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The Projected Role of Government in Developing Public Policy to Strengthen the Liquefaction Disaster Resilience System: A Case of Indonesia

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Abstract

Based on and increased intensity and frequency of the natural hazards, many parts of the world are continuously adopting measures to strengthen the liquefaction disaster preparedness systems. Therefore, the current study aims to systematically analyze the government's role in developing public policy to strengthen the liquefaction disaster resilience system, particularly linked with public health in a developing nation, i.e., Indonesia. For that purpose, the literature review and experts' opinions in the form of a self-administrative survey and interviews were utilized to collect the data. Cross-impact Direct Influence (CDI) matrix was applied to formulate the questionnaires. Simultaneously, for the analysis of the data, MICMAC analysis, and Scenario Wizard software were applied. The research results of MICMAC analysis revealed 11 important/key variables with a prominent role in controlling and minimizing the damage caused by natural disasters in developing nations. Additionally, 33 probable states of the key variables were explored and conceptualized by applying the Scenario-Wizard Method. The findings presented four scenarios depicting stronger consistencies. Besides, the most desirable and ideal features to strengthen the liquefaction disaster resilience system linked with public health in Indonesia were found in scenario one. Furthermore, this research is a valuable addition to the public policy in presenting the important predictors of mitigating the effect of liquefaction disasters and preparedness of an advanced system to minimize the damage caused by such disasters.

Key words:

Liquefaction Disaster Preparedness System; Public Policy; Scenario-Based Planning; Micmac Analysis

Introduction

A wide range of natural and man-made risks and hazards has a global impact. The severity and number of these hazards have increased in recent decades (Fan et al., 2019; Xu et al., 2020). As per the United Nations international strategy for disaster reduction (UNISDR), many parts of the world are drawn to environmental and natural hazards, i.e., heat islands, extreme heat landslides, hurricanes, floods, droughts, earthquakes, etc. (Parizi, Taleai, & Sharifi, 2021). Besides, the main drivers of these natural hazards are population growth, rapid urbanization, and climate change (due to uncontrolled emission of greenhouse gases and human activities) (Habibullah, Din, Tan, & Zahid, 2022). Research also reports a 2% increase in natural hazards over the last 15 years (Sajjad, Chan, & Chopra, 2021). This further decreases the resistance and coping capabilities of different areas by imparting various physical, economic, social, and environmental dimensions (Bottero, Datola, & De Angelis, 2020). Hence there is a dire need to develop and strengthen the disaster readiness system all over the globe (Bottero, Datola, & De Angelis, 2020; Sajjad, Chan, & Chopra, 2021).

Earthquakes are among the most complex and destructive natural hazards. More specifically, earthquakes in developing nations disrupt the physical connectivity of various areas and destroy the infrastructure, resulting in severe property damage and human casualties (Urlainis et al., 2022). In recent decades, the world has experienced several major earthquakes. For instance, the Kathmandu earthquake in Nepal on April 26, 2015, has been reported to generate force 20 times greater than that of a hydrogen bomb causing 22,000 injuries and 9,000 casualties. Likewise, the Kermanshah earthquake in Iran on November 12, 2017, resulted in more than 8,100 injuries and 630 casualties and caused 70,000 homeless (Ghasemi, Khalili-Damghani, Hafezalkotob, & Raissi, 2020). More recently, in January 2021, Indonesian people faced a major earthquake with a magnitude of 6.2. As a result, more than 92,000 people were displaced when it struck Majene and Mamuju districts in West Sulawesi province. It also resulted in 6,500 injuries in 105 casualties. These earthquakes further presented serious challenges for developing nations (Nazmfar, Saredeh, Eshgi, & Feizizadeh, 2019). Hence, the main aim of the current study is to deal with such challenges and present the projected role of governments in developing public policies to strengthen the liquefaction disaster preparedness system to avoid the damages caused by these natural hazards.

Moreover, the findings of the experimental and scientific studies following the guidelines provided by the National Academy of Science (NAS) regarding natural and man-made hazards, particularly earthquakes, call for the significance of advanced preparation for such disasters and enhanced resilience of settlements in different dimensions (Jon & Li, 2021; Sarian et al., 2020). This resilience further deals with coping, adaptive, and preparedness capabilities to mitigate the negative impacts of hazards and shocks (Lyashenko, Khomenko, Chekushina, & Topolnij, 2020). This further attracted the attention of scientific communities, policymakers, planners, and experts to present their opinions and solutions to this issue (Rana, 2020). Hence, advances in literature moving beyond vulnerability to resilience are evident nowadays. It further helps to strengthen the system of developed nations to deal with such natural disasters with minimal damage (Meilianda et al., 2019). It also helps bridge the gap between resistance being a static attribute and adaptations being dynamic attributes (Sajjad, Chan, & Chopra, 2021). Besides, preparedness of the vulnerable areas for natural disasters can further save many physical, social, economic, and human resources by enhancing coping capabilities, decreasing the hazards and risks, and promoting rapid reconstruction (Shamsuddin, 2020).

