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Study on the Cooperative Mechanism of Earthquake Emergency Rescue in China

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Abstract: After the earthquake, on-site emergency rescue coordination is very important to minimize the disaster losses. Limited by communication tools, channel resources and network coverage, China's current earthquake emergency rescue coordination mechanism still has problems such as backward technology and low level of information sharing. In this paper, a new design method of earthquake emergency rescue cooperation platform is proposed by using advanced integrated communication network and communication technology. The earthquake emergency rescue cooperation platform is based on the current new mode of emergency management cooperation and linkage. Each department carries out collaborative disposal and response to the disaster situation according to its own functional responsibilities. It can improve the informatization level of information sharing and dynamic update among all cooperative members.

1. Introduction

In recent years, earthquake disasters have occurred frequently. A large number of earthquake emergency rescue cases show that the disposal of major earthquake disasters is actually a battle to mobilize and organize the whole society to cope with earthquake disasters. The emergency rescue work at the earthquake site usually shows urgency, timeliness and coordination, requiring response in the shortest time after the earthquake, coordination of multiple departments, and completion in a limited time [1]. This particularity makes information sharing the basis of the earthquake site coordination, which requires the construction of a set of coordination network to provide a means of rapid interconnection for teams across the country rushing to the disaster area to participate in earthquake relief, realize efficient sharing of information, rapid transmission of instructions and reasonable allocation of resources.

At present, with the development and application of communication technology, the command transmission and situation feedback at the earthquake site have been basically realized. However, limited by communication tools, channel resources and network coverage, the on-site information sharing is mainly through telephone, SMS and file copy, and there are problems such as inconsistent format, untimely sharing, complex operation, and low collaboration efficiency.

In order to strengthen the effective development of rescue cooperation after an earthquake, this paper proposes to use advanced communication technology and communication network to build an emergency rescue cooperation platform, so as to meet the needs of disaster early warning, on-site

information communication, rescue materials and personnel scheduling and auxiliary decision-making.

2. The Importance of Earthquake Emergency Rescue

Earthquake emergency rescue refers to activities such as pre-earthquake emergency preparation, pre-earthquake emergency prevention and post-earthquake emergency rescue taken to deal with sudden earthquake disaster events [2]. The main purpose of emergency rescue is to ensure the safety of people's lives and property, quickly and effectively control the expansion of earthquake disasters after the occurrence of earthquake disasters and ensure that all emergency rescue work can be carried out smoothly, minimize casualties and reduce property losses, maintain social security and stability, and promote economic recovery and development in disaster areas.

Earthquake disasters have the following characteristics:

a) Suddenness. There are certain difficulties in the accurate early warning of earthquakes. A few seconds of early warning may double the number of disasters. Therefore, at the beginning of the earthquake emergency, it is chaotic and disorderly, which cannot be solved by conventional methods. It can only be solved by changing the emergency strategy and taking different emergency measures according to the site conditions.

b) Complexity. The unpredictability of earthquake essentially causes its complex characteristics. On the one hand, the teams involved in the rescue include professional teams, medical personnel, military personnel, armed police officers and soldiers, volunteers, local people, and so on, so the number of personnel is relatively large and complex, which is not easy to manage uniformly; on the other hand, after the earthquake, due to the collapse of houses, road congestion and other reasons, it is bound to cause chaos at the scene and completely disrupt the pace of people's life. All these make the earthquake rescue work more difficult and complex.

c) Urgency. As the impact of earthquake disaster is huge, and it will cause great losses in an instant, and the disaster will continue to escalate as time goes on, so how to quickly carry out the rescue is an important factor to avoid the further expansion of the disaster, which requires the state, government, and relevant departments to reflect that they can quickly collect information, carry out the rescue as quickly as possible, and avoid greater losses [3].

In China, earthquakes mostly occur in mountainous areas, with complex terrain, poor seismic resistance of buildings and inconvenient traffic. Most counties, towns and other places where people gather are built along the river. Once a major earthquake occurs, it is most likely to block roads and bridges, making it an island, and heavy rescue facilities cannot reach it, which has virtually increased the difficulty of rescue.

An investigation into the cause of death of earthquake victims shows that, the death rate is as high as 50% due to not being rescued in time and secondary injury, as shown in Figure 1. After each earthquake, a large number of casualties caused great harm to the people in the earthquake area. Many people lost their loved ones after an earthquake, which cast a shadow on their psychology. So after the earthquake, in order to reduce casualties, reduce social losses, and maintain social stability, high-speed and effective rescue must be carried out to ensure that more survivors are rescued in time, and reasonably arrange survivors to avoid losing their lives due to secondary injuries.

