A systematic literature review on multi-criteria decision making in disaster management

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ABSTRACT

This paper through a systematic literature review portrays the academic work that has been done in disaster management by applying multi-criteria decision making. This study reviews 36 academic articles that applied multi-criteria decision-making planning and management of natural disasters i.e. tsunami, floods, heavy rains, earthquake, land sliding, epidemic, pandemic, etc. This study finds out that lack of effective planning and management pre and post disasters is causing loss of human life, temporary migration of locals to safer places, loss of properties, and economic losses. Once the crisis is over, it requires efforts and additional finances to bring life to normal. There are regions where disasters are periodic such as floods in rivers or due to monsoon season. But with effective planning and pre-determined priorities, loss to human life can be mitigated. Disaster management departments need effective planning tools to forecast imminent disasters and prepare accordingly. This study is very relevant to the recent global pandemic COVID-19 that has caused human and economic losses and will leave footprints for the coming years and generations.

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Introduction

Applications for multicriteria decision making (MCDM) in decision making in different disciplines is burgeoning. MCDM is gaining popularity amongst both practitioners and academics for different problems. Van Wassenhove (2006) categorizes disaster into two categories, natural or human-generated. He further divided them into sudden-onset disasters (e.g., tsunami, earthquakes) and slow-onset disasters (e.g., hunger, drought). The author continuously presents phases of disaster; (i) mitigation, actions to prevent or reduce the disaster impacts; (ii) preparation, activities to be done before the disaster strikes; (iii) response, the reactive phase that includes activities to save lives and preserve the human and financial resources of the affected region; and (iv) recovery, aims to recover the affected region.

There is limited work done on disaster management in academia. Disasters can be easier to control especially if they happen seasonally or periodically. However, if they happen surprisingly, they can gradually have a greater impact on lives and properties of people from where it happens. Disaster management should therefore be the first focus of all governments in the world to be ready to combat a certain uncertain situation such as floods, earthquakes, storms, and volcanic eruptions. In some countries, an agency is established to address such situations in a responsive manner. This paper explored various articles to find out the relationship of disaster management models in controlling disasters.

Once the crisis is over, the disaster management control departments come together to plan and prepare for upcoming disasters. This study will explore what essential tools can be used for effective and efficient planning and management. It has been observed that forecasting of disasters is essential such as flood can be forecasted keeping in view the temperature forecast and flow of rivers etc. But different regions have different approach of dealing with disasters. Some governments are better prepared for upcoming disasters and concerned department such as emergencies are better prepared to respond to the disasters by being actively involved in rescue

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activities. On the other hand some regions that are relatively poor lack planning and preparation that cause bigger losses and longer recovery period.

This paper aims at providing a review of extant literature of disaster management with the application of MCDM. This paper contributes to the extant literature by providing a summary of burgeoning application of MCDM in disaster management. This study also includes a snapshot of disaster management models. However, this paper includes only natural disasters such as flood, earthquake, tsunami, epidemic, and pandemic.

The first section of this paper introduces the subject under study and aims to conduct this study. The second section is dedicated to the review of extant literature on the subject under study with a summary table of relevant academic articles. The third section presents a discussion and conclusion followed by the limitations and future recommendations to extend this same stream of research.

Literature Review

Due to global warming, world is likely to face more floods. Flood related problems are rather large scale and more complex. In a study about flood risks conducted by (K.S. Jun et al., 2013) in South Korea, they found out that the deployment of MCDM techniques considering uncertainty of weighting values and proxy variable data had a great impact on the decision of provinces to handle climate change using various strategies. Elsewhere, in a response to guide preparedness of emergency departments for disaster situations, (Ortiz-Barrios et al., 2017) in their study proposed A.D.T model based on AHP, DEMATEL and TOPSIS methods to evaluate how well the health system is performing and it was found out that their model bridges a gap because of its scalability and adaptability anywhere. Nevertheless, (Opricovic & Tzeng, 2003) concluded with their proposed model of fuzzy multicriteria model that it can be used to select alternatives for improving global safety within an area with potential natural hazards. However, when using AHP techniques, not all parameters can measure the performance of emergency response teams. This calls for the best technique to be selected to anticipate this underlying challenge at hand.

