Review

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Flood Management on GIS-Based Multicriteria Evaluation in Developing Countries : A Systematic Literature Review

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Review

Flood Management on GIS-Based Multicriteria Evaluation in Developing Countries: A Systematic Literature Review

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Abstract:. The objective of this study is to investigate the correlation between the advancement of flood research and the utilization of Geographic Information Systems (GIS) and multi-criteria evaluation techniques, both from a theoretical and practical standpoint. Additionally, this research seeks to identify potential ways to address the aforementioned relationship. The present study employs a thorough literature review methodology. In accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology, a total of 28 papers were identified and included in the analysis, as they fulfilled the predetermined criteria. The findings of the study indicate that current research pertaining to the utilization of Geographic Information Systems (GIS) and multicriteria evaluation in flood control mostly centers around five key areas, namely natural factors, technical considerations, institutional factors, socio-economic factors, and financial factors. However, the aforementioned studies have identified specific areas of focus, including natural factors pertaining to climate, technical factors related to infrastructure, institutional factors concerning flood management strategies, socio-economic factors associated with demographics, and financial factors pertaining to financial obligations. However, there is a limited amount of existing research that specifically addresses flood management in developing nations. Therefore, it is anticipated that this study can serve as a valuable resource for future research endeavors, particularly in informing decision-making processes pertaining to the establishment of priorities in flood control plans. The primary subject of this study pertains to flood management occurrences within developing nations.

Keywords: determining variables; flood management; GIS; multi-criteria evaluation; systematic literature review; PRISMA

1. Introduction

Natural disasters such as earthquakes, typhoons, flash floods, volcanic eruptions and landslides have long been a big threat in many developing and wealthy countries. Annually, a significant number of individuals lose their lives and substantial financial losses are incurred due to the devastating impact of natural disasters on both human lives and the environment. The escalation of the global population has resulted in heightened occurrence and intensity of natural calamities. Flood disasters hold a distinct position within the realm of natural hazards. Floods are widely recognized as one of the most deleterious natural calamities on a global scale, accounting for a significant proportion of the economic losses incurred due to natural catastrophes, specifically amounting to 31 percent. River flooding has emerged as a significant global natural hazard in recent years. Notable instances include the flooding in Cleveland in 2006, Bolivia in January 2007, Namibia in February 2007, and Australia in March 2007. These events resulted in profound socio-economic impacts, affecting the lives of millions of individuals. Tragically, thousands of lives were lost, and the physical damages incurred exceeded 20 billion US Dollars. According to a report published in 2007 by the United Nations and the European Commission, The identification of flood-prone locations holds significant importance for decision-makers involved in the planning and administration of various operations.

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2. Literature Review

2.1. Systematic Literature Review

A systematic literature review (SLR) is a research process that involves the systematic collection and evaluation of works pertaining to a specific topic. Systematic literature reviews serve multiple objectives, encompassing the identification, examination, assessment, and interpretation of all pertinent research within a certain domain, guided by relevant research inquiries. A comprehensive examination of existing literature is necessary to establish the research priorities for a dissertation or thesis. A systematic literature review (SLR) is a research methodology that involves the systematic collection, identification, and critical analysis of existing research papers, such as articles, conference proceedings, books, and dissertations. This process follows a structured protocol to ensure rigor and comprehensiveness. The SLR (Systematic Literature Review) provides readers with up-to-date information from scholarly sources pertaining to a specific subject. The objective is to critically analyze the fundamental aspects of existing knowledge pertaining to a certain subject matter in relation to a research inquiry, with the intention of identifying potential avenues for future investigation. In this study, we aim to investigate the effects of a specific intervention on a particular population. [1]

2.2. Multi Criteria Decision Analysis

Numerous scholarly debates exist on the use of decision-making approaches across several disciplines and sectors. The utilization of multi criteria decision analysis (MCDA) methods can enhance the efficacy of flood risk management. MCDA, which stands for various Criteria Decision Analysis, is a comprehensive word employed to denote a collection of methodologies aimed at organizing and assessing alternatives by considering various criteria and objectives [2]. The aforementioned methodologies offer focused decision-making capabilities, as they are capable of effectively managing the inherent intricacies and uncertainties associated with these situations, while also incorporating the insights derived from the involvement of several stakeholders [3]. Multi-Criteria Decision Analysis (MCDA) has emerged as a robust methodology for effectively addressing flood management challenges. This approach has garnered significant interest and engagement, not only from the academic community but also from decision makers and practitioners operating outside the realm of scientific research.

3. Research Methods

In June 2023, a comprehensive review of the literature was undertaken following the principles outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The present study employed a systematic approach to identify scientific publications published within a certain time frame of five years, specifically focusing on journals released between 2018 and 2023. The Scopus database was utilized as the primary source for retrieving these articles. A total of 28 papers were assessed in the final selection of journals. The suitability of the journal is determined by the methodological clarity employed, and there is coherence observed between the title, aims, discussion, and conclusions.

Liberati et al. [1] delineate a multi-stage process for this approach, which can be summarized as follows:

1. The phrase "eligibility criteria" refers to the specific requirements or conditions that individuals must meet in order to be considered eligible for a particular study or research project.
2. The identification of the source of information entails the process of determining the origin or location from which relevant data or materials will be obtained for the purposes of a study or research endeavor.
3. Study selection involves the systematic and rigorous process of choosing which studies or research articles will be included or excluded from a review or analysis based on predetermined criteria and objectives.
4. The data collection process encompasses the systematic gathering of information or data from various sources, such as surveys, interviews, observations, or existing databases, in order to address the research questions or objectives of a study.

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5. The selection of data items refers to the careful and deliberate choice of specific variables, measures, or elements that will be collected and analyzed as part of a research study, based on their relevance and significance to the research objectives.
6. The eligibility criteria, in the context of a study or research project,

The systematic literature review was guided by the following inclusion criteria (IC):

- IC1: This study focuses on literature and reviews that are written in the English language.
- IC2: The research investigates the variables that influence flood management strategies in developing nations.
- IC3 encompasses both quantitative and mixed methods research, which includes both qualitative and quantitative approaches.

