a way to clean and preserve paper documents for an office.

5 Recovery Watcher

It takes long to recover and reconstruct the towns and cities at disaster area. Meanwhile the interests into such recovery and reconstructions would be faded out outside the disaster area as time goes by. Accordingly we came up with the idea on recovery watcher to keep people being aware of what is happening. On the other hand, we could use the system for situation awareness at the early stage of disaster management cycle such as emergency response and even at the rescue phase.

In the beginning, we use the u-stream service and located a camera at the town hall of Yamada, Iwate, Japan. The system used video so that it took some bandwidth at the town hall. We implemented a still image-base system which did not need so much bandwidth [8]. It recorded images in a calendar so that people can look back on the past. We located the system in other two cities in Iwate as well. The system was operated for several years but due to administration changes, we needed to stop.

This time, once again we implemented the system with the use of smartphones as cameras. Figure 1 shows the model of the system. Smartphone cameras are to be located at multiple places in the disaster area. Images are to be uploaded to the server which provides the image share space through Open Street Map (OSM). Uploaded photos are located in the space so that one can look them up thought the OSM. The information manager may manage the uploaded sites so that if we add a new camera site, the new calendar will be prepared by the manager so that we control the camera sites. The user look up for a particular place over the OSM and look up for the images, current ones as well as archives through the calendar. The smartphones will use either Wi-Fi connections or telecommunication links.

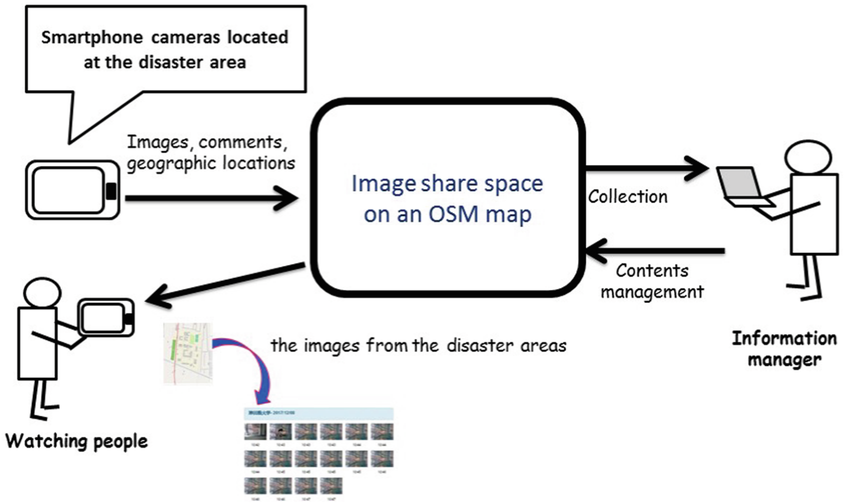

Fig. 1. The model of the new recovery watcher system

We have implemented with the use of android smartphones. In order to examine the operability within our university, we used the system for inclusive support in such a way that barrier free information is provided through this system for the people with disabilities as well as their supporters to find out the situation of the university campus. It is interesting to know that such situation awareness is required for inclusive support as well as for disaster.

Elevant [20] is working on sharing weather information. Presumably natural disaster could be considered a kind of the weather, so that a service for sharing weather information could be used at disaster. Indeed, one of our findings was that at disaster people would not dear to use a new interface of a system; they prefer familiar interfaces. If we provide a service to share weather information for a daily use, we could possibly make use of it for disaster as well.

For a long run, we could use this sort of sharing service to convey the warning information at disaster. One of the big issues at the disaster was that one needed to get out of Tsunami as soon as possible without caring your family members—i.e. we need to help ourselves first. This old wisdom was not passed correctly from generation to generation and brought the tragedy again. The coast area of Iwate was attacked by Tsunami once thirty to fifty years again and again. The question is how one can convey such a warning to remind people daily. One of the solutions could be such a weather sharing site. We need more research on sustainability of information delivery sites.

6 Conclusions

In this paper, we reported our experiences from our support activities just after the Tohoku earthquake and tsunami on March 11th, 2011, and introduced some of our work in this research area. From our experience, the major supporters at the disaster in Japan would be officers in local governments, some in the prefectural emergency response headquarters and volunteers, whereas in the other countries, international organization such as Red Cross would play a major role at disaster management with volunteers. Sahana was used in such an environment. In Japan, due to local language, i.e. Japanese as well as the popularity of python language, Sahana was not used so extensively.

We had better look into this issue in future as we have had so many different disasters since 2011.

We also presented a project to interview relief workers who supported disaster area in 2011 and reported the findings. One of the findings was situation awareness, so that we implemented recovery watcher once again. The system was introduced with a new model which makes use of smartphone cameras and OSM.

We presented trust is an important issue in disaster communications in our previous paper [2]. More work is required in terms of swift trust in future. From a sociological viewpoint, Yamagishi [21, 22] gave Japanese oriented characteristics compared to the concept of trust. In disaster communications we might need to consider such cultural differences.

We need to have further study on disaster communication to proceed as exploration in terms of social science [23]. Moreover, more documentation on what had happened in Japan is required to be published world-wide so that we can work on these important issues in more global manner [3].

Moreover, we are interested in investigating further on the use of social media in Japan. At the Great East Japan Earthquake and Tsunami, Social Networking Services (SNS) were not as popular as they are now. Research has been conducted to see the use in Tokyo area in which more people were using the service [20]. The use of SNS at the disaster was reported that those data could be used in emergency response in future [21]. More work could be reviewed thoroughly in future.

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How ICT Changes the Landscape of Disaster Risk Management

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Abstract. Nowadays, ICT has been broadly applied to all trades and professions, because of instant end-to-end connectivity and at-hand convenience. For sake of better enhancing disaster resilience, scientists, engineers and practitioners are make the most use of information and communication technology to all phases of disaster risk management- reduction, preparedness, response and recovery. Especially at the IOT age, the powerful tools provide both macro- and micro- viewpoints in both physical and social vulnerabilities that could help to make decisions on disaster risk reduction or emergency response. How to massage all informative and multiple inputs to meet demands of different users that requires several elements to succeed: (1) To identify fields to apply ICT for; (2) To design information intelligence for action; (3) To disseminate information through various channels; (4) To build up public-private partnership in information sharing; (5) To carefully utilize social media. During last decade, though team work between emergency responders and scientists, Taiwan has developed a systematic approach to integrate scientific outputs with emergency operation amid times of typhoons. The results do prove well-organized information shared by ICT both increase efficacy of emergency operation and public awareness.

Keywords: Information Communication Technology (ICT) · Disaster risk management · Emergency preparedness

1 ICT Offers Backbones Support to Disaster Risk Management

To fulfill end-to-end information facilitation, several key elements are required to build up a sound environment for decision support. These elements include (1) Data collection and monitoring system to raise situation awareness; (2) Broad-band wireless telecommunications to gather and disseminate information; (3) Protocols and standards to form cross-platform application of information; (4) Spatial demonstration of disaster alerts and emergency to enhance risk understanding through systematic approach; (5) Adoption of artificial intelligence (AI) to analyze structured- and non-structured big data. With the five backbones, to be explained in the follow context, ICT plays an important role at disaster risk management and emergency preparedness [1].

Before, during and after a disaster, a network of sensors to collect and measure environmental changes is offering baselines to estimate possible degrees of impacts.

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For example, to decide threshold values of flood in a river basin, the design of a sensor network usually includes several gauges to measure rainfalls, water levels, soil moisture and operation of pump stations. Since lots of sensors could be installed in remote locations, well-established broad-band wireless telecommunications will help to transmit data for processing. Observations from recent large-scale disaster events, broad-band wireless telecommunication had proven to be the key of successfully-coordinated operations at affected sites. No matter search and rescue, emergency relief allocation, or shelter management needs location-based information, which must be in line telecommunication.

As more ICT devices are able to bring information or alerts to diverse end users, the general public, emergency responders or decision makers, international standardized protocols interoperate computer codes into functional machine commands to trigger actions. Such like the Public Waning System (PWS) for mobile phone, it is based on the Common Alerting Protocol (CAP) to deliver alter messages to and alarm end users. Following rapid development of mobile communication, recent protocol updates to PWS will further upgrade functions and capacity compared with previous version.

An effective message for individual user taking actions amid a developing disaster must contain geo-spatial location, time-dependent description and suggested actions. Usually, it is ideal to present an informative map with all factors mentioned above. Amid emergency operation for typhoon, commanding officials in emergency operation center (EOC) demand for a clear operation picture to make decision. The Fig. 1 is a sample for making decision on road closure. On the slide, it provides rainfall information (both hourly intensity and accumulation) and real-time images captured from closed circuit television cameras (CCTV) on a GIS map. The map offers clear and direct intelligence to ensure the countermeasure [2, 3].

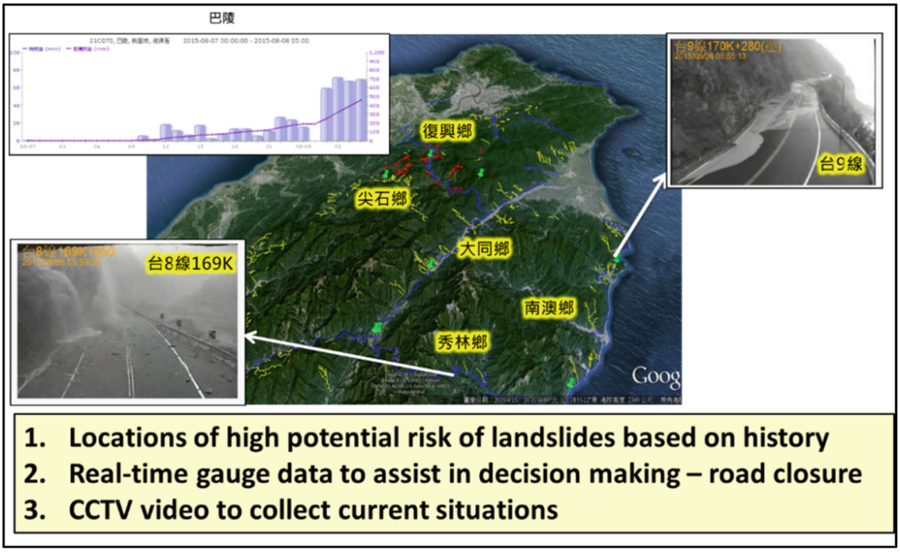

Fig. 1. Integration diverse information sources on a GIS map for decision support.

2 ICT Applications for Disaster Risk Reduction

Direct benefits of ICT to disaster risk reduction are: (1) To connect early warning system with message deliver system for reaching out possibly affected areas and residents; (2) To assist in decision making through offering common operating picture for better inter- and intra- agencies coordination; (3) To create innovative channels for risk communication among all stakeholders; (4) To provide scenario-based impact assessment for emergency preparedness. In the past, prior to broad adoptions of ICT, it was too hard to deliver a comprehensive situation map for planning disaster risk reduction. Especially, when a large-scale disaster or cascading impacts occurred, the difficult and evolving situations could be very challenging to cope with.

Early warning system has been a focal issue since the South-East Asia Earthquake and Tsunami in 2004 [4]. From detecting earthquake, measuring tidal pressure change, relaying signals, to issuing warning, the whole process requires ICT's assistances to complete each procedure. One case in Taiwan, since 2013, a public warning system in operation is designed to send earthquake alter to 4G cellular phones by using Cell Broadcast Service (CBS). The service is a typical end-to-end system for alarming possibly affected areas through linkage between public and private sectors. Figure 2 shows how relevant agencies join the mechanism to disseminate disaster alerts in seconds. In case of an earthquake, it might take 15–20 s to reach end users. The time differences depend on focal depth of hyper-center, user's distance to epicenter, user's location and signal strength of mobile phones.

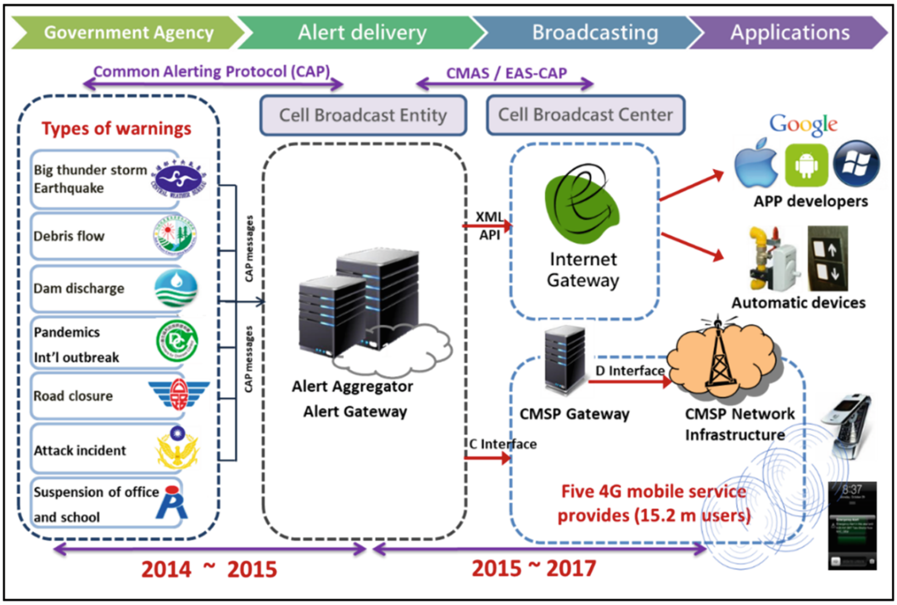

Fig. 2. The joint-effort mechanism to send alters through Cell Broadcast Service

Web-GIS-based system is an ideal platform to present and share information when emergency responders are executing their missions at different spots. However, in case of no common platform existing, the overwhelming result could be too many systems to check at a time, and the situation might cause delays and gaps of information facilitation. In order to narrow down information gaps between central and local government, the National Science and Technology Center for Disaster Reduction (NCDR) has gradually set up a decision support system to integrate all existing data shared by individual agencies on it and offers user-oriented design to display situations. The system receives high appreciation of users for its easily unstainable information and flexibility to accommodate operation demands. The Fig. 3 is a layout of webpage to display geo-spatial information with situation briefing and real-time readings. The design ideas for the system is to keep information clean and neat on one page. At end user side, the system could overlap more GIS layers to tell local circumstances.

Fig. 3. A typical layout of “common operating picture” designed by NCDR

Public-private-partnership highlights engaging the whole society, especially business sector, to leverage resources for covering shortages that government can’t immediately meet the demands. If any large-scale disaster hit, all residents must be eager for searching information on governmental websites to fetch the most updated news or notices. However, it is impossible for any agency to prepare huge Internet bandwidth for surging user at a very short period [3, 5]. An obvious phenomenon always repeated that most of governmental websites were down under too many simultaneous access requests. But Internet giants like Google, Yahoo or Amazon have always-ready and sufficient bandwidth to deal with access demand surges. A pilot project in 2013 brought NCDR and Google for collaboration in sharing disaster alerts and geo-spatial information on Google’s platforms – Google Alert and Google Crisis Map. That is a creative leap in Taiwan to effectively outreach citizens to inform disaster alters through sharing open data with private sector. During implanting the project, NCDR also introduced CAP to relevant governmental agencies, which are the authorized ones to issue disaster alerts. The results from 2014, 2015 to 2016, shows millions of users receiving disaster alters through Google. That is a win-win combination to increase information coverage and fulfill social cooperate responsibility (CSR). Figure 4 shows the numbers of end users receiving disaster alert or information from Google platform during 2014–2016.

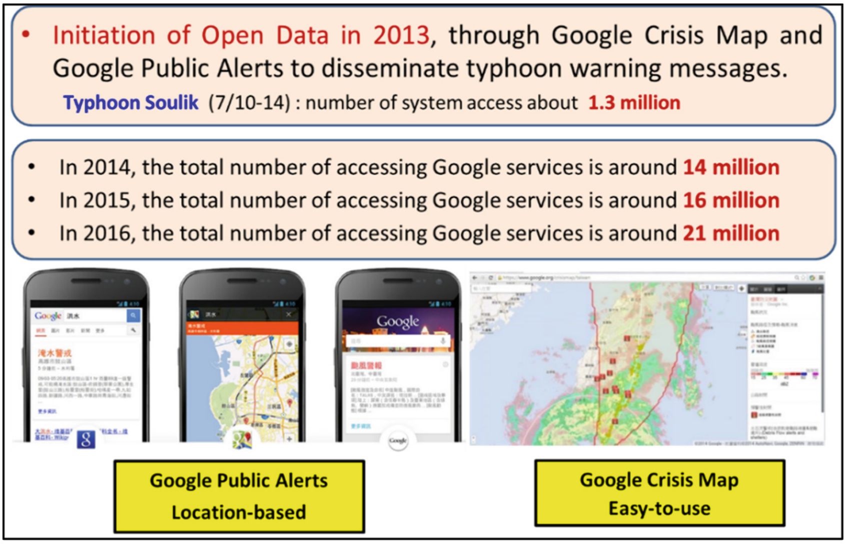

Fig. 4. Public-private-partnership with Google to distribute disaster alerts

3 Practical Improvements on Disaster Risk Reduction

Uncertainties at typhoon forecast do challenge decision making process at EOC, because unexpected casualties and losses might directly impact on commending officials. After years practices of collaboration between scientists and emergency responders in Taiwan, an innovative methodology has been developed and implemented that proves to be very effective for bridging scientific knowledge to emergency responders.

Because of focusing on impact assessment, all scientific outputs are transformed into understandable operation-oriented charts, GIS maps and suggestions on actions. During the transformation process, a learning-by-doing one, scientists and engineers co-work with emergency responders to catch what is the most appreciated information for them to make decisions and deliver operations. In case of typhoon emergency operation, at EOC, officers on duty eagerly want to know possible impacts brought by strong winds or torrential rains with clear information of “when?”, “where?”, “Scale of impact?” and “Scope of impact?” Through the process of impact assessment, scientists help to highlight possibly affected area with time-dependent factors (Fig. 5). These information intelligences support pre-disaster operations like dispatching reinforced troops, conducting early evacuation or allocating equipment. The information designed for emergency responders never shows any equations or mentions about probabilistic equations. By doing in that way, all information is clear and operational based on experiences and knowledge learned by extensive dialogues and opinion exchanges. In that way, a successful model of risk communication formulates a good eco-system, which proves "evidence-based" disaster risk management operable [6].

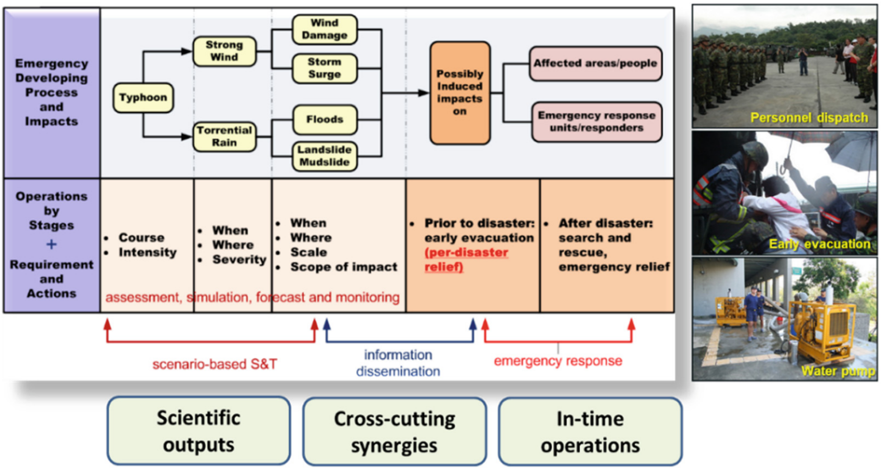

Fig. 5. Practical improvements on disaster risk reduction

4 Conclusions

Through broadly applying ICT for disaster risk management, the direct benefits include improving data collection; offering more dynamic and location-based information display; creating direct channels to reach end users; shortening knowledge gaps between scientists and emergency responder; and enhancing quality of decision making. However, the process is still evolving at fast pace and all stakeholders should keep open-minded to welcome future progress and implement changes through a team work.

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Initial Use of Big Data and Open Data on Disaster Risk Management

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Abstract. As more sensor networks, the Internet of Things (IoT) and smart devices are applied for data collection, including physical parameters or social responses, it is a growing trend that big data is dominating quality of disaster risk reduction, emergency preparedness and emergency operation. How to appropriately use big data depends on quality, transmission, exchange, storage, display and dissemination during the whole process data life cycle. "Data life cycle" means approaches to improve knowledge to use big data. Moreover, to solve issues related to disaster risk management is required to integrate diverse data sets based on the characteristics of individual requests. For example, an execution of early eviction before a typhoon makes landfall, demographic structure, weather forecast, real-time rainfall monitoring, threshold values to trigger flood or landslide and supporting resources are the essential elements for a successful operation. However, lots of digital preparedness need comprehensive coordination and arrangements in advance. In order to further make the most use of data for enhancing public awareness and decision formation, producing open data is also important to reach targeted groups of users through understating key information intelligence to take right reactions. Since embracing policy of open data, it needs enablers to set up a well-regulated environment among original data producers, data aggregator, app or system developers, transmission channel providers and final message receivers. An developing example tells the recent developments on big data and open data for disaster risk management.

Keywords: Big data · Open data · Disaster risk management · Emergency preparedness

1 Big Data and Open Data Fully Support Disaster Risk Management

Looking at digital preparation of big data for all phases of disaster risk management, it definitely demands longitudinal and latitudinal coordination among all stakeholders that usually takes time to build consensus on enabling an environment to maintain a smooth and data flow.

Outputs offered by the scientific community could include numerical simulations and data analysis with historical, statistical and spatial factors. That is one source of big data. The results could help at planning stage to understand potential risks, both physical or social; at emergency responding times to highlight possibly affected areas- disaster

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hot spots; and at period of post-disaster recovery to prevent emerging risks and implement “Build back better.” In recent decades, inter-disciplinary endeavors made by scientific community have gradually explored characteristics of natural hazards and all aspects of vulnerabilities. Through a systemic approach, it assists in unfolding likely impacts to infrastructure, livelihoods, economy and sustainable development. Nevertheless, any scientific model has its limits and assumption. There is no one-size-fit-all solution to cope with challenges resulted from natural hazards, physical environment or social aspects. Because no tow disasters or affected areas could be alike. Ever since taking scientific outputs for disaster risk management, disaster manager should be well aware of probable misleading or errors, which happened at any time.

To enhance performance of scientific results, inputs from monitoring networks offers instant calibrations in numerical models and close-ups at developing situations outside. Depending different measurements on rainfalls, earthquakes, water levels in river basins or reservoirs, soil moisture and other parameters, the over-whelming inputs might hamper decision making due to “too much information to digest” [1]. It happens if there is no well-organized mechanism to allocate resources to massage continuously incoming big data. But through real-time or near-real-time inputs, it does fill gaps that numerical methods fail to achieve. Even now the closed-circuit television (CCTV) is showing its great potential in collecting instant videos by remote control. Dynamic image recognition is another effective approach to detect immediate risks such like floods, landslides, storm surges, and rising water levels that will assist commanding officers in focusing on disaster hotspots. Figure 1 is a systematic diagram to explain how to integrate relevant ingredients to succeed disaster risk management.

Other than supports of science and technology, awareness of decision makers is an additional factor to carry out all necessary actions and reactions, which fulfill evidence-based management. Thus, all information should be neat and easily updatable, and content design meets demands for emergency preparedness and emergency response [2].

2 Operational Model on Big Data and Big Data

At information age today, more big data sets, both structured or non-structured types, have created new dimensions to measure or detect dynamic changes on physical and social risks. Considering ways to collect big data, apparently there are numerical channels to gather necessary information. To avoid overwhelming situations resulted in too much coming-in messages, a certain mechanism should be designed in advance to set up standards of data formats, communication protocols, exchange platform and storage policy [3, 4].

The data-collection process requires a “N to One” policy. “N” means all different data sets which could be applied for disaster risk management. However, the quality big data has great influence on making good decision. Definition of “quality big data” satisfies accurate precision, routine maintenance, easy accessibility and rapid readiness. Among the four factors, rapid readiness is the key when to produce informative outputs that requires lots of pre-set defaults requiring consensus and collaboration among individual big data producers. For example, to accelerate data application, data dissemination through cloud storage architecture, efficient algorithm to encrypt and decrypt data, and secure information exchange platform [5, 6]. Therefore, "One" means a leading agency to coordinate differential requests of all partners and monitor "health" of all data sets. And the "One" has to draw a comprehensive plan on how to "cook" all data to produce information intelligence which helps diverse end users – decision makers, citizens or emergency responders, to take actions. With appropriately assigned "One", the agency play a neutral role to settle down arguments and disagreements among key stakeholders. Furthermore, the process from data produces to designed users is an end-to-end framework for bringing and collecting information. Figure 2 explains the conceptual ideas of "N-to-One and One-to-Many".

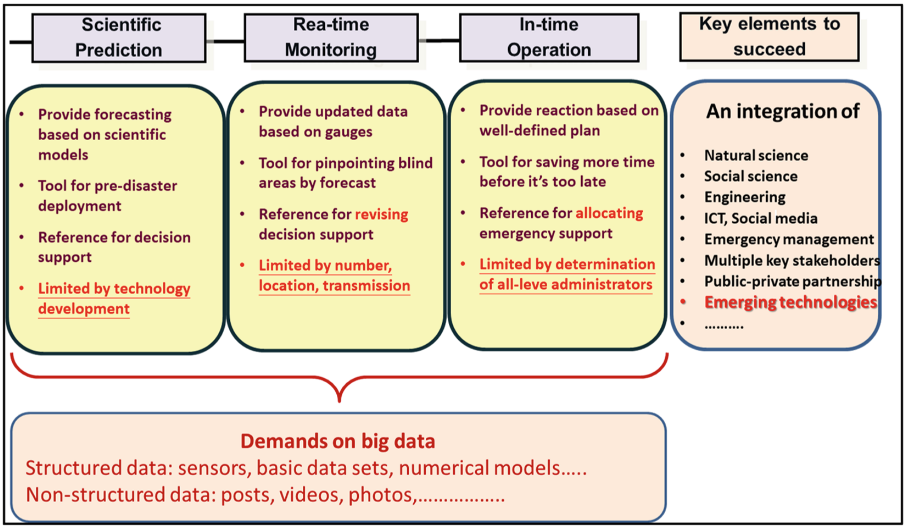

Fig. 1. A systematic diagram to make use of big dada for disaster risk management.

About meeting end users' demands, it is essential to generate tailor-made information for specific user groups. Messages to the general public should be single and actionable; notices to emergency responders must be clear to support taking actions; information to commanding officials has to offer integrated and comprehensive situation for decision on allocating resources, equipment or personnel to mitigate possible impacts. Besides information preparation, wide-coverage and multiple channels are the last mile to reach different pre-defined user groups.

The possible channels for information dissemination are the Internet, Public Warning System, Cell Broadcast Service, TV and other devices are able to display or announce information or disaster warning. In order to enable a robust environment to inform end users, basic standards or protocols are required to formulate rules to follow. This is a process to make big data into open data. For examples through introducing Common Alerting Protocol (CAP), the protocol will make disaster alerts communicable to all devices connected to broadband Internet or WiFi. Since CAP is a communication protocol, actionable commands or instructions could be embedded to activate mechanical equipment.

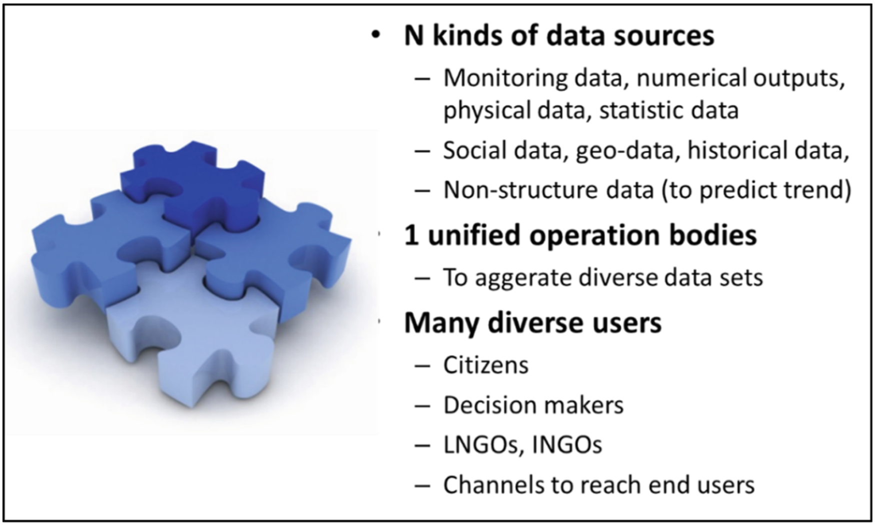

Fig. 2. The conceptual ideas to implement "end-to-end" information for disaster risk management

3 Key Considerations to Use Big Data and Open Data for Disaster Risk Management

Aforementioned discussions have addressed key factors to apply big data and open data for disaster risk management. There are other considerations should be addressed. Figure 3 depicts the key considerations on big data and open data.

For better information intelligence to communicate with end users, "Data presenting" is essential to deliver information in a efficient and effective way. Especially, GIS is broadly applied to disaster risk reduction and emergency operation. A illustrative GIS map with spatial and time factor offers decision supports to commanding officials. Risk communication with citizens also requires simple and understandable graphs to assist in risk perception. Pure text reports are not suitable for rapidly creating risk understanding [7–9].

Data exchange and sharing are always a critical issue to bring cross-cutting interagency collaboration. However, through introducing well-defined protocols that will guide circulation and application in information and also offer inventory list of all data sets ready for use. Internet security is another focal issue. Since some big data sets could be intelligence sensitive and should be well protected, any information leakage or operation interruption by anonymous hackers require higher anti-hacker countermeasures.

To conduct impact-assessment-based preparedness, integration between physical and social vulnerabilities is a trend to explore possible damages and casualties by scenarios or real situations. For decision making process, knowing social impacts is helpful to allocate resources in advance. Why impact assessment is important? Due to limitation of sciences, uncertainties and deviation always exist in all numerical results.

With examining social impacts, it will directly benefit in prioritizing possibly affected areas and risk communication with the general public.

Smart devices not only help bring daily convenience, but also form new channel to collect situations during a disaster event. Pictures, texts or videos are effective ways for citizens to report what is happening. Because most information transmitted by smart devices is marked with GPS tags that provides vast inputs to deliver a better-understood situation map. On the other hand, it needs attention to filter out "noise" from the inputs including duplications, rumors and fake news. Now scientific community is developing methodology to distinguish facts from noise with assistance of artificial intelligence. Before a mature system is delivered to screen out misleading messages, special care is needed to process massive inputs from the Internet.

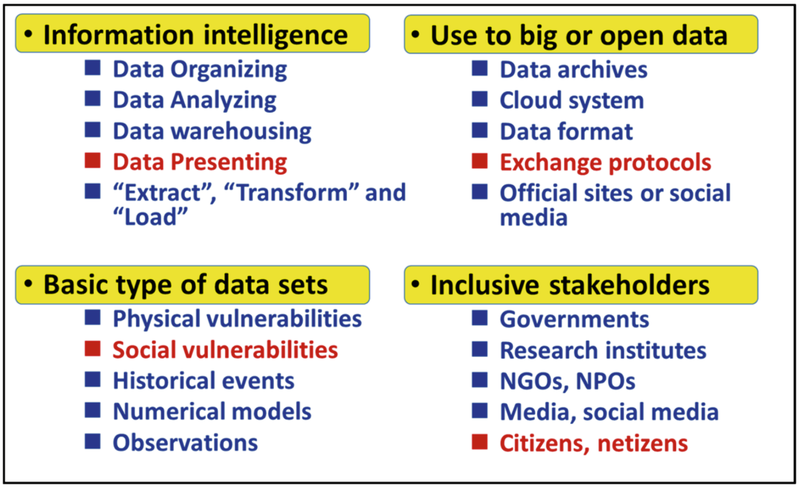

Fig. 3. Focal issues on big data and open data

4 Conclusions

By using big data and open data, it does offer new approaches to understand multi-faceted characteristics of natural disasters. More than traditional measurements on environmental changes, inputs from real-time and social-dynamic data expend the scope of emergency responders, researchers and decision makers to explore disaster impacts. To make better use of two different cetology data, special attention will help to produce useful information. Individual user groups, researchers, decision makers, disaster managers, emergency responders and citizens should build up constant dia-logues to make better preparation through multi-lateral understanding.

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Supporting Decision Making in Disasters: The DiMas Tool

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Abstract. Disasters leave a trail of destruction, casualties and ruined human lives. They can directly cause loss of life and injury, destroy cities, buildings, living and public spaces, and damage vital infrastructures necessary for everyday functions. The aims of this essay are to present the research tool, in its ongoing and yet undefined configuration, and at the same time for involving the many time ICT aspects and challenges of coping with disaster risk reduction and relief, definitely necessary in the operational and disseminating phases beyond the tool itself. Within the paper, along with the exposition of our idea in its actual form – which considers the possibility of further variations – we will present the reasons of the *whys* and reach to descript *how* we do believe the tool should be, passing through the other major issues like the *who* and the *what*. The tool is intended to be structured as the outcome of an applied research project, for creating a decision supporting instrument which will enable a broad range of relevant stakeholders to choose the most suitable sheltering solution, dwelling unit or machinery needed. The DiMaS Tool research project aims to present itself as a possibility for sorting and mapping already existing ready-to-use solutions, by specific parameters and characteristics, creating a taxonomy and a related system and expressing it in a universal and understandable language, through the ICT skills, in order to help choose the most adequate answer, managing the implementation and responsive process quickly and effectively.

Keywords: Design for disasters · Disaster relief resilience and research · Emergency preparedness

1 Introduction

Disasters leave a trail of destruction, casualties and ruined human lives. Their occurrence can directly cause loss of life and injury, accidentally can seriously affect and destroy cities, buildings, living and public spaces, as well damaging vital infrastructures necessary for everyday functions. The UNISDR Ten Essentials guide us, as researchers and experts, interested at the many operative level of Disaster relief and mitigation, in preparing and planning key elements for an effective response during and after a strike of a disaster. The Essentials, in fact, allow for quick, organized response vital for dealing and preventing the devastating consequences of disasters, in order to restore a meaning of 'normality' and even Build Back Better (BBB).

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This nodal concept has been largely treated in the many different areas that deal with disaster effects mitigation [19, 30] and can be accomplished by creating a 'prevention culture', letting preparedness for emergency assume its correct role, considering rehabilitation mechanisms something that is within and can be considered before. If these latter, nevertheless, are pivotal tools for managing potential disasters and their consequences in case of occurrence, it's a fact that good response and qualitative relief depart from the inherent possibility of being ready in advance [21].

If we do agree with the Practical Action that: «Disasters only occur when a natural hazard arises in vulnerable conditions» [25, 1] we still have to consider that in case of the occurrence of a disaster there is a variety of factors to be faced and with which every actor on the field, form the decision makers to the citizen, has to cope with. According to the Gaillard and Mercer, in fact:

«Most national risk reduction policies still rely on command-and-control and top-down frameworks, which emphasize scientific knowledge and national government intervention at the detriment of local actions. Only within the international arena have policy-makers considered ideas from the vulnerability paradigm. This led to the development of international policy documents, such as the Hyogo Framework for Action (HFA). However, such a non-binding treaty with no concrete targets remains too vague to entail concrete outcomes at the national level» [11, 94].

Finally, it is not so simple, in the end and even in the so-called advanced society hazards and consequent disasters create a deep change in the geography of everyday lives and the concept of Building Back Better is nodal to the correct repositioning of a natural life-cycle of complex environment. More than scientific essays in the words of those affected by a disaster, like we experienced on the field in the occurrence of the earthquake in central Italy in October 2016, there is the need for a new beginning, the possibility of feeling the Governmental support passes and somehow can be measured by the qualitative perception of the aiding activities in time.

On the other hand, when considering the aiders on the field we experienced the same feelings of discomfort in regard of the lack of information and coordination and the need of a supporting tool, to get and share information with effectiveness.

In fact, as expressed by Zlatanova, Crompvoets and Scholten:

«To fight the incident, safe lives and restrict the damaging consequences of the disaster, first responders of emergency forces go into action, i.e. the fire brigades, the police forces, paramedics and the government. These emergency forces have their own tasks, but they need to cooperate for effective disaster fighting» [36, 1–2].

As well, on another side, it's here proper to refer to the words of Kapucu and Garayev saying:

«Because if the uncontrollable and consequential nature of disasters affecting masses of people and requiring involvement of various sectors, organizations, and stakeholders, collaboration plays an important role to achieve ultimately successful results. It is equally inevitable for different entities to collaborate in order to increase response effectiveness and reduce casualties» [16, 368].

The whys of this paper, therefore, and of the on-going research work behind, are for supplying the demand for tailored and proper response, alongside the realization that there are already several existing ready-to-use solutions. This suggests the need for a system to better optimize adequate response, within the range of existing solutions, to cope in different disaster areas and with dissimilar disaster types. Within a wide range and a great variety of possibilities, supplying ineffective, unsuitable inhabiting solutions and connected services units, underestimating the cultural needs can delay, harm and deeply affect for the deterioration the rehabilitation process (Fig. 1).

Fig. 1. Arquata del Tronto, Italy, October 2016; tents provided to volunteers operating in the earthquake's area of central Italy, by Civil Protection. Containers are used as storage and as sanitary services.

2 Methodology

In the occurrence of a disaster, government agencies, local authorities, international aid organizations and non-profit organizations do their best to supply quick and effective responses to the dwelling problem that immediately arises. Diverse ideas, solutions and resources are often directed to disaster areas, in an attempt to meet the needs of the community and address the crisis as fast as possible, and this is especially true more in the cases of occurring of a disaster in developing countries and less industrialised, than in 'richer' societies, it could be argued.

This paper wishes to present an innovative research tool, in its on-going and undefined yet configuration, based on design thinking experience and knowledge and dealing with the consistent conviction of the contribution that the design discipline may add to the issue; for sure, it has to be provided of a multi-disciplinary sight, by conveying in it necessarily research works, as well as concepts and inspirations from the variety of disciplines interested in facing the disaster response and relief and time.

For this reason the literature review has been extensive and vast, departing from keywords, i.e. disaster managing, design and disaster, the results convey together from Psychology to ICT aspects, of course.

We strongly believe that, as said by Gaillard and Mercer, about the multilayer operational support on the field and that:

«We hereby suggest that DRR should be inclusive rather than exclusive. Here 'inclusive' means (1) recognizing that different forms of knowledge are valuable in addressing disaster risk, (2) that actions at different scales, from the top down and from the bottom up, are necessary to reduce the risk of disaster in a sustainable manner, and (3) that both previous points require a large array of stakeholders operating across different scales to collaborate» [11, 95].

Indeed, we do believe - after the literature examination - the compulsory prerequisite to set under the umbrella of design thinking either for a multidisciplinary approach either for involving as a basis the many time ICT aspects; otherwise the challenges of coping with disaster risk reduction and relief, couldn't be definitely satisfied, as for necessary in the operational and disseminating phases beyond the tool itself. Many researches and studies have shown that adequate and tailored dwelling and responsive solutions (whether for the short or long term) can have a great impact on the rehabilitation process of individuals as well as the community as a whole.

The tool we have in mind will respond to a precise idea of sharable and understandable data source: even if the architecture behind will be, of course, necessarily, articulated and layered, the tool itself will appear easy to be used and consulted at its best. We do think it shall be structured as the outcome of an applied research project, for creating a decision supporting tool which will enable a broad range of relevant stakeholders to choose the most suitable sheltering solution, dwelling unit or machinery needed. Thus, as for its multidisciplinary aspects, already highlighted and also reinforced by the literature examination, in which evidently different sources converge on one single articulated issue, the tool requires to be composed with the contribution of geographers, anthropologists, engineers, economists, psychologists, architects, urban-planners, designers, organization consultants, disaster managers and, last but not least, the communities interested by the disaster, as for the importance of their know-how as end-users.

If we want to consider the problem in its real application, for instance this has been an enormous problem in the occurrence of the earthquake in the regions of central Italy, in 2016, as the dwelling units were not ready to be conveyed on the site, the necessary operational systems, perfectly working in the immediate emergency tended to lack with the advancement of months and for responding to the Winter season and in addition. after a short while, the dwelling units, here solved as small wooden houses revealed not to be completely proper to the requirements of the territory.

All of the who on the field and before should find in the common sharable chose language an answer and the needed information to better address and 'read' the territory, the emergencies on the field and the disaster to be faced.

Nonetheless, it is here proper to report that many researches have been in the past ten-fifteen years conducted over the possibility of supporting tools, and even experienced and tested on the field but as reported by Ochoa, Neyem, Pino and Borges many of these systems have failed when in action [23] because they do lack in communicational effectiveness and operability or they do not consider the many different possibility of the users. The authors, in fact, highlight that:

«The problems related to decision delivery and implementation are based on the lack of an inter-organizational structure able to establish responsibilities and decision making levels» [23, 149].

In addition, it might be said with the words of Gaillard and Mercer that:

«For example, solutions offered by a DRR effort based on solid scientific parameters may fail for not fitting within local wisdoms, whereas solutions based on contextual specific local knowledge may fail in light of the increased pace of change experienced today. Hence there is an obvious need to combine the most effective and applicable local and scientific knowledge. A technical know-how adapted to local wise practices could greatly enhance DRR strategies» [11, 96].

In fact, whilst we observe a wide range and a great variety of solutions, especially of dwelling solutions for the longer terms and the so-called 'second emergency', we have to take into account that everyone of them actually responds with its own features, meeting only determinate requirements.

These requirements, often, consider or are the basis for choosing and designing the operative solution and may go from the compatibility to different climate zones, or topographic and geographic structures of the territories, the direct costs of the dwelling unit and the additional ones for putting in service; as well, the requirements are related to the size, materials, the complexity either architectural and internal either for assembling/deploying it and, last but not least, the time, efforts and expertise which are needed for the implementation in situ.

Probably it is wrong to say that any possible solution has been designed and produced, and every time that a new dwelling unit demonstrate its effectiveness, here it comes again the question if there is or there could ever be the 'one' and the 'best' unique solution. Actually, in our previous studies, we have already demonstrated that the nature of the disaster but also the climate zone in which this occurs, as well as the territorial structure along with the community one determinate different needs [8].

Supplying ineffective, unsuitable inhabiting solutions and connected services units, underestimating the cultural needs can delay, harm and deeply affect the rehabilitation process. The demand for tailored and appropriate response, alongside the realization that there are already several existing ready-to-use solutions, suggests the need for a system to better optimize suitable reaction, within the range of existing solutions, to cope in different disaster areas and with dissimilar disaster types.

Within the development of the DiMas tool, therefore while there would be no need to define the disasters as we will refer to the ones already identified by the UNSDR, there will be the necessary definition of other parameters that will care about the issues cited above.

It is envisioned, hence, that a decision-support tool will enable the relevant stakeholders, to identify through determined classes of types and ranges the most relevant solution, for the certain needs ensuring effective disaster response to the specific situation.

In the structuring operational activities of this tool, that we called the DiMas tool, the ICT technology plays a crucial and fundamental role. ICT technology is, in fact, the path to manage and gather together information before, as for inserting all the needed data in the tool to make it work, and at the same time IT structuring skills are fundamental for making the DiMas tool working as a dissemination instrument and as an operational support.

Actually the closest research work, that is here worth to cite, made by Ochoa, Neyem, Pino and Borges describes:

«… a proposal to include first responders as decision makers and it describes a technological platform to record, represent and distribute contextual information during disaster relief efforts. The platform intends to improve the decision-making and coordination processes among first responders and the command post. The platform is composed of a software, hardware and communication system. It runs on mobile computing devices and it allows two information representations. Visual representations support the decision-making during disaster relief efforts, and the digital (internal) representation ensures the information's interoperability. The communication support enhances the communication and coordination capabilities of participant organizations. The platform also includes the support for information delivery in heterogeneous technological scenarios» [23, 146].

Even if the work appears very close to our own one, we argue to say it lacks the design point of view, in the meaning of a consistent perspective about the users of dwelling units and their effective adequateness to the scenario.

We imagine the tool able to provide relevant information, almost immediately, such as availability, response time, costs and, at the same time, taking into consideration even different parameters such as cultural compatibility, adaptability, transportation requirements in terms of time and, not less important possibility to be delivered in short time.

In fact, in average distinctions made in particular for dwelling unit, two are the ways of intending and looking at the solutions [8, 37]: one of them categorises the units according to their structural consistency and so identifies hard casing and flexible casing; the other one, presented by Zanelli [37] examines the dwelling units according to their inner possibility of moving, distinguishing transportable, semi-transportable and self-moving.

In addition to this preliminary research work, even in the case based on the studies and the research works we had the chance to conduct in the years before, the aim is to highlight the importance of a supporting tool, properly built through the collection and systematization using the IT involvement for reaching an adequate preparedness, in order to better cope with disasters in the case of occurrence.

The DiMas tool, as for its multi-disciplinary aspects, recalls indeed different sources in one unique issue: for this reason the tool requires to be structured with the contribution of many disciplines as even explained before and has to be understandable and sharable for all of them, safeguarding each disciplines' features, but compulsory communicating in a common language for a single meaning.

Thus, one of the issue we think can be nodal: too often, unfortunately we face an enormous quantity of data which analysis needs and can take an amount of time, unfortunately not available in time of emergency. So we do strongly believe, that what will not work during routine times, will not work during an emergency. Again, so, it is clear how important is the preparation in advance of an adequate managing of the tool, in order to first of all highlight the lacks within, being able to implement and correct the results in 'routine' time and as well in order to conduct appropriate training that may allow an easier usage on the field in a condition of stress and pressing.

In fact, if it is true what Ochoa, Neyem, Pino, and Borges say, placing the issue at the basis of their paper and research, is even one of our major concern that:

«For that reason, the availability and understandability of the contextual information that supports the decision process should be high. Compiled information with a graphical representation (e.g. teams' location, task assignments and resource allocation presented on a map) can be used to be easy to understand by persons making decisions in different organizations» [23, 149].

For these reasons, we talk about collaborative images and pictograms, to be used as a simple structuring language that may be accompanied by lettering, which we all know not always will be understood. Writing, hence, will be a problem, if we consider the lack of time in emergency and, more than this that not everyone of us share the same language and even alphabet.

Images are everywhere, in nowadays life, and their power is strengthened and demonstrated by the massive use. Images, anyway, after their codification in understandable pictograms, whose significance today anyone (apparently) knows are widely used as a language, sharable and - maybe - not a matter of misunderstanding. Anyhow, the many different targets and users whom enter in contact with collaborative images on the field, within the emergency reasons of a disaster, require from the design point of view a further research discourse and development observation, in particular to avoid cultural misunderstanding that again can harm all the process (Fig. 2).

Fig. 2. Katmandu, Nepal, May 2015; blue tents provided by the P. R. of China on the back, with uncertain collective coverture as a social area. (Color figure online)

3 Conclusions (and Expected Results)

One of the biggest and longest lasting problems in disaster areas is homelessness, as a result of the disaster itself. Being forced to leave one's own house, becoming homeless can have devastating results: it is more than mere property loss. It is related to experiencing the loss of personal and financial security. The stress caused by the situation and uncertainty of the future can endanger personal behaviour in everyday life, the strength of the family structure and the fabric of the affected and neighbours communities.

As in the thought of Ochoa, Neyem, Pino and Borges: «When extreme events affect urban areas the response process should be fast and effective because the population and civil infrastructure densities potentially increase the impact of such events. These situations have shown the need to improve the group decision making process and the coordination of relief activities carried out by relief organizations» [23, 143].

At the same time, it's worth to remember what Kapucu and Garayev highlight in their research work:

«Decision-making in emergencies requires non-traditional approach and tools characterized by non-hierarchical structure and flexibility. The dynamic environment of disasters makes it imperative to invest in inter-sector and inter-agency cooperation and coordination» [16, 366].

Indeed, the DiMas Tool is thought and expected for being structured as the outcome of an applied research project, for creating a decision supporting tool which will enable a broad range of relevant stakeholders to choose the most suitable sheltering solution, dwelling unit or machinery needed.

The project, in our idea of structuring it, will sort and map existing ready-to-use solutions, by specific parameters and characteristics, creating a taxonomy and a related system and expressing it in a universal and understandable language, in order to help for choosing the most adequate answer, for managing the implementation and responsive process quickly and effectively.

And additional effect, in undertaking this aim, is that the project will be able to identify possible deficiencies in already existing responses, thus becoming an inspiration for designers, engineers city managers and citizens.

As for the how of our designing development of the DiMaS Tool research project we are not leaving behind our experience on the field, well expressed by Gaillard and Mercer:

«Top-down policies have largely failed to prevent the occurrence of disasters, thus prompting practitioners supported by some social scientists to suggest an alternative, bottom-up framework for reducing disaster risk» [11, 97].

About the representation and the language to be used we are still undertaking these serious efforts, because as for the design discipline perspective we do ask ourselves if in the era of emoji and visual narrative, is there still place for conceptualized iconographic representation and iconological additive process, so long beloved?

According to our previous experience, we do expect that using pictograms and an additive system for structuring a DRM tool, could go along with the compulsory and needed help of personal reading and interpretation in understanding the path of reality, and for these further researchers on the field with the actors-aiders will be a demand.

As long so, if we can consider images capable to form the knowledge, the know-how and the knowing and able to become a sharable and understandable language, as well in this process we are automatically encompassing a personal and individual knowledge procedure that mind operates to transform an iconographic language in readable and operational concepts together with the required creative work, beyond personal and common archetypes, to picture again physical solutions and their adherence to the issue. This is what we do link with the concept of preparedness and being trained already in the case of the occurrence of a disaster.

According that the images as visual artefacts, are 'designed objects', in the design process the final user has to be taken into account, in our opinion, to accomplish his/her background, necessary in sustaining the creativity to fill the gaps which might undermine and override all the efforts to communicate concepts and bring them from reality to abstraction and back.

