Journal of Engineering Science | Vol. XXXI, no. 2 (2024), pp. 17 - 27
Fascicle Industrial Engineering | ISSN 2587-3474
Topic Applied Engineering Sciences and Management | eISSN 2587-3482

https://doi.org/10.52326/jes.utm.2024.31(2).02
UDC 355.58:614.8.01

ANALYSIS OF MODERN POPULATION ALERT TECHNOLOGIES IN EMERGENCY SITUATIONS

Serghei Peancovschii [1,2]*, ORCID: 0000-0002-7414-1127

[1] *Free International University of Moldova, 52 Vlaicu Pârcălab Str., Chisinau, Republic of Moldova*
[2] *General Inspectorate of Emergency Situations of the Republic of Moldova*
* Corresponding author: Serghei Peancovschii, *an_stern@hotmail.com*

Received: 06. 04. 2024
Accepted: 06. 30. 2024

Abstract. This article explores the factors influencing the selection and development of an emergency population alert system in the Republic of Moldova. An analysis of modern systems in Eurozone countries is conducted, along with a brief overview of their functioning. Here there are identified main factors influencing the choice of modern alert systems. The article also presents an analysis of the advantages and disadvantages of various alert technologies, at the same time it identifies the key requirements for the user interface, including the need for cross-platform software technology.

Keywords: *public warning systems, early warning systems, alert technologies, cross-platform software technology, emergency situations.*

Rezumat. În articol sunt investigați factorii care influențează alegerea și dezvoltarea unui sistem de avertizare publică pentru populația din Republica Moldova. A fost efectuată o analiză a sistemelor moderne din țările din zona euro și a fost prezentată o scurtă recenzie a modului lor de funcționare. Au fost identificați factorii principali care influențează alegerea sistemelor moderne de alertare. De asemenea, articolul prezintă o analiză a avantajelor și dezavantajelor diferitelor tehnologii de alertare, precum și definirea cerințelor principale pentru interfața utilizatorului, inclusiv necesitatea tehnologiei cross-platform pentru software.

Cuvinte cheie: *sisteme de avertizare publică, sisteme de avertizare timpurie, tehnologii de alertă, tehnologie software multiplatformă, situații de urgență.*

1. Introduction

With the increasing impact of natural disasters, especially in the context of climate change and technological catastrophes [1,2], there is a need for the development of a modern population alert system in the Republic of Moldova.

Considering that in 2021, the outdated siren-based alert system was dismantled [3] due to its inefficiency in real emergencies and lack of modernization. The popularity of modern alert systems is rapidly increasing, making their implementation increasingly relevant.

Currently, the only means of alerting and warning the population is through mass media. However, this source often carries the risk of misinformation due to the proliferation of fake news. In the context of the war that has been ongoing in Ukraine since February 24, 2022, with a massive influx of refugees from the neighboring country, it is crucial to avoid the spread of fake news. There is an increasing need to establish effective dialogue with society to emphasize the importance of primary actions and protective measures.

Emergency messages received from the official government bodies responsible for security are the most reliable and trustworthy source of information for society. Therefore, the state should place special emphasis on creating and maintaining public alert systems that provide accurate and timely information about emergencies.

Such a system should ensure a high level of security and efficiency, aimed at maximum coverage of the population within the geographic region. It should also utilize all available mass media channels and modern technologies, such as GSM, radio, television, electronic sirens, specialized mobile applications, and others.

2. Analysis of modern early warning systems

The analysis of modern early warning systems reveals a logical similarity in their functioning, as illustrated in Figure 1, which is based on two main components:

