

Logistical challenges and strategies for drinking water supply in times of crisis

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Abstract

Purpose – This paper addresses the logistical challenges of ensuring a potable water supply in crisis management, with an emphasis on the role of technological innovation. Rapid access to safe drinking water is identified as a prerequisite for sustaining human health and dignity during emergencies such as natural disasters and armed conflicts.

Design/methodology/approach – The study identifies and evaluates five mobile water treatment technologies suitable for deployment in crisis scenarios. The evaluation is based on a systematic selection framework and conducted through the analytic hierarchy process (AHP) according to Saaty's method, which applies pairwise comparisons to determine the relative importance of predefined criteria.

Findings – The analysis highlights the effectiveness of mobile water treatment units in addressing critical logistical issues such as distribution efficiency, storage capacity and water quality assurance. The relevance of these results is particularly evident in Central and Eastern Europe (CEE), where geopolitical instability and the war in Ukraine have exposed critical vulnerabilities in water infrastructure and emergency logistics systems. The findings confirm that advanced mobile solutions, capable of rapid deployment and adaptation to diverse environmental conditions, represent a viable means of securing a safe water supply where conventional infrastructure is disrupted or absent.

Originality/value – This paper contributes an AHP-based decision-support framework that links the technical performance of mobile water treatment units with crisis logistics requirements, enabling more effective deployment planning and resource allocation. Future research should focus on validating the framework across different crisis scenarios and examining the sensitivity of results to operational and logistical priority changes.

Keywords Crisis management logistics, Drinking water, Mobile water treatment units, Supply strategies

Paper type Research article

1. Introduction

Ensuring an adequate supply of drinking water for the growing global population represents one of the major challenges of this century (Harlan *et al.*, 2009). The current threat of climate change increases the vulnerability of water resources (Vörösmarty *et al.*, 2000), thereby creating pressure to conduct studies that address knowledge gaps and improve practical solutions related to the effective management of water systems, water treatment processes and the distribution of water to users (Ziafati Bafarasat, 2021).

At the turn of the millennium, more than 2 billion people from developing countries lacked access to sufficient water to meet basic human needs (Girardet, 2004; Gleick, 2003). Thanks to

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the United Nations' (UN) policy focusing on "Clean Water and Sanitation" as the sixth goal among the "17 Sustainable Development Goals" (Voituriez *et al.*, 2019), this number has decreased, with 73% of the global population having access to safely treated drinking water by 2022 (United Nations, 2024). Despite these efforts, the situation remains strained by population growth, economic development, ongoing environmental pollution and climate change, all of which threaten the Earth's water supplies (Postel *et al.*, 1996). This issue is not confined to developing countries; in recent decades, parts of the European Union (EU) have experienced deepening water scarcity, with up to 38% of the EU population at risk of water shortages in 2019 and 29% of the Union's territory facing similar threats (European Commission, 2015, 2022). Water consumption itself is growing faster than population growth, driven by excessive and inefficient water use in developed countries (Princen *et al.*, 2002). As studies have shown (Corral-Verdugo *et al.*, 2003; Hanak and Browne, 2006; Mainieri *et al.*, 1997), reducing water consumption in higher-income households is one of the key factors for effective water conservation (Kurz, 2002).

Reducing household water consumption alone is insufficient; broader measures must be implemented. One is the adoption of circular economy policies (Hanakova *et al.*, 2025). Transitioning to a circular economy, in which the value of products, materials and resources is maintained for as long as possible, is a crucial step toward sustainability. However, this principle has not yet been fully applied to water use, which continues to follow a linear model, with water often returned to natural systems unused. Water scarcity and drought are key priorities within the *European Green Deal*, reflected in strategies such as the *EU Strategy on Adaptation to Climate Change* (2021), the *Circular Economy Action Plan for 2030* and the *Biodiversity Strategy for 2030*. Although water quality in the EU has improved since 1991, eutrophication persists, primarily caused by nutrient runoff from land and wastewater discharge, posing an ongoing challenge to maintaining healthy aquatic ecosystems.

Ensuring reliable and safe drinking water has become a critical challenge, particularly in times of crisis. The conflict in Ukraine highlights a return to large-scale warfare, with significantly increased logistical demands.

The relevance of this issue is particularly pronounced in the context of CEE, where geopolitical instability, aging water infrastructure, uneven crisis preparedness and increasing climate-related risks create additional pressure on emergency logistics and supply chain systems. The war in Ukraine has demonstrated the vulnerability of critical infrastructure across the region and highlighted the strategic importance of resilient water supply chains capable of operating under disrupted transport, energy and distribution conditions (Snizhko *et al.*, 2024). In many CEE countries, emergency response capacities still rely heavily on centralized infrastructure and conventional supply systems, which may become insufficient during prolonged crises, military conflicts, or large-scale natural disasters. Consequently, the development and selection of mobile water treatment technologies represent not only a technical challenge, but also a strategic logistics and supply chain management (SCM) issue linked to resilience, rapid deployment capability and continuity of essential services.

As noted by Ministry of Defence (2019), future military operations are expected to occur across all domains, especially physical space. Unlike the asymmetric wars of the early 21st century (Lind *et al.*, 1989), conventional warfare places far greater demands on logistical support. Recent humanitarian evidence demonstrates that insufficient integration of water security indicators – such as water availability, quality and access – into crisis monitoring and response frameworks limits proactive decision-making and delays the timely deployment of emergency water supply solutions, thereby increasing operational risks and humanitarian impacts (Veness *et al.*, 2025).