We found ourselves agreeing with Kapucu and Garayev, saying that:

«The increase of frequency and scope of natural and human-made disasters during last decades made it clear that traditional emergency, crisis, and disaster management tools have proved to be ineffective» [16, 366].

Again, in their work, as already said very close as for its basis – but anyhow dissimilar for its development and results – to our own one we found exemplary that:

«When decisions are to be made by a certain agency or coordinating body, it is crucial to have a comprehensive mechanism that would facilitate and enhance decision-making process through various administrative, structural, and behavioral changes and adjustments» [16, 368].

These papers aims to highlight the importance of fostering our research methods and developing it with the needed interdisciplinary skills and multidisciplinary accents to obtain as a result a very complex outcome, easily understandable, and more easily sharable and applicable on the field in the case of the occurrence of a disaster (Fig. 3).

Fig. 3. Arquata del Tronto, Italy, October 2016; tents and machineries in the camp belonging to Italian Fireman, illustrating variety of structures and provisions.

Authors Contributions. The research here presented and the concept behind this work is directly and equally divided between the two authors, and part of an on-going research featured with international partners.

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Weather Data Handlings for Tornado Recognition Using mHGN

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Abstract. The usage of the mHGN as a pattern recognizer cannot necessarily be used to recognize tornados. Two important issues that need to be solved first are related to data handlings of not-accurately recorded data, and to those of complex weather data. The not-so-appropriate data handlings will produce high false positive and true negative rate of the recognition results. Yet, the latest development of those data handlings has been carried out, and has shown positive and promising results. Such a new approach of data handlings can, therefore, be used to improve the quality and the accuracy of forecasting a tornado. The results taken from a simulated circumstances of a multidimensional pattern recognition have shown, that the tornado can be recognized around 9 h earlier with 90% of accuracy. However, several improvements related to the data representation within the mHGN architecture need to be implemented. The deployment of mHGN in several risky areas of tornados can then be expected as an alternative way of reducing damages, losses, and costs.

Keywords: Graph neuron · Hierarchical graph neuron · Multidimensional hierarchical graph neuron · Natural disaster forecast · Tornado forecast

1 Introduction

The latest storms that hit several countries across the gulf part of American continent have given a clear evidence that natural disasters are real, and they will occur regularly. Although the upcoming of a storm can be monitored and people are usually notified many hours before it arrives, damages, injures, and casualties are usually still involved. The reason to this is maybe because not only the upcoming is important, but also the lack of preparation of people contributes to those damages and casualties. The clear evidence to this is the two tsunamis: in Indonesia in 2004, and in Japan in 2011. The situation is worse when the disaster is a tornado, because it occurs without an adequate notification (siren, alarm, or radio announcement). In the US [1, 2] the number of occurrences of a tornado is the highest compared to those in other countries.

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The reason why the occurrence of natural disasters cannot be forecasted is due to its randomness. Furthermore, many people are not aware of the precondition of its occurrence, and they are not prepared to face that. Such a randomness is not the case of a tornado. In the US, tornados are not random. Most of tornados occurred between April and June. The area of occurrences is in the southeast area of the US. Nevertheless, every single tornado appears very suddenly. Prior to its appearance there is no sign that can be recognized beforehand, for instance at least 10 h earlier, so that people have adequate time to get away of it. As the result, damages, losses, and costs totally cannot be predicted.

Researchers have worked on handling natural disasters. The general term that they have developed is called disaster management. The management deals with prior, while, and post disaster. The most difficult part dealing with natural disaster, such as a tornado, is to forecast it. It is true that some kind of early warning system has been built in many countries. In the US, a siren is started when the system detects an upcoming of a tornado. However, the time distance between the siren and the occurrence of tornado is very short. It is usually less than 30 min. Such period of time is inadequate for people to protect themselves from the fierce of tornado's force. For centuries researchers have worked on discovering ways to forecast the upcoming of a natural disaster. Some of them are still at the stage of now-casting [3–7], not yet forecasting. Some believe that the most difficult part of forecasting natural disasters is producing the mathematical formulas of it [8].

So, it is a strong indication that other methods than mathematical formulas to forecast a tornado are required. A number of researchers [8] have developed an artificial intelligent technology to forecast an upcoming tornado. Although there is no definite mathematical functions that can be used to determine the condition of a tornado, wind-speed, wind-direction, air-temperature, and air-pressure that constitute a tornado, are all caused by physical states [9]. It means that the time-series of several physical values of wind-speed, wind-direction, air-temperature, and air-pressure determine particular tornado condition. It can then be figured out that the upcoming of a tornado is generally produced by particular physical patterns.

The physical patterns that have been used in mHGN [8] were not yet ready for forecasting tornados, although mHGN is able to recognize incomplete alphabetical patterns [9]. There are two major issues why mHGN is not ready to forecast tornados. First, the physical values of weather data need to be represented using sophisticated scheme so, that false positive and true negative rates can be reduced significantly. Second, the occurrence of a tornado not at the location where the measuring sensors of weather for wind-speed, wind-direction, air-temperature, and air-pressure are located. Therefore, a sophisticated approached is required so that the patterns from previous occurrences of tornados can be used as the training pattern for future purposes.

In this paper, those two issues are elaborated in order to improve the accuracy of mHGN in forecasting tornados.

2 Tornado Recognition

Natural disasters have become common issues in the world. United Nation's UNISDR has been the primary organization that works tightly with disasters around the world. Since natural disasters have occurred in many countries, people across the world are hand in hand helping each other in facing natural disasters. This situation has helped researchers in gaining data from sensors scattered in the world. Researchers have started since long time ago investigating new approaches in forecasting natural disasters. As many parameters and conditions need to be considered, many issues related to forecasting natural disasters need to be investigated further.

The possibility of the occurrence of a natural disaster varies, but it is still there in most parts of the world. For instance, the tsunami that hit Indonesia in 2004 had never been experienced by Indonesians for hundreds of years. This situation applies for other natural disasters. Some countries have experienced natural disasters more than others [8]. This situation has been the main reason why a country such as the US has spent a lot of efforts to deal with natural disasters. When the circumstances of a tornado to come up in an area have reached, it is very likely that the area will suffer from a tornado. Most tornados occurred in the US have caused damages, losses, and costs. However, this does not mean that only the US must concern with the occurrence of tornados.

The randomness of the occurrence of a natural disaster is not only in terms of the location, but also in terms of the time and the severity. However, the location and the time (season) of tornados to occur is generally the same. Previous tornados occur between April and June, and the most countries that have been hit are those in the southeast area of the US. Although many researchers in opinion that the severity and the average magnitude of natural disasters have increased since the last decade. However, it is still not clear how severe future natural disasters might be. The impossibility of measuring, or predicting the severity of natural disasters, has been the major cause of the difficulties in anticipating their occurrences. Many other researchers have suggested that, one way to deal with the randomness of the occurrence of natural disasters is through a disaster forecaster.

Early warning system [2] and now-casting [1, 3, 5, 6, 10, 11] that have been investigated and developed are not yet able to help people avoiding and mitigating natural disaster. If the time frame of detecting a tornado is short, people will not be able to save themselves away from the tornado. For instance, the forecasting approach that they [4, 7, 12] have attempted is able to forecast the disaster, but only within one hour time frame. Despite those efforts of researchers, Sorensen [2] argues that in terms of prediction and forecasting, still no radical breakthroughs have occurred in the past twenty years. Due to its complexities, most natural disaster researchers are working on technologies that are not focusing on the forecasting techniques. Rather, they are concerned with how natural disaster alerts can be disseminated to the public [2]. They suggest that most difficult part in facing a natural disaster is about how to handle people when a natural disaster occurs. Additionally, most common recommendation for an early warning system is "how to evacuate." In relation with natural disaster alerts, it is also important that special attention must be taken for those who have disabilities.

It seems to be that researchers have tried to find an appropriate approach for working on three areas: natural disaster forecaster, now-casters, or early warning systems. However, they [2, 10, 13] also still integrate their system with disaster management systems. Even Doong et al. [13] suggest that the success of a disaster mitigation concept lies in the quality of the disaster management. This shows that their approach alone is not yet adequate to handle natural disasters nor tornados. The potential reason to this case is the fact that a system for handling tornados requires very complicated mathematical analysis. Many parameters and values need to be considered and included in their calculation [1, 4, 5], and it is time consuming [11], but the system must run fast [1], that it can be used to warn people as early as possible.

As already mentioned, although the randomness of the occurrences of a natural disaster has caused difficulties in handling it, the development of every natural disaster still follows natural science characteristics and rules. Each part of a natural disaster of tornado owns specific location, time, patterns and characters. A tornado develops its twist due to hot and cold winds that move from the opposite directions. Not only the opposite winds play a role in developing a tornado, specific air pressure and air temperature are also significant contributors for a tornado's development. Yet, the difficulty to gain the measured values of those characteristics has become a new challenge in recognizing tornados before it turns up.

The steps that a tornado builds before its strong and winding wind can be regarded as a pattern. It means that the recorded data from previous tornado disasters plays a big role in recognizing it. Therefore, the data must be kept properly. The data is the important source of clues for researchers to analyze the pattern of a tornado. When patterns of tornados can be memorized, it is a strong possibility that when one of the patterns turns up, a system that can recognize patterns can be used to recognize a tornado early before it becomes a strong and destructive one. Such patterns are the most important part of mHGN for forecasting tornados hours before they strike. Unfortunately, the data provided by weather stations such as data of NOAA is not so accurate. The location of weather sensors is not exactly where the previous tornados occur. Before discussing the approach through the deployment of mHGN, it is still important to review the fundamental concept of mHGN.

3 Multidimensional Hierarchical Graph Neuron (mHGN)

The purpose of describing mHGN [9] in this paper again, is to provide an easy way for readers to review its concept and its principle.

The need for solving multidimensional problems has been discussed since a long time ago. People are aware of that to handle complex problems, values taken from numerous dimensions must be considered and calculated. Otherwise, the result that comes up after the calculation—analyzing just a few parameters—cannot be considered correct. In most cases, such a condition will produce very high false positive and true negative error rates. Another issue related to solving multidimensional problems is the method that will be implemented. In a complex system, not only the number of dimensions is large, but how all the dimensions are interrelated to each other, or independent on one another, is often not clear.

Natural disaster system is a suitable example as a multidimensional system. Therefore, forecasting natural disasters can also considered as solving a multidimensional problem. Not only the longitude and the latitude determine the condition of natural disasters, air-temperature, air-pressure, air-humidity, wind-direction, and wind-speed also play a big role in causing natural disasters of tornados. A problem that still exists is the interdependency amongst those tangible and intangible values (industrial development, people movement, etc.). It is so difficult to figure out a formula that constitutes such interdependency. This is, therefore, a strong indication that such multidimensional problems may be solved using artificial intelligent approaches such as mHGN.

3.1 Experiment Results

For the experiment, each neuron (GN) is operated by a thread. Various 2D-, 3D-, 4D- and 5D-pattern recognition have been scrutinized. The compositions used in the experiment are: 15 × 15 mHGN, 5 × 15 × 15 mHGN, 5 × 5 × 15 × 15 mHGN, and 5 × 5 × 5 × 15 × 15 mHGN respectively. For instance, in the 15 × 15 pattern recognition the composition requires: 225 + 195 + 165 + 135 + 105 + 75 + 45 + 15 + 13 + 11 + 9 + 7 + 5 + 3 + 1 = 1009 neurons per value of data. As for creating patterns, binary data is used, then two values (i.e. 0 and 1) of data are required. Therefore, 2018 neurons are deployed in the 15X15 mHGN composition. So, 2018 threads have been run in parallel during this 2D pattern recognition. By using threads, the activity of neurons is simulated so that the functionalities are close to the real neuron functionalities.

The experiment has worked on all the patterns of 26 alphabetical figures. Following the composition of the neurons, the alphabet patterns consist of 15 × 15 pixels. For the training purpose, the mHGN is first fed one-cycle with all the 26 non-distorted patterns. The order of the patterns during the training phase has been determined randomly. Then, to acquire the recognition results the mHGN is fed with a lot of randomly distorted patterns of alphabets. The recognizing accuracy is taken by calculating the average value of the results.

For the sake of the experiment, 20 distorted patterns for each alphabetical figure have been prepared. After acquiring the results, the experiment is repeated 10 times with the same steps, but each time the mHGN is trained with 26 patterns of alphabetical figures with randomly different order. So, for each alphabetical figure for particular percentage of distortion, in total 200 distorted patterns have been prepared as testing patterns.

There are 7 levels of distortion that have been tested, they are: 1.3%, 2.7%, 4.4%, 6.7%, 8.0%, 8.9%, and 10.7%. These levels have been so chosen based on the number of distorted pixels. The sizes of pixels represent the factor and the non-factor of the dimension of the patterns. By doing so, we can observe all the possibilities of distortion. So, in total there are 5200 (26 × 20 × 10) randomly distorted testing patterns. The following Fig. 1 shows 5 samples of different orders of the training patterns:

1	E	N	W	L	I	S	P	G	H	J	D	Y	A	X	Q	R	C	M	F	V	O	T	U	K	Z	B
2	R	P	J	S	O	Q	D	V	C	K	L	E	F	G	X	Y	A	T	Z	B	U	W	T	H	M	N
3	G	B	H	R	Z	C	I	Y	X	S	J	K	D	A	N	T	Q	V	E	W	F	U	P	O	L	M
4	L	N	I	F	R	X	B	K	O	C	T	Z	A	Y	G	V	U	H	P	J	Q	S	W	E	D	M
5	C	E	T	U	N	R	H	Y	G	D	B	K	F	M	I	X	V	S	Q	J	Z	W	O	A	L	P

Fig. 1. Five different randomly ordered alphabets.

The following shows some results taken from testing 4.4% randomly distorted patterns, and the mHGN was previously stored with alphabetical figure patterns, and the order was IEFXMQYJHPDKTORZCUALBGVWNS. The value on the right side of each alphabet show the portion (percentage) of the pattern that is recognizable as the corresponding alphabet (Fig. 2).

PATTERNS RANDOMLY DISTORTED 4.4 %

Patterns Stored		Distorted Pattern	Recognised patterns and their recognized portion (%) from 20 different randomly distorted patterns																																						Recognised Correctly
			1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		20		
	I	A	A	9	A	8	A	8	A	54	A	13	A	3	A	8	A	13	A	16	A	6	A	15	A	14	A	15	A	14	A	14	A	2	A	1	A	54	A	17	A	15	20
	E	B	B	3	B	4	B	36	B	37	B	11	B	36	B	11	B	11	B	37	B	10	B	5	B	36	B	13	B	10	B	12	B	11	B	6	B	9	B	11	B	36	20
	F	C	C	40	C	7	C	38	C	15	C	8	C	39	C	8	C	7	C	7	C	8	C	15	C	7	C	0	C	14	C	15	C	40	C	14	C	1	C	14	C	39	20
	X	D	D	26	D	10	D	4	D	27	D	9	D	10	D	10	D	2	D	26	D	12	D	25	D	11	D	5	D	12	D	6	D	9	D	9	D	10	D	11	D	10	20
	M	E	E	10	E	6	E	30	E	29	E	12	E	11	E	11	E	10	E	10	E	29	E	11	E	10	E	10	E	11	E	12	E	29	E	31	E	6	E	10	E	9	20
	Q	F	F	20	F	4	F	19	F	3	F	20	F	9	F	7	F	8	F	4	F	1	F	7	F	21	H	19	F	22	F	8	F	9	F	21	F	8	F	4	F	8	19
	Y	G	G	51	G	14	G	51	G	13	G	15	G	51	G	14	G	50	G	7	G	51	G	14	G	15	G	6	G	15	G	15	G	7	G	3	G	14	G	6	G	7	20
	J	H	H	8	H	14	H	54	H	14	H	15	H	56	H	15	H	14	H	7	H	54	H	13	H	3	H	16	H	55	H	14	H	54	H	9	H	15	H	55	H	54	20
	H	I	I	54	I	6	I	1	I	53	I	6	I	14	I	14	I	55	I	15	I	15	I	54	I	14	I	14	I	15	I	54	I	6	I	15	I	14	I	16	I	5	20
	P	J	J	54	J	5	J	5	J	14	J	15	J	13	J	54	J	14	J	55	J	6	J	55	J	15	J	15	J	6	J	54	J	55	J	14	J	13	J	14	J	3	20
	D	K	K	4	K	7	K	8	K	8	K	6	K	6	K	8	K	5	K	8	H	22	K	9	K	6	K	7	K	6	K	4	K	2	H	22	K	9	K	7	K	5	18
	K	L	L	9	L	11	L	5	L	38	L	11	L	11	L	11	L	39	L	6	L	40	L	12	L	39	L	10	L	6	L	5	L	10	L	7	L	10	L	12	L	38	20
Order Type 0	T	M	M	22	M	19	M	21	M	4	M	21	M	22	M	8	M	4	M	8	M	6	M	7	M	6	M	5	M	7	M	5	M	4	M	7	M	7	M	6	M	7	20
	O	N	N	19	N	4	N	3	N	7	H	19	N	8	N	8	N	4	N	7	N	6	N	7	N	8	H	18	N	8	N	6	N	7	N	8	N	5	N	7	N	5	18
	R	O	O	54	O	16	O	15	O	14	O	14	O	7	O	56	O	14	O	54	O	8	O	3	O	16	O	14	O	16	O	55	O	54	O	6	O	15	O	7	O	54	20
	Z	P	P	10	P	32	P	10	P	9	P	9	P	10	P	5	P	6	P	5	P	33	P	10	P	0	P	8	P	10	P	10	P	32	P	5	P	9	P	11	P	11	20
	C	Q	Q	44	Q	15	Q	4	Q	15	Q	45	Q	15	Q	16	Q	13	Q	14	Q	13	Q	6	Q	14	Q	15	Q	15	Q	15	Q	45	Q	6	Q	44	Q	14	Q	45	20
	U	R	R	11	R	12	R	12	R	5	R	12	R	11	R	38	R	5	R	6	R	10	R	10	R	7	R	37	R	10	R	37	R	37	R	38	R	11	R	2	R	12	20
	A	S	S	14	S	15	S	8	S	14	S	13	S	13	S	3	S	7	S	13	S	14	S	46	S	45	S	13	S	15	S	46	S	7	S	7	S	13	S	14	S	15	20
	L	T	T	14	T	15	T	14	T	15	T	15	T	16	T	13	T	7	T	15	T	55	T	15	T	14	T	15	T	55	T	16	T	54	T	55	T	54	T	14	T	14	20
	B	U	U	4	U	7	U	10	U	7	U	10	U	11	U	11	U	9	U	11	U	5	U	30	U	11	U	5	U	30	U	4	U	10	U	10	U	10	U	11	U	2	20
	G	V	V	56	V	14	V	54	V	15	V	54	V	8	V	55	V	55	V	6	V	14	V	14	V	9	V	2	V	15	V	1	V	56	V	16	V	14	V	16	V	15	20
	V	W	W	6	W	14	W	30	W	29	W	13	W	13	W	13	W	3	W	14	W	6	W	12	W	14	W	11	W	13	W	13	W	7	W	30	W	30	W	11	W	12	20
	W	X	X	15	X	53	X	16	X	15	X	15	X	14	X	15	X	14	X	14	X	14	X	7	X	6	X	16	X	54	X	15	X	14	X	54	X	14	X	13	X	54	20
	N	Y	Y	15	Y	16	Y	15	Y	13	Y	14	Y	51	Y	8	Y	2	Y	51	Y	13	Y	51	Y	15	Y	14	Y	13	Y	52	Y	16	Y	15	Y	15	Y	5	Y	15	20
	S	Z	Z	7	Z	15	Z	15	Z	14	Z	13	Z	14	Z	16	Z	17	Z	0	Z	51	Z	14	Z	51	Z	50	Z	7	Z	6	Z	7	Z	51	Z	14	Z	13	Z	51	20

Fig. 2. The result of all the 26 alphabetical patterns that are twenty times 4.4% randomly distorted.

The following shows 10 samples of distorted patterns of the alphabetical figure of "A" taken from the experiment of recognizing 5.8% randomly distorted patterns (Fig. 3).

After collecting the results taken from testing 5200 patterns we can summarize how accurate the mHGN is, in recognizing different levels of distortion of 26 alphabets. The summary is taken based on the average accuracy values from all the steps. The following shows the summarized result taken from testing distorted patterns using five-dimensional $5 \times 5 \times 5 \times 15 \times 15$ mHGN.

It can be seen from Fig. 4 in the last column that the mHGN is able to recognize 91% of the 10.7% distorted patterns of 26 alphabetical figures. Some alphabetical figures of A, C, E, G, I, J, L, O, S, T, U, V, X, Y, Z, are even 100% recognizable. Other patterns of alphabetical figures of H, K, M, N, are not very well recognized because they are visually and physically very similar. In fact, if this architecture is used to recognize different states of the same alphabet, such as regular-A, bold-A, and italic-A as the same alphabet, then mHGN will be able to gain better accuracy values.

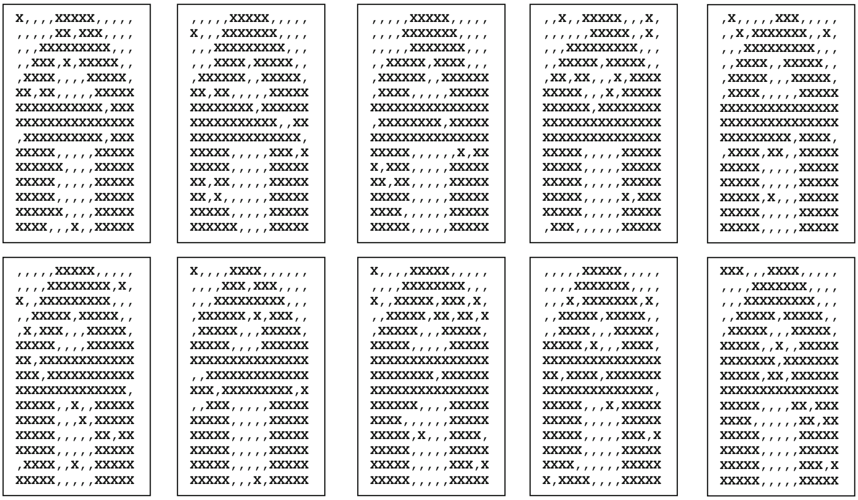

Fig. 3. Ten different randomly 5.8% distorted patterns of alphabetical figure of "A"

5X5X5X15X15 Patterns		Distortion (%)						
		1.3	2.7	4.4	6.7	8.0	8.9	10.7
Recognition Accuracy for Each Pattern (%)	A	100	100	100	100	100	100	100
	B	100	100	100	100	98	97	94
	C	100	100	100	100	100	96	100
	D	100	100	100	100	100	100	98
	E	100	100	100	100	100	100	100
	F	100	99	94	89	83	85	74
	G	100	100	100	100	100	100	100
	H	100	100	89	67	48	50	55
	I	100	100	100	100	100	100	100
	J	100	100	100	100	100	100	100
	K	100	100	98	81	70	72	67
	L	100	100	100	100	100	100	100
	M	100	100	93	76	55	66	49
	N	100	100	97	77	63	60	55
	O	100	100	100	100	100	100	100
	P	100	99	87	79	80	81	81
	Q	100	100	100	100	100	94	99
	R	100	100	100	95	100	99	95
	S	100	100	100	100	100	100	100
	T	100	100	100	100	100	100	100
	U	100	100	100	100	100	100	100
	V	100	100	100	100	100	100	100
	W	100	100	100	100	99	98	92
	X	100	100	100	100	100	100	100
	Y	100	100	100	100	100	100	100
	Z	100	100	100	100	100	100	100
Average		100	100	98	95	92	92	91

Fig. 4. The summary of the result using 5 × 5 × 5 × 15 × 15 mHGN [14]

The following figure shows the differences of recognition accuracy amongst 15×15, $5 \times 15 \times 15$, $5 \times 5 \times 15 \times 15$, and $5 \times 5 \times 5 \times 15 \times 15$ mHGN architectures when recognizing 10.7% distorted patterns of alphabets (Fig. 5).

Comparison Result		Distortion = 10.7 %			
		15X15	5X15X15	5X5X15X15	5X5X5X15X15
Recognition Accuracy for Each Pattern (%)	A	99	100	100	100
	B	58	69	92	94
	C	67	93	94	100
	D	78	92	94	98
	E	85	80	100	100
	F	61	71	81	74
	G	87	98	100	100
	H	23	63	69	55
	I	95	100	100	100
	J	77	95	100	100
	K	68	59	84	67
	L	50	80	100	100
	M	38	36	35	49
	N	53	42	63	55
	O	100	100	100	100
	P	61	59	75	81
	Q	63	73	73	99
	R	79	90	95	95
	S	78	97	100	100
	T	93	95	100	100
	U	89	84	85	100
	V	100	100	100	100
	W	75	82	98	92
	X	85	100	100	100
	Y	100	100	100	100
	Z	99	100	100	100
Average		75	83	90	91

Fig. 5. Differences of recognition accuracy amongst four different architectures

3.2 Time-Series in Pattern Recognition

Recognizing patterns of time series problem utilizes data that have previously been recorded regularly in timely manner [14]. For instance, if the parameter that needs to be recorded is a single value, and the recording step is every six hours, then there will be 4 values recorded every day. In order to constructs the recorded values as a pattern, the data representation of the recorded values need to be developed so, that they can fit into a pattern recognition architecture. The following figure shows six ways of representing recorded data for 8 values of measurement.

Definition: The distance between two values is the number of different bits between them. For instance, the distance between 001 and 110 is 3, whereas the distance between 00000001 and 10000000 is 2. Some people know it as Hamming Distance.

It can be seen from Fig. 6 that the data (value) is represented using binary numbers, and there are six possible data representations (Ver1 till Ver6). For the Ver1 (Binary Code Decimal), the distance between adjacent values varies. It is therefore not suitable for mHGN. For the Ver2 (Grey Code), the distance between two adjacent values is constant, which is one. However, the distance between Value 2 and 7 is also one. This is not suitable, as for mHGN the distance of 1 also means that the two values are very close to each other. In fact, value 2 and 7 are very different and very far from each other. Again, this is not suitable for mHGN. For the Ver3 and Ver4 (Ring Counter), the distance between any two values is constant, which is two. These are again not suitable for mHGN. For the Ver5 and Ver6 (Johnson Counter) the distance between adjacent values is constant, which is one. Additionally, the distance between any two values is linear with the value differences.

Value	Ver1	Ver2	Ver3	Ver4	Ver5	Ver6
1	000	000	00000001	10000000	00000001	10000000
2	001	001	00000010	01000000	00000011	11000000
3	010	011	00000100	00100000	00000111	11100000
4	011	010	00001000	00010000	00001111	11110000
5	100	110	00010000	00001000	00011111	11111000
6	101	111	00100000	00000100	00111111	11111100
7	110	101	01000000	00000010	01111111	11111110
8	111	100	10000000	00000001	11111111	11111111

Fig. 6. Six examples of data representation for 8 levels of value

It seems to be that the Ver5 and Ver6 are the most suitable data representation that can be used with mHGN. However, such data representation will not efficiently utilize the binary combination. Using 3-bit data, only 3/8 or 0.375 is the occupation ratio. Using 4-bit data is the occupation ratio 4/16 or 0.25. The occupation ratio is 5/32 or 0.15625 when using 5-bit data. The facts show that the Ver5 and Ver6 data representation will produce less occupation ratio, the more bits is used. This is an indication that due to such an occupation ratio the pattern recognizer will have less recognition accuracy, the more bits is used. So, these are again not suitable for mHGN. The following is a better data representation.

In Fig. 7, there are three examples of 3-bit, 4-bit, and 5-bit data representation. It is shown that the distance between any adjacent levels in all samples is constant, which is one. Furthermore, between any two values which have value difference of two, the distance is also constant, which is two. Last, the distance between any two values

Value	3-bit	4-bit	5-bit
1	101	0101	00101
2	**100**	**0100**	**00100**
3	110	0110	00110
4	010	1110	01110
5	**011**	**1111**	**01111**
6	001	1101	01101
7		1001	01001
8		**1000**	**01000**
9		1010	01010
10		0010	11010
11		**0011**	**11011**
12		0001	11001
13			11101
14			**11100**
15			11110
16			10110
17			**10111**
18			10101
19			10001
20			**10000**
21			10010
22			00010
23			**00011**
24			00001

Fig. 7. Three examples of a better data representation for 3-, 4-, and 5-bit binary values

which have value difference of three, the distance is again constant, which is three. For mHGN, such constant distances of 1, 2, and 3 are adequate to be used in tornado recognition architecture. Another characteristic of these data representations is that the representation is cyclic. It means that, if it is required the order of binary representation can be modified circularly without affecting the characteristic related to the distances. Using such better data representations, in all examples is the occupation ratio constantly 0.75. With such a constant occupation ratio the pattern recognizer will have constant recognition accuracy, regardless how many bits of data representation is used.

The Fig. 8 shows an example of recorded data taken from a single location measurement and each value has 3×5-bit values.

It can be seen from Fig. 8 that the recorded values from parameter of 15-bit data construct a two-dimensional pattern of 10×15 architecture. Utilizing these recorded data, the pattern recognizer can forecast a tornado 6 h earlier, when the same tornado occurs again. It means that if values have been recorded and the same pattern is recognized by the pattern recognizer, then the tornado is forecasted to occur again within 6-h time with around 90% of accuracy.

1	0	1	1	0	0	1	1	0	0
1	1	1	1	0	1	1	1	1	0
0	0	0	1	1	1	1	1	0	1
1	1	1	0	0	1	0	0	1	0
1	0	0	1	0	1	1	0	0	0
1	0	1	0	1	0	1	1	0	0
1	1	1	0	1	1	1	1	1	1
0	1	1	1	0	0	0	1	0	1
1	1	0	0	1	1	1	0	1	1
1	1	0	0	0	0	0	1	0	1
0	1	0	0	0	0	1	0	1	1
0	1	1	1	1	1	1	0	1	1
1	0	1	0	1	1	1	1	1	0
0	1	1	1	1	1	0	0	0	1
0	1	1	0	1	1	0	0	1	1
00.00	03.00	06.00	09.00	12.00	15.00	18.00	21.00	00.00	03.00

Time →

Fig. 8. Time series data of 15-bit values build a 2D-Pattern

4 Multidimensional Graph Neuron for Tornado Forecasting

In the previous section, time series value is described and represented so, that it can be forecasted through utilizing a pattern recognition, such as mHGN. In case of tornado forecasting, single parameter in a location, such as air-pressure, is not the only value that determine the occurrence of a tornado in the location within 6-h time. Several other parameters, such as wind-speed, wind-direction, air-temperature, and air-humidity, play a big role in the occurrences as well. It means that the number of levels or a measured value will increase according to the number of parameters. In case 5 parameters need to be measured and each parameter contains 5-bit value, the required pattern structure would be 10×25.

Also described in the previous section that measuring a parameter at particular point of location for several periods of time will generate a two dimensional pattern. If a series of points of the location need to be measured for several period of time, then the measured values will become a three dimensional pattern. The following figure depicts how some part of it will look like (Fig. 9).

Also described in the previous section that measuring parameters at particular point of location for several periods of time will generate a two dimensional pattern. If a series and linear of locations need to be measured for several periods of time, then the measured values will become a three dimensional pattern. If the location that need to be measured is an 2D area, then the measured values will generate a 4D pattern. Furthermore, if the location that need to be measured is a 3D area, then the measured values will generate a 5D pattern.

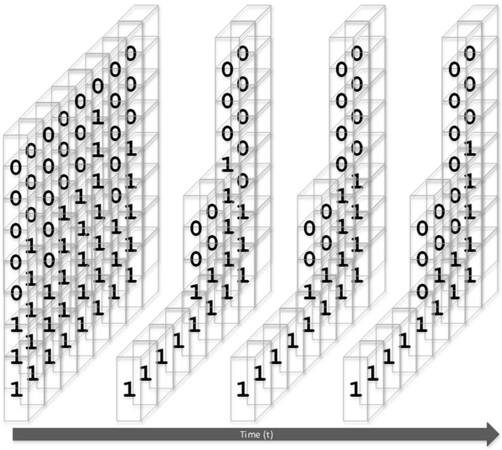

Fig. 9. A row of data of 8-bit value build a 3D-Pattern

4.1 The Architecture of mHGN for Time-Series Tornado Data

The utilization of mHGN has introduced a new approach that a local tornado forecast can be operated using small and cheap components. The values of air-temperature, air-humidity, air-pressure, wind-speed, and wind-direction can be gained through ordinary sensors. The area that is covered by those sensors can be a 3D area, because such small sensors can be easily mounted in valleys or hills, or even vehicles. The sensors can be embedded in a tiny computer, such as Raspberry Pi. The tiny computer will be responsible to run several GNs. The values taken from the sensors will then be worked out within the GNs. The connectivity of neurons is developed within a tiny computer and through the interconnectivity of the tiny computers.

In short, to build a tornado forecast for particular location, five parameters need to be measured. They are: wind-speed, wind-direction, air-temperature, air-humidity, and air-pressure. So, if one parameter is represented through 5-bit binary data, then for the measurement of 5 parameters 25-bit data is needed. For the time series, 15 series of measurement will be carried out. For an area that needs to be protected by mHGN, $3 \times 3 \times 3$ measurement points will be deployed. So, the mHGN dimension will be $3 \times 3 \times 3 \times 25 \times 15$.

The positions of the $3 \times 3 \times 3$ GNs will form a cylinder shape. In the cylinder, there will be three layers of circles. Each layer contains 9 GNs, in which 8 GNs will be on the border of the circle, and one GN will be located in the centre of the circle. The following figure shows the architecture of the positions of the sensors (Fig. 10).

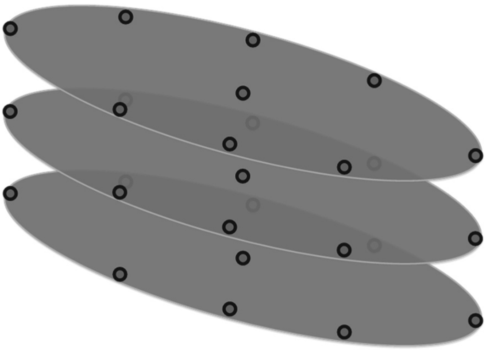

Fig. 10. The architecture of 3 × 3 × 3 sensors

The cylinder shape of the architecture has been chosen so, that mHGN still has an ability to recognize the same tornado pattern but developed with the direction different from the ones already stored. For the purpose of training, patterns from the previous tornados will be stored in the mHGN. Each pattern of a tornado will then be stored in mHGN eight times, following the number of eight major compass directions. It will look like as if the mHGN has stored 8 patterns of tornados. By having eight patterns for each tornado stored in mHGN, whenever the same characteristics of a tornado turn up but from different direction from the already stored ones, mHGN will be able to recognize it.

4.2 Data Handlings for Real Tornados

Two deadliest tornados occurred quite recently are the tornado that struck Joplin, Missouri on May 22, 2011 and the one in Hackleburg–Phil Campbell, Alabama on April 27, 2011. To store the circumstances, several parameters in these areas need to be stored in mHGN. Fortunately, the National Oceanic and Atmospheric Administration (NOAA) provides lots of data of: air-temperature, air-humidity, air-pressure, wind-speed, wind-direction in most areas of the US. These data will be the major source for mHGN to store previous occurrences of tornados. In the case of Joplin, the following are several locations of stations that have recorded those data from their sensors including the map in the state of Missouri.

The following is the list of tornados scale F5/EF5 (the strongest) occurred In the US. The indicator F stands for Fujita and EF stands for extended Fujita. The scale has been named the same as the meteorologist Ted Fujita, who developed the scale.

1. May 4, 2007, Greensburg, Kansas
2. May 25, 2008, Parkersburg–New Hartford, Iowa
3. April 27, 2011, Philadelphia–Preston, Mississippi

4. April 27, 2011, Smithville, Mississippi
5. April 27 2011, Hackleburg–Phil Campbell, Alabama
6. April 27 2011, Tuscaloosa–Birmingham, Alabama
7. April 27, 2011, Rainsville–Sylvania, Alabama
8. May 22 2011, Joplin, Missouri
9. May 24, 2011, El Reno–Piedmont, Oklahoma
10. May 24, 2011, Chickasha–Blanchard–Newcastle, Oklahoma
11. May 24, 2011, Washington–Goldsby, Oklahoma
12. May 20, 2013, Moore, Oklahoma
13. May 31, 2013, El Reno, Oklahoma
14. April 27, 2014, Vilonia, Arkansas

It can be seen from the map above, that based on the close location and the same time frame the data of Joplin's tornado can be used to test the Oklahoma's tornados (five tornados). Similarly, the data of Philadelphia-Preston's tornado or Smithville's tornado can be used to test Alabama's tornados (three tornados) (Figs. 11, 12, 13 and 14).

Fig. 11. The locations of F5/EF5 tornados

In order to collect the suitable data that fit with the architecture of mHGN, the locations of the chosen weather stations that the data will be taken from, must build a figure like a circle, and the middle weather station must be located in the area in which a tornado has hit. The following is an excerpt of the data taken from a weather station Joplin in the State of Missouri.

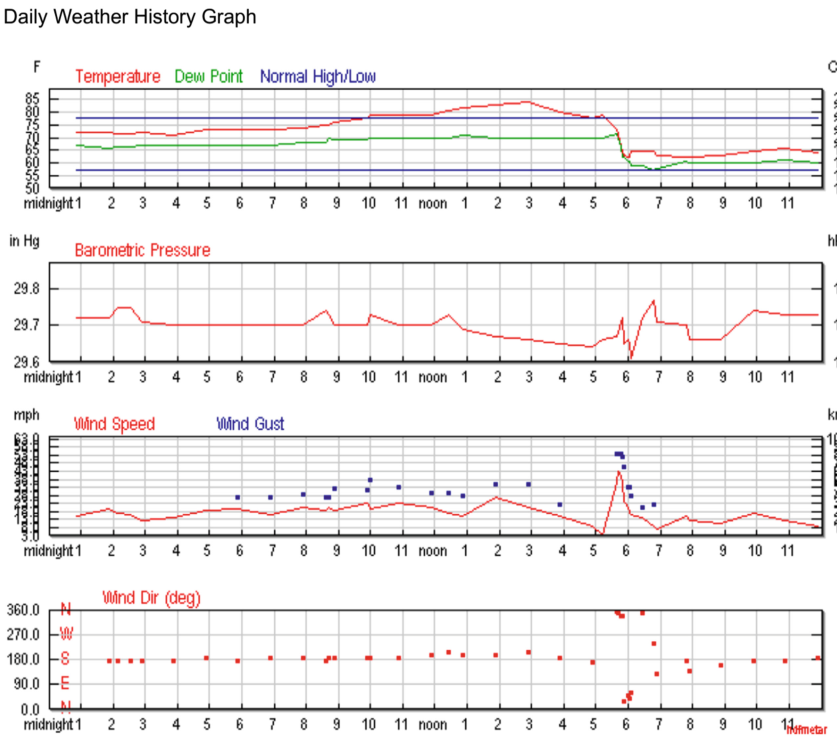

Fig. 12. The weather data of Joplin Station on May 22, 2011

Hourly Weather History & Observations

Time (CDT)	Temp.	Heat Index	Dew Point	Humidity	Pressure	Visibility	Wind Dir	Wind Speed	Gust Speed	Precip	Events	Conditions
12:53 AM	**22.2** °C	-	**19.4** °C	84%	**1006.4** hPa	**12.9** km	South	**24.1** km/h / **6.7** m/s	-	N/A		Clear
1:53 AM	**22.2** °C	-	**18.9** °C	81%	**1006.4** hPa	**12.9** km	South	**31.5** km/h / **8.7** m/s	**42.6** km/h / **11.8** m/s	N/A		Partly Cloudy
2:10 AM	**22.0** °C	-	**19.0** °C	83%	**1007.3** hPa	**12.9** km	South	**27.8** km/h / **7.7** m/s	-	N/A		Mostly Cloudy
2:33 AM	**22.0** °C	-	**19.0** °C	83%	**1007.3** hPa	**12.9** km	South	**25.9** km/h / **7.2** m/s	-	N/A		Scattered Clouds
2:53 AM	**22.2** °C	-	**19.4** °C	84%	**1005.9** hPa	**11.3** km	South	**20.4** km/h / **5.7** m/s	**37.0** km/h / **10.3** m/s	N/A		Clear
3:53 AM	**21.7** °C	-	**19.4** °C	87%	**1005.8** hPa	**11.3** km	South	**22.2** km/h / **6.2** m/s	-	N/A		Partly Cloudy
4:53 AM	**22.8** °C	-	**19.4** °C	81%	**1005.7** hPa	**11.3** km	South	**29.6** km/h / **8.2** m/s	**40.7** km/h / **11.3** m/s	N/A		Overcast
5:53 AM	**22.8** °C	-	**19.4** °C	81%	**1005.5** hPa	**11.3** km	South	**31.5** km/h / **8.7** m/s	**42.6** km/h / **11.8** m/s	N/A		Overcast
6:53 AM	**22.8** °C	-	**19.4** °C	81%	**1005.6** hPa	**9.7** km	South	**25.9** km/h / **7.2** m/s	**42.6** km/h / **11.8** m/s	N/A		Haze
7:53 AM	**23.3** °C	-	**20.0** °C	82%	**1005.8** hPa	**9.7** km	South	**33.3** km/h / **9.3** m/s	**46.3** km/h / **12.9** m/s	N/A		Haze
8:36 AM	**24.0** °C	-	**20.0** °C	78%	**1007.0** hPa	**9.7** km	South	**29.6** km/h / **8.2** m/s	**42.6** km/h / **11.8** m/s	N/A		Haze
8:43 AM	**24.0** °C	-	**21.0** °C	83%	**1006.7** hPa	**9.7** km	South	**33.3** km/h / **9.3** m/s	**42.6** km/h / **11.8** m/s	N/A		Haze

Fig. 13. The detailed weather data of Joplin Station on May 22, 2011

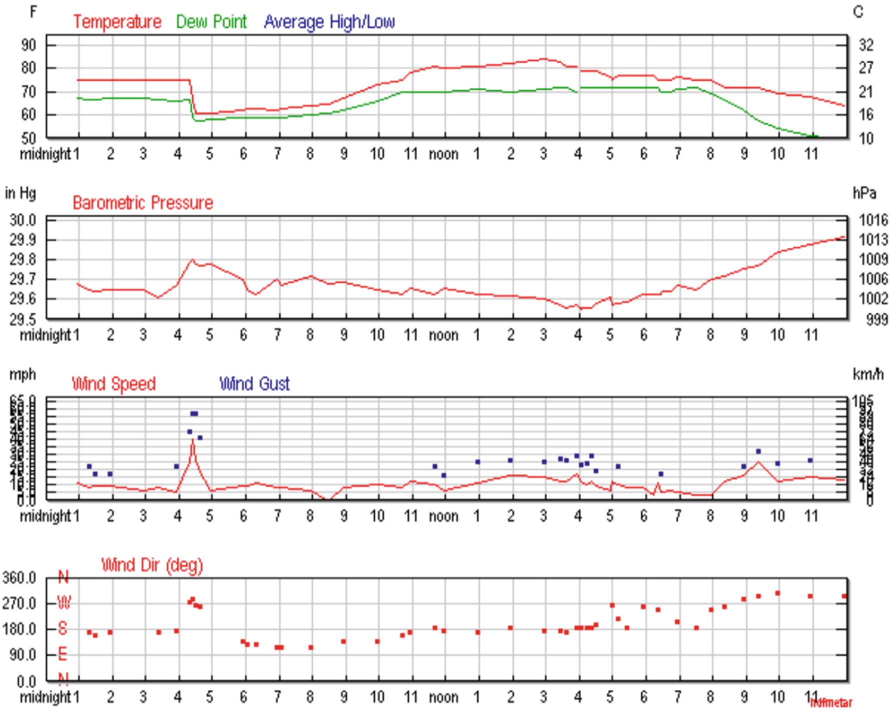

Fig. 14. The weather data of Philadelphia-Preston Station on April 27, 2011

5 Discussion

As is the case with pattern recognition of alphabets, patterns are more or less different to one another. However, in time series measurement data patterns, which are constructed from the measured values of the sensors, can be very similar to one another. Therefore, data representation of measured values before data is fed to the architecture of mHGN plays a big role in having very accurate results. False positive and true negative rate will also be indications to determine the quality of mHGN in forecasting natural disaster.

The data that will be used to validate this work will be the data taken from different cities and different countries. As mHGN is trained one-cycle only, it is a challenge to choose which data is the right data for the training purpose, or the data is the consolidated data from a number of occurrences. When the appropriate training data has been applied, mHGN will then have a capability to forecast a tornado.

The main thing that needs to be developed for supporting the tornado forecasting technology is a sequence of binary values. Since the analog values taken from sensors (temperature, humidity, pressure, wind speed, and wind direction) need to be precise, so at least 5-bit binary values are required.

The requirements for the sequence of the 5-bit binary values are:

1. The Hamming Distance of any binary value to its first adjacent neighbour value is 1.
2. The Hamming Distance of any binary value to its second adjacent neighbour value is 2.
3. The Hamming Distance of any binary value to its third adjacent neighbour value is 3.
4. The sequence should be cyclic, which means that any binary-value can be either the first or the last member of the sequence.

The following are those mentioned binary values (Fig. 15).

Index	Value	Index	Value
1	00101	**13**	11101
2	**00100**	**14**	**11100**
3	00110	**15**	11110
4	01110	**16**	10110
5	**01111**	**17**	**10111**
6	01101	**18**	10101
7	01001	**19**	10001
8	**01000**	**20**	**10000**
9	01010	**21**	10010
10	11010	**22**	00010
11	**11011**	**23**	**00011**
12	11001	**24**	00001

Fig. 15. The binary values for 5-bit data

It can be seen from the table above that all four requirements are fulfilled. To prove that the sequence is cyclic, it can be done through inserting the value at the index of 1 underneath the value at the index of 24. It can then be seen that all three requirements of the sequence (about Hamming Distances) are still fulfilled. So, after the index of 24, the sequence can be continued with the values of the index of 1, and 2, and 3, and so forth (Fig. 16).

5.1 The Bold Binary Values

The bold binary values in the sequence is used as the values of clusters. In an artificial intelligence approach, an intelligent system must first be trained so, that it will memorize patterns. Having such memory makes the system be capable of for instance recognizing previously trained patterns. The memorized values of those for-training patterns will be clustered into those bold values. In this research, it will be investigated, how many clusters are the best configuration that will achieve the most accurate results. Now, whenever a pattern needs to be recognized by the mHGN, all the values bold or not will be recognized as bold values. For instance, if the value taken from particular sensor is 10001 (index 19), the mHGN will recognize it as 10000 (index 20). The reason to this is because the smallest Hamming Distance of the value 10001 happens to

	00101	00100	00110	01110	01111	01101	01001	01000	01010	11010	11011	11001	11101	11100	11110	10110	10111	10101	10001	10000	10010	00010	00011	00001
00101	0	1	2	3	2	1	2	3	4	5	4	3	2	3	4	3	2	1	2	3	4	3	2	1
00100	1	0	1	2	3	2	3	2	3	4	5	4	3	2	3	2	3	2	3	2	3	2	3	2
00110	2	1	0	1	2	3	4	3	2	3	4	5	4	3	2	1	2	3	4	3	2	1	2	3
01110	3	2	1	0	1	2	3	2	1	2	3	4	3	2	1	2	3	4	5	4	3	2	3	4
01111	2	3	2	1	0	1	2	3	2	3	2	3	2	3	2	3	2	3	4	5	4	3	2	3
01101	1	2	3	2	1	0	1	2	3	4	3	2	1	2	3	4	3	2	3	4	5	4	3	2
01001	2	3	4	3	2	1	0	1	2	3	2	1	2	3	4	5	4	3	2	3	4	3	2	1
01000	3	2	3	2	3	2	1	0	1	2	3	2	3	2	3	4	5	4	3	2	3	2	3	2
01010	4	3	2	1	2	3	2	1	0	1	2	3	4	3	2	3	4	5	4	3	2	1	2	3
11010	5	4	3	2	3	4	3	2	1	0	1	2	3	2	1	2	3	4	3	2	1	2	3	4
11011	4	5	4	3	2	3	2	3	2	1	0	1	2	3	2	3	2	3	2	3	2	3	2	3
11001	3	4	5	4	3	2	1	2	3	2	1	0	1	2	3	4	3	2	1	2	3	4	3	2
11101	2	3	4	3	2	1	2	3	4	3	2	1	0	1	2	3	2	1	2	3	4	5	4	3
11100	3	2	3	2	3	2	3	2	3	2	3	2	1	0	1	2	3	2	3	2	3	4	5	4
11110	4	3	2	1	2	3	4	3	2	1	2	3	2	1	0	1	2	3	4	3	2	3	4	5
10110	3	2	1	2	3	4	5	4	3	2	3	4	3	2	1	0	1	2	3	2	1	2	3	4
10111	2	3	2	3	2	3	4	5	4	3	2	3	2	3	2	1	0	1	2	3	2	3	2	3
10101	1	2	3	4	3	2	3	4	5	4	3	2	1	2	3	2	1	0	1	2	3	4	3	2
10001	2	3	4	5	4	3	2	3	4	3	2	1	2	3	4	3	2	1	0	1	2	3	2	1
10000	3	2	3	4	5	4	3	2	3	2	3	2	3	2	3	2	3	2	1	0	1	2	3	2
10010	4	3	2	3	4	5	4	3	2	1	2	3	4	3	2	1	2	3	2	1	0	1	2	3
00010	3	2	1	2	3	4	3	2	1	2	3	4	5	4	3	2	3	4	3	2	1	0	1	2
00011	2	3	2	3	2	3	2	3	2	3	2	3	4	5	4	3	2	3	2	3	2	1	0	1
00001	1	2	3	4	3	2	1	2	3	4	3	2	3	4	5	4	3	2	1	2	3	2	1	0

Fig. 16. The distances of bold binary values to other values

be between this value and the value 10000, which is 1. Similarly, if the value taken from particular sensor is 10010 (index 21), the mHGN will recognize it as 10000 (index 20) as well. The reason to this is because the smallest Hamming Distance of the value 10010 happens to be between this value and the value 10000, which is 1.

