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Using the Binary Matrices for Modeling the Complex Relationships among Enablers of Combating the Damages by Floods

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Abstract
The aim of study is modeling the complex relationships among enablers of combating the damages by floods. The study's overall design entails of a literature-review, data-collection, and analysis. Population under study is all stakeholders of phenomenon of floods in Pakistan. Sampling design is non-probability based focus group (i.e. panel of experts). Data gathering is done from experts on a matrix type questionnaire. The data is aggregated through mode using some functions of MS excel. Results of the literature review reveal that there are total twenty enablers of combating the damages by floods. Results of ISM modeling show that the enablers improved drainage system, afforestation, strict construction regulations, adherence to flood early warning system, elevate furnaces, water heaters, and electric panels, install check valve in sewer traps, seal walls in basements, keep an adequate supply of food, candles and drinking water, listen to designated radio/TV emergency alert systems, secure outdoor hazardous equipment, move valuable items to upper floors, seek high ground, beware of flash flood areas, be ready to evacuate, use a stick to test depth while leaving homes, do not drive over a flooded road, stay away from flood water, avoid downed/fallen power lines, and do not drink tap water until advised by health officials occupy Level I whereas only one factor i.e. beware of weekend and collapsed roads fall at Level II of ISM structural model. Results of Scale-centric MICMAC analysis show that the independent, dependent and autonomous quadrant are empty. All the enablers are classified in linkage quadrant. Results of Data-centric MICMAC analysis show that autonomous quadrant is empty. Enabler 'install a check valve in sewer traps' is classified in independent quadrant. Enabler 'beware of weekend and collapsed roads', is classified in dependent quadrant. All other enablers are classified in linkage quadrant. The findings of the study are highly useful for all the stakeholders. It is an original valuable study because it is based on real-time experimental first-hand data collected by authors who have hands on jobs of data collection for decades. It also uses unique and different methodologies to collect data, modeling, and analysis.

Keywords: *Binary matrices, flood, ISM, MICMAC, modeling, Pakistan*

INTRODUCTION
The damages caused by floods in the form of destroyed infrastructure, inundated properties, loss of lives, shattered businesses and essential public services are priority agenda of research in this climatically changing world (Boyland et al., 2024; Manandhar et al., 2023). Loss of lives and the economic impacts caused by the floods are increased in the Asian region over the past many decades. The fatalities and economic losses resulting from such extreme events are more significant in developing countries than the wealthier nations (Lai et al., 2023). The continuously rising temperature, increasing storms, and urbanization make flood management extremely difficult (Kuang & Liao, 2020). Whatever the causes may be, either natural or human-induced, when floods become unstoppable, mankind has to live with them by creating ways to combat those (Gaisie & Cobbinah, 2023). The term combat indicates the approaches and strategies adopted by the individuals as a response to flood events. Combating refers to the immediate and short-term actions by individuals and long-term strategies by the authorities in response to the floods. Long-term measures are adopted to prevent the impacts of hazards such as increasing channel capacity, building dams, adopting strict construction regulations, and installation of sewer traps. Strengthening personal and community resilience is increasingly needed. One of the disaster mitigation strategies is household preparedness which helps households to minimize the effects of natural hazards. According to Chai and Wu (2023), worldwide urbanization is leading towards more flooding. Although comfortable and convenient

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for the people, urban areas are more vulnerable to flooding where disasters can cause intense damage to property and infrastructure. Upgrading the infrastructure, maintaining the drainage systems, and adopting strict construction regulations could help mitigate the disastrous events. Freeman et al. (2018) found that dissemination of information is a key to household preparedness and combating floods. Individuals have informational needs such as designated television and radio that is still a backbone for risk communications and early warnings during disasters (Zander et al., 2022). Musolino et al. (2022) found that most of the fatalities during floods are a result of walking through flood water. It is strongly advised to use a stick to test depth while leaving homes, beware of collapsed roads and fallen power lines, and avoid driving on flooded roads. Defensive measures alone could not protect against extreme floods, some nature-based solutions are an additional option that could lessen the destruction and loss of lives. As a mitigation measure for flooding, natural infrastructure is considered the best measure such as making use of natural land features, and afforestation to increase infiltration and slow down run-off (Kurki-Fox et al., 2022; Abass, 2023; Van Hespen et al., 2023). The objectives of the study include: i) to uncover the enablers of combating the damages by floods, ii) to reveal direct and indirect enabler relationships, iii) to model the complex relationships among enablers, iv) to classify the conundrum array of enablers into order of dependencies and v) to prepare policy guidelines for stakeholders to benefit from the enablers. Research questions, therefore, are: i) what are the enablers for combating the damages by floods on a priority basis? ii) Which enablers are relatively less important?, and iii) What is the contextual relationship among enablers for combating the damages by floods? To answer these questions wide range of methods is available in literature. An Array of methodological choices was considered to achieve the objectives of the study (Fu, et al. 2022; Niazi, et al. 2021; Niazi, et al. 2023; Qazi, et al. 2020; Qazi, et al. 2022). It includes considering Grey Relational Analysis (GRA), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Stepwise Weight Assessment Ratio Analysis (SWARA), VIekriterijumsko KOmpromisno Rangiranje (VIKOR), Interpretive Structural, Modelling (ISM), Cross Impact Matrix Multiplication Applied to Classification (MICMAC), Total Interpretive Structural Modelling (TISM), Modified-TISM, Polarized-TISM, Fuzzy-ISM/TISM, Data Envelopment Analysis (DEA), Decision making trial and evaluation laboratory (DEMATEL), Wavelet Analysis (WA), Structural Equation Modelling (SEM), Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), Artificial Neural Networks (ANN), as possible choices Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) (Abbass, et al., 2022). It is also considered to use the methods in combination. ISM in combination with MICMAC is found to be the most appropriate because of its simplicity and ease of application & understand (Basit, et al. 2021; Qazi, et al., 2019; Niazi, et al., 2021a; Niazi, et al., 2023c). From this array, ISM plus MICMAC is therefore used in this study. The remaining part of the article is arranged as a review of the literature, methodology, discussion, and conclusion.