Recent studies focusing on infrastructure recovery in conflict-affected regions further emphasize the importance of resilience-oriented decision-support frameworks for prioritizing critical infrastructure systems and allocating limited operational resources effectively (Kopiika *et al.*, 2025). In this context, mobile water treatment technologies represent an

important component of resilient crisis logistics and emergency supply chain systems in the CEE region.

This paper aims to delineate logistical constraints shaping potable water provision in emergencies, profile mobile water treatment technologies for field use and develop and apply a transparent selection framework using the analytic hierarchy process (AHP) based on Saaty's method.

2. Logistical challenges in potable water supply

2.1 Potable water distribution and supply in crisis situations

Considering climatic, economic and social developments across the world, most countries are facing serious water crises (Sheffield *et al.*, 2018). Management and preservation of water resources are of high importance in both developing and developed countries (Soleimani *et al.*, 2022). The issue of combating drinking water supply gained relevance in 2014 in Eastern Ukraine, when it became evident that traditional methods prescribed in regulations were difficult to implement, required highly skilled personnel, or had become largely obsolete. At present, several technological solutions to water supply challenges in the field are available in Ukraine (Kuzminichuk and Astrelin, 2018). The distribution and supply of potable water represent a critical component of crisis management in situations where access to safe water is jeopardized. During natural disasters, such as floods or earthquakes, or in cases of infrastructure disruption, the availability of potable water for affected areas may be severely constrained (Ghandi and Roozbahani, 2020; Harris-Lovett *et al.*, 2015).

Water supply in crisis situations represents a critical factor for ensuring survival and preserving human dignity. Water is indispensable for a wide range of essential needs, and its shortage or contamination triggers a devastating chain reaction affecting health, hygiene, social stability and economic activity. Key logistical challenges include rapid and effective distribution, the security of distribution routes, sufficient storage capacities and the maintenance of water quality throughout transport and storage. In the event of a crisis, it is therefore necessary to provide emergency water supply until the repair and restoration of infrastructure are completed. Potable water consumption varies significantly depending on location – for instance, in arid regions it is substantially higher, as drinking water is used even for activities that would normally be covered by non-potable sources (Touš *et al.*, 2021). In such contexts, potable water distribution is typically carried out through bottled water or mobile tankers.

In the case of non-military crisis situations, such as floods, ensuring the supply of potable water during and after the event is of critical importance. Floodwaters can easily contaminate drinking water sources (wells, boreholes) as well as distribution networks. In affected areas, the use of local water sources is prohibited until their safety has been verified by public health authorities. In such situations, emergency supply measures are implemented, typically through the distribution of bottled water coordinated by municipal crisis management teams. In addition, water tankers are deployed, with their routes and utilization determined by water utility operators in cooperation with flood response authorities. An equally important role may be played by mobile water treatment units, which can draw upon surface water sources and convert them into potable water directly in the field (Smith *et al.*, 2022).

In the context of armed conflict, community water points and new wells are established in areas with critical water shortages to provide access to potable water for populations without connection to public distribution networks. Emergency water supply can also be organized through the armed forces' own capacities, although water withdrawal is usually quantitatively limited, as it takes place outside the standard distribution infrastructure. The water must comply with legally prescribed quality standards and is subject to systematic monitoring. A notable example is the provision of drinking water in war-torn Ukraine, which is logistically highly demanding and requires coordinated efforts by Ukrainian authorities and international humanitarian organizations. The ongoing war has caused extensive damage to water

management infrastructure, including distribution networks, wastewater treatment plants, pumping stations, reservoirs and wells. According to World Bank estimates, the costs of reconstructing water supply and sanitation infrastructure between 2025 and 2033 will amount to several billion USD (Osbert, 2025). Consequently, access to potable water remains severely restricted or entirely disrupted in many regions, threatening millions of people. One of the possible solutions is the deployment of mobile water treatment units. For instance, in 2023, the Czech Republic delivered thirteen mobile treatment plants to the Dnipropetrovsk region, which now provide potable water for approximately 130,000 people (Stingl, 2025).

2.1.1 Water treatment technologies. In the event of disruption to the public water supply network or damage to storage facilities, alternative solutions are required, most notably the deployment of water treatment units. In crisis situations, close cooperation between logistics, military engineering, chemical units and medical service specialists is essential to ensure the rapid and effective water supply. Water treatment is always necessary when raw water does not meet potable water quality standards. For this purpose, both mobile and stationary treatment plants are employed, ensuring the production of safe drinking water while adhering to proper technological procedures.

The primary objective of water treatment is the protection of public health. Potable water must be entirely free from pathogenic microorganisms and hazardous chemical substances (Kuzminichuk and Astrelin, 2018). Ideally, drinking water should be clear, without turbidity, unpleasant odor, or taste. The process of producing safe water involves a series of technological steps, which are illustrated in Figure 1.

Substances present in water in colloidal, ionic, or molecular form can be transformed through appropriate chemical reactions into an insoluble state, which enables their removal by sedimentation or filtration (NATO, 2010). This principle underlies water treatment methods based on precipitation. A distinction is made between primary precipitation, which relies on the low solubility of certain compounds such as calcium carbonate (CaCO_3) or magnesium hydroxide ($\text{Mg}(\text{OH})_2$), and secondary processes involving coagulation and flocculation. These processes consist of destabilizing and aggregating colloidal particles using coagulants, most commonly iron or aluminum salts (e.g. FeCl_3 , $\text{Al}_2(\text{SO}_4)_3$), leading to their subsequent settling and removal from water (Bratby, 2016; Sheng *et al.*, 2022; Zaki *et al.*, 2023).

