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RESEARCH ON THE INTEREST OF LOCAL GOVERNMENTS IN THE USE OF ARTIFICIAL INTELLIGENCE IN FLOOD RISK MANAGEMENT IN POLAND

ANALIZA STOPNIA ZAINTERESOWANIA SAMORZĄDÓW LOKALNYCH WYKORZYSTANIEM SZTUCZNEJ INTELIGENCJI W ZARZĄDZANIU RYZYKIEM POWODZIOWYM W POLSCE

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Quote as: Wrzalik, A. (2021). Research on the interest of local governments in the use of artificial intelligence in flood risk management in Poland. *Business Informatics*, (3).

Abstract: The aim of the article was to analyse the degree of interest in the implementation of artificial intelligence methods in the area of crisis management related to flood risk in local government units in Poland. Pilot studies were carried out with the use of a questionnaire and direct telephone interview in 47 selected local governments located in Poland. The respondents assessed the current crisis management system and referred to the possibility of using artificial intelligence solutions in the analysed area. On the basis of the obtained results, it can be concluded that the surveyed entities show significant interest in the proposed solution and have specific expectations towards them. Most of the works devoted to flood risk management in Poland focus on solutions intended for the national level, not local one. The article aimed to highlight the need to fill this research gap.

Keywords: crisis management, flood risk management, artificial intelligence.

Streszczenie: Celem artykułu jest analiza stopnia zainteresowania implementacją metod sztucznej inteligencji w obszarze zarządzania kryzysowego związanego z ryzykiem powodziowym w jednostkach samorządu terytorialnego w Polsce. Badania, mające charakter pilotażowy, przeprowadzono z wykorzystaniem kwestionariusza ankietowego i bezpośredniego wywiadu telefonicznego w 47 wybranych samorządach lokalnych zlokalizowanych w Polsce. Respondenci dokonali oceny obecnego systemu zarządzania kryzysowego i odnieśli się do możliwości wykorzystania rozwiązań sztucznej inteligencji na analizowanym obszarze. Na podstawie uzyskanych wyników można stwierdzić, że badane podmioty wykazują duże zainteresowanie proponowanym rozwiązaniem i mają wobec niego określone oczekiwania. Warto podkreślić, że większość prac poświęconych zarządzaniu ryzykiem powodziowym w Polsce koncentruje się na rozwiązaniach przeznaczonych na poziom krajowy, a nie lokalny. W artykule podjęto próbę wypełnienia tej luki badawczej.

Słowa kluczowe: zarządzanie kryzysowe, zarządzanie ryzykiem powodziowym, sztuczna inteligencja.

1. Introduction

Crisis management is a set of actions that involve planning, decision-making, organizing, leading, and controlling directed at the held resources (of human, material, non-material and financial nature), and used in an effective way to achieve the intended objectives. The implementation of those tasks is a multi-criteria activity which almost always requires the decisions to be made under the pressure of time and situational burden. Such conditions may cause an inaccurate assessment of a situation and a decision that is not optimum at the time. Therefore, it is justified to seek solutions that can support the decision-making process. Such a solution seems to be artificial intelligence methods, which due to their specificity can be applied in uncertain, dynamic, and non-linear situations. The possibilities, ways, and advantages resulting from artificial intelligence implementation in crisis management are presented in numerous publications in the literature of the subject. They indicate various analyses based on mathematical models as well as the potential for their application in particular areas of crisis management. The existing publications in this area refer to all four crisis management phases – prevention, preparation, response, and recovery (Sun, Bocchini, and Davison, 2020, pp. 2631-2689). Fotovatikhah and others (2018) noted the possibility of using selected methods of artificial intelligence in flood-related situations and highlighted the important role of fuzzy systems and neural networks. Youan, Zhang, and Liu (2015) described the possibility of automatic monitoring, detection, and combating forest fires using remote sensing techniques based on artificial intelligence solutions. Other solutions based on artificial intelligence such as robotics, ontology, semantic networks, and multi-agent systems are also reported to be applied in crisis management (Khalil, Abdel-Aziz, Nazmy, and Salem, 2008). This literature reviewon also encountered publications regarding the use of artificial intelligence in the area of social media to obtain necessary information from the affected areas (Kejriwal and Zhou, 2019; Nguyen, Joty, Imran, Sajjad, and Mitra, 2016).