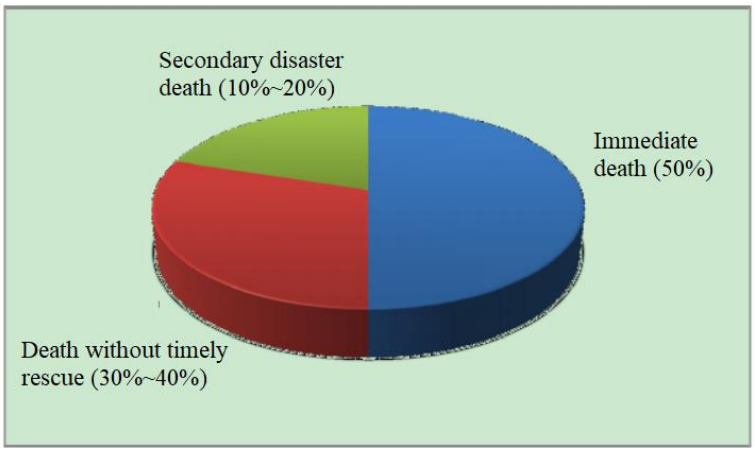

Figure 1: Cause of Death Due to Earthquake.

Proper search and rescue measures are essential to minimize the loss of life in the first few days of earthquake disaster. After the earthquake, the international rescue community believed that there was a golden rescue time of 72 hours after the earthquake [4]. In these 72 hours, the survival rate of survivors decreases with time. Especially 2 hours after the earthquake, the death rate of suffocation increased to more than 58.6% of the buried. According to some seismic data, the relationship between the survival time and survival probability of survivors is shown in Figure 2.

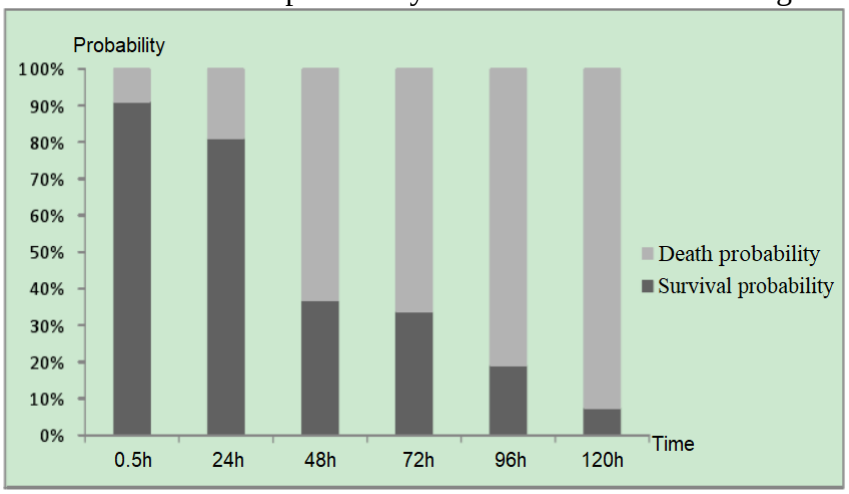

Fig.2: Relationship between Rescue Time and Survival Probability of Earthquake Trapped People.

No matter what the situation is, the trapped people will be rescued in the shortest time, and their survival probability will be greater. Therefore, the earthquake rescue must be started quickly in the shortest time. The ability to arrive at the rescue site to participate in the rescue is a very important measurement factor. Its length is directly related to the lives of the rescued people, and also directly affects the ability of the rescue team.

China's earthquake rescue team is establishing and improving its rescue technology and support system. The scene of the emergency faced by the rescue team is complex, and the scope of the affected area continues to expand. The rescue team will no longer deal with the rescue task as an independent team, but must cooperate with other professional forces to complete the rescue task. The professional forces in various fields, including their industry experts, practitioners, facilities and equipment involved in any emergency, will continue to provide technical support for the rescue team in the field of rescue, such as scientific solutions, coordination and information, called the rescue technical support system [5]. The development degree and role of the rescue technical

support system in the field of rescue are directly related to the rescue effect and safety of the rescue team.

