



Application of the Qualitative Multi-Criteria Decision-Making Model DEX in the Selection of Media for Informing Affected Populations in Emergency Situations

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ABSTRACT

Emergency situations represent one of the most prevalent phenomena with a threatening character when societal security is concerned. Prevention occupies the most important position within the system of protection and rescue of people and material assets. The transmission of a signal about an impending danger is of exceptional importance. Therefore, the decision regarding which medium should be used to transmit the signal is crucial, particularly in terms of speed and accessibility. This paper examines the possibilities for selecting media through which endangered populations can be informed in emergency situations, taking into account the required qualitative characteristics of individual media. The DEX method was applied to analyze the applicability of specific media, as it enables the establishment of criteria and the determination of their interdependencies in relation to combinations of criteria. The particular significance of this method lies in the fact that the analysis does not rely on assumed scenarios, but on the knowledge and needs of a real system.

1. Introduction

Emergency situations represent a state of high threat to the social community. Their consequences are numerous and have far-reaching effects. Given the scale of risks posed by various natural hazards, technical–technological accidents, and other crisis events, timely warning and public information play a crucial role. Preventive action through informing and alerting the population forms the foundation for reducing the consequences of emergency situations.

„There are different categories of the population that need to receive information about the impending danger. The most vulnerable are people with special needs, then the elderly, women and children, and finally people who can save themselves independently“ [1]. „Informing the endangered population is an important element of the protection and rescue system. The efficiency of this

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process depends on the choice of appropriate media, because different population groups have different opportunities to access information. The lack of timely and accurate information can significantly increase the risk to their safety“ [2].

In emergency situations, the problem of choosing media for informing the population becomes complex due to several factors:

- i. Territorial coverage of the signal – some media, such as television and radio, have limited reach, while others, such as the Internet, depend on the availability of infrastructure.
- ii. Functionality and availability of media – crisis situations may cause interruptions in electricity supply, which affects the efficiency of information transmission.
- iii. Demographic differences in media use – elderly persons and populations in rural areas use digital media less frequently than younger generations.
- iv. Speed and reliability of information transmission – certain media can disseminate information faster and more efficiently to a wider population.

The choice of communication methods is most often conditioned by the specific characteristics of an emergency situation and available resources. However, by analyzing relevant criteria, it is possible to identify optimal media for information dissemination to ensure the widest possible coverage and timely notification of endangered populations during emergencies.

This paper addresses the problem of selecting media for informing endangered populations in emergency situations by applying the DEX (Decision EXpert) method, which enables qualitative multi-criteria decision making. This method is suitable for situations in which criteria are not easily measurable and where it is necessary to integrate multiple decision-making aspects. The aim of the paper is to identify, based on defined criteria and expert evaluations, through the application of the DEX model, the optimal medium or combination of media that ensures the fastest and most reliable notification of endangered populations in emergency situations.

2. Media for Informing Endangered Populations in Emergency Situations

The focus of this paper is the identification of a qualitative model that enables the optimal selection of media for informing the population in emergency situations. The need to inform the population following the occurrence of a natural disaster or a technical–technological accident depends on the level of threat to the social community. Signals indicating an impending danger are issued by competent authorities in accordance with the law. The level of danger, that is, the degree of threat, constitutes the basis for declaring an emergency situation [3].

An emergency situation is declared by the competent emergency management headquarters. An emergency is proclaimed when risks, threats, or the consequences of a disaster reach such a scale and intensity that they cannot be prevented or mitigated through the regular activities of competent authorities and services. In such cases, it is necessary to apply special measures, additional forces and resources, and an intensified operational regime to mitigate and eliminate the consequences [4], [5].

The declaration of an emergency is made immediately upon learning of an imminent danger. This moment represents a turning point in the protection and rescue of the endangered population, material goods and the environment. Until the moment of learning of the imminence of the danger, the Emergency Headquarters does not declare an emergency or provide information, but this is done by the competent specialized services (the Republic Hydrometeorological Institute (RHMZ), the Republic Geodetic Institute (RGZ), the Public Health Institute (ZZJZ) and others). These services usually inform the public through television, radio, and the Internet by publishing information on their official websites. During this period, the emergency management headquarters collects

information and may provide additional notifications through local communities or designated representatives.

In specific situations, electric power utilities, water management organizations, and other companies that operate hydro-accumulations, tailings dams, or ash disposal sites are obliged to ensure timely public notification about impending dangers [4]. Emergency management headquarters have access to local radio and television stations, and by submitting a request to the national emergency headquarters, they can ensure that notifications are disseminated through other media as well. The law also prescribes the obligation of mobile network operators to transmit emergency warning messages to the population.