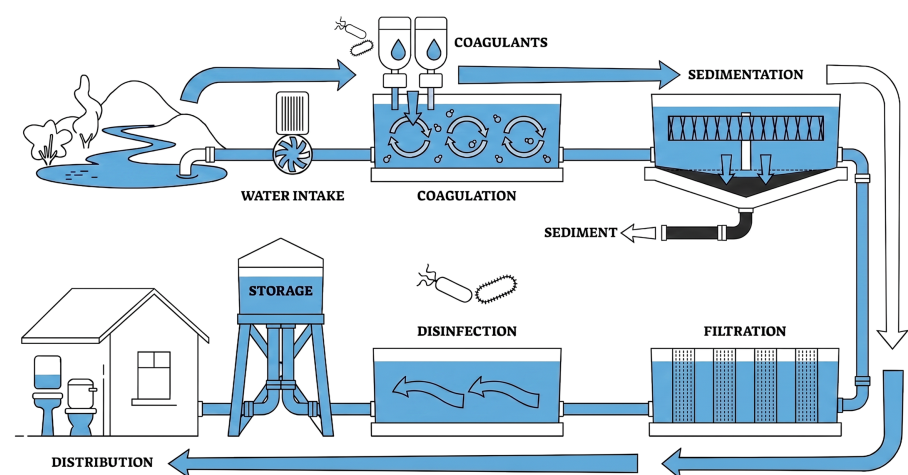


Figure 1. Multiple treatment stages. Source: Authors' own work

Coagulation. This process combines colloidal particles into larger aggregates that can be removed by sedimentation, flotation, or filtration (SDWF, 2019). The addition of a coagulant introduces oppositely charged particles, which neutralize the charges of colloids, cause them to agglomerate and further increase in size under mixing. Aluminum (Al^{3+}) and iron (Fe^{3+}) salts are the most commonly used. In the case of soft water, alkalizing agents (e.g. NaOH or $\text{Ca}(\text{OH})_2$) are added to provide suitable conditions for effective coagulation.

Flocculation. It is a process that facilitates the removal of fine particles from water using flocculants (e.g. activated silica or organic polymers). These agents promote the aggregation of small, suspended particles into larger structures known as flocs. Flocs are formed under slow mixing. Flocculation usually follows coagulation, where chemical additives destabilize fine particles to enable their easier aggregation into larger clusters.

Sedimentation. Sedimentation is a fundamental process in water treatment, designed to separate suspended solids by gravitational settling under quiescent conditions. During this stage, larger particles settle to the bottom, thereby facilitating subsequent purification steps. Sedimentation basins are typically rectangular or circular in plan, with a depth of approximately 3–5 m (Farhaoui and Derraz, 2016; Hinch, 1988). To enhance efficiency, multiple units are often operated in parallel, with clarified water discharged via overflow weirs. Settled sludge accumulates at the bottom and is continuously collected by mechanical scrapers and conveyed to designated hoppers for further processing. The performance of sedimentation depends primarily on the surface area of the basin rather than its depth or total volume; shallow tanks with a larger horizontal area generally achieve higher removal efficiency due to lower surface loading rates (Hinch, 1988).

Filtration. Filtration is an essential treatment step for removing residual suspended particles that cannot be completely eliminated by coagulation, flocculation, or sedimentation. In this process, water passes through a porous medium, such as sand, which effectively retains fine particles, natural organic matter and protozoa (Cescon and Jiang, 2020; Kolya and Kang, 2023). Two main filtration approaches are commonly applied: (1) granular media filtration, where particles smaller than the grain size (typically 0.5–3.0 mm for sand, anthracite, or activated carbon) are removed within the filter bed and (2) depth-aid or precoat filtration, in which suspended solids are captured on a layer of filter aid deposited onto a synthetic fabric or similar support medium. Diatomaceous earth and perlite are most frequently used as filter aids in this process (Shayo et al., 2024).

Membrane processes. They are increasingly applied when conventional treatment methods such as chlorination, coagulation and granular filtration are insufficient to remove trace contaminants, including pesticides and pharmaceutical residues. These processes employ semipermeable membranes to separate substances based on molecular size or chemical properties. Under applied pressure, water is forced through membranes with pore sizes smaller than the retained particles. Membrane technologies encompass microfiltration, ultrafiltration, nanofiltration and reverse osmosis, each providing different degrees of contaminant removal ranging from suspended solids to dissolved organic compounds and inorganic ions (Bodzek and Konieczny, 2018; Kafle et al., 2024; Konradt et al., 2021).

Disinfection. This process represents a critical treatment stage aimed at eliminating pathogenic microorganisms, including viruses, bacteria and parasites. It is typically applied as the final step of water purification to ensure microbiological safety for human consumption. Disinfection is generally divided into primary disinfection, which involves oxidation processes and forms an integral part of groundwater or surface water treatment and secondary disinfection, which ensures hygienic protection of distributed drinking water by maintaining a residual disinfectant effect. Commonly employed methods include chlorination, ozonation, ultraviolet irradiation, chloramination and advanced oxidation processes. The selection of an appropriate disinfection strategy depends on the quality of the raw water, operational costs and requirements for residual disinfectant levels in the distribution system (García-Espinoza et al., 2021; Golfopoulos et al., 2024; Paggiaro et al., 2024). In particular, ultraviolet (UV) systems, while effective, are sensitive to water turbidity, which can reduce disinfection

efficiency; this limitation can be mitigated by coupling UV units with pre-filters to enhance light penetration and overall performance (Gadgil *et al.*, 1998).