Someone might raise a question, whether there is a chance that the Hamming Distance 1 of the values 10001 and 10010 is not only compared to the bold value 10000, but also to one or two other bold values? To answer this question, the following Hamming Distance table shows the answer.

In the above table, it can be seen that in any bold row or in any bold column, the Hamming Distance of 1 is located in two places only. It means that the Hamming Distance of 1 belongs to those on the first adjacent neighbor values.

6 Conclusion

From the experiment results it is shown that mHGN has the capability to recognize multidimensional patterns. For simulating a tornado forecast, we have presented results of up to 5D architecture. As already discussed in [15] and [9] there is no modification required if the architecture needs to be extended to bigger sizes of patterns. In the future this capability will be improved to the extent so, that multi oriented of multidimensional patterns will also be recognizable. At this stage it is also observed that mHGN still use a single cycle memorization and recall operation. The scheme still utilizes small response time that is insensitive to the increases in the number of stored patterns.

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The Concept of a Regional Information-Analytical System for Emergency Situations

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Abstract. The concept of a regional information-analytical system for emergency situations is presented. The three-level architecture of such a system and the functions of its main components are described. A generalized model for assessing plans for eliminating the consequences of emergencies is described. The goals and peculiarities of the structural modules for the regional information and analytical system for the prevention and elimination of emergencies are detailed; some examples of the implementation of local subsystems for Ukraine are considered.

Keywords: Disaster response · Disaster communication · Information processing for emergency management

1 Introduction

In the situations associated with modern risks of both anthropogenic and natural type leading to emergency situations, an urgent issue is the development of information and analytical system for eliminating and preventing such situations [1].

A number of requirements have to be imposed on efficiency of such systems: the minimization of both human and economic losses during the elimination of emergency situations; the prevention of possible emergencies in the monitoring mode as soon as possible [2–4].

All possible causes for emergency can be divided to natural and anthropogenic ones. Natural factors that can lead to emergencies can be classified as follows [5]:

– droughts;
– floods;
– earthquakes;
– tsunami;
– etc.

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In this case, the natural causes have such basic characteristics as:

- complexity of warning;
- complexity of forecasting;
- need for the development of complex prediction models.

At the same time, the following points can be considered as risks in the appearance of natural emergencies [5]:

- a large scale of destructions that often happen;
- large human, financial and infrastructural losses.

The following anthropogenic factors can be considered:

- chemical or biological pollution in enterprises;
- traffic accidents;
- military actions;
- etc.

The main characteristics of anthropogenic causes for emergencies are as follows:

- it is necessary to keep the technical passports of all technogenic objects;
- in the presence of the initial information, it is possible to construct quite accurate models;
- the probability of a warning is high.

The main risks of anthropogenic factors of emergencies are these:

- long-term consequences (pollution of the territory) are possible;
- large human, financial, infrastructural losses;
- a large multiplier effect on the economy is possible.

2 Problem Formulation

The consideration and solution of such problems and tasks separately are ineffective as it doesn't allow taking into account all the interrelations between factors of occurrence of emergencies themselves and their consequences. Besides, the separate solution to each such a task can lead to an inefficient use of the available forces and it means eliminating the consequences of emergencies as well as a poor coordination of services and departments. Thus, the creation of a concept of an information and analytical system for preventing and eliminating the consequences of emergency within the region and the country in general is relevant [4, 6, 7].

For each of the possible causes of an emergency situation, the information and analytical system should provide the opportunity to address the following issues:

- prevention of an emergency;
- timely response to an emergency situation, if it occurs;
- the formation of an effective emergency response plan through the coordination of all departments of forces and assets;

- the coordination of the plan of eliminating the consequences of an emergency;
- the formation of conclusions on an emergency situation and taking them into account in the future.

The main functions of such a system are the following:

- the registration of messages and emergency situations;
- the classification of emergencies;
- the certification (monitoring) of potentially dangerous objects;
- conducting directories;
- geoinformation support;
- creating reports;
- modeling (the forecasting of emergencies).

3 Solution

Emergency prevention and elimination in Ukraine is engaged in State Emergency Service of Ukraine (SESU). The structure of the SESU consists of such units [8]:

- rescue units of special purpose;
- units of the technical service;
- state fire-fighting units;
- supply centers;
- operational coordination centers;
- centers for operational communications, telecommunications systems and information technologies.

3.1 Goals and Objectives of the Regional Information-Analytical System for Emergency Situations

The Regional Information-Analytical System for Emergency Situations (RIASES) is an integral part of the program for informatization and a unified state system for the prevention and elimination of accidents, catastrophes and other emergencies.

The purpose of creating RIASES is to provide the operational executive authorities with expert analytical, predictive, reference, statistical, factual, control, reporting and management information by using modern information technologies for solving problems related to technological and environmental safety and emergency situations.

The main tasks of creating RIASES are the following:

- providing the central executive authorities, the regional and district state administrations with reliable information related to man-caused and environmental safety and emergency situations;
- ensuring compatibility of information on emergency situations through the use of unified principles for building databases, unified certified cartographic information, common classifications and standards;

- obtaining a research-based forecast of the possible occurrence of an emergency and its possible consequences;
- providing operational access to information resources;
- obtaining reasonable recommendations as to a rational allocation and using of the available resources for the elimination of emergency consequences;
- ensuring information exchange and coordinating the actions of the executive authorities in preventing the occurrence of emergencies or the elimination of its consequences.

The goal is achieved by solving the following main tasks:

- system-wide:
  - the analysis of the technology for information exchange between the executive authorities responsible for treating emergencies;
  - the development of an architecture for RIASES, the description of its structural elements;
  - determining information flows in RIASES;
  - the development of mechanisms for information exchange within RIASES;
  - defining requirements for RIASES;
  - the development of specifications for software and hardware of RIASES and the installation of the technical facilities and the system software, the establishment of telecommunications between the structural elements of RIASES;
  - the creation of a technological stand for RIASES, the development of its main functions and their phased implementation;
- functional:
  - determining the main functions that should be implemented in the RIASES;
  - determining, setting and developing of a set of functional tasks, the solution of which will be carried out at different levels of RIASES;
- The development of regulatory and legal support.

3.2 The Main Functions and Tasks of RIASES

In order to achieve the above goals, the RIASES performs the main functions, which are grouped into four groups:

- informing;
- analysis and forecasting;
- planning activities and preparing solutions;
- monitoring the implementation of decisions and activities.

The implementation of the basic functions of these generalized groups provides the solution to the following series of problems.

The tasks of the “Informing” group.

To implement the functions of the “Informing” group it is supposed to resolve the following main problems using the RIASES elements:

- the automation of the processes for obtaining complete and reliable information on emergencies in the territory of Ukraine at all levels of RIASES;

- informing the management of the central and local executive authorities and other organizations, if necessary, about emergencies that have occurred, the threat of appearing new emergencies, the elimination of the consequences of the emergency, the damage caused, etc. according to the regulations;
- a rapid automated access of relevant experts and analysts of the subdivisions of ministries, departments, and regional state administrations to priority information on emergencies.

The tasks of the group of functions “Analysis and Forecasting”.

Regarding the group of functions “Analysis and forecasting,” their implementation involves solving the following generalized problems:

- aggregation data of emergency and the prerequisites for their occurrence, which will get into the RIASES and accumulate in the databases;
- define an expert evaluation of the nature of the corresponding emergency situations and the necessary resources to eliminate their consequences;
- background analysis and prediction of emergencies;
- analysis and modeling of the consequences of certain types of emergencies that occurred and the modeling of their impact on the possibility of other (derivatives) emergencies;
- predicting the impact of the most dangerous potentially possible emergencies;
- formation of regular reports on specific emergencies for the management.

The information analysis should provide for the initial stage of transformation of documentary and other important information and extracting the most essential information. Information synthesis should be connected with the process of generalization of the information obtained as a result of the information analysis of documents and the preparation of aggregation results in the text (or other) form. Depending on the nature and objectives of the work performed, the results of the synthesis can be different: from the simplest (specific description, abstract) to more complex ones (inspection, classification, selection of facts).

Task of group functions “Planning activities and preparing solutions”.

Implementation of the RIASES functions of the group “Planning actions and preparing solutions” requires the solution of the following main tasks:

- the preparation of draft decisions on the planning of measures to eliminate the consequences of emergencies;
- the formation of expert information on the basis of analyzing the information from the database of precedents for specific emergencies;
- determining the criterion for the assessment of necessary resources and the development of plans that will be followed during the elimination of the consequences of emergency situations.

The tasks of the group of functions “Monitoring the implementation of decisions and activities”.

In turn, to implement the functions of the group “Monitoring the implementation of decisions and activities,” the following tasks must be accomplished:

- monitoring the elimination of the consequences of emergencies;
- monitoring the implementation of the decisions that should be made as a result of resolving problems related to emergencies;
- monitoring the implementation of scheduled-preventive measures to prevent emergencies.

3.3 Model

The problem of predicting possible emergencies and planning their elimination is the most difficult but at the same time the most important one. This is due to the fact that in the case of a correct plan of actions for eliminating an emergency, there is a high probability of the timely response to the emergency situation and the minimization of possible losses. In case of the correct identification of the scenario for the emergency, it is possible to prevent all possible consequences.

In addition, by practicing repeatedly developed plans of eliminating possible emergencies during exercises, it is possible to improve efficiency of staff and improve the coordination of actions for services and departments.

The complexity of this task is conditioned by incomplete information in the event of natural disasters. The most effective way to solve such problems is to simulate the appearance of emergencies and the formation of possible plans for their elimination. Modern information technologies make it possible to create such simulation plans and evaluate their effectiveness during acceptable time.

At the same time, there is a relevant problem of evaluating the entire set of created plans for eliminating emergencies and selecting the most effective ones. Such a task is not trivial as it is necessary to take into account a number of conflicting characteristics (criteria). Therefore, the use of multifactor estimation and selection of optimal plans is proposed [9–11].

Generally, the problem of multicriteria optimization can be presented as follows:

$$x^0 = \arg \underset{x \in X}{extr}\, F(K(x), \Lambda) \tag{1}$$

where X is a set of permissible plans (including aspects of the emergence, prevention or elimination of emergencies);

$K(x) = \{k_1(x), \ldots, k_n(x)\}$ is a set of local criteria for evaluating plans;
$\Lambda = \{\lambda_1, \ldots, \lambda_n\}$ are numerical characteristics of the importance of local criteria.

An additional condition for the characteristics of importance is the following:

$$\sum_{i=1}^{n} \lambda_i = 1. \tag{2}$$

Local criteria in many aspects depend on the specific type of emergency, but at the same time it is possible to allocate the general ones that characterize any kind of emergency:

– minimum of costs for the elimination of possible emergency consequences:

$$C = \sum_{j=1}^{m} c_j \rightarrow \min, \quad (3)$$

where c_j is the cost of j-th activity for eliminating the consequences of emergencies.

– minimum possible economic losses after the implementation of this plan

$$U \rightarrow \min, \quad (4)$$

– minimum time spent on eliminating potential emergency consequences

$$T \rightarrow \min, \quad (5)$$

where T is a complex parameter that can take into account both sequential and parallel actions for emergency elimination.

– minimum of possible human losses in the form of wounded persons and the victims

$$L = \sum_{q=1}^{v} l_q + \sum_{h=1}^{s} l_h \rightarrow \min, \quad (6)$$

where v is the number of possible wounded persons and s is the number of possible victims.

Since the criteria are heterogeneous and have different dimensions they can be transformed to a uniform dimension by means of one of the normalization types, for example

$$\left(\frac{k_i(x) - k_i^-}{k_i^+ - k_i^-} \right)^{\alpha_i} \quad (7)$$

where $k_i(x)$ is the value of the i-th local criterion;

k_i^- is the worst value of the i-th criterion;
k_i^+ is the best value of the i-th criterion;
α_i is a parameter determining the variant of dependence ($\alpha_i = 1$ is linear, $0 < \alpha_i < 1$ is concave, $\alpha_i > 1$ is convex).

3.4 Organizational and Functional Structure of RIASES

Architecturally, RIASES represents three-level structure (Fig. 1). Each level resolves its own problems, based on the scale of the arising emergencies and existing forces, and the means at this level to eliminate it.

According to the organizational and functional characteristics, RIASES will include the following structural elements (Fig. 2):

– central subsystem of RIASES;
– functional subsystems of the central executive authorities;
– territorial subsystems of the local executive authorities;
– remote functional units or remote workstations of enterprises and organizations;
– providing the subsystems of RIASES.

The general organizational and functional structure of RIASES is shown in Fig. 2. The first four structural elements of RIASES perform the basic functions of RIASES, therefore they are the functional and structural elements of RIASES.

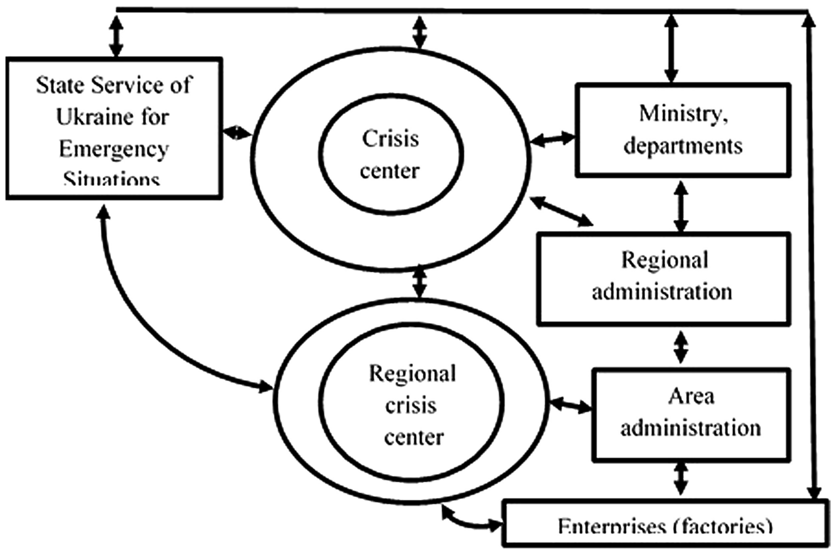

Fig. 1. Three-level structure of RIASES

Subsystem of monitoring potentially dangerous territories and objects.

– maintaining the directory of hazardous substances;
– monitoring the main sources and types of danger for objects;
– monitoring dangerous objects, structures and territories of the region;
– monitoring chemical hazards in the region;
– monitoring the hydrodynamic danger of the region;
– monitoring forces, assets and technical base.

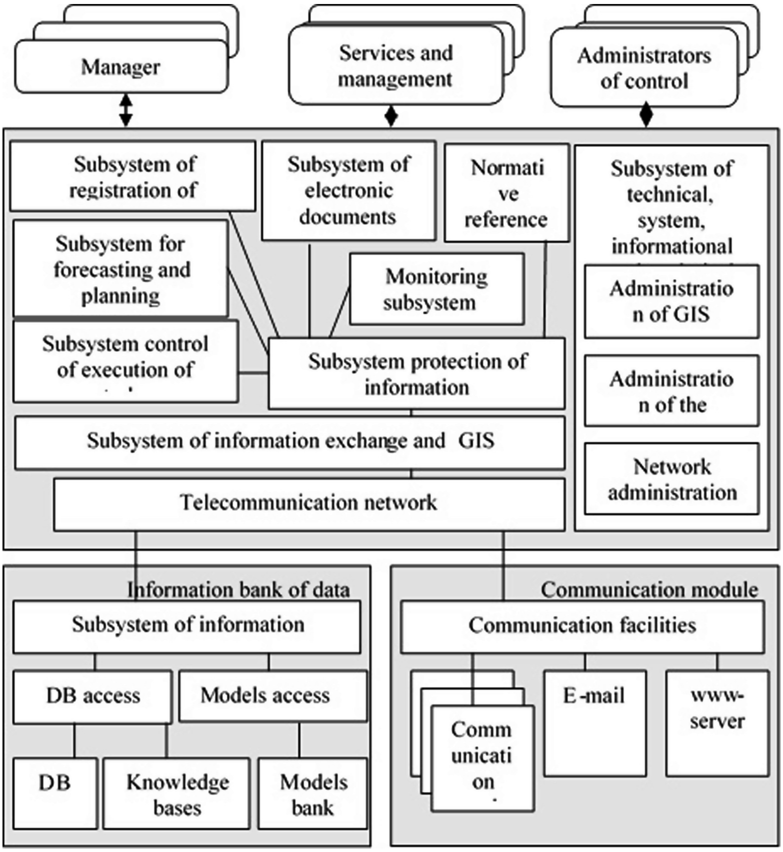

Fig. 2. Structural-functional scheme of RIASES

System for the preparation and control of decisions made

– assessment of the forces and facilities necessary for the localization of emergencies.
– forming possible sources for attracting the necessary forces and resources.
– assignment of forces and means by criteria (a promotion time minimum, minimum costs, by a generalized criterion).
– assessment of possible consequences of emergencies.
– determination of the level of the involved forces and assets, and their costs.

Function of certification (monitoring) of objects of potential danger.

The basic information that should be stored in the certificate of the technical object is shown in Fig. 3.

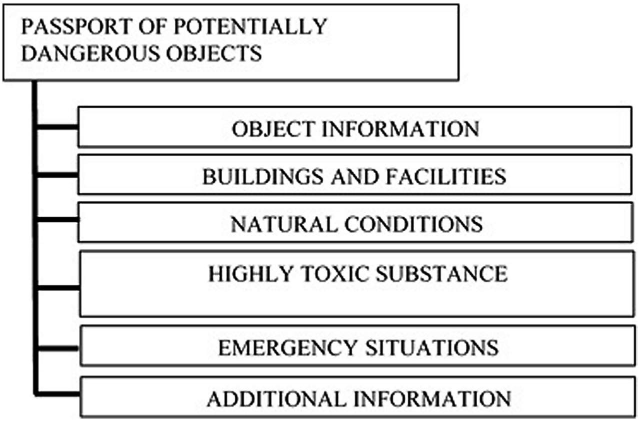

Fig. 3. Structure of the information of the passport for a technogenic object

Geoinformation System

The subsystem of geoinformation support is one of the most important elements of the system. The main task of this subsystem is the visualization of an operational environment. The examples of the work of such an implemented module are shown in Figs. 4 and 5.

Fig. 4. - Example of an area map with identified potentially hazardous enterprises

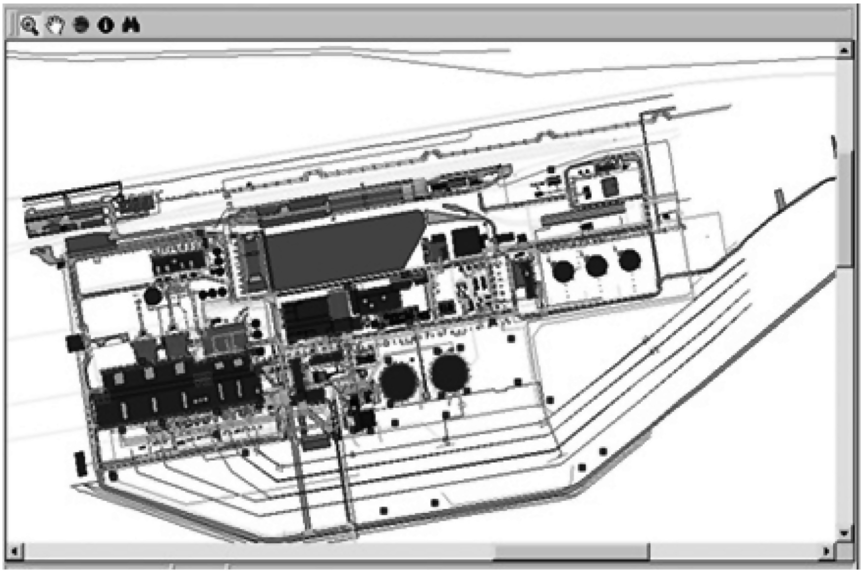

Fig. 5. Example of the scheme of a potentially hazardous enterprise

Results of the Simulation of an Emergency Situation

Based on the results of modeling emergencies, it is possible to analyze both numerical parameters and visualize the results (Fig. 6).

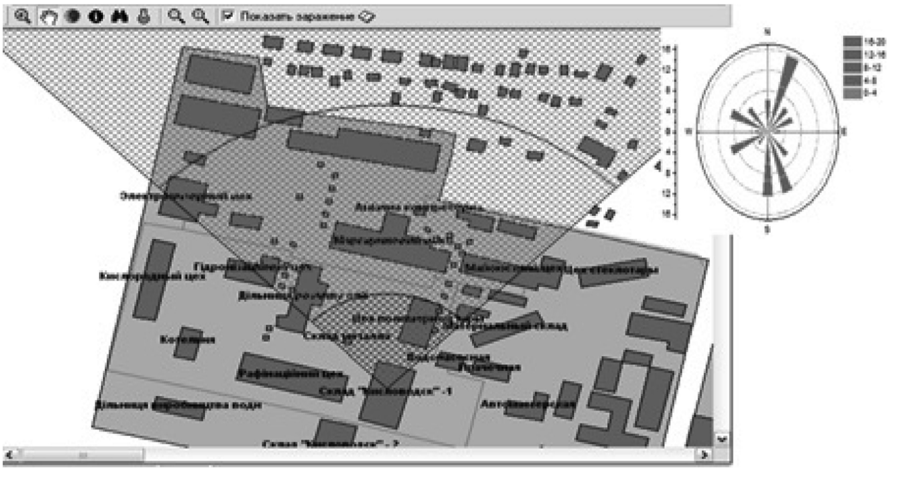

Fig. 6. Example of simulation results for the distribution of harmful emissions taking into account wind

4 Conclusions

The concept of a regional information and analytical system for the prevention and elimination of emergencies is presented. The architecture of the system and main features of its components are described, their goals and tasks being formulated. Some examples of the implementation of individual subsystems for Ukraine are considered.

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Adaptation of the Rules of the Models of Games with Nature for the Design of Safety Systems

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Abstract. The article presents a manner of formulating the problem of designing safety systems in terms of decision-making problems solved with the use of the models of the so-called games with nature. The models of this type are very frequently used to make decisions under conditions of uncertainty. The situation also occurs in the process of designing safety systems. For the purposes of solving the problem, the appropriate understanding of the basic components of the models of games with nature, i.e. the game strategy and the state of nature, was assumed. In this context, a definition of a system and a safety system was provided, along with an interpretation of the relationships between safety system elements (risk reduction measures) and domain elements (hazard factors/sources, hazards), on account of which these systems are designed. The specificity of the functioning of safety systems also required a modification of the decision rules applied within the models used. The modification was illustrated with the example of Wald's rule. A general concept of formulating the problem of designing safety systems as a decision-making problem was presented, along with the general algorithm of selecting risk reduction measures for safety systems with the use of the modified rules of the models of games with nature. Next, a mathematical model of the research problem was provided, including: creation of the risk reduction measure efficacy matrix, creation of the hazard source – hazard relationship matrix, determination of the payoff matrix, and the modification of decision rules. Usually, there is a need to select more than one risk reduction measure. An already developed original concept of sequential selection of these measures was used. The application of the rule adaptation proposed here was illustrated with an example of a fire protection system for railway vehicles. Hazard sources were identified and hazards related to electrical systems in railway vehicles were formulated. A list of examples of risk reduction measures which may form a safety system was presented.

Keywords: Safety systems · Games with nature · Risk reduction measures

1 Introduction

The need for the selection of the appropriate combination of risk reduction measures in reference to potential states of analysis domains poses a certain decision-making problem for the safety system designer. Their ill-considered selection may lead to the

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creation of extensive systems involving high maintenance costs or make it impossible to bring the risk value to an acceptable level. A reasonable approach is to make the choice based on the achieved 'goodness' level of the solution. For instance, it would be reasonable to achieve a solution which changes the degree of exposures coming from hazard factors (hazard sources) in the most favourable way or makes it possible to achieve the highest possible degree of risk reduction.

The problem lies in searching for a solution if the probabilities (probability distribution) of hazard factor occurrence or activity are unknown. We may assume that there is – as far as this activity is concerned – a certain kind of uncertainty understood (as cited in [17]) as a kind of randomness, whose probability distribution is unknown. In this case, the selection of risk reduction measures is paramount to making a decision under conditions of uncertainty.

It is possible to solve the problem with the use of mathematical models describing conflict situations, i.e. the class of models of the so-called games with nature [12, 17]. This requires the adaptation of the decision rules used within these models to the distinctive decision-making problem.

The article presents the manner of adapting known models of games with nature to the process of designing safety systems. It consists in formulating the decision-making problem in the appropriate way and introducing a certain logical condition to the decision rules. The modification of the rules was illustrated with the example of Wald's rule. Moreover, an already developed original concept of sequential selection of risk reduction measures presented in [5] was used.

2 Materials

2.1 HS-H-RRM Relationships

The basis for the solutions presented herein is the interpretation of the relationships between the main elements of the hazard identification process, i.e. between hazard sources (HS; also called hazard factors or risk sources [2]), hazards (H), and safety system elements, i.e. risk reduction measures (RRMs).

The term 'hazard' is crucial for risk management. However, its meaning is not well established. Mostly, a hazard is understood as a state or condition of the analysis domain, leading to loss or damage [8, 21]. The definitions generally indicate the need to identify the causes (sources) of hazards and the damage related to hazard activation. The international standard for machinery safety, EN-ISO 12100:2010, states that 'the term hazard can be qualified to define its origin (mechanical hazard, electrical hazard) or the nature of the potential harm (electric shock hazard, cutting hazard, toxic hazard, fire hazard)'.

It could be pointed out that each hazard can be attributed to one or several different causes (sources), and that all the causes must occur at the same time to activate the hazard. Thus we get a concept of hazard sources as a general term, which we use in this paper to express the causes of hazards. A hazard is therefore a coincidence of a specific combination of hazard sources, however its occurrence – hazard activation – is not a certain event. We understand the term hazard source as each physical, chemical, biological, psychophysical, organisational or personal formation (HS definition – among others in [6, 13]), whose presence in the given analysis domain or whose condition or properties are the cause for the formulation of a hazard.

Identifying hazard sources, formulating hazards, and showing the amount of damage (losses) that may emerge as a result of hazard activation is called hazard identification [6, 21]. In order to formulate a hazard, information concerning just one source is enough in most cases. However, hazard formulation usually becomes possible only on the basis of knowledge about several hazard sources. Figure 1 presents a risk analyst who looks at the analysis domain, realises the occurrence of two hazard sources (HS1 and HS2), and formulates a hazard (H) as a possibility of the occurrence of consequences (losses or damage) when the third hazard source emerges (HS3).

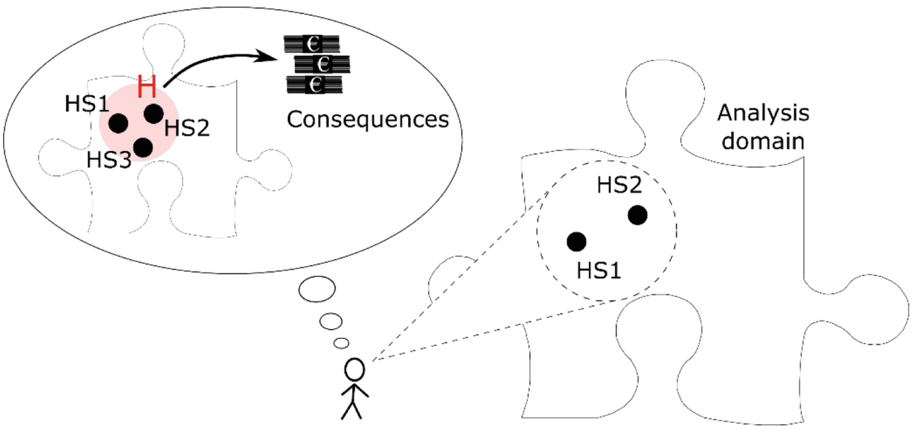

Fig. 1. Graphical interpretation of the relationships between the basic elements of hazard identification – hazard sources (HS), the hazard (H), and the consequences of hazard activation.

2.2 Safety Systems

The system theory says that a system exists when there are interdependent but related components achieving a valued pre-set objective or purpose or function [11]. The systems may be supported further by principles and based on the theories and information applicable to the situation. Therefore, a safety system (SS) can be defined as a set of cooperating elements, which form a unit oriented towards purpose [4]:

$$SS = D(\mathbf{SSC}, \mathbf{A}, \mathbf{R}), \mathbf{SSC} = [SSC_1, \ldots, SSC_n], \mathbf{A} = [A_1, \ldots, A_m], \mathbf{R} = [R_1, \ldots, R_r], \quad (1)$$

where: SSC is a set of safety system components, A is a set of attributes (properties), R is a set of relationships between the safety system components and the attributes, D is an entity – existing whole (not necessarily space-time, often in the world of ideas or symbols). The definition of a safety system provided by [21] indicates what an SSC may be and suggests what its attributes are: ‘A system is a combination of people, procedures, facilities, and/or equipment all functioning within a given or specified working environment to accomplish a specific task or set of tasks'.

When the aim of the system is the rationalisation of the risk of hazards in analysis domains so that an acceptable or tolerable risk level is provided for the hazards identified within them, it can be called a safety system.

Safety system elements can perform certain special functions – the so-called safety functions (SFs). In practice, this consists in these elements having an impact on the factors whose presence, condition or properties cause the formulation of hazards. The impact occurs in various ways. Defining the safety function, Harms-Ringdahl [9] states that: 'A safety function is a technical, organisational or combined function that can reduce the probability and/or consequences of accidents and other unwanted events in a system'.

The effect of the impact of safety system elements is therefore a reduction of one or more values which are the components of risk measures. This is why these elements are called risk reduction measures. It should be added that the impact of these measures usually comes down to the elimination of hazard sources, breaking their impact pathway (i.e. isolating the source or isolating the receiver on which the source has an impact), and informing about hazard source activity. In reference to the exposure limiting measures, the term 'barrier' is used (for instance according to the Commission Implementing Regulation (EU) 2015/1136): 'technical, operational or organizational risk control measure outside the system under assessment that either reduces the frequency of occurrence of a hazard or mitigates the severity of the potential consequence of that hazard'.

In most cases, risk reduction measures are also systems and in this context, we can speak of safety system subsystems.

2.3 Games with Nature

Decision-making under conditions of uncertainty is an important research problem, in particular in economic sciences, attempting to describe the behaviour of market participants. A certain variant of this issue are the so-called 'games with nature', in which one of the 'players' is the natural environment [24]. In models of this type, the so-called game strategy or decision-maker (player) strategy is selected. A strategy is, in general, one of the available ways of proceeding in the given situation. It has become customary to call such situations – created by the environment (nature) – states of nature.

The game strategy is selected in accordance with one or several decision rules: Wald's rule, Savage's rule, Hurwicz's rule, Bayes' rule [24, 25]. The strategy selection decision is made based on the so-called payoff matrix (benefit matrix, etc.). It is assumed that the decision-maker is able to identify the acceptable decision area, possible states of nature, and achievable results. The decision-maker does not know the probability distribution of the occurrence of the given states of environment in the future or does not want to use the available knowledge.

Wald's Rule. One of the several generally known rules used in 'games with nature' is the strategy of minimising the maximum risk, proposed by Wald [22] in the 1940s. In spite of the passage of time, it is still being developed [23] and applied, both in economics [19] and to solve more thematically distant problems, e.g. in residential building construction [20].

Assuming that the choice is made based on Wald's rule, the smallest value (minimum payoff) should be determined for each strategy (each line) of the payoff matrix, and then the strategy for which the minimum payoff/benefit is the biggest should be selected. A strategy may be considered as optimal with respect to Wald's criterion if:

$$g_w = \max_i \{\min_j g_{ij}\} \tag{2}$$

where w denotes the number of the strategy considered to be optimal.

Decision-making in accordance with Wald's rule may involve two stages:

Step 1 – The lowest possible payoff (lowest possible benefit), i.e. the minimum for each line, is selected for each strategy.
Step 2 – Out of all the strategies, strategy number w is selected, for which the payoff value is the maximum out of the possible lowest values of this payoff.

3 Results

3.1 General Concept of the Problem

The key issue is to formulate the problem of selecting risk reduction measures as a decision-making problem (conflict situation) possible to solve with the use of the models of games with nature. It was therefore assumed that the game strategy will be the application of the appropriate RRM having an impact on the hazard source. States of nature are considered to be hazards identified in the analysis domain. In this case, the selection of the risk reduction measure is treated as a selection of one of the game strategies. In the context of supporting the process of selecting these measures with decision-making procedures, the following assumptions were formulated:

- hazard risk reduction measures are known,
- hazard sources present in the domain analysis are known,
- the efficacy of the hazard risk reduction measures is known,
- a hazard risk reduction measure has an impact on one or more hazard sources present in the domain analysis,
- the degree of efficacy of the hazard risk reduction measure assumes values from the set of positive real numbers within the range of $\langle 0; 1 \rangle$,
- a hazard is formulated as a coincidence of hazard sources,
- one hazard source may be the cause of identification of several hazards,
- the number of risk reduction measures and the number of hazard sources is finite,
- the aim of the safety system under design is to limit the risk of all the identified hazards,
- no other risk reduction measure is selected for a hazard whose sources are already being limited by a different measure.

Figure 2 presents the general algorithm of risk reduction measure selection according to the proposed concept. A detailed description of the individual steps of this algorithm was presented further in the article (Sect. 3.2).

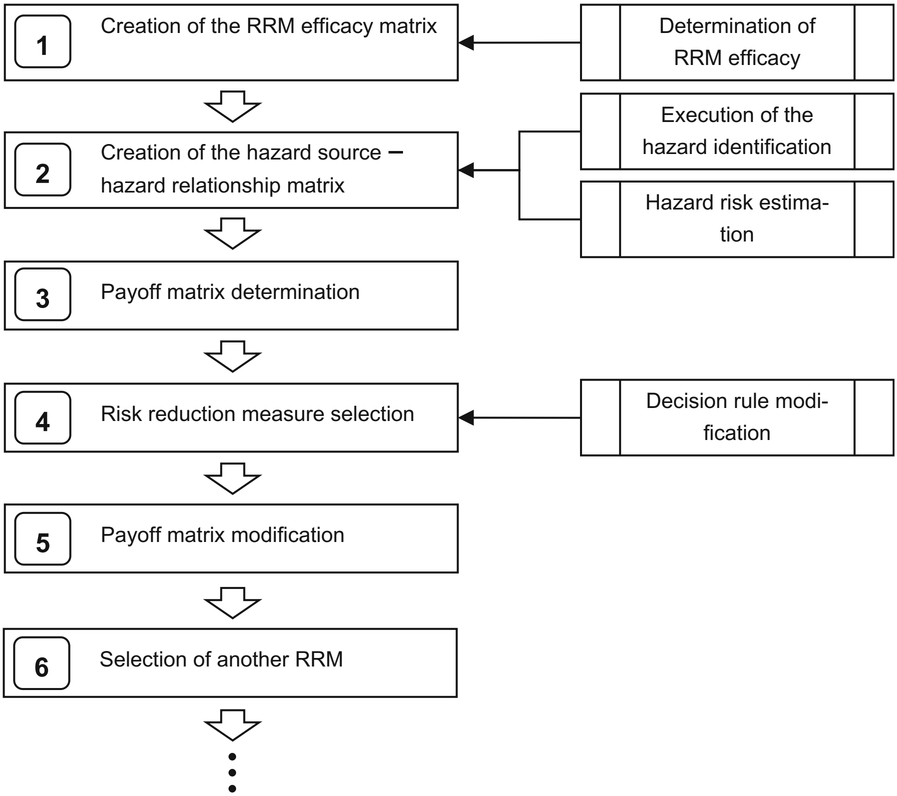

Fig. 2. General algorithm of risk reduction measure (RRM) selection for safety systems with the use of modified rules of games with nature.

The basis for the concept is the assumption that the payoff obtained by the designer of the safety system is the appropriate risk reduction. The risk reduction values obtained in the case of the selection of the *i*-th RRM and the occurrence of the *j*-th hazard source were therefore adopted as elements of the payoff matrix. In order to determine this matrix, information about the efficacy of risk reduction measures and information about the connections between hazard sources and hazards is needed. It is proposed that this information be presented also in the form of appropriate matrices.

Usually, due to a considerable number of hazard sources or the level of risk of these hazards, there is a need to select more than one risk reduction measure. In accordance with the concept developed and presented in [5], this may be done in two ways. The first one consists in the appropriate formulation of the decision-maker's strategy in the form of a specific combination of measures. The second one consists in selecting the game strategy several times, taking into consideration the selected rule or several different decision rules. The second way will be used in this paper.

3.2 Mathematical Model

Creation of the RRM Efficacy Matrix. Let **E** be a matrix mapping the possible actions of the designer of the safety system with regard to the hazard sources identified within the analysis domain. Matrix **E** is a rectangular matrix with the following form:

$$\mathbf{E} = \left[e_{ij}\right]_{m \times n}, i = 1, 2, \ldots, m;\ j = 1, 2, \ldots, n \tag{3}$$

where e_{ij} denotes the efficacy of the i-th RRM with regard to the j-th hazard source.

The efficacy of the RRM may be expressed as a combination of two variables [18]:

- the probability of RRM effect/activation,
- hazard source vulnerability to the effect of the given RRM.

It should be noted that the probability of the RRM having an effect is independent from the hazard source affected by the given RRM. And vulnerability is a feature of the hazard source and is understood here in the manner proposed in [1] as an extent to which the given RRM may positively impact this source.

The above definition may also be presented in a more illustrative way. For example, if we apply a certain RRM to 10 identical hazard sources whose vulnerability to this RRM equals 0.7, then statistically, seven hazard sources will be neutralised and three will remain active.

Drawing on the above explanations, the following events may be defined:

A – RRM activation,
B – positive reaction of the hazard source to the effect of the RRM,
C – RRM fulfilling its function.

In the statistical sense, event B depends on event A. If $P(B|\overline{A}) = 0$, then the probability of the product of events A and B equals [7]:

$$P(A \cap B) = P(C) = P(B|A) \cdot P(A). \tag{4}$$

Assuming that:

$$P(A) = p \text{ and } P(B|A) = v, \tag{5}$$

value e_{ij} – of the efficacy of a single RRM affecting the given hazard source may be expressed with the following formula:

$$e_{ij} = p_i \cdot v_{ij} \tag{6}$$

where p_{ij} denotes the probability of the effect of the i-th RRM, v_{ij} denotes the vulnerability j-th hazard source to the effect of the i-th RRM.

Creation of the Hazard Source (HS) – Hazard (H) Relationship Matrix. Because the previously specified relationships occur between hazard sources and hazards (see Sect. 2.1), matrix **H** – a matrix of relationships between HS – H elements may be determined. Therefore, let matrix **H** assume the following form:

$$\mathbf{H} = \lfloor r_{jk} \rfloor_{n \times l}, j = 1, 2, \ldots, n;\ k = 1, 2, \ldots, l \tag{7}$$

where r_{jk} denotes the value of risk determined for the k-th hazard.

For the decision-making purposes related to the optimisation of the structure of safety systems, the form of risk measure as a value of the following function [13] is assumed:

$$R : H \rightarrow V \subset \mathsf{R}, \tag{8}$$

which assigns values from a certain subset V of a set of real numbers R to hazards from set H.

The mathematical risk measure model usually includes several components whose values (levels) are determined in the risk analysis process according to specific criteria. In accordance with the typical definitions of risk (see for example [2, 10, 16, 21]), the components usually belong to two groups – a group of components expressing the possibility of the so-called hazard activation or materialisation and a group of components expressing losses after the activation of the hazard [14]. When the levels of all the risk components are determined, the total risk of the k-th (k = 1, 2, …, l) hazard may be notated as follows:

$$R(h_k) = f_1(r_1(h_k), r_2(h_k), \ldots, r_m(h_k)),\ k = 1, 2, \ldots, l. \tag{9}$$

where $r_i(h_k)$ is the i-th component of the risk of the k-th hazard.

So assuming one of the typical forms of the risk function and the fact that the elimination of a single hazard source is enough to not activate the hazard, value r_{jk} may be determined as follows:

$$\underset{j=1,2,\ldots,n}{\forall} \ \underset{k=1,2,\ldots,l}{\forall} r_{jk} = f(p_k, s_k) \Leftrightarrow r_{jk} = p_k \cdot s_k \tag{10}$$

where: p_k is the value of the probability of activation of the k-th hazard, s_k is the value of the results (damage/losses) of the activation of the k-th hazard.

If the events of the occurrence or activity of hazard sources are independent, then value p_k may be determined as follows:

$$p_k = \prod_{j}^{n} q_{jk} \tag{11}$$

where q_{jk} is the probability of the occurrence or activity of the j-th hazard source of the k-th hazard.

Payoff Matrix Determination. Let matrix **G** be the payoff matrix (benefit matrix, etc.). Matrix elements g_{ik} denote the decision-maker's benefit in the form of the values of risk reduction obtained in the case of selecting the i-th risk reduction measure for the j-th hazard source. Using matrices **E** and **H** defined before, matrix **G** is determined as follows:

$$\mathbf{G} = \mathbf{H} \times \mathbf{E} \tag{12}$$

Another step is the selection of the risk reduction measure with the use of the selected rule or several decision rules.

Decision Rule Modification. In the typically formulated decision-making problems which are solved using methods of games with nature, there is rarely a lack of benefits related to the occurrence of the established states of nature. In the case of the functioning of risk reduction measures, it is the other way round. Each risk reduction measure is usually dedicated to a single hazard source and does not affect other sources. This leads to zero values often occurring in matrix **E** and respectively in matrix **G**.

In such case, direct application of rule (1) may not lead to a solution being obtained. And so Wald's rule was modified by the introduction of a certain condition which makes it possible to establish the value of the solution with the occurrence of zero values of risk reduction measure efficacy. Using relationship (2), this was notated as follows:

$$g_w : \underset{g\_ij > 0}{\forall} g_w = \max_i \{\min_j g_{ij}\} \tag{13}$$

where w denotes the number of the line of payoff matrix **G** corresponding to the number of the risk reduction measure whose selection is considered to be optimal.

Risk Reduction Measure Selection. The last stage is the selection of a specific decision rule or the application of their selected sequence. Therefore, the not too optimistic variant may be assumed for instance, consisting in the occurrence of the least beneficial situation for the decision-maker, i.e. the hazard for which the least effective RRM was selected will be activated. Even in such situations, it is desirable that the system designer obtain the maximum benefit. It is therefore proposed to provisionally apply conservative rules, i.e. Wald's rule for example.

4 Case Study

The application of the proposed concept was illustrated with an example of a fire protection system for railway vehicles. Fires in railway vehicles are a special type of events, as the vehicles usually move with considerable speed and the breaking distance often exceeds several hundred metres. Moreover, in trains, fires develop differently than e.g. in buildings, which is due to a number of factors, including the elongated shape of the vehicle, good thermal insulation accumulating heat and causing a large temperature increase because of the low heat capacity of the vehicle. In such conditions, fire and smoke spread very quickly and evacuation from the vehicle which is on fire is difficult.

It is hindered by narrow corridors, doors not opening while the vehicle is moving, and unopenable windows used in air-conditioned trains. Additional difficulties in carrying out rescue operations occur when the accident takes place in an area which is hard to reach, e.g. far from access roads, on a bridge, and particularly in a tunnel.

In connection with thus specified analysis domain, hazard sources were identified (Table 2), and based on them, hazards were formulated (Table 1). The scope of losses or damage related to the activation of these hazards is very broad and arises out of the previously mentioned determinants of the domain analysis.

Table 1. Hazards related to electrical systems in railway vehicles.

ID*	Hazards
H1	Possibility of losses related to a fire caused by a short-circuit of wires in the control cabinet
H2	Possibility of losses related to a fire caused by heating of electrical system equipment in passenger compartments
H3	Possibility of losses related to a fire caused by sparking of electrical connections
H4	Possibility of losses related to a fire caused by accidental arson (butt-end)
H5	Possibility of losses related to smoke

*Hazard identifier

Table 2. Hazard sources related to electrical systems in railway vehicles and the probability of their activity/occurrence.

j	ID*	q**	Hazard sources	H1	H2	H3	H4	H5
1	HS1	0.10	Damaged wire insulation layer caused by vibrations	x				
2	HS2	0.01	Contamination (dust, dirt, grease, etc.) e.g. in ventilating ducts	x		x		x
3	HS3	0.39	Electric power of devices (e.g. air-conditioning)	x		x		
4	HS4	0.01	Actions of people – passengers				x	
5	HS5	0.06	Thermal output of the electrical system equipment		x			x
6	HS6	0.05	Sparking of electrical connections			x		

*Hazard source identifier
**Probability of the occurrence of hazard sources assumed based on [15] among others

Very often, before any losses or damage occur, the effect of the coincidence of hazard sources is the occurrence of the so-called undesirable events (UEs). The term is used to describe events which may cause losses or damage (definition – [6, 13]). An example of an undesirable event is mechanical or chemical damage to the insulation layer of the electrical system wires in the vehicle. The reason for mechanical damage may be a coincidence of the following hazard sources: vibrations, contamination (e.g. particles of sand), deformations, and wire displacement. Reasons for chemical damage may include chemical compounds (such as oils, greases, fuels, liquids). Connecting undesirable events with corresponding hazard sources should lead to the formulation of a hazard. This was presented in diagrammatic form in Fig. 3.

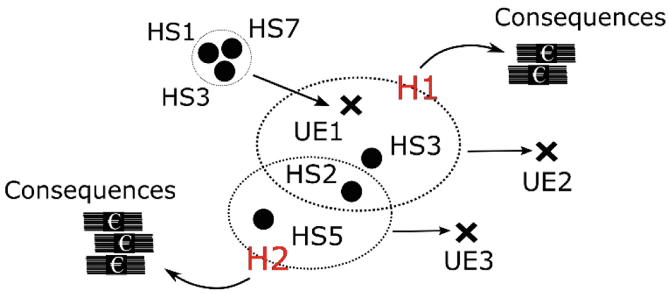

Fig. 3. A fragment of the relationships between the elements of the identification of hazards concerning electrical systems in railway vehicles, where: UE1 – mechanical damage to the outer layer of wires, UE2 – a fire caused by a short-circuit of wires in the control cabinet, UE3 – a fire caused by heating of electrical system equipment in passenger compartments, HS7 – contamination e.g. particles of sand, (HS and H identifiers in accordance with Tables 1 and 2).

Table 3. Risk reduction measures related to electrical systems in railway vehicles.

ID*	Risk reduction measures	HS1	HS2	HS3	HS4	HS5	HS6
RRM1	Fuses with a fault indicator			x			
RRM2	Cable ducts	x	x				
RRM3	Pictographs and information about fines				x		
RRM4	Voice information				x		
RRM5	Regular maintenance (cleaning)		x				
RRM6	Ventilation of enclosed spaces					x	
RRM7	Insulation of wires from cross-linked polymers	x					
RRM8	Spring connectors						x

*Risk reduction measure identifier

Using the information presented in Tables 1 and 2, the following HS – H (hazard source – hazard) relationship matrix was prepared:

$$\mathbf{H} = \begin{bmatrix} 7.80 & 0 & 0 & 0 & 0 \\ 7.80 & 0 & 1.37 & 0 & 3.00 \\ 7.80 & 0 & 1.37 & 0 & 0 \\ 0 & 0 & 0 & 10.00 & 0 \\ 0 & 60.00 & 0 & 0 & 3.00 \\ 0 & 0 & 1.37 & 0 & 0 \end{bmatrix} \tag{14}$$

Risk values in matrix **H** were calculated in accordance with the relationship of (10) and (11), using the values of probability q_{jk} provided in Table 2, and the following values of the results (damage/losses) of hazard activation were assumed: s_1 = 20,000, s_2 = 1,000, s_3 = 70,000, s_4 = 1,000, s_5 = 5,000.

Using the information presented in Tables 2 and 3 and relationship (6), the following RRM efficacy matrix was prepared:

$$\mathbf{E} = \begin{bmatrix} 0 & 0 & 0.99 & 0 & 0 & 0 \\ 0.90 & 0.95 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.60 & 0 & 0 \\ 0 & 0 & 0 & 0.70 & 0 & 0 \\ 0 & 0.80 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.90 & 0 \\ 0.95 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.85 \end{bmatrix} \quad (15)$$

Next, in accordance with relationship (12), the payoff matrix **G** was determined:

$$\mathbf{G} = \begin{bmatrix} 7.72 & 0 & 1.35 & 0 & 0 \\ 14.43 & 0 & 1.30 & 0 & 2.85 \\ 0 & 0 & 0 & 6.00 & 0 \\ 0 & 0 & 0 & 7.00 & 0 \\ 6.24 & 0 & 1.09 & 0 & 2.40 \\ 0 & 54.00 & 0 & 0 & 2.70 \\ 7.41 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1.16 & 0 & 0 \end{bmatrix} \quad (16)$$

The result of the first iteration of the calculation algorithm in which rule (13) was used is the value of 7.41, indicating RRM number 7, which is the insulation of wires from cross-linked polymers. In accordance with the assumptions of the method presented herein, no other RRM is selected for a hazard whose sources are already being limited by a different measure. Therefore, as can be inferred from Tables 1 and 2, the application of RRM7 will make it possible to deactivate hazard H1. This should be included in matrix **H** by zeroing the values in the first column. Thus modified matrix **H** can be 'passed forward' for another iteration if there are still some hazards remaining whose risk has to be mitigated.

As part of the case study presented herein, further iterations were performed, again with the use of modified Wald's rule. The result is the numbers of the following risk reduction measures which the safety system should include: insulation of wires from cross-linked polymers (RRM 7), voice information (RRM 4), ventilation of enclosed spaces (RRM 6), cable ducts (RRM 2), and regular maintenance – cleaning (RRM 5).