3. Current Situation of Earthquake Emergency Rescue Cooperation

The earthquake site coordination is mainly divided into two major areas: the first is the field of on-site emergency response, including a series of work urgently carried out at the destructive earthquake site to provide the technical data required for rescue, disaster relief and recovery and reconstruction; the second is the field of on-site rescue, including a series of emergency actions to save lives and property and prevent the spread of disasters at the earthquake site.

3.1 Emergency Coordination at Earthquake Site

The emergency work at the earthquake site mainly includes earthquake situation trend judgment, earthquake monitoring, earthquake intensity assessment, disaster loss investigation and other businesses. These work are characterized by strong timeliness, coordination, professionalism, high technical content and high socialization requirements. It requires that the staff should complete all work tasks in a short time after the earthquake in accordance with unified technical procedures and refined division of labor.

In order to promote the coordination of earthquake site emergency response, the China Seismological Bureau has successively issued a series of on-site work standards and established an earthquake site emergency command system, including the on-site disaster acquisition and transmission subsystem, the scientific investigation subsystem, the building safety appraisal subsystem, the on-site database management subsystem, the GIS geographic information processing subsystem, the on-site dynamic tracking management system of the rear headquarters, the emergency satellite network management centre, etc., as shown in Figure 3.

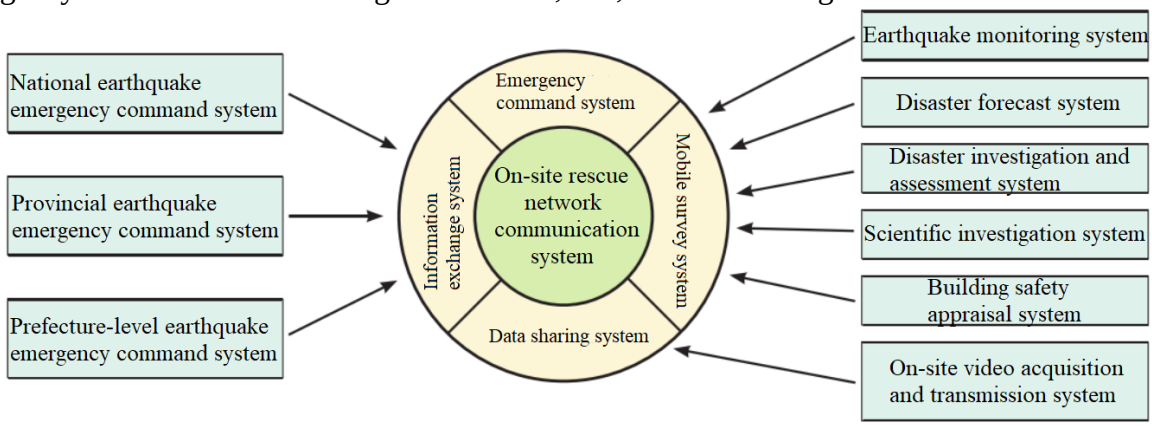

Fig.3: Emergency Command System at Earthquake Site.

Under the specifications of technical standards and the support of various subsystems, the earthquake site emergency staff will sort out the collected data and upload it to the earthquake site emergency headquarters through GSM mobile communication system, satellite communication system, wireless LAN and other communication systems, so as to realize the recording of on-site disaster investigation, intensity assessment and scientific research data, and realize the functions of command issuance, personnel scheduling, information sharing, etc.

3.2 Rescue Coordination at Earthquake Site

In recent years, China's professional earthquake rescue team has been growing, and professional

rescue teams have been established in various industries. Comprehensive rescue teams and emergency rescue volunteer teams have also been established in various regions. These teams have differences in team capacity, personnel composition, equipment allocation, etc. Therefore, at the scene of earthquake disaster, it is necessary to coordinate and implement rescue under the unified leadership.

According to the current principle of "territorial priority" for earthquake disaster response and disposal in China, after the rescue team arrives at the disaster area, its rescue operations are under the leadership and command of the local earthquake relief headquarters in the disaster area, including receiving tasks from the local headquarters and reporting progress. However, the on-site rescue operation still reflects the lack of necessary technical means to support the on-site rescue coordination [6]. The communication between the rescue team and the local earthquake relief headquarters is mainly through phone calls, text messages and other means. The scope of information sharing is limited, and the coordination efficiency is relatively low.