According to (Z. Nivolianitou et al., 2011), in their work funded by EC, it was suggested that AHP approach supported decision making in Emergency preparedness through alternatives structured into a weighed multi-criteria framework. The time it takes to implement strategies when a disaster occurs is long and communication lines in-between departments is vital but can cause delays especially when information is outdated. (J.G. Leskens et al., (2014), concluded that most of the existing models are inflexible for current situations or to predict the effect of responses. In addition, they argued that existing models also have too long calculation time to keep up the frequency in which decisions can be ignited. When information is made available, it can be used to help decision makers to make informed decisions in emergence issues such as health and disasters, this may not be possible for all industries because of the nature of a problem available can make information limited.

A study carried out in mining fields to determine different levels of risks in different zones found in one field, (M.M. Merad et al., 2003) found out that it was easy to conduct sensitivity analysis using ELECTRE TI multicriteria, provided accuracy of inputs. Moreover, to understand more on origins and existing landslides, (Feizizadeh & Blaschke, 2011) employed geographical information system and AHP to create a landslide susceptibility map of the area under study. This helped them to prioritize efforts for combating future landslide hazards. Managing public or communities by government is crucial. However, poor government leads to corruption, enacting of unrealizable targets by cabinets. To employ MCDM in the real world, (J. Li et al., 2012) proposed a community-based virtual database strategy which would connect to local data bases in the community. This kind of strategy would facilitate information sharing among private companies, Non-government organization. They also found out that communities would work together to fight any disaster.

Chen et al proposed a hybrid approach of Data Envelopment Analysis (DEA) and Technique for order performance by similarity to ideal solution (TOPSIS) to improve the multiple criteria decision analysis. Here the decision maker can choose unique features from both methods, which includes identifying parameter information for criteria weights from DEA and TOPSIS (Dincer et al., 2019; Dincer et al. 2016; Dincer et al; 2015; Hacıoglu and Dincer, 2013). facilitates in quantifying qualitative criteria (Chen, Li, Xu, & lu, 2008). Different spatial support systems (SDSS) based on simulation are used in worldwide for earthquake risk, early warnings, rapid response, and loss estimation but in Turkey HAZTURK is considered more advantages over other SDSSs. The competitive advantage includes because of its structural based analysis used to loss estimation calculations during earthquake, datum transformation module, customization capability, user defined fragility curves, post-earthquake assessments and many more. (Nyimbili & Erden, 2018)

In the city of Romania spatial GIS based multi criteria analysis was used to address the earthquake risk. The data obtained from GIS support was then supported by the process of formulation of objectives, criteria formation, ranking, grouping, standardization and then weighted on criteria trees. Despite the difficulties in the weights, obtained results by GIS based multi criteria analysis were accurate (Armas, 2012). GIS-based spatial analysis has a great use in Landslide susceptibility making (LSM) with the combination of multi-criteria evaluation (MCE) methods. So, unlike GIS-based AHP, integrate the fuzzy set theory with the AHP provides high flexibility and reliability in landslide susceptibility maps (Feizizadeh, Roodposhti, ankowski, & Thomas Blaschke, 2014) .

Eckhardt, D., & Leiras, A. (2018) applied AHP to find out the most critical elements to be prioritized in developing a disaster response tool to figure out what should be in focus during the operational disaster response phase. AHP result shows that resource planning and management is the top priority followed by communication Management and systems and technology, respectively. The use of

GIS- based Multi criteria decision analysis helps to identify the most vulnerable spots for the flood. Further it provides detailed information that is what and who is at the most risk and where the strategies should be implemented (Fernandez, Mourato, & Moreir, 2016). A knowledge-based decision support system helps decision making in emergency situations such as natural hazards or technology hazards by assessing the history which is based on interconnected probability of stimulation (Caroleo, et al., 2018).

Roads transportation is very important especially during a disaster when you need to supply emergency equipment's to rescue area. It became more vulnerable when the roads get affected by that disaster and become a huddle in disaster management practices. So, there is a requirement of to find out which network will be most important or to evaluate the transportation network performance in case of the emergency. GIS with MCDM methods especially AHP plays a greater role in evaluation of vulnerability, accessibility, capacity of the transportation network by sensitivity analysis (Ghavami, 2018). When it comes to earthquake aftermath lack of availability and accessibility of the reliable and up to date geospatial data cause huge loss of life and properties. However, use of the GIS based spatial decision infrastructure helps in decision making and it facilitates disaster management. The GIS based SDI helps to achieve better results from the spatial decision making for the selection of rescue centers and it emphasis which area needs more attention (Alinia & Delavar, 2016).