For the selection of studies in IC1, only those written in English were included, as English is commonly used by researchers. In the context of flood control, IC2 pertains to the utilization of Geographic Information Systems (GIS) and Multi-Criteria Decision Analysis (MCDA) for defining flood management strategies. The categorization of developing countries in this study is derived from the "World Economic Situation and Prospect" report.

In the context of IC3, it is worth noting that research endeavors tend to choose a quantitative or mixed method approach, which encompasses both qualitative and quantitative methodologies. This research does not encompass journal papers employing qualitative approaches.

3.1. Information Source

Online information searches were conducted using a prominent academic study repository, specifically Elsevier's SCOPUS. The present study did not incorporate articles that were inaccessible in their entirety.

3.2. Selection of Studies

The data was manually collected by text analysis-based data extraction. This process involved extracting various information such as article type, journal name, year of publication, topic, title, study methodology, respondents/research data, nation of research site, and factors linked to flood management.The process of study selection is conducted in three distinct stages, which are outlined as follows:

1. To align with the study purpose, employ appropriate search phrases such as "determinants of flood mitigation" or other relevant terms seen in previous publications, like "flood hazard," "flood risk," "flood susceptibility," or "flood vulnerability." The query includes the logical operators "AND" and "OR" to combine the terms "mcde" and "mcda" with the terms "GIS" and "geospatial".
2. The task at hand involves thoroughly examining and evaluating all titles, abstracts, and keywords in accordance with predetermined eligibility criteria to determine their significance.
3. Conduct a comprehensive review of all articles that have not been excluded in the previous round of selection, ensuring adherence to the established eligibility criteria, in order to make a final selection.

During the entirety of this procedure, all publications were analysis by a minimum of two writers, and any discrepancies that arose were deliberated about and resolved through consensus. The screening process yielded a compilation of papers that were deemed suitable for inclusion in this systematic review, referred to as the included studies. The extracted data from each article is summarized in the following manner: the year of publication, the researcher's name, the nation and sample used in the study, the research aims, the research variables examined, the determinants of flood management, and the research findings about the impact of these determining variables.

3.3. Inclusion and Exclusion Criteria

The author intends to incorporate research of peer-reviewed articles that focus on flood control using GIS-based Multi-Criteria Decision Analysis (MCDA) as the inclusion criteria. The exclusion criteria for articles in this study were as follows: (1) absence of an abstract, (2) non-English language, (3) unavailability of full text, (4) in the form of a book, workshop report, or special publication announcement, (5) reporting research that is not relevant to the objectives of this systematic review, (6) reporting research that has already been covered by other articles (e.g., when two articles report

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the same research in different venues such as a scientific journal and a conference, the less comprehensive article will be excluded), and (8) published prior to January 1, 2018.

3.4. Data Extraction

In relation to the process of data extraction, the authors of the study produced a data sheet to record the following information for each included study: The analysis should include the examination of various demographic factors such as the authors' affiliations, the year and source of publication. Additionally, it is important to assess the scope and objectives of the study, as well as the reporting objectives related to smart city applications. The adequacy of the research context should be evaluated, along with the research methods employed. The findings of the research should be thoroughly discussed, and any limitations of the study should be acknowledged. Furthermore, detailed information about the technology used, including data sources, context-aware features, algorithms, and security mechanisms, should be provided. Lastly, the stages of application development reported by the research should be outlined. Figure 1 provides a complete presentation of the many processes involved in conducting a systematic literature review.

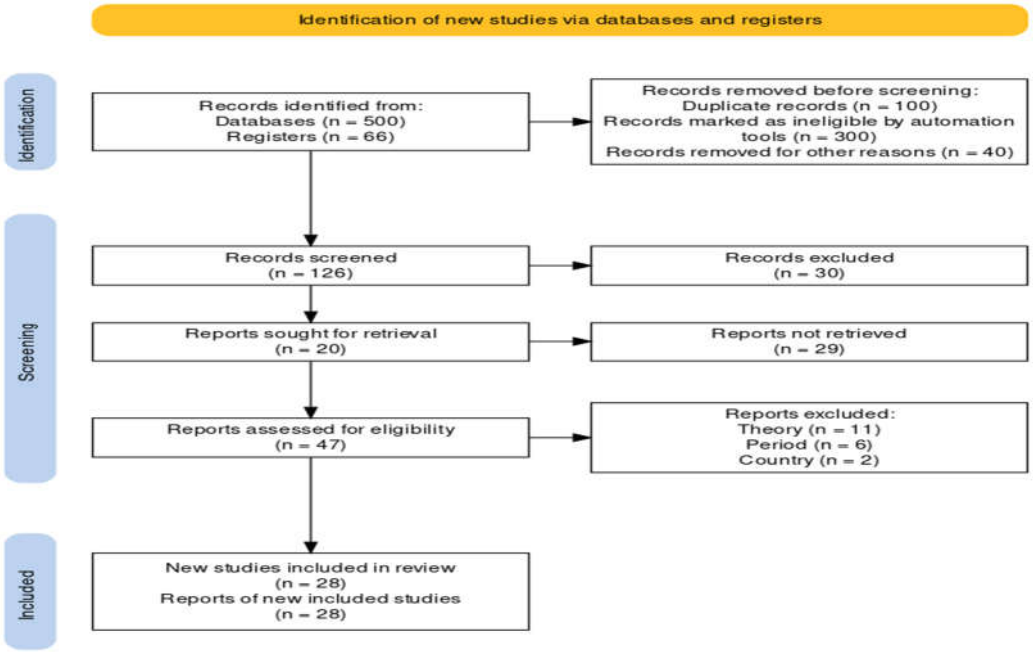

Figure 1. PRISMA flow diagram.