At the same time, researchers highlighted the significance of the multi-aspect nature of resilience based on physical, environmental, institutional-organizational, economic, and sociocultural dimensions (Parizi, Taleai, & Sharifi, 2021). Previously, researchers have focused on improving urban resilience, primarily focusing on non-physical dimensions of resilience, i.e., economic, organizational social, and environmental dimensions (Ainuddin & Routray, 2012; Aydin, Duzgun, Wenzel, & Heinimann, 2018; Parizi, Taleai, & Sharifi, 2021). In contrast, the main focus of the current study is not only on devising public policies to strengthen resilience in developing nations regardless of rural or urban discrimination. However, this study also considered the physical morphologies and structures of the vulnerable areas based on the utmost importance of withstanding earthquakes and bearing initial shocks as earthquakes mostly cause physical damage, casualties, and injuries (Ao et al., 2021).

Hence, the physical dimension of resilience must be given significant importance, and the physical structure of the most vulnerable areas must be strengthened to enhance protection against natural disasters. Regardless of more than three decades of research regarding cities' resilience against natural disasters and hazards, the field of physical resilience of the most vulnerable areas still lacks an operational and comprehensive understanding (Peek-Asa, Ramirez, Seligson, & Shoaf, 2003). Research also reports that very few areas worldwide are applying appropriate strategies and measures to improve physical resilience, presenting a large gap between its implementation and the theory addressed in the current study (Soltane, Mimoune, & Guettiche, 2022). Moreover, the physical dimension of resilience is closely linked with the public health system based on humans as the major victims of shocks and natural disasters, especially earthquakes (Ma, Guo, Deng, & Xu, 2021). As stated earlier, earthquakes cause several human injuries and casualties; hence, improving the disaster logistics infrastructure linked with the public health resilience system is of utmost importance. Also, research lacks evidence regarding improving emergency facilities and social recovery systems for victims of liquefaction disasters (Ma, Guo, Deng, & Xu, 2021; Papathoma-Köhle, Thaler, & Fuchs, 2021) which has been addressed in the current study.

Additionally, the current study has utilized MICMAC analysis and scenario-based planning to extract the factors important in the liquefaction disaster resilience system. The prime focus of this study lies in the cross-impact analysis, which is mostly utilized in future study quantitative methodologies at national levels (Mehta, Bhattacharyya, & Pandey, 2022). Simultaneously, applying Scenario Wizard and MICMAC, the key factors and main drivers required for a resilient disaster system linked with public health were identified in phase one. Later, future scenarios were planned based on strategic management, applying planning models and future research approaches in the second phase. Hence, analyzing the overall causes of natural hazards and considering the experts' views using scenario-based strategic planning, the main objectives of the current study include;

- What key factors and driving forces can be used to improve disaster logistics infrastructure that is integrated with the public health resilience system.
- Which scenario-based strategic planning would be the most appropriate for devising government policies to improve emergency facilities and social recovery for victims of liquefaction disaster.

Literature Review

Resilience and its Role in Liquefaction Disaster System

In several scientific disciplines, the concept of resilience is widely applied with a complex multidisciplinary nature. Nowadays, scholars and disaster management planners are paying much attention to the resilience concept (Ainuddin & Routray, 2012). The researchers have also highlighted the significance of resilience in disaster management and suggested exploring the concept in terms of its definition and application for liquefaction disaster preparedness systems to ensure public health all over the globe (Aydin, Duzgun, Wenzel, & Heinimann, 2018; Ma, Guo, Deng, & Xu, 2021; Parizi, Taleai, & Sharifi, 2021; Pribadi et al., 2021). Among the several dimensions of resilience, the current study focuses on its physical dimension with its integration with public health. Simultaneously, the United Nations Office for Disaster Risk Reduction (UNISDR) conceptualized resilience as the extent to which a system absorbs and handles risks and adapts to variable situations while recognizing itself (Sajjad, Chan, & Chopra, 2021). Hence, it can be asserted that resilience is a combination of "preparedness," "absorption of disruptions and reaching a state of balance," "self-organization" and "increased capacity for learning and adaptation" (Freddi et al., 2021). This conceptualization of resilience further emphasizes process-based as well as outcome-based resilience (LeCrom & Martin, 2019).

Where preparedness refers to the process-based resilience, it includes the pre-disaster planning and preparation activities so that the disaster vulnerable areas can withstand and adapt to potential shocks and risks of natural disasters, including earthquakes (Zhuang, He, Deng, & Xu, 2021). Simultaneously, the absorption phase is mostly linked to outcome-based resilience (Ao et al., 2021). It is linked with the immediate communication efforts and activities required right after the event. At the same time, affected areas and their physical components should be arranged to withstand the initial shocks in the beginning by avoiding crippling damages to the system (Ainuddin & Routray, 2012). Likewise, the absorption system must be strong enough to repel the disruptions for spilling effects. It further minimized the level of damage based on protective capabilities. Moreover, the self-organization phase presents the process-based resilience, which deals with restoring the performance of affective areas in a shorter time after the events occur (Pribadi et al., 2021). Various elements affect the ability of a system to rebuild the affected areas, i.e., prevent preparation efforts, the capability of absorbing shocks right after the event, and the prudence and rate of rebuilding activities (Ma, Guo, Deng, & Xu, 2021).