5 Final Remarks

The application of the rules of the models of games with nature (decision rules) makes it possible to make decisions under conditions of uncertainty in a relatively easy manner. Such situation occurs in the process of designing safety systems, as the possibilities of the occurrence of certain domain states for which safety systems are established and designed are usually unknown or only assumed. However, it is not possible to apply the algorithms of the presented decision rules directly. Above all, it is necessary to determine the basic components of the models, i.e. the game strategy and the state of nature. The game strategy should be the application of the appropriate risk reduction measure having an impact on the hazard source(s). States of nature should be defined as hazards identified in the analysis domains. The selection of the risk reduction measure can then be treated as a selection of one of the game strategies.

In the typically formulated decision-making problems which are solved using methods of games with nature, there is rarely a lack of benefits resulting from the selection of a game strategy in reference to states of nature. It is different in the case of functioning of safety systems, as the risk reduction measure may not have an impact on some of the hazard sources. In other words, zero values often occur in the efficacy matrix and respectively in the payoff matrix. This is solved by the introduction of a logical condition which does not take into consideration the lack of impact and the zero values in the payoff matrix. This particularly concerns decision rules in which the ‘min’ operator is used.

The presented specific nature of the functioning of safety systems often necessitates the selection of not just one measure, but their appropriate combination. This may be solved by applying the so-called sequential selection, which consists in selecting the game strategy several times, taking into consideration one selected rule or several different decision rules. In accordance with the assumptions of the method presented herein, no other risk reduction measure is selected for a hazard whose sources are already being limited by a different measure. It should be kept in mind that this should be included in the payoff matrix by zeroing the values in the appropriate column of this matrix. Thus modified payoff matrix can be ‘passed forward’ for another iteration if there are still some hazards remaining whose risk has to be mitigated.

As an example of the adaptation of the rules of the models of games with nature for the design of safety systems, the case of fire protection systems in railway vehicles was selected. This is a special type of the so-called high-risk domains, as the activation of the hazards identified there can manifest itself in disastrous consequences. The example is a study case, but it shows the consecutive steps of problem solving in detail. It also makes it possible to draw a conclusion about the substantial utility of the proposed approach. The maximum effect (reduction of the risk of all the hazards) is achieved with the use of the least effective (and maybe the least expensive) measures. Moreover, the structure of the safety system may be limited, which considerably simplifies its management, and in particular may significantly influence its maintenance costs.

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Universal Design of Information Sharing Tools for Disaster Risk Reduction

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Abstract. Disaster information sharing tools are an important aspect of disaster resilience, and it is of utmost importance that these tools are accessible and usable for as many potential users as possible. In this paper, we evaluate the accessibility of a selection of tools for crowdsourcing disaster situation information. As our evaluation shows that the selected tools are not fully accessible, we provide recommendations for mitigation, as well as highlight the importance of further research in this area.

Keywords: Disaster information sharing tools · Disaster resilience · Disaster Risk Reduction (DRR)

1 Introduction

A majority of the world's population now lives in urban areas. Several global reports concern this rapid urban growth symptom introducing new vulnerabilities and increasing risk of disasters, e.g. more people living in disaster-prone areas. One of the vulnerable groups are people with disabilities. UNISDR global survey involving 5,717 respondents worldwide on People with Disabilities (PWDs) indicates that PWDs are rarely consulted about their needs in potential disaster situations. Majority of them neither have participated in community disaster management and risk reduction processes currently in place in their communities, nor have a personal preparedness plan in the event of a disaster. In fact, these PWD respondents face some hazard risks, especially, floods, extreme weather, tornadoes, earthquake and cyclones [1].

Stough and Kelman [2] documented narratives from disaster survivors with disabilities and find that they are characterized by passivity, helplessness and a lack of resilience. The narratives also reveal the barriers where both social and environmental factors prevent them from being fully included in their communities and from participating in the disaster risk reduction. At the organizational level, the practice of exclusion of the diversity of people causes the emergency services to not be well prepared to handle all forms of disabilities.

With today's development on the Information and Communication Technology (ICT), both scientists and practitioners concur that appropriate ICT technology can

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improve disaster management and crisis communication in all cycles: preparedness, response and recovery in terms of the needs of PWDs [3, 4].

The accessibility of crisis communication tools intended for enhancing societal resilience has not yet been fully taken into account. These tools are particularly important for reaching out to the vulnerable groups in the societies, including PWD, especially in highly populated and dense areas such as cities.

The Hyogo Framework Action (HFA) outlines the importance for building the resilience culture in all levels, and encourages pro-active community participation [5]. Resilience itself has been defined as “the capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure” [6].

However, HFA has little attention toward the needs of PWD although Phibbs et al. [16], for instance, try to clarify the linkage between emergency management agencies working with PWD and the HFA. The issue of PWD are defined better in the Sendai Framework for Disaster Risk Reduction (SFDRR) [7] which also addresses themes linking the PWD and universal design.

First theme is related to universal design with support tools and build environment. Ramps, for instance, assists PWD in disasters, such as fastening the evacuation of people with wheelchairs. With universal design, the build environment should not put the vulnerable people in a disadvantaged group in a disaster. Second theme emphasizes inclusivity of disaster preparedness, response and mitigation activities. This approach incorporates the needs and viewpoints of other marginalized groups and potentially strengthens overall resilience. Third theme deals with accessible technology and communication during the disasters. Fourth theme highlights the importance of stakeholders such as individual person with disabilities and disability organizations to collaborate during the emergency planning and recovery. In brief, the concepts of inclusion, universal design and accessibility have been included in SFDRR to empower people with disabilities in disaster and eventually strengthen the community resilience in general.

In the context of community engagement, the role of ICT tools to enable the society in general to adapt and recover from hazards and stresses is evident as reflected in one of the pivotal themes in SFDRR, especially to ensure that the crisis information flows smoothly to the intended audience. Many ICT tools have been created for alerting citizens and for community engagement purposes, which allow information flows from the public to the government, from government to public, or information sharing among communities [3, 8–13]. Typically, information sharing tools are provided in the form of web sites or mobile phone apps. The question is then: have these tools taken into account the universal design aspect into the tool development process?

Universal design is the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design. However, in this paper we refer to universal design primarily in terms of web accessibility. According to WAI/W3C, for the web, accessibility means that people with disabilities can perceive, understand, navigate, and interact with websites and tools, and that they can contribute equally without barriers [14]. For the purpose of ensuring accessibility of web pages, the Web Content Accessibility Guidelines (WCAG) have been developed, currently at version 2.0 with a new version 2.1 in the pipeline. These guidelines include success criteria that can be used to evaluate the accessibility of web pages.

Our research goal is to identify the accessibility issues in the tools for disaster resilience and provide recommendations for improvement. We will in particular focus on accessibility of web-based information sharing tools for disaster resilience.

1.1 Research Question

Our main research question in this paper is to what extent universal design and accessibility has been taken into account in existing samples of engagement tools in selected countries intended for disaster resilience. To answer this question we conduct tests based on WCAG 2.0 on samples of pages from selected information sharing tools.

1.2 Organisation

The rest of the article is organised as follows. Section 2 briefly cover related work. The method is explained in Sect. 3. The results of the tests are reported in Sect. 4, and discussed in Sect. 5. Section 6 concludes this paper and lays down our future research agenda.

2 Literature Review

Disaster management and crisis communication that support and include PWDs have been discussed in the literature [2, 3, 6–12, 15–17]. Alexander [18] makes clear the distinction between disaster management and response for the general public and measures also intended to accommodate PWDs where the latter requires a specific adjustment that can ensure inclusivity.

According to Stough and Kang [7] “Accessibility” within the disaster context not only refers to physical access to emergency evacuation vehicles and shelters but also access to emergency communications and disaster resources. The term “inclusive” within the disability community is used to convey the notion that people and societies should accommodate the needs of people with disabilities. Community engagement through ICT supported tools has been proposed as a way to improve resilience. The understanding of the ecosystem concerning PWDs at the micro, meso, exo and macro levels are highly important to get a comprehensive understanding on response to reduce the disaster risks [19]. In this paper, we will focus on the universal design of communication technology support, especially web accessibility.

Literature [18, 20] point out the importance of information systems (ISs) for crisis response and management for supporting people with disabilities and other vulnerable groups, which is in fact often overlooked by emergency response organizations in rescue operations. This literature, however, only identifies the gap in current practice where information on the vulnerable groups is not included. The recommendations to improve this situation, among other things are to include this information in the ISs for emergency response [20] and to improve the coordination among the agencies that deal with the needs of PWD.

Kent and Elis [11] discuss the use of social media mash-up (Facebook, Twitter, YouTube) as communication channels for disaster situations that are not always accessible for PWDs. They extend the definition of disability to also include digital disability, in terms of access communication and internet. This is because digital disability affects a person's ability to survive in a disaster. The study reveals that Twitter, Facebook, and MySpace, for example, are inaccessible for people with disabilities [10, 11]. Despite lacking the inclusivity and universal design principles, these social media are continuously recommended [12] as alternative tools to increase community engagement that eventually will improve the community disaster resilience. Likewise, adoption of the alert systems for emergencies using mobile phone is growing, but still the needs of people with disabilities are not entirely addressed. For example usage of visual symbols depicting threats and appropriate actions are rarely taken into account [10]. Therefore, Hakkinen et al. [9] address that the development of accessible web content has allowed software developers to render information in a combination of synthetic or natural speech, in Braille, and visually, with the styling of the presentation to include speech and non-speech cues. Hence, the information is accessible to PWDs.

On the use of technologies to improve accessibility, Benneth et al. [3] suggest the use of wireless technologies to empower PWDs regarding individual preparedness (technology outreach), response (warning and reaction), recovery (enable location of accessible shelters) and mitigation (wireless technologies integrated into post-disaster reconstruction). Benneth et al. provide an excellent, comprehensive framework on the use of wireless technologies and how it helps PWDs, at different emergency management stages and different ecosystems of PWDs at micro, meso, exo and macro levels. However, many of these futuristic technologies have not yet been embraced in current disaster management practices, and how far the web-based platform will be a part of the suggested future disaster response are still vague. Therefore, despite sounding promising in improving accessibility for PWDs, it is still hard to evaluate the practical implementation of these notions.

While web accessibility testing is a quite common approach to testing webpages, studies that focus on accessible web information for emergency management are rare. We found literature on web accessibility testing for emergency webpages, for example, Wentz et al. [21]. The authors evaluate the accessibility of 26 emergency alert sign-ups in Massachusetts, New York, and Maryland, and point out that the sign-up process for emergency-related information is in fact inaccessible. An extensive hybrid approach, i.e. a usability test and an expert inspection is applied. The inspection tasks focus on accessibility of the link to the sign-up page, the description, the form field, button labels, required field notification, CAPTCHA, progress indicator and alternative mean to register the alert service. The authors found that out of 26 sign-up pages, 21 have one or more accessibility violations. Slightly different in our study, we evaluate the content of webpages for information sharing in crisis situations using automatic tests, and we do not look at the login process of the selected webpages listed in Sect. 3.1.

To sum up, there are increased global awareness on inclusive emergency management, and efforts to empower and build resilience among vulnerable groups including PWDs with the help of technology, but still, universal design and accessibility are lacking at the practical level.

3 Method

In this section, we cover the test method, metrics and tools for assisting in the testing, as well as the selection of tools to be evaluated.

3.1 Selection of Information Sharing Tools for Evaluation

Ushahidi [22] or Google Crisis Response [23] are examples of platforms for community mapping. Some of these ICT-based tools support crowdsourcing. In different countries, smartphone apps for emergencies have been widely used as communication tools by the government such as FEMA App, Hurricane App (USA), Disaster Alerts, Emergency+, First Aid or Fire Near Me (Australia). Globally, some apps have been developed to alert of earthquakes such as QuakeWatch [24], Earthquake buddy [25] or Disaster Alert [26]. Other platforms include Wiki for professionals [27] and Emergency 2.0 Wiki [28].

For this evaluation, we have selected the tools Ushahidi Syria-tracker, Google Crisis Response Person Finder demo, Quake Watch Prediction Center, Wiki for professionals and Emergency 2.0 Wiki.

3.2 Test Metrics

For evaluation of the selected tools, we have primarily used automatic evaluation based on Web Content Accessibility Guidelines (WCAG) 2.0. WCAG 2.0 is divided into 4 primary principles. A web page should be: perceivable, operable, understandable, and robust. Based on these principles, 12 guidelines are stated. They provide the objectives for accessible web design, but are not testable as such. Therefore, each guideline comes with success criteria that can be tested either automatically or manually. These success criteria facilitate conformance testing, and the automatically testable subset of these success criteria provides the basis for the evaluation performed in this paper.

WCAG 2.0 defines three levels of conformance, A, AA and AAA (the highest), to be achieved depending on which success criteria are passed. Usually, AA is recommended as a target for conformance testing instead of AAA, as stated in the documentation for WCAG 2.0 "It is not recommended that Level AAA conformance be required as a general policy for entire sites because it is not possible to satisfy all Level AAA Success Criteria for some content." [29] Conforming to Level AA means that all success criteria for Level A and AA are passed.

3.3 Selection of Automatic Evaluation Tool

Several tools both commercial and free are available for automatic checking of WCAG 2.0 compliance. Example of free tools are AChecker [30] and Mauve [31], while powermapper, Siteimprove, and FireEyes are examples of commercial ones. We needed a tool that could support WCAG 2.0 tests, and support validation through URL, HMTL file upload or direct html input. In this work, we have selected AChecker since it satisfies these requirements.

3.4 Test Method

We have selected a sample of 2 pages from each site, the main page, and a page related to information submission. This is to check if the crowdsourcing functionality is accessible. Normally one can put the URL of the page to be tested and AChecker will provide the test results. In our test, we found that if we give the URL, Syria Tracker serves a blank page. Therefore, we opened each web page to be tested in the Google Chrome browser (version 60.0.3112.113), and pasted the page source into AChecker.

The following options were selected in AChecker:

- HTML Validator is enabled.
- WCAG 2.0 (Level AA) is selected as conformance level to check against.

The validation of the HTML source is an extra check to verify that the page complies with the HTML standard. Although many web browsers are quite capable of repairing broken HTML, valid HTML ensures that the page can be read with a variety of user agents (web browsers) including screen readers and other assistive technologies.

Some tests are not fully automatable. In addition to known problems, AChecker reports issues that are likely problems and potential problems. Both of these classes of issues require manual verification, and the difference is that while likely problems refer to an element or combination of elements that tend to indicate a problem, potential problems refer to common web page elements that has potential problems, and while there are no specific indications that there are problems present, it cannot be determined automatically. Here, we have performed a manual check on all reported likely problems.

4 Experiments

In this section, we report the results of testing the web site primary page (not necessarily the front) and information submission page of the selected web sites using AChecker against WCAG 2.0 level AA.

4.1 Results Overview

Tables 1 and 2 give an overview of the problems detected by AChecker for the main pages and the information submission pages, respectively. They are divided into known problems (problems identified with certainty), likely problems (probably a problem but require manual check to be certain), and potential problems (problems that may or may not be present, and require human interaction to determine). In addition, we asked AChecker to report HTML Validation errors, as mentioned above in the Method section. In the tables we also provide the URL to the tested page.

Table 1. Overall results main page (AChecker)

	Known problems	Likely problems	Potential problems	HTML validation
Ushahidi Syria Tracker https://syriatracker.crowdmap.com/	6	1	308	11
Google Crisis Response Person finder demo https://google.org/personfinder/demo	1	1	68	0
Quakewatch Prediction Center http://quakewatch.net/predictioncenter/	8	3	190	0
Crisis Communication Wiki for prof. http://www.crisiscommunication.fi/wiki/	19	1	267	0
Emergency 2.0 Wiki http://emergency20wiki.org/wiki/index.php/	16	1	266	22

Table 2. Overall results information submission page (AChecker)

	Known problems	Likely problems	Potential problems	HTML validation
Ushahidi Syria Tracker https://syriatracker.crowdmap.com/reports/submit	85	1	300	10
Google Crisis Response Person finder d. https://google.org/personfinder/demo/query?role=provide	1	1	66	0
Quakewatch Prediction Center http://quakewatch.net/forums/	16	0	212	0
Crisis Communication Wiki for prof. http://www.crisiscommunication.fi/index.php?option=com_users&view=registration	1	0	171	0
Emergency 2.0 Wiki http://emergency20wiki.org/contact-us	12	1	522	62

4.2 Known Problems

Tables 3 and 4 show the detected known problems, with a reference to the success criteria in question. The referenced guidelines and success criteria are provided in Subsect. 4.5.

Table 3. WCAG 2.0 AA known problems for main page (AChecker)

	Perceivable	Operable	Understandable	Robust
Ushahidi Syria Tracker	1.3.1a	2.4.6	3.3.2	4.1.1
Google Crisis Response Person finder demo	1.3.1a			
Quakewatch Prediction Center	1.3.1a, 1.4.4	2.4.4a	3.3.2	4.1.1
Crisis Communication Wiki for professionals	1.4.4	2.4.4a	3.3.2	4.1.1
Emergency 2.0 Wiki	1.1.1, 1.4.4, 1.4.6	2.4.6		

Table 4. WCAG 2.0 AA known problems for information submission page (AChecker)

	Perceivable	Operable	Understandable	Robust
Ushahidi Syria Tracker	1.3.1a	2.4.6	3.3.2	
Google Crisis Response Person finder demo	1.3.1a			
Quakewatch Prediction Center	1.1.1, 1.3.1a, 1.4.4		3.3.2	
Crisis Communication Wiki for professionals			3.3.2	
Emergency 2.0 Wiki	1.3.1a, 1.4.3	2.4.6	3.3.2	

4.3 Likely Problems

In addition to the clear problems detected in the previous subsection, the following likely problems were detected, as shown in Tables 5 and 6. They are marked with strikethrough in the cases where they were found not to be a problem after manual checking.

Table 5. WCAG 2.0 AA likely problems for main page (AChecker)

	Perceivable	Operable	Understandable	Robust
Ushahidi Syria Tracker			~~3.2.2~~	
Google Crisis Response Person finder demo			~~3.2.2~~	
Quakewatch Prediction Center	~~1.3.1b~~			
Crisis Communication Wiki for professionals			~~3.2.4~~	
Emergency 2.0 Wiki	1.3.1b			

Table 5 shows that Usahidi Syria Tracker as well as Google Crisis Response Person Finder Demo triggers a likely problem regarding success criteria 3.2.2, which refers to making web pages appear and operate in predictable ways. The select element could cause extreme change in context. However, here it is used as a language picker, changing the content to the selected language, but not the context.

1.3.1b refers to a paragraph element that may be used as header. That is not the case for Quakewatch, however, in the case of Emergency 2.0 Wiki a manual examination confirms that there is a bold p paragraph used as a header without being tagged as such. Finally, Crisis Communication Wiki for professionals triggers the 3.2.4 test case concerning list item used to format text. However, this is triggered by an actual list.

Table 6. WCAG 2.0 AA likely problems for information submission page (AChecker)

	Perceivable	Operable	Understandable	Robust
Ushahidi Syria Tracker			~~3.2.2~~	
Google Crisis Response Person finder demo			~~3.2.2~~	
Quakewatch Prediction Center				
Crisis Communication Wiki for professionals				
Emergency 2.0 Wiki		2.4.4b		

As shown in Table 6, Ushahidi Syria Tracker and Google Crisis Response person finder demo trigger 3.2.2, but as in the previous case it refers to a harmless language picker and not a problem. Emergency 2.0 Wiki triggers test case 2.4.4 referring to making the purpose of a link clear, with a "suspicious link text" "More". In this case it refers to more ways to share the page, and is not part of the essential functionality of the page. However, for users of screen readers that list up all links on a page, the lack of clear link text is actually a real issue.

Table 7. WCAG 2.0 AA problems for main page (AChecker)

	Perceivable	Operable	Understandable	Robust
Ushahidi Syria Tracker	Fail (1.3.1)	A (2.4.6)	Fail (3.3.2)	Fail (4.1.1)
Google Crisis Response Person finder demo	Fail (1.3.1)	AA	AA	AA
Quakewatch Prediction Center	Fail (1.3.1, 1.4.4)	Fail (2.4.4)	Fail (3.3.2)	Fail (4.1.1)
Crisis Communication Wiki for professionals	A (1.4.4)	Fail (2.4.4)	Fail (3.3.2)	Fail (4.1.1)
Emergency 2.0 Wiki	Fail (1.1.1, 1.3.1, 1.4.4, 1.4.6)	A (2.4.6)	AA	AA

4.4 Evaluation Results

In Tables 7 and 8, results for each category are given as Fail, or pass level A, AA; and failed success criteria are given in parenthesis. More details on these failed criteria are provided in Sect. 4.4 above.

Table 8. WCAG 2.0 AA problems for information submission page (AChecker)

	Perceivable	Operable	Understandable	Robust
Ushahidi Syria Tracker	Fail (1.3.1)	A (2.4.6)	Fail (3.3.2)	AA
Google Crisis Response Person finder demo	Fail (1.3.1)	AA	AA	AA
Quakewatch Prediction Center	Fail (1.1.1, 1.3.1, 1.4.4)	AA	Fail (3.3.2)	AA
Crisis Communication Wiki for professionals	AA	AA	Fail (3.3.2)	AA
Emergency 2.0 Wiki	Fail (1.3.1, 1.4.3)	Fail (2.4.4, 2.4.6)	Fail (3.3.2)	AA

4.5 Guidelines, Tests and Success Criteria

The success criteria mentioned in the sections above refer to the following guidelines and success criteria from WCAG 2.0:

Principle 1 Perceivable: Information and user interface components must be presentable to users in ways they can perceive.

- *Guideline 1.1 Text alternatives*: Provide text alternatives for any non-text content.
  - 1.1.1 Non-text content (A): Image used as anchor is missing valid Alt text.
- *Guideline 1.3 Adaptable*: Create content that can be presented in different ways (for example simpler layout) without losing information or structure.
  - 1.3.1a Info and Relationships (A): Missing labels.
  - 1.3.1b Info and Relationships (A): p element may be misused (could be a header).
- *Guideline 1.4 Distinguishable*: Make it easier for users to see and hear content including separating foreground from background.
  - 1.4.3 Contrast (Minimum) (AA) The contrast between the colour of selected link text and its background is not sufficient.
  - 1.4.4 Resize text (AA): *i* (italic) element used instead of *em* or *strong*; *font* used.

Principle 2 Operable: User interface components and navigation must be operable.

- *Guideline 2.4 Navigable*: Provide ways to help users navigate, find content, and determine where they are.
  - 2.4.4a Link purpose (in context) (A): Anchor contains no text.
  - 2.4.4b Link Purpose (In Context) (A): Suspicious link text (contains placeholder text).
  - 2.4.6 Headings and Labels (AA): Incorrect header nesting.
  - 2.4 Navigable: Provide ways to help users navigate, find content, and determine

Principle 3 Understandable: Information and the operation of user interface must be understandable.

- *Guideline 3.2 Predictable:* Make Web pages appear and operate in predictable ways.
  - 3.2.2 On Input (A): Select element may cause extreme change in context.
  - 3.2.4 Consistent Identification (AA): List item used to format text.
- *Guideline 3.3 Input assistance*: Help users avoid and correct mistakes.
  - 3.3.2 Labels or Instructions (A): Empty label text.

Principle 4 Robust: Content must be robust enough that it can be interpreted reliably by a wide variety of user agents, including assistive technologies.

- *Guideline 4.1 Compatible*: Maximize compatibility with current and future user agents, including assistive technologies.
  - 4.1.1 Parsing (A) id attribute is not unique.

5 Discussion of Implications and Limitations

5.1 Summary of Results

From the results shown in the previous section, we see that none of the tools are fully compliant even to level A. For the main pages, three of them fail at 3 of the 4 main principles of WCAG 2.0. For the information submission pages, the situation is a bit better, and we see that all of them conform to level AA on the robustness criteria, and all are operable at least at the A level. The most common detected issues include:

- Missing labels (1.3.1) is an issue present in all tested tools except *Crisis Communication Wiki for professionals.* Missing labels could affect screen reader users who rely on screen readers to understand the meaning and intention of the web elements (e.g. buttons).
- Resizing issues (1.4.4) affects *Quakewatch Prediction Center*, *Crisis Communication Wiki for professionals* and *Emergency 2.0 Wiki.* Resizing affects users with visual impairments, making it more difficult to adapt the web site to their needs.
- Lack of instructions or help (3.3.2) affects all sites except *Google Crisis Response Person finder demo.* Instructions or help are essential for users to learn how to use the web sites and get help when needed. They can also help users to prevent errors and understand error messages. Without appropriate instructions or help function, it is often difficult for users to understand what they should do and how to interact with certain functions.
- Compatibility issues (4.1.1) affects *Ushahidi Syria Tracker*, *Quakewatch Prediction Center* and *Crisis Communication Wiki for professionals*. Lacking the robustness to ensure compatibility with current and future user agents, including assistive technologies.

5.2 Implications for Emergency Management

It is important to be aware that situational disabilities may affect people in emergencies. In general, issues such as being unable to type messages on a mobile phone virtual keyboard due to cold, wet and shaky hands, noisy background, only using one hand, bumpy roads, eyes are busy observing surrounding areas. These situations are likely to occur in a disaster situation, adding to the importance of the universally designed information sharing tools. Little research has focused on accessibility and universal design of disaster information sharing tools with respect to situational disabilities. We would like to highlight that following recommendations and guidelines for accessibility and universal design will also benefit users in these situations greatly.

When such a system is not accessible, it could in the worst case lead to some users not being able to access life-saving information. It is not only the lives of PWD that are at stake, and we can easily imagine that because of an inaccessible system, some users might not be able to submit important information, that could help facilitate the rescue of many potential disaster victims.

Although the set of criteria tested as well as the selection of pages from each site are limited in this study, it is enough to be able to say that the websites in question are not fully accessible for all users. Since most of these sites are experimental and not fully relied on in an emergency situation yet, it may be tempting to think that universal design and accessibility is an aspect that can be added in later versions of the tools. However, it is important to be aware that to be successfully realised, universal design should be factored into the process from the start. It should be explicitly stated in the requirements, emphasized through the design and development, and verified through extensive testing. Not only conformance testing for WCAG 2.0 and HTML validation should be performed, but also user testing with a broad diversity of users and user agents including assistive technologies.

5.3 Limitations

Access to disaster information is important to citizens. This study illustrates an exploratory examination of the accessibility on a set of samples of web pages intended for communicating information for improving disaster risk reduction and effort for enhancing community resilience, empowering vulnerable group and PWDs emergency. In some countries, emergency information is sometimes hidden as a pre-set setting of the main e.g. municipality portals, and will be activated when disasters strike. In this case, it is difficult to assess if actually the pages meet accessibility criteria.

However, there are some limitations in this research that could be addressed in the future research projects. First, user testing and expert testing are not implemented in this study, which actually can provide more comprehensive overview of web barriers. Second, we use very limited samples of webpages. Third, the quality of automatic testing tools varies and can contain some weaknesses, resulting inconsistent results from one to another tool. In this paper, we do not evaluate or compare the quality of the testing tools. A thorough heuristic testing and user testing with a broad diversity of users will likely reveal some barriers that have not been detected by the automatic testing [32], while some automatically detected barriers may not be a problem in practice.

6 Conclusions and Future Work

Our experiments reveal that improvements of web-based information sharing tools are required in order to include as wide range of users as possible. This can be achieved by putting stronger focus on the importance of universal design and web accessibility of these tools which eventually will enhance the disaster resilience of communities. More specifically, improvement of the tools should focus on the following aspects:

1. Providing labels for web elements in order to support screen reader users.
2. Providing and improving resizing functions.
3. Providing instructions and help.
4. Improving compatibility with current and future user agents, including assistive technologies.

Future work includes using a broader range of manual and automatic test methods and tools to evaluate the universal design of the selected disaster information sharing tools. We will perform heuristic evaluation as well as user testing, with a focus on different user groups. Finally, testing a broader range of tools including mobile apps and tools for different aspects of emergency management is part of the future work.

Since we have focused on dedicated tools for disaster information sharing, we have not covered the crowdsourcing of disaster information through social media. Smartphone apps are also out of our scope in this study. However, they are highly relevant when it comes to universal design of disaster information sharing, and will be covered in later studies.

For future directions, more recent technologies such as wearable devices can be used by the first responders in emergency response Benneth et al. [3], to improve communication with people. Wearables can assist by providing accessible information such as braille, text, voice or ASL interpretation. In combination with the recent trend of interconnected devices, they can improve a quick response for people needing rescue.

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Estimating the Probability of Earthquake Magnitude Between Mw = 4 and Mw = 5 for Turkey

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Abstract. Earthquake is a type of disaster that occurs suddenly in different magnitudes. When magnitude of an earthquake increases it is expected that the effects are much more. Earthquakes in varying magnitude between 4 Mw and 5 Mw cause uneasiness among the public even if they do not cause heavy damage. The aim of this study is to estimate the probability of an earthquake between 4.0 and 5.0 by using artificial neural network model. Monthly real data between 2006 and 2015 is used for the model. Data is analyzed in MATLAB neural network tool, then estimated output value obtained via analysis and output of test value is compared with regression equation. Besides, seasonal effects on magnitude of earthquake are examined. Results show that 90.51% of the earthquake probability between 4.0 and 5.0 can be estimated by using artificial neural network model.

Keywords: Artificial neural network · Earthquake · Magnitude · Seasonal effect · MATLAB

1 Introduction

Earthquake is a sudden, rapid shaking of the Earth that causes losses in terms of human and materials also leaving psychological impact. Estimating the magnitude of the next earthquake, within a restricted area and time, appears as an almost impossible task [1]. Adeli and Panakkat [2] presented earthquake magnitude estimation between 4.5 and 6.0 using eight parameters including significant seismic events, mean square deviation etc. On the other hand, for this model studied interval for earthquake magnitudes is estimated between 4.0 and 5.0 because earthquake frequency in this interval is more than frequency of interval with Mw > 5 and effects are much more than the small magnitudes. The parameters used as independent variables in this study are the total number of earthquakes in various magnitudes. Magnitude between 4.0 and 5.0 for earthquake is unsettling among people and it creates a fear of a bigger earthquake because of average severity and high probability. Because of this unsettlement among people, probability of earthquake magnitude between 4.0 and 5.0 is chosen as

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dependent variable. Data is analyzed for Turkey because large part of Turkey is included in the earthquake zone because of the many small plates among the large plates. Contribution of this study is by looking at the numbers of earthquakes in different magnitudes within a month, it can be estimated the probability of an earthquake in the specified magnitude interval.

The rest of the study is arranged in the following steps. Section 2 presents related works about the topic. Section 3 presents methodology of study with subsections: normalization of data, artificial neural network model and analyses, seasonal effects of earthquakes. Section 4 describes results of the study and finally, conclusion is summarized in the last section.

2 Literature Review

Artificial neural networks are computing systems based on interpretation of the process of biological neuron networks. Neural networks have been implemented in wide area such as transportation [3, 4], signal processing [5], medical [6, 7] etc. Many scientists tried to implement Artificial Neural Networks (ANNs) to the issues related to earthquakes, getting attractive and encouraging results [8]. Alves [9] developed earthquake forecasting method integrating several tools in a neural network for financial analysis. This method was tested within different years with wide time and location perspective. Chattopadhyay's [10] predicted the magnitude of earthquake over Indian subcontinent benefitting artificial neural network with backpropagation learning. ANN model established by Gul and Guneri [11] for the earthquake casualty estimation, which takes into account earthquake time, earthquake magnitude, and population frequency as the parameters for training network in Turkey from 1975. Murru et al. [12] proposed time-dependent and time-independent earthquake breakings for the Marmara Region in Turkey based on new fault segmentation model. Asencio-Cortes et al. [13] appraised correctness of artificial neural networks when used to estimate earthquakes magnitude in Tokyo. Azam et al. [14] classified earthquake patterns concerning identified characteristics using ANN based networks, and then either supervised or unsupervised techniques were used for estimation. Fawzy and Arslan [15] tried to estimate building reactions to big earthquakes benefitting actual data collected from surveys carried out after the real earthquakes. A neural network model was proposed to estimate the horizontal displacement of the ground in both ground slope and free face situations in order to liquefaction-induced lateral spreading by Baziar and Ghorbani [16]. Reyes et al. [17] presented a novel earthquake estimation system based on artificial neural networks for estimating earthquakes in Chile. Paper proposed by Alarifi et al. [18] demonstrated the implementation of artificial intelligent estimation model which used to estimate the magnitude of future earthquakes in northern Red Sea area including Sinai Peninsula, the Gulf of Aqaba, and the Gulf of Suez. In Sect. 3, the approaches in this study are discussed. Li and Liu [19] presented a different approach of combining particle swarm algorithm and back propagation neural network to estimate earthquake magnitude. Their model gave better results and faster convergence rate. Radial basis function network and adaptive neuro fuzzy ınference system were applied to predict earthquake occurrences in Iran considering spatial-temporal variations [20]. LM-BP algorithm was implemented by Zhou and Zhu [21] to the earthquake prediction considering fast velocity and the strong fault tolerant. Moustra et al. [22] evaluated artificial neural network performance using time series magnitude data and seismic electric signals to estimate earthquakes. The results were relatively accurately. A Time series was also used by Srilakshimi and Tiwari [23] making a comparative analyses including non-linear forecasting model and artificial neural network. Results acquired by two methods were consistent and in good accord. Seismic indicators have been also widely used in neural network to predict earthquakes [24–26].

Neural networks have been implemented successfully to deal with complex problems with different tools to estimate earthquakes.

3 Methodologies

Earthquake is a disaster type that takes place almost every day and the impact of a strong earthquake is disruptive. Technically, the earthquake is a phenomenon of vibrations that suddenly emerge in waves due to breaks in the earth's crust, and thus shake the earth. Magnitude is too significant in terms of earthquake effects. Magnitude is a measure of the energy generated during an earthquake. In this study, earthquakes with magnitude between 4.0 and 5.0 have been analyzed using artificial neural network model with subsections: normalization of data, artificial neural network model and analyses, seasonal effects of earthquakes. Components of model and model design have been examined in detail. The model is formed by using MATLAB neural network tool.

Artificial neural networks are computing systems based on interpretation of the biological neuron networks process. These models bring solution to real world problems which interrelate between a set of given input patterns and set of known target output [27]. Structure of a classic neural network model is shown in Fig. 1.

Properties of neural networks are nonlinearity, input-output association (mapping), adaptability, evidence-based response, contextual information, analysis and design standard, neurobiological metaphor, applicability to large-scale technology and fault tolerance [28]. These systems are based on gaining the ability to learn by manipulating

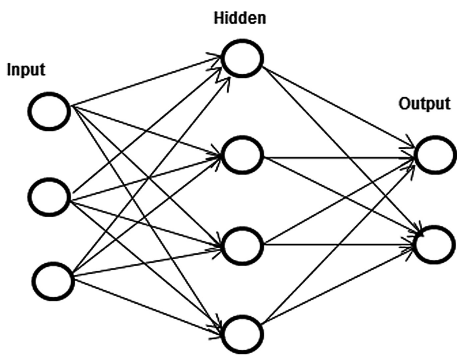

Fig. 1. Test and estimated output values

inputs over time. Many nerve cells have parallel learning capacity in one piece, and this is probably the most important aspect [29].

The steps to be taken in the next stages of the study are as follows; normalization process is applied to provide data consistency. After the normalization of the data is completed, artificial neural network model is conducted. Test and training sets and the most appropriate activation function is determined. After the network type is determined, the number of layers and the number of neurons in hidden layers are determined. For the simulation process, weights are obtained by via training parameters and they are available to obtain the desired output. After all a new neural network model is created.

3.1 Normalization of Data and Determining Output Value

Data is normalized to increase accuracy of data. The following formula in Eq. 1 is used for normalization [30]. In the model log-sis function is used as transfer function because it is a continuous derivable function and network type is chosen as feed-forward backprop.

$$\mathrm{Mr} = 0.8 * [(\mathrm{Mr} - \mathrm{Mmin})/(\mathrm{Mmax} - \mathrm{Mmin})] + 0.1 \quad (1)$$

Mr = Real observed data
Mmin = Minimum of data
Mmax = Maximum of data

In Appendix 1, all data is shown before the normalization process insert in a table. The last column shows output values. These output values are computed according to statistical analyses and linguistic variables.

Firstly, probabilities of earthquake occurrence between Mw = 4 and Mw = 5 are statistically analyzed and following results are obtained.

Data Summary;
Number of Data Points = 120
Min Data Value = 0.0043
Max Data Value = 0.0482
Sample Mean = 0.0171
Sample Std Dev = 0.00935

Table 1. Converting linguistic expressions to numbers

	Very low	Low	Medium	High
Formulation	<=(sample mean-std dev)	<=(sample mean), >(sample mean-std dev)	<=(sample mean + std dev), >(sample mean)	>(sample mean + std dev)
Digitization	1	2	3	4

Accordingly, these probabilities are expressed as linguistic expressions. In Table 1, linguistic expressions and then their digitized states are shown.

Linguistic expressions are normalized after being digitized and used as output values.

3.2 Artificial Neural Network Model and Analysis

After all, above mentioned processes, model is formed by using MATLAB neural network tool. The following steps have been implemented:

- While 84 samples (months) are used for training set, 36 samples (months) are used for test set.
- Number of epochs is chosen 1000 and max-fail is estimated as 6.
- After training network, weights are obtained and used for computing output value when input values are given. Weights are shown in Table 2. MATLAB code which is written in respect to weights is shown in Appendix 2 for computing output values [30]. In MATLAB code, E is the normalized output value. The actual output value is obtained by applying the inverse of the normalization process. Accordingly, network is simulated using test input values, and then test output values and estimated output values are compared as shown Fig. 2.

Table 2. Weight of layers

Iw{1,1}-Weight to layer 1	Iw{2,1}-Weight to layer	B{1}-Bias to layer 1	B{2}-Bias to layer 2
[−2.4199 1.667 −3.7098 −0.071999; −0.45022 0.99641 −2.7364 3.5565; 3.9526 −1.1322 −1.3897 1.8254; −0.0059579 4.1033 0.98436 2.1465; −1.1492 −3.5649 −1.5197 2.7367; −2.7365 2.258 4.2554 0.15928; 0.088907 1.7687 3.3905 1.0296; 1.202 2.9674 1.564 −3.0521]	[−1.5627 0.66908 −0.40774 0.87236 0.90156 3.7318 −3.169 1.4499]	[4.6993; 3.6089; 2.0318; −0.14941; 0.20621; −1.1002 −4.7703; 4.754]	[−1.1608]

- 2 layers and 8 neurons are used for this model. 3 years data is constituted test earthquake counts [31].

Estimated data and real data have similar characteristics. According to the regression analysis done in excel, value of R2 is equal to 0.9051. This result shows that 90.51% of the variability in the magnitude of earthquake between 4 Mw and 5 Mw can be estimated with using artificial neural network model.

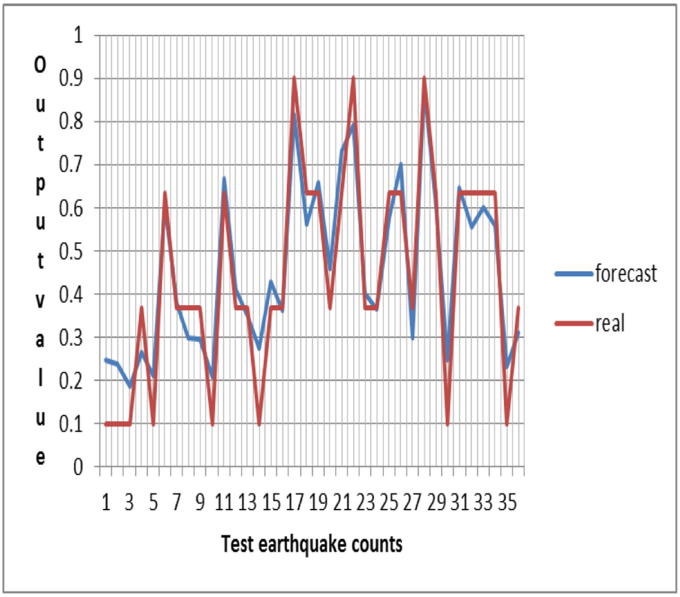

Fig. 2. Test and estimated output values

3.3 Seasonal Effects of Earthquakes

When seasonal effects of earthquake are considered, it is observed that the frequency increases especially in spring and autumn as in the Fig. 3. There are relatively few earthquakes in winter months compared to summer months.

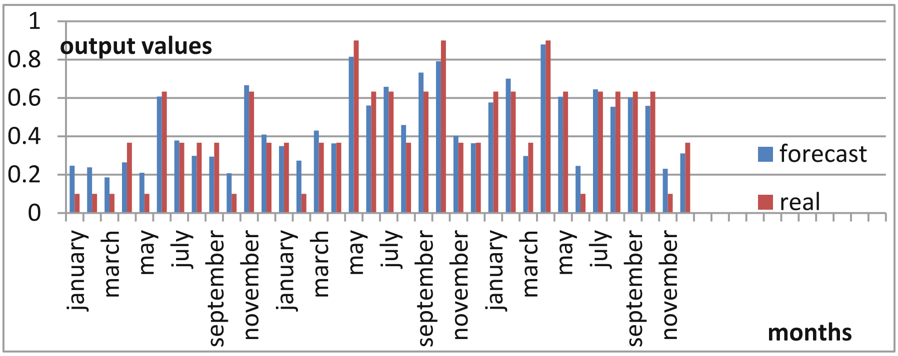

Fig. 3. Earthquake seasonal results

4 Results

First 86 data (first 86 months) is selected as training set and last 36 data is selected as test set before data entry to the system. 2 layers and 8 neurons are used and log-sis function is benefitted as transfer function. Network type is chosen as feed-forward

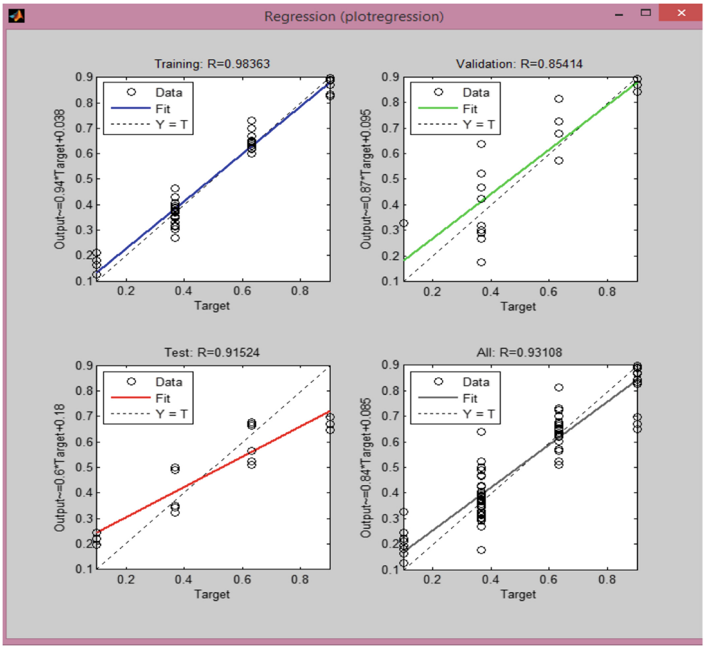

Fig. 4. Regression in neural network

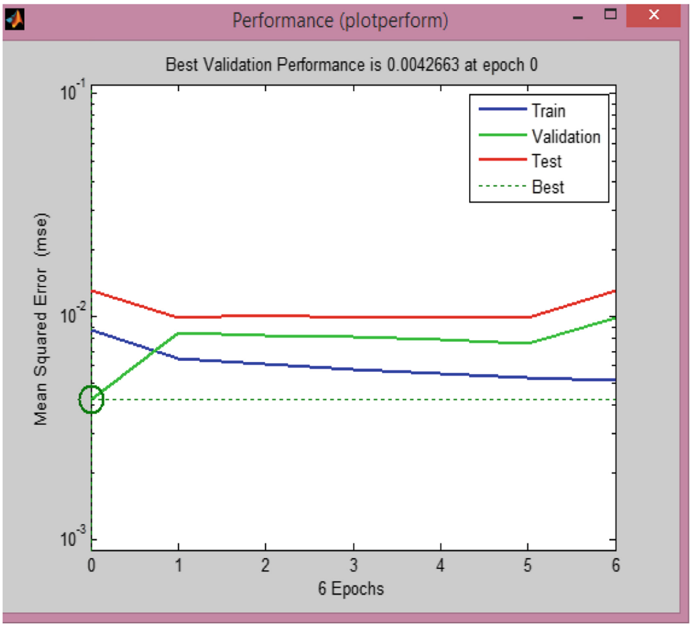

Fig. 5. Best validation performance

Table 3. Comparison of test output values and estimated output values

	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Real	0.1	0.1	0.1	0.37	0.1	0.633	0.37	0.37	0.37	0.1	0.633	0.37
Forecast	0.247	0.238	0.185	0.26	0.21	0.607	0.38	0.298	0.29	0.20	0.67	0.41
Real	0.37	0.1	0.37	0.37	0.9	0.63	0.63	0.37	0.63	0.9	0.37	0.37
Forecast	0.34	0.27	0.43	0.36	0.81	0.56	0.65	0.459	0.73	0.79	0.40	0.36
Real	0.63	0.63	0.37	0.9	0.63	0.1	0.63	0.63	0.63	0.63	0.1	0.37
Forecast	0.576	0.70	0.297	0.87	0.60	0.24	0.64	0.55	0.60	0.56	0.231	0.31

backprop. After training system, regression plots are handled as seen Fig. 4. Regression plots display the outputs of networks in connection with targets for training, validation, and test sets.

For this problem, R value for training set is above 0.93 [32] so fit is good for this data set. For test set, R value is 0.91 that is below 0.93 but comparatively the fit can be said well. For validation set, R value is equal to 0.85 is below 0.93. For more accurate results the sets could be retrained. But for all results, R value is equal to 0.93 and these results are accurate.

As seen in Fig. 5, best validation performance has occurred at epoch 0 and is equal to 0.0042663.

Accordingly, the test set error and the validation set error has same features. So, the results are logical in the light of these characteristics. In Table 3, test output values and estimated output values are shown.

Except that, the new output values can be obtained with the randomly selected input values. MATLAB code in Appendix 1 shows output value calculations.

5 Conclusion

Earthquakes can cause many tangible or intangible losses. Uneasiness can be an example for intangible losses. Actually, earthquakes in varying magnitude between 4 Mw and 5 Mw cause uneasiness among the public even if they do not cause heavy damage. In this study, artificial neural network model is implemented for estimating probability of future earthquakes magnitudes between 4.0 and 5.0. Artificial neural networks have capabilities to analyze and tackle with complicated relations to estimate earthquake magnitudes. Proposed model has used four magnitude intervals as independent variables. Probability of earthquake occurrence in varying magnitude is used as dependent variable. Monthly real data between 2006 and 2015 for Turkey has been used for analyses. Results show that model can display estimation of magnitudes between special intervals accurately. Furthermore, 90.51% of the variability in the magnitude of earthquake between 4 Mw and 5 Mw can be estimated with using artificial neural network model. Besides, when seasonal effects of earthquake are considered, it is observed that the frequency increases especially in spring and autumn. In addition to determining the probability of an earthquake for different magnitudes, magnitude of earthquake can be estimated by different parameters using this model. Thanks to this study, the number of earthquakes in the range of Mw = 4.0 to Mw = 5.0 in a season can be estimated for next years.

