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Review Article

INNOVATIVE SOLUTIONS FOR FLOOD RISK MANAGEMENT

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Abstract: Starting from the importance of innovative solutions for improving the needs of different practitioners as flood risk managers, the purpose of this review was to describe and analyze, evaluates, and prioritizes the various available different innovative solutions that have sufficient potential to be useful and used by practitioners. A systematic review of the literature was conducted using the DAREnet knowledge base (an integral feature of the DAREnet online community platform) which identified critical challenges for flood management and the relevant field or source of innovation, as well as the current scientific literature in the field of disaster studies. A fourth stage selection procedure identified candidate original or review papers and evaluated the degree to which papers met predetermined requirements for inclusion extracted from prior systematic reviews. Included in the study were over 100 studies that met the requirements for predetermined inclusion. The findings of this review showed that there is a huge untapped potential for innovative solutions in the field of prevention, preparedness, civil protection, communication, cooperation, etc. The findings of this review contribute to a growing body of knowledge regarding innovative solutions for flood risk management useful for practitioners.

Keywords: disasters, floods, risk management, innovative solutions, review, DAREnet.

1. Introduction

In disaster studies, there are different definitions of disaster risk management: a) discipline and profession that applies science, technology, planning and management to control extreme events that can injure or kill large numbers of people, cause great damage to property and disrupt life in society (Phillips & Jenkins, 2010, p. 26); b) risk management so that societies can live with natural and technical hazards and control the disasters they cause (Waugh, 2001, p. 98); c) discipline dealing with risk and risk avoidance (Haddow, Bullock, & Coppola, 2007, p. 76); g) state of responsibility and capacity for management of all types of disasters, through coordination of actions of a number of entities and protection and rescue forces (Flint & Brennan, 2006, p. 2). Certainly, it should be noted that there is a difference between traditional and modern disaster management and it is reflected in the modes of operation, organizational structure, character of information, goals and criteria of management (McLoughlin, 1985, p. 53). Dragićević et al. (2009) explicitly emphasize the modern approach to managing the risks of natural disasters, implying three main phases of analysis and planning: risk analysis (risk analysis) - identification of possible natural disasters that may occur in a particular area, as well as the consequences that may cause; risk assessment - selection and selection of the most significant, priority risk in a certain area, based on a comparative analysis of all potential risks; and risk management - the final phase of a risk study in a particular territory.

Integrated management of natural disasters assumes that people can recognize, identify and assess many risks of natural disasters. It is a systematic approach that includes risk assessment, prevention, mitigation and preparation for natural disasters (Zhang, Okada, & Tatano, 2006). According to the Law on Disaster Risk Reduction (Official Gazette of the Republic of Serbia, 87/18), risk management is a set of measures and activities implemented with the aim of implementing disaster risk reduction policy, as well as administrative-operational and organizational skills and capacities for their implementation. Thus, it is a policy that is established and conducted to prevent new or reduce existing risks by implementing integrated and inclusive economic, social, educational, normative, health, cultural, technological, political and institutional measures, which strengthen the resilience and preparedness of the community. In recent decades, the focus has shifted from the concept of "disaster recovery and response" to the concept of "risk management and mitigation". The change also relates to a shift from an approach that focuses primarily on hazard as a key causal factor and to reducing risk through the use of physical protection measures, to an approach that focuses on community vulnerability and ways to reduce that vulnerability by implementing a warnings (Cvetković, 2020). The three key phases in disaster risk management are: a) the pre-disaster phase (preventive and proactive); b) disaster phase (reactive); and c) the disaster recovery phase. Within the first phase, activities are undertaken aimed at reducing potential and material losses in the event of a natural disaster (Haque, 2005). Preparedness includes measures that enable authorities, communities and individuals to respond quickly to disasters in order to deal with them effectively (Brown, 1993). It involves designing sustainable disaster plans, developing warning systems, maintaining inventory and training emergency services (Edward, 2005). In contrast to preparedness, mitigation includes measures to reduce the impact of natural disasters in order to reduce the scale of future disasters. (Shneid, 2001). Thus, mitigation activities may relate to the disaster itself or to the elements exposed to the threat. Examples of mitigation measures are water management in drought-prone areas, relocating people away from areas prone to some types of natural disasters, and strengthening structures to reduce damage when a disaster strikes (Aleksandrina, Budiarti, Yu, Pasha, & Shaw, 2019; Chapman, 1999; Cvetković & Janković, 2020; Cvetkovic, 2019; Mano & Rapaport, 2019; Ocal, 2019; Perić & Cvetković, 2019; Vibhas, Adu, Ruiyi, Anwaar, & Rajib, 2019; Cvetković, 2020).

In the literature, as Cvetković (2019) points out, the proactive phase includes the following activities: risk assessments, measures to prevent and mitigate natural and technological hazards; measures to improve structural and non-structural preparedness; formulation and implementation of disaster management policies and programs; risk monitoring; development of protection and rescue plans; warning, information and alert systems, education and training of citizens for proper and safe handling In the second phase (reactive) means activities, measures and actions taken to take care of victims as effectively as possible and reduce the damage suffered. The second phase (reactive) implies activities, measures and actions that are taken in order to take care of the victims as effectively as possible and reduce the damage suffered (Brown, 1993). The activities undertaken at that stage are called immediate disaster response measures. It includes all strategic, operational, tactical and technical measures for protection and rescue of people and their property from short-term or long-term consequences of manifested dangers. The mentioned measures are aimed at saving lives, reducing damage to property and increasing the recovery rate in the shortest possible time (Hussaini, 2020; Kaur, 2020; Thennavan, Ganapathy, Chandrasekaran, & Rajawat, 2020). In this phase, as Cvetković points out, the intervention and rescue services are taking all operational measures that are within their competence, using the material and technical means at their disposal, in order to save people and their property (Cvetković, 2019, p. 27). The post-disaster phase involves taking the initiative to respond to the rapid recovery of the affected population immediately after the disaster has occurred. Such activities are called rapid response and recovery measures (González, 2005). It includes a variety of activities such as reconstruction, reconstruction, restoration, rehabilitation and post-disaster redevelopment measures. All activities that are directly or indirectly undertaken in order to transform the harmful effects of danger, returning people to normal flows fall into the mentioned phase of integrated disaster risk management (Cvetković, 2020). In order for flood risk management to be able to respond effectively to all requirements, it is necessary to continuously monitor innovative solutions in all mentioned segments. Thereby, innovation is something new, productive or creative that has been introduced and then incorporated into a market or process, and occurs in several ways (Alexy & Dahlander, 2013; Guerriero & Penning-Rowsell). That is why it is necessary to conduct research with the aim of identifying and selecting the best solutions in this area, in order to improve the process of disaster risk management. A very significant initiative to improve creative strategies for flood risk management is the DAREnet project (http://darenetproject.eu/) which is creating a diverse multi-disciplinary community of professionals working in a network of civil protection organisations. In addition, a diverse variety of partners from politics, business and research endorse the network. Together, they are developing an interdisciplinary ecosystem that promotes synergies, creativity and its adoption in the Danube region On the other side, in the Danube River Region, the DAREnet project will enable Flood Management Practitioners which is important for connecting and exchanging with national and European stakeholders in a fully open environment; finding and evaluating specific innovation gaps on their own; turning gaps into a collective innovation plan with a view to enhancing future flood resilience (http://darenetproject.eu/).