The floods cause damages to human life, so it is the necessary decision from sustainable development to have flood risk management, in the case study of Gorganrood River in Iran, the difference between the multi criteria decision making model and the most conclusive model. The aggregation models, the sensitivity analysis and non-parametric stochastic tests are applied so at the end it will conclude the most suitable model for this case study. At a result the elimination et choice translating reality (ELECTRE III) is the one that comes the first comparing to the other models, and with the use of Kendall Tau Correlation Coefficient test, that helps to give the weights to the criteria, after that, it found out that the highest priority of criteria is for Expected Average Number of Causalities, also for the top rank measure belongs to the pre and post disaster effectiveness, with this alternative composed for the flood insurance and warning system (N. Chitsaz, & M.E. Banihabib, 2015).

The group decision making given for multi person emergency decision support. After identifying decision makers for the GDM, each one gives their decision, after the collection of the multiple decisions, that it comes the MCDM process, which is selection of criteria, formulating alternatives, weighting the criteria and assessing the alternatives, at the end it gives this MCDM the MD results that will be weighted and consensus of decision results at the end of the all the process. Moreover, the distance based multi criteria GDM methodology is for sure the solution of MCDM problems, as a result the DBMC GMD methodology gives the best results and it is the suitable tool for the MCDM problems for disasters (L.Yu, & K.K.Lai, 2010).

By using 4 models that are essential for the flood susceptibility maps, which are: frequency ratio, weight of evidence, analytical hierarchy process and ensemble of frequency ratio with AHP. Furthermore, preparing the location and flood conditioning factors for the next step, after the operating characteristic curves for the flood susceptibility maps, and analyzing the data with a predicted rate, the results gives that the frequency ratio model is the one with the highest AUC comparing with the other models. (Khosravi, et al., 2016).

For the emergencies that comes with naturel disaster, it is necessary to take decisions for the mobilization of people. As to reduce the human losses of life and suffering, for that it comes the disaster management, as an important tool in the decision making. For this decision-making process, it is used for multi criteria model, as for a global view of situations, and with the criteria that are related to the decision making, it is on the first step to identify them, so as a result a multi criteria model begin with the presentation of the criteria that define the problem in the disaster and all what it is related with it, a qualitative and quantitative aspects are helping for this process to sum up at the end the perfect model for the risk management. (Marques, et al., 2014).

For identifying research gaps, applying an MCDM is highly recommended, and for the flood risk management that have been observed for long time and many papers that have been discussed this topic as much as it is important for the humanity, the analytical hierarchy process is the most popular method on FRM, followed by TOPSIS, and simple additive weighting (SAW). The MCDM is the most important that was applied certainly in flood issue studies, so in the stage of choosing the criteria weights in the MCDM, the participation of multiple stakeholders is fragmented. To increase the quality of decisions for the measures to be implemented, it should explore the uncertain judgments of stakeholders and endorsing the participation in all steps of decision making. (Brito, & Evers, 2016).

An approach has been introduced as an innovative one, for flood hazard, is that a site selection conducted by a multi criteria and disciplines that is taken. After taking the model of stormwater management, that is based on the technique of order of prioritization by similarity to ideal solution (TOPSIS), it gives the flood hazard the score, that is used in multi criteria decision making for the selection of framework. For this it uses the case study of Darakeh river Catchment and utilized for the development and management practices because of its versatility (E.Ahmadisharaf et al., 2015).

For the zonation and mapping of the landslide hazard, it is used the GIS-MCDA technique. It is a way that can integrate the different data layers together with different levels of uncertainty. For this it is used three methods of GIS-MCDA, with nine landslide factors, and parameters were taken from an associate database. After evaluating the factors and giving the weight and class weight for each factor. Based on weighted overly techniques with AHP, weighted linear combination and ordered weighted average, the landslide maps are produced. With the consideration of dempster-shafer theory to check out of uncertainty of GIS-MCDA results, it comes out

the possibility to compare the results of the case study in the paper, at the end the results indicate that the AHP is the best option that performs good in the landslide susceptibility mapping then after it comes the OWA method after the WLC that gives poor results (B. Feizizadeh, & T. Blaschke, 2012).

