

DOI: 10.7409/rabdim.025.013

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Activities of civil-military services during floods: identification of technical, organizational, and legal issues related to the natural disaster that occurred in Poland in 2024

Abstract: Floods are among the most destructive natural disasters, causing extensive damage to infrastructure, disrupting social and economic life, and posing a challenge for emergency response systems. The September 2024 floods in southwestern Poland exposed multiple weaknesses in the country's flood preparedness, response coordination, and legal frameworks. This study aims to identify key technical, organizational, and legal issues associated with flood response by analyzing data collected from a Focus Group Interview (FGI) conducted with representatives from civil and military services. The research utilizes a simplified version of Haddon's Matrix to classify flood management solutions into three stages: pre-disaster, during the disaster, and post-disaster. Findings highlight deficiencies in emergency preparedness, coordination between agencies, and resource allocation. The study emphasizes the need for improved early warning systems, enhanced legal frameworks for inter-agency cooperation, and better technical solutions for flood impact mitigation. The results provide recommendations for optimizing crisis management strategies and strengthening national flood resilience.

Keywords: flood, legal issues, organizational issues, technical issues, Haddon Matrix.

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1. INTRODUCTION

Floods cause severe disruptions in the functioning of cities, significantly impacting society, the economy, and the environment [1]. Their effects can be further exacerbated by climate change and socio-economic factors [2]. Consequently, systemic actions aimed at mitigating the impacts of floods are necessary. This need is reflected in the concept of urban infrastructure resilience – a key approach currently employed by urban planners and decision-makers in flood risk management [3].

The impact of floods results from a combination of natural factors and those induced by human activity. As demonstrated by recent floods in Pakistan, Brazil, Sri Lanka, and Australia, these events can occur worldwide, and their consequences can be so severe that even the most prepared countries and cities struggle to cope with them [4]. Research by Kocornik-Mina et al. [5] on large-scale floods indicates that over the past thirty years, floods worldwide have caused more than 500,000 deaths and displaced over 650 million individuals.

Despite significant technological progress in mitigating flood effects, flood risk remains a major challenge. Floods are among the most frequently occurring natural disasters globally, causing extensive damage [6-7]. Forecasts suggest that climate change will further increase the frequency and intensity of extreme rainfall events [8-9]. Studies show that even minor changes in the average level and variability of precipitation can significantly heighten the occurrence and severity of extreme rainfall events [10]. Consequently, in a warming climate, extreme rainfall is highly likely to become more frequent and intense. The increasing flood risk associated with climate change is also emphasized by Milly et al. [11], who highlight the necessity of revising current flood management strategies to better address emerging threats.

Studies indicate that in recent decades, economic and environmental losses resulting from floods have risen sharply [12]. The primary drivers of this trend include the intensification of rainfall in a warming climate and the growing population and asset value in flood-prone areas. One notable manifestation of these trends is urban flooding, whose consequences are multifaceted and encompass both social and economic dimensions [13]. Floods can affect various aspects of city life, including public health, real estate values, and the condition of transportation infrastructure.

They also trigger a range of adverse outcomes, such as job losses, disruptions to public services, and material damage to both private households and public facilities.

The literature provides numerous examples illustrating the negative impact of floods on road infrastructure [14-18]. Extreme weather events, such as floods, pose a serious threat to infrastructure durability, defined as a structure's ability to maintain its properties and functionality over time [19]. Lu et al. [20] report that up to 39% of annual transport infrastructure losses worldwide result from urban flooding. Research by Michielsen et al. [21] indicates that road maintenance costs linked to weather conditions account for 30% to 50% of total road maintenance expenditures, with 10% attributed specifically to the effects of extreme weather events.

In Poland, flooding is particularly severe in riverbank areas and locations with inadequate flood protection infrastructure. The events of September 2024, along with previous flood episodes, exposed multiple shortcomings in emergency preparedness, the coordination of rescue operations, and existing legal frameworks.

Therefore, this article aims to: 1) identify key challenges related to flood preparedness and response, 2) examine the main technical, organizational, and legal issues that emerged during recent flood events, and 3) propose improvements and solutions to enhance the effectiveness of pre-disaster, emergency, and post-disaster actions.

2. METHODS

The article, in the section concerning research results, is based on an analysis of primary sources. To obtain primary data, a Focus Group Interview (FGI) was conducted with 14 respondents and 2 moderators. The research sample included 3 representatives from the Territorial Defense Forces Command, 3 representatives from the Engineering Troops, 1 representative from the Military Transport and Traffic Directorate – Military Traffic Coordination Center, and 3 representatives from the Road and Bridge Research Institute. Additionally, representatives from the Polish Chamber of Civil Engineers, PGW Wody Polskie, ECCBIM, and TELDAT Sp. z o.o. participated in the study.