2. Methods

Aim

The purpose of this review was to describe and analyze, evaluates and prioritizes the various available different innovative solutions that have sufficient potential to be useful, usable and used by practitioners. A systematic review of the literature was conducted using the

DAREnet knowledge base (https://cmt.sym.place/knowledge/group/152285/all) which identified critical challenges for flood management and the relevant field or source of innovation, as well as the current scientific literature in the field of disaster studies.

Search strategy

To find appropriate research, a search of electronic databases was performed. DAREnet Knowledge Base, Web of science, SCOPUSS, google scholar, were the main source used for literature searches. Darenet knowledge base is integral feature of the DAREnet online community platform which identified critical challenges for flood management and the relevant field or source of innovation. It has a standards for describing, cross-referencing and categorising the entries. Also, a vast range and types of potential innovations is structured and categorised: technical and non-technical, mature (on the market or high TRL) or emerging (low/medium TRL, requiring additional RTD), low cost or requiring major investments and third party support, limited or extensive training needs, etc (DAnube river region Resillience Exchange network, No 740750).

Inclusion and exclusion criteria

Articles were considered for review if the objective of the research was some kind of inovative solutions for flood risk management. Furthermore, articles were included for review if they met the following criteria: (1) peer-reviewed, (2) useful and used by practitioners and (3) related to these topics prevention, preparedness, civil protection, communication, cooperation, information, communication and cooperation, (4) related to subtopics as technical equipment, tactical logistics, human factors/lessons-learned, standardisation, warning systems, flood risk maps, evacuation plans, supply and logistics and etc. that did not attempt to measure preparedness of nurses were excluded from review. Articles that included some unusable solution, insufficiently tested, scientifically unproven were excluded from review.

Search outcomes

The initial search resulted in 458 papers and this number diminished to 158 after a review of titles and abstracts found that 300 articles had no relevance to the objectives of the review. A full text reading of the remaining articles resulted in 100 studies that were considered appropriate for review.

3. Results and discussion

Results are divides in fourth parth: innovative solutions for flood prevention; innovative solutions for flood preparedness and mitigation; innovative solutions for flood response; and innovative solutions for flood recovery.

3.1. Innovative solutions for flood prevention/mitigation

Literature review identified a large number of innovative solutions for flood prevention (Wang et al., 2017; Priyadarshinee et al., 2015; Gevorkov et al. 2019; Petit-Boix et al. 2017; Kim & Lee, 2015). For example, Eijgenraam et al., 2017 proposed a dike height optimization model to determine economically efficient flood protection standards. Then, Klerk et al. (2020) described a greedy search algorithm that can find (near) optimal combinations of reinforcement measures for dike segments. On the other side, Berkhahn et al. (2019) suggested a design strategy to maximize the stabilization of the dike structure. In order to make this computationally feasible, they used a greedy search algorithm, for which they derived heuristic rules that could be used for designing dike strengthening projects in flood protection systems with a wide number of independent components. Then, Vuik et al. (2019) showed that marsh elevation change due to sediment accretion mitigates the increase in wave height, thereby elongating the lifetime of a dike-foreshore system. Liu et al. (2020) suggested a flood hazard resilience assessment model based on an updated random forest model used to address the issue of fuzziness in resilience assessments. The model uses the whale optimization algorithm (WOA) to evaluate key parameters in the conventional random forest regression (RFR) model and incorporates the assessment index set by the Driving Forces-Pressure-State-Impact-Response (DPSIR) model to output the resilience index of the study area. Adeniyi et al. (2019) produced a maturity model for assessing flood resilience capability maturity of businesses, and technically provides an outline of steps for improving flood resilience of business premises.

On the other side, Petit-Boix et al. (2017), proposed use of green and grey stormwater management infrastructures, such as the filter, swale and infiltration trench (FST), to prevent flooding events. Estrela et al. (2017) discussed how Emergency Response (ER) structures can be modeled as a Cyber-Physical System (CPS) with control units, sensors, and actuators for environmental observing. Regarding to that, authors proposed the ways that salvaged electronic components can assist far away and economically deficient locations. In the field of information technologies that can be used in flood prevention, Petit-Boix -Suchoń' (2017) showed the possibilities of using advanced methods of GPR signal processing and its analysis with the help of signal attributes for detecting zones threatening the stability of the structure of flood embankments. Author propose quick detection of potential weak zones of the embankments, and consequently give means to ameliorate them, which may prevent damage to the embankments during rise in the level of river water. On the other side, Priyadarshinee et al. (2015) were employing Wireless Sensor Networking (WSN) technology for predicting & preventing the flooding condition. WSN is preferred due to its cost effectiveness, faster transfer of data & accurate computation of required parameter for flood prediction & prevention. Another beauty of the WSN technology is that we could compute the required parameter by considering very few number of environmental parameter. Saravi et al. (2019) used the application of the state-of-the-art techniques i.e., Machin Learning (ML) approaches on big data, collected from previous flood events to learn from the past to extract patterns and information and understand flood behaviours in order to improve resilience, prevent damage, and save lives. The classification results can lead to better decision-making on what measures can be taken for prevention and preparedness and thus improve flood resilience. O'Donnell et al. (2018) evaluated the LAA (Learning and Action Alliance) framework as a catalyst for change that supports collaborative working and facilitates transition to more sustainable flood risk management.