LITERATURE REVIEW

Since literature review provides the foundation of knowledge on the topic, prevents duplication, and helps to give credit to other researchers, uncovers questions left from other research, verifies justification of further research, the relationship of works in the context of its contribution, and places the research study within the context of existing literature therefore it is always advisable to review the contemporary relevant literature in a bit depth. It is also important that the reviewer should mention the extent of access to literature they have got in fact. A survey of contemporary literature has been conducted by way of exploring the renowned research databases of the world to which the Higher Education Commission of Pakistan has provided official access to Higher Education Institutions (i.e. Wiley Online Library, Taylor & Francis Online, Springer Link, Emerald Insight, Elsevier-ScienceDirect, JStor, etc.) through advanced search tab with appropriate filters. The key used for the search includes ‘flood early warnings’, ‘social obstacles to implement floods early warning systems’, ‘early warning systems of floods’, ‘floods in Pakistan’, ‘issues of floods early warnings’, ‘social issues of flood warnings’, etc. The search resulted in thousands of research papers that have been screened based on relevance. Highly relevant research articles have been reported to set out the very outset of the study. Many studies are at hand having their focus on climate change (Tang et al., 2024; Echendu, 2023; Hussain & Khan, 2024), destructions after floods (Waseem & Rana, 2023; Ullah et al., 2023; Knippenberg et al., 2024; Shehzad 2023) , monsoon rainfall and floods (Zia et al., 2023; Otto et al., 2023; Muzammil et al., 2023; Hussain et al., 2024) economic losses from floods (Lai et al., 2023; Ashraf et al., 2023; Amirmoradi & Shokoohi, 2024; Kawasaki & Shimomura, 2024), nature based

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solutions for flood management (Liao et al., 2024; Theochari & Baltas, 2024) importance of resilient infrastructure (Birkmann et al., 2023), safe evacuation from flooded areas (Borowska-Stefańska et al., 2023; He et al., 2023), route planning during floods (He et al., 2021), flood risks for vehicle occupants (He et al., 2023), , importance of early warning systems before floods (Zang et al., 2022: Shah et al., 2022), managing extreme rainfall and battling with urban floods (Chen et al., 2023; Manandhar et al., 2023). The focus of these studies is either the causes of floods or a specific enabler to combat the floods. Based on the current knowledge, we could not find a single study that lists the enablers of combating the damages by floods, hierarchizes them, and categorizes them based on their driving-dependence powers. In recent years, floods surfaced as most disastrous events around the world occur as a result of urbanization and climate change (Santoro et al., 2022; Grahn & Jaldell, 2019; Lan et al., 2022). The deaths related to flood events are on a rising trend (Li et al., 2024). The Asian region, particularly Pakistan is highly prone to climate-induced disasters. Being the most frequent and deadly natural hazard, floods have caused extensive damage to crops, agriculture, human life, and infrastructure (Shah et al., 2023). Most of the fatalities happen due to drowning when people attempt to move either on foot or by vehicles in floodwaters. During the occurrence of catastrophic events, emergency operations for evacuation become crucial due to unwillingness, unpreparedness, and failure of risk-reduction strategies. Risks of drowning from rapid water rise, and the probability of injuries from collapsing structures or debris increase while evacuating from flood sites. Additionally, inadequate shelter can lead to health issues further worsening the conditions (Abass et al., 2022; Rezende et al., 2019; Grahn & Jaldell, 2019; Bischiniotis et al., 2020; Li et al., 2020). Globally, flood combating measures include structural measures such as dams and non-structure approaches such as land use planning and early warning systems, and nature-based approaches such as afforestation. Another pivotal component is community education. The economic constraints in Asian developing countries make access to advanced solutions nearly impossible (Osuide, 2022). Basic flood barriers are the structural measures whereas, the focus of non-structural approaches is the community-based early warning systems, emphasizing low-cost short-term methods exploiting the local knowledge. Challenges are faced by developing Asian countries due to limited infrastructure and resources (Manzoor et al., 2022; Membele et al., 2022). Proactive planning is crucial for fighting against floods. Combating the floods involves the interplay of response, preparedness, prevention, and recovery measures (Karpouza et al., 2023). According to Ringo et al. (2023), adhering to flood early warning systems is an important preparedness measure to ensure safety and reduce damage. Flood-prone areas are vacated by the people upon receiving the warning from early warning systems. Conduction of evacuation training, forming flood management camps, preparation of shelter centers, keeping an adequate supply of food, and maintaining the drainage systems are the steps that could be taken when early warnings are received. People can take more precautionary steps to prepare themselves well before the time when they are informed. Mapili et al. (2022) assessed that tap water becomes contaminated with flood water. Water systems are damaged by floods leading to unsafe water contaminated by chemical sewage and debris. It is advised to use boiled or bottled water until declared safe by local authorities. Evens et al. (2024) emphasized on the preventive measures. Potential risks are posed to those traveling by car. Damages are likely to be more severe when people in their vehicles are caught in the flood water. Dangerous debris and eroded roads are concealed by the flood waters, while quick currents can drag the vehicles away from the track leading to accidents. Strict construction regulations and resilient infrastructure are essential in flood-prone areas to enhance safety and mitigate damage. Strict regulations make sure that the buildings can withstand extreme floods through proper drainage systems, elevated foundations, and flood-resistant material. Efficient stormwater management and flood-resistant material help combat floodwaters, prevent severe damage, and support quicker recovery (Stefanidis et al., 2022). Additionally, a nature-based solution such as afforestation is another enabler to combat the occurrence of floods. In many parts of the world, rapid deforestation due to economic pressure and population growth is a great concern. Afforestation for natural flood management is an attractive idea where trees play a role in locking up large amounts of carbon helping biodiversity, environmental rehabilitation, and suppressing disastrous events (Liao et al., 2024). The critical literature discourse identifies twenty major enablers of combating the damages by floods (Table 1).