Appendix 1 (Numbers of Earthquakes in Different Magnitudes Between 2006 and 2015)

No	Season	M>=2-M<=2.9	M>=3-M<=3.9	M>=4-M<5	M>=5-M<6	Pro.	No	Season	M>=2-M<	M>=3-M<	M>=4-M<	M>=5-M<	Pro.
1	january	155	170	9	0	4	61	january	657	122	8	1	2
2	february	167	129	12	1	4	62	february	661	199	15	1	3
3	march	187	161	9	0	3	63	march	761	186	10	0	2
4	april	254	202	11	0	3	64	april	727	154	17	0	3
5	may	313	167	8	0	2	65	may	2094	440	24	3	2
6	june	245	198	6	1	2	66	june	1172	261	16	1	2
7	july	251	142	15	0	4	67	july	1048	134	12	1	2
8	august	246	125	6	2	2	68	august	826	142	14	0	2
9	september	202	134	9	0	4	69	septembe	1010	186	15	3	2
10	october	249	172	11	2	3	70	october	1563	774	100	9	4
11	november	192	106	7	0	3	71	novembe	2292	534	62	6	3
12	december	206	162	11	1	4	72	decembe	1545	208	24	0	2
13	january	163	249	9	1	3	73	january	1295	270	25	2	2
14	february	274	232	10	3	3	74	february	1089	166	11	1	2
15	march	254	271	18	0	4	75	march	1303	182	15	2	2
16	april	219	219	13	1	4	76	april	1576	239	19	0	2
17	may	269	202	7	0	2	77	may	1919	223	22	3	2
18	june	245	191	6	0	2	78	june	1934	181	27	3	2
19	july	254	147	8	0	3	79	july	1447	99	10	2	1
20	august	228	185	11	2	4	80	august	1400	107	7	1	1
21	september	242	157	12	1	4	81	septembe	1439	119	14	2	2
22	october	252	183	21	1	4	82	october	1377	109	9	0	1
23	november	213	236	13	3	4	83	novembe	2289	167	15	0	1
24	december	397	393	17	2	3	84	decembe	1332	141	10	3	1
25	january	422	339	19	0	3	85	january	1601	213	12	2	1
26	february	289	212	5	1	2	86	february	1299	100	10	0	1
27	march	321	230	12	2	3	87	march	1364	101	9	3	1
28	april	607	330	11	1	2	88	april	1480	123	13	1	2
29	may	399	256	8	0	2	89	may	1659	110	10	1	1
30	june	418	218	16	1	3	90	june	1213	110	25	1	3
31	july	347	244	15	1	3	91	july	1098	116	15	1	2
32	august	386	214	11	2	3	92	august	1136	90	12	1	2
33	september	389	166	13	0	3	93	septembe	1123	120	13	3	2
34	october	474	191	25	2	4	94	october	977	124	5	0	1
35	november	472	186	17	0	3	95	novembe	886	102	20	2	3
36	december	618	238	8	2	2	96	decembe	895	99	13	1	2
37	january	502	196	11	1	2	97	january	618	85	7	0	2
38	february	491	204	6	1	2	98	february	599	61	4	0	1
39	march	709	218	5	0	1	99	march	659	94	10	0	2
40	april	561	180	11	0	2	100	april	606	96	8	2	2
41	may	730	261	9	0	2	101	may	937	199	34	1	4
42	june	677	268	16	3	2	102	june	687	108	14	2	3
43	july	476	210	28	1	4	103	july	686	110	17	0	3
44	august	473	161	14	0	3	104	august	805	114	14	3	2
45	september	474	173	22	1	4	105	septembe	631	93	17	1	3
46	october	446	170	6	1	2	106	october	531	75	17	0	4
47	november	362	177	12	0	3	107	novembe	661	121	10	2	2
48	december	349	157	7	2	2	108	decembe	740	108	10	2	2
49	january	492	196	10	0	2	109	january	633	96	13	1	3
50	february	569	209	9	1	2	110	february	535	78	14	0	3
51	march	949	352	24	4	3	111	march	628	108	6	1	2
52	april	826	155	8	1	2	112	april	580	162	28	3	4
53	may	951	206	8	0	1	113	may	633	122	15	0	3
54	june	678	148	9	0	2	114	june	671	126	5	2	1
55	july	779	138	8	0	2	115	july	736	111	17	1	3
56	august	823	144	10	0	2	116	august	548	90	11	0	3
57	september	583	145	16	0	3	117	septembe	641	95	14	0	3
58	october	708	142	10	1	2	118	october	626	111	13	2	3
59	november	992	212	7	2	1	119	novembe	606	90	3	1	1
60	december	662	131	13	0	2	120	decembe	868	87	10	2	2

Appendix 2

```
%%input data
N1=input('enter a value');
N2=input('enter a value');
N3=input('enter a value');
N4=input('enter a value');

%%  Normalization
A=0.8*((N1-155)/(2292-150))+0.1;
B=0.8*((N2-61)/(774-61))+0.1;
C=0.8*((N3-3)/(100-3))+0.1;
D=0.8*((N4-0)/(9-0))+0.1;

%%Formulation of forecast
E1=A*(-2.4149)+B*1.667+C*(-3.7098)+D*(-0.071999)+(4.6993);
E2=A*(-0.45022)+B*(-0.99641)+C*(-2.7364)+D*(3.5565)+(3.6089);
E3=A*(3.9526)+B*(-1.1322)+C*(-1.3897)+D*1.8254+(-2.0318);
E4=A*(-0.0059579)+B*(4.1033)+C*(0.98436)+D*(2.1465)+(-0.14941);
E5=A*(-1.1492)+B*(-3.5649)+C*(-1.5197)+D*(2.7367)+(0.20621);
E6=A*(-2.7365)+B*(2.258)+C*(4.2554)+D*(0.15928)+(-1.1002);
E7=A*(-0.088907)+B*(1.7687)+C*(-3.3905)+D*(1.0296)+(-4.7703);
E8=A*1.202+B*(2.9674)+C*(1.564)+D*(-3.0521)+(4.754);
F1=1/(1+exp(-E1));
F2=1/(1+exp(-E2));
F3=1/(1+exp(-E3));
F4=1/(1+exp(-E4));
F5=1/(1+exp(-E5));
F6=1/(1+exp(-E6));
F7=1/(1+exp(-E7));
F8=1/(1+exp(-E8));
E9=F1*(-1.5627)+F2*(0.66908)+F3*(-
0.40774)+F4*(0.87236)+F5*(0.90156)+F6*(3.7318)+F7*(-
3.169)+F8*(1.4499)+(-1.1608);
F9=1/(1+exp(-E9));
Emin=min([E1 E2 E3 E4 E5 E6 E7 E8]);
Emax=max([E1 E2 E3 E4 E5 E6 E7 E8]);
E=((F9-0.1)/0.8)*(Emax-Emin)+Emin;
```

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Enhancing Regional Disaster Resilient Trade and Investment – Business Continuity Management

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Abstract. Large Corporates or global brands benefit from economic globalization and continues to grow in terms of comparative advantages across borders with synergy from integrated supply chain. When the large-scale disasters and catastrophes strike the Asia-Pacific Economic Cooperation (APEC) region - such as the 2004 Indian Ocean Tsunami or 2011 Great East Japan Earthquakes and Tsunamis, the impact on global value chain highlight the needs to promote business continuity planning/management (BCP/BCM). Disasters bring along the threats with opportunities in the market place. For mitigating the impact, most of the world leading corporates urge to allocate resources to further strengthen the disaster resilient capability and secure business environment. In APEC, each economy is unique in its geopolitical conditions, but common in its goal to be BCP/BCM capable. With missionary vision on promoting BCP/BCM. APEC deployed strategies in stages of preparatory work to managing risk and impact of large-scale natural disasters. APEC, as a pioneer, seeks to achieve the goal of sustainable quality growth and serve as learning points for interested economies who are in the midst of their BCP/BCM implementation. With review of the global and regional lessons learned from the large-scale disasters, this paper shared the regional efforts on disaster resilience, describe the strategic approaches and operational concept for emergency preparedness through technology and collaboration for enhancing global supply chain resilience across border.

Keywords: Business continuity planning/management (BCP/BCM) · Resilience · Collaborations · Asia-Pacific Economic Cooperation (APEC)

1 Disaster Governance Strategic Approaches – Scaling Up Disaster Resilience Capability Through Technology and Collaboration

Globalization shows its vulnerability and complexity in business and manufacturing process as well as escalate the level of logistics support. Recall the economic impact of 2004 The South-East Asia Earthquake and Tsunami, 2011 the Great East Japan

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Earthquakes and Tsunamis coupled with the INES level 7 Fukushima nuclear power plants accident and 2016 Kaohsiung Earthquakes in Taiwan; these earthquakes caused the significant economic losses and challenged the continuity of business operations across the continents.

The market place may highly sensitive to natural disaster such as extreme events or large-scale earthquakes or floodings in terms of global value chains (GVCs) or supply chain interruption. Failure to respond can lead to mass closures and bankruptcies. Followed the 2011 Great East Japan Earthquake and Tsunami and Thailand floods in 2011, the industries struggle for managing suppliers of information and communication technology (ICT) products ranging from hard-drives to component parts used in cars, cameras, electronics devices and etc. due to the supply chain interruption across border.

1.1 Public Private Partnership (PPP) Engagement on Regional Business Continuity Planning/Management (BCP/BCM) Through Technology and Collaborations

Disaster Risk Reduction (DRR) is key toward national security, economic quality growth, environmental sustainability and people's livelihoods. For regional consideration, a large-scale disaster could impact the GVCs/supply chain and hamper the regional economic growth and corporate profitability and even cease to exist. Hence, engaging regional join efforts on DRR becomes a global trend. After the 2011 Great East Japan Earthquakes and Tsunami, the Asia-Pacific Economic Cooperation (APEC) initiate a multi-year project [1] to promote business resilience and implementing BCP with capacity building/training workshop to help the small and medium size enterprises (SMEs), the multinational or international corporations to minimize supply chain interruption and enhance resilient manufacturing, trade and investments in APEC region.

The APEC successful stories shared as best practice in promoting BCP and PPP drawn the attention of global community. The Sendai Framework for Disaster Risk Reduction (SFDRR) [2] enforced during the Third UN World Conference on Disaster Risk Reduction (UN 3WCDRR) in 2015 promoted the value of resilience as well as encourage the PPP engagement and collaborations. SFDRR also encourages to adopt innovation, science and technology on DRR approaches such as big data and open data to facilitate the value-added information sharing on enhancing capacity building for multisectoral disaster resilience over higher public risk awareness and level of preparedness. In 2017, the 5th Global Platform for Disaster Risk Reduction in Cancun, Mexico further highlight the importance of DRR agenda with four priorities to declare the momentum 'From Commitment to Action' and special focuses on 'International Cooperation Initiatives' to promote international collaboration, public private partnership (PPP), critical infrastructure resilience with stakeholders' participation to achieve the goals of improving preparedness and national coordination for disaster response supported by strengthened modalities of international cooperation [3].

1.2 Options for Tackle the Risks

The ability of a supply chain in coping with disasters are vary. It depends on the corporate risk tolerance (a limitation), preference (a choice) or appetites (a policy) for formulating appropriate strategy on DRR (Fig. 1).

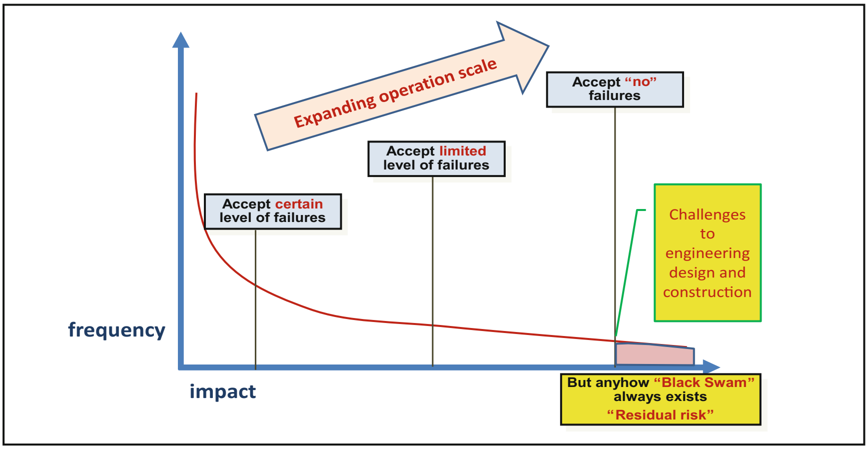

Fig. 1. Characteristics of risks for different scale of business – allowance of failure and interruption

When tackle the risks, supply chain disaster managers have difficult options on whether: (1) to lean an operation and secure cost efficiency; (2) to build redundancy and secure supply and keep the shipping and delivery on time; (3) to maintain remaining or residual capacity for operation and manage the shipment while supply chain interrupted if too big to build redundancy for the capital intensive investment. Each approach has its pros and cons and applicable case by case. Hence, it is important to scaling up disaster resilient capability through state-of-the art technology and PPP collaboration on information sharing, resources allocations and risks communication across border via clear common picture of situation for operation. It is made possible if we can recruit local knowledge, join scenario based excises and drills based on the synergy of PPP in managing risks to mitigate the impact. With review of the global and regional lessons learned from the large-scale disasters, it is critical to formulate a strategic join operational framework for emergency preparedness via technology and collaborations on regional BCP/BCM to enhance GVCs and supply chain resilience.

Looking at disaster-resilient business through the GVCs and supply chain - trans-boundary and end-to-end issues illustrated (Fig. 2), the risks can be divided into:

External – Managing by the Public Sector

External (outside of the business complex or free trade zone): (1) ensure the lifeline systems and utilities such as power, water, gas, telecommunications and transportation are available; (2) identify the targeted types of natural hazards and impacts (direct and indirect) such as earthquakes, typhoons, landslides and droughts; (3) facilitate supply chain resilience such as coordinate end-to-end connectivity from upstream supplies to customers with common standards to follow such as ISO 22301; (4) encourage information sharing and exchange in different phases of planning, emergency response and recovery support by a systematic mechanism as an interface; (5) build up an inclusive platform to encourage dialogue.

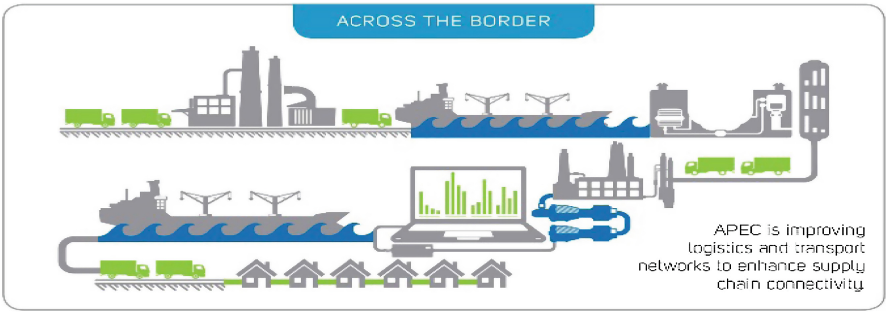

Fig. 2. Supply chain across the border [4]

Internal – Managing by the Private Sector

Internal (inside of the business complex or free trade zone): (1) Connecting with business continuity plan for contingency, constantly monitoring risks and update key players to take same step and having join exercise; (2) Hosting scenario-based table-top exercise and drill according to the realistic situations and demands for better understanding on coping capability and capacity in extreme situations; (3) Facilitate internal information flow and decision making process by establish "N" to "1" and "1" to "Many", identify key information helping key decision makers, ensure the responsible authority of executing BCP for sharing information with key stakeholders outside.

1.3 Taiwan Economy at Risk

Taiwan's ICT industry has played an important role in the global market. Taiwan established science parks (Fig. 3) since 1980 for enhancing industry competitiveness, technology transfer to attract foreign direct investments and state-of the art technology to boost the economy growth.

Targeting to build the science parks in Taiwan as one of the research and development hub in the Asia-Pacific, we clustered the upstream and downstream industries within the science park. Looking at the strategy and structure of the industry in Taiwan, it is similar to most of the APEC member economies. SMEs contribute more than 70% of industrial output in Taiwan (Fig. 4). These SMEs usually produce products on an original equipment manufacturer (OEM) or original design manufacturer (ODM) basis [6].

The Science Park contribute 2.94% of economic growth and shoulder billions of trade and investment in Taiwan. ICT industry clustered in the science parks are the engine of Taiwan economic growth. In 2016, ICTs shoulder real rate of 3.2% GDP growth [7]. Major investments include the expansion of Taiwan Semiconductor

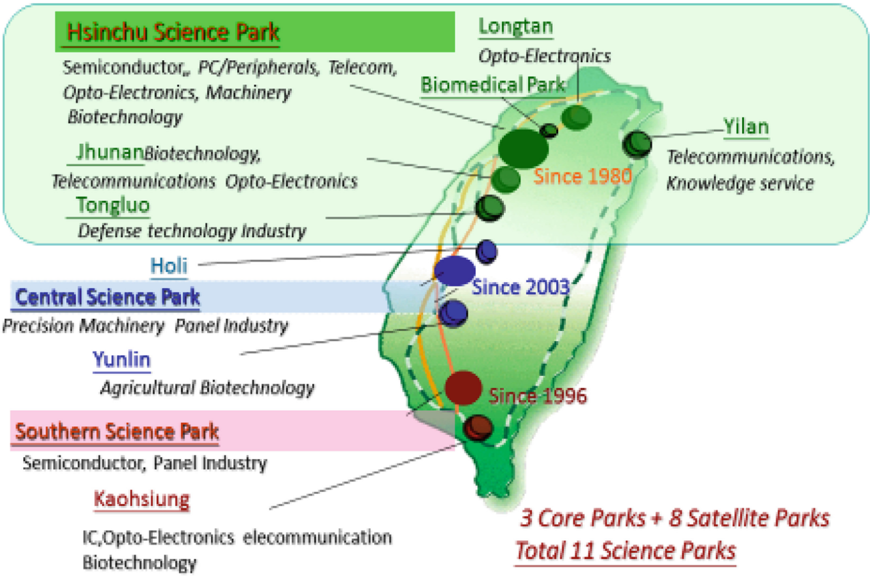

Fig. 3. Taiwan Science Park [5]

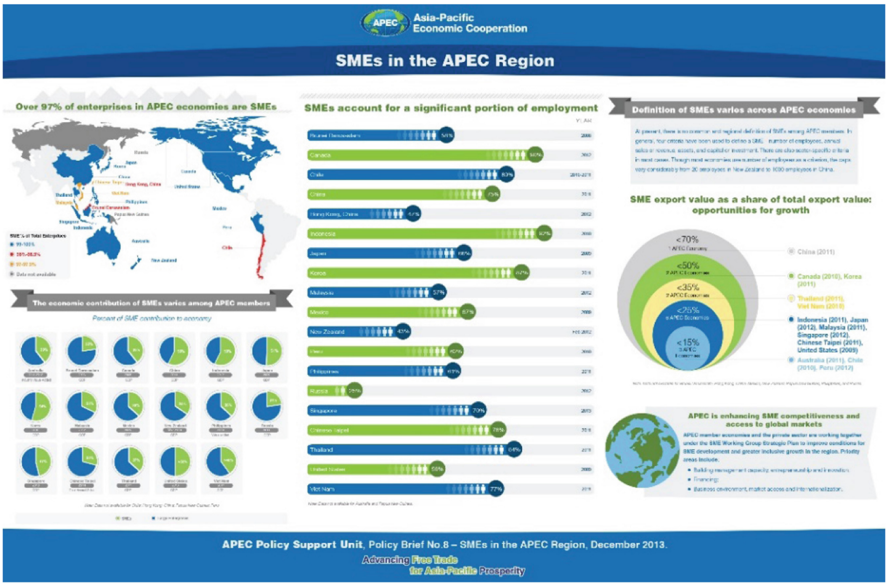

Fig. 4. SME in the APEC region

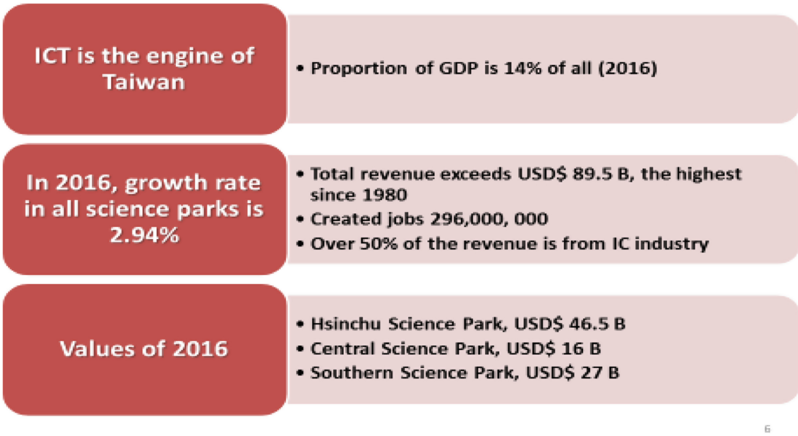

Fig. 5. Economic contribution by Science Park in Taiwan

Manufacturing. The total revenue exceeds US$89.5 billion in 2016, up 2.94% year on year to a record high. ICTs industry contributes to total of 14% of GDP [8] (Fig. 5).

To sustain the economic growth, Taiwan government helps to bridge the information gap for emergency respond in the science parks and enhance the data process of the central emergency operation center (CEOC) operation while emergency. To interface with science park emergency operation, National Science and Technology Center for Disaster Reduction (NCDR) collaborated with Hsinchu Science Park Bureau to promote BCP/BCM from the viewpoint of public and private partnership collaborations.

1.4 TSMC Risk Management vs. Disasters in Taiwan

Under the concept of business clustering, Taiwan Semiconductor Manufacturing Company (TSMC) and United Microelectronics Corporation (UMC), the world's largest and second largest semi-conductor manufacturers were established in the science parks to synergy the integration of industrial resources and product management connect with major international suppliers. TSMC coached the future BCP implementation from the experience of 1999 Chi-Chi Earthquakes [9] to minimize the impact on supply chain and uphold the ICT industry worldwide.

Response Dilemma

While disaster, it will escalate the intensity of a competitive market place. The strategy process among Micro Small and Medium Size Enterprises (MSMEs), SMEs, the large and global brands become more emergent than intended [10]. The threat comes from substitutes and bargaining power of buyers will higher the industry rivalry in the business environment to certain extent [11]. The emerging BCP/BCM on supply chain resilience initiative can help stabilizing industries but cease to exist if disasters. BCP is a powerful approach to identify the strategy's potential profitability if mitigating impact from disasters.

However, business sectors are having doubts and concerns to further respond or involve in the public private partnership engagement and tend to be hesitated to be transparent. The information disclosure to the market and their competitors may threat the corporates existence if credit ranking downgrade for loss. The corporate financing may become difficult than before. Moreover, the financial markets tend to be highly sensitive and vulnerable if panic in the marketplace while disaster strike. The hostile takeover, merge and acquisition will be active and easier through the financial markets while corporates in disasters if the stock prices plummeted.

On the other hand, emergency preparedness need transparency on just-in-time decent appropriate information disclosure to some extent to succeed the team effort while disasters preparedness, response and recovery.

TSMC delivered a successful story after the 1999 Chi-Chi Earthquakes. Right after the quake, TSMC informed clients and set up hot-lines for Q&A. Within first two days, 2 public announcements and 12 new releases. 5 days after, 100 interviews in 4 languages. A guarantee, "No delay to shipments". TMSC received more news coverages, 57%, and 86% of them offered neutral or positive comments. TSMC's emergency response to their staff and clients is to send out the clear message at official level to protect their business and keep the shipment on time over implement disaster pre-emptive mechanisms at corporate level. A business owners challenges on the worst case and unexpected one to identify coping capacities and capability are key to survive the disaster. Thus, quick and decent responses, just-in-time information disclosure and team efforts are the key to succeed the corporate crisis management in this case. This case share the value and importance of risk communication and proper information disclosure in time of disaster.

For long-term sustainability, TSMC established its Enterprise Risk Management (ERM) program based on both its corporate vision and its long-term sustainability and responsibility to both industry and society. Meanwhile, TSMC BCM is implemented to managing the safety of production lines, services and shipment if disasters. In the case of TSMC, the capital intensive industry, cannot afford to have redundancy and have to go for no failures approaches. Base on the targeted goal and risk strategic approaches, a proper BCP can be realistic for implementation to achieve corporate disaster resiliency. Following the standards for the whole supply chain - ISO 22301, area BCM, TSMC exercised scenarios simulation to make plans and conduct drills for the worst or realistic worst case to test disaster resilient capacity and capability.

1.5 Kaohsiung Earthquake on February 6th, 2016

Taiwan, in the ring of fire, sits between the Eurasian Plate (EP) and the Philippine Sea Plate (PSP) is prone to earthquakes experiencing strong ground motions. On February 6, 2016 at 3:57 am local time, a magnitude 6.4 in land and shallow earthquake hit southern part of Taiwan and the casualties of 117 died and 546 wounded. More than 60 buildings totally or partially collapsed. The epicenter is located at Meinong, Kaohsiung City with a focal depth of 16.6 km. According to the shake records, the strongest intensity reached scale 6 (334.1 gal) (Fig. 6).

For better emergency preparedness, response and recovery; we conduct the seismic risk and situation assessment to further support the CEOC operation while earthquakes.

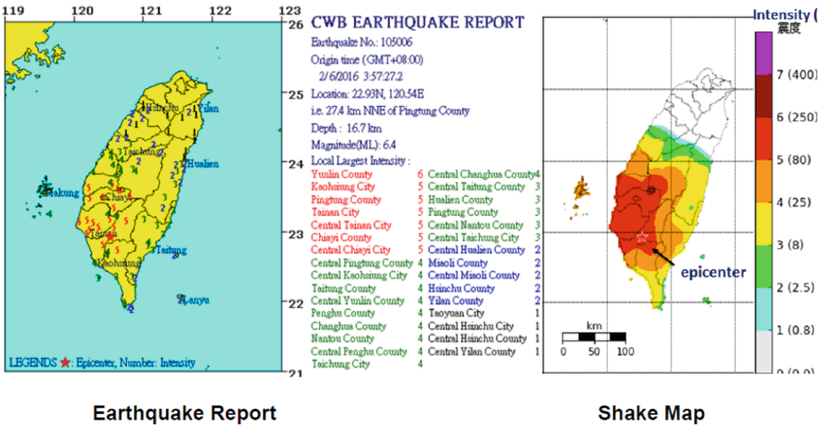

Fig. 6. A strong ground motion in 2016 [12]

NCDR, as the DRR think tank, provided the integrated multidisciplinary scientific suggestions on scenario-based GIS mapping for decision-making. The Earthquakes Impact Analysis Models were developed for urban areas to tackle the large-scale earthquakes and further identify weak points of critical infrastructure, i.e., buildings, roads, and lifelines (Fig. 7).

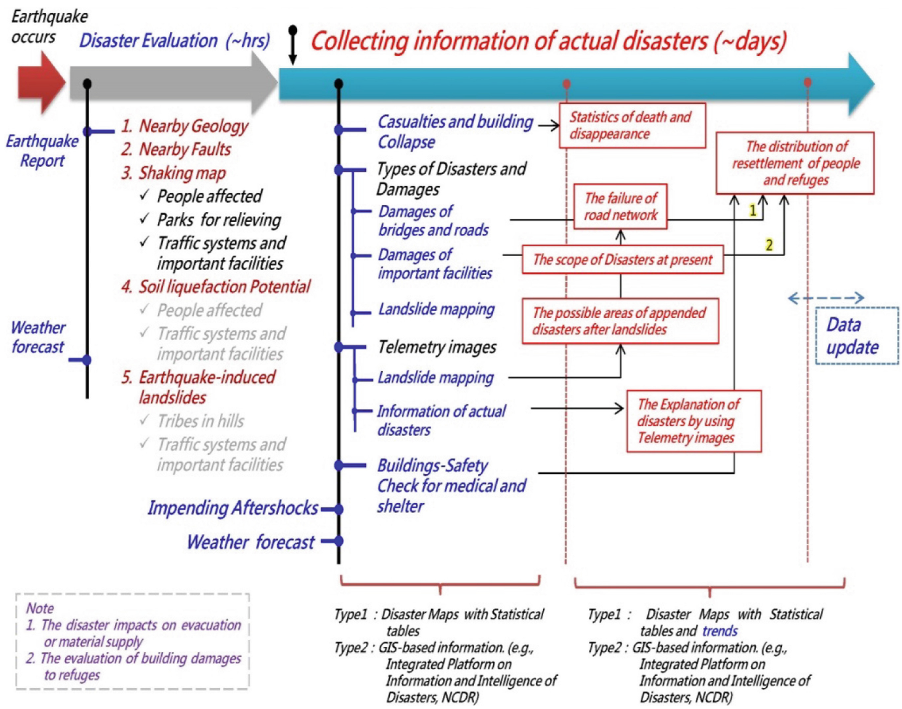

Fig. 7. Data process framework in the case of earthquake in Taiwan CEOC operation [13]

Emergency Operations

Right after the strong quake, the Ministry of the Interior activated quick damage survey at and elevated level of emergency operation to level 1 at 4:15 am on Feb 6 to collect situations, and coordinated search and rescue efforts. The operation of search and rescue ended at 4:00 pm on Feb 14. In total, 29,000 of urban search and rescue team, firefighters, police officers, volunteers and soldiers had ever joined the operation.

Economy of Taiwan is an indispensable partner in the Global Value Chains of Electronics Industry [14]. Most of the manufacturing lines of high tech industries are vulnerable to vibration. Regions most at risk when Kaohsiung Earthquake shook an electronics hub in Southern Taiwan (Fig. 8), where lies at the heart of Apple's supply chain [15] a couple of days before Chinese New Year, a big day for family reunion. The water, electricity, transportation and communications services interrupted within 2 to 7 days. Major highways, highway bridges, railway. Taiwan High Speed Rail (THSR) system suspended south bound service from Taichung for 2 days.

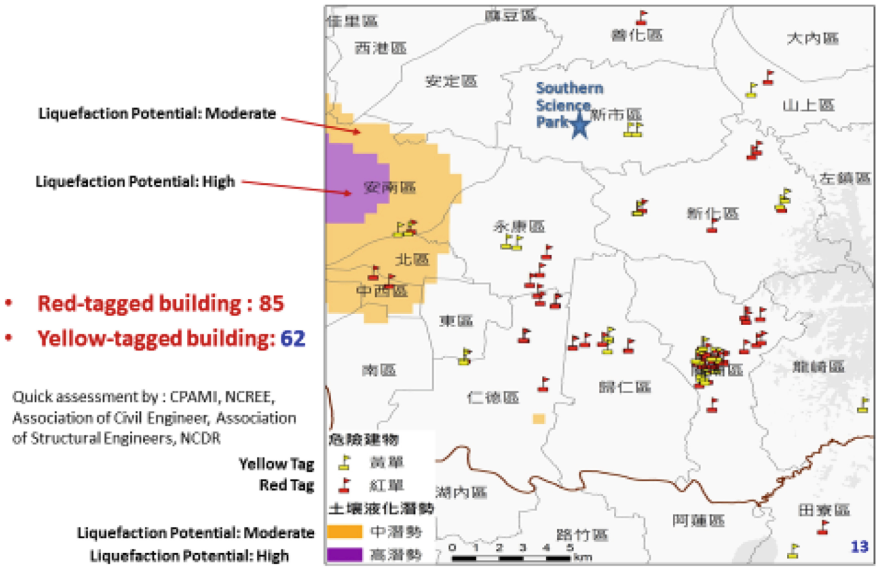

Fig. 8. Locations of Southern Science Park and damaged buildings and liquefaction zone

TSMC, APPLE's sole supplier and Qualcomm's supplier, operated its largest 12-inch wafer production facilities in the Southern Taiwan Science Park. As a leading company, TSMC incorporated BCP in its risk management with its suppliers. In the case of Kaohsiung Earthquake, TSMC minimized the losses at 'work in progress' no more than 1% of its first-quarter shipments [16]. It is inevitable to have loss. The automatic safety measures at a plant in Tainan triggered equipment shut-down but soon resume to operate. Fortunately, TSMC's maintained more than 95% of the tools fully function after restored in two to three days. Staff were safe and the firm's Tainan facilities were structurally intact.

In the past two decades, TSMC invested resources on BCP/BCM to strengthen the capability of its suppliers and endeavored to minimize the supply chain interruption in time of disasters. Nowadays, emerging technologies speed up the telecommunications development and shorten the lead time from data to deliverable messages in the digital age. Hence, the Taiwan government operated the emergency response to help business in responding to the disaster and provide big data and open data assessment as well as take preemptive measure to enhance disaster resiliency in the science park.

TSMC also learned to improve and restructure disaster management framework for emergency operation both after the Typhoon Morakot in 2009 which brought record-breaking rainfalls with massive floods and large-scale landslides in the southern Taiwan and the Great East Japan Earthquakes and Tsunami in 2011 [17].

2 APEC Enhances Disaster-Resilient Trade and Investment

APEC active involvement with voluntary effort contribute to host the train the trainer workshop in the region and explore the future strategies to develop regional BCM approaches after the Great East Japan Earthquakes and Tsunami. Promoting systematic project for capacity building to facilitate the regional collaborative efforts on improving business resilience since 2011, APEC BCP related deliverables are listed as following:

- Improving Natural Disaster Resilience of APEC SMEs to Facilitate Trade and Investment
- Developing Governments' Capacity to Promote and Facilitate the Effective Use of Business Continuity Planning for Disaster Resiliency (EPWG, Australia)
- APEC Seminar on Capacity Building for Disaster Recovery and Rehabilitation (EPWG)
- Policy Dialogue on Emergency Response Travel Facilitation (ERTF) (EPWG, BMG, SCCP)
- Business Continuity Planning: Policies, Practices and Programs (EPWG, Australia)
- Peer Group Review of BCP booklet/project effectiveness (EPWG, Australia)
- Workshop on Global Supply Chain Resilience (TPTWG, EPWG)
- Seminar on Enhancing Regional Supply Chain Resilience to Disasters in APEC (EPWG)
- Improving the Resilience of the Global Supply Chain (TPTWG, EPWG)
- High Level Policy Dialogue on Resilient SMEs for Better Global Supply Chains (SMEWG, EPWG)
- Sharing outcomes of BCP/PPP at the 6th Asia Ministerial Conference on Disaster Risk Reduction (UNISDR)
- Secure Infrastructure Workshop on Critical Infrastructure Security and Resilience (CTWG, EPWG)

Concerning the complexity of the regional business and emergency preparedness demands, APEC put the efforts on improving business resilience since 2011, after the Great East Japan Earthquakes and Tsunami. APEC aimed at pursuing regional quality and sustainable growth on the concept of building the public and private partnership capacity to promote and facilitate the effective of business continuity planning for disaster resiliency and deliver number of train-the-trainer workshops. Take into account of critical infrastructure security and resilience, APEC continued to promote the BCP and BCM in a broader landscape from policy making to capacity build at regional level to enhance disaster-resilient trade & investment. For SMEs easy implementation, ten easy steps and guidelines of business continuity planning on strengthening supply chains. Forty one SME disaster resilient policies/programs from 12 APEC economies have been collected and organized to help economies design their own disaster resilience policies [18].

BCP project has been recognized as the top 10 APEC milestones to chart 25 Years of APEC Progress in 2014. Since 2011, APEC Leaders emphasis on fostering business continuity, the application of science and technology in disaster preparedness and risk reduction to build sustainable and resilient communities and to secure global supply chains and facilitate trade and investment. The outputs and its impacts successfully drew the global attention and recognized by UNISDR. APEC continued to promote, share the achievement and supported BCP/PPP implementation in APEC region.

2.1 The Concept of Regional Collaborations

BCP/BCM capable is the key to maintain the country's comparative advantage [19], the corporate competitive advantage [20] and stabilize the industries while disasters. We safeguarded the transboundary economic activities with end-to-end concept for join operation at regional level for GVC/supply chain resiliency (Fig end to end). With sustainable buyers and suppliers, the quality growth of regional economic activities can be sustained if supply chain stay connected against natural disasters.

Engaging regional collaboration on capacity building for disaster risk reduction (DRR), emergency response, preparedness and recovery is the global trend. With the synergy of the PPP, the whole society can work more closely together and share the best practices on DRR for better management/business process and emergency preparedness. For DRR synergy on supply chain resiliency, the join efforts to develop international, regional, subregional and transboundary cooperation through innovative technology/tools is a must. The emergent BCP/BCM can help to enhance the GVCs/supply chain resilience if interruption in terms of quick recovery. To fulfill the goals, the global community shall work together to build networking on the regional BCP/BCM with PPP collaborations on DRR.

A disaster resilient supply chain network can coach its strategic process for operations to adapt to risk that affects its capacities. The upstream and downstream activities can be sustainable through collaboration across the network coping with the dynamic market place in terms of demand and supply with flexibility. Incorporating regional BCP/BCM into business operations leads to an emergent competitiveness for sustainability in the global market. It is critical if enhancing the risk awareness of SMEs to uphold the economic growth in APEC region. We can benefit from sharing the natural disaster risks and the best practices while formulating BCP/BCM.

The increasing frequency and intensity of large scale disasters such as typhoon, extreme weather and volcano eruption can disrupt public services on transportation - flights, rail service for shipping where production networks depend on. To take reference on NHK Special - disasters on big data [21] that illustrate the key to overlapping of hazard map and business operation on exposure to hot spot, identifying the problem of social development and the complexity of doing business in product delivery. The ever changing situation became to be supply chain's major challenges in DRR for resilience. Using innovative Internet of Thing (IoT) tools, big data and open data for business vulnerability assessment at regional level is convenient, mostly accepted and welcomed by APEC economies to mitigate the supply chain interruption.

Continuing the effort in promoting supply chain resilience, it is critical to build a GIS-based information intelligence platform for information sharing. Through technology support and collaborations, the interoperability can be feasible to promote scenario-based exercises. From the historical events, we share the experience to improve in the future. The implement of BCP/BCM at regional level can enhance regional disaster resilient trade and investment through:

2.2 End-to-End Scenario-Based Information Sharing and Join Exercises

It is critical to incorporate the major large-scale disasters and historical data in the region for exercises. For example, the Great East Japan Earthquakes and Tsunami or the floods in Thailand [22] which hamper the cross-border supply chain resilience. APEC EPCC will continue to promote BCP/BCM and build up an operational framework at regional level to build the information intelligence platform for DRR and emergency preparedness. It will be the hub of the APEC region to share the common picture for emergency preparedness via regional digital preparedness [23] initiatives.

2.3 Concept of Regional Operational Framework for Emergency Preparedness

For encouraging wider, more effective BCP in APEC economies to mitigate risks, APEC Emergency Preparedness Capacity Building Center (EPCC) [24] and NiTech co-hosted ‘the 2017 APEC Summit on Resilience and Capacity Building Training Workshop on Promoting Business Connectivity in Nagoya’ [25] to explore the challenges with actions on BCM. Connecting the ‘Business Clusters’ cross-border toward supply chain resiliency, we conclude the preliminary approaches for regional BCM are to collaborate on: (1) information and risk sharing; (2) BCM-based operation; (3) possible damage assessment to critical infrastructure protection (CIP) impact on business operation for recovery; (4) join operations networking; (5) common operating picture for join operation.

To sum up, a user friendly evidence-GIS-based emergency operation for cross-border join operation is key to succeed the end-to-end scenario-based exercise and shoulder the knowledge-based experience transfer and sharing for the regional BCM. The cross-border join operation required newly innovative IoT tools, ICTs, big-data and open data for cross-border situation assessment to facilitate business resumption. With common operation picture built upon the real-time monitoring data integration, the GIS-Web-based platform can synergized support though the join discussion for cross-border collaboration on public private partnership.

3 Conclusion to Move Forward – Enhancing Cross-Border Collaboration in Promoting Regional BCP/BCM

The ever-changing environment triggered the frequency and intensity of natural disasters which scaling up the risks level and impact of the economic activities. APEC pursue the GVCs and supply resilience to host the APEC Summit on Resilience and Capacity Building Training [26] in Japan to invite the stakeholders' participation to brain storming the future perspectives on developing regional BCP/BCM in two dimensions including:

3.1 Synergize Work on Regional BCP/BCM – Cross Sectorial Collaborations

- **Managing risks and impacts of natural disasters to business in the Asia-Pacific region with Public-Private Partnership**
  - To offer feasible solution package to enhance regional resilience
  - To initiate a pilot study on BCM-based supply chain
- **Seeking leadership and coordination for cross-sectorial coordination**
  - To engage key stakeholders though Public Private Partnership
  - To keep flexibility among Private Sector, NGOs, NPOs and government to take leading role
  - To manage risk of critical infrastructures

3.2 Accumulation of Knowledge, Experience and Know-How of BCP and BCM

- **Information-intelligence knowledge Platform**
  - To build up Integrated systems and database adopt Open Data Approach
  - To design scenario-based joint drill in the APEC region
  - To involve the disaster risk management with financing sectors
  - To keep BCM rating transparent
  - To discuss Disaster sign standard for risk communication
- **Knowledge transfer and the best Practices sharing of BCM**
  - To share information
  - To share experiences of formulating BCPs
  - To provide solution package on challenges while implementing BCPs

To work as a team, it is important to ensure no business know-how will be disclosed for disaster management, adopt innovative user friendly technology for collaboration, provide common picture on situation and clearly define the role, level of response and involvement for both public and private sectors are key to success. As a whole, the regional strategies through technology and collaboration for large-scale disasters must be: (1) smart and convenient using common picture of situation for operation instead of language communication; (2) on scenario-based; (3) cost effective for response and preparedness.

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GIS Application for Economic Assessment of Direct Disaster Losses

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Abstract. The article is aimed at presenting the proof-of-concept system for automated direct disaster losses, developed within a scientific project of University of National and World Economy, Sofia. The idea behind the project was to create a system that can be used by customers without expert knowledge on physical or economic modeling of disaster effects. Thus alleviating the initial phases of disaster planning in administration, providing raw picture of disaster threats. The article describes in general conceptual and physical schemes of the system and gives main requirements for data and GIS applications that can be used. The process of developing such system shows that it is a complicated, but possible task. The system is not production ready and it is implemented with one physical model for floods. Nevertheless, the possibility to use and reuse the physical model by automation of main model estimation phases gives opportunity for creation and assessment of different alternatives for disaster prevention and relief.

Keywords: GIS · Disaster losses · Disaster modeling

1 Introduction

Under the conditions of increasing climate change, good resource management for the protection of the population in disasters and accidents is becoming an even more up-to-date topic. Decisions on the allocation of defense costs should be made after a thorough analysis and public consultation.

At the same time, modeling and analysis of natural disasters, as well as construction of appropriate defense facilities, are activities that require a considerable amount of knowledge and experience. Such a level of expertise is difficult to ensure at all times, especially at the regional and municipal level of the state administration.

In this connection, the importance of creating and using GIS applications with a high degree of automation of the analysis process can be seen in all its stages - from physical modeling to economic analysis of alternatives for prevention and management of the consequences of natural disasters.

The purpose of this article is to present the possibilities of using GIS to standardize and automate the economic analysis of disasters and accidents.

The paper explores the results of a project work carried out at the University of National and World Economy to develop an integrated information system for

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economic analysis of the damage caused by natural disasters. The presented system is not a finished product ready for use but rather an example of proving the concept that it is possible to integrate and automate the analysis of prevention and the consequences of risk events using modern GIS technologies.

2 Requirements to the System and Software Applications

Economic effects of disasters can generally be described as direct and indirect effects.

Direct damages may be inflicted on immovable assets and on stock (including final goods, goods in process, raw materials, materials and spare parts). In essence, this category consists of damage to assets that occurred right at the time of the actual disaster. It may include the total or partial destruction of physical infrastructure, buildings, installations, machinery, equipment, means of transportation and storage, furniture, damage to farmland, irrigation works, reservoirs and the like. In the special case of agriculture, the destruction of crops ready for harvest must also be valued and included as direct damage.

Direct disaster losses refer to directly quantifiable losses such as the number of people killed and the damage to buildings, infrastructure and natural resources.

Indirect disaster losses include declines in output or revenue, and impact on wellbeing of people, and generally arise from disruptions to the flow of goods and services as a result of a disaster. The definitions of these concepts may fundamentally differ from one author to the other.

The proposed experimental integrated system focuses only on the determination of direct losses from potential disasters and accidents. The identification of indirect losses requires further analysis to determine the logistical connectivity between enterprises, the state of the transport network, the state and factors affecting the demand and supply of different products, the availability of substitute products, etc. Inclusion of a requirement for indirect cost analysis would lead to significant system complexity and the implementation of multiple additional analytical actions.

In addition, the direct effects and economic losses are estimated only on the basis of possible infrastructure damages.

The objective of accelerating and mitigating the work of the consumer analyzing the effects of natural disasters can be achieved if the following requirements are met:

- usability – the ability of the user to easily identify the region of research, the main characteristics of the terrain and the economic sites;
- standardization – using standards for information and protocols for the services provided. As a basis for these standards, those provided by Open Geospatial Consortium (OGC) [1] were chosen;
- automation – automating as much of the economic assessment as possible, starting with the choice of the region for evaluation, going through physical analysis and predicting the impact of the natural disaster, to the application of the cost model for economic evaluation of the affected sites;

- the ability to use software and data with free licenses and free access. This requirement was established to protect against dependence on the software and the dependence of company decisions, which is one of the EU requirements in such cases.

The idea behind the creation of the system is the use of a web interface. This provides a number of advantages, such as simplifying the use of the system and significantly better control and security. Moreover, the use of web-based systems is in line with the established practice of leading countries, organizations and companies in this field.

2.1 Conceptual Model

Taking into account the fact that the disaster analysis system must have a high degree of autonomy and independence, it can not rely on information from general or global mapping systems. It is therefore necessary to set up a proprietary mapping and information system.

Another significant argument to the system was taken into account here – the system shall not only provide, but also analyze the user's requests with the highest possible degree of automation. This in turn means that the basics of the model must be placed in the "Methods and Analytical Applications" field in Fig. 1. In other words, the conceptual scheme of the system shall be tailored to the selected analytical software and from there compatible applications for visualization and presentation of the results shall be sought.

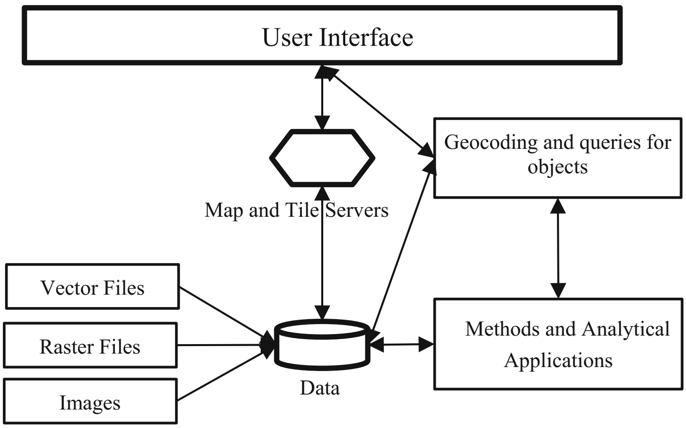

Fig. 1. Conceptual model of the integrated software system

Taking into account the system requirements described above, the GRASS GIS [2] application was selected. This is one of the open source software applications developed for the longest time, by a vast community of designers, and is based on perhaps the most powerful geographic software of general application – GDAL [3]. The GRASS GIS application was originally developed by the U.S. Army Construction Engineering Research Laboratories. There is hardly anything from the proprietary geographic software that these two applications cannot accomplish. Most of the methods described in the first stage of the study are implemented in GRAS GIS, and the rest can be implemented by GDAL, or another application using this library.

For the analysis, we need to have vector, raster and photo (orthographic or geo-referenced satellite or aerial images) data. The latter are not so important for the analysis itself, but are important to the user who, by having them, can better navigate the research area.

The data should cover the entire region of a given country and, if possible, the neighboring countries (natural disasters are not limited by administrative boundaries). This is a huge amount of information and its presentation is impossible unless multiple-level maps are used. In popular geographic systems, this is called the zoom function, which allows the illusion of zooming in and out of objects, through detailing and aggregation. This feature is realized using the so-called Map Tile Servers. The use of tiles reflects exactly what these apps do – split or summarize the map into smaller or larger, equal in size to the visible tile region.

Mapnik [4], one of the most popular, fast and seriously developed open-source map applications, was selected for the developed system. Mod Tile [5] was chosen as a Tile Server for maps provided by Mapnik.

2.2 Geocoding and References

The installation and use of a map server do not exhaust the necessary services required for system operation. The map server actually provides maps based on raster or vector data in a photo format (usually png, jpeg, svg, or tiff) that are further stylized according to a predefined color scheme for the terrain, forests, roads, and so on. There is no way to perform search or interactive mapping in these formats. These two features require two additional software applications.

For the needs of the model, the following specialized applications were selected:

- R [6], Shiny [7] and Shiny Server [8] – the software platform and the statistical language R were chosen as a common software application management environment. Shiny Server was selected as a server application to be used in Shiny Web environment and its associated R packets, which should provide visualization of the results;
- Nominatim [9] – server for geocoding and search of objects by name;
- OverPass API [10] – Application programming interface (API) to search by object types.

The importance of such search for automating the analysis is obvious - the system must be able to quickly and accurately identify all important objects and classify them - for example, residential buildings, industrial buildings, shops, etc.

2.3 Data Sources

Due to the fact that in Bulgaria there are practically no free available sources of official geographic information, the following global sources were used.

Vector Files

The only publicly available global vector data is provided by OpenStreetMap. This source uses “osm” format files based on the XML standard. Initially, information was introduced by volunteers - businesses and individuals. Later, municipalities and whole countries joined the system. Currently, most of the EU leading countries are to provide all non-classified geographic data in “osm” format.

Raster Files

The GISCO portal of the European Commission (the Geographical Information System of the COmmission) [11] is installed on the EUROSTAT website and provides publicly available information for the EU. For the purposes of this study, the files used are in raster format - improved and extrapolated Digital Elevation Model from Landsat capture with a resolution of about 27 × 27 m of the tiff format cell for the EU member states.

Other relevant data sources for physical disaster modeling can also be the INSPIRE portal of the EC containing different environmental and geographic data of the EU Member States as follows:

- US Geographic Survey (USGS) [12] geographic portals provide vast geo-spatial information across the Earth in the form of a variety of raster formats;
- Joint Research Centre European Soil Data Centre (ESDAC) [13] provides data in a raster format about the soils on the entire land surface;
- the geo-referenced European Environment Agency’s temperature database provides significant information in different geographic file formats about temperatures, winds, currents and pollution within the EU.

Information from the EU Copernicus Crisis Monitoring and Management Portal [14] can be used as a source for verification of the applied models.

3 Working Process of the System

The logical sequence of the workflow of the system can be summarized in three main stages - Select a region and create a physical disaster model, Determine losses, Analyze alternatives for prevention.

The chosen physical model for analysis is a 1D flood pattern. There are two main reasons for choosing this model.

First, the model only requires vector and raster data that can be provided by available free sources - more complex disaster models require much more information, such as soil type and humidity, afforestation, etc. that cannot be provided by free sources.

Secondly, the application of the model can provide sufficient information to make an economic assessment of the effects of the flood.

The use of more complex models for both floods and other types of disasters is possible if the necessary input geo-referenced information on their application is available. The two major cartographic applications - Mapnik and Overpass API - allow the addition of supplementary information from third sources. The same applies to the platform used for visualization and control – R.

The mathematical model of the flood falls into the so-called model type 1D hydrodynamic model (For full description of the model and its software application see Marzocchi et al. [16]) and uses the following mathematical equations to describe the physical model of the event.

The software model is embedded in the *r.inund.fluv* [15] application of GRASS GIS.

There are two input data for the model. Vector river and coastline data and raster relief data – Digital Elevation Model (DEM) of the research region.

3.1 Selecting a Region and a Physical Model

Having a map of the area, the user should be able to choose a region for the event. Therefore, a software application is required to work with the user (in the case of the system – in the user's browser) to transmit to the server data about the region selected by the client.

In the selected visualization and management framework, Shiny, and its associated R packages, there is a clear separation between the user and server parts of the applications being developed. The R leaflet [17] package is used as a client software that allows the user to interactively identify the region of interest.

In this case, the Draw function from the leaflet is used, which can draw a rectangle encompassing that part of the map which the user is willing to explore. Figure 2 shows how the user can select a region.