In 2017, Wang et al. investigated the possibility of creating a kind of artificial flood-prevention stone using the alkali-activated process of Yellow River silt. The findings of their work revealed that the specimen made from the optimum proportion of the mix will fulfill the flood-prevention stone criterion. The results on the compressive strength of the artificial flood-prevention stone of alkali dose, slag content and curing age were analyzed. In order to stop unintended faults of the electric drives or the pumps themselves, Gevorkov et al. (2019) suggest a way to build a smart control device for fault diagnosis of pumping stations. Suryaman (2020), proposed flood control model using a pump house system interconnection to minimize water logging, accelerate the water flow process and maximize already current reservoir activity and work. Via one-dimensional numerical analysis, Kim & Lee (2015) demonstrated the efficacy and efficiencies of flood prevention measures and the purpose of this research is to help water management make effective decisions by using the XP-SWMM two-dimensional urban run off model in the flooded region and contrasting it with flood prevention measures. Örs (2018), studies the strategies and scenarios of green infrastructure applied to facilitate the convergence of the use of green infrastructures to reduce the danger of urban flooding and to promote new solutions for ecosystem services in policy and planning principles, including the potential introduction of urban green developments. Nikonorov at al. (2016), based their work on analysis of flood events using GIS-environment and managerial solutions to prevent them. They developed the test models, which allow analyzing possible engineering solution with the aim of minimization of risks and consequences.

Wang et al. (2019) presented a new model for the forecast of urban flooding under heavy rainfall. The model divides an irregular metropolitan region into several grid cells with no spatial resolution constraint as long as DEM data of the same resolution are available. It is capable of representing regular inflow or outflow interactions between grid cells and of collecting the rapid generation of surface runoff in urban areas during heavy rainfall. The model also represents the usual features of urban environments, such as large impermeable surfaces and urban drainage networks, in order to predict urban flooding more realistically. From the other side, Petit-Boix et al. (2017) proposed an integrated eco-efficiency solution to flood prevention and preventative loss. Their aim was to assess the viability of post-disaster emergency actions carried out after a major catastrophe through an integrated hydrological, environmental and economic strategy. The Life Cycle Assessment (LCA) and Cost Assessment (LCC) were used to evaluate the eco-efficiency of these activities, and their net effect and payback were measured by combining avoided flood damage. Khalid and Ferreira (2020) presented a newly developed real-time total water flood guidance system that is fully automated on the basis of the coupled wave model (ADCIRC + SWAN) and provides forecasting of the water level in the Chesapeake Bay for a lead time of 84 h twice a day on a web-based public interface. In addition, it has been shown that the bias adjustment scheme and the multi-member ensemble forecast boost the overall flood forecast.

Integrated long-term memory (LSTM) and reduced order model (ROM) architectures were developed by Hu et al. in 2019. Furthermore, this combined LSTM-ROM is capable of reflecting the spatial-temporal propagation of floods, taking advantage of both ROM and LSTM. Wu et al. (2020) established an urban flood data warehouse with available structured and unstructured urban flood data. Based on this, a regression model to predict the depth of urban flooded areas was constructed with deep learning algorithm, named Gradient Boosting Decision Tree (GBDT). Insights into the factors for determining strategic goals for urban green space planning, in particular for flood protection and the co-leverage of flood adaptation and mitigation steps were developed by Afriyanie et al., in 2020. They also showed how to re-frame urban green space design through socio-ecological sustainability in order to educate the decision-making phase in the implementation of inclusive urban ES. Fang et al. (2020) proposed a local space sequential long-term neural memory network (LSS-LSTM) for flood susceptibility prediction in Shangyou County, China.

Landholders should be allowed to use their land in a manner that increases its water retention ability. However, questions of justice may occur when, based on the usage of other properties, the landowner may gain or lose. Alvarez et al. (2019) sets out to study the feasibility of incorporating game theory in a cooperative game to tackle land use in a way that increases the water retention ability of landowners. They addressed the improvement of upstream water retention and centered on the function of forests as natural water retention features. Besides that, Lourenço et al. (2020) explored a potential analytical method for community planning and the creation of flood control options, using a multi-functional open space structure that integrates water dynamics into existing and future urban solutions. They also developed a series of recommendations to express local needs with environmental constraints, with the goal of helping to design urban flood protection alternatives, but at the same time increasing environmental value and retrofitting urban proximity. Sekuła et al., 2018 presented the possibilities of the ISMOP – IT Levee Monitoring System. This device is capable of gathering data from the reference and experimental control and measurement networks. The breakthrough is the use of a set of sensors to track changes in the levee body. It can be achieved by combining the outcomes of numerical simulations with the results of two classes of sensors installed: reference sensors and experimental sensors. Ward et al. (2020) suggested that it is necessary to understand interactions between these closely related phenomena in order to build better disaster risk mitigation (DRR) design initiatives and strategies. Examples have been shown: (a) how flood or drought DRR interventions can have (unintended) positive or negative impacts on the risk of the opposite danger; and (b) how flood or drought DRR measures may have a negative effect on the opposite threat. In paper by Costache et al. 2020, new hybridisation of the FAHP, the Entropy Index (IoE), and the Vector Support Machine (SUM) have been proposed in order to forecast areas vulnerable to flooding. Moreno et al. (2020) attempted to develop and incorporate a model that helps forecast floods over the Magdalena River by analyzing three artificial intelligence techniques (Artificial Neuronal Networks, Adaptive Neuro Fuzzy Inference Method, Support Vector Machine) and thus deciding which of these techniques are most successful in the case study.