4. Results and Discussion

4.1. Research Results

A search was conducted in the SCOPUS database using the following keywords: "flood hazard*", "flood risk*", "flood susceptibility*", and "flood vulnerability*". A total of 566 articles written in English were published between 1949 and 2021, focusing on the topics of "mcde" or "mcda" and "GIS" or "geospatial". The articles were subsequently retrieved and chosen using IC2 and IC3 criteria, taking into account the title, abstract, and keywords, resulting in a total of 126 articles. In the subsequent phase, the remaining 102 articles underwent further filtration based on IC2 and IC3 criteria through comprehensive reading. The inability to access a certain article resulted in its classification as either excluded or unexamined. Following the completion of this procedure, a total of 28 articles were retained for subsequent study. Furthermore, it is important to note that the aforementioned points are not exhaustive and there may be Numerous scholarly publications pertaining to flood management utilizing Geographic Information Systems (GIS) and employing multi-criteria decision-making approaches are released annually, with a significant number emerging in the year 2020. These scholarly publications employ both qualitative and quantitative methodologies. Subsequently, a qualitative synthesis was conducted on the 28 papers that were chosen for analysis, as depicted in Table 1.

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This suggests that there is ongoing relevance in recent years for research pertaining to GIS-based flood management and multi-criteria judgments, as illustrated in Figure 2.

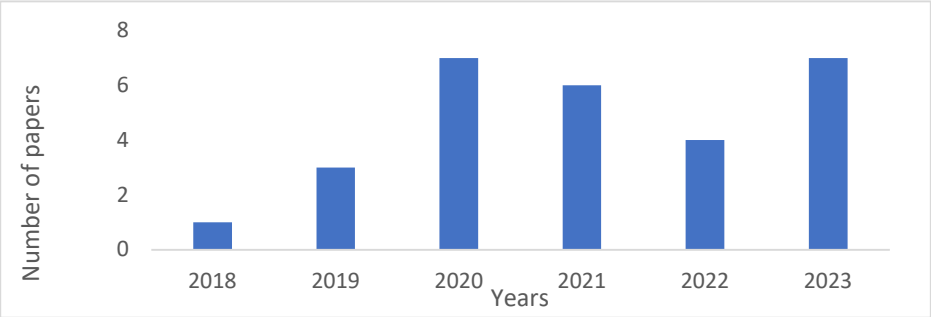

Figure 2. Distribution of selected studies over 5 years.

4.2. Factor's Systematization

The present study further examined the influencing elements for flood control in GIS-based multicriteria judgments by analyzing additional criteria, using a sample of 28 selected papers.

1. The dependent variable in this study is Flood Management based GIS-MCDA.
2. The measurement or calculation of GIS-MCDA flood management, as a dependent variable, encompasses several forms including disclosure, quality, area, or score.
3. The influencing elements considered in this study are based on research findings from at least two journals and are utilized as independent variables.
4. The research is primarily centered on developing nations.
5. Studies with factors connected to developed nations were eliminated;

In accordance with the aforementioned criteria, the identification of influential factors, discernible indications, obtained results, derived conclusions, and pertinent references. The presentation of sustainability reporting is depicted in Table 2.

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Table 1. List Articles and qualitative synthesis.

No	Years	Tittle	MCDM	GIS Data	Purpose
1	Shuayb Jayanta, 2023	GIS-based lood risk assessment using multi-criteria decision analysis of Shebelle River Basin in southern Somalia	AHP : Based on the chosen flood contributing criteria, a pairwise comparison matrix table was created. Following that, based on the Expert's assessment, each aspect was given a specific weight.	The flood hazard map was constructed using seven important causative factors: elevation, slope, drainage density, distance to river, rainfall, soil and geology.	to analyze flood hazard, vulnerability and risk in the part of SRB using GIS-based Multi-Criteria Decision Analysis (MCDA).
2	Mehrnoosh Taherizadeh Reza Sarli · Arman Niknam · Thong Nguyen-Huy · Gábor Mezősi	Flash lood-risk areas zoning using integration of decision-making trial and evaluation laboratory, GIS-based analytic network process and sate lite-derived information	The hybrid MCDM model combines the decision-making trial and evaluation laboratory (DEMATEL) with GIS-based analytic network process (ANP) to evaluate flood vulnerability in Golestan province,Iran.	Fourteen criteria related to flood potential, including elevation, slope, aspect, vegetation density, soil moisture, low direction, river distance, rainfall and runof, low time, geomorphology, drainage density, soil type, lithology, and land use,	Assessing areas prone to flashf loods is crucial for efective disaster management and mitigation. This Study proposes a framework for mapping flood-prone areas by integrating geographic information system (GIS), remote sensing data, and multi-criteria decision-making (MCDM) techniques.
3		Integrating spatial cost path and multi-criteria Analysis for finding alternative routes during Flooding	The AHP technique was used to determine the significance or usefulness of a set of paired criteria. Each criterion was paired and assigned a score ranging from 1 to 9 based on significance	Five influential flood criteria in the study area include (a) slope; (b) rainfall; (c) LULC; (d) distance from the river; and (e) river density. It was established that these five criteria are crucial to the occurrence of floods.	This study aims to investigate an alternative route access for safe travel because of flood hazard.