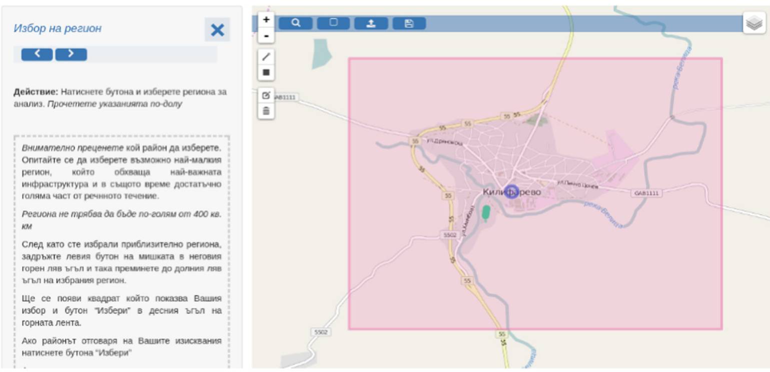

Fig. 2. Selection of a region by the user

Once the region is selected, its coordinates are transmitted to the server of the system. Coordinates are used to submit a request to Overpass API to establish the rivers in the region. The result from the request is a vector file containing the river lines that is visualized to the user in the way shown in Fig. 3.

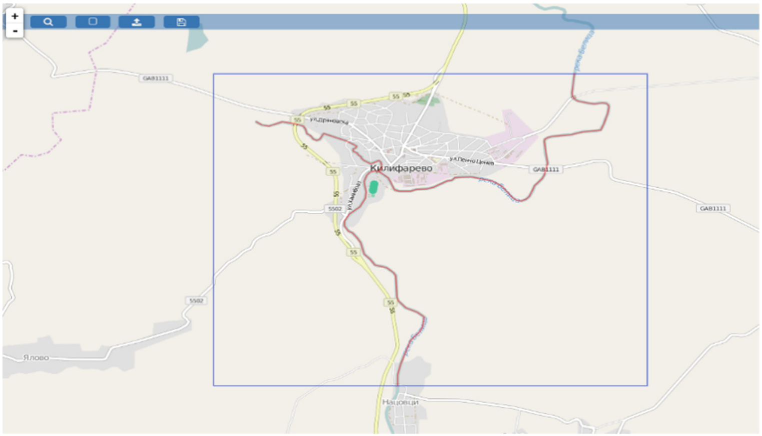

Fig. 3. Visualization of rivers in the region

Following user approval, the following actions are performed in the server part of the system:

- The region is "cut off" the DEM. As a result, a raster file with resolution 27 × 27 m is produced with the size of the region. Due to model requirements, the file is interpolated to a resolution of 3 × 3 m;
- Using the vector file for river lines, reference is made as to the height of the river bed in the raster file of the region. Riverside lines of only the largest rivers are mapped in available vector files. In order to make work easier for the user, the latter will not have to "paint" the shore lines, but an automated coastal calculation is used on the region's raster file using the build_chans() function of the R dynatopmodel [18].
- Once the required input data is available, the model is implemented by r.inund.fluv from GRASS GIS. The communication between R and GRASS GIS is performed through the spgrass6 [19] package from R.

The result of the model application is a raster file with the expected depth of the flood. The file is visualized to the user as shown in Fig. 4.

3.2 Identifying the Affected Infrastructure Sites

Once we have the flood raster file, it is possible to determine the scope of the flood and thus to identify the affected sites. All objects in the region are established by sending a request to the Overpass API with the coordinates of the region. As a result of the request, we receive a file containing both the coordinates of the objects and information about their type - road, building, type of building, etc. After vectoring the flood raster file, we can determine the overlay between the request file and the flood range. This overlay shows us the affected objects.

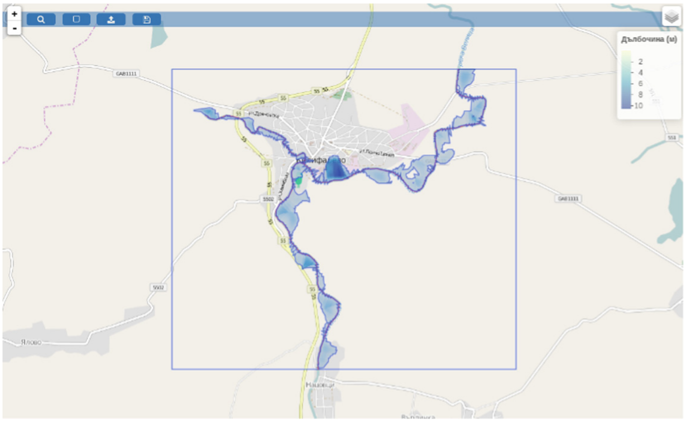

Fig. 4. Results of the model application

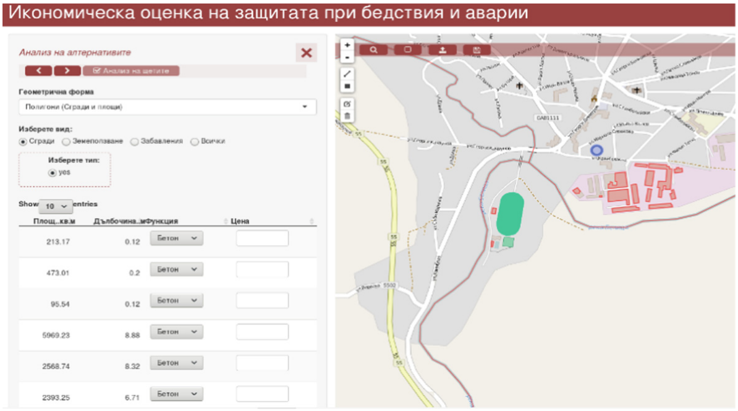

Fig. 5. Objects of the infrastructure in the flood range

The results are visualized to the user in the way shown in Fig. 5. The user already has a list of objects that he can identify according to type and cost.

3.3 Determination of Direct Economic Losses

As stated above, the experimental integrated system focuses only on the determination of direct losses from potential disasters and accidents.

The application of the physical flood pattern so far has allowed us to locate the flood area and identify the affected sites. The next step is to determine direct losses as the cost of recovering the affected sites.

The first approach that can be used here is to determine costs by identifying the intensity of impact of the event on an object and based on this to determine the recovery costs.

This approach has been used by the US Federal Emergency Management Agency (FEMA) to apply models for economic analysis of the consequences of natural disasters in the software application HAZUS [20]. Based on detailed studies of the relationship between flood intensity, on the one hand, and different materials, on the other hand, tables are created to determine the consequences for the relevant sites. Based on a study of average recovery rates for different types of objects, FEMA also sets the values for expected recovery costs at given breakpoints. The intensity of the flood is determined by the depth of the flood, the type of material and the type of the building site. The damage functions dependencies are shown in Fig. 6.

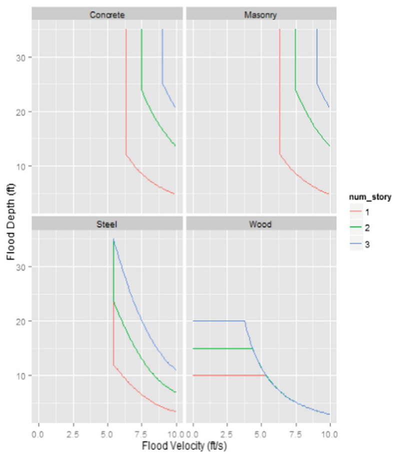

Fig. 6. Dependencies between flood depth, flood velocity and facilities materials

Having the raster file with water depth for each cell (file resolution has cell size 3×3 m) and taking advantage of the FEMA damage functions for each site, it is possible to determine the cost of flood damage recovery. In this case, they are available for use in R through the hazus [21] package.

The second possible approach is the direct input of the expected cost of damage recovery based on expert estimates or on the basis of an analysis of the damage from previous events.

The third possible cost estimation option in the integrated system is the use of landuse data from the European Commission's CORINE database [22]. In this geo-referenced database, 44 landuse categories were identified in a raster file with a resolution of approximately 100×100 m. CORINE landuse reference for the flood area is presented in Fig. 7.

If we have an average estimate of the recovery costs for each category, we can determine the average expected costs for a category based on the flood intensity estimate for each cell of the raster file. Such an average estimate is possible in the integrated system and is presented in Fig. 8.

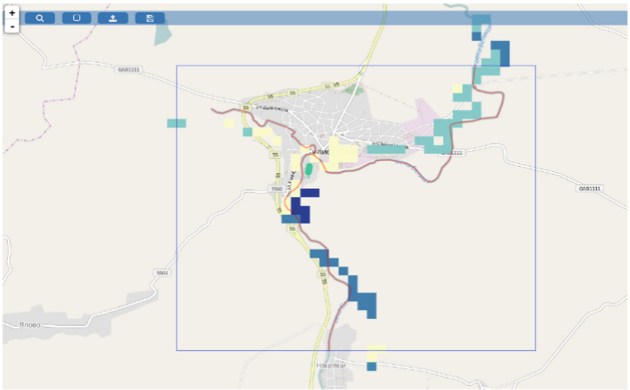

Fig. 7. Categories of affected areas according to CORINE geographic database

Show 10 entries Search:

	corine	n	min	max	range	mean	stddev	varian	cf_var	sum	first	median	third	x90
1	2	32509	9.553419	96.99413	88.440711	56.179063	22.142309	38.242323	1140.652343	99080.358478	41.676811	55.871981	72.970913	82.926816
2	12	59390	4.082396	80.405296	77.3229	37.127781	18.720241	13.091457	2354.11654	61683.717104	23.72973	35.865693	49.66171	60.37315
3	21	32412	1.186694	65.890033	65.703339	27.692736	16.177847	16.722875	1203.116264	46268.293462	14.811953	26.60121	39.067633	48.034255
4	29	9421	1.528795	15.507687	14.978892	8.371898	4.266037	3.075667	270.823409	12075.254548	6.037447	8.605558	10.871019	12.075183
5														

Showing 1 to 5 of 5 entries Previous 1 Next

Fig. 8. Table of results on flood intensity broken down by categories of affected areas

The first column of the table presents the identification numbers of the CORINE categories (2 - Discontinuous urban fabric, 12 – Non-irrigated arable land, 21 – Land predominantly occupied by agriculture, 22 – Agro-forestry areas), the remaining columns of the table present the intensity values, such as the number of affected cells, the average depth of the flood, the mean and standard deviation of the flood depth for each category.

Evaluating the three approaches to assess costs deployed in the integrated system, we can see that the third approach requires the least time for assessment and is the most inaccurate, the two more precise approaches require more time to be implemented, as recovery costs need to be determined for the specific region (let us recall that the costs used in the FEMA tables refer to the US regions).

3.4 Alternatives for Prevention and Protection – Dikes and Canals

In the experimental integrated system, another module for analysis was introduced - the possibility of generating different alternatives for prevention and protection. In the case of floods, this means changing the terrain in two possible directions - digging rivers or building dikes.

The change of the terrain is implemented in the basic version by selecting the river line to be excavated and by marking the places for construction of dikes. Figure 9 presents these options.

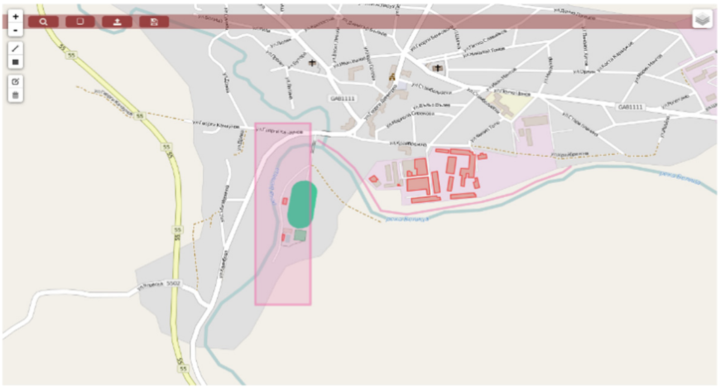

Fig. 9. Setting prevention and protection measures

In the figure, a rectangle is used to help select the part of the river in which a canal is to be dug, and by "drawing" lines the location of dikes to be built is determined. The user has the opportunity to specify a certain width, as well as the depth/height of the canals and dikes.

The lines of the resulting vector file of channels and/or dikes are buffered to the required width by the rgeos [23] application of R. The resulting polygons are used to establish a new overlay with the raster file. Altitude values for cells in the cross section are increased or decreased by the desired value depending on whether they are channels or dikes.

Once the region's DEM has been changed to the user's wishes, the entire workflow of the system is performed again - from the application of the flood model to the damage detection. In this way, the user can quickly identify and compare different prevention and protection alternatives.

4 Conclusion

The presented experimental integrated system for assessing economic losses from disasters and accidents largely fulfills the goal of facilitating user work by integrating activities on modeling events, determining economic losses and identifying alternatives to prevention and protection.

At the same time, the following features should be noted in the development of such systems:

Firstly, the task of encompassing a large region within one country and implementing the chosen model in any part of the region greatly complicates the system's operation and requires considerable effort to install and share complex server applications using large volume and complexity of data.

Secondly, freely available data on flood modeling is sufficient only for the simplest models, with data for economic damage being most difficult to provide.

Last but not least, the development of a working integrated and automated system for economic assessment of disasters and accidents requires previously agreed national norms on the approaches, models and activities for disaster and accident assessment. The availability of such guidance would lead to comparability and stability of the performance of the system.

In the end, it can be stated that even if the results of the work of the proposed system are not accurate with a detailed economic study of costs based on geodesic and geo-physical exploration of potential disasters in a given region, the system provides the opportunity for rapid comparison and evaluation across multiple regions, and focusing efforts (further detailed research) on potentially the most dangerous of them.

The ability to reduce expert complexity by automating most of the analytical activities can bring the use of such systems closer to the lower regional and municipal levels of administration, thus providing a cheaper and easier tool to support the rather difficult budget decisions related to the prevention and protection of the population in case of disasters and accidents.

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Evacuation Planning for Disaster Management by Using the Relaxation Based Algorithm and Route Choice Model

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Abstract. Research in the field of disaster management is done by utilizing information and communication technology. Where disaster management is discussed is about evacuation planning issues. The evacuation stage is a very crucial stage in the disaster evacuation process. There have been many methods and algorithms submitted for the evacuation planning process, but no one has directly addressed evacuation planning on dynamic issues concerning time-varying and volume-dependent. This research will use the Relaxation-Based Algorithm combined with the Route Choice Model to produce evacuation models that can be applied to dynamic issues related to time-varying and volume-dependent because some types of disaster will result in damage as time and evacuation paths are volume-dependent so as to adjust to the change in the number of people evacuated. Disaster data that will be used in this research is sourced from Disaster Information Management System sourced from DesInventar. The results of this study are expected to produce an evacuation planning model that can be applied to dynamic problems that take into account the time-varying and volume-dependent aspects.

Keywords: Disaster management · Evacuation planning · Time-varying · Volume-dependent

1 Introduction

In real life situations, disasters such as floods, earthquakes, hurricanes and terrorist attacks can occur to threaten human life. The evacuation problem has attracted much attention from various researchers. The current modeling approach for evacuation planning can be divided into two categories, namely analytical approach and simulation based approach [1].

An analytical approach has been widely used to generate an optimal evacuation plan for disaster response. The research conducted by [2] illustrates a model to minimize the evacuation path time for emergency evacuation. [3] presented a Two Network

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Flow method using Dijkstra's algorithm to generate an evacuation plan through minimizing the total distance traveled. [4] produced several models that can be applied to evacuation problems in multi-story buildings with an approach that uses the dynamic network flow model. The network flow model was then refined by [5] to identify the optimal evacuation route plan for complicated evacuation route situations. Furthermore, [6] developed the Integrated Lagrangian Relaxation and Tabu Search approach to the problem of optimizing the evacuation routes on land. [7] has conducted research to overcome capacity constraint problem by using heuristic algorithm.

[8] proposed an optimal dynamic traffic assignment formulation system to minimize total evacuation time. [9] has proposed frame work to obtain an optimal route. [10, 11] have proposed stochastic system method-optimal dynamic traffic assignment formulation to improve evacuation model using probabilistic demand constraints. [12] uses a noisy genetic algorithm to design an evacuation path that can save more and more people within a specified time limit. [13] used a heuristic algorithm to optimize the evacuation path associated with the process of endogenous risk minimization in the evacuation process. Research conducted by Li and Ozbay [13] has been able to overcome the problem of uncertainty (uncertainty) in the evacuation process.

Research that has been done by some researchers, have not pay attention to side constraint aspects such as distance and cost. [1] has developed [13] research and incorporated it with the Lagrangian Relaxation-Based approach to address side constraint issues in the evacuation process. However, the weakness of [1] is not yet applicable to dynamic issues such as time-varying and volume-dependent. Some types of disasters will result in damage as time increases and evacuation routes are volume-dependent. Research conducted by [1] overrides the time as well as the volumes acceptable to an evacuation route by assuming the number of persons to be evacuated is known.

Reference [9] has resulted in research in selecting routes that are best adapted to the volume or capacity of a route. The results of research from a number of researchers can be summarized in Table 1.

In Table 1, it can be seen that there are 2 (two) objective functions used by a number of researchers, namely: Minimizing the Total Evacuation Time (MTET) and Minimizing the Total Evacuation Distance (MTED) and there are also a number of algorithms used. While the application of the network used also there are 2 (two) forms: Transportation Network and Building Network.

Researchers in this study will use the Relaxation-Based Algorithm combined with the Route Choice Model to produce an evacuation model that minimizes the evacuation time that can be applied to dynamic issues related to time-varying and volume-dependent because some types of disaster will result in damage as time increases and the evacuation route is volume-dependent in order to adapt to changes in the number of people evacuated.

2 Evacuation Model with Relaxation-Based Algorithm and Route-Choice Model

Research that has been done by some researchers, have not pay attention to side constraint aspects such as distance and cost. [1] has developed [13] research and incorporated it with the Lagrangian Relaxation-Based approach to address side constraint issues in the evacuation process. However, the weakness of [1] is not yet applicable to dynamic issues such as time-varying and volume-dependent. Some types of disasters will result in damage as time increases and evacuation routes are volume-dependent. Research conducted by [1] overrides the time as well as the volumes acceptable to an evacuation route by assuming the number of persons to be evacuated is known.

Researchers in this study will use the Relaxation-Based Algorithm combined with the Route Choice Model to produce an evacuation model that can be applied to dynamic issues related to time-varying and volume-dependent because some types of disaster will result in damage as time and evacuation paths are volume-dependent so that it can adapt to changes in the number of people being evacuated.

Table 1. Comparative research table

Objective function	Algorithm	Application-network	Side costraint	Uncertainty	Publication
MTET	NETVACI	T	No	No	Sheffi *et al.* [2]
MTED	Dijkstra's algorithm	T	No	No	Yamada [3]
MTED	CPLEX solver	T	No	No	Cova and Johnson [5]
MTET	Heuristic algorithm	B	No	No	Lu *et al.* [7], (2005)
MTET	Heuristic algorithm	T	No	No	Sbayti and Mahmassani [8]
MTET	DYNASMART-P	T	No	No	Han *et al.* [9]
MTET	LIPSOL solver	T	No	No	Chiu and Zheng (2007)
MTET	P-Level efficient points	T	No	Yes	Yazici and Ozbay [10]
MDEF	Noisy genetic algorithm	B	No	Yes	Miller-Hooks and Sorrel [12]
MTET	GAMS slover	T	No	Yes	Ng and Waller (2010)
MTET	Heuristic Algorithm	T	No	Yes	Li and Ozbay [13]
MTET	Relaxation-based algorithm	T	Yes	Yes	Wang *et al.* [1]

2.1 Heuristic Algorithm

The heuristic algorithm for the evacuation planning process was first introduced by [13] and this algorithm is a type of algorithm that uses the objective function of MTET with its ability to handle uncertainties in the evacuation process. The stages of the Heuristic Algorithm in the disaster evacuation process can be seen in Fig. 1.

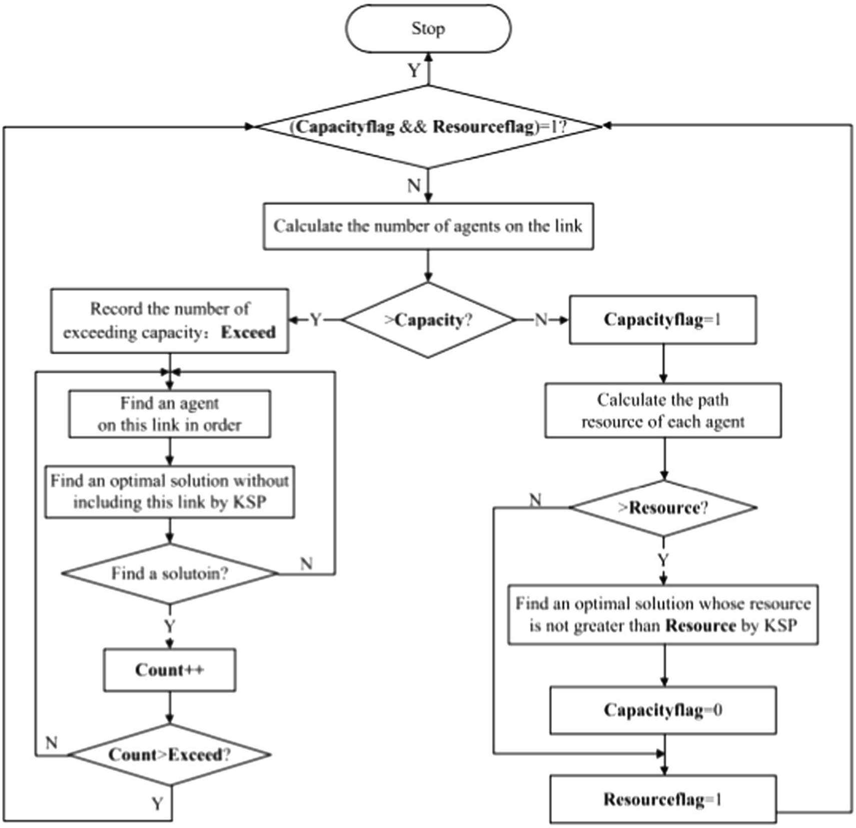

Fig. 1. Flowchart stages of Heuristic Algorithm

2.2 System Constraint on Evacuation Process

There are a number of constraints that are considered in the evacuation process, as follows [1]. The mathematical parameters used for constraints can be seen in Table 2.

Flow Balance Constraint. Flow Balance Constraint is a constraint related to the origin region (Origin O_k) and Destination Region (Destination D_K). Flow Balance Constraints are used to generate paths using Eq. 1

$$\sum_{(i,j)\in A} x_{ij}^{ks} - \sum_{(j,i)\in A} x_{ji}^{ks} = \begin{cases} 1, & i = 0_k \\ -1, & i = D_k, \quad k = 1, 2, \ldots., K, \; s = 1, 2, \ldots, S \\ 0 & otherwise \end{cases} \tag{1}$$

Capacity Constraint. Capacity Constraint will be applied to a number of agents through a link in a scenario with the aim of ensuring travel efficiency and avoiding congestion. The Capacity Constraint can be seen in Eq. 2.

$$\sum_{k=1}^{K} x_{ij}^{ks} \leq u_{ij}^{s}, \forall(\mathrm{i,\ j}) \in \mathrm{A,\ s = 1,\ 2, \ldots,\ S} \tag{2}$$

Side Constraint. Side Constraint is used to ensure the total load required for an agent K does not exceed the upper limit of the required resources. This can be seen in Eq. 3.

$$\sum_{(i,j)\in A} x_{ij}^{ks}.w_{ij}^{kl} \leq w^{kl}, \; s = 1, 2, \ldots, S, \quad k = 1, 2, \ldots., K, \; l = 1, 2, \ldots, L \tag{3}$$

Table 2. Subscript and mathematical parameters used

Symbol	Definition
N	The set of nodes
A	The set of links
i, j	The index of nodes, $i, j \in N$
(i, j)	The index of directed links, $i, j \in A$
s	The index of scenario
S	The number of scenarios
k	The index of agent
K	The total number of agents
l	The index of side constraint
L	The total number of side constraints
u_{ij}^{s}	The capacity of link (i, j) in scenario s
t_{ij}^{ks}	The travel time of agent k on link (i, j) in scenario s
p_s	The probability in scenario s
w_{ij}^{kl}	The l-th resource weight of agent k on link (i, j)
w^{kl}	The upper limit of the l-th resource for agent k

2.3 Lagrangian Relaxation

The Lagrangian Relaxation model is used to overcome side constraint problems in the evacuation process. Lagrangian Relaxation is used to correct the gap between the lower bound and upper bound of the relaxation model. The lower bound will be applied to the objective value generated from the relaxation model and the upper bound will be used for the objective value generated from the original model.

The objective value of the original model can be calculated using Eq. 4

$$E(X,\, s) = \sum_{k=1}^{K} \sum_{(i,j)\in A} t_{ij}^{ks}.x_{ij}^{ks},\; s = 1,\, 2, .., \,S \tag{4}$$

The objective function used is the time-based objective function so that the maximum time for the entire scenario can be calculated using Eq. 5.

$$E_{max}(X) = \max_{1\le s\le S} \mathrm{E}(X,\, s) \tag{5}$$

Since there are several applicable scenarios, the final objective value of the original model can be formulated using Eq. 6.

$$\min Z = \sum\nolimits_{s=1}^{S} \sum\nolimits_{k=1}^{K} \sum\nolimits_{(i,j)\in A} p_s \cdot t_{ij}^{ks} \cdot x_{ij}^{ks} \tag{6}$$

In the relaxation model there are some additional constraints that can be given that can be symbolized by α, β, γ so that the objective value of the relaxation model can be calculated using Eq. 7.

$$\textbf{\textit{Relaxed Model}} : \begin{cases} \min \quad \mathrm{R}(\alpha,\, \beta,\, \gamma) \\ \text{s.t. Constraints (1) and (5)} \end{cases}.$$

Where

$$\begin{cases} \mathrm{R}(\alpha,\, \beta,\, \gamma) = \sum\limits_{k=1}^{K} \sum\limits_{s=1}^{S} \sum\limits_{(i,j)\in A} \mathrm{p_s.t_{ij}^{ks}.x_{ij}^{ks}} + \sum\limits_{s=1}^{S} \sum\limits_{(i,j)\in A} \propto_{ij}^{s} \left(\sum\limits_{k=1}^{K} \mathrm{x_{ij}^{ks}} - \mathrm{u_{ij}^{s}} \right) \\ \qquad + \sum\limits_{k=1}^{K} \sum\limits_{s=1}^{S} \sum\limits_{l=1}^{L} \beta_l^{ks} \left(\sum\limits_{(i,j)\in A} x_{ij}^{ks}.w_{ij}^{kl} - w^{kl} \right) \\ + \sum\limits_{k=1}^{K} \sum\limits_{(i,j)\in A} \left(\sum\limits_{s=1}^{S-1} \gamma_{ij}^{ks} \left(x_{ij}^{ks} - x_{ij}^{k,s+1} \right) + \gamma_{ij}^{ks} \left(x_{ij}^{ks} - x_{ij}^{kl} \right) \right) \end{cases} \tag{7}$$

2.4 Relaxation-Based Algorithm

Relation-Based Algorithm was proposed by [1] and is the result of integration between Heuristic Algorithm with Lagrangian Relaxation. A small gap between the lower bound and the optimal objective value of the original model will result in a high quality solution. The stages of the Relaxation-Based Algorithm are as follows.

Step 1: Initialization. Let iteration number $\mu = 1$. Initialize the Lagrangian Multiplier Vectors $(\alpha,\, \beta,\, \gamma)$

Step 2: Solve the Relaxed Model.

Step 2.1: Compute the optimal solution X of **SP1** by the label-correcting algorithm; calculate the objective value of relaxed model, denoted by Lower Bound (LB).

Step 2.2: Evaluate whether the solution X achieved by **Step 2.1** is feasible for the original model. If the solution is feasible, go to **Step 4**; otherwise go to **Step 3.**

Step 3: Implement Adjustment Heuristic. Execute the adjustment heuristic to deal with the infeasibility until a feasible solution $X^{'}$ is obtained

Step 4: Update Relative Gap.

Step 4.1: Compute the objective value of the original model, which is denoted as the Upper Bound (UB).

Step 4.2: Compute the relative gap between the Upper and Lower Bounds, which is calculated by RG = (UB–LB)/UB

Step 5: Update Lagrangian Multipliers. Update Lagrangian Multipliers $\alpha_{ij}^{s}, \beta_{l}^{ks}, \gamma_{ij}^{ks}, \forall(i,j) \in A, s = 1, 2, \ldots., S, k = 1, 2, \ldots, K,$

$l = 1, 2, \ldots, L$ by using the sub − gradients below :

$$\nabla R_{\alpha_{ij}^{s}} = \sum\nolimits_{k=1}^{K} x_{ij}^{ks} - u_{ij}^{s}$$

$$\nabla R_{\beta_{l}^{ks}=\sum_{(i,j)\in A} x_{ij}^{ks}.w_{ij}^{kl}-W^{kl}}$$

$$\nabla R_{\gamma_{ij}^{ks}=x_{ij}^{ks}-x_{ij}^{k,s+1},s=1,2,\ldots.,S-1}$$

$$\nabla R\gamma_{ij}^{ks} = x_{ij}^{ks} - x_{ij}^{kl}$$

Step 6: Termination Condition Test. If the relative gap RG is less than the predetermined value or $\mu > \mu_{max}$ (a predetermined maximum iteration number), stop; otherwise, let $\mu \leftarrow \mu + 1$, go to **Step 2**.

2.5 Route Choice Model

Route Choice Model (RCM) proposed by [9] by incorporating an approach in choosing the route best adapted to the volume or capacity of a route. The RCM approach is based on the Available Evacuation Route Set (AERS). The basic idea is that when a scenario is selected for a criterion it must first be calculated the capacity of a route. The stages in the Route Choice Model process are as follows.

1. Take all possible routes on AERS.
2. Determine the parameters to consider in the AERS, including: radius between evacuees, mass M of evacuees, and velocity.
3. Select 5 (five) best route from AERS to make the route set (route set).

2.6 Integration Between Relaxation Based Algorithm with Route Choice Model

The basic idea of integration of the Relaxation Baed Model with the Route Choice Model is to select all available routes on AERS that meet the requirements and also include additional parameters used in the Route Choice Model as the new hard constraint for the Relaxation Based Algorithm.

3 Research Methodology

The stages of research conducted by researchers from this study can be seen as a whole in Fig. 2.

4 Result and Discussion

Researchers in this study used the Relaxation-Based Algorithm combined with the Route Choice Model to produce an evacuation model that minimizes evacuation time that can be applied to dynamic issues related to time-varying and volume-dependent because some types of disaster will result in damage as time increases and the evacuation route is volume-dependent in order to adapt to changes in the number of people evacuated.

Our paper has not provided relevant terms such as strategy, measure, situation and the interconnections of these terms in the implementation of this model. The importance of this research for future studies is that the results indicate that the evacuation process much consider about distance and cost and can be applied in dynamic issues involving time-varying and volume-dependent.

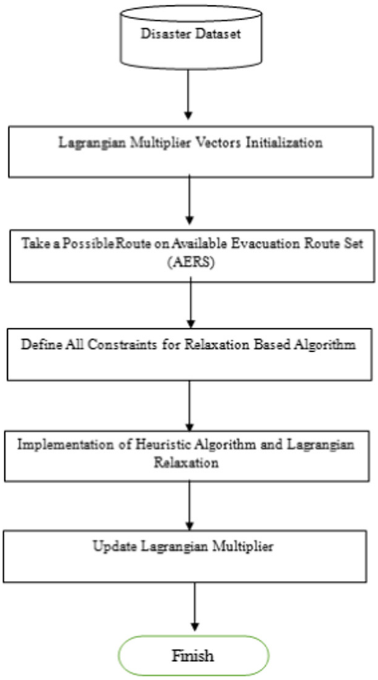

Fig. 2. Research methodology

5 Conclusion

The conclusion of this research are as follows. First, In the evacuation process, it is necessary to consider a number of side constraints such as distance and cost and also produce evacuation models that minimize evacuation time that can be applied to dynamic issues involving time-varying and volume-dependent. Second, it is confirmed that the resulting model using the Relaxation-Based Algorithm combined with the Route Choice Model have produced an evacuation model that can be applied to dynamic issues related to time-varying and volume-dependent because some types of disasters will result in damage as time increases and the evacuation path is volume - dependent so that it can adjust to changes in the number of people being evacuated.

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Data Processing for Assessment of Meteorological and Hydrological Drought

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Abstract. Accurate and reliable data processing is of primary importance for drought assessment. It helps decision makers to lay out mitigation measures within the context of drought preparedness planning and water resources management. In order to understand meteorological and hydrological drought, we need to identify drought characteristics (duration, severity and spatial extent). Drought indices are essential tools quantifying drought severity and identifying its frequency and duration. For the calculation of drought indices, availability of long time series of undisturbed, good-quality observational data is essential. The studied area cover a Bulgarian part of the catchment of Struma River which is one of the largest Bulgarian rivers. The general aim of this research is to evaluate the occurrence of hydrological and meteorological droughts in Struma River basin and to show utilization of various indices for comparative analysis of meteorological and hydrological drought. Drought events are identified using the following indices—Standardized Precipitation Index (SPI), Standardized Precipitation Evapotranspiration Index (SPEI) and Streamflow Drought Index (SDI) for time scales 6 and 12 months. Additionally to these indices, we use also Rainfall Anomaly Index (RAI) and introduce Streamflow Anomaly Index (SAI). The main investigated period is 1962–2016.

Keywords: Drought · Precipitation · River runoff · SPI · SDI

1 Introduction

Drought is a major natural hazard with multiform impacts on the environment, the economy and society. Drought affects more regions and more people globally than many other natural hazards [1]. The American Meteorological Society have grouped various kind of drought into four categories: meteorological, agricultural, hydrological and socioeconomic droughts. The four categories are associated with different components of the hydrologic cycle. Generally, precipitation is the driving and critical factor in the hydrologic cycle. Meteorological drought is an extreme weather phenomenon having the character of an atmospheric anomaly caused by a period of below-normal rainfall. Disruption of the water balance of a given area due to a shortage of rainfall and strong evapotranspiration (meteorological drought) consequently causes excessive drying of the soil (soil drought), lowering the groundwater level and reducing water flows in the rivers (hydrological drought). Among the different types of droughts, the hydrological component is the most important, given the high dependence of many

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activities (industrial, urban water supply and hydropower generation), on the surface water resources [2]. Hydrological droughts also have a significant impact on water quality by disturbing the river's natural processes of self-purification. Hydrologically, the region impacted by drought is not only limited to the river network and its vicinity, but also to the whole basin [3]. Reasons for the occurrence of hydrological drought are complex, because they are dependent not only on the atmosphere, but also on the hydrological processes that feed moisture to the atmosphere and cause storage of water and runoff to streams [4]. According to Van-Loon [5], hydrological drought has the most significant effects in almost all different sectors as shown in Table 1. Efficient early warning system against drought and integrated water resource management requires proper interpretation of area monitoring data at the drainage-basin scale. The success of drought preparedness planning and mitigation depends, in particular, on how accurate the droughts are defined and drought characteristics are quantified. Therefore it is important to investigate both - hydrological and meteorological droughts in the river basin.

Table 1. The major drought impacts for different drought categories

Impact category	Impact sub-category	Hydrological drought	Meteorological drought	Agricultural/soil moisture drought
Agriculture	Rain-fed Irrigation	x	x	x x
River basins/ecosystems	Terrestrial Cooling	x x	x	
Energy and industry	Hydro-power	x		
Navigation		x		
Drinking water		x		
Recreation		x		

Source: Van-Loon [5]

The number of droughts will increase on a global basis due to global warming which leads to higher temperatures and favors dry conditions [6, 7]. In the European Union (EU), more than 4800 drought-related impacts entries have been identified in the European Drought Impact Report Inventory (EDII) across 15 different impact categories from agriculture to water quality [8] and financial losses over the last 3 decades were estimated to over EUR 100 billion [9]. Climate change studies project longer, more frequent and severe meteorological droughts in southern Europe, especially in the Mediterranean and the Balkans including Bulgaria [10]. Both, geographic location and climatic conditions are favorable to the occurrence of droughts in Bulgaria. The country has experienced several drought episodes during the 20th century, most notably in the 1940s and 1980s. Drought in Bulgaria was most severe in 1945 and especially in the year 2000, with precipitation 30% less than the current climatic values [11]. Studies revealed that there is a general tendency towards drying during the last two decades in some parts of Bulgaria [12].

To counteract the negative effects of drought and to take appropriate action and preventive measures, reliable and proven indicators of the intensity of drought should be available. Drought indices are very important tools to monitor and to assess drought [13]. Although a multitude of drought indices exist, we select a subset of three indices to evaluate different types of drought: the Standardized Precipitation Index (SPI) [14], the Standardized Precipitation–Evapotranspiration Index (SPEI) [15, 16]; [17], the Streamflow Drought Index (SDI). A significant part of the drought indicators, described in the literature and used in the monitoring of drought in various regions of the world, is based on the amount of atmospheric precipitation. These include the Standardized Precipitation Index (SPI), recommended for use in the practical monitoring of drought [14, 18–20]. SPI is used to detect periods of drought and assess its severity. It is used in the USA (for operational monitoring of drought by the National Center for Drought Prevention), and in Europe, among others in Germany [21], Greece [22], Portugal [23], Poland [24] and Bulgaria [25–27]. Another index recommended by WMO is the Standardized Precipitation-Evapotranspiration Index (SPEI). The original SPEI input parameters are precipitation and temperature data. Mathematically, it is similar to SPI, but it includes the effect of temperature variability. The SDI index has not been used and studied in Bulgaria, but it was applied to the analysis of regional droughts in Europe [28, 29], Asia [30–32], Turkey [33] and USA [34].

The main purpose of this study is to determine the frequency of occurrence of meteorological and hydrological drought in different periods over many years (1962–2016), based on the Standardized precipitation index (SPI), Streamflow drought index (SDI) and additionally Standardized precipitation evapotranspiration index (SPEI) and comparison of these indicators as criteria for assessing drought.

2 Study Area and Data

The trans-boundary Struma River basin has a total area of 16,747 km^2 and is the second largest catchment area in Bulgaria and the fifth longest Bulgarian river. Its basin is shared by four countries: Bulgaria (50.6%, 8,473 km^2), Greece (35.8%, 5,990 km^2), FYROM (9.8%, 1,641 km^2) and Serbia (3.8%, 643 km^2). The total length of the river is about 390 km. It springs from the Southern slopes of the Vitosha Mountain, in Bulgaria, (2180 m a.m.s.l.) and ends up in Aegean Sea (Strymonikos Gulf). After a south-southeast route of 290 km, Struma River leaves the Bulgarian territory near the Kulata village (85 m a.m.s.l.). The basin has a pronounced mountainous character sculpted by the hydrographic network and glacial denudation, with an average elevation of about 900 m above sea level. The climate in the Upper Struma River is moderate continental, while in the middle part - transitional continental with significant Mediterranean influence. Mean annual precipitation in the basin is 566 mm and potential evapotranspiration is 629 mm. Most precipitation is concentrated in the winter months, with peak rainfall occurring from November through March and the summer is quite a dry season [27]. Annual precipitation values have ranged from 480 mm (in lower and southernmost parts, station Sandanski) to mm to 700 mm at the altitude higher than 1100 m (station Rila monastery).

The mean annual flow of the Struma River is 2,242 × 10^6 m^3, which constitutes 13% of the country's total precipitation and runoff with the coefficient of variation Cv = 0.32 and Cs = 0.57. The internal variability of river runoff depends on combinations and distribution of rainfall, snow cover and air temperature. In the high mountain parts of the area, the river flow in the winter is low, with a minimum in February, as a result of the reduced water flow under the thick snow cover and low temperatures. In this part, heavy rainfall in the spring and the presence of intense snowmelt led to high water period with a peak in May (up to about 30% of the annual runoff). With the decrease of the altitude of the basins high water period shifts to the winter months, the maximum in the southernmost parts of the basin is in February. The low water period begins in July and continues until winter, with monthly minimum in September.

The Bulgarian part of the River Basin is home to 485 000 people (7% of Bulgaria's total population). The main water users of surface water are domestic supply, livestock farming, industry, energy production and to a less degree irrigation [35]. The runoff variability is analysed on the bases of monthly data from nine stream gauging stations (see Table 2).

Table 2. List of stream gauging stations used in the research

River	Stream gauging station	Drainage area (km^2)	Average elevation of drainage area (m)	Meteorological station	Altitude (m)
Struma	Pernik	284.0	1018	Pernik	768
Struma	Boboshevo	4320	974		
Sovolianska Bistrica	Garlyano	41.90	1682	Kyustendil	520
Eleshnica	Vaksevo	315.3	1058		
Rilska	Pastra	222.0	1918	Rila monastery	1150
Bistritsa (Blagoevgrad)	Slavovo	105.0	–	Rila	505
Biistritsa (Blagoevgrad)	Blagoevgrad	206.5	1467	Blagoevgrad	424
Sushitska	Polena	32.10	–		
Sandanska Bistrica	Lilyanovo	118.4	–	Sandanski	206

The information about the precipitation is from six meteorological stations situated close to the stream gauging stations in an area with different geographical and climatic conditions (see Table 2). The main investigated period is 1962–2016. The studied area with the geographical position of stream gaging and meteorological stations is represented on Fig. 1.

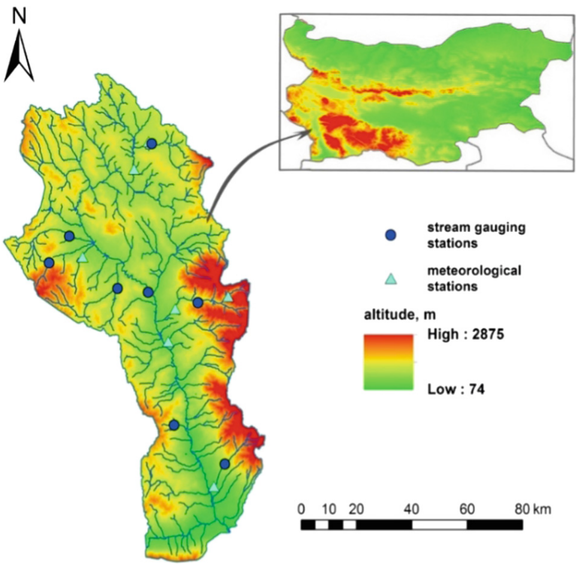

Fig. 1. Studied area and location of stream gauging and meteorological stations

3 Methods

The drought indices are important tools for clarifying the severity of drought events. They are mainly represented in a form of time series and are used in drought modeling and forecasting [4]. SPI was developed in Colorado by McKee et al. [14] to serve as a "versatile tool in drought monitoring and analysis". It is standardized and can be computed at different time scales, allowing it to monitor the different kinds of drought [36]. The SPI calculation for any location is based on the long-term precipitation data for a chosen period. This long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI for the location and desired period is zero [37]. The software provided by the National Drought Mitigation Center, University of Nebraska (https://drought.unl.edu/droughtmonitoring/SPI/SPIProgram.aspx, accessed by 10 February, 2019), is used for calculation of SPI.

Standardized Precipitation Evapotranspiration Index (SPEI.) is a relatively new drought index. The study of drought by SPEI in Bulgaria is still not well developed. SPEI uses the basis of SPI but includes a temperature component, allowing the index to account for the effect of temperature on drought development through a basic water balance calculation [15]. The multi-scalar character of the SPEI enables its use in various scientific disciplines to detect, monitor and analyze droughts [15]. SPEI can measure drought severity according to its intensity and duration and can identify the beginning and the end of drought periods. It can be calculated for time steps of as little as 1 month up to 48 months or more. Monthly updates allow practical application, and the reliability of the results increases with the increasing of the available time-series data.

Streamflow Drought Index (SDI) is a very simple and effective index for hydrological droughts [28]. The SDI for each gauged station was determined using the following relation:

$$V_{i,k} = \sum_{j=1}^{3k} Q_{i,j} \quad i = 1, 2\ldots j = 1, 2\ldots, 12 \; k = 1, 2, 3, 4 \tag{1}$$

in which $V_{i,k}$ is the cumulative streamflow volume for the i-th hydrological year and the k-th reference period, k = 1 for November-January, k = 2 for November-April, k = 3 for November-July, and k = 4 for November-October. Based on the cumulative streamflow volumes "$V_{i,k}$", the Streamflow Drought Index (SDI) is defined for each reference period k of the i-th hydrological year as follows:

$$SDI_{i,k} = \frac{V_{i,k} - V_k}{S_k} \; i = 1, 2\ldots, \; k = 1, 2, 3, 4 \tag{2}$$

where "V_k" and "S_k" are respectively the mean and the standard deviation of cumulative streamflow volumes of the reference period "k" as these are estimated over a long period of time. In this definition the truncation level is set to "Vk" although other values based on rational criteria could be also used. Nalbantis and Tsakiris [28] quantify 4 states (classes) of hydrological drought for SDI, which are determined in an identical way to those used in the meteorological drought indices SPI and SPEI. States of drought are defined by an integer number using criteria as per Table 3.

Table 3. Classification of drought conditions according to the SDI, SPEI and SPI

State	Description	Criterion
1	Extremely wet	SDI;SPI;SPEI $\geq$ 2.0
2	Very wet	1.5 $\leq$ SDI;SPI;SPEI $\leq$ 1.99
3	Moderately wet	1.0 $\leq$ SDI;SPI;SPEI $\leq$ 1.49
0	Non-drought	SDI;SPI;SPEI $\geq$ 0
−1	Mild drought	−1.0 $\leq$ SDI;SPI;SPEI $\leq$ 0.0
−2	Moderate drought	−1.5 $\leq$ SDI;SPI;SPEI $\leq$ −1.0
−3	Severe drought	−2.0 $\leq$ SDI;SPI;SPEI $\leq$ −1.5
−4	Extreme drought	SDI;SPI;SPEI $\leq$ −2.0

In the proposed methodology, the reference periods start from November of each year, which is considered the beginning of hydrological year in Bulgaria. The drought assessment is made using two overlapping periods: at annual level - hydrological year (November – September) and at seasonal level – cold half-year (November – April). In order to evaluate the drought during these two periods SPI, SPEI and SDI are calculated with a 12 and 6 month step, respectively.

The present paper aims to show the utilization of various indices for drought detection and analysis. Additionally to the above mentioned indices, we calculate also Rainfall Anomaly Index (RAI) which can be used for assigning the magnitudes to positive and negative precipitation anomalies. For analysis of negative anomalies and drought events the index is calculated by

$$RAI = -3\frac{P_i - \bar{P}}{\overline{E - \bar{E}}} \quad (3)$$

where P_i is precipitation for every year, P - average e precipitation for the investigated period, and E is average of ten lowest annual precipitation totals (driest years) for the investigated period.

RAI is used as a tool for meteorological drought investigation by Olukayode Oladipo [38], Keyantash and Dracup [36], Nikolova and Vassilev [39], Hänsel and Matschullat [40], Hänsel et al. [41], Fluixá-Sanmartín et al. [42] etc.

The same method was applied to annual streamflow data and Streamflow Anomaly Index (SAI) was calculated. The classification of dry periods according to RAI and SAI is shown in Table 4.

Table 4. Classification of droughts according to Rainfall Anomaly Index and Streamflow Anomaly Index

RAI/SAI	Classification
−0.49 to 0.49	Near normal
−0.99 to −0.50	Slightly dry
−1.99 to −1.00	Moderately dry
−2.99 to −2.00	Very dry
≤ −3.00	Extremely dry

4 Results

The SPI, SPEI and SDI values based on the meteorological and hydrological data from the Struma River Basin were calculated for the 6 and 12 month time scales during 1962–2016. We investigate hydrological year from November to October. Due to the climatic conditions in South Bulgaria, where a minimal rain period lasts from June to October, the SPI and SDI values of 6 months and above time scale step seem more useful than the 3 months one. The first period (November through April) includes the high-flow period of the rivers in the investigated area. The distributions of drought indices (SPI, SPEI and SDI) for the period November-April are provided in Figs. 2.

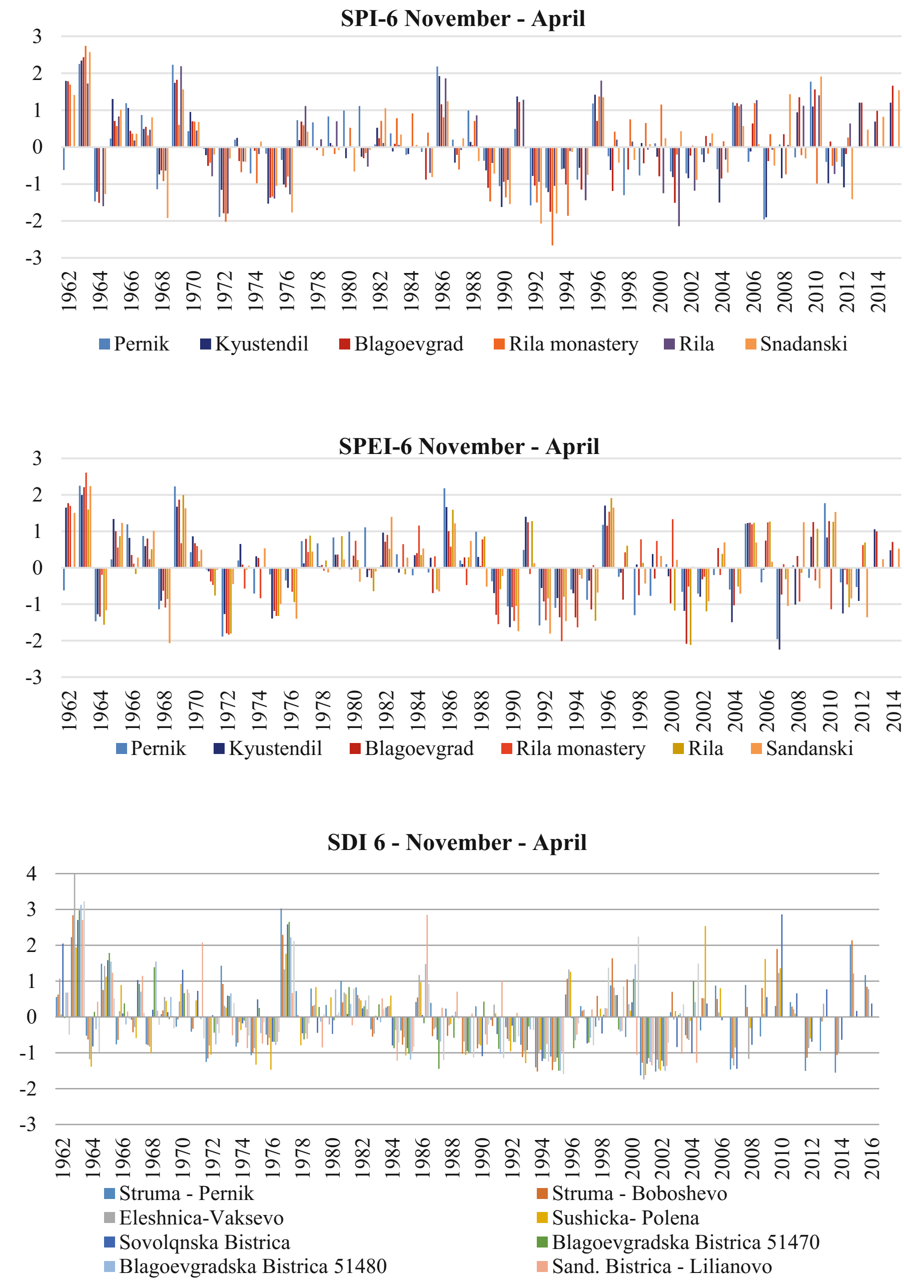

Fig. 2. Chronological distribution of drought indices for the period November – April

The SPI distributions demonstrate that some stations exceed the threshold of classes for extreme drought (SPI < −2) during the years 1993 and 2001, when SDI indicates moderate drought (SDI < −1,5). There is a good synchronicity between the SPI and SPEI. Small differences have been detected in separate cases in relation to drought severity only. However SPEI confirms the occurrence of meteorological drought established by SPI. The indexes showed that there was a significant drought problem during the years 1989–1996 and 2000–2002, in the middle and the south part of the basin.