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Table 1: List of Enablers of Combating the Damages by Floods

Code	Enablers of Combating the Damages by Floods	Source
1	Improved drainage system	(Haghbin & Mahjouri, 2023; Bibi et al., 2023).
2	Afforestation	(Kurki-Fox et al., 2022; Abass, 2023).
3	Strict construction regulations	(Munawar et al., 2021; Ameh et al., 2024)
4	Adhere to flood early warning system	(Ringo et al., 2023)
5	Elevate furnaces, water heaters, and electric panels	(Endendijk et al., 2023; Van Hespen et al., 2023)
6	Install check valve in sewer traps	(Ameh et al., 2024)
7	Seal walls in basements	(Ameh et al., 2024; Liao et al., 2024)
8	Keep an adequate supply of food, candles, and drinking water	(Toland et al., 2023)
9	Listen to designated radio/TV emergency alert systems	(Freeman et al., 2018; Zander et al., 2022)
10	Secure outdoor hazardous equipment	(Endendijk et al., 2023)
11	Move valuable items to the upper floors	(Berghäuser et al., 2023; Yusoff & Yusoff, 2022)
12	Seek high ground	(Borowska-Stefańska et al., 2023)
13	Beware of flash flood areas	(Evans et al., 2024)
14	Be ready to evacuate	(Ringo et al., 2023)
15	Use a stick to test depth while leaving homes	(Evans et al., 2024; Borowska-Stefańska et al., 2023)
16	Do not drive over a flooded road	(Evans et al., 2024; Das et al., 2022)
17	Stay away from floodwater	(Musolino et al., 2022)
18	Beware of weekend and collapsed roads	(He et al., 2023),
19	Avoid downed/fallen power lines	(Borowska-Stefańska et al., 2023; He et al., 2023)
20	Do not drink tap water until advised by health officials	(Mapili et al., 2022; Gunipe & Das, 2023)

Table 1 contains the list of enablers of combating the damages by floods along with the sources from literature and the study is built on the enablers in the context of Pakistan.

METHODOLOGY

The study follows qualitative paradigm of research and interpretivism as research philosophy research approach is inductive by design. The study's overall design entails of a literature-review, data-collection, and analysis. Population under study comprises of all stakeholders of phenomenon of floods in Pakistan. Sampling design entails on non-probability based focus group (i.e. panel of experts' recruited keeping in view the nature of the study) as used in Tariq, et al. (2023), Shaukat, et al., (2023), Qazi, et al., (2023), Qazi, et al., (2023a). Data gathering is done from experts on a matrix type questionnaire in field setting. The data collected is noted in MS Excel sheets and is aggregated using the concept of mode (one of the popular measure of central tendency in statistics) through some functions of MS Excel (Niazi, et al., 2020a; Niazi, et al., 2020b; Farid, et al. 2023). An array of methods for generation of list of enablers was considered like: expert opinion, case study, Delphi method, EFA, meta-analysis, idea-engineering-workshop and brainstorming, random words analysis, brain-mapping, literature review etc. Because of authority of literature review over others as aforementioned techniques, the study opted for generating list of enablers through literature (Qazi, Niazi, & Basit, 2020). The list of enables is finalized from critical review of contemporary literature. The background of the study is first briefed to experts before data collection and face to face one on one method of completing the questionnaire is used (Niazi, Qazi, & Basit, 2019; Basit, Khan, & Qazi, 2021; Basit, Qazi, & Khan, 2021). The field survey is administered by the authors themselves. Interpretive

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Structural Modelling (Rashid, et al., 2021; Qazi, et al., 2020a; Qazi, Niazi, & Inam, 2019; Abbass, et al., 2022a; Niazi, et al. 2023a; Niazi, Qazi, & Sandhu, 2019) is used as a technique for modeling, whereas, Matriced' Impacts Croise's Multiplication Appliquée a UN Classement (Cross Impact Matrix Multiplication Applied to Classification) is used for structural analysis (Basit, et al., 2019; Basit, Qazi, & Niazi, 2020; Niazi, et al., 2020; Niazi, Qazi, & Basit, 2019b).

Panel of Experts

The recruitment of experts on panel to collect data on certain issue on which the data is not available or is insufficient/inaccurate is common in research (Niazi, et al., 2019a; Niazi, Qazi, & Basit, 2021; Basit, Qazi, & Niazi, 2020a). The phenomenon under investigation in this study is also similar case therefore a panel of experts is constituted for eliciting the data. As a first step the criteria to recruit the panel is decided by the authors according to norms of these type of the studies (Niazi, Qazi, & Basit, 2019a; Basit, et al., 2023). The criteria includes: minimum exposure to floods as phenomenon, minimum education level as university graduate, reasonable understanding of flood related areas & issues, reasonable research acumen, and willingness to participate in the study as a respondent. For data collection a matrix type VAXO based questionnaire is used with semi-structured interview (Qazi, et al., 2021a; Qazi, Niazi, & Basit, 2021; Niazi, et al. 2023b). The technique of data elicitation used is face-to-face one-on-one interrogation and compilation of *ij* part of the questionnaire in field setting (Shaukat, et al. 2021; Qazi, et al., 2021; Niazi, et al., 2019).