Effective crisis management is very important in the context of sustainable de-velopment, especially in recent years when climate change has been leading to an increase in weather hazards in the form of violent hurricanes and floods (Chatziioannou, Bakogiannis, Kyriakidis, and Alvarez-Icaza, 2020) – hence the formulated objective of this study. It considers the level of interest in the possibility of implementing artificial intelligence solutions in the field of crisis management related to flooding and flash floods among local government bodies in countries that are not leaders in economic development. It has been assumed that a lower level of economic, technological, and scientific development, when compared to the leading countries in this aspect, may pose a barrier that restricts the use of advanced IT tools as part of crisis management. To confirm the assumption, the authors conducted research in 47 communes in Poland. The research developed the reflections undertaken in 2018 among local governments of the Silesian voivodeship concerning the possibilities of using expert systems in crisis management procedures (Wrzalik and Jereb, 2019, pp. 406-411).

Given this objective, the study attempted to answer the following research questions:

1. Are local governments interested in the implementation of artificial intelligence solutions in the area of crisis management relating to flood risk management?
2. What are the expectations of local governments in applying artificial intelligence methods in flood risk management?

This study contributes to the literature on the implementation of artificial intelligence in the field of crisis management.

2. Flood risk management

Crisis management is a field of public management in the form of a public service performed by local government units. It plays an important role in solving crisis situa-tions that affect the security of the local community. Crisis management takes place on three levels: counteracting threats, preparing for their occurrence and taking actions to restore stabilization. It can be said that crisis management is a specific form of man-agement in which there are many mutually interpenetrating and determining areas. These include, first of all, people, goals, values, communication, learning, IT tools, and all of them together constitute a specific ecosystem (Wrzalik and Jereb, 2019, pp. 406-411).

In its wide range of activities, crisis management also applies to areas related to flood risk. The threat of flooding is an indispensable element of the existence of many geographic regions, especially now, in the period of the strong impact of climate change. The intensification of catastrophic natural hazards, with particular emphasis on flood phenomena, determines taking actions that will contribute to the conscious shaping of the risk level of these events. It will additionally determine their effective prevention with the use of modern technologies, including IT solutions (Iqbal, Perez, Li, and Barthelemy, 2021; McCallum et al., 2016, pp. 198-204). Flooding occurs in many EU countries, they are becoming a cyclical, not sporadic, phenomenon, as was the case in past years. The last major floods took place in Europe in 2010. They affected Central Europe, in particular Poland, the Czech Republic, Slovakia, Hungary, Romania and France (Jarosinska, 2016, pp. 801-821).

The flood risk management policy is a sequence of the decisions and the consequences of actions taken by entities that shape this policy. As part of the flood risk management policy, it is necessary to indicate the objectives that are related to reducing the occurrence of flood hazards throughout the country or its parts, strengthening the resilience of the socio-ecological system and increasing adaptability (Dumienski, Lisowska, Bedryj, and Tiukalo, 2017).

Referring to the specificity of the flood-risk management policy, one should also point out the importance of involving a number of stakeholders in the decision-making processes related to floods. Ensuring the participation of local stakeholders in a manner that leads to the expected benefits is fraught with challenges and difficulties (Thaler and Levin-Keitel, 2016). An example may be studies conducted in Great Britain and Germany, where the process of flood-defence planning and related decisions were analysed. The results of the case study indicate that stakeholder involvement in decisions related to flood protection programmes is limited and can lead to conflict and frustration, and potentially increase inequality (Begg, Callsen, Kuhlicke, and Kelman, 2018).

The scope of stakeholder participation cannot be reduced only to public administration bodies. The EU Flood Directive 2007/60/EC implemented in this case requires the involvement of citizens in the flood management cycle and the development of appropriate mechanisms to activate such public participation. The use of innovative solutions and technologies can provide citizens with a new role in the decision-making process, in which such solutions may be civic observatories based on information and communication tools (When, Rusca, Evers, and Lanfranchi, 2015).