To solve the classification problem, the methodology of MCDM that is TODIM-FSE is the chosen one, it analyzes a set of alternatives to give their order of performance. To decide the suitable contingency plans for oil spill situation, this methodology helps the users to take that suitable decision, it is specialized for the Portuguese acronym for An Information System for Oil Spill Planning (Passos et al., 2013). Levy, J. K., et al (2007) applied ANP for modeling the preferences of the stakeholders in the 2000 Tokai flood and concluded that food and shelter were the top priority.

Table 1: Summary table of most relevant work in Disaster management with MCDM

#	Authors	Year	Journal	Research Methodology	Nature of Disaster	Region
1	Jena et al.	2020	International Journal of Disaster Risk Reduction	AHP-VIKOR	Earthquake	Indonesia
2	Suthirat et al.	2020	International Journal of Disaster Risk Reduction	AHP	Flood	Thailand
3	Li et al.	2019	International Journal of Disaster Risk Reduction	VIKOR	Flood	China
4	Nassereddin et al.	2019	International Journal of Disaster Risk Reduction	AHP and PROMETHEE	Earthquake	Lebanon
5	Nyimbili and Erden	2018	Natural Hazards	Observations	Earthquake	Turkey
6	Eckhardt and Leirasa	2018	Production	Triangulation method	Disaster management system	Brazil
7	Caroleo et al.	2018	International Journal of Information Technology & Decision Making	ELECTRE	Natural and Technology Hazard	
8	Seyed Morsal Ghavami	2018	International Journal of Critical Infrastructure Protection	Case Study	Transportation Network	Iran
9	Ortiz-Barrios, et al.	2017	Journal of MCDA	AHP model, DEMATEL model	Public health emergencies	Columbia
10	Alina	2016	Research Gate	Conceptual model	Earthquake	Tehran, Iran
11	Khosravi et al.	2016	Natural Hazards	Case study Frequent ratio model AHP model FR-AHP hybrid model WOFE model	Flood	Iran
12	Fernandez et al.	2016	Geomatics, Natural Hazards and Risk	Case study	Flood	Portugal
13	Mariana Madruga de Brito and Mariele Evers	2016	Natural Hazards	MCDM	Flood	Germany
14	Chitsaz et al.	2015	Water Resource Management	Case Study Evaluation Criteria Evaluation of Quantitative Criteria	Flood	Iran
15	Eckhardt and Leiras	2015	Annual proceedings of Production and operations management society	AHP	Disaster management tool assessment	
16	Ahmadisharaf et al.	2015	Journal of Environmental Planning and Management	Case study, AHP method	Flood	USA
17	Feizizadeh et al.	2014	Computers & Geosciences	Integration of an AHP with fuzzy set theory, Fuzzy Membership Function (FMF)	Landslide	Izeh Basin, Iran
18	Wood et al.	2014	International Journal of Disaster Risk Reduction	AHP	Tsunami	USA
19	J.G. Leskens et al.	2014	Environmental Modelling & Software	Flood simulation model	Flood	Netherlands
20	Marques et al.	2014	Natural Hazards	Multi criteria model AHP method	Naturel disaster and mobilization of people	Brazil
21	Lee et al.	2013	Natural Hazards and Earth System	TOPSIS and Delphi	Flood	South Korea

			Sciences			
22	K-S. Jun et al.	2013	Expert Systems with Applications	MCDM technique, WSM, TOPSIS	Flood risk	South Korea
23	Kavzoglu et al.	2013	Landslides	AHP	Landslide	Turkey
24	Passos et al.	2013	Computers & Operations Research	Case study MCDM TODIM FSE	Oil Spill	Brazil
25	Bakhtiar et al.	2012	Natural Hazards	Case study GIS-MCDA AHP OWA WLC	Landslide	Iran
26	J. Li et al.	2012	Computers & Operations Research	MCDM	Natural and manmade disasters	USA
27	Iuliana Armas,	2012	Natural Hazards	exploratory	Earthquake	Bucharest, Romania
28	Wang et al.	2011	Water Resource Management	AHP	Flood	China
29	Feizizadeh & Blaschke	2011	Arabian Journal of Geoscience	GIS Multi-Criteria Evaluation	Landslides	Iran
30	Z. Nivolianitou et al.	2011	International journal of MCDM	AHP	Flood	Worldwide
31	Lean Yu & Kin Keung Lai	2010	Decision Support Systems	GDM Experimental analysis	emergency events like earthquakes and hurricanes,	Hong Kong
32	Ye et al.	2009	Journal of Systems Science and Systems Engineering	Case Study	Emergency Management	Australia
33	Levy et al.	2007	Journal of the American water resources association	ANP	2000 Tokai floods	Japan
34	Jason K. Levy	2005	Stoch Environ Res Risk Assess	ANP	Jinjiang flooding	China
35	Opricovic & Tzeng	2003	Natural Hazards review	Fuzzy multicriteria model (FUMCO)	Earthquake	Taiwan
36	Merad et al.	2003	Tunneling and underground space technology	ELECTRE TRI	Mining induced hazards	France