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4		Assessment of the performance of GIS-based analytical hierarchical process (AHP) approach for flood modelling in Uttar Dinajpur district of West Bengal, India	The study quantitatively verified the AHP output with the flood inventory map through ROC-AUC, MAE, MSE, and RMSE assessments. The ROC-AUC has been performed by comparing the FSZ map with the flood point and non-flood point employing the 'ArcSDM' tool in the ArcGIS software.	Flood susceptibility parameters of the Uttar Dinajpur district: (a) Elevation, (b) Slope, (c) Topographical wetness index (TWI), (d) Topographical positioning index (TPI), (e) Normalized difference vegetation index (NDVI), (f) Modified normalized difference water index (MNDWI), (g) Drainage density, (h) Distance to river, (i) Stream power index (SPI), (j)Sediment transport index (STI), (k) Modified fournier index (MFI) and (l) Lithology. Flood vulnerability parameters of the Uttar Dinajpur district: (a) Distribution of population, (b) Population density, (c) Land use land cover (LULC), (d) Distance to flood shelter, (e) Distance to hospital, (f) Distance to road, (g) Road density, (h) Illiteracy rate (%) and (i) Employment rate.	employed an integration of the Geographic information system (GIS) and Analytical Hierarchy Process (AHP) method for identifying the flood susceptibility zonation (FSZ), flood vulnerability zonation (FVZ), and flood risk zonation (FRZ) of the humid subtropical Uttar Dinajpur district in India. The study combined a large number of thematic layers (N 12 for FSZ and N 9 for
5	Akram AlSukker	Flood Risk Map Using a Multi-Criteria Evaluation and			

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	, Marah Al-Saleem , Morad Etier 2023	Geographic Information System: Wadi Al-Mafraq Zone	Multi-Criteria Decision Analysis (MCDA) is used in a GIS context to combine spatial data layers that reflect the criteria and determine how the layers are combined.	The major GIS layers used to map spatial data include (a) rainfall, (b) geology, (c) soil, (d) climate and (f) hydrology. The secondary data were collected from various national organizations working in Jordan. Data includes digital maps in addition to integration of physical and socio-economic aspects of the study area.	This study aims to explore and identify the flood hazard vulnerability zones in Wadi Al-Mafraq (a Valley located in Jordan) using Geographic Information System (GIS) and Multi-criteria Design Analysis (MCDA).
6	Nani Nagu , Lita A. Latif , Bebi H , And Nurhalis Wahiddin 2022	GIS Based Method for Flood Hazard Assesment in Kobe River Watershed - North Maluku Province	(MCDA) were used in conjunction with the application of the analytical hierarchy process (AHP) method to create the flood hazard map	. The flood hazard map was generated by using selected hazard factors including land use, topography, slope, and rainfall pattern.	The objectives of this study are to mapping the hazard-prone area and to analyse the flood vulnerability index in Kobe Watershed, Central Halmahera District. In order to determine the optimal selection of weights for the factors that contribute to flood risk, GIS and multi-criteria decision analysis
7	Preeti Ramkar · Sanjaykumar M. Yadav 2022	Flood risk index in data-scarce river basins using the AHP and GIS approach	Datasets based on the Analytical Hierarchical Process (AHP) in combination with Geographic Information System (GIS) were used as criteria and sub-criteria. The weights were derived using a questionnaire survey.	The flood hazard map is developed considering slope, distance from the main river, land use, land cover, soil, drainage density and rainfall. The flood vulnerable index is developed using population density, crop production and density of road–river intersection.	This research intends to develop a lood risk index map of data-scare river basins using an integrated approach of Geospatial technique and Multiple Criteria Decision-Making Technique (MCDM)

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8	Wail Faregh & Abdelkader Benkhaled 2022	GIS-based multicriteria approach for flood risk assessment in Sigus city, east Algeria	Using the AHP method, to assess vulnerability to flood risk, requires, first, the design of the hierarchical structure	We considered four criteria that are the most influencing: distance from the main stream “C1,” site elevation “C2,” slope “C3,” andlanduse“C4.	To provide a reliable tool for the urban planner, mainly, to avoid construction in flood-prone areas, this paper presents a useful multicriteria decision analysis (MCDA) methodology for mapping vulnerability to flood risk in urban areas.
9	K. S. Vignesh · I. Anandakumar · Rajeev Ranjan · Debashree Borah 2022	Flood vulnerability assessment using an integrated approach of multi-criteria decision-making model and geospatial techniques	FVZ preparation in this study involves the series of steps: identifying and defining the complex problem, generate the AHP model-based hierarchical structure for the selected criteria.	The formulation of the model requires the ten-flood influen cing physical variables viz. rainfall, slope, drainage density, LULC, DEM, soil, geology, geomorphology, surface runoff, and TWI	The current research focusses on the identification of Flood Vulnerable Zones (FVZ) of Kanyakumari district with the integration of Remote Sensing (RS) and Geographic Information System (GIS), and the Multi-criteria Decision Making Analysis (MCDM)-based Analytical Hierarchy Process (AHP) model in the geospatial environment.
10	Abimbola Oyewole Atijosan*, Ibrahim Isa and Alaga Abayomi 2021	Urban flood vulnerability mapping using integral value ranked fuzzy AHP and GIS	This section presents the variables used as factors in the development of the FAHP MCDM system. Choice of input factors where identified from within relevant literature and their significance in causing flood in the study area.	The factors considered are: elevation, slope, soil, rainfall, drainage density, geology and land use land cover (LULC) information	In this research, an effective FAHP and GIS-based MCDM system for urban flood vulnerability mapping of Ile-Ife is presented.
11	A. Balogun , S. Quan , B. Pradhan , U. Dano , and S. Yekeen	An Improved Flood Susceptibility Model for Assessing the Correlation of Flood	The flood susceptibility map developed from the fuzzy Analytical Network Process (F-ANP) model. The flood susceptibility	It considered Hydrology (Distance from stream (DS) Runoff (RO)), Land Use Forest (FO) Mixed agriculture (MA) Paddy (PA) Palm oil (PO)	To develop a spatial fuzzy-ANP model to accurately classify the flood susceptibility of the study area, addressing the limitations of uncertainty, imprecision and bias inherent in conventional ANP models and to assess