The suggested mitigation control method is based on the prediction of hydrographs and the estimate of the amount of water to be collected. It contributes to an optimum peak flow Shah et al. (2017) introduced a new Innovative Decision Supportive Structure for Sustainability Appraisal (SA) of flood mitigation schemes over the life cycle of the scheme, based on two major aspects: the project's continuous flood mitigation and the economic growth of the floodplain. Li et al. (2020) suggested a multi-criteria GIS assessment framework to define target areas for green infrastructure sites, based on five criteria: 1) reduction of storm-water runoff; 2) protection of disadvantaged populations for social flooding; 3) protection of vulnerable road infrastructure areas for floods; 4) protection of critical areas for floods and 5) environmental justice. By statistically evaluating open space performance for flood mitigation purposes through a nationally representative sample of local jurisdictions, the Brody & Highfield (2013) study addressed this question. In their analysis of 2019, Dzulkarnain et al. demonstrated flood control in agriculture using a device dynamics approach. They used the information obtained from interviews with important government leaders. Du et al. (2019) indicated that the recently adopted Sponge City Plan considered concave green land (CGL) to be an important method to reduce pluvial floods. And, Phonphoton & Pharino (2019) established realistic ways to effect prevention and preparedness of MSWM facilities during floods. The Multi-Criteria Decision Analysis (MCDA) report uses a panel of responsible manufacturers and waste management and town planning experts to determine effective impact reduction alternatives. The research by Hu et al. (2019), measured the mitigating extent of urban floods by LIDs for the retrofit of urban areas at a viable level using a hydrological model. A number of storms of differing precipitation durations and intensity-duration-frequency curves have been used to test the hydrological output of LIDs. Phonphoton & Pharino (2019) established realistic ways to effect prevention and preparedness of MSWM facilities during floods. The Multi-Criteria Decision Analysis (MCDA) report uses a panel of responsible manufacturers and waste management and town planning experts to determine effective impact reduction alternatives. Mei et al. (2018) applied an evaluation system focused on the Storm Water Management Model (SWMM) and Life Cycle Cost Analysis (LCCA) to conduct integrated evaluations of the production of flood mitigation GIs to promote rigorous decision-making on sponge city construction in urbanized watersheds. Haghighatafshar et al. (2018), coupled one-dimensional (1D) sewer and two-dimensional (2D) overland flow hydrodynamic models were designed to test the flood control performance of the famed blue-green stormwater retrofit. In their 2018 report, Huang et al. developed a revolutionary systemic optimization model for megacity flood mitigation by integrating several Low Impact Construction (LID) instruments, taking into account the benefit-cost (B/C) analysis. This framework can be used to evaluate the effects of floods on the growth of megacity, to develop a technological methodology that allows an automated and efficient optimization process, to link up with the built-in Storm Water Management Model (SWMM) and to propose adaptive solutions using a combined layout design scheme. Besides that, Sadler et al. (2020) indicated that low-lying, low-relief coastal cities have seen increased flooding due to climate change. Also, they suggest the utility of model predictive control (MPC) of stormwater actuators to reduce flooding in a coastal urban setting made worse by sea level rise. Shah et al. (2017) introduced a new Innovative Decision Supportive Structure for Sustainability Appraisal (SA) of flood mitigation schemes over the life cycle of the scheme, based on two major aspects: the project's continuous flood mitigation and the economic growth of the floodplain. Besides that, Hadid et al. (2019) proposed that one of the solutions to minimize the effects of the flooding would be the use of flood storage areas and the design of a management strategy to dispatch water volumes and reduce the peak flow.

The capacities of indigenous precipitation techniques (RWHT), which should be utilized as a viable flood mitigation solution, were examined by Tamagnone et al, in 2020. Their study analyzed the hydraulic performance in terms of the flow peak reduction (FPR) and the volume reduction (VR) at the field and basin level of the most used micro-catchment RWHT in the sub Saharan regions. In order to replicate the extreme precipitation of Sahelian countries during rainy season, parameterised hyetographer were constructed. In their work, Cristiano et al. (2020) sought to define the potential retention capacity of the non-maintenance-cost spontaneous green roof of the CAM located at the entrance of the University of Cagliari (Italy) and to compare it to the C3 type of vegetation. The structure has been equipped with gauges to measure the flow of water in and out of the roof. Local observations are used for the calibration of a conceptual ecohydrological model. Tembata et al. (2020) estimated how forests decrease the occurrence of storms, resulting in two main results. Second, they confirmed that the rise in forest area mitigates the risk of flooding even after monitoring socio-economic and meteorological variables and time-invariant individual effects. Second, large-leaf and mixed-tree forests have a flood-reduction effect, while coniferous trees do not; these findings are stable to alternate model requirements. Alves el al. (2020) focused on a method for analyzing trade-offs when different benefits are pursued in the planning of stormwater infrastructure. A hydrodynamic model was coupled with an evolutionary optimization algorithm to evaluate different combinations of green-blue-grey measurements. This assessment includes the mitigation of floods as well as the improvement of co-benefits. Optimization has been confirmed as a useful decision-making tool to visualize trade-offs between flood management strategies.

3.2. Innovative solutions for flood preparedness

Literature review identified a large number of innovative solutions for flood preparedness (Abunyewah et al., 2020; Cvetković et al., 2018; Mei et al., 2018; Sadler et al., 2020; Haghighatafshar et al., 2018;Aleksandrina et al., 2019; Cvetković & Janković, 2020; Cvetković, Roder, Öcal, Tarolli, & Dragićević, 2018; Kumiko & Shaw, 2019; Ocal, 2019; Jovana Perić & V. Cvetković, 2019; Tam, Chan, & Liu, 2019; Xuesong & Kapucu, 2019) and mitigation (Ezemonye & Emeribe, 2014; Haghighatafshar et al., 2018; Shah et al., 2017; Hadid et al. 2019). Coughlan de Pérez et al. (2017), suggested that the detection of seasonal flood drivers should be used to enhance the prediction knowledge on flood preparedness to prevent misleading decision-makers. On the other side, Rodriguez-Espíndola et al. (2018), introduced an emergency preparedness system focused on a mix of multi-objective optimisation and regional information systems to enable multi-organizational decision-making. A cartographic model is used to prevent the collection of flooded facilities, advising a bi-objective optimization model used to assess the location of emergency facilities, stock prepositioning, allocation of resources and delivery of relief, along with the amount of actors needed to carry out those operations. Demir et al. (2018) launched Iowa Flood Information System (IFIS) vision, deployment and case studies to include next-generation flood support decision supporting structures. IFIS is an end-to-end web-based framework that integrates different elements of the flood risk management decision-making process. The IFIS offers information on streams and weather patterns in real time, integrates sophisticated hydrological simulations for flood prediction and mapping, and multiple data collection and visualization methods to promote successful decision-making.