MODELING, ANALYSIS, RESULTS AND DISCUSSION

This section of the study consists of stepwise application of the procedure of ISM from modeling, and MICMAC for analysis, compilation of results from literature discourse, modeling & analysis, and discussion on the same**.**

Modeling

A procedure of ISM modeling is applied that starts with aggregating the survey data using the majority rule popularly used in this method. Structural Self-Interaction Matrix (SSIM) Table-2 is prepared as a result of aggregation.

Table 2: Structural Self-Interaction Matrix (SSIM)

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1		X	V	V	V	V	V	X	A	O	V	O	V	X	O	O	X	X	X	O
2			V	O	V	V	A	O	O	X	V	X	V	O	O	V	V	V	X	V
3				V	V	A	X	V	X	A	V	V	A	X	A	V	V	A	A	O
4					V	V	A	O	X	V	V	O	O	O	V	V	O	V	V	V
5						A	A	O	X	A	O	A	V	V	A	X	O	O	O	A
6							V	V	X	A	A	V	A	A	A	O	O	A	A	X
7								A	O	A	V	V	A	X	X	A	A	A	O	O
8									V	V	A	V	X	X	X	A	O	O	A	V
9										A	A	A	A	O	A	O	A	O	A	V
10											A	A	X	A	V	V	V	X	X	A
11												A	X	A	O	A	A	A	A	O
12													O	A	X	X	V	O	X	X
13														X	O	O	X	X	X	A
14															O	X	X	V	X	X
15																A	X	X	A	A
16																	A	V	X	O
17																		X	X	X
18																			A	V
19																				O
20																				

Table 2 (Structural Self-Interaction Matrix-SSIM) is converted into Table 3 (Initial Binary Reachability Matrix) using coding rules of ISM modeling.

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V: $i \rightarrow j$	A: $i \leftarrow j$	X: $i \leftrightarrow j$	O: $i \not\leftrightarrow j$
1	0	1	0

Table 3: Initial Binary Reachability Matrix

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1	1	1	1	1	1	1	1	0	0	1	0	1	1	0	0	1	1	1	0
2	1	1	1	0	1	1	0	0	0	1	1	1	1	0	0	1	1	1	1	1
3	0	0	1	1	1	0	1	1	1	0	1	1	0	1	0	1	1	0	0	0
4	0	0	0	1	1	1	0	0	1	1	1	0	0	0	1	1	0	1	1	1
5	0	0	0	0	1	0	0	0	1	1	0	0	1	1	0	1	0	0	0	0
6	0	0	1	0	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0	1
7	0	1	1	1	1	0	1	0	0	0	1	1	0	1	1	0	0	0	0	0
8	1	0	0	0	0	0	1	1	1	1	0	1	1	1	1	0	0	0	0	1
9	1	0	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1
10	0	1	1	0	0	1	1	0	1	1	0	0	1	0	1	1	1	1	1	0
11	0	0	0	0	0	1	0	1	1	1	1	0	1	0	0	0	0	0	0	0
12	0	1	0	0	1	0	0	0	1	1	1	1	0	0	1	1	1	0	1	1
13	0	0	1	0	0	1	1	1	1	1	1	0	1	1	0	0	1	1	1	0
14	1	0	1	0	0	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1
15	0	0	1	0	1	1	1	1	1	0	0	1	0	0	1	0	1	1	0	0
16	0	0	0	0	1	0	1	1	0	0	1	1	0	1	1	1	0	1	1	0
17	1	0	0	0	0	0	1	0	1	0	1	0	1	1	1	1	1	1	1	1
18	1	0	1	0	0	1	1	0	0	1	1	0	1	0	1	0	1	1	0	1
19	1	1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0
20	0	0	0	0	1	1	0	0	0	1	0	1	0	1	1	0	1	0	0	1

Table 3 (Initial Binary Reachability Matrix) is converted into Table 4 (Transitive Binary Matrix) by checking and incorporating transitive relations for each 0 in Table 2.

Table 4: Transitive Binary Matrix

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Driving
1	1	1	1	1	1	1	1	1	1*	1*	1	1*	1	1	1*	1*	1	1	1	1*	20
2	1	1	1	1*	1	1	1*	1*	1*	1	1	1	1	1*	1*	1	1	1	1	1	20
3	1*	1*	1	1	1	1*	1	1	1	1*	1	1	1*	1	1*	1	1	1*	1*	1*	20
4	1*	1*	1*	1	1	1	1*	1*	1	1	1	1*	1*	1*	1	1	1*	1	1	1	20
5	1*	1*	1*	1*	1	1*	1*	1*	1	1	1*	1*	1	1	1*	1	1*	1*	1*	1*	20
6	1*	1*	1	1*	1	1	1	1	1	1*	1*	1	1*	1*	1*	1*	1*	0	1*	1	19
7	1*	1	1	1	1	1*	1	1*	1*	1*	1	1	1*	1	1	1*	1*	1*	1*	1*	20
8	1	1*	1*	1*	1*	1*	1	1	1	1	1*	1	1	1	1	1*	1*	1*	1*	1	20
9	1	1*	1	1	1	1	1*	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	1*	1	20
10	1*	1	1	1*	1*	1	1	1*	1	1	1*	1*	1	1*	1	1	1	1	1	1*	20
11	1*	1*	1*	1*	1*	1	1*	1	1	1	1	1*	1	1*	1*	1*	1*	1*	1*	1*	20
12	1*	1	1*	1*	1	1*	1*	1*	1	1	1	1	1*	1*	1	1	1	1*	1	1	20
13	1*	1*	1	1*	1*	1	1	1	1	1	1	1*	1	1	1*	1*	1	1	1	1*	20
14	1	1*	1	1*	1*	1	1	1	1*	1	1	1	1	1	1*	1	1	1	1	1	20
15	1*	1*	1	1*	1	1	1	1	1	1*	1*	1	1*	1*	1	1*	1	1	1*	1*	20
16	1*	1*	1*	1*	1	1*	1	1	1*	1*	1	1	1*	1	1	1	1*	1	1	1*	20
17	1	1*	1*	1*	1*	1*	1	1*	1	1*	1	1*	1	1	1	1	1	1	1	1	20
18	1	1*	1	1*	1*	1	1	1*	1*	1	1	1*	1	1*	1	1*	1	1	1*	1	20
19	1	1	1	1*	1*	1	1*	1	1	1	1	1	1	1	1	1	1	1	1	1*	20
20	1*	1*	1*	1*	1	1	1*	1*	1*	1	1*	1	1*	1	1	1*	1	1*	1*	1	20
Dependence	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	19	20	20	

Table 4 (Transitive Binary Matrix) is partitioned into sub-matrices (Tables 5 & 6) below through the iteration method by employing the elementary concept of intersection sets from set theory.