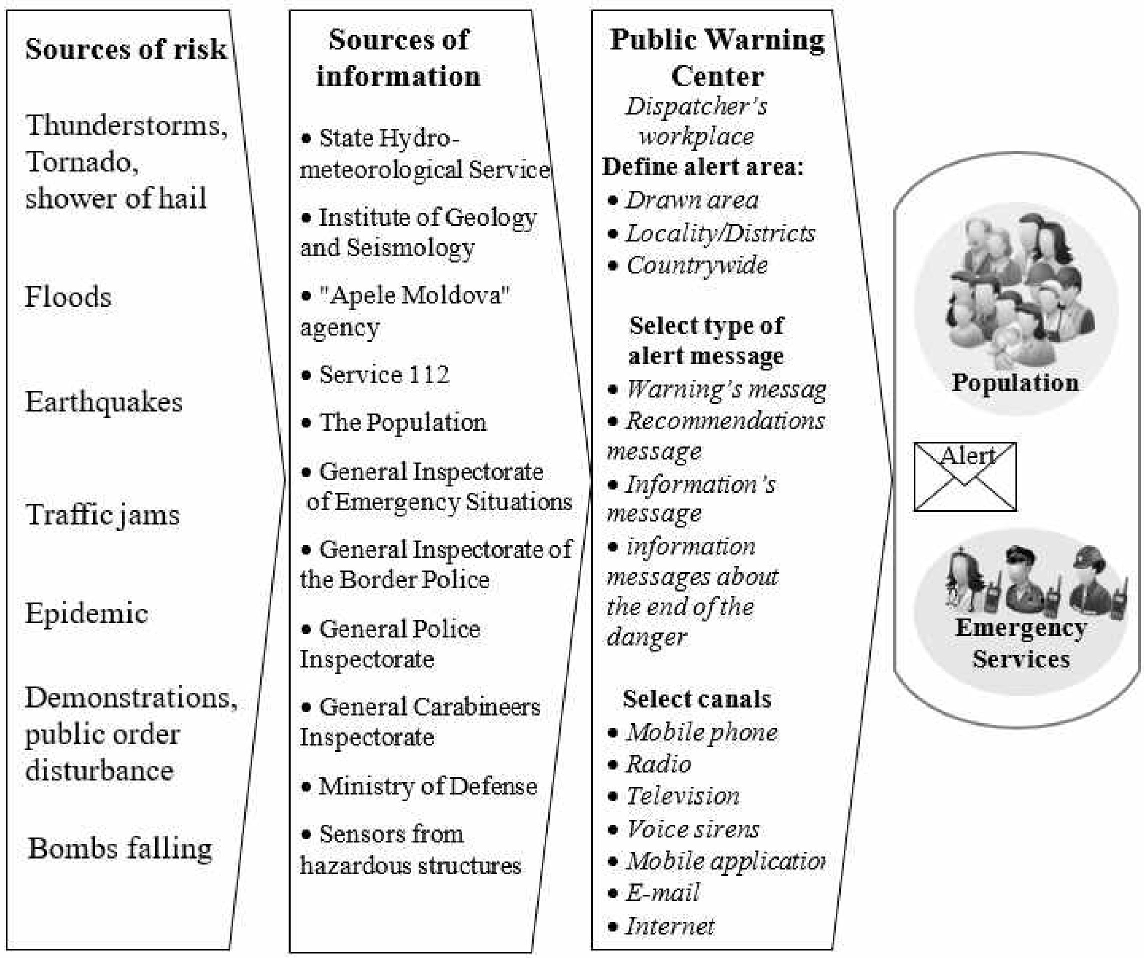

Figure 1. Model of Early Warning Systems Operation for the Population
(Compiled by the Author).

a. Monitoring systems, which involve the collection and processing of incoming information about emergencies, depend on the dynamics of their occurrence [4]. Such systems are based on sensor technologies such as seismic, hydrological, meteorological, acoustic, and Internet of Things (IoT) [5] for monitoring various parameters. Recently, artificial intelligence (AI) has also been included in this group, enabling the processing and identification of patterns in large volumes of information.
b. Systems incorporating technologies related to alerting the population based on radio and telecommunication, mobile technologies.

Early warning systems are widely recognized as indispensable for saving lives and reducing damage. Moreover, they have proven effective in enhancing resilience to climate change and providing support in the adaptation process.

Various countries employ diverse technologies to alert the population about emergencies. In some cases, a single technology is used, while in others, a combination of several different technologies such as sirens, Cell Broadcast, Location-Based Short Message Service (LB-SMS), mobile applications, television and radio, and social media are utilized [6].

When analyzing public alert systems, mobile phones are the first to come to mind, as they are widely accessible and commonly used. However, in addition to mobile phones, other technologies are also employed, including sirens, social media, television and radio broadcasting, as well as satellites, which can disseminate various relevant information to a wide audience [7].