By using the Structural Equation Modeling (SEM), Abunyewah et al. (2020) established a model to assess the mediating and moderating impact of 'group engagement' on the relationship between 'knowledge suficiency' and 'preparation intentions.' Results have demonstrated that emergency intelligence, which is available, accurate and customized to the needs of the public, has a positive effect on disaster preparedness. They explored the role of group engagement in enhancing the efficacy of the IDM in disaster preparedness. Shah et al. (2020) found that awareness and training programs are needed at the school level to increase knowledge and preparedness for future floods. Besides that, Kanakis & McShane, 2016, demonstrated in their analysis that expected vulnerability to a potential extreme weather occurrence, social connectivity, and self-efficacy greatly predicts part of the variation in preparatory behaviour. Cvetković et al. (2018) proposed that emergency management agencies and land planners should account for differences (men seemed to be more confident in their abilities to cope with flooding, perceiving greater individual and household preparedness) in gender awareness and preparedness. Based on that, doing so may increase citizen participation and shared responsibility under flood hazard scenarios. Ezemonye & Emeribe (2014) recommended the exploration of family preparedness as the first coping technique to resolve the helpless nature of households in the event of a flood catastrophe. Sensitization of households on the need to save resources to boost flood impacts is required while improving institutional preparedness for disaster risk reduction.

Karunarathne & Lee (2020) showed empirical and convincing evidence of support for the social network and its spatial and temporal mechanisms of evolutionary patterns of preparedness and recovery for flood disasters, as demonstrated in the case of the 2017 mass flood incident in rural areas of Sri Lanka. The findings showed an important empiric finding that social support networks play a key role in the preparedness and regeneration of disasters before, after and after floods. In 2019, Das demonstrated a groundbreaking study of flood maps through the method of analytical hierarchy (AHP) and hydro-geomorphic response to floods through geospatial analysis and unit stream power modeling. In a very interesting paper, authors demonstrated that the combination of dune restoration and revegetation is the best way to mitigate the effects of coastal erosion and floods under present and potential sea-level scenarios. Also, they showed the possible advantages of incorporating and enhancing emerging green-based strategies, such as coastal hazard risk mitigation, to reduce coastal risk in both present and future scenarios (Fernández-Montblanc et al. 2020). Hu et al. (2019) measured the degree of urban flood prevention by Low Impact Construction Technologies (LIDs) to retrofit urban areas to a viable level using a hydrological model. The findings showed that LIDs were successful alternatives for alleviating urban floods in the urbanized sector. On the other side, Sen et al. (2020) introduced a resilience evaluation system for housing infrastructure using a combination of Best Bad Process and Hierarchical Proof Justification based on Dempster-Shafer flood threat theory. Convertino et al. (2019) introduced an information-theoretic Portfolio Decision Model (iPDM) to maximize the structural benefit of the basin environment by analyzing all possible flood risk reduction plans. iPDM measures the expected ecological importance of all possible combinations of flood control systems (FCS) based on natural, social and economic asset parameters.

3.1.1. Flood warning and forecasting

Most flood warning systems research is pre-occupied with official or structured systems intended to alert other agencies and the public at risk through government organizations (Parker & Handmer, 1998). A wave run-up control system and a model to predict the wave run-up height on a seawall have been developed by Huang et al. (2020). To measure the wave run-up heights, electrical conductivity sensors have been mounted on the seaward slopes of seawalls. In order to relay the calculated data in real time to the desired remote position, the general packet radio service protocol was used. Intrieri et al. (2020) proposed a structure offering guidance about what the information transmitted in a flood warning alert should be and by what means of communication it should be issued, on the basis of the degree of criticality of the predicted flood, on the capabilities of the warning organization and on the particular benefits of each tool. A system of logistical aspects of emergency measures (Vibhas et al., 2019; Xuesong & Kapucu, 2019) has been developed by De Leeuw & Jonkman (2012) to promote the avoidance of disastrous flood protection breaches during acute scenarios. By combining a graphics processing unit (GPU) accelerated hydrodynamic model with NWP products, Ming et al. (2020) developed a new forecasting method to provide high-resolution, catchment-scale prediction of rainfall-runoff and flooding processes caused by extreme rainfall. The goal of the research by Rio et al. (2019) was to design, create and implement an image-driven model of an early warning system based on an Android mobile phone so that the public will be expected to be able to obtain information from their respective cell phones about possible flash floods. Image processing forms the basis of this innovation by means of the Background Subtraction technique, which is used by an IP camera to automatically detect high amounts of water (TMA) on the control panel (Peil), which is the input parameter of the system and is converted into information for interested parties. Handmer (2001, p. 20) in his summary based on vide range of literary review (Parker & Fordham, 1996; Parker & Handmer, 1998) suggested that warning messages should: be timely and reliable, have local and individual meanings, be forward looking suggest appropriate responses, come from locally credible sources, be reinforced socially (e.g. through personal networks), go to those at risk (usually a diverse group). On the other side, its suggested that warning systems should make provision for easy confirmation and extra information, use an appropriate range of message dissemination modes, employ multiple channels for dissemination, incorporate continuous learning and updating procedures, weaknesses in warning systems that should be avoided: complex arrangements for decision-making and/or communication, centrally run systems that are poorly connected to local needs, lack of sufficient time to accomplish all communication steps, decision bottlenecks where systems become overly reliant on, single persons, assumptions that the broadcast media will disseminate a warning, assumptions that those at risk are a homogeneous group with, uniform needs, forgetting that convincing arguments are more likely to succeed, than are orders, failure to draw on the full range of available experience.

Yao et al. (2019) found that by using the WRF (the weather analysis and forecasting model) precipitation projections, the Grid-Xinanjiang model is capable of providing better flood predictions. They also found that the precipitation forecasts' temporal and spatial trends have a major influence on the estimation of both the timing and the severity of incoming floods. The, Yoon et al. (2014) revealed that for hydrological flood forecasting, the CMAX (The column maximum) provides valuable information. In order to help disaster control, Hostache et al. (2018) contributed to the creation of more detailed global and near-real-time remote sensing flood forecasting systems. Using SAR images, they took advantage of recent algorithms for accurate and automated flood scale delineation and showed that near real-time sequential assimilation of SAR-derived flood extensions would greatly boost flood forecasts. Dersingh (2016) proposed the design and development of a flood alert system that includes an embedded module for data acquisition that can be installed in a remote area in order to regularly capture environmental data such as rainfall volume, water level, and image. The collected data is then transmitted over the Internet to a server through a cellular data network, and is stored in a database and analyzed on the basis of historical data to assess early flood alerts in the region. A web application and a mobile application have been designed and developed for users to view measured data. Moreover, the mobile application is capable of receiving a push notification of a warning message of potential. In very interesting paper, Intrieri et al. (2020) presented guidance about what should be the information transmitted in a flood warning notice and in what contact mechanism it should be given, based on the criticality level of the predicted flood, on the capabilities of the organization in charge for the warning and on the particular advantages of each medium. For example, during a red alert, the use of megaphones, loudspeakers or sirens by municipal staff, with the support of voluntary associations, may be useful for alerting citizens in small towns or in specific areas at risk, for reaching people of all ages, particularly the elderly, and for those who do not follow any of the aforementioned channels and for reaching people of all ages, particularly the elderly.