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Table 5: Partitioning Iteration-I

Code	Reachability	Antecedence	Intersections	Level
1	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	*I*
2	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	*I*
3	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	*I*
4	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	*I*
5	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	*I*
6	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,19,20	*I*
7	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	*I*
8	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	*I*
9	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	*I*
10	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	*I*
11	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	*I*
12	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	*I*
13	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	*I*
14	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	*I*
15	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	*I*
16	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	*I*
17	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	*I*
18	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,19,20	*II*
19	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	*I*
20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	*I*

Table 6: Partitioning Iteration-I

Code	Reachability	Antecedent	Intersection	Level
18	18	1,2,3,4,5,6,7,8,9,10,11,12,13,14, 15,16,17,18,19,20	18	*II*

After partitioning the transitive matrix is converted into a conical matrix and digraph but as these are optional in reporting for brevity have been omitted here. ISM model prepared from digraph is given below as Figure 1.
From Figure 1 it can be learnt that the enablers coded as (1), (2), (3), (4), (5), (6), (7), (8), (9), (10), (11), (12), (13), (14), (15), (16), (17), (19) and (20) occupy *Level I* whereas only on factor coded as (18) fall at *Level II* of ISM structural model.

Analysis

For the purposes of analysis the driving power and dependence power from the transitive binary matrix (Table 4) is used. This analysis classifies the factors/elements of the phenomenon in to four quadrants on the bases of dependencies.

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Figure 1: ISM Model

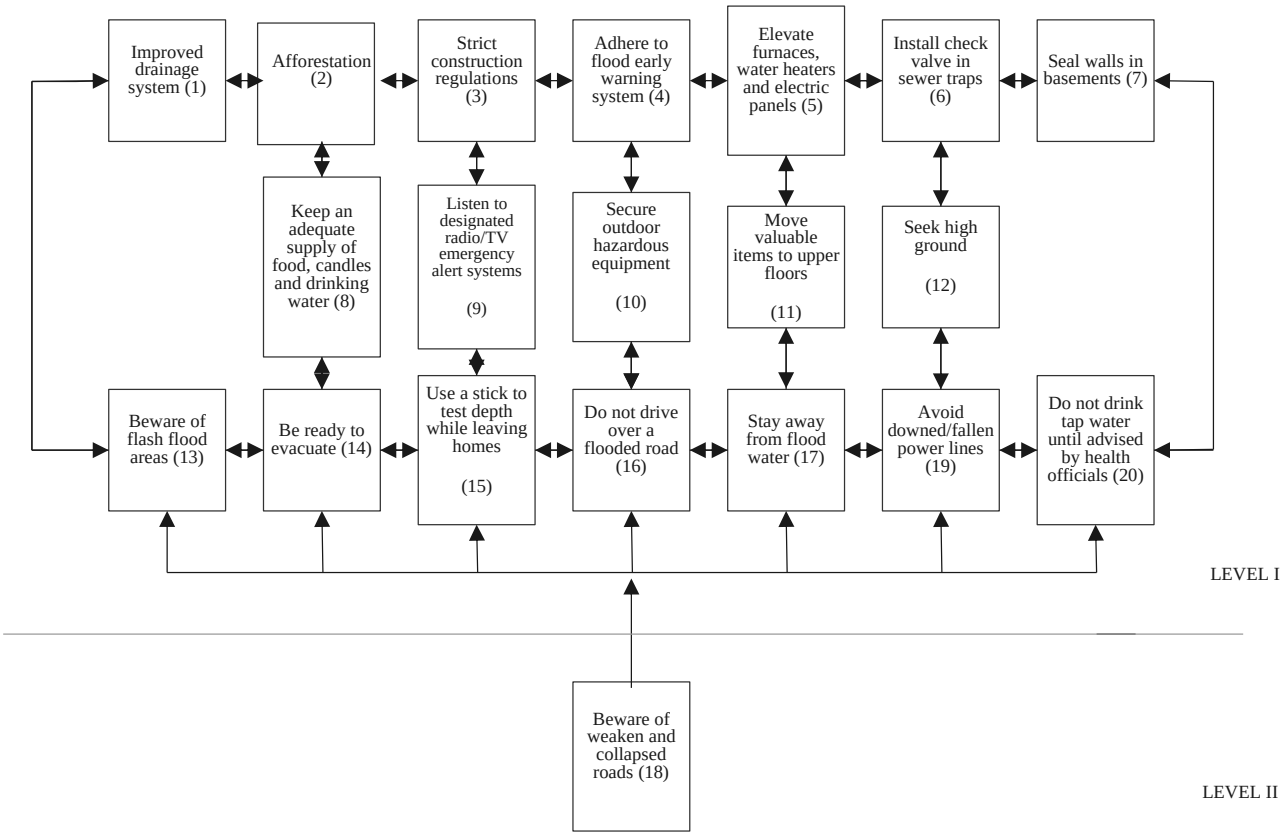
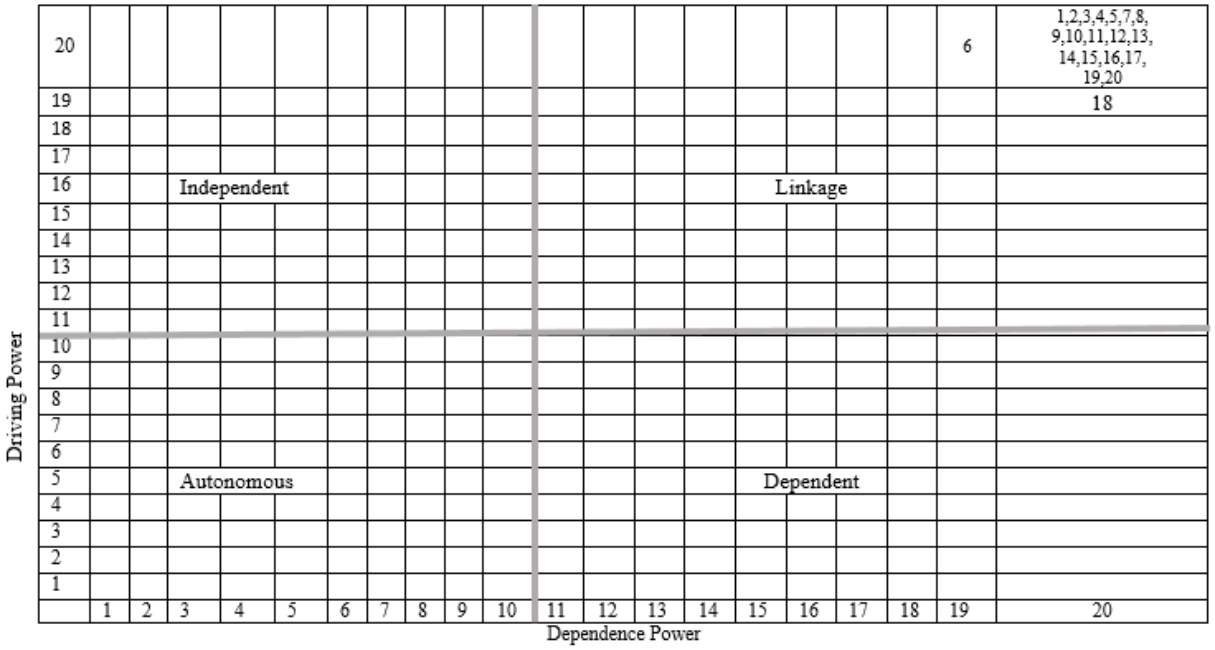