The data presented in Table 1 indicate a lack of uniformity in the use of population alert systems among different countries.

Table 1

Analysis of existing public warning systems in the European Union zone [7-9]

No.	States	Sirene	TV, Radio or Social media	LB-SMS	Cell Broad cast	Specific application	Satelit
1.	Austria	√	√			√	
2.	Belgium		√	√			
3.	Bulgaria	√					
4.	Croatia	√	√				
5.	Cyprus	√					
6.	Czech	√		√			
7.	Denmark	√			√	√	
8.	Estonia		√		√		
9.	Finland	√	√			√	
10.	France	√					
11.	Germany	√	√		√	√	√*
12.	Greece	√	√		√		√*
13.	Great Britain	√	√		√		
14.	Hungary	√		√		√	
15.	Ireland				√*		
16.	Italia				√		√*
17.	Latvia	√	√		√*		
18.	Lithuania	√	√		√		
19.	Luxemburg			√		√	
20.	Malta		√				

Continuation Table 1

21.	Moldova		√				
22.	Norway	√	√		√*		
23.	Netherlands	√	√		√		
24.	Poland	√	√	√		√	
25.	Portugal			√			
26.	Romania				√	√	
27.	Slovakia	√	√				
28.	Slovenia	√	√				
29.	Spain				√		
30.	Sweden	√	√	√		√	
31.	Ukraine	√	√		√	√	
	Total	**21**	**18**	**7**	**14**	**10**	**3**

Note: √ - indicates what technology is being used; √* - At the time of compiling the table, the systems are in the testing phase.

However, in Eurozone countries, the implementation of Cell Broadcast technology is recommended, as it has the capability to simultaneously alert the population via mobile networks.

The experience of countries demonstrates differences in the funding and implementation timelines of warning systems. For example, for Sell Broadcast technology, the funding amount varies from 5 to 15 million USD, depending on the technical infrastructure, technologies used, and geographical characteristics of the country. As for implementation timelines, they are shortened in case of emergency decisions following disasters, such as the 2016 hurricane in Romania or the 2022-2024 war in Ukraine, where implementation took 6-9 months. In the absence of global catastrophes, implementation timelines can extend up to 5 years.

3. Overview of existing Public Warning Systems (PWS)

Each of the technologies mentioned has its own advantages and disadvantages. For instance, a siren-based alert system depends on several factors, including the type of sirens, their placement, the surrounding environment, and weather conditions. The audible range of sirens typically ranges from 1 to 3 kilometers [10]. However, in open spaces and favorable atmospheric conditions, the effective distance for perceiving the siren signal may increase, while in urban areas or in the presence of interference, it may decrease. Thus, the precise distance parameters can vary depending on the specifications of the sirens and the surrounding environment. Moreover, this technology does not guarantee alerting residents located more than 3 kilometers away from the siren placement point or those travelling by ground transport. The minimum estimated number of sirens for the Republic of Moldova is approximately 2800 installations.

Traditional TV and radio alert systems have limited coverage, relying on broadcast infrastructure and subject to delays in disseminating information. They cannot reach the entire audience, especially those not watching TV or listening to the radio during a crisis. Despite these drawbacks, they still play a crucial role in informing the public about emergencies.

The next technology is LB-SMS, which sends short text messages to mobile devices based on their location. Despite its widespread use and advantages such as wide coverage and low cost, LB-SMS has drawbacks. These include low reliability due to network congestion and delivery delays, especially in urban areas or during mass events. It is also ineffective indoors due to mobile signal obstructions, limited in functionality, and raises concerns about data privacy and security. The coverage of LB-SMS may also be limited due to location consent requirements or lack of network coverage in some areas [11].

The use of app-based notification technology, while convenient, may prove ineffective in case of network congestion or unavailability during emergencies when instant notification is required. Additionally, they require downloading and installation, which can be problematic for users without internet access, and are limited to those who own smartphones.

Although Cell Broadcast technology can reach a large number of subscribers, it has limited compatibility with mobile devices, restrictions on information dissemination, inefficiency in enclosed spaces, limited customization options, and a risk of system abuse.