3.1.2. Flood risk communication and management

In flood risk control, risk communication has a more and more central role, but there are a host of contradictory recommendations as to whether, when, how and to who is being communicated (Demeritt & Nobert, 2014). Rollason et al. (2018) have shown that respondents want knowledge on where and how a flood will occur, so that they can consider their risk and feel responsible about their choices about how to react. Four designs that turn information requirements into new approaches to flood risk communication were also suggested. Created by study participants, these proposals satisfy their knowledge needs, improve their flood literacy and increase their response capacity. In the other hand, Haer et al. (2016), which analyzed numerous flood risk communication strategies, has found that customized, human-centered, flood risk communication can be considerably more efficient than a traditional approach to top-down government communication, even though less people are targeting targeted communication. Communication on how to protect against floods is much more effective than the traditional flood risk communication strategy, in addition to providing information on flood risks. Then, Pathak (2019) emphasized the need to provide a user-friendly method of crisis communication to support resilient societies. A robust emergency response infrastructure would integrate all communication networks, including television and radio, smartphones, open source data and social media. Cantoni et al. (2020) endorsed a participatory approach in favor of public organizations by diverse classes of citizens (volunteering, awake, unaware) in various stages of the calamitous case (homeostatic process, disorderly period, rebooting phase). The model they propose envisages an impressive change in the way the citizen and the public administration act and abandon the dichotomous and distant relationship. In separate phases of the calamitous case (homeostatic operation, disorderly phase, booting phases) Cantoni et al., (2020) endorsed a participatory approach for public institutions by diverse classes of citizens (voluntary work, conscience and unknowledge). The model they propose envisages an impressive change in the way the citizen and the public administration act and abandon the dichotomous and distant relationship. Raza et al. (2020) suggested a user-centric solution to connectivity in disaster-affected regions and communication outages. The proposed scheme would form ad hoc clusters to promote emergency coordination and link end-users/User Equipment (UE) to the central network. On the other side, Dong et al. (2020) proposed a probabilistic model for the estimation of the probability of cascading disruptions in co-located road and channel networks. The suggested Bayesian network analysis method combines systemic features of the network and analytical evidence on the distribution of floods to model the spread of floods. Lin et al. (2020) concluded that cross-scale risk coordination not only has a significant effect on individual decision-making on restoration and resettlement, but also has consequences for long-term planning and development. Also, Mel et al. (2020) suggested a method that uses hydrodynamic modeling and professional expertise to assess an equitable distribution of flood risk in the river system to mitigate flood risk by the optimum application of current control systems, without substantial increased costs. The authors have acknowledged the importance of partnering with public institutions and technicians in charge of maintaining river networks, encouraging the sharing of information and skills, and optimizing the realistic effect of scientific study.

3.1.3. Flood mapping

Flood maps can contain a wide range of flood-related details and there are therefore unique subtypes of flood maps (Van Alphen, Martini, Loat, Slomp, & Passchier, 2009): land-use developers are involved in the location of flood-prone areas, the agencies responsible for flood protection are involved in areas with high potential damage and casualties and authorities responsible for emergency preparation and response are involved in areas with high numbers and number of vulnerable populations etc. There is no formal nomenclature or accepted flood mapping procedure in Europe (Merz, Thieken, & Gocht, 2007). Degiorgis et al. (2012) suggested strategies to classify flood-prone areas from automated elevation models. Adopted approaches are focused on characterization of patterns and geomorphological characteristics. On the other side, Sanders et al. (2020) showed that residents' views and knowledge of floods are improved more by fine-resolution depth contour maps than by the Federal Emergency Management Agency (FEMA) flood hazard classification maps and that displaying fine-resolution depth contour maps helps to reduce discrepancies in interpretation of floods among subgroups within the population, generating mutual understanding. Also, Tripathy et al. (2020) implemented a new definition of spatial flood risk mapping and weather forecasting in the medium term focused on expected risks, vulnerabilities (topographic and socio-economic) and exposure information. In addition, flood hazard maps can be based on various flood conditions, taking into account particular flood dynamics from a number of failure sites, presented as variations of flood probability, depth and current velocity (Van Alphen et al., 2009). Besides that, Panahi et al. (2020) identified the possible use for spatially explicit flash flood predictions and mapping of two architectures of deep learning neuronal networks, i.e. convolutionary neural networks (CNNs). Some authors (Feng et al, 2020) proposed a novel process for mapping flood magnitude from location-based social media photos and applied it to a specific flood event as a proof of concept. The method involves the compilation and filtration of photographs from social media for flood-related eyewitness images, and the removal of identical images (and thus possibly duplicates). Moreover, flood-related photographs of people have been categorized according to water level in four stages of flood severity with reference to the various parts of the body in the picture.