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	2021	Hazard and Property Prices using Geospatial Technology and Fuzzy-ANP	indices from the model were classified into five categories using the reclassification tool in GIS: very-low, low, moderate, high and very-high. The classification signifies	Rubber (RU) Urban Area (UA) Waterbody (WB) Soil Type Alluvium (AL) Granite (GR) Limestone (LS) Sand & gravel (SG) Shale & siltstone (SS) Topography Elevation (EL) Slope Angle (SA) SPI TWI	the impacts of flood susceptibility and occurrences on property prices in the study area..
12	Hua Morea & Sailesh Samanta 2021	Multi-criteria decision approach to identify flood vulnerability zones using geospatial technology in the Kemp-Welch Catchment, Central Province, Papua New Guinea	This research paper is focused on flood risk analysis using multi-criteria decision approach (MCDA), analytical hierarchy process (AHP), and the weighted linear combination (WLC). AHP is a tool under MCDA that is used for dealing with complex decision-making and helps decision-makers set priorities and draw better decisions.	In the present study, nine independent variables, namely elevation, slope, soil texture, soil drainage, landform, rainfall, distance from the main river, land use/land cover, and surface runoff, are used for flood vulnerability analysis.	. to analyse flood risk and hazard mapping with remote sensing technologies which provides an alternative to the conventional/traditional survey techniques. And Multi-criteria decision analysis (MCDA) decision-makers in properly structuring multi-faceted decisions and evaluating the alternatives. AHP is a tool under MCDA that is used for dealing with complex decision-making and helps decision-makers set priorities and draw better decisions. Altogether, GIS-based MCDA-AHP became an efficient technique in flood risk mapping where multiple flood influential factors/criteria are incorporated into the GIS analysis process to producing better flood risk maps.
13	, Omar M. Habiba Karim I. Abdrabo * , Sameh A. Kantoush , Mohamed Saber , Tetsuya Sumi , Dina Elleithy and Bahaa Elboshy	Integrated Methodology for Urban Flood Risk Mapping at the Microscale in Ungauged Regions: A Case Study of Hurghada, Egypt	This study recommends improving the AHP approach for weighting the vulnerability indicators by including statistical weighting techniques (e.g.,	Selected vulnerability indicators from the city strategic plan (CSP) data sets (current). (A) Land Use. (B) Building Height. (C) Building	It aims to enhance the quality of both hazard and vulnerability maps at the urban microscale in ungauged regions. The proposed methodology integrates remote sensing data and high-quality city strategic plans (CSPs) using geographic information systems (GISs), a 2D rainfall-runo

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	2021		principal component analysis (PCA) and fuzzy logic).	Conditions. (D) Building Materials. (E) Land Value. (F) Population Density. (G) Total Population. Calibration process indicateParameter River Roughness Coecient Hillslope Roughness Coecient Soil Depth Soil Porosity Vertical Sat. Hydraulic Conductivity Suction at the Vertical Wetting Front Lateral Sat. Hydraulic Conductivity Unsaturation E . Porosity	-inundation (RRI) simulation model, and multicriteria decision-making analysis (MCDA, i.e., the analytic hierarchy process (AHP)).
14	Ashraf Abdelkarim Ibtesam I. Alkadi * , Seham S. Al-Alola , Haya M. Alogayell , Soha A. Mohamed and Ismail Y. Ismail 2021	Integration of GIS-Based Multicriteria Decision Analysis and Analytic Hierarchy Process to Assess Flood Hazard on the Al-Shamal Train Pathway in Al-Qurayyat Region, Kingdom of Saudi Arabia	The analytic hierarchy process (AHP) is applied to extract the weights of eight criteria	flooding hazards, including flow accumulation, distance from the wadi network, slope, rainfall density, drainage density, and rainfall speed.	The objectives of this study are (1) to develop a flood vulnerability map identifying flood-prone areas along the Al-Shamal train railway pathway; (2) to forecast the vulnerability of urban areas, agricultural land, and infrastructure to possible future floods hazard; and (3) to introduce strategic solutions and recommendations to mitigate and protect such areas from the negative impacts of floods. In order to achieve these objectives, multicriteria decision analysis based on geographic information systems (GIS-MCDA) is used to build a flood hazard map of the study
15	Piyush Gourav , Rajesh Kumar , Akhilesh Gupta	Flood Hazard Zonation of Bhagirathi River Basin using Multi-Criteria Decision-Analysis in Uttarakhand, India	AHP : After assigning ranks for all four thematic layers, the	Using four physical parameters like land-use	This study would be very helpful to reduce the losses of life, property, and infrastructure during floods in the future,

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	and Mohammad Arif 2021		sum weight (W) of 10 was assigned after dividing all four parameters as per the priority of importance.	landcover, elevation,slope, and distance to river.	the outcomes of the study can be used as a ready reference to support the management and mitigation of rescue and rehabilitation policies of the banks of river Bhagirathi.
16	Salah B. Ajjur & Yunes K. Mogheir 2020	Flood hazard mapping using a multi-criteria decision analysis and GIS (case study Gaza Governorate, Palestine)	Weighting step AHP is an important process in GIS-MCDA, as it affects the results significantly. The criterion that has a large weight has the most influence in the final map classification.	Five criteria are considered: distance to stormwater drainage network, land use (cover), height, slope, and groundwater depth.	This study aims to present a geographic information system multi-criteria decision analysis (GIS-MCDA) method to identify flood-prone areas.
17	Nimrabanu Memon · Dhruvesh P. Patel · Naimish Bhatt · Samir B. Patel 2020	Integrated framework for flood relief package (FRP) allocation in semiarid region: a case of Rel River flood, Gujarat, India	Criteria analysis was used to calculate the risk factor for the basin and AHP-MCE method was used to find the normalized weights of each factor that were significant to the flood disaster	LU/LC, CF, soil, slope, drainage density	To identify the flood hazards and flood risk and assess the flood vulnerability in Rel River catchment. The study helped to clearly identify villages vulnerable to flood risk where more relief and flood insurance packages need to be allotted. Thus, the present method and integrated approach would be a useful tool for the decision maker to distribute the flood relief package in flash flood-prone area.
18	Mariana Madruga de Brito, Adrian Almoradie & Mariele Evers, 2020	Spatially-explicit sensitivity and uncertainty analysis in a MCDA-based flood vulnerability model	This study has employed the OAT method to examine criteria weight sensitivity in an ANP-based vulnerability model aiming to provide information for its effective implementation	ANP weights used in the base run. Social vulnerability : Persons under 12 years, Persons over 60 years, Persons with disabilities, and monthly per capita income. Structural vulnerability: households with improper	This study presents a methodology for conducting sensitivity and uncertainty analysis of a GIS-based multi-criteria model used to assess flood vulnerability in a case study in Brazil.