All instruments of mass communication are applicable for informing the population during emergency situations, as well as preventively, prior to the occurrence of an emergency. A particular challenge arises in situations of immediate threat to people, material assets, and the environment. All actors in the affected area experience fear for their personal safety, the safety of their families, and their property. A similar situation occurs in business entities which, in addition to protecting assets, must engage employees whose families may also be endangered. A particularly vulnerable and specific target group includes persons with special needs, the elderly, women, and children.

Communication instruments in emergency situations are most often limited to certain mass media. These primarily include television, radio, and the Internet, especially social networks and mobile telephony [6]. Printed media may also be used; however, their application is limited by the type of emergency and the speed of its development.

„The practical application of effective information is the basis for successful management in emergency situations“ [7]. Information and warning are of great importance in reducing human casualties, damage to material goods and the environment. Timely information enables the population to respond quickly and correctly to the danger.

„The timeliness of information depends on the type and nature of the danger. Natural disasters and accidents that occur suddenly and develop rapidly are more difficult to announce. In these cases, the conditions for transmitting information are very complex, so the probability that a large part of those at risk will not receive information is significant“ [8]. On the other hand, dangers that develop over a longer period of time are easier to announce when the first signs appear.

The law defines that the right to inform in emergency situations belongs to the competent headquarters and specialized state institutions (RHMZ, RGZ, etc.). „This approach is necessary to control the flow of information and ensure the receipt of verified data for a wider circle of the vulnerable population“ [5].

For effective public information, emergency management headquarters have the following media at their disposal:

- i. Television and radio;
- ii. Internet – social networks;
- iii. Early warning, notification, and alert systems;
- iv. Printed media;
- v. Mobile telephony.

2.1 Television and Radio

Television and radio belong to the group of widely distributed and accessible media. It is assumed that every home has access to at least one of these media. The main advantages are the wide distribution of the signal and the speed of information transmission.

Limitations in the use of these media:

- i. The possibility of the municipal emergency headquarters transmitting information via national television and radio networks, which are followed by a larger number of people.
- ii. The possibility of signal interruption if there is a problem with the electricity supply.

2.2 Internet and Social Networks

The Internet is a medium that enables very fast and massive transmission of information. Social networks stand out as a tool for rapid information dissemination and distribution. Social networks could quickly reach many people, especially the younger population.

The main limitations of using the Internet and social networks are:

- i. Availability of an Internet connection in the affected area.
- ii. The possibility of Internet service disruption is due to technical failures.
- iii. Lower usage and understanding of these media among elderly people and populations in rural areas.

2.3 Early Warning, Notification, and Alert System

The early warning, notification, and alert system (sirens and public address systems) is directly available to the competent emergency management headquarters. This system enables immediate response and rapid notification of the population over a wide area.

The limitations of this system include:

- i. Technical functionality and maintenance of sirens and public address equipment.
- ii. Territorial coverage and availability of the system in all endangered areas.
- iii. The ability of all population categories to understand warning signals and messages.

2.4 Printed Media

Printed media represent a slower means of information transmission and are more suitable for preventive activities and prolonged crisis situations. They provide the opportunity for more detailed information dissemination to the population.

Limitations in the use of printed media include:

- i. Slow distribution and delivery difficulties during emergency situations.
- ii. Municipalities rarely have their own printed media outlets and therefore depend on the capacities of publishing companies.
- iii. The inability to transmit information instantly, which is critical in cases of sudden and rapidly developing disasters.

2.5 Mobile Telephony

Mobile telephony represents a powerful, widely distributed, and rapidly accessible medium for information dissemination. A large number of individuals from all endangered groups possess mobile phones, which makes this medium highly effective.

The main limitations in the use of mobile telephony are:

- i. The need for databases containing the phone numbers of endangered persons or those responsible for them.
- ii. Signal and network coverage problems in rural or remote areas.
- iii. Potential overload of mobile networks during critical moments of an emergency situation.

3. Description of Criteria for the Selection of Media for Informing Endangered Populations in Emergency Situations

For the successful application of the DEX method in selecting media for informing the population in emergency situations, it is necessary to define appropriate criteria. These criteria must be common to all media and enable their clear and consistent comparison [9].