2.1.2 Water storage and distribution. Water storage takes place in storage tanks that must secure supplies of both drinking and technical water, considering local climate conditions and demand. Bottled water should be stored in line with manufacturer recommendations and protected from adverse conditions, particularly direct sunlight (NATO, 2022). Drinking water may only be kept in containers and vehicles that have been properly cleaned, inspected and approved by the medical service. Tanks must be cleaned regularly, with the frequency adjusted to local conditions and wastewater from cleaning must be disposed of in compliance with an approved wastewater management plan (NATO, 2022). Tanks intended for potable water must be clearly marked and kept separate to prevent cross-contamination.

Water distribution under emergency conditions relies on two main approaches. The first is piped or hosed supply with strategically placed filling stations. A circulation loop connecting the main storage facilities ensures continuous flow and a reduced risk of contamination. The system should be regularly monitored to minimize water losses. The second method involves delivery by tank trucks, which is essential when treatment plants are located outside consumption areas. Bottled water may serve as a supplementary source. For efficient management, flow meters should be installed on pipelines and vehicles to record distributed volumes and reduce losses. Backflow preventers must be integrated, and potable water must be inspected by medical personnel prior to distribution (Bross *et al.*, 2019; Song *et al.*, 2018).

2.2 Water treatment facilities for crisis management

The following section builds upon a market survey and a technological assessment of water treatment systems. To ensure potable water supply under emergency conditions, the review focuses on units capable of operating in harsh climatic environments while providing sufficient capacity to serve larger populations affected by crisis situations. Within this context, selected mobile water treatment units were analyzed for their applicability in emergency water supply. Although other atmospheric water generators, such as the Water Cat 500, UVA 500 and WTC 700, are available on the market, they were excluded from this evaluation due to their relatively low potable water production capacity. The systems assessed in this review include:

- (1) Crystal Clean Water (CCW) 10,000.
- (2) Mobile Water Trailer (MWT) 1500.
- (3) River Well Technology (RWT) 15 and RWT 100.
- (4) Water Clean System (WTC) 8000/15,000 RO/UF C.
- (5) Solar Air Water Earth Resource (SAWER).

2.2.1 CCW 10000. This unit was developed through cooperation among three entities and represents a modern, efficient solution for converting raw water into potable water. With a maximum capacity of up to 10,000 L/h, the system can meet the daily drinking water needs of approximately 45,000 individuals, assuming an average consumption of 5 L per person per day. The CCW 10000 employs a two-stage purification process. In the first stage, raw water undergoes pretreatment involving the removal of coarse mechanical impurities, pH adjustment using chemical agents and sedimentation of suspended solids through a pulsating clarifier. The water then passes through a floc cloud, which acts as a natural filtration medium. In the second stage, Turbidex filter media are applied to capture fine impurities, followed by granular activated carbon filtration to remove dissolved contaminants such as heavy metals and ammonia. Final disinfection and stabilization are achieved using ultraviolet (UV) irradiation, ensuring both quality and microbiological safety. The unit is

equipped with a pump, a diesel generator and a field kit for water quality monitoring. The total weight of the system is 4,000 kg (CZ Defence, 2025).

2.2.2 MWT 1500. This modern mobile water treatment unit is designed as a flexible solution for rapid deployment in diverse and demanding conditions. Mounted on a trailer, the system is easily transportable and can be immediately deployed in emergency situations, such as natural disasters, or for humanitarian relief operations. The MWT 1500 is capable of effectively removing a wide spectrum of contaminants, including suspended solids, bacteria, viruses, pesticides and heavy metals. With a treatment capacity of 1.0–1.5 m³/h, the unit can supply potable water for up to 7,000 individuals per day, assuming an average daily consumption of 5 L per person. Its power supply is highly adaptable, allowing operation via an electrical grid, a generator, or solar panels, thus providing a practical and sustainable water supply solution in crisis conditions (HUTIRA, 2025).

2.2.3 RWT 100. Containerized water treatment plant is constructed according to ISO 1C standards. They are available in different capacities, which determines whether the plant is configured in two or three containers, depending on the required output. The single-container model with the highest performance, the RWT 15, provides a treatment capacity of 15,000 L/h, with a total weight of 8,800 kg and a power consumption of 12 kW. For higher demand, the RWT 100 offers a capacity of 100,000 L/h. Both systems are equipped with automated operation and remote control, which enhances operational efficiency (IWET, 2018).

2.2.4 WTC 8000/15,000 RO/UF C. Water treatment plant is designed for demanding environments where large volumes of potable water must be supplied rapidly. The unit combines reverse osmosis (RO) and ultrafiltration (UF) technologies, enabling the treatment of saline and brackish water (“WTC 8000/15,000 RO/UF Data Sheet”, n.d.). The system is housed in a standard shipping container for ease of transport and rapid field deployment. A modern control panel provides automated operation, reducing the need for extensive on-site personnel. The total weight of the unit is 9,500 kg. Its performance capacity reaches 8,000 L/h in RO mode and 15,000 L/h in UF mode, corresponding to a daily output of up to 350,000 L. A smaller model, the WTC 3,200, based solely on reverse osmosis, delivers 3,200 L/h. The unit features an adjustable output, offering three selectable performance levels to meet varying operational demands. It is further equipped with dosing capability for up to five dosing pumps, which enhances treatment efficiency. The WTC system provides high durability, resistance to saline water and corrosion, and supports reliable transport with rapid deployment in the field (ESUT, 2025; Kärcher Futuretech, 2025).