It is worth noting that very often conditions change dynamically in a crisis situation, and the very assessment of such a situation requires the analysis of many factors. The complexity of the decision-making problem related to flood risk management determines the high degree of difficulty of the decisions made (Da Silva, Alencar, and De Almeida, 2020). It is also significant that these decisions usually concern human health and life, which additionally raises their importance. In this situation, it seems reasonable to look for solutions supporting the decision-making process. An effective way to improve the accuracy of decisions may be the application of artificial intelligence methods.

3. Artificial intelligence

The use of artificial intelligence in crisis management, especially flood-risk management, should be associated primarily with the fact that when making decisions in crises, the decision-making criteria that occur are most often both quantitative and qualitative, and the process itself is characterized by non-linearity. These circumstances predispose artificial intelligence to be used in the discussed area because of its specificity related to the processing of information that reflects the thoughts and decision-making processes in the human brain.

The specificity of artificial intelligence methods allows for its application in uncertain situations when information and knowledge are incomplete, inaccurate, and not effectively algorithm-based. Furthermore, artificial intelligence methods allow to significantly reduce the participation of the human factor in the decision-making process, due to their autonomy.

The above-mentioned premise make it possible to select three methods of artificial intelligence which – in the authors' opinion – may be applied while making a decision related to crisis management in the area of flood-risk management. They include expert systems, neural networks, and fuzzy systems; a brief description of each of the selected solutions is presented below.

An expert system is a computer program that uses knowledge and inference mechanisms to solve problems that require experience and expertise (Wagner, 2017). The concept of expert systems includes the transfer of field expert knowledge into a knowledge base which is used by an inference engine controlled by the user interface. Since the process of acquiring knowledge from experts and translating it into rules written in the expert system structure is a labour-intensive activity, the effort put into creating an expert system is justified if it is to be used over a long period and by a sufficiently large number of users. The expert systems, having the field expert knowledge at their disposal, can be used multiple times in an economically effective way, without the participation of an expert. This allows freeing the experts from repeating analogous expert opinions and focusing their attention on other tasks (Ruiz-Mezcua, Garcia-Crespo, Lopez-Cuadrado, and Gonzalez-Carrasco, 2011).

Neural networks are computational systems that process information within the mapping of phenomena occurring in the human brain (Wu, 1991, pp. 391-403). Typical uses of neural networks focus on notions related to prediction, classification, recognition, and analysis of images. The basis of an artificial neural network structure is a model of a biological neuron (a nerve cell) constituting a fundamental component of a biological neural network. An artificial neuron model is not a copy of a biological neuron but an element whose properties correspond to those of a biological neuron.

Artificial neural networks process the information through a grid of computing nodes and connections among the neurons. A large number of connections and the ability to process the information in parallel determine some unique features of neural networks that allow them to be considered as a simulator of the nervous systems in living organisms (Abiodun et al., 2008).

Fuzzy systems are a solution based on the fuzzy sets theory, which allows for a fuzzy description of real systems. The main area of the fuzzy sets theory is fuzzy logic applied in modelling and controlling the fuzzy systems.

Fuzzy logic extends classic logic to the real range values logic [0, 1]. The most important fuzzy logic concept is a linguistic variable, defined as an input, output, or state variable to be evaluated by linguistic values (Zadeh, 1975, pp. 199-249).

Fuzzy logic is a tool for describing, formalising, and analysing inaccurate human reasoning. It is primarily used in ambiguous situations, thus its predestination for various qualitative variables that are difficult to quantify. The essence of fuzzy logic is related to fuzzy sets commonly used for qualitative evaluation of, among others, physical values or states of objects. It should be noted that the specificity of a fuzzy set allows for the mathematical expression of linguistic values used to describe linguistic variables. A degree of membership of a given element in a fuzzy set is determined with a correctly formulated function of membership. In the case of troubleshooting, when there is more than one input variable (fuzzy set) and there are some relations between the input variables, they are recorded using logical operators. The knowledge takes the form of a set of rules operating on fuzzy sets. These solutions, which enable inaccurate and ambiguous information to be defined using logical expressions and then used to convert input variables into output variables, are called fuzzy systems (Dernoncourt, 2013).

In the context of the application of artificial intelligence in the area of flood risk management, there is a need to choose an appropriate method of artificial intelligence. This is where the AHP method can be helpful, as it allows to define the best decision option in a multi-criteria manner. In the course of the considerations undertaken in this study, the authors decided to present their own hierarchical model allowing for the selection of an appropriate artificial intelligence method used in flood risk management. This model is presented in Table 1.