Figure 2: Scale-centric MICMAC Diagram



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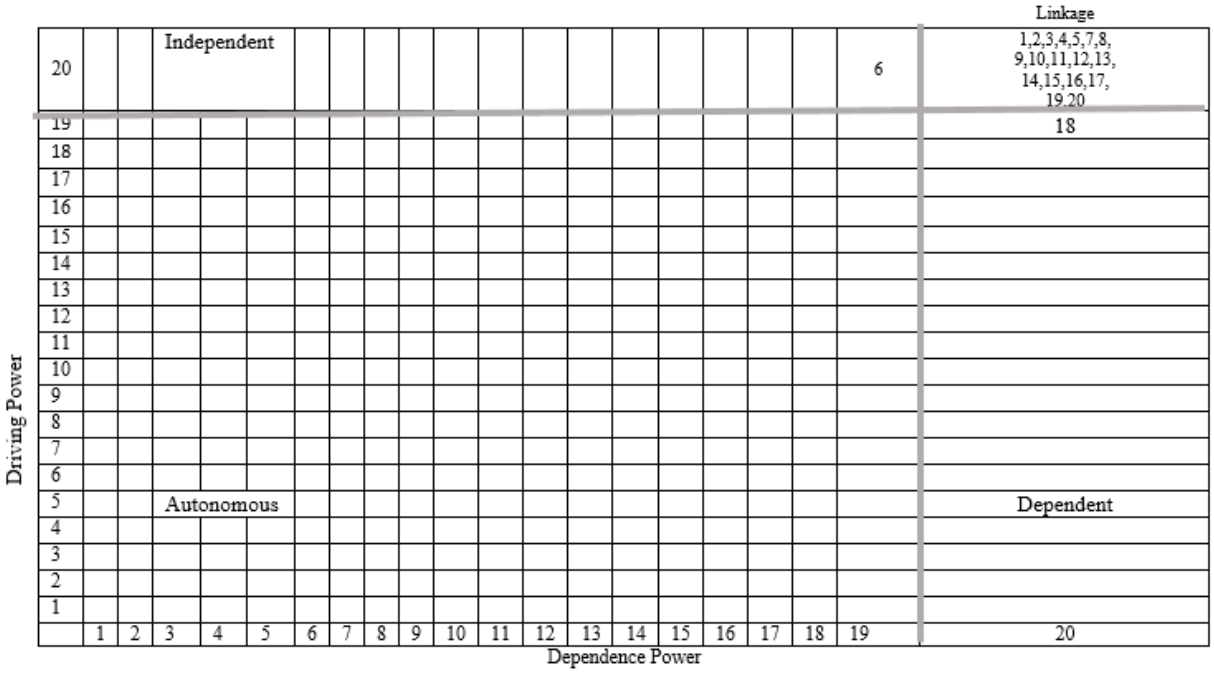
From the Figure 2 (Scale-centric MICMAC Diagram), it can be learnt that the independent, dependent and autonomous quadrant are empty. All the enablers (i.e. enables coded as 1-20, Table 1) are classified in linkage quadrant (Kim, et al., 2023). They all have high driving and high dependence power.