Satellite-based alert systems are costly, reliant on satellite infrastructure, complex to deploy, and have limited coverage. In the event of satellite infrastructure failure due to technical issues or cyberattacks, the alert system may become unavailable, rendering it vulnerable in critical situations [12].

Each of the mentioned systems has its uniqueness and can have the most significant impact depending on the nature of the emergency situations. For instance, sirens installed in populated areas are most effective for alerting about bombings, as during a war, the population is concentrated in residential areas. In open spaces, the likelihood of bombings decreases.

Satellite alert systems are effective in warning about approaching extreme weather events, especially when used in conjunction with Cell Broadcast technology.

One of the critical technical parameters affecting the reliability of all information systems is the critical dependency on continuous power supply, and power outages can lead to serious operational issues.

From an operational and technical support perspective, the effectiveness of the notification process directly depends on the functionality and reliability of endpoint devices such as sirens, televisions, radios, mobile phones, and smartphones, which serve as endpoints for information delivery. The more of these devices are utilized, the more population can be informed, contributing to a wider coverage and effectiveness of the notification process. From an economic perspective, funds need to be allocated for the continuous maintenance of functionality and technical servicing of endpoint devices, including salaries for specialists performing these tasks. If the endpoint devices are owned by the government, the expenses for their maintenance are covered by public funds, whereas if they are privately owned, these expenses fall on the citizens, reducing the financial burden on the state budget.

4. The choice of the basic technological platform for a modular notification system

Modular systems refer to various technologies used for public population notification, such as Cell Broadcast, LB-SMS, sirens, specialized mobile applications [13] and internet services [14], notification systems via Bluetooth and Wi-Fi [15], satellite technologies, TV Broadcast [16], Radio Broadcast [17], IP telephony and VoIP [18]. These systems include both governmental and local notification mechanisms, such as digital and analog radio stations, specialized radio systems, electronic information boards, and displays. This also encompasses smart home technologies and devices, as well as systems including smart speakers, smartwatches, and other IoT devices [19]. Additionally, it encompasses the emergence of new technologies in the future.

All the listed technologies represent various communication channels through which emergency messages about critical situations are transmitted to the population using diverse end-user devices.

It is necessary to determine the priority technology that corresponds to the cross-platform architecture based on technical and technological parameters and will be implemented first. Additionally, the chosen technology should align with the technical capabilities existing in the country, as it is not economically feasible to implement a technology that does not inherently allow integration with other systems and is closed, meaning there is no possibility for further development or modernization.

To determine the foundational technology for the public alert system, the author proposes using the following key criteria and characteristics:

1. **Cost-effectiveness**: Reasonable balance between implementation and maintenance costs, functionality, and efficiency.
2. **Compatibility**: Ability to work with different modules and devices without losing functionality.
3. **Unified protocols**: Utilization of common standards and protocols for information transmission, ensuring compatibility and integration with other systems.
4. **Flexibility**: Ability to adapt to various needs and changes in system requirements without significant modifications.
5. **Scalability**: Ability to expand and scale the system as the volume of data transmitted by risk monitoring systems increases, automating this process, as well as increasing the number of users and communication channels.
6. **Security**: Ensuring data protection during information transmission between technological platforms.
7. **Performance**: Ensuring high speed and efficiency of information transmission while operating on different platforms.
8. **User-friendliness**: Clear and convenient user interface facilitating system operation on various devices.
9. **Reliability**: Guarantee of stable system operation without failures and interruptions even under intensive load.
10. **Support**: Provision of proper technical support and updates by developers for continuous system operation.

As a unified protocol, it is proposed to use an open standard protocol for exchanging information about emergency situations and hazard warnings between different systems and devices, such as the Common Alerting Protocol (CAP), which was introduced in 2004.

The Common Alerting Protocol (CAP) was jointly developed by the United States Federal Emergency Management Agency (FEMA) [20] and the Organization for the Advancement of Structured Information Standards (OASIS) [21], It is also regulated by Recommendation X.1303 of the International Telecommunication Union (ITU-T) [22].

The main advantages of CAP are as follows [21]:

1. **Structured** XML file format for presenting emergency information, including event type, location, time, hazard level, and other details.