4. Key Technologies for Earthquake Emergency Rescue

4.1 Integrated Communication Network

As the basic communication platform supporting the development of earthquake emergency rescue work, the emergency communication link is constructed by using ultrashort wave combined with wireless bridge [7]. At the same time, integrate the existing 4G/5G/wired network of the public network to ensure the smooth operation of the integrated communication network platform in daily exercise and earthquake emergency.

In addition, we have developed the ultra-short wave silence management platform software to achieve the function of daily silence and automatic opening during the earthquake, which will not interfere with the use of other users in the occupied frequency band, but also meet the need to automatically open the emergency communication link at the first time after the earthquake.

4.2 Td-Lte Communication Technology

As an advanced technology, LTE has been recognized as one of the best technologies to meet the needs of private network users. TD-LTE has the technical advantages of not only high spectrum efficiency, but also flexible scheduling capability for uplink and downlink, and can also carry diversified high-bandwidth services.

In this study, TD-LTE technology is applied to the field communication of earthquake rescue, field audio and video acquisition, field visual command and dispatching, etc. We will effectively integrate on-site LTE communication, ultrashort wave communication, wireless bridge, wired optical fiber and public network communication. It effectively meets the dual requirements of daily emergency drill and post-earthquake emergency communication. We make full use of the audio and video acquisition function and visual command and dispatching function of LTE individual equipment to transmit the real-time information of the earthquake scene back to the emergency command center in real time.

4.3 Earthquake Emergency Mobile Terminal

The earthquake emergency mobile terminal can use the latest computing model and data resources in the earthquake industry to automatically generate the earthquake simulation map, auxiliary decision-making report, emergency plan and other information within 20 minutes after the earthquake and push it to the commanders at all levels. It can also provide real-time online query

function of rescue information such as rescue forces, medical facilities, fire forces, material reserves, etc. based on GIS map. In addition, the visualized earthquake emergency command function of district, city and county linkage can obtain the disaster situation in the earthquake area, rescue team personnel, rescue routes, etc. in real time, providing comprehensive and three-dimensional communication and service guarantee for the visualized command and dispatching.

4.4 Uav Flight Time Subsystem

The UAV aerial photography subsystem adopts the current advanced six-rotor aerial photography aircraft, which can carry out aerial photography flight missions in the earthquake area that cannot be penetrated after the earthquake [8]. The real-time video images are transmitted back and pushed to the commanders at all levels at the first time, providing a reliable means to obtain more intuitive scene images of the disaster area, and providing a basis for accurate decision-making of the earthquake relief command.

5. Construction of Earthquake Emergency Rescue Cooperation Platform

5.1 Overall Architecture

The overall architecture of the earthquake emergency rescue cooperation platform is divided into three layers: terminal/display layer, system control and service layer, and data layer, as shown in Figure 4.

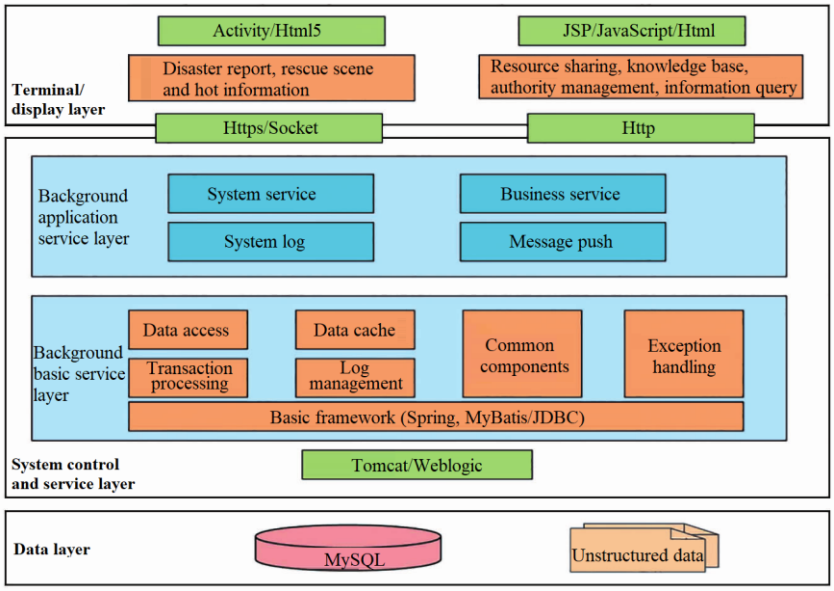

Fig.4: Overall Architecture of the Earthquake Emergency Rescue Cooperation Platform.