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			in flood risk management.	building material, households with accumulated garbage, households with open sewage Coping capacity : disaster prevention institutions, evacuation drills and training , distance to shelters and health care facilities	
19	Lin Lin · Zening Wu · Qiuhua Liang, 2020	Urban flood susceptibility analysis using a GIS-based multi-criteria analysis framework	AHP method is used for investigating and exploring the interaction and relative importance of the susceptibility influencing parameters. ,	A composite urban flood risk index (FRI) is derived from various flood conditioning factors. The FRI consists of flood vulnerability index, hazard factors, and resilience capacity indicators.	This paper proposes a GIS-MCDM framework to predict the susceptibility of cities to pluvial flooding, which is particularly suitable for data-scarce environments where it is difficult to apply hydraulic model and machine learning methods.
20	Yousef Kanani-S dat, Reza Arabsheibani , Farid Karimipour , Mohsen Nasseri, 2020	A new approach to flood susceptibility assessment in data-scarce and ungauged regions based on GIS-based hybrid multi criteria decision-making method	interdependencies of the criteria, DEcision-MAking Trial and Evaluation Laboratory (DEMATEL) approach are used to form the network of relations among the criteria. Analytic Network Process (ANP) are implemented to calculate the final weight of every single criterion. AHP methodology is implemented too.	To achieve this goal, a spectrum of geophysical, geomorphological, meteorological, hydrological, and geographical criteria have been addressed.	The current research presents a framework for the preparation of flood prone areas' maps by the integration of Geospatial Information System (GIS), fuzzy logic, and Multi-Criteria Decision Making (MCDM).
21	N. Hazarika , D. Barman , A. K. Das	Assessing and mapping flood hazard, vulnerability and risk in the Upper Brahmaputra	MCE provides a dynamic platform to the user in	The study area is dotted with palaeochannels, ditches,	This investigation is an endeavour to assess hazard, vulnerability

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	, A. K. Sarma and S. B. Borah 2020	River valley using stakeholders' knowledge and multicriteria evaluation (MCE)	which hazard and vulnerability indicators and their weightages could be manipulated and calibrated as per the needs, considering the differences in topography, geology and climate, socioeconomic and infrastructural setup across different regions .	swampy land, waterlogged area, rivers and natural levees and is an example of an active riverine environment. Drainage pattern is mostly dendritic.	and risk due to fl ooding, using an indicator-based methodology incorporating stakeholders' knowledge and multicriteria evaluation in geographic information system (GIS) to achieve community-based assessment.
22	L. A. Hadi, W. M. Naim, N. A. Adnan, A. Nisa, and E. S. Said 2020	GIS Based Multi-Criteria Decision Making for Flood Vulnerability Index Assessment	For this study only Rank Sum and Analytical Hierarchy Process (AHP) techniques in MCDM were used. Based on these MCDM techniques, FVI models were developed and FVI maps were generated.	For this study, four different vulnerability components, i.e. social, economic, infrastructure and physical were considered. The criteria for each of components were determined based on expert opinions and literature review.	This paper is intended to highlight the potential integrated of Geographic Information System (GIS) and Multi Criteria Decision Making (MCDM) to develop Flood Vulnerability Index (FVI) map.
23	Azazkhan Ibrahimkhan Pathan · Prasit Girish Agnihotri · Saif Said · Dhruvesh Patel 2019	AHP and TOPSIS based flood risk assessment- a case study of the Navsari City, Gujarat, India	In this study, two statistical MCDM approaches, namely The analytical hierarchy process (AHP) and the technique for order preference By similarity to ideal solution (TOPSIS), have	. A total of 14 lood indicators, Seven each for hazard (i.e., elevation, slope, drainage, density, distance to river, rainfall, soil, and low accumulation) and vulnerability (i.e., population density, female population,	. The study demonstrates the potential of AHP and TOPSIS integrated with GIS Towards precise identiication of flood-pronemareas for devising efective flood management strategies.

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			been employed to generate flood risk maps during floods.	land use, road network density, household, distance to hospital, and literacy rate) were considered for evaluating the flood risk.	
24	Nur Mohammad Ha-Mim, Jannatun Nahar Fariha , Md. Abdur Rahman , Md. Zakir Hossain, Khan Rubayet Rahaman 2019	Employing multi-criteria decision analysis and geospatial techniques to assess flood risks: A study of Barguna district in Bangladesh	The specific method contemplates four major steps as: (i) used the analytical hierarchy process (AHP) generate comprehensive weights of hazard exposure and vulnerability; (ii) prepared a hazard exposure map using the multi-criteria decision-making (MCDM) approach; (iii) deployed the indexing method to calculate the vulnerability indices for the study area;	Hazard Exposure :Distance from river (DFR) Elevation (El) Distance from coastline (DFC) Rainfall (Ra) LULC Drainage density (DD) Slope (Sl) NDVI Vulnerability Criteria : Population density (PD) Katcha housing structure (KHS) Literacy (Li) Agricultural employment (AE) Electricity connection (EC) Working age population (WAP) Unemployment rate (UR) Service & industry employment (SIE) Population with disability (PWD) Young children (YC) Senior citizen (SC)	This research paper ponders a systematic methodological approach by considering quantitative data obtained from secondary sources to generate maps of flood-induced risks and vulnerability in the Barguna district.
25	Laxmi Gupta Jagabandhu Dixit 2019	A GIS-based flood risk mapping of Assam, India, using the MCDA-AHP approach at the regional and administrative level	Three indices, namely flood hazard index (FHI), flood vulnerability index	The selected hazard and vulnerability indicators define the topographical, geological, meteorological, drainage	In the present study, the flood hazard, vulnerability, and risk maps of Assam at the regional and administrative levels are developed by combining MCDA-AHP and