According to SDI-6 for November – April, hydrological drought is observed in about 50 to 60% of the years in the investigated period. On the other side, the precipitation data and SPI-6 shows, that meteorological drought for the winter-time is manifested in about 40 to 50% of the investigated years, but the severity is often higher than for the hydrological drought.

The distribution between mild, moderate, severe and extreme drought events at the different stations for the winter-time (November – April) for all the years is presented on Fig. 3. Mild drought was the dominant drought state in all of the stations. Further results based on SDI do not show any extreme drought events as compared to the SPI index which shows extreme drought occurrences (SPI $\leq$ −2.0) in three stations (Rila monastery, Rila, Sandanski) located in mountainous and south part of the basin.

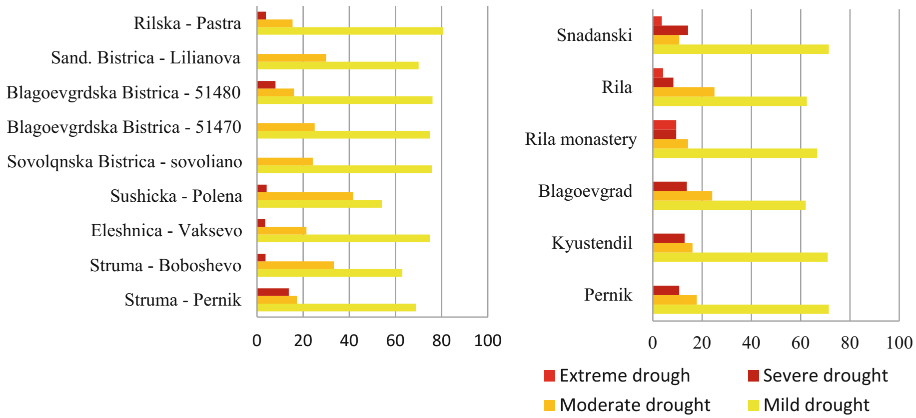

Fig. 3. Comparison of percentage of drought severity categories – 6 - month time step (November – April) of (a) SDI (b) SPI

In the second step, the analysis of the indices SPI, SPEI and SDI 12 months' time scale has been executed in order to evaluate the long-term drought episodes. The most widespread extreme 12-month drought occurs, according to SPI, in 1993. SPEI also shows drought occurrence in 1993, but the severity of the drought is lower than the one detected by SPI. On the other side, SPEI detects severe and extreme drought in 2000 and 2001 while SPI shows mainly, moderate drought (see Fig. 4).

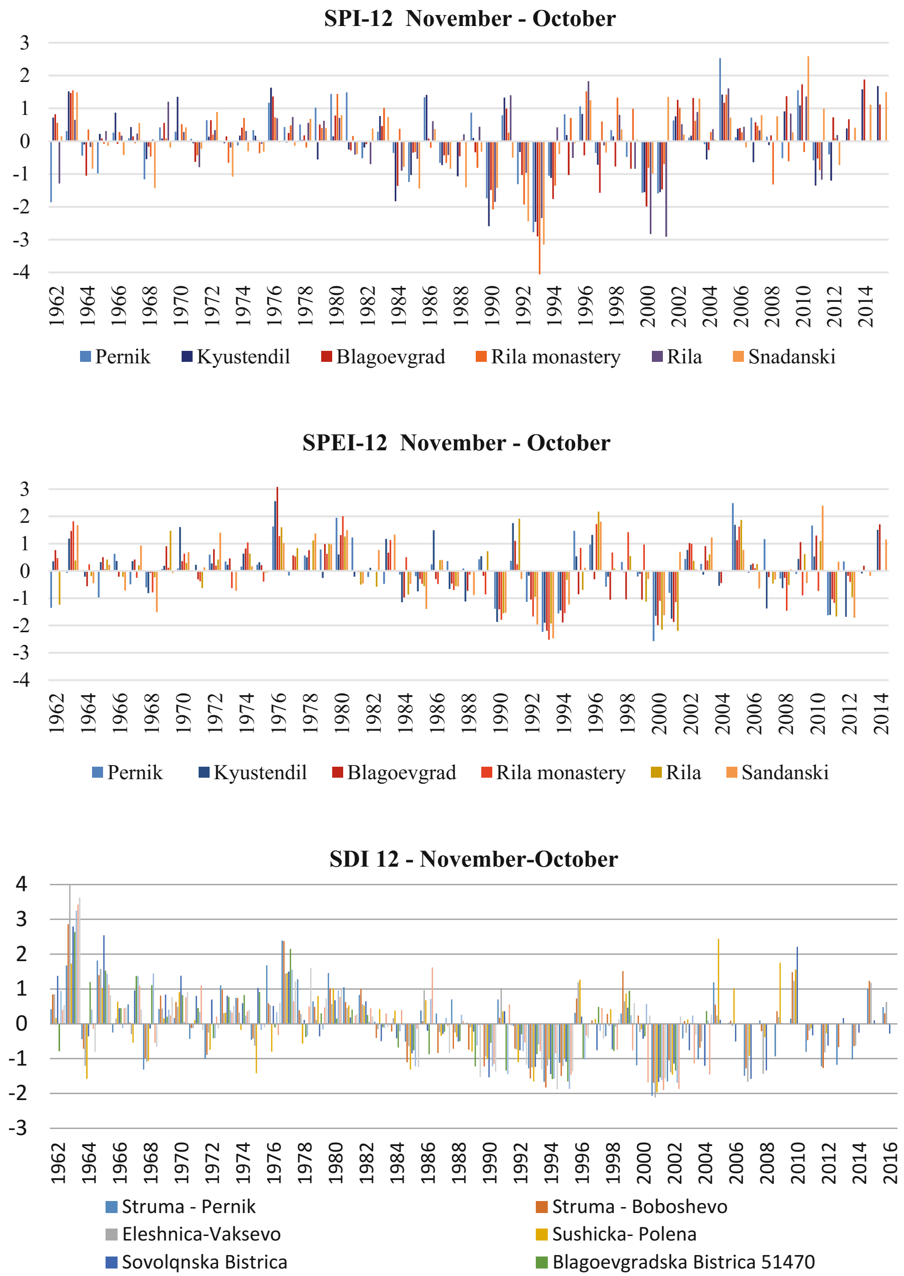

Fig. 4. Chronological distribution of drought indices for hydrological year (November – October)

Sequences of dry periods (SPI, SPEI and SDI < −1,5) took place in 1983–1985, 1992–1995, 2000–2002, and for SDI, also in 2011–2014 (see Fig. 4). The severest meteorological drought among all the stations was detected in mountainous part of the basin i.e. Rila monastery and Rila stations. The year 1993 was identified as the driest year in terms of drought severity, as extremely dry (SPI value - 4.12). The years 2000 (−2.83) and 2001 (−2.91) also were characterized as Extremely Dry. The longest hydrological droughts occurred in the periods 1992-1995 with a peak intensity of −1.83 (severe drought), and a mean intensity of −1.17, and in 2000–2002 with peak intensity −2.114 (extreme drought) and a mean intensity of −1.13.

Mild drought was the dominant drought intensity in all the stations (see Table 5). An average of 65.68% for SPI and 64% for SDI of mild drought occurred in the investigated area. Moderate drought intensities occurred at an average of 17.1% for SPI and 23% for SDI. Severe drought occurred at an average of 8.8% for SPI and 13% for SDI, respectively. According to SPI results extreme drought intensity is 8.2%. There are only two cases of extreme drought in Struma River basin within this period according to SDI.

Table 5. Number of years and percentage (%) occurrence of various degrees of drought in each of the stations according to SDI 12

Stations	States of drought			
	Mild	Moderate	Severe	Extreme
Struma - Pernik	13 (50)	10 (38.46)	2 (7.69)	1 (3.85)
Struma - Boboshevo	16 (64)	5 (20)	4 (16)	0
Eleshnica - Vaksevo	20 (69)	7 (24.1)	1 (3.45)	1 (3.45)
Sushicka - Polena	15 (60)	7 (28)	3 (12)	0
Sovolqnska Bistrica	20 (69)	6 (20.7)	3 (10.3)	0
Blagoevgradska Bistrica 51470	16 (72.7)	3 (13.65)	3 (13.65)	0
Blagoevgradska Bistrica 51480	12 (60)	4 (20)	4 (20)	0
Sand. Bistrica - Lilianovo	13 (65)	4 (20)	3 (15)	0
Rilska - Pastra	14 (63.6)	5 (22.8)	3 (13.6)	0

Both indices SPI and SPEI show that at annual scale the drought is widespread in 1993 and 2000, when the drought is observed in all of the investigated stations, and in 2011 (the drought is observed in about 80–85% of investigated stations).

SPI and SPEI as well as SDI show great difference for the years 1984 and 1990. According SPI the year 1984 was dry in about 60% of investigated stations. On the other hand, the SPEI shows drought only in 20% of the stations. This can be explained by comparatively low values of air temperatures in 1984. Due to high temperatures in 1990, SPEI shows dry condition in all of the investigated stations and this was not the case when only precipitation (SPI) was considered.

Annual values of Rainfall Anomaly Index and Streamflow Anomaly Index are in coincidence with the results from the drought analysis by SPI and SDI. According to RAI and SAI the driest year is 1993, when extreme drought was observed (see Fig. 5.). Both indices show also very dry period 2000–2001 and moderately dry 1983–1984.

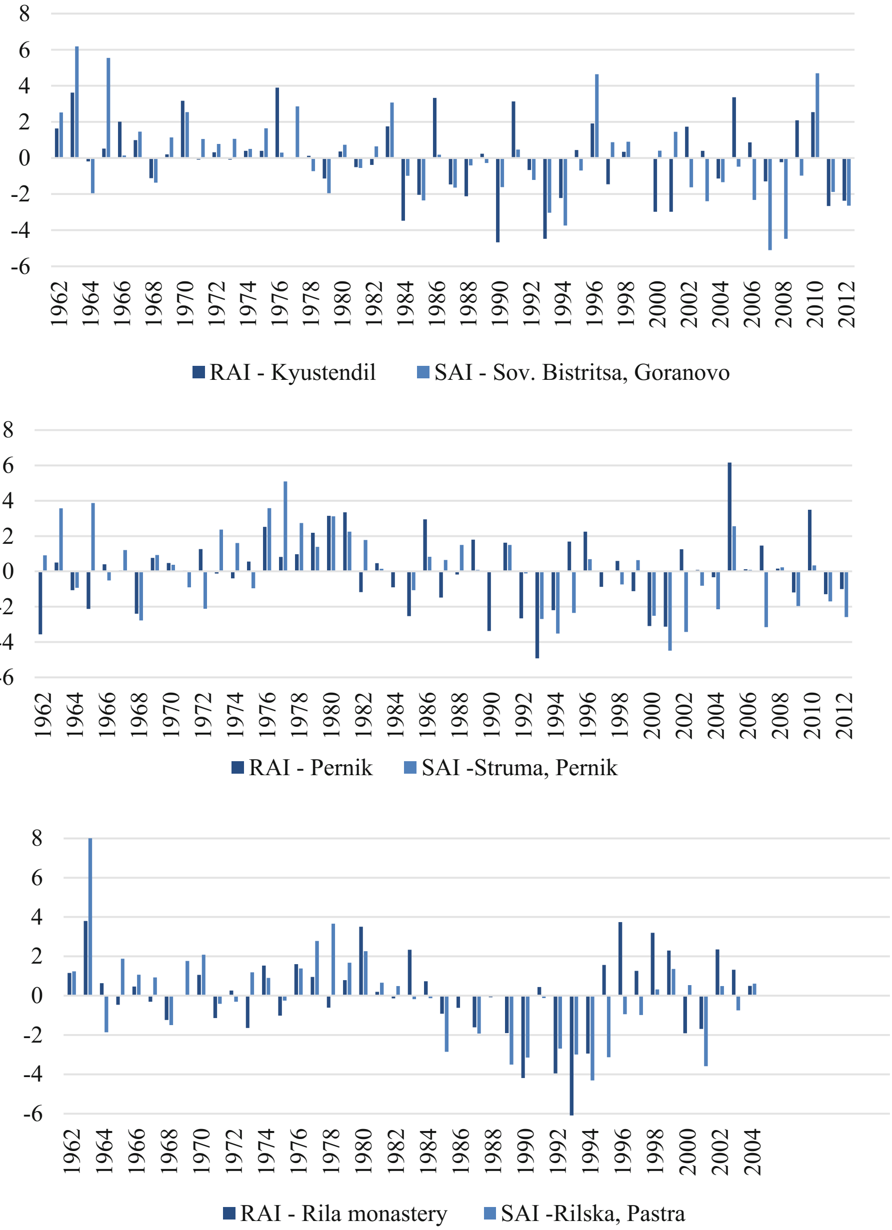

Fig. 5. RAI and SAI for selected stations

The good synchronicity between RAI and SAI, as well as the results of SPI and SDI, allow us to conclude that SAI could be used for hydrological drought investigation. The advantage of RAI and SAI is the simplicity of the calculation and the fact that they are based only on the data for precipitation or streamflow respectively. According to Olukayode Oladipo [38] there is a negligible difference between RAI and the more complicated Palmer drought index. Hänsel et al. [41] suggest modification in the calculation of RAI and the use median instead of average and find high correlation with SPI. The utilization of RAI for drought analysis is pointed out by Fluixá-Sanmartín [42] who compare various indices as SPI, RAI, and percent of normal (PN)

5 Conclusion

Drought assessment indicators allow for easy interpretation of results and comparison of regions with different climatic conditions. The SPI and RAI are preferred for drought investigation due to easy provision with source data (precipitation only) and simplicity of the calculations. The same advantages have SDI and SAI for hydrological drought analysis. On other side, the indicators based only on climatic factors do not fully account for the drought development process. The use of only one element in the form of precipitation as input data (SPI) reflects in principle only one phase - atmospheric drought. The introduction of a second factor, as air temperature (SPIE), gives a more complete picture of the meteorological and humidity conditions of the area. The drought assessment using indicators based on flow data is a summary of the development of the drought process. According to the results most of the investigated area is drought-prone and it should be a priority of regional water management projects focusing on drought mitigation.

The SPI extreme drought category on the 12-month time scale occurs most frequently in the middle part of the basin. Similarly, results based on hydrological drought analysis shows that the severest drought events occurred in the upper and middle part of the basin during 1994–1993, 2000–2001 and 2007–2008. In most of the investigated areas the cases of mild and moderate drought increased, particularly over the last two decades (1990–2010).

The SDI analysis results in this work show that significant drought characteristics can be found in analysis periods of six months (November to April) and twelve months (November to October). The results based on SPI also suggested that the drought severity is very critical in the mountainous areas, which in general, are more vulnerable to drought phenomenon rather than other parts of the country.

Calculating Data Driven Drought Indices for the Struma River Basin provides the foundation to evaluate hydrometeorological drought and to serve as preliminary assessment of the risk of drought events in other drought exposed basins.

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Formal Methods for Railway Disasters Prevention

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Abstract. Due to the increasing complexity of railway signalling systems, the design of those systems is more difficult and the demonstration of their safety can be extremely tedious. In this article, the verification and validation of railway signalling systems is investigated. We explain how railway signalling functions are designed, we show how they can be mathematically modelled using formal methods and we discuss some ways to use formal methods mechanisms to design, verify signalling systems and to prove the validity of their safety properties.

Keywords: Railway signalling systems · Formal methods · Safety verification

1 Introduction

About two centuries ago, the railway revolutionized our lives, allowed an acceleration of exchanges and redesigned our territories. Since then, it has constantly evolved and improved, complying with two contradictory requirements: speed and safety. The railway transport typifies one of the oldest safety cultures, in which, there is the willingness to create systems and installations that are not susceptible to the risk of human error. The aim being to reduce the frequency and the consequences of accidents which can be dramatic in terms of human and financial losses, due to the speed of the trains, the number of passengers and the cost of infrastructures. Nowadays, railway accidents are very rare and their consequences are far less disastrous than they have been at the beginning of the railway era. However, the safety of railway transport is not granted. In France for example, the number of people seriously injured in a railway accident has increased by 22%, in 2016 [21]. Thus, designers must constantly adapt to technological developments to maintain a high level of safety. The railway signalling is a crucial element of this safety. Its task is to give to the driver, via well-defined codes and signals, all the needed information to safely circulate, and, via the interlocking functions, it guarantees a secured track status and inhibits the movement of track devices, such as points, while a train is traveling along a route. In addition to their safety function, signalling systems must improve operations by ensuring traffic optimization. The mission of railway signalling design offices is to offer safe and optimum solutions while meeting the economic feasibility constraints. In order to do so, they rely on experts' knowledge and experience. Nowadays design offices are facing

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new challenges: the increasing number of passengers that requires more efficient operations, the extension of the rail networks that leads to a congestion of the installations. Moreover, due to technological evolutions such as computerization and automation, the design of signalling systems requires the ability to combine old and new technologies.

In this context, new design and verification methodologies must be provided and those methodologies must be adapted to safety systems by offering rigor and automation, and must be adapted to the specificities of the railway field. Formal methods are suitable. Indeed, thanks to its rigorous and exhaustive nature, a formal methodology could guarantee, via proof of properties, that the designed system is consistent with the specifications.

In this paper, we want to show how formal methods could be introduced in signalling design offices to assist verification, to encourage innovation and to lighten safety demonstration processes. Section 2 describes the main issues of designing signalling principles. In Sect. 3 we give an overview of formal methods. In Sect. 4 we explain how to model an electromechanical system of signalling with formal methods through, a concrete example. In Sect. 5, we discuss the modelling approach and its limits.

2 Evolution, Constraints, Standards

Railway is one of the safest means of transport. In railway transport, the concept of safety is essential and it is based on four factors: regulation, staff alertness, braking devices and railway signalling. Railway regulation, expressed as standards and directives, describes all the organizational, technical and legal arrangements that govern the operations and the design processes of railway systems. The standards are regularly revised to adapt to technological changes. For instance, the standard EN50128 [1] applicable for information systems of signalling has recently been revised, in 2011.

The safety integrity level (SIL) is a quantization index of risk reduction, based on a scale of one to four, and a risk analysis defines, for each function of a system, its SIL requirement. For example, the route setting commands are SIL0 because there is no need of risk reduction, while the signal opening is SIL4 because it is a safety function. The standards IEC 61508 [2] describe the development activities and the techniques to be used to comply with the SIL level. The higher the level, the more constraining are the development activities imposed by the standards. When a system is designed, it is assigned a SIL level, which expresses a safety objective, and then, the system is evaluated by certifying bodies; compliance with applicable standards means obtaining a SIL certificate. Railway signalling, was at first rudimentary; for example, on the first railroad lines, track surveillance was carried out by humans, using signal flags, marker lights and whistles to transmit signals. Now, it is a highly precise technical field, based on modern technologies, combining electromechanical devices and computer science. Since the early days of railway, the science of accident investigation started to transform railway systems to improve their reliability and engineers introduced automation to avoid human fault. For instance, one of the first major innovations was the continuous automatic compressed-air-brake, invented in the nineteenth century and still used to date in current trains. The latter system is based on the safety principle that allows to release the brake only if it is pressurized and not damaged.

Modern systems are still designed with a view to reducing the risk of human fault. In fact, since the seventies, information technology has been introduced in operations support systems, then in interlocking systems, such as the System of solid-state interlocking (PAI). More recently, this technology takes also action to automate metro lines (e.g. System METEOR) or for predictive maintenance using Internet of Things (IoT). The emergence of all these new technologies leads to more complexity and need to be supported by modern, adapted methods.

2.1 Railway Signalling in France

The railway signalling is an information system, the function of which is to control, monitor and interlock points, signals and other appliances, in order to ensure a safe train-running over track sections. The main purposes of this system are to:

- maintain a safe separating distance between trains going in the same direction,
- avoid derailment due to speed excess,
- avoid traffic in both directions on the same track (face to face),
- ensure a safe traffic at level crossings,
- prevent trains from taking conflicting routes (converging traffic lanes, traffic cut…).

Another function of railway signalling systems is to ensure optimum operations while guaranteeing safety; and the growth of the number of passengers in urban transportation networks makes it a real challenge, promoting the emergence of systems as the SACEM (Système d'Aide à la Conduite à l'Exploitation et à la Maintenance) which provides optimum speed instructions to the driver.

In France, hard-wired logic systems have been favored due to their reliability, maintainability and to the intrinsic safety of their equipment. In fact, electromechanical interlocking devices are a safe bet for the railway signalling and a good knowledge of the equipment is essential for the maintenance of a system. For this reason, computerized signalling technology has not witnessed the same success. Moreover, the implementation of computer-based systems is mostly constrained by the cost of their development because that implies to be able to prove their Safety Integrity level (SIL). In fact, meeting the requirements of standards such as EN50128 [6] in terms of resources, organization and development cycles can be difficult and expensive because it imposes, at each stage, a quantity of documents (specifications, plans…), verifications and tests, carried out by independent teams. Furthermore, the software maintainability can hardly reach the safety relay's which is ensured by the endurance of the equipment. Nevertheless, there are some good examples of the use of digital systems such as the Computer-Controlled All-relay Interlocking (PRCI) which allows the computerized command of routes, while the interlocking and the monitoring of the routes are ensured by the safety relays NS1 [3].

Besides, the French regulation requires, for all new systems or any alteration of an existing system, to demonstrate a safety level at least equal to the safety level of the existing systems [4]. Hence, it is easier to achieve an equivalent level by using the technologies of existing systems rather than trying new technologies. Therefore, we can say that the tediousness of safety demonstration can be a slowing point to innovation which is regrettable considering that signalling systems need more innovation than they ever did before Indeed, the installations are increasingly complex, congested, making them more difficult to maintain. Maybe by optimizing logic circuits or by interfacing them with digital systems, it would be possible to reduce the quantity of equipment and, as a result, reduce wire and congestion in installations Innovation on principles of hard-wired logic can also improve the operations. A perfect example [3] is the passage of rigid transit (which allowed the setting of a route only after all the occupied transit zones of the conflicting route were released) to flexible transit (which allowed the setting of a route as soon as the convergence zone with the conflicting route was released).

The design of signalling principles is a creative task based on experts' reasoning and this reasoning is usually checked manually. In fact, the verification of these principles is a real issue for design offices because it requires specific skills and good experience and knowledge of systems and equipment. Besides, it has to be carried out by two experts with a sufficient level of independence in terms of the standard EN50126 [4], who have not been involved in the design part of the system. This whole independent organization represents a significant cost for companies. In addition, an installation cannot be tested until it is totally wired, which makes the correction of errors much more expensive as it generates much more reworking. Providing designers with modeling and verification tools that afford a theoretical support to the design choices would be a good way to reduce verification costs. As pointed by [5], the automated verification of signalling systems design, especially for the interlocking part, is an open research subject for which the challenge is to handle the growing complexity of the systems.

Formal methods are useful mathematical techniques for modelling complex system designed on a logical reasoning because they provide a verification of the consistency and the validity of this reasoning [6], through proof of properties which requires a precise statement of system's properties. This constraint is the opportunity for the designers to unambiguously specify the essential requirements of the system. These methods offer many advantages, in addition to enhancing confidence in the safety and the efficient functioning of systems; they provide a better automation of design and verification tools. The automated proof can be done in different ways, such as model checking.

As mentioned above, digital systems have not been able to replace electromechanical interlocking. But, before considering a whole transition from so-called "classical" signalling systems to computer-based systems, we can start by modernizing the methods of verification on old technologies. Formal methods could be a way of modernization. The modeling of railway signalling systems would allow doing the verification at the same time as they are designed. Formal methods, such as B method, require this verification through the proof of properties at each refinement. Finally, there is an obvious analogy between the logic of the electromechanical signalling circuits and the Boolean logic, which makes the modeling in formal language quite feasible. This analogy will be explained in Sect. 3.

3 Formal Methods Overview

Formal methods originate in logics which is, to some extent, the science of reasoning. In ancient time, Aristote characterized well reasoning as succession of sentences respecting precise patterns. It traced the path for the reduction of reasoning to a question of shape that can be verified by machines ignoring semantics. With mathematical logic [7], languages are mathematically defined by way of formal syntax. They are provided with mathematical models, i.e. precise non-ambiguous semantics. Then proving patterns are defined on a purely syntactic base. Thus, they can be handled by computer to monitor proving activity. Mathematician proves that these patterns are sound: they only allow proving true things in semantics. It guarantees that proofs using them are sure. Computer monitoring exclude human error. Of course, provided guarantees are only valid if mathematical models are relevant with respect to real world, which can only be checked by human.

Formal methods rely on such kind of foundations. They provide a lot of logical languages and associated computerized tools. They were initially developed to support software engineering [8] and enhance software reliability. Nowadays their scope extends to many domains, kind of problems or applications. Their aim is to guarantee the behavior of systems following rigorous approaches. The choice of one method depends, of course, on how the method fits into the development process as a whole. In this paper, we do not describe or classify all the methods. We provide an overview of two approaches used in the railway domain the B method [9] and model checking method [10].

Both approaches consider state machines as models for mathematical semantics. States are simplified views of snapshots of real world states and state changes in models are "transitions" which can be events, actions, time… depending of approaches. When the number of state is finite, state machines (also called automata) are often graphically represented by graphs with labeled states linked by labeled arrows as transitions. For example, transition labels may express conditions constraining states changes. These models are discrete: state evolves step by step and not continuously and thus modeling of continuous systems requires discretization. Lot of applications can be modeled this way, and complementary approaches [11, 12] are available for a more precise handling of continuity.

The B method enables describing machines with a language that allows comprehensive characterizations of transitions and description of properties expected from the system. And then, a support is provided to ensure and exhaustive proof of these properties. Proofs are similar to usual mathematical proof. Tools provide monitoring and assistance to human work. This proof approach can't be fully automated but its power takes benefit of human mining. The second advantage of B method is to offer a fully guaranteed refining process: a way to move from high level models (abstract simple view of application) to low level ones (detailed view of implementation) in a rigorous way. This allows expressing and proving properties on simple and user-level models, and by refinement, to ensure that these properties hold in the final technical implementation of the system. Two variants of this approach exist. The B method is dedicated to software development and in this case, state transitions are calls of software procedures. It has been widely used for developing certified railway software [14]. The “Event B” version considers events as transitions and its scope is more generally system modeling, and not only computer or IT domain [15].

“Model checking” denotes a family of algorithms offering automated verification for finite-state automata. The principle consists in exploring the model entirely, going through all states, to verify, through logical questions, the validity (or not) of provided expected properties. Thus, it is more proof by exhaustive inventory of cases (states) than a mathematical comprehensive proof (as proofs with B method are). The approach is mathematically sound: proved properties are sure. The advantage is automation, whereas, the limit is the size of the set of states to explore, which must be finite. Model checking is often combined with abstraction techniques (the converse of refinement), which allow to forget details in models which are not significant with respect to properties of interest. Abstraction leads to simpler models, with less state and easier to check. Moreover, computing capacity increased a lot and despite the intrinsic character of complexity, model checking approaches are nowadays relevant for many applications. In the railway domain, a lot of works [5, 16–19]) studies how to apply them to the interlocking problems, which is hard to solve by a general comprehensive reasoning.

Model checking and comprehensive proof are not exclusive. For example, the second can take benefit of the first to prove some intermediate results (lemmas), and conversely. Expertise leads to choose the most efficient approaches depending on the properties to prove. A domain specific methodology may provide support to help such choices and combine results. Such a methodology may also give access to the numerous theoretical and concrete primitive and tools allowing to decompose problems and specifications in order to make proof and verification simpler following the “divide and conquer” idea. Refinement and abstraction are part of this structuring toolkit. Even though no complete methodology exists for railway, as pointed by Author’s name [8], formal methods have been applied for years in railway domain; a proof of this is the fact that European Standards CENELEC [1] applicable for development of software in railway control system requires the use of formal methods for specification, design and V&V activities for software of the highest safety and integrity level.

4 Railway Infrastructure Modelling Example

A railway signalling network is composed of different electrical equipment mainly: points, shunting signals and train detection devices. Basically, a track layout consists of, at least, two tracks and it can include many routes. A route delimits the space between two signals, it is a succession of sections to be traversed, and these sections could be points. A point is a convergence spot between two tracks; it is locked in a position allowing either to traverse a route in one track, or to traverse a junction route between two tracks. A signal can be open or closed, authorizing or banning downstream the traversing of the transit zones (route). In railway signalling, an interlocking [3] physically bans the handling of signals and equipment under any condition incompatible with the traffic safety.

The main purpose of a signalling system is to open a signal if all the conditions that allows the driver to cross it are satisfied and to close it, if, at least, one condition is missing. In order to do so, information has to be exchanged. This information is classified into two types: Supervisor's commands and local information. A supervisor is in charge of the control of the signalling system, he gives commands, for example route setting, via a user interface. On the other hand, local information gives the state of the track, for example, the position of the points, the presence of a train, etc.

In hard-wired logic systems, the signalling functions for a given network layout, are described in two complementary documents: functional diagrams and scheme plans. Both must be modeled for using a rigorous approach employing formal methods. The relationship between logic and functional diagrams is simple and direct, so we will explain it in this section. The relationship is less trivial with scheme plans and it brings some methodological questions, thus, we will only give explanations about the methodologies of the domain, in this section, and the formalization will be detailed in the following section.

4.1 Functional Diagrams

Functional diagrams are relay logic circuits, i.e. electrical networks that control outputs. A function (or an output) is materialized by an electromagnetic coil and controlled by a combination of conditions represented by relays connected in series or in parallel. The set of all the functional diagrams represents the global behavior of the signalling.

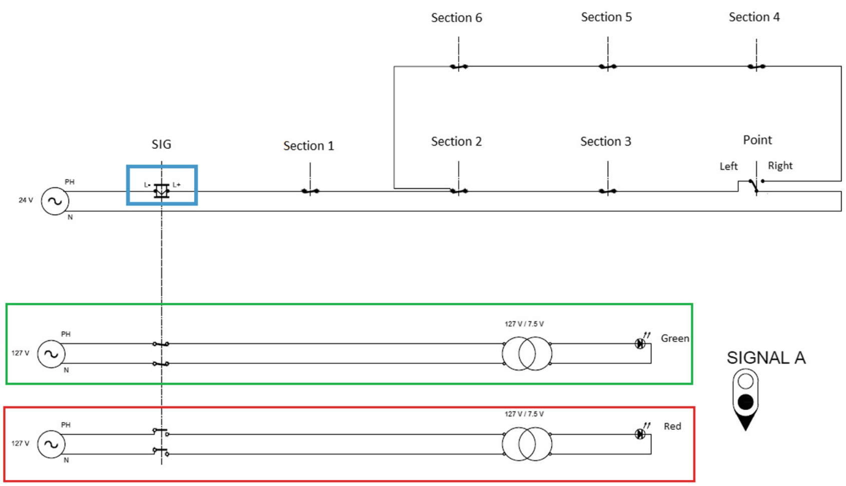

Fig. 1. Functional diagram of railway infrastructure example.

The functional diagram Fig. 1 describes the conditions of opening and closing a signal, respectively, allowing or disallowing the driver to cross the signal. The opening of the signal is materialized by the electromagnetic coil SIG (Surrounded by a bleu rectangle on the figure) which, once energized, closes the circuit (Surrounded by a green rectangle on the figure) that powers the green bulb of the signal and opens the circuit (Surrounded by a red rectangle on the figure) that powers the red bulb of the signal.

The coil SIG belongs to two circuits, it is energized when one of them is closed. The relays that close the circuits are the images of the state of equipment on the field. The first circuit represents one route downstream the signal A, it closes if the relays “Section 1”, “Section 2”, “Section 3” are closed, which means that, on the field, every section of the route downstream the signal are free (the track is clear), and if the relay “Point” is on a position that corresponds to the Left position of the point traversed by the route. The second circuit represents another route downstream the signal, it closes if the relays “Section 4”, “Section 5”, “Section 6” are closed and the relay “Point” is on a position that corresponds to the Right position of the point traversed by the route.

The functional diagram Fig. 1 can easily be transcribed in a logical diagram, as shown in the Fig. 2 below.

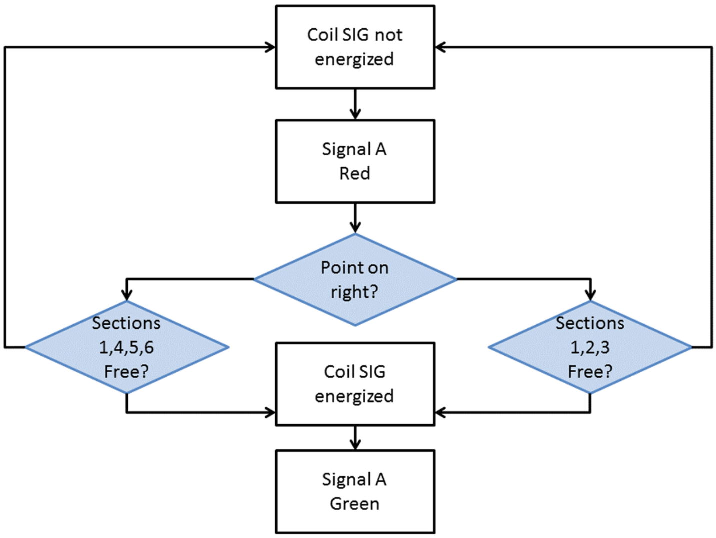

Fig. 2. Logical diagram issue of functional diagram of railway infrastructure example.

Using the logical diagram on Fig. 2, we can describe the function “Coil SIG” through Boolean logic, as showed by the following table (Table 1).

With Boolean logic, le function “Coil SIG” is described by the equation below:

$$S = (A \ and \ B \ and \ C) \ or \ ((Not \ A) \ and \ E \ and \ F \ and \ G) \tag{1}$$

This example shows how the analogy between functional diagrams and logical diagram is perfectly viable. Because they have been conceived for computer science, formal methods are suitable for signalling principles.

Table 1. "Coil SIG" description.

Function	Symbol	Boolean values
Coil SIG	S	Energized (1), not energized (0)
Position of the point	A	Left (1), Right (0)
Section 1	B	Free (1), Buzy (0)
Section 2	C	Free (1), Buzy (0)
Section 3	D	Free (1), Buzy (0)
Section 4	E	Free (1), Buzy (0)
Section 5	F	Free (1), Buzy (0)
Section 6	G	Free (1), Buzy (0)

4.2 Scheme Plans of the Example

Scheme plans comprises a track plan and various tables, among them control tables [5]. A track plan is a graphical representation of all the railway tracks in a station and control tables specify, for each route in the network layout, all the conditions for setting this route.

The Fig. 3 is an example of a track layout plan. It contains one point PT1 that links the track 1 and the track 2. In the case of this example, the train detection devices are axle counters. An axle counting section is marked out by at least two counting heads (CH). When a train traverses one of the counting heads which marks out a section, the number of axles of the train is recorded. This section is considered occupied until the same number of axles passes the counting head at the exit of the section. For example, the ACS1 section is marked out by the counting heads CH1 and CH3, depending on the direction of the train, each of these could be an entrance or exit point of the section. The ACS3 section is marked out by the counting heads CH3, CH5 and CH0. When the train runs the route from A to B, the counting head CH3 will be the entrance point and the CH5 will be the exit point. Whereas, for the route from D to A, the CH0 will be the entrance point and CH3 will be the exit point.

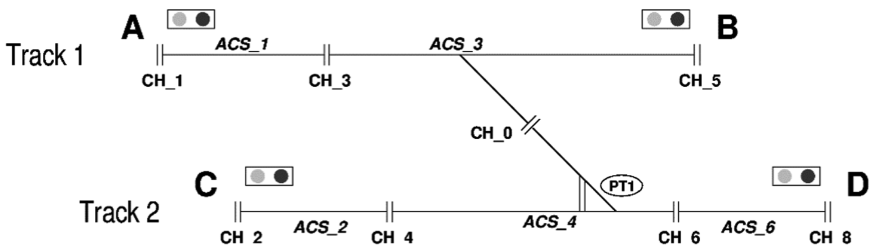

Fig. 3. Track plan corresponding to the infrastructure example.

Abbreviations of the drawings:

PT:	Point
SA, SB, SC, SD:	Signal A, B, C and D
CH:	Counting head
ACS:	Axle counting section
CPT:	Command of point

The two vertical and parallel lines connecting the two switch blades of the PT1 point represent the "fouling point limit", that is to say, the limit zone where a train can stop without approaching the convergent track gauge. Furthermore, in this example, the PT1 point is a trailable and reversible point. In opposition to motorized points which receive a point's electrical command (CPT) sent by the signalling system; in a position depending on the route's direction, a trailable and a reversible point turns in a position depending on the occupied heel section. When a route traverses it in a facing mode (which is case of the routes DC and DA), the point is positioned through a manual command, by an authorized operator, at a building site respecting the safety conditions. In the case of the PT1 point:

- If the ACS2 section is occupied through the traversing of the CH2 counting head: the point turns Left.
- If the ACS3 section is occupied through the traversing of the CH3 counting head: the point turns Right.
- The default position of the point is to the Left (represented by the small line under the point).

A signalling system, for the track layout Fig. 3, must ensure the following safety features:

- Avoid collisions between trains going the same direction by prohibiting the opening of a signal if a section of the route is occupied,
- Avoid collisions between trains going in two opposite directions on the same track (face to face), by prohibiting the simultaneous opening of incompatible signals,
- Avoid collisions between trains taking conflicting routes, by prohibiting the simultaneous opening of conflicting signals.

The track table below (Table 2) inventories, for each route of the track layout, all the conditions required to open the signal upstream the route. The events that can change the state of the system are:

1. The supervisor sets a route: which can open the signal upstream the route if all the sections of the route are free and all the conflicting routes are destroyed
2. The supervisor destroys a route: which closes the signal upstream the route
3. A train traverses a counting head: which can occupy or release a section. if it occupies a section and if this section is a heel section of the point PT1, the point will turn to the corresponding position

In design offices, the verification of the two documents (functional diagrams and scheme plans) consists in checking manually and thoroughly that all the conditions described in track tables are met by the system's behavior described in functional diagrams and also, checking that the track tables are complete according to the track layout plan. This verification could be automated using model checking, this is the topic of the following section.

Table 2. Track table.

Route's characteristics					Conditions		
Signal	Setted route	Departure	Arrival	Points' position	Released sections	Destroyed incompatible routes	Destroyed conflicting routes
SA	AD	CH1	CH26	PT1: Right	ACS1, ACS3, ACS4, ACS6	DA	BA, CD
	AB	CH1	CH15	PT1: Left	ACS1, ACS3	BA	DA
SB	BA	CH5	CH11	PT1: Left	ACS3, ACS1	AB	DA
SD	DC	CH6	CH22	PT1: Left	ACS6, ACS4, ACS2	CD	AD, DA
	DA	CH6	CH11	PT1: Right	ACS6, ACS4, ACS3, ACS1	AD	CD, BA
SC	CD	CH2	CH28	PT1: Left	ACS2, ACS4, ACS6	DC	AD

5 Formalisation

In the scientific literature, there is many examples that confirms the suitability of model checking for the modeling of interlocking systems. Nevertheless, this method is not that easy to implement. In fact, its application can be tedious if the system is complex and it is based on the quality of the modeling which depends on human expertise. This is what we want to illustrate, in this section, by giving an overview of what can be done with model checking, and then, by justifying the importance of rigorous methodological complements.

5.1 Model Checking for Interlocking

To create a formal model of the system, we need to define abstract states. We use a current way to do this: we provide a finite state of state variables. A state is fully characterized by the values of these variables. Choosing relevant variables is an important aspect of modeling: they define an abstraction and they must allow to describe the system and to express the expected property with respect to this abstraction. In our pedagogical example, they must allow to represent concepts and ideas expressed in Table 2, Fig. 3 and event description in the previous section. We choose to represent the signals, the axle count sections, a generic OUTSIDE section, the point and the routes:

– Signal_A, Signal_B, Signal_C, Signal_D accept OPEN or CLOSED as value
– Section_1, Section_2, Section_3, Section_4, Section_6, OUTSIDE accept BUSY or FREE as values
– Point accepts LEFT or RIGHT as values
– Route_AB, Route_AC, Route_BA, Route_DA, Route_CD, Route_DC accept SET or UNSET as values.

Then the temporal behavior of the system must be rigorously described in a methodical way. Various languages are usable depending on tools and formalisms. Here we use events described by two aspects: the way they modify the state and the conditions under which they can happen. Description must not only reflet reality but also provide all information required to prove the expected property, although we omit or abstract some (train direction for example), here, to simplify presentation. The three events of Sect. 10 become are methodically described and something must be added to make train appear: a new event "New".

– Set(R): set the route R. Conditions: associates sections are FREE and conflicting routes are UNSET. Modifying: Signal opening the route becomes OPEN
– Unset(R): unset the route R. Conditions: none. Modifying: Signal opening the route becomes CLOSED
– Trav(S,S'): traverse counting head between sections S and S'. Conditions: S is BUSY and if S is OUTSIDE, then the signal associated to S' is OPEN. Modifying: S becomes FREE and S' becomes BUSY. If S' is Section_3 or Section_4, Point becomes LEFT OR RIGHT, following indications provided in previous informal description.
– New: a train appears. Conditions: none. Modifying: OUTSIDE becomes BUSY.

Tools are able to build automaton from such descriptions. The single additional information they need is an initial state. They compute the set of all reachable states by successions of events, and these events are the transitions. Figure 4 provides a partial view of the example's graph, considering an initial state without train and set route. On the figure, variables are abbreviated by their indexes. Black text is used for busy sections, set routes and open signals, and grey is used for other situations

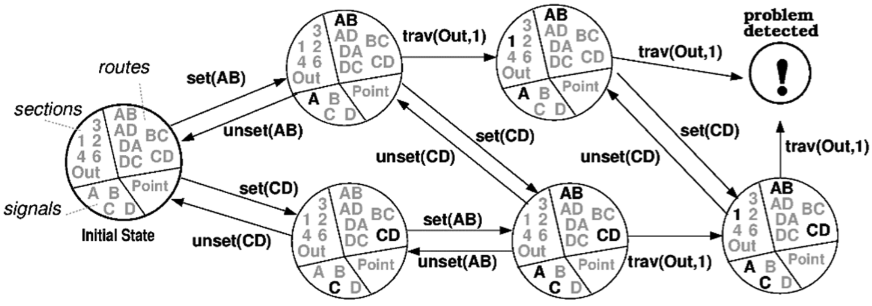

Fig. 4. Partial graph of studied system

A model checking algorithm can then automatically explore the entire automaton to verify formally expressed properties. In our case, we don't want two trains to be on the same section at the same time, thus we could require that each time a train enters a section (except OUTSIDE), the section is free. More formally: if two states in automaton are linked by a "Trav(S,S')" transition, then S' is FREE in the source one, which can be obviously checked by an exhaustive exploration. If checking fails, a counterexample is generally provided to help the designer to find the error. In our example, signals remain open after a train passed them which compromise the expected property. The suit "set(AB);trav(Out,1);trav(Out,1)" is a counterexample as shown on Fig. 4.

Errors can be errors in the real system. They can be also errors in the model, when for example the specifier forget some implicit information and allows then behaviors that do not exist in real world. This shows how the demand of proof helps to correct errors and construct safe solutions [20]. The model checking avoids the risk of human error or oblivion in complex verifying. However, even if a formal verification is not susceptible to errors of reasoning, it is susceptible to errors of modeling. This is what we will explain in what follows.

5.2 Human Impact

Formal approaches appeal to human expertise for various reasons. First, to avoid unnecessary complexity and to obtain optimized models, easier to implement. In fact, choosing the right variables and the right abstractions limits the number of states, in the model checking, and reduces the number of proofs. Else, the properties checked must, above all, be relevant vis-a-vis the real problems. The model must reflect the system, and the properties expressed in mathematical language must correspond to the properties that the system should ensure. For the example above, the model must reflect the signalling system's behavior described in functional diagrams and the properties checked must be conform to the track tables. In some other areas, such as software engineering, there are design environments with graphical interfaces and various tools that help the test and visual verification of specifications. For the field of railway transport, whose experts are less accustomed to formal ratings than in computer science, such assistance is even more necessary. However, even if the methodologies used in design offices are informal, they are based on standards that provide a framework, with well-defined processes and nomenclatures, which could facilitate the formal modeling.

The specification of the signalling system, in the example above, is based on a strong hypothesis: "two trains cannot clash if they are in two different sections". This hypothesis is true with a fixed length of trains. But, if the length grows up, the hypothesis become invalidated. Indeed, when the DA route is set (the PT1 point is previously positioned to the Right), a train (Train 1) will traverse the ACS6 section and then the ACS4 section and when the counting head CH21 counts out the last axle, the ACS4 section will be released and the ACS3 section will then be occupied. If the train stops right before passing the counting head CH21, we will be facing a problem. If the supervisor destroys the DA route and sets the CD route, another train (Train 2) could enter the point section ACS4 (left heel). Since the distance between the two tracks (track 1 and 2) is small, it is possible that the second train strikes the rear of the first train (See Fig. 5). This error would never have been detected by a model checker with the model defined in the previous section.

Formal methods must be used carefully and cannot replace human judgment; it shows the importance of the specification phase. In fact, to obtain a viable and exhaustive model, the system's features should be expressed precisely and for this case of study, the property that is missing from the requirements is that we should not have the sections ACS3 and ACS4 busy at the same time, if the point PT1 is on the right position.

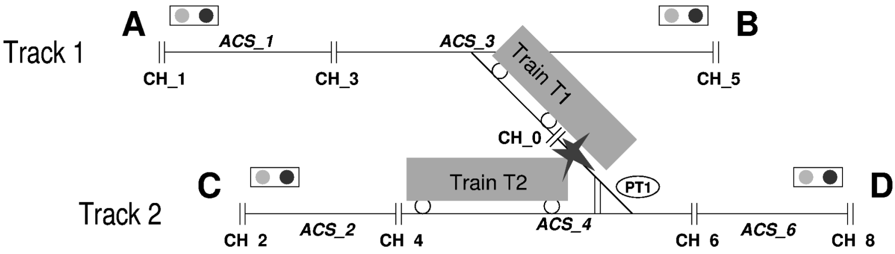

Fig. 5. Example of track plan (accident case)

The presented reasoning is based on a hypothesis: two train on different sections can't collide together. It is the base of block signal systems which has been used in railway development for a long time (long before formalization) to facilitate the design of safe interlocking. Historically, blocks exactly corresponded to physical sections. The modeling for model checking proposed above depends on this. But, as explained in Sect. 2, railway evolves. It is more and more demanding and static block systems limits optimizations and performances. Thus, practices in the domain have also evolved from static to dynamic block systems. Now blocks do not always correspond to physical sections. They are virtual: they can comprise several sections and they can change over time. In our example, ACS3 and ACS4 should be a single block, precisely when PT1 is on the right direction. A simpler solution would have been to forbid the opening of the signal SC when the ACS3 section is occupied. This makes the routes CD and BA incompatible and we have then virtual static blocks. But this compromise is restrictive and would significantly decrease operations.

Experts of railway signaling are able to propose technical solutions to implement the dynamic model of block systems, using new equipment and technologies. As block system principles remains, the new reasoning model is quite similar to the previous one but more complex. Formal modeling may be adapted by adding state variables to characterize dynamic blocks and new events to describe the behavior of new equipment. Then their complexity increases too. Adding custom modifying to existing solutions can progressively lead to useless complexity. Thus, when reasoning paradigms evolves too much, it is required to reconsider in more depth the model, choosing new abstractions and variables in order to recover simplicity. Experience resulting from previous modelling generally makes the developing of new ones much faster, as a lot of ideas remains relevant although they are not always applied in the same way.

This example shows how it is possible to improve operations by creating new signaling principles. To verify and validate new principles, designers need reliable tools and methodologies to prove the safety of their innovative solutions. Formal methods could provide those tools and methodologies. For this, new expertise in formal methods is required. This difficulty can be overcome by simple consensus, for example the verification of the correspondence between the track tables and track layout plans can still be the task of signaling experts and the formal modeling be assigned to staff trained on the formal methods. In addition, providing intuitive graphical modeling tools could be a way for signaling experts to participate concretely to formal methods implementation.