Table 1. The structure of the decision problem – hierarchical model

<table>
<tr><td colspan="3">Choice of artificial intelligence</td></tr>
<tr><td colspan="3">Criteria</td></tr>
<tr><td>Economic</td><td>Technical</td><td>Organizational</td></tr>
<tr><td>• commissioning cost
• implementation time
• duration
• cost of the decision-making process</td><td>• functionality
• flexibility
• business continuity
• intuitive operation
• quantitative data analysis
• analysis of qualitative data</td><td>• automation of the process
• compatibility with the software used
• knowledge base
• scope of the decision
• repeatability
• accuracy of the forecast
• learning to learn</td></tr>
</table>

Source: own analysis.

The hierarchical model formulated in this way allows, on the basis of pairwise comparisons and in accordance with the principles of the AHP method, to select the most useful artificial intelligence method for a given local government unit. It needs to be stressed here that the selection is conditioned by a multitiude of factors and direct pairwise comparisons of the proposed criteria which is in the model. Each territorial government unit should conduct such comparisons with reference to its own economic and technical resources and expectations towards artificial intelligence. It should be noted that the literature on the subject indicates that most frequently in the area of flood risk management application solutions can be found in the scope of neural networks that utilise machine learning. However, this is not the only appropriate solution, as the selection of an artificial intelligence method depends primarily on the specificity of a local government unit, and also on the nature of local flood phenomena.

4. Research methodology

When analysing this problem the authors conducted surveys in September-November 2020 in 47 local government units in Poland located in five voivodeships – Dolnośląskie, Opolskie, Śląskie, Małopolskie, and Podkarpackie. The research developed the reflections made in 2018 among local governments of the Śląskie voivodeship concerning the possibilities to use expert systems in crisis management procedures. The choice of communes to conduct the survey was not random, and it considered the localities where crises related to flooding and flash floods had occurred most frequently in the last 10 years. To achieve the set goal, a purpose-built questionnaire was used, directed at people supervising the decision-making process in the field of crisis management. The basic scale used in the questionnaire was the five-point Likert scale, with 1 meaning "Definitely yes" and 5 meaning "Definitely no". A non-parametric statistical method based on Spearman's rank correlation coefficient was used for data analysis due to the nature of the Likert scale. Each time its significance was set at 0.05 and the Statistica 13 software package was used. The reliability of the questionnaire was verified using Alfa-Cronbach ($\alpha = 0.742$).

The surveys were intended to assess the existing state of crisis management and the interest on the side of local government units regarding the possibility to implement artificial intelligence solutions in the area of flood risk management. It should be noted here that the undertaken research is an initial stage of broader considerations to assess the possibilities of using artificial intelligence in crisis management in Central and Eastern European countries.

Information from the respondents was collected using the CAWI method, with the questionnaire sheet being sent to each of the units preceded by a telephone call, which was an invitation to take part in the research, and was intended to familiarise the participants with the subject of the survey. Each unit was also contacted by telephone after the results analysed to obtain additional information with the use of a direct interview which complemented the surveys.

5. Survey results – discussion

The first part of the survey pertained to obtaining information on the respondents' evaluation of the crisis management system so far. Most of the respondents indicated that their system allowed for minimising or removing any adverse effects of the crises that occurred. Such an answer was obtained from 26 surveyed units of local government. The remaining group indicated that the effects of crises were at (3 local government units) or above the expected level (18 local government units). This information is shown in Figure 1.

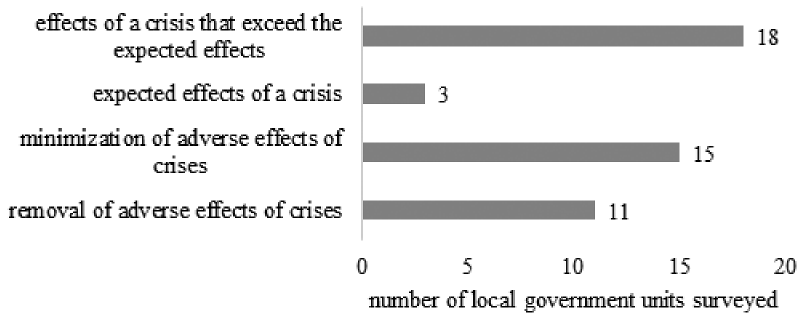

Fig. 1. Evaluation of the effectiveness of the existing crisis management system

Source: own analysis.