Taking into account the specific characteristics of emergency situations and the features of different media, the following qualitative criteria were identified for the application of the DEX method:

- i. **Frequency of information dissemination** – refers to the ability and speed of repeating information within a short time period. Higher frequency increases the likelihood that the population will receive the notification in a timely manner.
Qualitative values: low, medium, high.
- ii. **Territorial coverage** – represents the availability of the media across all parts of the affected area at the time of the emergency. Media with better coverage are more suitable for informing a larger number of people.
Qualitative values: poor, satisfactory, good, excellent.
- iii. **Representation among target groups** – indicates the extent to which a particular medium is used by different population categories, especially vulnerable groups (persons with special needs, the elderly, women, and children).
Qualitative values: low, medium, high.
- iv. **Availability of the media under emergency conditions** – represents the ability of the media to remain operational and accessible during an emergency situation. This criterion includes technical reliability, independence from electricity supply, and resistance to interruptions.
Qualitative values: very poor, poor, medium, good, excellent.
- v. **Cost of media access** – refers to the costs required to use a specific medium in an emergency situation, including infrastructure, broadcasting, transmission, or message delivery costs.
Qualitative values: high, medium, low.

All the defined criteria are presented qualitatively, as the DEX method relies on descriptive scales for evaluation. Qualitative assessment enables simpler and more practical decision making under conditions of urgency and uncertainty that characterize emergency situations.

In the continuation of this paper, a DEX model will be constructed using the defined criteria and their qualitative values in order to select the optimal medium, or a combination of media, for effective public information dissemination.

4. The DEX Multi-Criteria Decision-Making Model and DEXi Software

Decision making represents a process of selecting one option among several alternatives. In practice, the criteria used to evaluate alternatives are often mutually conflicting. For this reason, decision makers require a system that facilitates and supports the decision-making process. One such system is a Decision Support System (DSS) [10].

Decision Support Systems (DSS) are interactive computer systems that assist decision makers in identifying, structuring, and solving complex problems. DSS do not replace the decision maker but rather provide support in selecting the optimal alternative. Due to the rapid growth in the volume of data, traditional information systems are no longer sufficient for analysis and effective decision making, which has led to the development of systems based on machine learning and artificial

intelligence models. One of the most used decision support methods in situations where criteria are difficult to quantify is the DEX method and the corresponding DEXi software [11].

The DEX (Decision EXpert) method is a qualitative multi-criteria decision-making model developed at the Jožef Stefan Institute in Ljubljana. Due to the impossibility or difficulty of quantitatively evaluating certain criteria, DEX relies on qualitative attribute values and enables decision makers to compare alternatives in a simple and transparent manner.

The basic principles on which the DEX method is based are as follows [12]:

- i. The decision-making problem is decomposed into smaller, more manageable subproblems, represented by hierarchically organized attributes (criteria).
- ii. Higher-level attributes depend on lower-level attributes and are obtained through their aggregation.
- iii. Attribute values are defined using qualitative (linguistic) scales rather than numerical values.
- iv. The DEX model is based on expert knowledge, experience, and professional judgment.
- v. The final evaluation of an alternative is obtained by aggregating attributes through predefined “IF–THEN” rules.

The DEX method combines two approaches [13]:

- i. **Multi-criteria decision analysis (MCDA)** – structuring the problem across multiple hierarchical levels.
- ii. **Expert systems (ES)** – defining decision rules and using qualitative values.

The DEXi software provides computer-based support for the creation and implementation of DEX models [14], [15]. DEXi enables the definition of attributes, the creation of qualitative scales, and the formulation of rules for attribute aggregation. DEXi is particularly suitable when:

- i. there is a large number of criteria (attributes) and/or alternatives;
- ii. reliable quantitative data are insufficient or unavailable;
- iii. criteria are difficult to measure;
- iv. clear interpretation of the obtained results is required.

The operating principles of the DEXi software include [12]:

- i. the use of qualitative scales for attribute evaluation;
- ii. flexibility in defining aggregation rules for criteria;
- iii. reduction of complexity through hierarchical decomposition of attributes;
- iv. clear and straightforward interpretation of results.

The development of a DEX model involves several clearly defined steps [16]:

- i. **Structuring the DEX model** – forming a hierarchy of attributes, which can be implemented using:
 - a top-down approach;
 - a bottom-up approach.
- ii. **Defining qualitative scales** – linguistic values are defined for each attribute, such as:
 - low, medium, high, excellent.
- iii. **Defining decision rules (aggregation)** – expert knowledge is used to define rules that determine the values of higher-level attributes.
- iv. **Input of alternatives** – values of elementary attributes are entered for each alternative.
- v. **Evaluation and analysis of results** – DEXi evaluates the alternatives and enables additional analyses, including:
 - plus/minus one analysis – assessing the impact of changing an attribute value by one level on the overall result;

- selective explanation – highlighting the strengths and weaknesses of individual alternatives;
- comparison of alternatives – comparing alternative results across attributes.