2. Facilitates message transmission in multiple languages, expanding audience coverage and ensuring accessibility for multilingual users, thus supporting **multilingualism**.
3. The protocol can be used in various alerting systems, including television, radio, mobile applications, websites, and other digital and analog platforms, demonstrating its **universality**.
4. The protocol allows for the inclusion of various types of data such as text, images, audio, and video, providing **flexibility** in conveying diverse information about emergency situations.

Therefore, due to its ability to adapt to various scenarios and its flexibility, CAP significantly enhances the effectiveness of alerting and response systems to emergency situations, ensuring efficient information exchange and safeguarding public safety. Among all the technologies listed earlier, CAP has found the most application in the Cell Broadcast technology.

The Cell Broadcast technology relies on the Cell Broadcast Protocol (CBP), specifically designed for delivering critical event messages to mobile devices within a specified geographic area. This protocol is tailored for mobile communication networks and ensures efficient and rapid delivery of emergency information to mobile phones and other devices supporting Cell Broadcast technology. The mentioned technology utilizes a separate transmission channel within the mobile network, bypassing issues with SMS servers or GSM channel congestion. Even in the event of SMS or GSM network failures, Cell Broadcast messages can be successfully delivered to subscribers' mobile devices, ensuring reliable emergency alerts.

The Cell Broadcast technology is implemented using two interconnected modules: the Cell Broadcast Entity (CBE), located in the Alert Aggregator block, and the Cell Broadcast Center (CBC), located in the Alert Disseminator block [23]. In Figure 2, the sequence of information flow between the main blocks of the early warning system is depicted.

This combination distinguishes the technology from other similar alert solutions, primarily due to the reduction in financial and operational costs achieved through a centralized architecture. Such an approach provides control over the entire power and functionality of cell broadcasting in case of emergencies, both nationwide and in the selected area.

The chosen technology should be compatible with Application Programming Interfaces (APIs) [24], enabling the integration of various systems and facilitating their interaction. APIs play a crucial role in modern web programming and software development, facilitating efficient data exchange between systems. They define the fundamental principles of interaction between programs and enable them to share information. This simplifies development by allowing the use of existing data and functions to create new products, thereby saving time and resources.

At the initial implementation stage, choosing a technology that supports CAP and API will allow for expanding the capabilities of the Early Warning System through the integration of standardized technologies. This will ensure stability and enhance the effectiveness of population notification. It will also pave the way for integrating future technologies that have not yet been developed or are in the process of development.