Research Methodology

Since the application of MCDM in disaster management is at rudimentary stage, it was preferred to use the more generic database i.e. Google scholar to access the relevant literature. The preliminary search was made with the combination of keywords “MCDM” and “disaster management”. The database extracted 6050 results. After a vigilant scrutiny, 89 papers relevant to objective of this study were shortlisted. In second phase of scrutiny, papers that do not investigate natural disaster were eliminated. Hence, the final number of 36 papers were shortlisted for review. A summary of relevant studies is presented in Table 1. Since the application of MCDM and MCDA is a new approach used by academics, a limited literature is available on the subject. But it is gaining attention of scholars from different parts of the world. There is room to enlarge this stream of research for effective planning and management.

Conclusions

According to MCDM techniques, various techniques can distinctively be applied by institutions to synthesize input data desired to define construe problems relating to disasters. However, the most formidable problem can result from selecting the best technique to be harnessed into the core process of preventing or otherwise controlling disasters. Undertakers of such projects are fond of making decisions intended to satisfy their stakeholders or otherwise personal interests which may be good for the short run but detrimental to the main purpose of implementing MCDM.

This paper applied a theoretical perspective to study underlying ways of making quicker decisions through employing multiple criteria decision-making techniques in disaster management practices. As listed above, the main critical stages when enforcing MCDM include, (1) defining objectives, criteria, and sub-criteria (2) retrieving input data needed to structure problems (3) understanding the amplitude to implement and to control the analysis (4) establishing a timeframe for resolving and carrying out evaluation are all crucial to the success of implementation of MCDM. Finally, disaster management should be collectively achieved by expert teams through implementing MCDM methods to resolve questions that still underlies in disaster and preparedness

department around the world. Decisions which are complex, involving multiple objectives raised from environmental or social needs MCDA that help decision makers in such complex situations. Situation including land sliding and earthquake are destructive natural hazards, which do not just cause human death but huge damage to property along with natural resources. In the case of earthquakes decision makers take help from geospatial and SDSS, whereas mapping plus visualization support SDDS for easier output interpretation. After careful review that give us a conclusion about the right and the optimistic methodology used for any of disasters that happen for the humanity, nature one, and that is concluded as the best option and flexible for the kind of situations that decision makers have to make a decision without mistakes and that can save the humanity, for the same time or for the coming predicted disasters that happens in the same place or other. The Multiple Criteria Decision Making is the methodology obtained for all kind of disasters as the base one that decision makers have to start the study with and select the alternatives give the premier solutions, and as the Analytic Hierarchy Process is the technique that also used to analyze complex decisions like disasters, when they come in a unprotectable time as nature so it have no cases, it just happen, so it counted as the most complex situations that the humanity facing, moreover, we have to find a technique to reduce the consequences, as a result the best option that perform very good with all the case studies of disasters, is the AHP that gives good solutions.

The scope of this paper is limited to natural disasters only. This work is theoretical in its nature. No empirical data was used for the analysis which tends to be biased and insignificant when suggestions are needed to solve problems. This also limits our study to real problems that may require a lot of effort and commitment from MCDM implementors. This paper may contribute to the research in progress after the outbreak of pandemic COVID-19. This pandemic is a rather gradual disaster in contrast to other natural disasters that are focus on this study, but the challenges of precaution, recovery, national and global economy are similar. A comparative study of how developed and developing regions deal with disasters can be of great contribution for academia. How countries are prioritizing their human and economic losses and how they are planning to recover should be a basis for further studies.

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