In this way, the DEX method and DEXi software provide decision makers with a transparent analytical process and support the selection of the most appropriate alternative according to the defined criteria.

5. Application Of The DEX Multi-Criteria Decision-Making Model in the Selection of Media for Informing Endangered Populations in Emergency Situations

Step 1: Structuring the DEX Model

The process of applying the DEX method begins with the definition of the target attribute and its subcriteria through hierarchical structuring. In this case, the target attribute is defined as:

Selection of the most appropriate media for informing the population in emergency situations.

Hierarchical structure of the model is presented in Figure 1.

This target attribute is decomposed into the following subcriteria:

- i. **Frequency of information dissemination**
- ii. **Territorial coverage**
- iii. **Representation among target groups**
- iv. **Media availability**
- v. **Cost of media access**

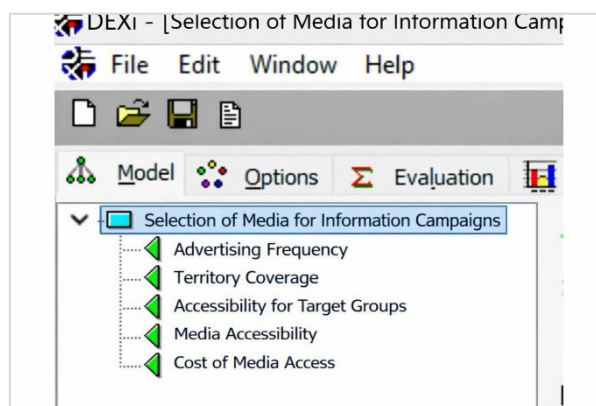


Fig. 1. Hierarchical structure of the model

Step 2: Definition of Qualitative Value Scales of Attributes

Each of the defined criteria has its own qualitative scale, as presented in Table 1.

Table 1

Criteria and corresponding qualitative scales

Criterion	Qualitative value scale
<i>Frequency of information dissemination</i>	Low, Medium, High
<i>Territorial coverage</i>	Poor, Satisfactory, Good, Excellent
<i>Representation among target groups</i>	Low, Medium, High
<i>Media availability</i>	Very Poor, Poor, Medium, Good, Excellent
<i>Cost of media access</i>	High, Medium, Low

Value scales in the DEXi software using the example of information frequency are presented in Figure 2.

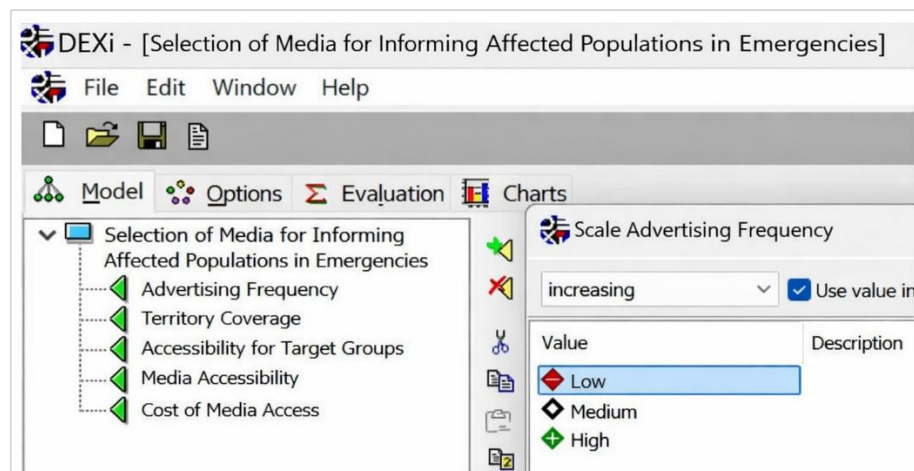


Fig. 2. Representation of value scales in the DEXi software using the example of information frequency

Step 3: Defining Decision Rules

The DEX model is based on the definition of decision rules (IF–THEN rules) through which lower-level criteria are aggregated into higher-level criteria (Figure 3).