All respondents were involved in activities related to mitigating the effects of flooding, although the scope of their tasks varied. The diverse composition of the research sample allowed for a broad perspective on the research

problem, taking into account the viewpoints of multiple entities engaged in these efforts. The respondents' statements were grouped using semantic analysis and a simplified version of Haddon's matrix, a research technique designed to address road traffic safety issues [22-23]. In this analysis, flood impact mitigation is treated as a set of technical, organizational, and legal measures distributed over time and categorized into actions that need to be taken before, during, and after the flood.

3. THE NATURAL DISASTER STATE IN SOUTHWESTERN POLAND IN 2024

In September 2024, intense rainfall caused extreme flooding in five provinces of Poland: Małopolskie, Opolskie, Śląskie, Dolnośląskie and Lubuskie. As a result, 9 people lost their lives, 4,978 residents were evacuated, and a significant portion of the infrastructure was destroyed [24]. Due to the scale of destruction and the catastrophic nature of the disaster, on September 16, 2024, the Council of Ministers – based on the Regulation of the Council of Ministers of September 16, 2024 – declared a state of natural disaster in the flood-affected areas. This declaration covered a total of 310 municipalities, home to 3,104,571 people.

According to the findings of the Ministry of Infrastructure, the flood caused extensive damage to road, rail, and hydrotechnical infrastructure. The most significant losses were suffered by Wody Polskie, particularly in the areas of retention reservoirs, levees, weirs, and other hydrotechnical facilities, whose repairs will require financial expenditures estimated in the billions of zlotys. The road infrastructure was also severely affected – preliminary estimates from the General Directorate for National Roads and Motorways indicate losses of approximately 155 million PLN. In general terms, 3,014 road sections were damaged, totaling over 2,000 km in length, and 834 bridge structures were affected. Meanwhile, damages to railway infrastructure were estimated at no less than 125 million PLN, and the railway operator PKP Intercity reported losses exceeding 100 million PLN [25].

4. IDENTIFICATION OF TECHNICAL, ORGANIZATIONAL, AND LEGAL PROBLEMS

At the outset, the study participants were asked to identify the main issues related to flood response preparedness.

The analysis of the collected data allowed for the identification of key challenges concerning the readiness of civil and military services, which focused on: 1) increasing the effectiveness of preparatory actions, 2) improving task coordination, 3) enhancing the acquisition of equipment and human resources, and 4) streamlining cooperation at various levels of crisis management. Particular attention was given to deficiencies in the organizational preparedness of local government units, especially regarding their familiarity with procedures and operational plans related to crisis management. The crucial role of training and military exercises in increasing the readiness level at the local level was also emphasized.

Respondents pointed out that past flood response efforts often overlooked the need to involve experts in assessing the condition of infrastructure. In their view, studies conducted before a crisis situation arises, as well as expert analyses carried out after a flood, could significantly contribute to a more reliable verification of infrastructure conditions and better preparedness for future threats.

The discussion then addressed key technical problems occurring at various stages of flood response. The need to improve resource availability and the use of modern technologies in information exchange was highlighted. Attention was drawn to difficulties related to the coordination of equipment and resource deployment during crisis operations, as well as the necessity for effective management of technical infrastructure using information systems. Challenges in receiving damage reports, particularly imprecise ones, were also noted, as they hindered the proper assessment of the technical condition of bridges and road infrastructure.

Subsequently, organizational problems, including resource management and inter-organizational cooperation, were analyzed. Difficulties in information exchange and communication were identified, resulting in a lack of comprehensive knowledge about the actions undertaken by different entities involved in flood response. As a result, coordination efforts were hindered, and various services duplicated certain tasks. Special attention was given to cooperation with private entities possessing equipment that could be effectively utilized in rescue operations. Another significant challenge was the limited availability of crisis management experts and individuals capable of serving as local-level coordinators, which negatively impacted the effectiveness and efficiency of crisis response efforts.

In the final part of the discussion, difficulties arising from existing legal regulations concerning inter-agency cooperation, administrative barriers, and legal liability issues were emphasized. The lack of clear regulations regarding access to private land and the use of resources owned by various institutions or private individuals was noted. The need to introduce a more transparent division of responsibilities and competencies was highlighted, which would enable more efficient crisis management and improve the effectiveness of response actions.