At the same time, more than half of the respondents (31) stated that they saw the need to improve the functioning of the crisis management system.

The survey also highlighted the importance of success factors in crisis management. For this purpose, the authors asked the respondents to assess the factors selected and described in the literature [14]. This assessment consisted of determining the importance on a scale from 1 to 10 (where 1 – the least important criterion, 10 – the most important one). The respondents gave the highest score to professionalization and the possibility to accelerate development and the lowest to allocation and mobilization of resources (Figure 2).

The respondents' indication of the possibility of accelerating development as one of the most important factors may suggest an openness to new solutions that may im-prove the decision-making process.

The information obtained from the respondents during the telephone contact before the questionnaires had been sent, allowed to obtain information that none of the analysed units of local government had applied artificial intelligence solutions in their flood risk management systems. This was primarily due to the limited budget and low level of knowledge about artificial intelligence among the personnel dealing

Fig. 2. The importance of success factors in crisis management

Source: own analysis.

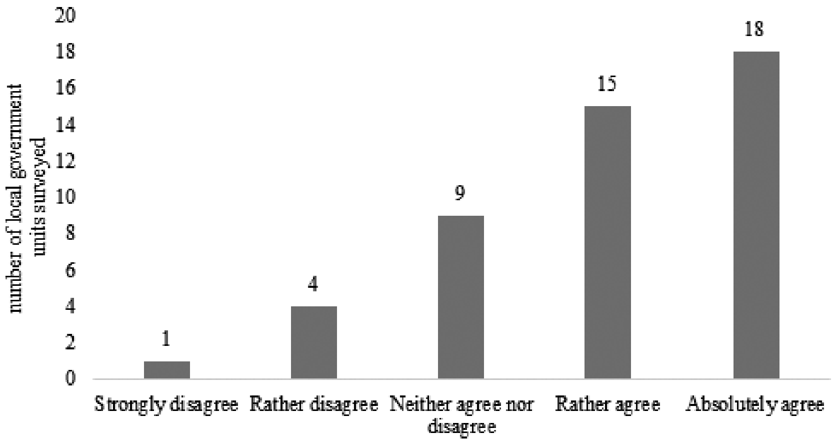

Fig. 3. Respondents' attitude to the statement that the implementation of artificial intelligence as a part of IT support in flood risk management would constitute an improvement of this area

Source: own analysis.

with crisis management. However, the lack of knowledge is not associated with a lack of interest in such solutions−the vast majority of the respondents showed a willingness to implement artificial intelligence into systems supporting decision-making in crises. This was first of all determined by the fact that ignorance of the mentioned solutions was not correlated with a lack of knowledge about their existence or awareness of their growing use in various spheres of life. At the same time, it confirmed the respondents' belief that there is a need to support traditional methods with IT solutions that have not been previously used in the discussed scope. The respondents' interest in the improvement of the decision-making process within crisis management in terms of flooding and flash floods with the proposed IT method was reflected in their response to the supposition related to the improvement of the process under discussion (Figure 3). More than two-thirds of the respondents agreed that the implementation of artificial intelligence as part of IT support in crisis management of flooding and flash floods would constitute an improvement in this area. The remaining respondents had no opinion on the subject. It should also be stressed that only every tenth local government unit surveyed opposed this statement.

The respondents' expectations related to the use of artificial intelligence methods in flood-risk management mainly concerned the facilitation of decision-making, reduction of human factor involvement, and noticeable savings of time spent on finding an appropriate solution (Figure 4).