Examples of defined rules include:

- i. **If** the frequency of information dissemination is high, territorial coverage is excellent, representation among target groups is high, media availability is excellent, and the cost of media access is low, **then** the medium is rated as excellent.
- ii. **If** the frequency of information dissemination is medium, territorial coverage is satisfactory, representation among target groups is medium, media availability is good, and the cost of media access is medium, **then** the medium is rated as acceptable.
- iii. **If** the frequency of information dissemination is low, territorial coverage is poor, representation among target groups is low, media availability is poor, and the cost of media access is high, **then** the medium is rated as unacceptable.

Decision rules Media selection for informing population at risk

Unacceptable ☒ Use scale orders ☐ Use weights

	Frequency	Coverage	Representation	Availability	Cost	Media choice
1						
2	low	poor	small	very poor	high	unacceptable
3	low	poor	small	very poor	medium	unacceptable
4	low	poor	small	very poor	low	unacceptable
5	low	poor	small	poor	high	unacceptable
6	low	poor	small	poor	medium	unacceptable
7	low	poor	small	poor	low	unacceptable
8	low	poor	small	medium	high	unacceptable
9	low	poor	small	medium	medium	unacceptable
10	low	poor	small	medium	low	unacceptable
11	low	poor	small	good	high	unacceptable
12	low	poor	small	good	medium	unacceptable
13	low	poor	small	good	low	unacceptable
14	low	poor	small	excellent	high	unacceptable
15	low	poor	small	excellent	medium	unacceptable
16	low	poor	small	excellent	low	unacceptable
17	low	poor	medium	very poor	high	unacceptable
18	low	poor	medium	very poor	medium	unacceptable

Rules: 24/540 (4.44%), determined: 51.44% [unacceptable:532, medium:515, acceptable:519,excellent:103]

OK Cancel

Fig. 3. Representation of the definition of decision rules

Step 4: Input of Alternatives (Media)

In this step, the specific alternatives (media) under consideration are entered into the DEXi software and attribute values for each alternative are presented in Figure 4.

Television and Radio					
Option	Television	Internet	Radio System	Print Media	Mobile Telephony
Advertising Frequency	High	High	Low	Low	High
Territory Coverage	Good	Good	Satisfactory	Satisfactory	Excellent
Accessibility for Target Groups	High	Medium	Medium	Low	High
Media Accessibility	Excellent	Good	Medium	Low	Medium
Cost of Media Access	Low	Medium	High	Low	Medium

Fig. 4. Attribute values for each alternative

Step 5: Evaluation of Alternatives and Result Analysis

DEXi automatically performs the evaluation and presents the results in tabular form (Figure 5).

File Edit Analysis Window Help					
Model Options Evaluation Charts					
medium					
Option	Television	Internet	Public address system	Print media	Mobile telephony
Media selection for informing at-risk population in emergency	acceptable	acceptable	unacceptable	unacceptable	acceptable
• Frequency of advertising	high	high	low	low	high
• Coverage area	good	good	satisfactory	satisfactory	Excellent
• Representation within target group	high	medium	medium	low	high
• Availability of media	excellent	good	medium	small	medium
• Cost of media access	low	medium	high	Low	medium

Fig. 5. Results of alternative evaluation using the DEXi software

DEXi enables additional sensitivity analysis of the results with respect to changes in individual criteria (Figure 6).

DEXi	Selection of Media for Informing Affected Populations in Emergency Situations.dxi	Page 1
Weak points		
None		
Strong points		
Attribute	Television and Radio	
Advertising Frequency	High	
Representation among Target Groups	High	
Media Accessibility	Excellent	
Cost of Media Access	Low	

Fig. 6. Sensitivity analysis of the results with respect to changes in individual criteria

According to the results of the sensitivity analysis, television and radio represent a highly stable and reliable media choice, as they maintain a good or excellent overall rating even when individual

criteria are slightly weakened. This indicates their effectiveness in crisis situations, with a low risk of losing efficiency due to potential deterioration of a single attribute [17].

Based on the presented results, it can be concluded that the DEX method represents an efficient and systematic approach to selecting the most suitable media for public information in emergency situations, as it clearly takes into account all relevant criteria. The DEXi software enables fast, clear, and comprehensible visualization of the decision-making process (Figure 7), thereby significantly supporting decision makers in selecting the best alternative.