5. HADDON MATRIX WITH TECHNICAL, ORGANIZATIONAL AND LEGAL SOLUTION BEFORE, DURING AND AFTER THE FLOOD

In this FGI study, respondents were asked to identify technical, organizational, and legal solutions that should be implemented at three stages of flood management: before its occurrence, during the event, and after it has subsided. This section of the study was structured in such a way that focus group participants first independently proposed possible solutions, which were then discussed in a group setting, leading to their acceptance or rejection. The outcome of these discussions was the development of the Haddon Matrix, which provides a comprehensive overview of analyzed solutions at different stages of flood risk management. The proposed solutions serve as a general framework for future interventions and remedial actions.

The study results emphasize that the implementation of the proposed courses of action should begin with the establishment of working groups composed of experts from relevant fields. These teams should be responsible for conducting an in-depth analysis of existing solutions, identifying current gaps based on past experiences, and developing improvements. As a result of their work, detailed action plans should be formulated, taking into account specific local, technical, and organizational conditions to enhance the effectiveness of the implemented solutions.

The first group of solutions includes preventive and preparatory measures aimed at reducing the likelihood of damage and increasing the level of preparedness of communities and institutions. The second group focuses on actions taken during the flood, encompassing immediate rescue, technical, organizational, and legal responses to minimize losses and ensure the safety of people and property. The final group pertains to recovery efforts,

infrastructure reconstruction, and drawing lessons for the future to strengthen resilience to subsequent flood risks.

Based on the information in Table 1, a total of 29 solutions were identified, covering all stages and categories of action. The majority of proposals relate to organizational aspects – 13, followed by legal measures – 10, while the fewest address technical solutions – 6. In terms of timing, the pre-flood stage is the most represented, with 11 identified solutions. During the crisis, 10 remedial actions were identified, while the post-flood phase includes 8 measures.

The dominant position of organizational solutions suggests that the most crucial role is attributed to coordinating actions, fostering collaboration among various services, and planning (e.g., in the areas of training, evacuation procedures, and strategic reserve creation).

A particularly well-developed characterization of the pre-flood phase is evident, covering technical aspects (enhancing the early warning system), organizational measures (establishing cooperation procedures among emergency services), and legal aspects (regulations on spatial planning and institutional responsibilities). This underscores the key importance of preventive actions in mitigating the consequences of potential natural disasters.

Table 1. Haddon Matrix with technical, organizational and legal solution before, during and after the flood

Specification	Technical Solutions	Organizational Solutions	Legal Solutions
Before the Flood	<ul style="list-style-type: none"> • Improvement of the early warning system for hazards. • Digitization of data and creation of a platform for real-time information exchange with individual access levels tailored to assigned tasks. 	<ul style="list-style-type: none"> • Training and exercises for civil and military services on crisis cooperation. • Establishing procedures for cooperation between civil and military units. • Developing evacuation and supply plans. • Creating strategic reserves. • Prioritizing facilities based on safety, mobility, and social importance (at the municipal level). 	<ul style="list-style-type: none"> • Drafting legal acts regulating the allocation of financial resources for disaster recovery. • Framework agreements with entities possessing heavy equipment necessary for rescue operations. • Defining the responsibilities of public institutions and other entities in disaster situations. • Spatial planning that considers flood risk.
During the Flood	<ul style="list-style-type: none"> • Activation of monitoring systems and assessment of the threat scale. • Use of drones and satellite technology for real-time monitoring of affected areas. 	<ul style="list-style-type: none"> • Establishing a crisis management team with representatives from military and civil units. • Defining a clear command chain. • Coordinating rescue and evacuation efforts at the regional and local levels. • Ensuring rapid communication between emergency services and residents (e.g., via SMS alerts, social media). • Securing shelters and providing essential resources. 	<ul style="list-style-type: none"> • Activation of emergency regulations allowing faster decision-making (including temporary acquisition of private land and technical resources for rescue operations). • Developing regulations to protect the rights of disaster victims. • Establishing laws to facilitate quick access to private resources for rescue purposes.
After the Flood	<ul style="list-style-type: none"> • Assessment of damage extent and prioritization of recovery actions. • Data collection and analysis to improve early warning systems. 	<ul style="list-style-type: none"> • Compiling reports on rescue operations and infrastructure reconstruction. • Reorganizing procedures based on lessons learned from completed actions. • Providing social and psychological support for affected individuals. 	<ul style="list-style-type: none"> • Enabling the rapid disbursement of compensation for affected individuals and entities. • Modifying legal regulations based on conclusions from conducted actions (e.g., clarifying responsibilities of different services, improving spatial planning). • Creating regulations supporting reconstruction, including simplifications in administrative procedures.