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			(FVI), and flood risk index (FRI), are developed using multi-criteria decision analysis (MCDA) – Analytical hierarchy process (AHP) approach in GIS environment for the regional and administrative level of Assam.	characteristics, land use land cover, and demographical features of Assam.	GIS tools. The flood hazard and vulnerability layer are created using different indicators, and AHP is applied to assigned weightage to the indicator. The final flood risk map is obtained by integrating hazard and vulnerability indices in GIS software and validated by confusion matrix, RME, and RMSE based on historical flood events.
26	Jay R.S. Doorga Sophia Watkins , Leonard Magerl , Priyal Bunwaree , Jiaxin Zhao , Caroline G. Staub , Soonil D.D.V. Rughooputh , Tyagaraja S. M. Cunden , Roddy Lollchund 2018 , Ravindra Boojhawon	GIS-based multi-criteria modelling of flood risk susceptibility in Port Louis, Mauritius: Towards resilient flood management	The flood risk map of Port Louis, delineating regions of high, intermediate and low risks, is generated using the WLC technique. Falling under the domain of bivariate statistical analysis, this technique combines factors by assigning respective weights acquired from AHP.	It implement a multi-criteria model consisting of a physical-oriented, a social-oriented and an economic-oriented scenario to identify highly vulnerable sites to flooding in the capital city, Port Louis. Social, technical, economic and legal perspectives are incorporated to propose comprehensive floodmanagement strategies.	The aim is to minimize the physical impacts of floods while also addressing the broader social and economic risks. Location-based flood management strategies are thereafter proposed to increase the resilience of the city to flooding.
27	Marina T. Aidinidou , Konstantinos Kaparis , Andreas C. Georgiou	Analysis, Prioritization and Strategic Planning of Flood Mitigation Projects based on sustainability dimensions and a spatial/value AHP-GIS system	Analytical Hierarchy Process (AHP), is coupled with a spatial database environment, generated in a Geographic Information Systems (GIS) software.	vulnerability is chosen to be expressed as a function of 18 multidimensional factors which are further categorized under the three sustainability pillars; that is the environment, the society and the economy.	This study aims to establish a set of risk criteria concerning the comprehensive urban flood risk assessment and to investigate the criteria changes on different weighted sets, in both value and spatial distribution.
28	Mohammed O. Idrees, Abdulganiyu Yusuf, Ernieza S. Mokhtar & Kouame Yao	Urban flood susceptibility mapping in Ilorin, Nigeria,	To obtain the weights of each factor, the Analytical	Eight factors considered the most influential variables for	The objective of this study is to assess and map flood hazard zones in Ilorin

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		using GIS and multi-criteria decision analysis	Hierarchical Process (AHP) was applied.	runoff accumulation and stagnation in the city during excess rainfall and surface water runoff were taken into account. These factors include elevation, slope, topographic wetness index, convergence index, drainage density, altitude above channel, land use, and rainfall.	(North-Central, Nigeria).

Table 2. Determinants of flood Management Reporting.

No	Determinant Variabel	Indicator	Result	Conclusion	Previous research
1	Natural Factor	Climate Geomorphology	The utilization of several geomorphological elements is prevalent in academic research.	The present study aims to identify and address the research gap pertaining to the influence of climate conditions on a given phenomenon.	Shuayb and Janata (2023)[4], Taherizadeh et al (2023)[5], Rauf et al (2023)[6], Mitra et al (2023)[7] Sukker et al (2023)[8], Nagu et al (2022)[9], Ramkar et al (2022)[10], Faregh et al(2022)[11], Vignesh et al (2022)[12], Oyewale et al (2021)[13], Balogun et al (2021)[14], Morea and Samanta (2021)[15], Habiba et al (2021)[16], Abdelkarim et al (2021)[17], Gouray et al (2021)[18], Ajjur and Mogheir et al (2020)[19], Dhruvesh et al (2020)[20], Zening et al. (2020)[21], Kanani et al.(2020)[22], Hazarika et al (2020)[23], Hadi et.al (2020)[24],Khan et al (2019)[25],Mohammad et al (2019)[26], Gupta et al (2019)[27], Doorga et al (2018)[28], Aidinidou et al (2023)[29], Idrees et al (2023)[30]
2	Technical Factor	Infrastructure O&M Hydraulic system alterations	Infrastructure indicators are commonly utilized in numerous studies.	The existing literature reveals a study need in the areas of O&M indicators, hydraulic	Abdelkarim et al (2021) [17] ; Habiba et al (2021) [16] Ramkar et al (20220 [10] Hazarika et al (2020) [23], Hadi et.al (2020)[24] Khan et al (2019)[25]