a) Terminal/display layer. The terminal/presentation layer mainly includes the front page and the background management system. The front page mainly displays the functions of disaster quick report, hot information, resource sharing, knowledge base, etc. The background management system mainly displays the functions of resource sharing, knowledge base management, pre-evaluation service, authority management, daily log management, etc.

b) System control and service layer. The system application service layer is divided into the background basic service layer and the background application service layer. It is mainly used to process the data interaction between the presentation layer and the business layer, as well as the system platform basic services, and provide corresponding business service components for

different businesses.

c) Data layer. The data layer provides an interface for external access to the data source. MyBatis is an excellent persistence layer framework that supports common SQL queries, stored procedures and advanced mapping. MyBatis eliminates almost all the manual setting of JDBC code and parameters and the retrieval encapsulation of result sets. MyBatis can use simple XML or annotations for configuration and raw mapping to map the interface and Java POJO to records in the database.

5.2 Functional Module Design

The functional modules of the earthquake emergency rescue cooperation platform mainly include earthquake early warning, auxiliary decision-making, command and dispatching, emergency support, simulation drill, etc.

5.2.1 Earthquake Early Warning Module

In the whole stage of earthquake occurrence, the prediction and early warning system has the function of monitoring earthquake development and automatic early warning. The prediction and early warning system is composed of Internet of Things monitoring and intelligent sensing equipment, including automatic early warning subsystem and dynamic monitoring and tracking subsystem. The Internet of Things technology is used to collect remote data, collect various information from different departments and collect earthquake site information. After processing, the value of state-related variables is obtained. Through the comparison of the relevant model base in the decision support system, the standard value of state measurement is obtained. After the comparison with the set threshold value, the conclusion of whether to start automatic early warning is drawn. If the early warning conditions are met, the automatic early warning subsystem is obtained.

Through the coordination and cooperation of all departments, the development of earthquakes can be effectively predicted, and data support for emergency response and command decisions can be provided, so that the decision-makers can grasp the current state. The application of Internet of Things technology improves the real-time and accuracy of information. The function of automatic early warning is to take a series of actions automatically to slow down the occurrence of the event if the parameter value is greater than the set threshold before the official start of the emergency management process.

5.2.2 Auxiliary Decision-Making Module

The auxiliary decision-making function of earthquake emergency is based on various information databases, combined with various methods, models, plans, cases and expert opinions, as well as the current situation of dispatchable emergency rescue materials, to carry out dynamic analysis and prediction, to provide decision makers with auxiliary decision-making, and to give the optimal decision scheme. Provide decision support for earthquake emergency decision makers. Decision support system provides method support and decision suggestions for decision makers. After the earthquake, in order to reduce the loss of earthquake disasters, effective response measures should be taken as soon as possible to implement rescue. Therefore, it is necessary to establish a corresponding emergency aid decision-making system in the system.

5.2.3 Command and Dispatching Module

Coordinate and unify the work of emergency management departments to ensure the correct and

effective implementation of decision-making. The command and dispatching auxiliary system integrates knowledge systems such as expert base, information resource base, knowledge base, and case base to provide auxiliary qualitative analysis support. Comprehensive application of system science, operational research and relevant professional scientific methods to optimize resource allocation and disposal scheme selection. Based on the corresponding model library, the system provides model generation tools and analysis and presentation support. At the same time, the simulation, deduction and evaluation of action plans are provided in combination with GIS system and tactical plotting system to obtain the best disposal process, so as to make the decision plan into a specific rescue plan, and optimize and drill the rescue plan, so as to improve the accuracy and scientificity of command. The commander shall understand the specific situation of the earthquake event by synthesizing various information, formulate a command and dispatching plan, and issue emergency response instructions to the emergency rescue personnel. According to the development of the earthquake situation and the supply and demand of emergency resources, the commander shall formulate the scheduling plan of emergency resources and issue relevant instructions.

The earthquake emergency command involves multiple departments and levels, and requires the relevant emergency departments to cooperate with each other to complete the earthquake emergency work. In order to meet the needs of the multi-sector collaborative management mode in the earthquake emergency command, on the basis of the existing earthquake emergency command system in each region, the cloud computing collaborative network system covering the whole country to deal with earthquake disasters is established. When the earthquake disaster occurs, It can not only achieve emergency command coordination among departments at the same level in the same region, but also achieve cross-department and cross-level department coordination.