6. SUMMARY AND CONCLUSIONS

The study aimed to identify key challenges related to flood response in Poland by analyzing technical, organizational, and legal aspects. The findings indicate significant shortcomings in the preparedness of both civilian and military services for crisis management, including inadequate coordination procedures and limited access to resources and

specialized equipment. Respondents also highlighted legal issues associated with crisis interventions, such as the lack of clear regulations regarding access to private land for rescue operations.

The application of a modified Haddon matrix allowed for the classification of key solutions that should be implemented at three stages of flood management:

- before the flood – improving early warning systems, digitizing data, and introducing clear procedures for cooperation between civilian and military services,
- during the flood – enhancing the coordination of rescue efforts, utilizing modern technologies (e.g., drones, satellite imaging), and activating procedures enabling swift decision-making,
- after the flood – conducting a thorough damage assessment, analyzing rescue operations, and revising regulations concerning reconstruction and future spatial planning.

Most of the proposed improvements relate to organizational aspects, such as the need to:

- standardize crisis response procedures across all services,
- establish integrated digital platforms for real-time coordination,
- conduct regular joint training and simulation exercises,
- strengthen public–private partnerships in logistics and support operations.

Key legal recommendations include:

- clarifying the legal basis for military involvement in civil crisis response,
- regulating emergency access to private property, including compensation rules,
- introducing a unified legal framework defining roles and responsibilities of all actors,

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- mandating local-level contingency planning aligned with national guidelines.

The findings also suggest that a crucial step toward increasing flood resilience is the establishment of interdisciplinary expert teams tasked with developing preventive and response strategies and supporting systemic reform efforts.

Moreover, future studies should assess to what extent the shortcomings observed during the 2024 flood stem from a failure to implement lessons from past disasters. For instance, the 1997 flood, although highly destructive, did not result in the breach of major retention structures, unlike the 2024 event. This suggests that the nature of contemporary threats may differ from past patterns and thus require adapted preventive strategies and infrastructure designs.

In comparison with international best practices, the challenges identified in the Polish context mirror those observed in other flood-prone countries. For example, the Netherlands has implemented an integrated flood risk management strategy known as *Room for the River*, which combines infrastructural solutions with adaptive spatial planning [26-27]. Japan, on the other hand, emphasizes comprehensive evacuation planning supported by real-time early warning systems and well-established civil-military coordination protocols [28]. Incorporating such elements – particularly in terms of legal clarity, operational interoperability, and community-level engagement – could significantly strengthen the resilience of Poland’s flood response system.

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Działania służb cywilno-wojskowych podczas powodzi: identyfikacja zagadnień technicznych, organizacyjnych i prawnych związanych z klęską żywiołową, która wystąpiła w Polsce w 2024 roku

Streszczenie: Powodzie należą do najbardziej niszczycielskich klęsk żywiołowych – powodują rozległe zniszczenia infrastruktury, zakłócają życie społeczne i gospodarcze oraz stanowią wyzwanie dla systemów reagowania kryzysowego. Powódź z września 2024 roku w południowo-zachodniej Polsce ujawniła liczne słabości w zakresie przygotowania kraju na tego typu zagrożenia, w tym w zakresie koordynacji działań ratowniczych oraz ram prawnych. Celem niniejszego badania jest identyfikacja kluczowych zagadnień technicznych, organizacyjnych i prawnych związanych z reagowaniem na powódź, poprzez analizę danych zebranych podczas wywiadu fokalnego (FGI) z przedstawicielami służb cywilnych i wojskowych. W badaniu zastosowano uproszczoną wersję macierzy Haddona do trójstopniowego podziału działań związanych z powodzią: przed jej wystąpieniem, w trakcie oraz po zakończeniu. Wyniki wskazują na braki w przygotowaniu do sytuacji kryzysowych, problemy z koordynacją między służbami oraz niewłaściwą alokacją zasobów. Podkreślono potrzebę usprawnienia systemów wczesnego ostrzegania, wzmocnienia ram prawnych dotyczących współpracy międzyinstytucjonalnej oraz wdrażania lepszych rozwiązań technicznych służących ograniczeniu skutków powodzi. Uzyskane rezultaty stanowią podstawę do sformułowania rekomendacji na rzecz optymalizacji strategii zarządzania kryzysowego i wzmocnienia odporności kraju na zagrożenia powodziowe.

Słowa kluczowe: kwestie organizacyjne, kwestie prawne, kwestie techniczne, macierz Haddona, powódź.