2.2.5 SAWER. The system is based on innovative technology capable of extracting water directly from the atmosphere in arid regions. It is a fully autonomous unit operating on a two-stage principle. In the first stage, a specialized desiccant material captures water vapor from the air. In the second stage, the vapor is released and subsequently condensed, producing water ready for further use. The system is designed for energy self-sufficiency through the integration of solar thermal collectors and photovoltaic modules, while also offering flexible power options (grid electricity or solar energy). The total weight of the unit is 6,000 kg. Under humid conditions, SAWER can produce up to 1,000 L/day when powered by electricity, and approximately 590 L/day when operating solely on solar power (SAWER, 2025).

3. Methods

As part of the literature review, an analytical approach was applied with the restriction that only water treatment facilities suitable for deployment in crisis situations were considered. The selected systems had to be capable of operating under demanding climatic conditions while providing sufficient capacity to supply potable water for larger populations. Units with low production capacity were excluded from the analysis, as outlined in Section 2.2.

The comparative evaluation of the selected units was carried out using the AHP, also known as Saaty's method. This decision-making approach enables the systematic and objective assessment of complex problems by structuring criteria and alternatives into a hierarchical model (Grasseová *et al.*, 2010). In this study, AHP was applied to calculate the weights of evaluation criteria and to select the most suitable water treatment unit for a model emergency scenario. Six evaluation criteria (K1–K6) were defined to facilitate the comparison of alternatives:

- (1) K1 “Capacity”: Maximum water treatment capacity (L/day).
- (2) K2 “Desalination”: Capability to process different water sources (freshwater, brackish water, seawater, atmospheric water).
- (3) K3 “Disinfection”: Disinfection and filtration methods.
- (4) K4 “Energy”: Energy requirements and the possibility of solar operation.
- (5) K5 “Weight”: Weight of the facility.
- (6) K6 “Mobility”: Mobility of the facility.

For context, ten mutually independent criteria – including costs, ease of deployment, ease of use, environmental impact, maintenance, performance, potential acceptance, energy requirements, supply chain demands and throughput – are typically identified to evaluate emergency water treatment units (Loo *et al.*, 2012). A scoring system based on these ten evaluation criteria has been developed. In contrast, for this study, a distinct set of six criteria was selected by the expert group, reflecting the specific operational priorities and constraints of mobile water treatment in crisis scenarios. This expert-driven selection ensured that the chosen criteria were directly relevant to the practical requirements of emergency water supply interventions.

From a logistics and supply chain management perspective, the selected criteria reflect key operational requirements associated with humanitarian logistics and crisis-response systems. Capacity and desalination capability influence the scalability and continuity of supply, while mobility and weight affect transportability, deployment speed and accessibility in disrupted environments. Energy autonomy is directly connected to supply chain resilience, as dependence on fuel or electricity infrastructure may limit operational sustainability during emergencies. The selected evaluation framework therefore integrates technical performance with logistical feasibility, enabling decision-makers to assess water treatment technologies not only from an engineering perspective, but also in terms of operational adaptability and crisis logistics effectiveness.

Among these, K1 (capacity) was considered the most important, since a stable daily output of approximately 800,000 L/day is essential. Units with insufficient throughput would not be able to supply the affected population adequately. Given the possibility of deployment in areas with brackish water, K2 (desalination) was also prioritized, as non-desalinating units would have limited applicability. K3 (disinfection) reflects the requirement that potable water must meet strict hygienic standards; therefore, the presence of reliable disinfection and filtration technologies (e.g. filtration, chlorination and reverse osmosis) is essential. In emergency operations, an independent energy supply is advantageous, making units with lower consumption or solar-powered options (K4) more practical than those relying solely on fuel. While heavier systems are less flexible and harder to transport, K5 (weight) is not critical if the unit is intended for long-term deployment. Finally, K6 (mobility) enhances operational efficiency, with trailer-mounted or portable systems preferred over containerized solutions that require specialized transport vehicles.

The evaluation incorporated both qualitative and quantitative criteria, enabling a comprehensive comparison of the alternatives. Pairwise comparisons were conducted using Saaty's 1–9 scale, where evaluators assign relative importance values between criteria. In

defining the criteria for selecting a water treatment unit, a five-member team was established and applied a structured approach. The team included specialists in technical, environmental, chemical and administrative fields, along with one representative of end users. Each member thus contributed a distinct perspective. The technical expert assessed performance parameters such as output, capacity and water quality; the environmental specialist evaluated ecological impacts; the administrative expert addressed legal and regulatory requirements; the chemist examined the technological process; and the user representative provided insights from the perspective of the final operator. The team reached consensus on two key questions: *What parameters must the unit meet? What are the long-term requirements for water treatment facilities?* Financial aspects were excluded from the discussion. The criteria defined through this process and applied within Saaty's AHP are presented in [Table 1](#).

The calculation of unnormalized weights for each criterion was based on the geometric mean, defined as the n -th root of the product of all relevant values, where n represents the total number of values ([Equation 1](#)). Normalized weights were subsequently derived using [Equation \(2\)](#). The overall score of each alternative was then calculated as the weighted sum of partial evaluations across all criteria ([Equation 3](#)).

$$v_i = \sqrt[n]{\prod x_{in}} \quad (1)$$

$$h_{ij} = \frac{v_i}{\sum_{i=1}^n v_i} \quad (2)$$

$$H^j = \sum_{i=1}^n v_i \cdot h_i^j \quad (3)$$

where v_i is unnormalized weight of the i -th criterion; i is the criterion 1, 2, . . . , n ; n is the total number of criteria; x_{in} is importance value of the i -th criterion in the n -th column; h_{ij} is normalized weight of the i -th criterion, v_i is total of unnormalized weights; H^j is total score of the j -th alternative, weight of the i -th criterion; h_i^j is partial score of the j -th alternative with respect to the i -th criterion; i is the criterion 1, 2, . . . , n ; and j is number of alternative 1, 2, . . . , m ([Grasseová et al., 2010](#)).