Figure 2: Data-centric MICMAC Diagram



From the Figure 3 (Data-centric MICMAC Diagram), it can be learnt that autonomous quadrant is empty. Enabler coded as (6) is classified in independent quadrant. Enabler coded as (18) is classified in dependent quadrant. All other enablers (i.e. enables coded as 1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 19, and 20) are classified in linkage quadrant.

RESULTS

Floods are high-impact natural phenomena that have both positive and negative effects on lives, properties, businesses, livestock, crops, natural resources, infrastructure, wildlife, forests, and so on. Hardly any community, group, or thing is left that is not affected by floods. Therefore, it has a high degree of importance in the research agenda. Issue understudy 'enablers for combating the damages by floods' is related to it hence very important. The study employed a qualitative design to address the issue. The overall design consists of a literature review, data collection, and analysis using literature discourse, ISM, and MICMAC analysis. The results of literature discourse identified total twenty enablers of combating the damages by floods (Table 1). The results of ISM modeling (Figure 1) show that all enablers i.e. improved drainage system (1), afforestation (2), strict construction regulations (3), adhere to flood early warning system (4), elevate furnaces, water heaters and electric panels (5), install a check valve in sewer traps (6), seal walls in basements (7), keep an adequate supply of food, candles and drinking water (8), listen to designated radio/TV emergency alert systems (9), secure outdoor hazardous equipment (10), move valuable items to upper floors (11), seek high ground (12), beware of flash flood areas (13), be ready to evacuate (14), use a stick to test depth while leaving homes (15), do not drive over a flooded road (16), stay away from flood water (17), avoid downed/fallen power lines (19), and do not drink tap water until advised by health officials (20) occupy *Level I* the ISM model. The enabler beware of weekend and collapsed roads (18) inhibits at *Level II* (Bottom level). The results of Scale-centric MICMAC analysis (Figure 2) show that all enablers

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i.e. improved drainage system (1), afforestation (2), strict construction regulations (3), adhere to flood early warning system (4), elevate furnaces, water heaters and electric panels (5), install a check valve in sewer traps (6), seal walls in basements (7), keep an adequate supply of food, candles and drinking water (8), listen to designated radio/TV emergency alert systems (9), secure outdoor hazardous equipment (10), move valuable items to upper floors (11), seek high ground (12), beware of flash flood areas (13), be ready to evacuate (14), use a stick to test depth while leaving homes (15), do not drive over a flooded road (16), stay away from flood water (17), beware of weekend and collapsed roads (18), avoid downed/fallen power lines (19), and do not drink tap water until advised by health officials (20) have high driving and high dependence power therefore classified in linkage quadrant. Other three quadrants this independent, dependent, and autonomous are empty so far. The results of Data-centric MICMAC analysis (Figure 3) show that autonomous quadrant is empty, enabler install a check valve in sewer traps (6) is classified in independent quadrant, enabler beware of weekend and collapsed roads (18), is classified in dependent quadrant, and all other enablers i.e. improved drainage system (1), afforestation (2), strict construction regulations (3), adhere to flood early warning system (4), elevate furnaces, water heaters and electric panels (5), seal walls in basements (7), keep an adequate supply of food, candles and drinking water (8), listen to designated radio/TV emergency alert systems (9), secure outdoor hazardous equipment (10), move valuable items to upper floors (11), seek high ground (12), beware of flash flood areas (13), be ready to evacuate (14), use a stick to test depth while leaving homes (15), do not drive over a flooded road (16), stay away from flood water (17), avoid downed/fallen power lines (19), and do not drink tap water until advised by health officials (20) have high driving and high dependence power therefore classified in linkage quadrant. Abridged results are presented below in Table 7.

Table 7: Juxtaposed Results of Literature, MICMAC, and ISM

Results of Literature Review		Results of MICMAC Analysis					Results of ISM	Comment
Code	Determinants	Driving	Dependence	Effectiveness	Scale-Centric	Data-Centric	Level	
1	Improved drainage system	20	20	0	Linkage	Linkage	*Level I*	
2	Afforestation	20	20	0	Linkage	Linkage	*Level I*	
3	Strict construction regulations	20	20	0	Linkage	Linkage	*Level I*	
4	Adhere to flood early warning system	20	20	0	Linkage	Linkage	*Level I*	
5	Elevate furnaces, water heaters and electric panels	20	20	0	Linkage	Linkage	*Level I*	
6	Install check valve in sewer traps	19	20	-1	Linkage	Independent	*Level I*	
7	Seal walls in basements	20	20	0	Linkage	Linkage	*Level I*	
8	Keep an adequate supply of food, candles and drinking water	20	20	0	Linkage	Linkage	*Level I*	
9	Listen to designated radio/TV	20	20	0	Linkage	Linkage	*Level I*	

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	emergency alert systems							
10	Secure outdoor hazardous equipment	20	20	0	Linkage	Linkage	*Level I*	
11	Move valuable items the to upper floors	20	20	0	Linkage	Linkage	*Level I*	
12	Seek high ground	20	20	0	Linkage	Linkage	*Level I*	
13	Beware of flash flood areas	20	20	0	Linkage	Linkage	*Level I*	
14	Be ready to evacuate	20	20	0	Linkage	Linkage	*Level I*	
15	Use a stick to test depth while leaving homes	20	20	0	Linkage	Linkage	*Level I*	
16	Do not drive over a flooded road	20	20	0	Linkage	Linkage	*Level I*	
17	Stay away from flood water	20	20	0	Linkage	Linkage	*Level I*	
18	Beware of weekend and collapsed roads	20	19	1	Linkage	Dependent	*Level II*	*Key Factor*
19	Avoid downed/fallen power lines	20	20	0	Linkage	Linkage	*Level I*	
20	Do not drink tap water until advised by health officials	20	20	0	Linkage	Linkage	*Level I*	

Table 7 depicts that an enabler 'beware of weekend and collapsed roads (18)' is the most critical and important enabler to combat the damages by floods. One thing more that is evident from the juxtaposed results of literature discourse, ISM modeling, scale-centric MICMAC analysis, and data-centric MICMAC analysis is that the phenomenon is complex and the data set and analysis could not completely decompose the intricacies of it. It clearly requires more analysis and investigation with some other techniques.