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		Stormwater Management Flood Control Measures Warning System		system alteration, stormwater management, flood control meters, and warning systems. Further investigation is needed to address these topics and contribute to the academic understanding of these subjects.	
3	Institusional Factor	Leadership Law Enforcement Institutional Arrangements Flood Management Strategy Disaster Assistance Public Education Public Participation	Numerous research employ indicators for flood management strategies.	There exists a research void within the domains of leadership, law enforcement, institutional arrangements, disaster aid, public education, and public engagement.,	Dhruvesh et al (2020)[20] Madruga et al (2020)[[31]]
4	Socio Economic Factor	Demography Industrialization Urbanization Land Development Information Poverty	Demographic indicators are commonly employed in numerous investigations.	One notable research gap in the field of industrialization , urbanization, land development, information and poverty	Mitra dkk 2023[7], Ramkar dkk [7] Madruga (2020) [18] Habiba (2021) [13] Hazarika et al (2020) [21] Hadi et.al (2020)[22] Khan et al (2019)[23] Mohammad et al (2019)[24] Aidinidou et al (2023)[27] Gupta et al (2019)[25] Doorga et al (2018)[28]
5	Financial Factor	• Limitation of Capital Investment • Financial Obligation • Financial Priorities	Many studies employ financial obligation indicators	The existing body of research lacks a comprehensive analysis of the indicators that highlight the limitations of capital investment and budgetary priorities.	Mitra et al 2023 [7] Madruga et al (2020) [18]

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4.3. Variable Determinants

4.3.1. Natural Factor

A total of 25 research employed natural determinants as variables. The incorporation of various geomorphological components is widespread in scholarly investigations. The primary objective of this study is to discover and rectify the existing research deficiency concerning the impact of climate conditions on a certain phenomenon.

4.3.2. Technical Factor

The technical elements employed in five investigations were identified. In his study, Abdelkarim (2014) employed infrastructure metrics as a means to assess the susceptibility of metropolitan areas to flood hazards. In her study, Habiba (2013) incorporates many characteristics like Building Height, Building Conditions, Building Materials, and Land Value. The density of road-river intersections is utilized by Ramkar et al. (7). Infrastructure indicators are frequently utilized in a multitude of investigations. The available body of literature indicates a research gap in the domains of O&M indicators, hydraulic system modification, stormwater management, flood control meters, and warning systems. Additional research is required to explore these areas and enhance scholarly comprehension of these themes.

4.3.3. Institutional Factor

Two research utilized institutional determinants as factors. The study conducted by Dhruvesh et al. (2017) examines the optimal allocation of flood insurance packages. Madruga et al. (2018) examined the role of disaster prevention institutions, evacuation drills and training, as well as the proximity of shelters and health care facilities in mitigating the impact of disasters. There exist a multitude of research-based employment indicators pertaining to solutions for flood management. There is a noticeable lack of study in the areas of leadership, law enforcement, institutional structures, disaster help, public education, and public engagement.

4.3.4. Socio Economic Factor

Socio economic determinants were considered in 10 research. In their study, Mitra et al. (4) employ the distribution of population parameter, while Ramkar et al. (7) focus on population density as a key variable. Habiba et al. (13) employed the concept of vulnerability, specifically focusing on population density and total population. The term "Madruga" refers to a cultural tradition observed in certain Latin American countries Individuals who are under the age of 12, individuals who are above the age of 60, and individuals with impairments. Demographic indicators are frequently utilized in a wide range of research inquiries. A significant research deficit exists within the realm of industrialization, urbanization, land development, information, and poverty.

4.3.5. Financial Factor

Two studies employed financial determinants as variables. Mitra et al. (4) employ the use of employment rate as a metric. The monthly per capita income of Madruga is 18. Numerous academic investigations utilize financial obligation indicators. The current corpus of scholarly literature exhibits a dearth of a thorough examination of the indicators that effectively illuminate the constraints associated with capital investment and the allocation of financial resources.

4.4. Discussion

In the present context, the Analytic Hierarchy Process (AHP) approach is frequently employed in a limited number of scholarly works, whereby it is utilized in conjunction with other Multiple Criteria Decision Analysis (MCDA) methodologies, specifically TOPISI and DAMSTEL. The convergence of Geographic Information Systems (GIS) with multicriteria decision analysis (MCDA) has garnered considerable attention in recent years. The integration of Geographic Information Systems (GIS) with Multi-Criteria Decision Analysis (MCDA) holds potential for mutual enrichment and advancement in both fields of study. Several studies have been conducted to examine the application of Analytic Hierarchy Process (AHP) as a decision-making technique in assessing the

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significance and weighting of various natural factors, including morphometric parameters, slope, land use, soil texture, and rainfall intensity, for the purpose of flood forecasting. The integration of Geographic Information Systems (GIS) with Multi-Criteria Decision Analysis (MCDA) represents a highly effective methodology for assessing the level of risk and devising appropriate solutions for mitigating its consequences. Based on a review of 28 scholarly works, which provide an analysis of the determinants of sustainability reporting variables as outlined in Tables 1 and 2, it is evident that there exist five key determinants. These determinants are categorized as natural elements, technical factors, institutional factors, socio-economic factors, and financial factors. The following are the five determining criteria.

Based on the preceding discourse, the examination of 28 chosen papers (prior scholarly investigations) reveals that the five criteria under consideration yield incongruous outcomes, hence highlighting the originality of this study. The findings of this study indicate that past research has yielded both consistent and inconsistent results with respect to the influencing factors. The findings of the study indicate a consistent focus on natural factors as determinants, while research on other determinants, such as technical factors, institutional factors, socio-economic factors, and financial factors, has been relatively scarce. This lack of consistency poses a challenge for future research in Indonesian companies.

5. Conclusion

A total of 28 studies were chosen and identified based on the predetermined inclusion and exclusion criteria. The analysis of primary works indicates that scholarly investigations pertaining to flood management publications predominantly concentrate on five key themes and patterns: technical considerations, institutional aspects, socio-economic factors, and financial elements. The findings of this study underscore novel advancements that draw upon pertinent prior research, hence contributing valuable insights to the evaluated papers. Nevertheless, the findings of the chosen articles exhibit discrepancies. Several research studies have demonstrated a noteworthy correlation between determining factors and natural factors, however other studies have yielded contrasting findings, indicating a lack of statistical significance in the link. Future academics are encouraged to conduct deeper investigations into this contradiction.

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