To ensure methodological reliability, the consistency ratios (CR) were calculated for all pairwise comparison matrices and a sensitivity analysis was conducted to examine how changes in criterion weights – such as increased emphasis on mobility or energy autonomy – might affect the stability of the rankings. This confirmed that the overall prioritization of alternatives remained robust under plausible variations.

Table 1. Saaty's method criteria

Descriptor	Value	Reciprocal value
Criteria are equally important	1	1
Criterion in the row is slightly more important	3	1/3
Criterion in the row is moderately more important	5	1/5
Criterion in the row is strongly more important	7	1/7
Criterion in the row is absolutely important	9	1/9

Source(s): [Grasseová et al. \(2010\)](#)

4. Results and discussion

4.1 Evaluation of water treatment facilities based on defined criteria

Table 2 lists the selected water treatment units alongside the evaluation criteria (K1–K6), while Table 3 summarizes the relative importance of each criterion. The criteria were assessed through a brainstorming session and compared pairwise using Saaty’s nine-point scale, which expresses the relative significance of one criterion over another (Saaty, 2000).

Diagonal values are 1, reflecting the equal importance of identical criteria. K1 (Capacity) is slightly more important than K2 (Desalination), with a value of 3, whereas K1 compared to K5 (Weight) yields 7, indicating that capacity is substantially more critical than weight.

The geometric mean v_i was calculated for each criterion to determine unnormalized weights. For instance, $v_4 = 0,7937$ for K4. Summing the geometric means produces a total of 8.3604, which was then normalized to obtain relative weights, expressing each criterion’s importance in the overall decision-making framework. The normalized weights sum to 1, ensuring consistency in accordance with multi-criteria decision analysis principles.

This methodology ensures objectivity in evaluating criteria importance and provides a quantitative basis for comparing water treatment units under crisis conditions. The established weights were subsequently applied in Section 4.2 to allow a transparent and reproducible ranking of alternatives.

4.2 Comparison of water treatment facilities based on evaluation criteria

Pairwise comparison of water treatment variants A–E was conducted according to the defined criteria, summarized in Table 4. In the Saaty matrix for K4 (Energy Efficiency), repeated values reflect the technological similarity among most units. Energy efficiency strongly

Table 2. Defined evaluation criteria

Title	K1	K2	K3	K4	K5	K6
CCW 10000 (A)	240,000	NO	UV, chlorination	Diesel	4,000	ISO container
MWT 1500 (B)	36,000	NO	UV, filtration	Solar panels	1,300	Trailer
RWT 15 (C)	240,000	YES	UV, filtration	Diesel	8,800	ISO container
WTC 8000/15,000 (D)	192,000–360,000	YES	RO, ultrafiltration	Diesel	9,500	ISO container
SAWER (E)	6,720–24,000	NO	UV, mineralization	Solar panels	6,000	ISO container

Source(s): Authors’ own work

Table 3. Determination of criteria weights using Saaty’s method

Criteria	K1	K2	K3	K4	K5	K6	v_i	h_{ij} [%]
K1	1	3	5	4	7	6	3.6889	44.12
K2	1/3	1	4	3	5	4	2.0758	24.83
K3	1/5	1/4	1	2	3	3	0.9826	11.75
K4	1/4	1/3	1/2	1	3	2	0.7937	09.50
K5	1/7	1/5	1/3	1/3	1	2	0.4303	05.14
K6	1/6	1/4	1/3	1/2	1/2	1	0.3891	04.66
Total							8.3604	100.00

Source(s): Authors’ own work

Table 4. Evaluation of variants A–E using Saaty’s method

Variant	A	B	C	D	E	v_i	h_{ij}
<i>K1 capacity</i>							
A	1	3	5	4	7	1.6952	0.3343
B	1/3	1	4	3	5	0.3589	0.0708
C	1/5	1/4	1	2	3	0.7248	0.1429
D	1/4	1/3	1/2	1	3	1.2457	0.2457
E	1/7	1/5	1/3	1/3	1	1.0456	0.2062
Total						5.0702	1.0000
<i>K2 desalination</i>							
A	1	1	1/5	1/5	1/5	0.3807	0.0590
B	1	1	1/3	1/4	1/6	0.4251	0.0658
C	5	3	1	1	1/2	1.4963	0.2317
D	5	4	1	1	5	2.5119	0.3890
E	5	6	2	1/5	1	1.6438	0.2545
Total						6.4578	1.0000
<i>K3 disinfection</i>							
A	1	3	3	1/5	2	1.2920	0.1711
B	1/3	1	1	1/7	1/2	0.4735	0.0627
C	1/3	1	1	1/7	1/2	0.4735	0.0627
D	5	7	7	1	8	4.5546	0.6031
E	1/2	2	2	1/8	1	0.7579	0.1004
Total						7.5515	1.0000
<i>K4 energy</i>							
A	1	1/5	1	1	1/7	0.4911	0.0674
B	5	1	5	5	2	3.0171	0.4140
C	1	1/5	1	1	1/7	0.4911	0.0674
D	1	1/5	1	1	1/7	0.4911	0.0674
E	7	1/2	7	7	1	2.7980	0.3839
Total						7.2884	1.0000
<i>K5 weight</i>							
A	1	1/3	3	3	1/2	1.0845	0.1965
B	3	1	1/8	1/4	1/6	0.4353	0.0789
C	1/3	8	1	1/2	4	1.3977	0.2533
D	1/3	4	2	1	1/5	0.8819	0.1598
E	2	6	1/4	5	1	1.7188	0.3115
Total						5.5182	1.0000
<i>K6 mobility</i>							
A	1	3	1	3	1	1.5518	0.2720
B	1/3	1	1/3	1/3	1/3	0.4152	0.0728
C	1	3	1	1	1	1.2457	0.2184
D	1	3	1	1	1	1.2457	0.2184
E	1	3	1	1	1	1.2457	0.2184
Total						5.7041	1.0000