3.1.4. Decision model for optimal flood management

There are a lot of innovative solutions regarding different types of a decision model for optimal flood management (Goodarzi et al., 2019; Lee et al., 2019, Jamali et al., 2020; Tyler et al., 2019). Goodarzi et al. (2019) proposed a decision-making model for determining flood warning level based on atmospheric ensemble forecasts. On the other side, Lee et al. (2019) presented a novel ensemble extension of the conditional bias-penalized Kalman filter, referred to herein as the conditional bias-penalized ensemble Kalman filter (CBEnKF), and apply it to flood forecasting. Jamali et al. (2020) developed a modern applied modeling system that applies a semi-continuous simulation approach to the mitigation of flooding and the benefits of RWH water supply. Some authors, proposed the creation of a decision-making method for emergency planning and response, especially in the case of a flood accident (Nivolianitou et al., 2015). The suggested method is a simulator (i.e. computer-based software) capable of detecting 'emergency machine' failures, and also enhances the basic areas of the emergency system, such as physical infrastructure, human factors, procedures, reaction time and sequence of actions. The built tool can be used as a technological tool to model the operational and inter-organizational assets of a multi-actor civil protection community with the goal of highlighting powerful and weak elements of civil protection systems. Tyler et al. (2019) established seven realistic lessons that, if applied, could not only allow decision-makers to better consider neighborhood flood risks, but could also reduce the effects of flood events and enhance community resilience to future flood disasters. These seven lessons include: (1) understanding that the acquisition of open space and the protection of wetlands are some of the most important ways to reducing flood losses; (2) recognizing that, based on the community's flood risks, various patterns of construction are more effective in reducing flood losses; (3) recognizing the risks and advantages of participation in FEMA's Community Rating System program; (4) engaging community stakeholders in flood planning and recovery processes; (5) considering socially disadvantaged communities in flood risk management programs; (6) focusing on a range of flood risk management tools; and (7) ensuring that flood reduction strategies are thoroughly implemented. On the other side, Zhang et al. (2018) described an innovative project in which disaster management planners in a dryland community in northwestern China treated flash floods as a resource rather than as a threat, and helped the community to benefit from this resource. The project produced ecological benefits (combating desertification), social benefits (flood control), and economic benefits (harvesting water for future use) that improved the community's adaptive capacity and facilitated sustainable development. Vinten et al. (2019) concluded that improving hydraulic management could mitigate the likelihood of flooding upstream, help protect mesotrophic wetlands, and facilitate low-flow downstream water sources. In addition, the authors found that: (a) installation of manually operated tilting wire, improved management of escape and flow routing from the common lade; (b) dredging of the common lade in combination or in place of tilting wire. On the other hand, Sanders et al. (2020) showed that collective flood modeling encourages the role of a wide variety of end-users in considering the risks of flooding and offers clear evidence that Flood Risk Management can effectively implement and apply the co-produced expertise. Then, Pham et al. (2020) proposed and validated three ensemble models based on the Best First Decision Tree (BFT) and the Bagging (Bagging-BFT), Decorate (Bagging-BFT), and Random Subspace (RSS-BFT) ensemble learning techniques for an improved prediction of flood susceptibility in a spatially-explicit manner.

3.1.5. Flood education and training

Dufty (2008) defines community flood education as learning process or activity that builds community resilience to flooding. He higlighted that community flood education can include: public communications, information products and services e.g. publications, Internet sites, displays; training, development and industry-specific programs; community development programs e.g. public participation programs; comprehensive personal education programs e.g. school curriculum, university curriculum. On other side, Dufty (2008) propouse new approach involves changes to the following aspects of community flood education: the participation of the learners; focus on building resilience; links with the 'flood cycle'; evaluation of flood education programs; links with other flood mitigation and resilience-building plans and methods; longevity of the flood education program (Cvetković et al., 2017; Cvetković & Filipović, 2018; Cvetković & Svrdlin, 2020; Cvetković, 2018). Charalambous et al. (2018) made suggestions for enhancing civic engagement: first, the need for a more participatory approach to the public participation process. Instead of discussing the measures selected by the authority, at public consultation sessions, members should be given time to address the benefits and drawbacks of possible flood control solutions in smaller groups and to prioritize all the measures proposed; secondly, there is a need for a clearer plan to advertise public consultation activities and to improve engagement in them. On the other side, Hijji et al. (2015) proposed an Expert System that could help anticipate, evaluate and improve civil defense flash flood training capabilities against scalable flash flooding risks. Then, Tanwattana & Toyoda (2018) proposed using gaming simulation (GS) as a tool to strengthen community-based disaster risk management (CBDRM). Kankanamge et al. (2020) found that: (a) the use of Twitter is a promising approach to reflect citizen knowledge; (b) Tweets could be used to identify fluctuations in the severity of disasters over time; (c) the spatial analysis of tweets validates the applicability of geo-located messages to demarcate highly impacted disaster zones. Then, Tsai et al. (2020) integrated a serious game, Battle of Flooding Protection, and Kolb's Experiential Learning Cycle to develop a learning package that would raise students' level of interest in learning, inspire their self-awareness, and increase their willingness to participate in disaster-related citizen actions. Tran & Rodela (2019) investigated whether and how adaptive expertise (i.e. experimental and experimental knowledge) obtained from farmers' day-to-day adaptation activities leads to local flood control and adaptation policies in selected areas. They find that while the highly bureaucratic operation of flood control causes input restrictions, the more informal structures placed in place at the local level offer versatile channels for transparent collaboration, mutual learning and information sharing between the various actors. Contrary to that, Banerski et al. (2020) explored whether the motivation of the local population could be improved by using 3D animation to imagine possible catastrophe situations and demonstrated the utility of using 3D animation in warning communications. Videos were given to groups of subjects living in flood-prone regions. Danger evaluation was only a major determinant of Self-Protection Motivation when the warning alert was delivered in the form of 3D enhanced graphics. It increases incentive to respond by stimulating two cognitive processes and does not limit the ability to memorize directions within the post.

3.1.6. Flood volunteers

In the case of disasters, the initial response comes from first responders and as necessary from the relevant local authorities and possible volunteer organizations and volunteer activity in such situations is crucial, bearing in mind that most survivors are saved in the first 48 hours (Cvetković, Milašinović, & Lazić, 2018). Also, Oloruntoba (2005) notes that without good strategic planning, where volunteers should be sent, how to organize, monitor and direct them, they can become a serious obstacle to the successful functioning of disaster management. When it comes to motives for providing assistance, it has been found that its various forms are conditioned by various motives (Houle, Sagarin, & Kaplan, 2005; Gazley & Brudney, 2005). Providing help is conditioned by social order, personal characteristics, attitudes and situational variables (Brand et al., 2008; Dass-Brailsford, Thomley, & de Mendoza, 2011; Forbes & Zampelli, 2014; Sloand, Ho, Klimmek, Pho, & Kub, 2012; Son & Wilson, 2012; Taniguchi & Marshall, 2014). Paciarotti et al. (2018) emphasized the importance of spontaneous volunteers during emergencies, and their appropriate management is crucial in achieving an efficient and effective volunteer service, even though it may be administered by a non-official responder organisation. On the other side, Ludwig et al. (2017) derived a technical concept that supports the task and activity management of spontaneous volunteers as well as the coordination both of the demands of affected people and the offers from spontaneous volunteers.