DISCUSSION

By reiterating the objective of the study that it is an investigation of complex relationships among enablers of combating the damages by floods using the technique of partitioning the binary matrices prepared by primary data, it is important to discuss certain main point to be made from the study. The discussion will help the readers to ascertain the lessons learnt from the findings. The literature discourse prepared a list of the enablers (Table 1) which in not exhaustive but still comparative to contemporary literature extensive. The ISM model extract from partitioning method consists of two levels. All the enablers occupy the *Level I* except one enabler that inhibits at *Level II*. This indicates that it is a complex phenomenon that could not even fully captured by the partitioning of binary matrices. It pertinent to iterate the portioning of binary matrices has the capability to extract the structural model on diagonals. The MICMAC analysis (scale-centric MIMAC analysis and data-centric MICMAC analysis) also corroborate the results of ISM modeling since almost all the enables are categorized in linkage quadrant. Which necessarily means the phenomenon in hand is agile, unsettled, unsystematic, unsettled, conundrum and needs further investigation with larger data set to be analyzed with more precision. In MICMAC independent quadrant consists of drivers, dependent, consists of driven factors, linkage consists of the factors that have both

driving and driven quality, and autonomous quadrant contains the factors that are not connected to system. Findings of the study depicts that enabler 'beware of weekend and collapsed roads (18)' is relatively independent and 'install check valve in sewer traps (6)' is relatively dependent. All others are not settled and are agile surfacing that the situation is conundrum and need further investigation. The study uses different approach, different variables, different respondents, different type of data set, different modeling method, different analysis technique, and generates different results having profound practical and theoretical implications for the stakeholders aforementioned in the study. It develops understanding of the stakeholders, provides information on intra-enabler relationships, insights into the phenomenon by way of classification and relevance diagrams. It also provides framework to policymakers and researcher for future discourse. The study also have some limitation to be mentioned here. Limitations of the study include: One, it is conducted in the context of Pakistan, therefore, findings of the study are accordingly limited to explain the phenomena. Two, a panel of experts is medium-sized and can be made even larger and the results may be verified. Three, it is a qualitative study using the simple basic version of ISM that also has methodological limitations therefore, verification with quantitative methodologies is needed. Fourth, the list of enables is not claimed to be comprehensive since it is extracted from a limited number of studies to which the authors have access. These limitations can be overcome by future studies using different methods like IRP, ANP, AHP, TISM, Fuzzy-ISM/TISM, SEM, PCA, AHP, ANP, TOPSIS, GRA, etc. that can enhance the interpretability to greater extent. Further literature can be explored the make the list of enablers exhaustive. The size of the panel and criteria and nature of the recruitment of experts on panel can also be varied. The context of the study i.e. geographical context is recommended to be changed.

Contribution of the study

The study has contributed a list of enablers for combating the damages by floods, the ISM model of relationships among them, the MICMAC diagram, and a set of inter-enablers for combating the damages by floods and policy guidelines towards the contemporary body of knowledge.

CONCLUSION

Floods are high-impact natural phenomena that have both positive and negative effects on lives, properties, businesses, livestock, crops, natural resources, infrastructure, wildlife, forests, and so on. Hardly any community, group, or thing is left that is not affected by floods. Therefore, it has a high degree of importance in the research agenda. Issue understudy 'enablers for combating the damages by floods' is related to it hence very important. The study employed a qualitative design to address the issue. The overall design consists of a literature review, data collection, and analysis using literature discourse, ISM, and MICMAC analysis. Results of the literature review reveal that there are twenty enablers of combating the damages by floods i.e. improved drainage system (1), afforestation (2), strict construction regulations (3), adherence to flood early warning system (4), elevate furnaces, water heaters, and electric panels (5), install check valve in sewer traps (6), seal walls in basements (7), keep an adequate supply of food, candles and drinking water (8), listen to designated radio/TV emergency alert systems (9), secure outdoor hazardous equipment (10), move valuable items to upper floors (11), seek high ground (12), beware of flash flood areas (13), be ready to evacuate (14), use a stick to test depth while leaving homes (15), do not drive over a flooded road (16), stay away from flood water (17), beware of weekend and collapsed roads (18), avoid downed/fallen power lines (19) and do not drink tap water until advised by health officials (20). Results of ISM modeling show that the factors (1), (2), (3), (4), (5), (6), (7), (8), (9), (10), (11), (12), (13), (14), (15), (16), (17), (19) and (20) occupy *Level I* whereas only on factor i.e. (18) fall at *Level II* of ISM structural model. Results of Scale-centric MICMAC analysis show that the independent, dependent and autonomous quadrant are empty. All the enablers (i.e. enables coded as 1-20, in Table 1) are classified in linkage quadrant. They all have high driving and high dependence power. From the Results of Data-centric MICMAC analysis show that autonomous quadrant is empty. Enabler coded as (6) is classified in independent quadrant. Enabler coded as (18) is classified in dependent quadrant. All other enablers (i.e. enables coded as 1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 19, and 20) are classified in linkage quadrant. The findings of the study are highly useful for all the stakeholders as aforementioned (i.e. governments, regulators, industry landowners, farmers, general public, scientific

community, institutions engaged in disaster management, donors, academia, flood-prone communities, NGOs, volunteers, etc. that can further be classified into: i) a social beneficiary group, ii) non-social beneficiary group, iii) social adversely affected group, and iv) on-social adversely affected group) since it provides lot of new deep insights to them and develops understanding of the stakeholders about the phenomenon.

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