Source(s): Authors’ own work

influences both economic and environmental aspects of a water treatment project and should therefore be prioritized in selecting treatment units (Magni *et al.*, 2025). Most units rely on diesel generators, resulting in nearly identical scores, whereas Units B (MWT 1500) and E (SAWER) incorporate solar panels, which accounts for their higher relative weights. Consequently, diesel-powered units were rated evenly, while solar-powered systems demonstrated greater importance due to their renewable energy capability. From a crisis

logistics perspective, energy-autonomous units allow extended operation without relying on fuel supply chains, reducing vulnerability in remote or resource-constrained environments.

Regarding K5 (Weight), lower mass facilitates handling and transport but may reduce performance and treatment capacity. In practice, available transport options mitigate these disadvantages, rendering weight a secondary consideration relative to overall system efficiency. For K6 (Mobility), ISO containers provide an optimal solution, combining high capacity with universal transportability. Their standardized dimensions allow efficient handling across rail, road and air, while also offering modularity, protection of installed technology, and ease of manipulation. Trailer-mounted or portable system are more flexible for rapid, short-term deployments, whereas containerized solutions are preferable for sustained operations where throughput and equipment protection are priorities. These findings illustrate the trade-offs between strategic reach (containerized units) and tactical agility (trailer systems), which are central to logistical decision-making in crisis response.

Table 5 presents partial and weighted scores for all variants across criteria K1–K6, with overall rankings reflecting normalized weights. Variant D (WTC 8000/15,000) emerges as the most suitable option due to high capacity, desalination ability and comprehensive treatment quality, while Variant B (MWT 1500) ranks lowest primarily due to limited throughput despite advantages in trailer mobility and renewable power options. A sensitivity analysis confirmed the robustness of these rankings: even when weights for mobility or energy autonomy were increased, Variant D retained its top position, demonstrating stability of the prioritization and reinforcing the reliability of operational recommendations.

In crisis situations, the primary objective is to ensure rapid access to safe drinking water, often taking precedence over financial considerations. Operational feasibility – including energy consumption, filter replacement, chemical requirements, routine maintenance, transport, installation and availability of spare parts – remains critical, particularly during extended deployments. Acquisition costs depend on unit specifications and applied technology, yet operational requirements frequently outweigh initial purchase price in emergency contexts. Units with advanced technologies such as reverse osmosis are essential for heavily contaminated sources, whereas mechanical filtration or UV sterilization may suffice for less polluted water. These observations provide actionable guidance for emergency planners, linking the technical characteristics of treatment units to logistical constraints and decision priorities.

Each crisis scenario requires a context-specific approach, considering contamination type, water availability, capacity needs and treatment speed. Evaluation criteria should therefore remain adaptable, allowing relative weighting to reflect operational priorities. Although financial aspects were excluded from the AHP evaluation due to limited data and situational imperatives, future studies could incorporate cost-efficiency alongside technological suitability, further strengthening the decision-support capability of the framework. Overall, this analysis demonstrates that a structured, multi-criteria assessment can directly inform both strategic and operational planning for mobile water treatment deployment under humanitarian and disaster-response conditions.

The findings have implications for crisis logistics and supply chain management in the CEE region, where infrastructure vulnerability and increasing exposure to natural and geopolitical risks require flexible and rapidly deployable water supply solutions. Mobile water treatment technologies therefore represent an important component of emergency preparedness and operational resilience in these systems (Song *et al.*, 2018).

4.3 Analytical discussion and methodological considerations

The results highlight the critical intersection of technical performance and crisis logistics. Recent research on infrastructure recovery in conflict-affected regions further emphasizes the importance of resilience-oriented decision-support frameworks for prioritizing critical infrastructure and allocating limited resources under disrupted operational conditions

Table 5. Selection of the optimal variant based on defined criteria

Criterion	Normalized weight	Partial scores					Weighted partial scores				
		A	B	C	D	E	A	B	C	D	E
K1	0.4412	0.3343	0.0708	0.1429	0.2457	0.2062	0.1475	0.0312	0.0631	0.1084	0.0910
K2	0.2483	0.0590	0.0658	0.2317	0.3890	0.2545	0.0146	0.0163	0.0575	0.0966	0.0632
K3	0.1175	0.1711	0.0627	0.0627	0.6031	0.1004	0.0201	0.0074	0.0074	0.0709	0.0118
K4	0.0950	0.0674	0.4140	0.0674	0.0674	0.3839	0.0064	0.0393	0.0064	0.0064	0.0365
K5	0.0514	0.1965	0.0789	0.2533	0.1598	0.3115	0.0101	0.0041	0.0130	0.0082	0.0160
K6	0.0466	0.2720	0.0728	0.2184	0.2184	0.2184	0.0127	0.0034	0.0102	0.0102	0.0102
Total							0.2114	0.1017	0.1576	0.3006	0.2286
Position							3	5	4	1	2
Source(s): Authors' own work											

(European Commission, 2015, 2022; Kopsiika *et al.*, 2025). In particular, studies focusing on Ukraine demonstrate that structured evaluation approaches are essential for guiding recovery strategies in environments affected by large-scale infrastructure destruction and constrained logistics capacities. These findings align with the present study, where the AHP-based framework provides a systematic tool for selecting mobile water treatment units as part of resilient crisis logistics and emergency supply chain systems in the CEE context. Units combining high capacity, energy efficiency and mobility provide the greatest operational flexibility, supporting rapid deployment and modular operation under diverse conditions. ISO-container systems exemplify this balance, allowing integration into existing transport networks while safeguarding sensitive equipment.