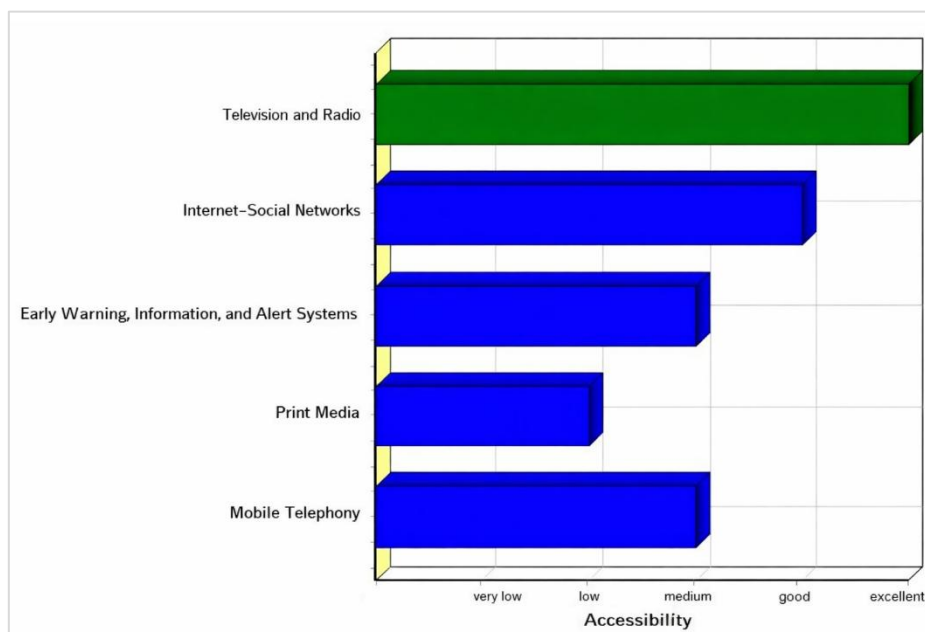


Fig. 7. Example of a Graphical Representation of Evaluation by the Media Availability Criterion

The DEX model enables decision makers to evaluate and compare different media in a simple and transparent manner, considering all key criteria such as frequency of information dissemination, territorial coverage, representation among target groups, media availability, and cost-effectiveness of use. The results of the analysis confirm that television and radio are the most stable alternatives, which maintain a good or excellent rating even with negative changes in some of the criteria. This confirms that the application of the DEX method is justified and advisable in decision-making processes in crisis and emergency situations, especially when clear visualization and reliable choice between multiple available options are necessary.

The analysis of the results obtained by applying the DEX method shows that the media of television and radio, the Internet and mobile telephony are assessed as acceptable for informing the population in emergency situations. On the other hand, media such as the early warning system, information and alerting and print media are assessed as unacceptable, primarily due to the low frequency of advertising, poor accessibility and limited representation among the target group.

It follows from this that the application of the DEX method is useful and allows for a clear distinction between acceptable and unacceptable alternatives, which significantly facilitates decision-making in crisis situations.

6. Conclusion

Based on the results obtained by applying the DEX method for selecting the best media for informing the vulnerable in emergency situations, as well as the sensitivity analysis conducted, it can

be concluded that the DEX method is applicable and fully meets the defined objective of the work. The analysis of the results indicates that media such as television, the Internet and mobile telephony represent acceptable alternatives, while the radio communication system and printed media are assessed as less suitable due to the weak values of certain criteria.

The sensitivity analysis confirms the stability of the proposed model, showing that the results of applying the method are sufficiently resistant to changes in the values of the criteria. This allows decision-makers to choose the most favorable media with greater certainty in conditions of limited time and high uncertainty, characteristic of emergency situations.

The contribution of this paper is reflected in the application of the DEX method as an alternative qualitative approach, which allows for a clear and concise visualization of decisions, which is especially important in situations that require rapid reaction and decision-making in conditions of risk and insufficient data precision. Also, the application of this method represents a significant step forward in the field of choosing media for emergency notification, since it has not been intensively applied in the available literature to solve this type of problem [18].

In addition, the model allows for easy adaptation and the possibility of application in other areas of emergency decision-making. The flexibility of the method is also reflected in the easy combination with other multi-criteria decision-making techniques, which represents significant potential for future research [19].

Given the importance of timely and effective notification in emergency situations, every step towards improving this process through the development and implementation of new models represents an important contribution to increasing the level of social security, as well as improving the entire system of prevention and response in case of danger.

Conflicts of Interest

The authors declare no conflicts of interest.

Declaration of Generative AI and AI-Assisted Technologies in the Manuscript Preparation Process

The authors declare that no generative AI or AI-assisted technologies were used in the manuscript preparation process.

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