6 Conclusion

In this paper, the application of formal methods for the design and the verification of railway signalling systems has been discussed. Considering the evolution of railway technologies and the need for increasingly efficient systems and operations, the usual means of verification are no longer appropriate. Formal methods provide solutions to deal with this context. These solutions have been detailed, as well as the reasons why a modeling a mathematical modeling of a railway system is perfectly feasible. First, an overview of formal methods has been given, focusing on two of the most widely used formal methods: B Method and Model Checking method. Next, the analogy between Boolean functions and functional diagrams has been described. Then, through an example of a track layout, the modeling process using model checking has been detailed. This example showed a way to define abstract variables to build an abstract model, in order to automate verification using algorithms of model checking. Those algorithms are not totally resistant to human errors; they are susceptible to errors of modelling. This has been illustrated by a case of accident due to equipment evolution that has not been taken into account in the model. This case allows to make a fundamental point: using formal methods does not free from the human factor. Human expertise, in the field of signaling as well as in the use of formal methods, is essential. Finally, a discussion about the way to organize a verification work by combining railway signalling expertise and formal methods knowledge, has highlighted the need for providing adapted tools dedicated to railway professions.

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Public Expectations of Social Media Use by Critical Infrastructure Operators During Crises: Lessons Learned from France

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Abstract. Previous research into the role of social media in crisis communication has tended to overlook how critical infrastructure (CI) operators might benefit from sites such as Facebook and Twitter, focusing instead on how emergency managers and the general public use such platforms. This paper sets out to address this gap by empirically exploring the expectations of French citizens in relation to the crisis communication strategies deployed by CI operators during major incidents. It does so by reviewing the literature on crisis communication, presenting the results of an online questionnaire, and comparing these results to the current practices of the A31 Highway in France, which were examined via a semi-structured interview. Results indicate that members of the public expect CI operators to communicate via traditional and social media. Therefore, the paper proposes that A31 Highway operators should expand their current practices to include social media.

Keywords: Social media · Crisis communication · Critical infrastructure operators

1 Introduction

Crisis communication can be defined as "the provision of effective and efficient messages to relevant audiences during the course of a crisis process" [1]. Social media has been identified as an increasingly important source of information during crisis situations [2]. Previous research in this area has tended to focus on how emergency response personnel or citizens use social media during such incidents [3–7], overlooking its benefits for other key stakeholders such as critical infrastructure (CI) operators. As such, there remains relatively little empirical research exploring public expectations of information provided by CI operators during crisis situations. The EU Horizon 2020 project IMPROVER (Improved risk evaluation and implementation of resilience concepts to critical infrastructure), makes use of Living Labs, or clustered regions of different types of infrastructure which provide specific services to a city or region. One such Living Lab is the A31 Highway in France. This paper will addresses these under-researched issues by presenting a succinct literature review on public expectations of

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disaster related information shared via social media. It then describes the French A31 Highway case study. After, the methodology of the online questionnaire and interview-based study of the A31 French Living Lab are described. This is followed by a presentation of the questionnaire and interview results, accompanied by a comprehensive discussion on the subject and a conclusion.

2 General Expectations of Social Media Use in Crisis

The public expect to be able to find information relating to disasters from both traditional and social media sources; recent research suggests that people use a combination of these sources to find information during disasters [6–9]. For example, both Facebook and Twitter were heavily used by German citizens to find information during 2013 European Floods [10]. One reason people turn towards social media is for its perceived efficacy in locating real-time information. During the 2011 Great East Japan Earthquake, a main reason that people turned to social media was the ease with which they could search for and obtain information [11]. Furthermore, a survey conducted in Europe by Reuter and Spielhofer found that 77% of respondents felt that information was made available faster during emergencies on social media than on traditional media [3]. The same Reuter and Spielhofer survey found that 43% of respondents have already looked for crisis information on social media, with 70% of those having looked for road or traffic conditions [3]. A study investigating Twitter data corresponding to 26 crises between 2012 and 2013 found that while on average 7% of tweets contained information related to infrastructure and utilities, these tweets were among the most retweeted during such incidents [12]. Therefore it appears that information related to CI is of great interest to the public in times of crisis. There is also evidence that the public turn to the social media accounts of emergency responders during crisis situations and studies show that the public also expect responses from emergency services to their questions and comments posted on these platforms [3, 6, 7]. As previously stated, less is known about public expectations of social media use by CI operators. Clearly, citizens appear to expect updates from CI operators about service restoration [2]. Reuter examined public information needs from energy operators during a blackout and found that both the duration and cause were of key interest [13]. Some operators are already using social media to meet these information needs [2].

3 Background on French A31 Highway Case Study

The French A31 Highway, also known by ‘E25’ in the European code, is an essential transport infrastructure network at a transnational scale. The section Nancy-Metz-Luxemburg is studied within the IMPROVER project. Its traffic is one of the most significant in France with 100,000 vehicles per day. The A31 Highway is used for intercity travel by the approximately 1,500,000 inhabitants of the Moselle valley and is also used by the numerous heavy goods vehicles from or to Luxemburg, Belgium, the Netherlands and Northern Germany. Significant traffic peaks can occur during holiday periods as it is used by Dutch, Belgian, German and French travelers. The traffic often reaches close to saturation conditions and traffic jams are observed daily from 15:00 to 20:00 in the section that connects Luxembourg to France and at the junction with A33 towards or from Metz. The studied infrastructure is managed by DIR Est (Direction Interdépartementale des Routes de l'Est – Eastern Interdepartmental Road Office), a decentralized service of French Ministry of Ecology which deals with the maintenance and the exploitation of public roads networks. In order to develop a policy regarding risk management, this service collaborates with the DDT57 (Direction départementales des Territoires de Moselle – Departmental Office of the Moselle Territories), another decentralized service of France, which deals with the sustainable development of territories, natural hazard prevention, implementation of regional planning politics and building permits. DIR Est also collaborates with other private roads exploitation companies (SANEF), regional authorities (DREAL), municipalities, dependent industries etc. in the event of a crisis. DIR Est and DDT57 are associated partners of the IMPROVER project [14].

4 Methodology

4.1 Research Questions

Specifically, two Research Questions emerged from the literature reviewed above:

1. What do French citizens expect of CI operators in regards to information provision during crisis situations?
2. How do these declared expectations compare to the current communication efforts of the French A31 Highway Living Lab?

An online questionnaire and interview-based study was designed to investigate these questions. Ethics approval was sought and obtained from the respective authorities prior to data being collected.

4.2 Questionnaire

The target population for the questionnaire was French citizens aged 18 years and over. In order to maximize the response rate, the questionnaire was translated into French and also made available in English. Convenience sampling was used for the questionnaire. It was structured as follows: First, a brief description of the project was provided and participants were informed of their right to withdraw from the project at any time, as well as how all data would be handled during the project. For the purposes of this questionnaire, respondents were presented with the following definition of a disaster: "an event which has catastrophic consequences and significantly affects the quality, quantity, or availability of the service provided by the infrastructure." Second, a Likert scale was used to measure participants' expectations. Participants were asked two questions regarding information provision. The first asked, "During and immediately after a disaster, I expect critical infrastructure operators to provide me with information…" and presented four scenarios: via calling their telephone number, on their website, on their social media site and through traditional media e.g. interviews with television networks or the radio, press releases. The second proposition asked, "During and immediately after a disaster, I expect critical infrastructure operators to respond to my questions and comments on their social media sites e.g. Twitter." The questionnaire also asked about the participants' demographics and social media habits. Data from the questionnaire was collected between 28 March 2016 and 30 April 2016. The questionnaires were translated back into English at the data entry stage. The questionnaire was disseminated through the IMPROVER consortium partners' contacts as well as through the Living Lab.

Sample Characteristics

A total of 67 participants from France completed the online questionnaire. Due to the dissemination method, this self-selected sample was not broadly representative of the French population. Sample characteristics showed that 58% of the respondents were men, 40% were women, and one respondent chose not to answer that question. For comparison, in France 48% of the population are men and 52% are women [15]. Most respondents were highly educated with 88% of them having a university degree or higher, whereas only 33.5% of the French population have a university level education [16]. Both young and old people appeared to be underrepresented in the study. Respondents aged 18–24 accounted for only 2% of the total sample (for comparison, French 18–24 year olds make up 8%), with 0.5% identifying themselves as aged 55 years and older (for France, 32% of the population is 65 years or older) [15]. Lastly, 91% of respondents have an account with a social media site such as Facebook or Twitter. For comparison, in France, 83% of households have Internet access and 85% of individuals have used Internet in the last three months [17]. When asked an open-ended question to list up to three social media sites the respondent used most, 81% listed Facebook and 18% or less listed other popular platforms (Fig. 1).

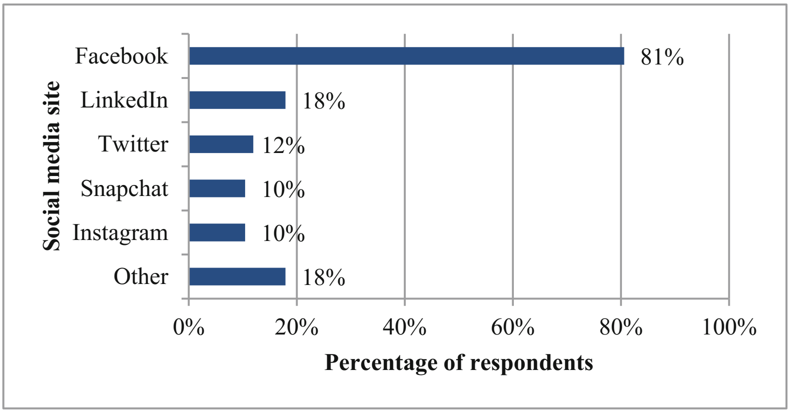

Fig. 1. Respondent's most frequently used social media sites (list up to three).

4.3 Interview

The findings were then compared to the current practices of the French A31 Highway. Two in-person, group interviews took place with actors from the Living Lab, one comprising of actors from DIR Est and another from DDT57. These included representatives from the office dealing with the intersection of the A31 between Nancy and Luxembourg, the office in charge of real time management for crisis interventions, the crisis management and alternative route designation office, and the urbanism and risk prevention office. Interviews were held in French and then data was translated into English for analysis. Data from the interview was collected on 25–26 May 2016.

5 Questionnaire Results

5.1 Expectations for Information to Be Provided on Social Media

When asked if respondents expected CI operators to provide disaster related information on social media, 79% strongly agreed or agreed (Fig. 2). Few respondents (16%) were unsure or neutral in regards to the use of social media by CI operators to push disaster related information to the public.

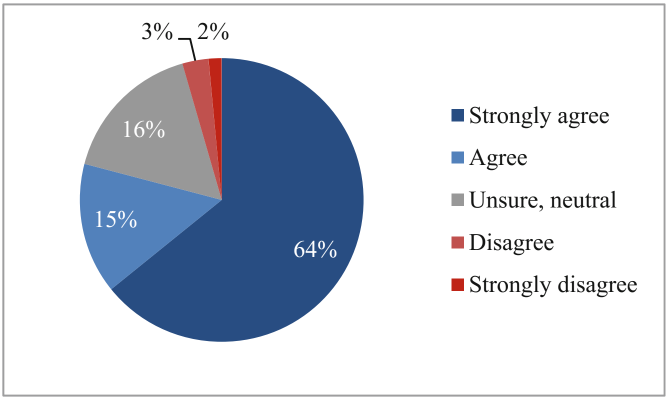

Fig. 2. Expectations that crisis information should be provided via social media

5.2 Expectations for Information to Be Provided via Other Channels

CI operators were expected to use traditional broadcast media such as newspapers, radio or television to communicate with members of the public during such incidents, with 99% of respondents having strongly agreed or agreed with this statement (Fig. 3). No respondents disagreed or strongly disagreed with this statement, and only 1% declared that they were unsure or neutral. The majority of respondents also had high expectations in relation to the availability of crisis information on the website of operators, with 94% having agreed or strongly agreed (Fig. 4). Only 4% of respondents were unsure or neutral. When asked if respondents expected operators to provide information via calling a telephone number, 67% agreed or strongly agreed (Fig. 5). 24% of respondents were unsure or neutral in regards to CI operators having a telephone hotline to make disaster related information available to the public.

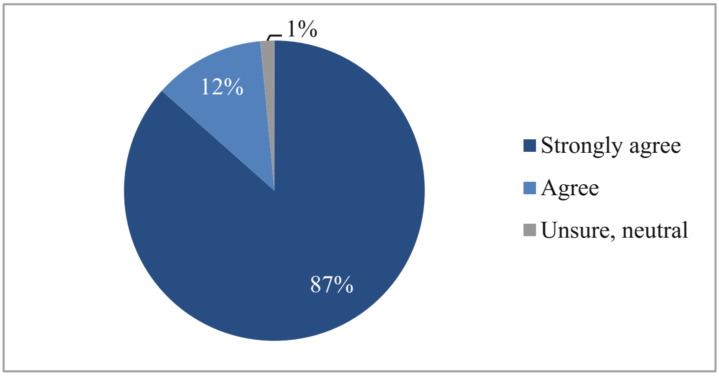

Fig. 3. Expectations that crisis information should be provided via traditional media

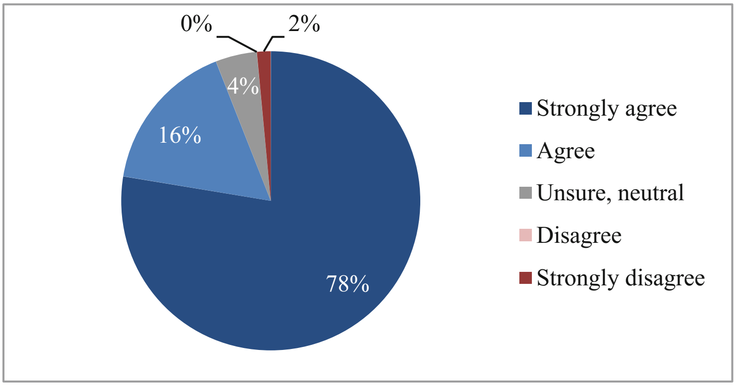

Fig. 4. Expectations that crisis information should be provided via websites

5.3 Expectations for Two Way Communication on Social Media

When asked if they expect CI operators to respond to comments sent by members of the public to their social media accounts, 61% of respondents agreed or strongly agreed (Fig. 6). There was high uncertainty/neutrality (26%) in regards to responding to queries, and a large portion of respondents selected disagree and strongly disagree (13%). Lastly, 77% of respondents who expected CI operators to communicate via social media also expected them to respond to questions or comments.

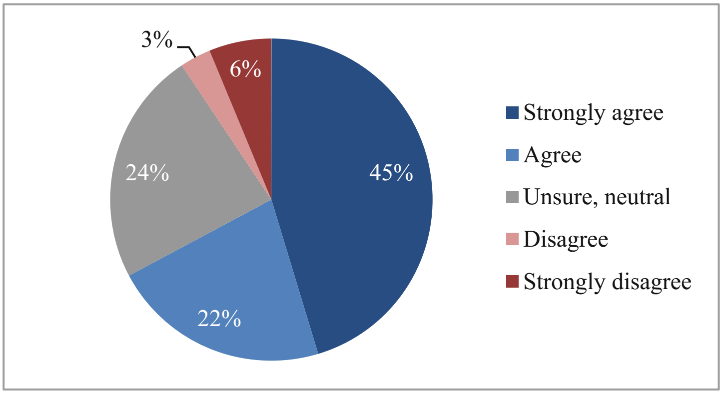

Fig. 5. Expectations that crisis information should be provided via calling a telephone number

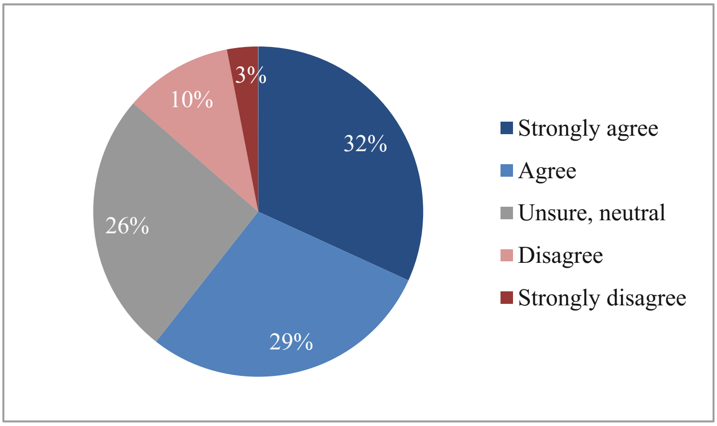

Fig. 6. Respondents' expectations for two way communication on social media during and after a disaster

6 Interview Results

French A31 Highway operators identified two different types of general public who use their infrastructure: individual users and professional users (truck drivers). However their communication intended for users of the infrastructure is not dependent on which type of user they are addressing. The DIR Est is charged with communicating with the public. Since they are a public institution, they "must guarantee the reliability, usefulness, and credibility of information" before they share it with the public (Interviewee 1). DDT57 gather and synthesize data to be shared with the crisis cell and with the Préfet in times of crisis and do not communicate with the public. The emergency response structure in France is such that the Préfet is the one who makes all the crisis management decisions, including those related to communication. As such, the DIR Est follows the guidelines and regulations in regards to crisis communication, waiting for approval from the appropriate persons before sharing information with the public.

They find when it comes to their crisis communication, two elements are absolutely necessary to convey to the public: (1) delays associated with the crisis and (2) the cause of the crisis. Furthermore, the information must be updated regularly in accordance with which crisis management stage they are in and the ever evolving traffic conditions. According to our interviewees, "users demand to be informed of the situation" (Interviewee 1). They have learned from past mistakes where they did not inform the public of the situation, such as the example shared in this anecdote:

"In 2013, part of the highway was stuck in a standstill traffic jam. Some people began to turn around and go the wrong way on the motorway! This was happening around the same time that the highway was starting to circulate again, and so going the wrong way was risking a major accident. If the users had been provided the information related to the traffic jam, this crisis could have been prevented" (Interviewee 2).

A strategy focusing on communication with their users exists and is applicable in both normal times and crisis times. Crisis communication involves more frequent communication and requires a greater mobilization of actors than day-to-day communication. In general, they distinguish between two types of communication: programmed (when the event can be anticipated, such as certain weather related events or foreseen traffic peaks, for example during holiday periods) and real time (when the event cannot be anticipated). Programmed communication uses three main channels: traditional media (via the press), the DIR Est website, as well as collaborating to put the information on Bison Futé, the official French government website relating to traffic conditions. They may also implement warning levels when appropriate. For real time communication, they have a partnership with the radio station France Bleu, which allows them to not only disseminate traffic information at scheduled times, but also in the form of "flash" information, whereby the regular programming is interrupted in order to warn the listeners/highway users. "These information 'flashes' are sometimes picked up by other radio stations," said one operator (Interviewee 3), "but we do not have partnerships with other stations." Lastly, they communicate via VMS (variable messaging signs – electric traffic signs used on road ways to convey relevant information), which "allow us to communicate as closely as possible to 'in real time' when an incident occurs" (Interviewee 3). During crisis times, the press takes on an even greater role in information sharing. The DIR Est inform not only the radio but also television news channels and online news sites about sudden onset crisis events. They see their job as provider of critical, crisis-related information to the press, and the job of the press as messenger of said information to the public.

The radio and the VMS are seen by the operators to be the most effective means of communicating with the public. The VMS are especially effective as they are seen by the current users and can be implemented very close to a given incident. The radio station France Bleu is listened to by many of the highway users, and in the case of an incident, operators from DIR Est said that users already know to turn on that station to find out more information. Concerning the radio, however, DDT57 brought up a limitation. "The problem with the A31 is that there is no dedicated radio station and the promotion of the partnership with France Bleu does not have as great an impact as a dedicated radio station would" (Interviewee 4).

They do not send out SMS warnings, nor do they use social media, as they believe their current strategy has "already proved its effectiveness" (Interviewee 1). They are aware that users may communicate information via social media, but they see this kind of information as being the subjective opinion of a given user and as such don't view social media as a reliable information source. They did mention that Loractu and ITLF (Info Traffic Lorraine et Frontière), two local news sources, are active on social media and discuss traffic conditions. However, there is no official partnership with them.

7 Discussion

7.1 High Expectations for Information to Be Available on Social and Traditional Media Channels

Results indicate that members of the public expect CI operators to provide disaster related information via both traditional and social media. Overall, expectations were high for all four channels studied. There was no disagreement among respondents when it came to expecting disaster related information relevant to CI to be available through traditional means such as radio or television. This further reinforces the idea that even to the public, digital media such as websites or social media platforms is meant to compliment more traditional crisis communication methods and not replace them. CI operator run websites should then be used as another channel for information dissemination, as 94% of respondents expected it. Respondents also have high expectations for information to be available on social media (79%) and as such social media should be included in crisis communication plans as well. High expectations for information to be available on the Internet via social media and websites demonstrate high expectations for operators to be proactive in pushing information to citizens. This is furthered by the high uncertainty/neutrality (24%) for there to be a telephone hotline available, which would consist of the respondent being proactive in searching for the information. Furthermore, this substantiates the importance of understanding the technological culture of the local population when putting into place crisis communication plans [18].

The majority of respondents expected operators to respond to queries, confirming the importance of two-way communication. However, the high amount of disagreement with this statement furthers the idea that pushing information to citizens should be more of a priority for operators than responding to queries. Respondents who expected CI operators to communicate via social media also had high expectations for a response. This can be explained by the fact that people tend to use the media platforms that they are already familiar with during crisis [19, 20]. High expectations for a response from operators further reflects the fact that social media generally encourages interaction and dialogue between users as it is an information space devoid of hierarchy [21].

7.2 Expectations for Social Media Use Are Not Currently Being Met by the Operator

The current public communication efforts of the operators at the A31 Highway appear to meet public expectations when it comes to using traditional media and website channels. They currently have partnerships with various members of traditional media, from print media to radio and online news. The importance in using traditional media as a means for crisis communication is acknowledged by the operators. The A31 Highway also publishes crisis related information on their website.

However, as they do not have social media accounts, they are not yet meeting this expectation. It is important however to keep in mind that this expectation may be an uninformed one as the IMPROVER questionnaire did not establish what the participants understood as crisis-related information on social media. Limitations with the use of social media include those laid out by the operators, namely reliability of information and the need to verify it. Despite this, the fact that respondents have high expectations for operators to use social media clearly indicates that this is an area where the operators can improve the effectiveness of their crisis communication. While the operators stated that they felt their crisis communication to already be efficient, respondents clearly demonstrate a desire for information to be shared on social media, indicating either that participants didn't understand the implications of using social media for crisis communication or a gap in perception of the crisis communication plan. As an institution of the French government, the A31 Highway operators must follow a hierarchical communication strategy, which is indeed the opposite of the information flows on social media. The A31 Highway appears to still be in a top-down approach, insisting on controlling information. The importance of providing verified information is also cited as a reason for not using social media. However, once verified, other institutions in the French government do communicate crisis information via social media (the Ministry of Interior for example). While the information in this case is indeed published less rapidly than that coming from ordinary users, it is still important to be able to find official information sources on social media. As the A31 Highway already provides verified, official messages in "near real time" on their VMS system, these messages could potentially be re-employed on social media. Indeed, multi-channel crisis communication is more effective [22, 23]. If the reason for not using social media is to avoid having to deal with queries that might be generated on such platforms, a transparent no response policy could help operators to meet citizens' expectations for information to be pushed via this channel, which were higher than expectations for queries to be answered, and continue with the current, top-down communication strategy.

Another solution to meeting social media expectations could be partnerships. As they already work in partnership with traditional media generally when it comes to public communication, it may be interesting to see if these actors' social media sites would be considered by the public as an appropriate source to find CI related disaster information. Perhaps an official partnership with either Loractu or ITLF could be envisioned, similar to the current partnership with Radio Bleu. As such, this approach could be another dimension of their existing relationships with news media. While the expectations studied here were for CI operators to provide the information directly, it may suffice to simply inform the public that crisis information related to the A31 Highway is available on social media at a partner's account in an official capacity. Further research should look into this. However, the comment on the limitations of using a partner radio station instead of a dedicated radio station during the interview also merits further investigation before putting into place more such partnerships, especially considering the results of the questionnaire, which asked about social media use by CI operators themselves.

The A31 Highway does not currently use information found on social media as they do not trust user provided information nor do they perceive it to be useful. Currently, social media is used by many different emergency response organisations to improve situational awareness. Indeed, social media monitoring leads to better situational awareness as it provides eye witnesses accounts. However, as expectations related to this were not asked of respondents, further research is needed to see if this is indeed an area that the public expect CI operators to further develop. In conclusion, it is suggested then that the operators expand their crisis communication strategy to include social media.

7.3 Limitations

The methods elaborated above have a number of limitations that should be acknowledged. As discussed earlier, the self-selecting sample engaged in the online questionnaire did not adequately represent the demographics of France. It should also be noted that the use of the website to distribute the questionnaire was likely to have skewed the sample in favor of those who used the Internet and social media on a regular basis.

8 Conclusions

Our findings suggest that CI operators should continue to use traditional media during crisis situations, and that this should be supplemented through the provision of disaster related information via the Internet, with websites and social media platforms maintained by CI operators. The French A31 Highway should expand their crisis communication efforts to include social media in order to meet public expectations. This may be difficult to put into place due to the current organisational culture which views social media poorly. Despite this, high expectations for information to be pushed via social media demonstrate the importance in including it in a multichannel crisis communication strategy. However, it should be acknowledged that this was a self-selecting sample that was not representative of the demographics in the population studied, and as it was an online questionnaire it most likely attracted people who generally use the Internet and social media. Further work is needed to explore the perspectives of citizens who are unable or unwilling to use digital media. A future questionnaire is being developed within the IMPROVER project to better understand these expectations. Lastly, the IMPROVER project is also currently working on the development of a communication strategy for CI operators to deploy during each stage of a crisis that will encompass both digital and traditional media platforms.

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Geoinformation Approach in Soil Erosion Susceptibility Assessment – A Tool for Decision Making: Case Study of the North-Western Bulgaria

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Abstract. The soil erosion is considered as one of the most serious environmental problem in a global scale. The development of the process could have negative impact on water, vegetation and ecosystem as a hole, as well as to influence on the quality of life. If the process is not mitigated in long term it could change the topographic surface and to trigger geomorphological hazards. The researches on soil erosion require analyses of large volume of information about soil properties, topographic surface, precipitation and land use. In the current research GIS technology is used for building the data base, spatial analyses and visualization of the results. The Universal Soil Loss Equation (USLE) is applied in Map Algebra and spatial distribution of soil loss is presented. The results are considered in relation to land use, particularly arable lands and vineyards. The application of computer technology provide opportunities for easy processing of data and updating the model by adding new data which can be used by territorial planning experts, local authorities and farmers in the planning process, monitoring and mitigating the soil erosion.

Keywords: Soil erosion · USLE · GIS · Land use · Geoinformation approach

1 Introduction

Soil erosion is a geomorphological process of loss of the soil layer due to the activity of rain and snowmelt water. It is characterised not only by the amount of soil lost, but also by reducing its fertility because of the removal of the superficial layer. The effects of soil erosion are not determined only by the reduction of agricultural productivity. Decreasing the soil quality reflects on the state of the vegetation as a whole and in this relation to the ecosystem conditions and ecosystem services. Soil erosion also affects the quality of water by increasing the rate of siltation which leads to limitation the initial storage capacity of the dam and this could be very dangerous because of the

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flood risk. In long term the soil erosion could contribute to the aggravation of the food problem and to influence the quality of life.

The average annual soil loss in natural conditions are between 0.0045 and 0.45 t/ha, and increase from a 45 to 450 t/ha at arable land [1] depending on the soil properties and slope. Soil losses between 20 to 40 t/ha caused by a rainfall in Europe may occur once every three years, and the erosion of extreme rainfalls reaches up to 100 t/ha once every 6 years. The researches show that water erosion takes 53% of total soil degradation [2]. Approximately 65% of the agricultural land in Bulgaria is at risk of water erosion and about 24% of wind erosion. A prerequisite for the development of water erosion processes is the prevailing hilly relief with slopes above 3°. Average nearly 70 intensive rains fall on the territory of the country in the period April–October, and nearly 14% of them are erosive [3].

All these issues ground the need of studying the soil erosion and looking for tools to limit the processes. Taking into account the nature of the erosion process a large volume of data about precipitation, soil properties, topographic surface, vegetation and land use have to be processed and analysed. This determines wide application of information technology in erosion researches, which shows rapid development. There are many publications in which GIS is applied to the conventional methods of erosions assessment [4–9]. Most of the publications are based on the calculation of the USLE and some modifications are added regarding the characteristics of the area and the available data.

The aim of the current research is to build a GIS data base containing the soil erosion triggering factors and soil properties in the North-Western Bulgaria and to assess the erosion susceptibility of the region. This could support decision makers in agriculture and spatial planning. The soil loss is spatially presented in GIS by calculating the USLE on the base of raster layers about MFI, soil erodibility, topography and vegetation cover. The results are compared with the land use in order to reveal how erosion is related to land use patterns.

2 Study Area

The area, subject of the current research is the north-western part Bulgaria (Fig. 1). Its limits are the Danube River at the north, the Bulgarian-Serbian border at the west, Stara Planina Mountain at the south and south-west and the river Iskar at the eastern side. It includes part of the Danube plain and Fore-Balkan. The total area is around 10217 km^2. This is mainly an agricultural land. The relief is predominantly flat and hilly, and low-mountainous in the southern part of the study area. Regarding the soil zonation the study area is in the border of Northern Bulgaria Forest-Steppe zone [10]. It is divided into three subzones – Danube sub-zone of chernozems; Danube plain, hilly Fore-Balkans sub-zone of gray forest soils and Fore Balkan sub-zone of light gray forest soils. The hilly-plain terrain deeply cut by river valleys and continental climate in this aria define soil erosion as the main degradation threat for the topographic surface.

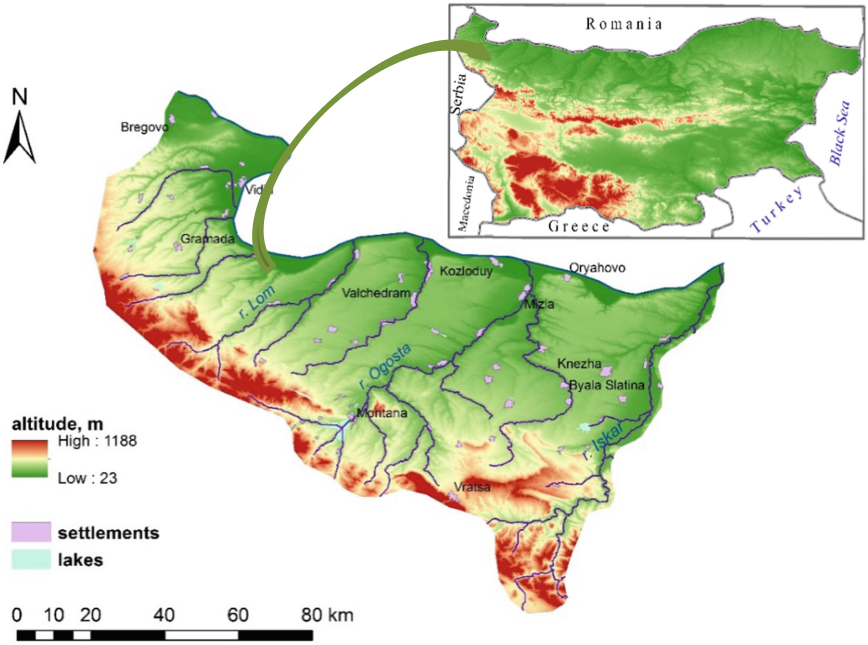

Fig. 1. Study area

3 Data and Methodology

Taking into account the identity of the modelled phenomena (soil erosion) a variety data is needed to be analyzed. This includes soils properties, rainfall intensity, slope of the topographic surface, vegetation cover and land use types.

The soil polygons are determined on the base of soil map of Bulgaria, M 1:400 000 and 12 soil units are outlined (Table 1). Soils profiles, representative for main soil types in Bulgaria are taken into consideration for determining the physical and chemical properties of the soils. The names of soils units are defined according to Bulgarian classification [11]. The soils are classified according to World Reference Base [12] and American classification [13]. The referencing of the soils in the studied region to the both classification systems cited here and the properties of the reference soil profiles [14] used as input data for GIS are given on Table 1.

The rainfall data used in the current research is taken from Meteorological bulletins (published by National Institute of Meteorology and Hydrology, Bulgaria) and form thematic climate data website: https://en.climate-data.org. Data from 8 meteorological stations in the study area is used in the research (Fig. 2). Other 8 stations, located in Romania and Serbia, near to the investigated area, are also used for spatial interpolation of the rain data. We did not consider for interpolation meteorological stations, located to the south of the study area because of the climate impact of the mountain ridge which borders the region and different climate conditions south of the Stara Planina Mountain.

Table 1. Soil units in the investigated area referred to the WRB and Soil Taxonomy and input data for GIS: main soil texture fractions - sand (2–0.050 mm), silt (0.050–0.002 mm), clay (<0.002 mm); total organic Carbon (OC).

No	Bulgarian soil classification	WRB (2006)	Soil Taxonomy (2010)	Sand, %wt.	Silt, %wt.	Clay, %wt.	OC, %wt.
1	Calcareous chernozems/Typical chernozems	Epicalcic Chernozem	Calcic Haploxerolls	14.4	51.4	34.1	2.3
2	Leached chernozems	Endocalcic Chernozem	Typic Calciustolls	14.6	46.9	38.6	2.6
3	Leached chernozem-karasolutcii	Endocalcic Vertic Chernozem	Vertic Haplustolls	7.3	40.9	51.7	4.1
4	Degraded chernozems	Luvic Chernozem	Typic Agialbolls	15.2	48.4	36.5	2.1
5	Dark Gray-Brown forest soil	Luvic Grayc Phaeozem	Typic Argiudolls	20.0	42.9	37.5	2.0
6	Gray-Brown forest soil	Cutanic Luvisols	Typic Hapludalfs	31.3	34.4	34.9	2.0
7	Light grey forest soils	Luvic Endogleyic Planosol	Typic Albaqualfs	26.3	46.7	26.7	1.9
8	Brown forest soil	Haplic Cambisol	Typic Dystrudepts	58.4	26.4	15.2	1.8
9	Alluvial and alluvial meadow soils	Haplic Fluvisol	Typic Fluvents	38.1	38.8	23.0	2.0
10	Deluvial and deluvial meadow soil	Haplic Cambisol (Colluvic)	Typic Orthents	50.0	30.8	19.2	2.24
11	Eroded soils	Regosols	Entisols	21.6	56.2	22.3	1.3
12	Rendzina soil	Rendzic Leptosol	Typic Haprendolls	18.3	37.5	44.2	4.05

The topographic data is derived from remote sensing (RS) data – SRTM DEM, http://srtm.csi.cgiar.org [15] RS data, Sentinel-2 images (ESA, Copernicus Sentinel Data [25]), is also used for determining the vegetation conditions. Land cover/land use data, taken from CORINE Land Cover Project [16], is used for evaluation of the relation between soil erosion susceptibility model and land use in order to suggest recommendations for more rational territorial planning.

The methods used in the current research are grouped the following groups: mathematical; spatial analyses/spatial interpolation and GIS application. The last ones could be considered as an integrated approach for analyzing a spatial data.

For the aim of the research, the soil erosion susceptibility is determined on the base of Universal Soil Loss Equation, USLE [17] and revised USLE (RUSLE), [18]:

$$A = R^{*}K^{*}LS^{*}C^{*}P,$$

where: A is the soil loss (t/ha/an);
R - the rainfall erosion factor;
K - the soil erodibility factor;
LS - the topographical factor (slope-length and slope-steepness);
C - the land cover and management factor;
P - the factor of the works for erosion prevention and control.

We applied the USLE in ArcGIS environment using Map Algebra tool on raster layers of the 5 indices involved in the model.

The rainfall erosion factor, R (rainfall intensity) is presented by modified Fournier index (MFI), proposed by Arnoldus [19]. It is calculated as the sum of monthly average amount of precipitation divided to the average annual amount of precipitation. The MFI is used in many publications for assessment the erosion and particularly when there is insufficient data for intensive rain, and also because of it can be easy calculated. The spatial distribution of the MFI is presented by inverse distance weighted (IDW) interpolation and a raster layer in ArcGIS is generated.

The soil erodibility (K factor) is defined as the rate of soil loss. It represents the susceptibility of soil particles to be detached. It is related to the integrated effects of rainfall, runoff, and infiltration on soil loss [7]. The K values are calculated on the base of physical properties of the soil, the content of silt, clay, fine sand and organic matter. As a base for calculation, we used soil map in vector format presenting different soil types. In case of insufficient information on soil structure and texture, we used the grain size and the content of organic matter for calculating the K factor. The equation suggested by Römkens [20] and revised in Renard et al. [18] is the base of calculation. In order to take into account the organic matter content in calculating the K factor we used the following equation, proposed by Wang et al. [21]:

$$K = 0.0067 - 0.0013[ln(SOM/Dg) - 5.6706]^{2} - 0.015\,exp\left[28.9589(log(Dg) + 1.827)^{2}\right],$$

where SOM is soil organic matter, and

$$Dg = \exp\left(0.01\sum\nolimits_{i=1}^{n} f_i\, lnm_i\right),$$

m_i is the arithmetic mean of the particle size,
f_i is the weight percentage of the particle size fraction.

The soil erodibility values are calculated using the data in the soil polygon attribute table. The values are recorded in a new field in the attribute table. In the next step, the soil map is converted in raster format using K value field to be applicable in Map Algebra calculations.

The topographic factor (LS - length of slope and steepness) is calculated using the flow accumulation and slopes values determined in ArcGIS environment on the base of DEM. Flow accumulation present the number of cells from which each cell in the raster collect flows. The following equation proposed by Moore and Burch [22, 23] is used.

$$LS = (A^{*}\text{cell size}/22.13)^{0.4}(\sin(\text{slope})/0.0896)^{1.3},$$

where A is flow accumulation.

Greater values of flow accumulation indicate more water quantity in the streams. LS factor presents the combined influence of the slope of the topographic surface and the length of slope. The steeper slopes determine more intensive erosion processes, while longer slopes could decrease the intensity of the erosion.

The land cover and management factor (C) is determined on the base of Normalized Difference Vegetation Index (NDVI). It is an indicator for the state of vegetation and could be used in soil erosion estimation in relation to the impact of vegetation on the runoff distribution. Vegetation plays an important role in protecting soil against erosion because the vegetation canopy intercepts the rainfall, increases the infiltration and reduces the surface runoff erosion activity. The Sentinel 2 images (ESA, Copernicus Sentinel Data [25]) are used for calculation of NDVI.

Satellite images used for determining the vegetation state are acquired in September when the crops are already collected from the field. In this regard, the values of erosion could be overestimated but following the precautionary principle, we decided to assess the soil erosion susceptibility taking into account the worse conditions.

The C factor is determined using the following Eq. [24]:

$$C = \exp(-2^{*}NDVI/(1 - NDVI))$$

No special actions for erosion prevention and control are taken in the investigated area and in this regard, 1 is accepted for P factor.

4 Results

The parameters of USLE are calculated and presented as a separate GIS layers (Figs. 2, 3, 4 and 5).

The location of the meteorological stations influence on the results of the interpolation but although some data imperfection the results show a regular increase of precipitation to the higher altitude (Fig. 2).

The values of soil erodability reflect the combined influence of mechanical composition of soils and the content of organic substance. The K factor has higher values at unconsolidated fluvisols and also at luvisols and planosols where silt and clay content is low.

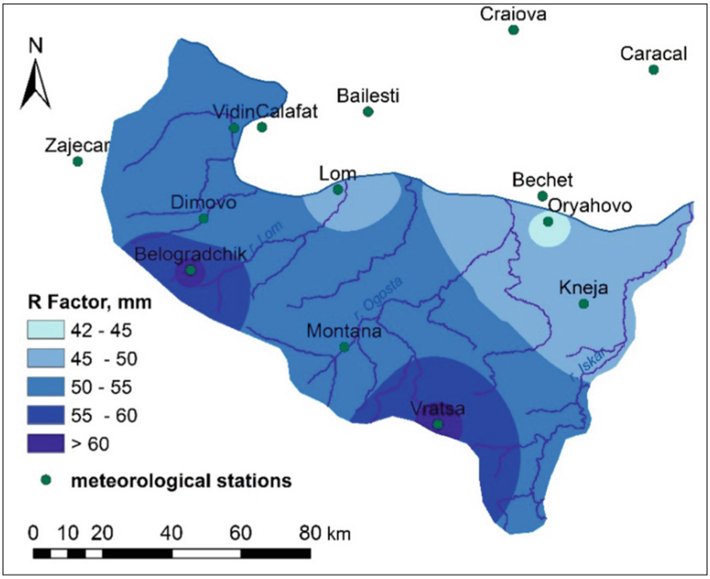

Fig. 2. Rainfall intensity

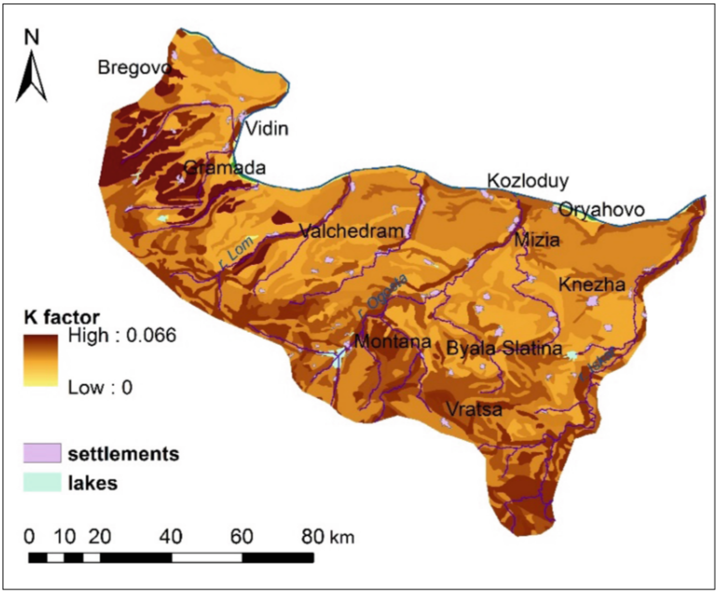

Fig. 3. Soil erodability (ha MJ mm)

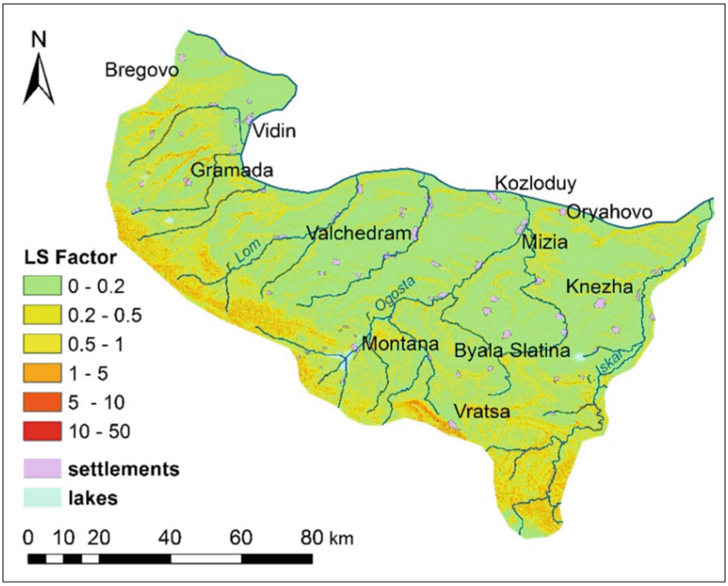

Fig. 4. Length of slope and steepness factor

Regarding the spatial distribution of LS factor the most of the investigated area (68.9%) has values less than 0.2 and 12.8% are between 0.2 and 0.5. The highest class of LS factor (10–50) takes only 0.1% of the investigated area and it could be skipped regarding the scale of the map.

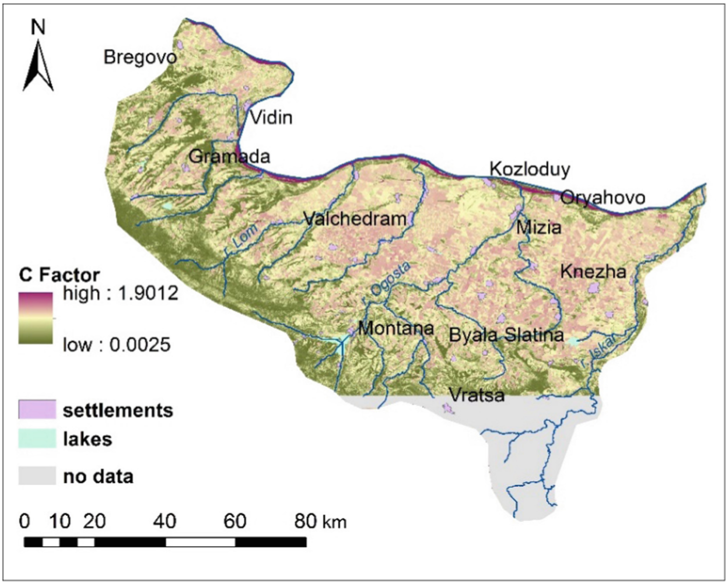

Fig. 5. The land cover factor

The spatial distribution of C factor shows increasing of the values from the mountain and forest area to the hilly and low agricultural lands.

Multiplication of the above four raster layers in Map Algebra results in output raster presenting the soil loss (Fig. 6).

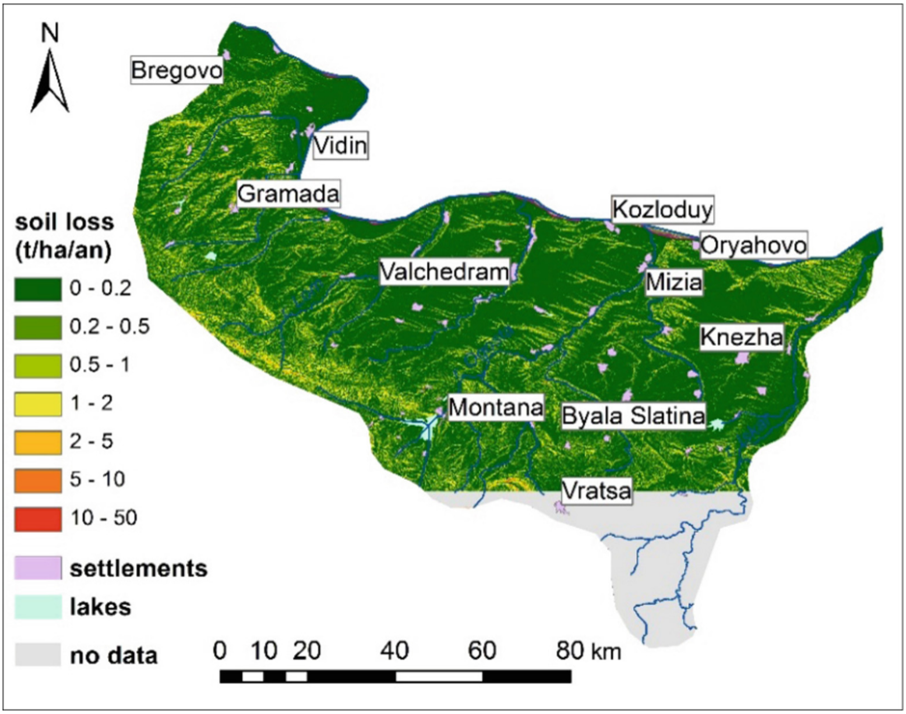

Fig. 6. Soil erosion

The generated model of soil erosion shows high values of soil loss in the high mountains at the southern part of the study area as well as to the north-west where hilly lands and rare vegetation are dominant. More than 1 t/ha/an is the soil erosion near to rivers and streams which shows a clear relation of the presented USLE model to the river and gully erosion. The soil loss values are the lowest on the low and flat watersheds. The soil loss is less than 0.2 t/ha/an in around 72% of the investigated area and in 0.06% of the area the calculated soil erosion is between 10 and 50 t/ha/an. The spatial overlay of the calculated soil erosion layer and land cover/land use (CORINE Land Cover Project) shows that 78.5% of the arable land and 62.7% of the vineyards have soil erosion less than 0.2 t/ha/an (Table 2).

More attention should be given to the arable lands and vineyards where erosion is between 0.2 and 1 t/ha/an, which have relatively high percent of the respective land use types. The relevant agricultural activities (tillage across the slope, crop rotation etc.) should be carried out in these cases.

Table 2. Soil erosion rates by land use

Soil loss, t/ha/an	Arable lands, %	Vineyards, %
0–0.2	78.4461	62.67932
0.2–0.5	13.08564	21.9962
0.5–1	6.070217	11.50664
1–2	1.95048	3.233397
2–5	0.396003	0.523719
5–10	0.04343	0.045541
10–50	0.008135	0.01518

5 Conclusion

The application of USLE and generated model of soil erosion show that the investigated area is not severely affected by erosion processes. A special attention should be given to the hilly land and steep slopes of river valley and gullies. In case of deforestation there is a risk of increasing the erosion processes in the high parts of the mountain. The time of the year in which the vegetation/land cover data has been collected influences on the result of the research and should be taken into account in analysis the values of soil erosion. The vegetation data for current model is calculated using satellite data acquired in September (Sentinel-2) when the crops are collected. The result would be different if the assessment is done for May when vegetation is in a growing season. Having regard the above we did not use data of May because of the higher values of clouds cover and also the aim of the research was to assess the erosion rate in the worst conditions.

Although some uncertainties of the model, using of remote sensing data and computer technology allows acquisition of data for large areas (even difficultly accessible on the field), processing of a large amount of data and easily performing of spatial analyses. The integration of the soil erosion calculation model in geographic information systems (GIS) leads to an automatic cartographic representation and better interpretation of land erodibility data.

The results of the research could support the decision making related to the landscape planning, agricultural planning and soil preservation activities.

Future researches will be directed to the minimizing data imperfections, adding other factors influencing the erosion processes, for example water of melting snow, support practice factor etc. and improving the model.

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