Methodological limitations of the analysis must also be acknowledged. The AHP relies on expert judgment for pairwise comparisons and weighting, introducing subjectivity. Furthermore, criterion importance is highly context-dependent; different crisis scenarios may require reweighting of factors such as energy efficiency, mobility, or weight. For example, in scenarios where transport infrastructure is constrained, mobility may become the dominant criterion, whereas in energy-limited environments, solar autonomy may weigh more heavily.

Nevertheless, the structured multi-criteria approach enhances transparency, consistency and repeatability, enabling informed decision-making in emergency water provision. The study demonstrates how AHP can systematically guide operational and strategic choices, while acknowledging that results are scenario-specific and contingent upon expert composition and context.

Future research could expand expert panels, incorporate operational field data and simulate scenario-specific variations to strengthen robustness. Effective selection of mobile water treatment units in emergencies requires balancing technical suitability, logistical feasibility and context-specific adaptability, ensuring timely access to safe water while optimizing resource allocation.

4.4 Methodological considerations and limitations

The application of the AHP enabled a structured, multi-criteria evaluation of mobile water treatment units for emergency deployment. Pairwise comparisons, however, inherently rely on expert judgment and may introduce subjectivity.

To address this, structured group discussions, cross-validation of individual assessments and iterative refinement of inconsistent entries were employed. Consistency ratios were calculated for all comparison matrices to ensure adherence to Saaty's standards.

Sensitivity analyses examined how variations in criterion weights affect the ranking of alternatives, confirming that the prioritization remains stable even under increased emphasis on mobility or energy autonomy. Nonetheless, the results remain context-dependent, reflecting specific operational scenarios, expert panel composition and the set of selected criteria.

While the framework provides a transparent and reproducible approach for prioritizing water treatment units, its application should consider scenario-specific adjustments. The approach contributes to the literature by linking technical performance to operational decision-making and providing a quantitative, transparent tool for crisis logistics planning.

Overall, acknowledging these methodological considerations – subjectivity, context dependence and the necessity of consistency and sensitivity checks – ensures that the AHP-based findings are interpreted with appropriate caution, while still offering actionable guidance for strategic, operational and methodological decisions in emergency water supply.

5. Conclusion

Securing safe drinking water under crisis conditions constitutes a core logistical challenge; mobile water treatment technologies provide a strategic capability for emergency response. Using a structured, multi-disciplinary criteria set and the AHP, five candidate systems were

compared across six dimensions: capacity, desalination capability, treatment/disinfection, energy, weight and mobility. The analysis indicates that high and stable throughput, the ability to treat brackish or saline water sources and robust treatment trains are decisive for large-scale, time-critical operations, while energy autonomy and mobility shape sustainment and deployment options. These insights enable emergency planners to align technological selection with available transport and energy resources, ensuring that units can be deployed rapidly and maintained efficiently in diverse crisis scenarios.

The AHP results identify WTC 8000/15,000 as the optimal plant for the model crisis scenario, due to strong performance in capacity, desalination (RO/UF) and overall treatment quality, with acceptable trade-offs in weight and containerized form factor. MWT 1500 ranks lowest, primarily because of limited throughput despite advantages in trailer mobility and renewable power options. Selecting a portfolio of complementary systems, including both high-capacity containerized units and lighter, more mobile systems, allows response organizations to optimize water provision across different scales and types of emergencies. These findings support evidence-based procurement and planning by linking technology characteristics to logistical constraints and mission profiles. Integrating high-capacity, desalinating, containerized systems such as WTC 8000/15,000 – complemented by lighter trailer units for niche tasks – can enhance the resilience of water supply during natural disasters and armed conflict.

In crisis situations such as natural disasters or humanitarian emergencies, the primary goal is to provide rapid access to safe drinking water, with financial considerations secondary to health protection and life preservation. However, logistical challenges and costs cannot be ignored, especially for long-term deployment of mobile water treatment units, where operational costs are critical. The choice of technology for drinking water supply depends on the level of water contamination and the available resources, with advanced methods like reverse osmosis for heavily polluted water, while cheaper solutions may suffice for less contaminated sources. The framework presented in this study not only guides immediate deployment decisions but also serves as a transparent, reproducible tool for scenario planning, helping organizations anticipate logistical bottlenecks and optimize resource allocation. The study is particularly relevant for CEE countries, where recent geopolitical developments, infrastructure vulnerability and climate-related risks have increased the importance of resilient crisis logistics and emergency supply chain systems. The war in Ukraine has demonstrated the necessity of decentralized, rapidly deployable water supply solutions capable of operating independently of damaged infrastructure and unstable energy networks. In this context, mobile water treatment technologies represent an important component of regional resilience, humanitarian response capability and civil–military logistical preparedness. The proposed AHP-based framework may therefore support public authorities, armed forces and humanitarian organizations in the CEE region when planning emergency water supply capacities and selecting suitable technologies for different crisis scenarios. Future research should assess conditions, logistics and effectiveness of these units in specific crisis scenarios.

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