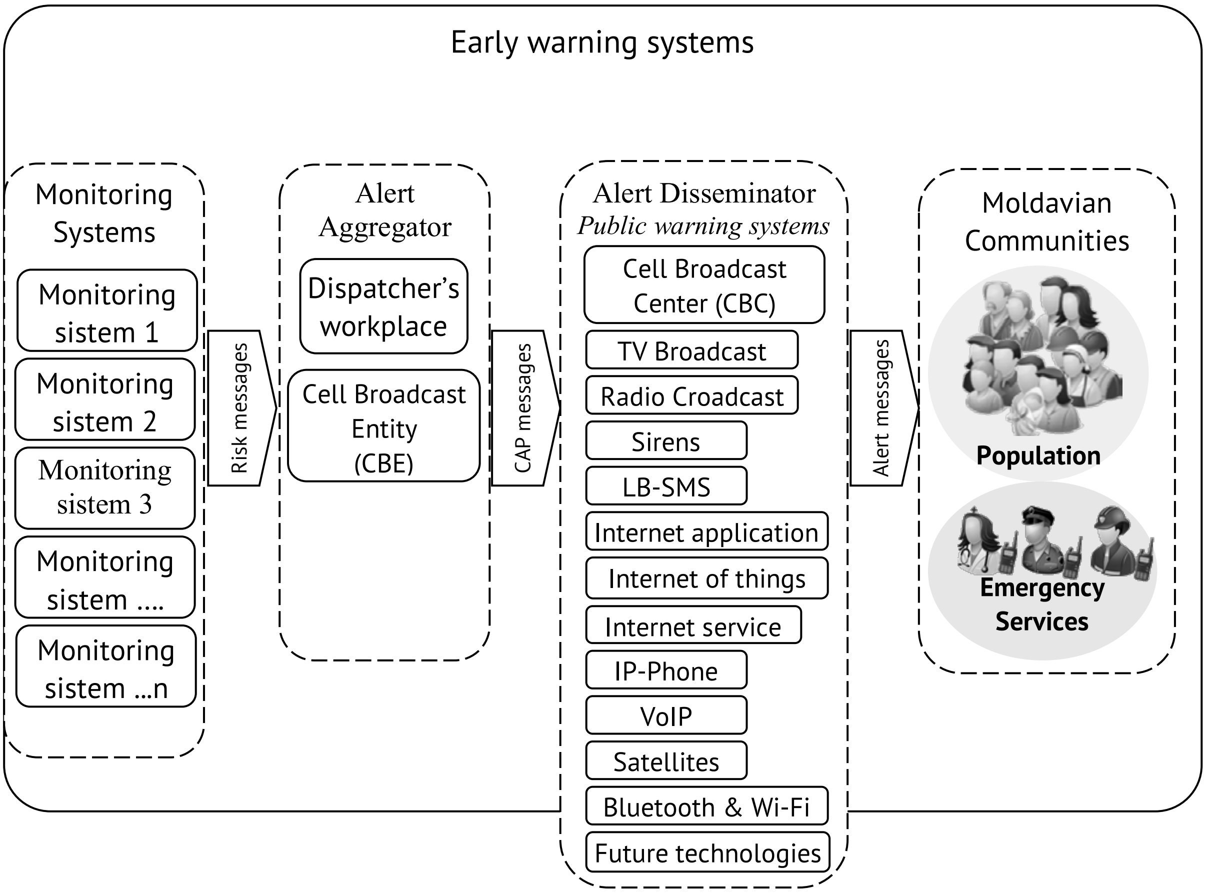

Figure 2. Model of information flow between the main blocks of the early warning system. (*Compiled by the author*)

5. Factors Influencing the Selection of Alert Systems in the Republic of Moldova

The Republic of Moldova, located in southeastern Europe, possesses unique characteristics that can influence the requirements for an early warning system. Its climatic features, including mild winters and warm summer months, demand flexibility in alerting about extreme weather conditions such as thunderstorms or floods. Geographically, the country exhibits diverse terrain, comprising hilly plains and small mountain ranges, which may pose challenges in disseminating alert signals in both urban and rural areas. Cultural and linguistic differences, along with social and economic factors such as high migration rates and uneven population distribution, must also be taken into account [25]. This necessitates additional efforts to select a system that best suits Moldova's multi-ethnic population and citizens of other countries, ensuring effective communication in case of emergencies.

The user interface structure for sending emergency messages should be intuitive and user-friendly. It should include an easy-to-use text input interface, a map for selecting notification zones, quick access to message templates, and system settings. The software should provide cross-platform architecture, enabling message delivery through various technologies and communication channels such as Cell Broadcast, TV and radio casting, internet applications, social media, sirens, etc.

It is important to note that the interface should be adapted to work in stressful situations, with a clear and understandable structure, minimal clicks required to send a message, and the ability to a quick respond to emergencies.

The operation of Public Warning Systems (PWS) in emergency situations begins with monitoring various data sources, followed by analyzing the information received to identify potential threats. Based on this data, the operator decides whether to send emergency alerts, determining the coverage area, selecting communication channels, and sending appropriate messages, Figure 3.

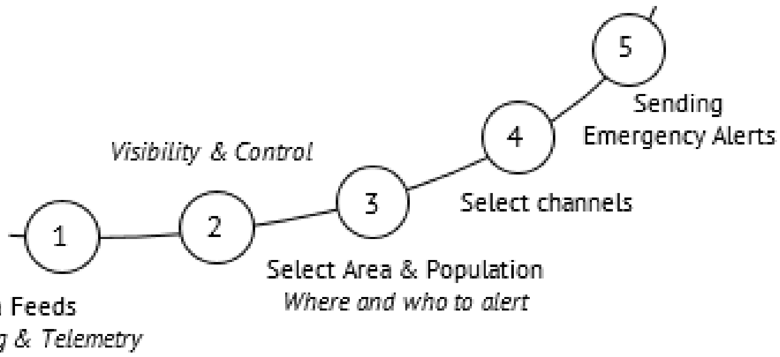

Figure 3. Sequence of logical steps in the Early Warning System (EWS).
(*Compiled by the author*)