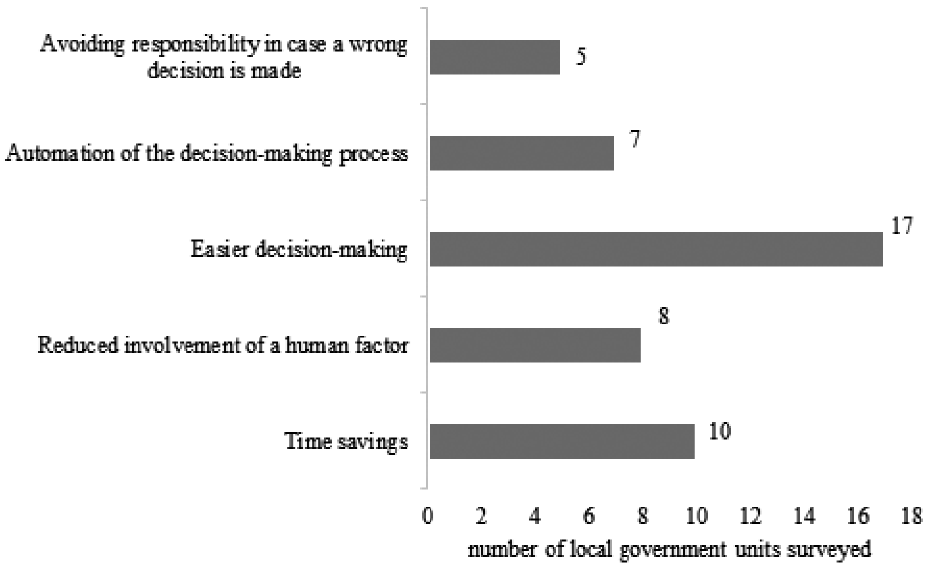

Fig. 4. Respondents' expectations related to the use of artificial intelligence in flood risk management

Source: own analysis.

To anlyse the results, the study first used non-parametric statistics in the form of Spearman's rank correlation. Table 2 presents a fragment of the relations between the data about the local governments and the respondents' answers to the posed questions. At this point, a strong negative correlation was observed between the number of inhabitants of the commune ("powiat") and the number of floods in the last 10 years and the assessment of the current flood management system. However, there was a strong positive relation between the number of floods and the variables relating to the need to improve the current crisis system in terms of flood risk management. The weakest correlations existed between the number of floods and the number of inhabitants, and the budget constraints available to the analysed local government units in the area of crisis management.

Table 2. Values of Spearman's rank correlation coefficients between ordinal variables and the number of inhabitants and the number of floods

Ordinal variables	Spearman's Rank Correlation Coefficients ($p < 0.05$)
Population & rating of the current system	–0.74
Flood count & current system rating	–0.83
Population & need to improve the current system	0.57
Flood count & need to improve current system	0.76
Population & artificial intelligence knowledge level	0.49
Flood number & artificial intelligence knowledge level	0.67
Population & budget constraints	0.42
Number of floods & budget constraints	0.31
Population & interest in the implementation of artificial intelligence	0.55
Flood count & interest in the implementation of artificial intelligence	0.77
Number of inhabitants & belief in the improvement of flood risk management as a result of the implementation of artificial intelligence	0.66
Flood number & belief in the improvement of flood risk management as a result of the implementation of artificial intelligence	0.83

Source: own analysis.

Table 3 presents the values of Spearman's rank correlation coefficients for the answers given by the respondents according to the ordinal scale. The strongest positive relation (0.88) can be seen between the perception of the need to improve the cur-rent flood-risk management system and the belief that artificial intelligence solutions will contribute to this improvement. This, of course, translates into an equally strong relation between the interest in artificial intelligence and the belief that its imple-mentation would positively affect the improvement of the flood-risk management process, whereas the strongest negative relationships concerned the strength of the links between the assessment of the current crisis management system in terms of floods and other variables.

The literature research carried out in the course of the analysis of the undertaken subject matter, as well as the pilot surveys, created an opportunity to answer the research questions presented in the introduction. The first question was about the local governments' interest in the possibility of using artificial intelligence solutions in the field of crisis management. The obtained results of the surveys indicated

Table 3. Values of Spearman's rank correlation coefficients between the ordinal variables ($p < 0.05$)

Ordinal variables	Need to improve the current system	The level of knowledge about artificial intelligence	Budget constraints	Interest in the implementation of artificial intelligence	A belief in the improvement of flood risk management as a result of the implementation of artificial intelligence
Assessment of the current system	–0.75	–0.66	–0.45	–0.67	–0.81
Need to improve the current system	–	0.59	0.44	0.81	0.88
The level of knowledge about artificial intelligence	–	–	0.42	0.62	0.60
Budget constraints	–	–	–	0.44	0.44
Interest in the implementation of artificial intelligence	–	–	–	–	0.83

Source: own analysis.

that the majority of the respondents were inclined in this direction. However, it must be borne in mind that the survey was of a pilot nature, and the analysed local government units did not have artificial intelligence experts at their disposal. This does not change the fact that the vast majority of the respondents were convinced of the correctness of taking actions aimed at improving crisis management through the implementation of artificial intelligence methods.