3.3. Innovative solutions for flood response

Literature review identified a large number of innovative solutions for flood response (Boukerche & Coutinho, 2018; Liu et al., 2018; Tan et al., 2016; Lamond et al., 2012). Boukerche & Coutinho (2018) proposed a novel architecture for smart disaster detection and response system for smart cities. They discussed the main building blocks of our envisioned smart system, as well as the critical challenges that will be faced ahead to implement our smart system. On the other side, Liu et al. (2018) evaluated the efforts and expertise gained in designing the Flood Prevention and Emergency Response System (FPERS) operated by Google Earth Engine, based on its applications during the three phases of the floods. FPERS incorporates various remote sensing images at the post-flood level, including Formosat-2 optical imagery to locate and track barrier dams, synthetic aperture radar imagery to derive an inundation map, and high-spatial-resolution photos taken to determine damage to river channels and infrastructure by unmanned aerial vehicles. At the pre-flood stage, an immense amount of geospatial data is incorporated into FPERS and classified as typhoon forecasting and archiving, disaster avoidance and notification, disaster occurrence and interpretation, or simple data and layers. During the flood season, three measures are put in motion to promote access to real-time data: to provide key statistics, to make sound recommendations and to improve decision-making. Tan et al. (2016) proposed an Agent-as-a-Service (AaaS)-based geospatial service aggregation to build a more efficient, robust and intelligent geospatial service system in the Cloud for flood emergency response. Salmoral et al. (2020) in their study evaluated how Unmanned Aircraft Systems (UAS) can be used in the preparation for and response to flood emergencies and develops guidelines for their deployment before, during and after a flood event. In order to unlock the full potential for Earth observation data in flood disaster response, Schumann et al. (2016) suggested in a call for action (i) stronger collaboration from the onset between agencies, product developers, and decision-makers; (ii) quantification of uncertainties when combining data from different sources in order to augment information content; (iii) include a default role for the end-user in satellite acquisition planning; and (iv) proactive assimilation of methodologies and tools into the mandated agencies. Besides that, Lamond et al. (2012) demonstrated that waste management can be an effective response to flood risk but, in order to remain successful, it requires that sufficient commitment and engagement can be mobilised in the long term. Katuket al. (2009) introduced the architecture of a web-based flood response support system in Malaysia. The proposed architecture is of interest to the flood control agencies involved in order to plan future changes to the existing flood response protocol. Also, Bullemer et al. (2011) shown that operator efficiency under sensor flood conditions can be increased if the operator configuration allows the operator to strategically display alarm subsets connected with particular equipment areas rather than a catalog comprising all alarms.

3.4. Innovative solutions for flood recovery

Literature review identified a large number of innovative solutions for flood recovery (Zeng et al., 2019; Crow & Albright 2019; Lu et al., 2017; Tammar et al., 2020). For example, Zeng et al. (2019) presented the full methodology for a novel flood footprint accounting framework – the Flood Footprint Model – to assess the indirect economic impact of a flood event and simulate post-flood economic recovery situations throughout productions supply chains. Within the framework of Input-Output (IO) analysis, the model is built upon previous contributions, with improvements regarding the optimization of available production imbalances; the requirements for recovering damaged capital; and an optimized rationing scheme, including basic demand and reconstruction requirements. Next to that, Crow & Albright (2019) analyzed intergovernmental relationships during disaster recovery. They discovered that learning within local governments is associated with higher levels of resource flows from state agencies as well as more collaborative intergovernmental relationships. They also indicated that state governments can improve processes for disaster recovery assistance and bring together disaster-affected local governments to promote learning during the recovery process. As an effort to broaden the ProSe coverage and expand integrated global-local information exchange in the post-flood SAR activities, Rahman et al. (2019) proposed a novel network architecture in the form of a cyber-enabled mission-critical system (CE-MCS) for acquiring and communicating post-flood emergency data by exploiting TV white space spectrum as network backhaul links. Futher, Lu et al. (2017) investigated how to network smartphones for providing communications in disaster recovery. By bridging the gaps among different kinds of wireless networks, they have designed and implemented a system called TeamPhone, which provides smartphones the capabilities of communications in disaster recovery. Experimental results demonstrated that TeamPhone can properly fulfill communication requirements and greatly facilitate rescue operations in disaster recovery. Besides that, Tammar et al. (2020) developed a social capital framework centered on resilience and post-disaster recovery. Gupta & Nikam (2014) suggested that a variety of innovative flood control systems have been planned and installed on the major Mithi River in the area. Weather stations have been designed to send rainfall level data in real time (every 15 minutes) to the disaster emergency control room and over the internet to the public. (every 15 min) to the disaster emergency control room and through internet to the public. Futher, Driessen et al. (2018) concluded that six key governance strategies will enhance 'flood resilience' and will secure the necessary capacities. These strategies pertain to: (i) the diversification of flood risk management approaches; (ii) the alignment of flood risk management approaches to overcome fragmentation; (iii) the involvement, cooperation, and alignment of both public and private actors in flood risk management; (iv) the presence of adequate formal rules that balance legal certainty and flexibility; (v) the assurance of sufficient financial and other types of resources; (vi) the adoption of normative principles that adequately deal with distributional effects. On the other side, Thaler & Fuchs (2020) recommended a better link between financial disaster-aid compensation and voluntary payout programmes, especially to reduce the uneven socio-economic distribution during the recovery phase. Because of that, Gilliland et al. (2020) highlighted critical needs for disaster planning and well user education in flood-prone areas, changes to flood risk maps, and concerns with the efficacy of disinfection strategies. Information and resources needs for flood-impacted well users are presented and recommendations on how to improve flood preparedness and recovery are made. Song et al. (2017) devised a new method to measure resilience via recovery capability to validate indicators from social, economic, infrastructural, and environmental domains. Their findings substantiate the possibility of using recovery measurement based on pollutant discharge to validate resilience metrics, and contribute more solid evidences for policy-makers and urban planners to make corresponding measures for resilience enhancement.

5. Conclusions

The results of the research show significant and progressive progress of innovative solutions in the field of flood risk management. It is interesting to mention that a large number of innovative solutions were created by conducting research after flood disasters that caused specific tangible and intangible consequences and also motivated researchers to find an adequate solution. However, in many countries the available innovative solutions are not implemented quickly enough for various reasons such as lack of money, lack of sufficient level of motivation, misunderstanding of the general public about the importance of such measures, unprofessional and unprofessional risk management in such situations. The paper reviews certain and selected innovative solutions, of which there are many more in practice, but due to technical limitations in writing the paper, we were unable to systematize them and give a brief overview of them. In the future, it is necessary to continue continuous research, develop national knowledge bases that would be nourished by innovative solutions and improve the exchange of knowledge and experience between developed and underdeveloped countries.

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