In Figure 3, the key modules of the population warning system in emergencies are presented. These modules are divided by functionality and are subordinate to various governmental structures. The diagram highlights two main groups of modules, each with its own lifecycle. Modules 1 and 2 belong to the monitoring system, while modules 3, 4, and 5 belong to the public alerting system. For the second group of modules, their operation is typically entrusted to a single service, in this case, the General Inspectorate for Emergency Situations in the Republic of Moldova [26]. However, responsibility for the first group of modules is distributed among several government bodies authorized to collect data on emergencies according to their competencies. The list of subdivisions can be seen in Figure 1 under the Sources of Information block.

This organization underscores the diversity of technologies and methods used for monitoring and analyzing data on emergencies in modules 1 and 2, while modules 3-5 form a unified public alert system, distinguished by their characteristics and technological structure. This complexity demonstrates the need to choose a technology that serves as a universal aggregator, ensuring effective and stable operation of the entire early warning system.

6. Conclusions

In the Republic of Moldova, currently, only television and radio are used to convey information about potential threats, but they have limitations in distribution and audience coverage. In their research, the author demonstrates that relying solely on one notification technology in various emergencies is ineffective and recommends combining different notification systems for maximum population coverage.

The author recommends combining different notification systems to achieve maximum population coverage. Combining various modern notification systems, including cross-platform capabilities, will allow emergency messages to be sent across different platforms, ensuring wide population coverage with minimal financial costs both during implementation and in operation.

Because these technologies have a social impact rather than a commercial one, the adoption process begins with choosing one technology that includes a cross-platform aspect.

The author proposes to use Cell Broadcast technology as a base, fundamental one, to which both existing and new technologies being developed will be integrated in the future.

Despite its drawbacks, it allows for the widest population coverage compared to other technologies, reducing implementation and maintenance costs as mobile phones serve as the endpoint for notifications. For the next stages of emergency notification system development, integrating TV and radio technologies, as well as notification systems using sirens and mobile applications, is proposed. This approach to implementing emergency notification systems is the best choice for the Republic of Moldova.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Peancovschii, S.P. Classifiers for decision support system in emergency situations. In: *Actual problems of naturaland human sciences among senior young scientists "Rodzinka-2019"*/XXI *All-Ukrainian ScientificConference of Young Scientists. Cherkasy: ChNU im. B. Khmelnitsky*, 2019, pp 241-243, [in Russian].
2. Peancovschii, S.P. Elaboration and application of graphical models to optimize the response time to emergency situations. *Journal of Engineering Science* 2022, 29 (1), pp. 86 – 96, ISSN 2587-3474.
3. The Government Decision regarding the repeal of Government Decision no. 1048/2005 for the approval of the Regulation regarding the organization of the notification and transmission system in case of danger or the occurrence of exceptional situations no.405 of 08.12.21. In: *Official Monitor 302-306/668 din 10.12.21*. [in Romanian].
4. Peancovschii, S.P. Classifiers for decision support system in emergency situations. In: *Actual problems of naturaland human sciences among senior young scientists "Rodzinka-2019"/XXI All-Ukrainian ScientificConference of Young Scientists. Cherkasy: ChNU im. B. Khmelnitsky,* 2019, 566 p. [in Russian].
5. Srinicek, N. *Platform Capitalism*. Polity Press, Cambridge, UK, 2016, 128 p.
6. Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code (Recast) Text with EEA relevance. https://eur-lex.europa.eu/eli/dir/2018/1972/oj
7. Vivier, B.V.; Van, A. C.; Straume, H.; Grangeat A.; Gomez P. Public warning systems. Available online: https://eena.org/wp-content/uploads/2021_02_18_PWS_Document_FINAL_Compressed.pdf (accessed on 04.06.2024).
8. Emergency Communications & the EU Legislative framework. Available online: https://eena.org/wp-content/uploads/2022_08_31_Legislation_Update_FINAL2.pdf (accessed on 04.06.2024).
9. BEREC Guidelines on how to assess the effectiveness of public warning systems transmitted by different means. Available online: https://www.berec.europa.eu/sites/default/files/files/document_register_store/2020/6/BoR_%2820%29_115_BEREC_Guidelines_on_PWS.pdf (accessed on 04.06.2024).
10. Jonathan, S.; Pierre, A.; Arnaud, C.; Paul, C.; Matthieu, P. Case study on the audibility of siren-driven alert systems. *Noise Mapping* 2023, 10(1), 20220165.
11. Bopp, E.; Douvinet, J. Spatial performance of location-based alerts in France. *International Journal of Disaster Risk Reduction* 2020, 50, 101909.
12. Bristow, L. Emergency Notification Technology Improves Severe Weather Response. *Disaster Recovery Journal* 2004, 17 (4), pp. 20–22.
13. Mulero C, J.; De Cola, T. 1-Public Warning Applications: Requirements and Examples. In: *Wireless Public Safety Networks 3,* Câmara, D., Nikaein, N. (eds), Elsevier, Amsterdam, The Netherlands, 2017; pp. 1-18.
14. Verma, P.; Verma, D.C. Internet emergency alert system, In: *MILCOM 2005 IEEE Military Communications Conference, IEEE March* 2006, ISBN:0-7803-9393-7.
15. Gomez, C.; Oller, J.; Paradells, J. Overview and evaluation of bluetooth low energy: An emerging low-power wireless technology. *Sensors* 2012, 12, pp. 11734–11753.
16. El-Hajjar, M.; Hanzo, L. A Survey of Digital Television Broadcast Transmission Techniques. *IEEE Communications Surveys & Tutorials* 2013, pp. 1924 – 1949.
17. Lindell, M.K.; Perry, R.W. Warning Mechanisms in Emergency Response Systems. *International Journal of Mass Emergencies and Disasters* 1987, 5(2), pp. 137-153.