The second research question was an extension of the first one. It covered the expectations of local government units in applying artificial intelligence methods in crisis management. The greatest expectations of the respondents were related to the facilitation of decision making. An indication related to avoiding responsibility for a decision made was at the opposite end of the scale. It is worth noting that this answer was not included in the framework of possible answers at the stage of developing the questionnaire, but it was proposed by the surveyed units. This may indicate the uncertainty of some of the crisis management professionals representing the local authorities concerned about their decisions.

It is worth stressing that the high interest from the local government units in the possibility to implement artificial intelligence in the flood risk management area was not sufficient for the appropriate use of such solutions. In the context of minimising flood risks, it is important to define the purpose for which modern IT techniques are to be used. At this point, the most frequent indications awere predicting the location of floods and identifying mitigation measures (Madhuri, Sistla, and Srinivasa Raju, 2021; Mosavi, Ozturk, and Kwok-Wing, 2018). The application was also observed in the field of combining flood susceptibility maps with flood effect maps (Pham et al., 2021).

As mentioned earlier, the wide spectrum of possibilities presented by artificial intelligence methods, determined by their specificity, allows to use them in various phases of crisis management. This may include predicting the location of a flood, but also optimising an intervention strategy when it occurs (Sayersa, Savića, Kapelana, and Kellagherb, 2014). It is therefore important to select the appropriate method of artificial intelligence depending on the decision-making situation. The choice of an artificial intelligence method in the context of crisis management, especially flood risk management, is a multi-criteria process. These criteria have three basic dimensions – economic, technical, and organizational, and each of these dimensions is described by a set of relevant sub-criteria (e.g. time and cost of implementation, the accuracy of forecasts, availability of knowledge bases, learning to learn). This list is a comprehensive hierarchical model that should undergo a comprehensive multi-criteria analysis. The Analytic Hierarchy Process (AHP), which is predestined to be used in multi-criteria situations, where the criteria have both quantitative and qualitative dimensions, may be useful here (Saaty, 2004, pp. 385-404). Its application could be an effective solution to the problem of choosing an appropriate artificial intelligence method depending on the phase, specificity, and type of decision problem embedded in the area of flood risk management.

6. Conclusions

Nowadays, crisis management is becoming increasingly more important for public security. Changing climatic conditions, cultural, philosophical and religious differences, and pandemic conditions at the beginning of 2020, determine the growing role of crisis management. It is a set of activities that relate primarily to local governments in operational terms, and these smallest local government units bear the greatest responsibility for the smooth functioning of crisis management. The fact that decisions made in the discussed area often directly affect both human health and life, and the activities of enterprises, and require immediate enforceability, means that there is a need to support the decision-making process through advanced IT tools. Artificial intelligence methods are a solution that can effectively respond to this need.

The paper presents the results of a pilot survey on the local governments' interest in artificial intelligence implementation in the crisis management area of flood-risk management. Based on these results, it may be concluded that the surveyed units manifested considerable interest in the proposed solution and had specific expectations towards it. It should be noted, however, that the possibility of implementing artificial intelligence in this area of flood risk management makes it necessary to choose an appropriate method for a specific phase of crisis management or a specific decision-making situation. This is where the need for a multi-criteria decision-making method arises. An appropriate solution, as proposed by the authors, may be the use of the AHP model. The conducted research had certain limitations – the fundamental one relates mainly to the small size of a research group that was the basis for the pilot studies. It should also be remembered that the study was only conducted in one region of Poland, which was also a limitation. When defining the directions of further research, it seems appropriate to consider the undertaken problem with regard to the countries of Central and Eastern Europe.

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