5.2.4 Emergency Support Module

Any emergency response needs to be supported by resources. Therefore, emergency security is an important part of emergency management, which is of great significance to emergency management. Especially for major emergencies such as earthquakes, due to the amount and variety of resources consumed, efficient emergency security management has more important significance. On the basis of the emergency support resource database and in accordance with the principle of graded management of emergency resources, the informatization dynamic management of emergency resources such as professional teams, rescue experts, reserve materials, rescue equipment and so on is realized.

There are two parts in the emergency support system management: material and human resource management. Material support is a system that provides specific materials for earthquake emergency rescue and material basis for the operation of the entire security system. In order to realize the reasonable layout and dynamic allocation of system resources, the system carries out resource allocation, storage and maintenance, so as to improve the comprehensive utilization and use efficiency of resources, and at the same time provides resource status information to ensure the normal operation of the entire system, so as to effectively respond to earthquake disasters. This function is also responsible for resource status assessment, rational layout and dynamic allocation of resources, and comprehensive utilization, integration and sharing of resources.

5.2.5 Simulation Drill Module

In the simulation drill module, GIS technology and computer simulation technology are introduced, the plan exercise and emergency knowledge base are adopted, and the methods and technologies such as text, graphics, animation and online education are used to provide corresponding simulation exercise services for the simulation exercise of the corresponding plan,

and provide publicity and training services for emergency laws and regulations and common sense of earthquake prevention, risk avoidance, self-rescue, mutual rescue, disaster reduction, etc.

In addition, big data technology is used to simulate massive, scattered and heterogeneous monitoring information, establish a knowledge base of earthquake accidents, provide decision makers with optimal decision-making under different states of earthquake emergency rescue, enhance the comprehensive quality of emergency commanders and emergency disposal personnel, so that they can be familiar with their respective responsibilities and disposal processes, and improve the collaborative work ability of all departments.

6. Conclusions

Earthquake emergency rescue capability and information service level will usher in new opportunities under the guidance of emerging technologies such as big data, cloud computing and artificial intelligence, and diversified information service products will also be further developed and enriched to provide information and intelligent services for earthquake emergency rescue.

This paper first expounds the importance of emergency rescue mechanism for earthquake disaster, and analyzes the current situation of earthquake emergency rescue cooperation in China. Then, the key technologies and their application path for earthquake emergency rescue are described, including integrated communication network, TD-LTE communication technology, emergency mobile terminal and UAV flight mobile terminal. Finally, in order to better organize and carry out earthquake emergency rescue cooperation work, this paper proposes the construction of an earthquake emergency rescue cooperation platform, including the design of overall architecture and functional modules. The earthquake emergency rescue cooperation platform is based on the current new mode of emergency management cooperation and linkage. Each department carries out collaborative disposal and response to the disaster situation according to its own functional responsibilities. It can improve the informatization level of information sharing and dynamic update among all cooperative members.

Acknowledgments

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References

[1] Peng M, & Wei C. (2020). Investigation on an application of emergency rescue in the initial natural earthquake by wavelet analysis. IOP Conference Series Materials Science and Engineering, 794, 12-72.

[2] Zhang X, Hu X, & Li H. (2019). The evaluation of emergency rescue capability for general aviation enterprises under specified rescue demand after earthquake. 2019 5th International Conference on Transportation Information and Safety (ICTIS), 18(1), 55-68.

[3] Liu X. R, Su J. Y, Wang W, & Ma D. H. (2015). A dynamic model for buried casualties and emergency rescue in densely populated areas after earthquake. Systems Engineering-Theory & Practice, 13, 128-135.

[4] Liang L. I, Liu B, & Chen J. (2021). Reflections on the construction of emergency rescue team for earthquake disasters. Natural science, 3(5), 101-152.

[5] Yamahata & Yoshihiro. (2010). The earthquake in haiti. A report from the international emergency rescue team. Nihon Naika Gakkai Kaishi, 99(5), 1111-1115.

[6] Youpo S. U, Chen Y, Chen J & Shi G. (2015). Emergency rescue of serious earthquake in aging society for the aged. World Earthquake Engineering, 12(4), 238-248.

[7] Alessandro F. (2014). Experiments with the robocup rescue simulator in a post-earthquake emergency italian scenario. Greystone Books, 8, 293-305.

[8] Cimellaro G. P, Domaneschi M., & Noori A. Z. (2020). Improving post-earthquake emergency response using indoor tracking: Earthquake Spectra, 36(3), 1208-1230.