18. Rezac, F.; Voznak, M.; Tomala, K. Voice messaging system as a form of distribution of an urgent information. *Wireless Personal Communications volume* 2015, 85, pp. 63-76.
19. Qi, L.; Wang, Z.; Zhang, D.; Li, Y. A Security Transmission and Early Warning Mechanism for Intelligent Sensing Information in Internet of Things. *Journal of Sensors* 2022, 199900.
20. The Federal Emergency Management Agency (FEMA) Integrated Public Alert and Warning System (IPAWS). Available online: https://www.fema.gov/emergency-managers/practitioners/integrated-public-alert-warning-system (accessed on 04.06.2024).
21. Jones, E.; Westfall, J. Common Alerting Protocol Version 1.2. Available online: https://docs.oasis-open.org/emergency/cap/v1.2/CAP-v1.2-os.pdf (accessed on 04.06.2024).
22. Common alerting protocol (CAP 1.2), ITU-T Recommendation X.1303. Available online: https://www.itu.int/en/ITU-D/Emergency-Telecommunications/Documents/2020/T-REC-X.1303bis-201403-.pdf (accessed on 04.06.2024).
23. Feasibility study on deployment and implementation of a Cell Broadcast Service (CBS) solution for sending Alert Messages. Available online: https://moldova.un.org/en/261304-feasibility-study-deployment-and-implementation-cell-broadcast-service-cbs-solution-sending (accessed on 04.06.2024).
24. Cooksey, B. An Introduction to APIs. Available online: https://zapier.com/resources/guides/apis (accessed on 04.06.2024).
25. Official Website Republic of Moldova, about the Republic of Moldova, 2024. Available online https://moldova.md/en (accessed on 22.05.2024).
26. LAW on civil protection No. 271-XIII of 29.12.1994 *Published in the Official Monitor No. 20* art. 231[in Romanian].

Citation: Peancovschii, S. Analysis of modern population alert technologies in emergency situations. Journal of Engineering Science 2024, XXXI (2), pp. 17-27. https://doi.org/10.52326/jes.utm.2024.31(2).02.

Submission of manuscripts: jes@meridian.utm.md