Finally, the adoption phase is also mostly linked to process-based resilience. It is a very important face that presents a series of continuous efforts to mitigate the impacts of natural hazards, including earthquakes (Zhuang, He, Deng, & Xu, 2021). It further helps the affected areas to presume their pre-event performance rate with advanced features. Moreover, it is mostly based on a continuous learning process resulting in two improvements in the physical system and enhancing the adaptive capabilities of the infected areas making them more flexible in dealing with future disruptions (Li et al., 2021). On one end, it is considered an opportunity to create ideal conditions over pre-event conditions. on the other end, many parts of the world are dynamic with constantly changing components (Parizi, Taleai, & Sharifi, 2021). These changing components help the system exploit the hidden sources and opportunities to strengthen the overall system further to overcome the complexities and uncertainties (Papathoma-Köhle, Thaler, & Fuchs, 2021).

The prime focus of the current study is the physical dimension of the resilience linked with buildings, critical infrastructures, including hospitals based on the four phases of resilience, including adaption, self-organization, absorption, and preparedness. This physical resilience can further be defined based on the connectivity of the different parts of the infrastructure, adoption capabilities, robustness of the recovery of the building, and many other significant measures (Parizi, Taleai, & Sharifi, 2021). Hence, it is very important to identify the key/ important factors to prepare various parts of the world for unexpected events like earthquakes and enhance their absorptive capabilities so that they can continue their routine matters regardless of the destructive impacts of such natural hazards (Ainuddin & Routray, 2012; Bottero, Datola, & De Angelis, 2020; Parizi, Taleai, & Sharifi, 2021; Rana, 2020).

Health Care and Disasters

Disasters severely impact the well-being and health of humans. Physical disruptions during the disasters severely impact human life, causing deaths and several injuries (Kumar, 2022). For instance, when buildings, including hospitals, collapse during earthquakes. There arises a shortage of medical facilities available to injured people (Daher et al., 2021). This further builds a psychological trauma of being unattended and deprived of necessary medical facilities to cope with such disasters resulting in deaths and mental injuries (Florentin et al., 2021). At the same time, overcrowding and population displacement enhance the risk level linked with evacuation or rehousing facilities, further leading to an enhanced risk of infectious disease outbreaks (Florentin et al., 2021). Likewise, nations face drastic human losses when overwhelmed medical services fail due to the lack of proper infrastructure to deal with damage caused by earthquakes (Lestari et al., 2021). It also results in the scarcity of life-saving medications like insulin for diabetes. For instance, during Typhoon Haiyan in the Philippines, the injury-related issues were not as lethal to maintaining public health in the region compared to the measures required for preventing infectious and non-communicable diseases originated due to the lack of access to medicines, housing, water, and food (Parizi, Taleai, & Sharifi, 2021). This further reflects the poor management system and loopholes in the infrastructure development to cope with such disastrous situations.

Moreover, the fear of being unattended and having the least opportunities to reach the medical facilities results in the disruption of mental health based on traumatic incidents (Li et al., 2021). These mental health issues can further be prolonged with anxiety and stress among people, families, societies, and communities leading to a fear of death and other clinical disorders (Xu et al., 2020). Hence, there is a need to focus on the physical dimension of resilience to strengthen the liquefaction disaster system. That can facilitate ensuring emergency responses after events adequately by implementing higher resource and clinical management standards to minimize loss of life, suffering, and injuries (Lestari et al., 2021; Xu et al., 2020). For that purpose, the current study adopted a future research approach to identify and conceptualize the key factors impacting the physical dimension of resilience linked with public health to strengthen the liquefaction disaster system, more specifically in developing nations.

Methodology

Cross-impact Analysis

The current study has applied a qualitative cross-impact structural analysis to identify the key factors in developing a liquefaction disaster resilience system. Besides, cross-impact analysis has been regarded as a powerful tool for analyzing the combinations of binary future events (Mehta, Bhattacharyya, & Pandey, 2022). As a flexible methodology, researchers mostly used cross-impact analysis to analyze and create different scenarios in combination with other methodologies like fuzzy logic, Delphi, multicriteria, etc. (Nematpour & Faraji, 2019). Moreover, to devise a disaster resilience system in developing nations, researchers highlighted the significance of analyzing a diverse set of variables (Sajjad, Chan, & Chopra, 2021), which can be attained with the help of cross-impact analysis (Nematpour, Khodadadi, & Rezaei, 2021).

Structural analysis

To analyze the direct and indirect associations among the constructs, structural analysis as a variant of original cross-impact analysis has been employed (Weimer-Jehle et al., 2020). Structural analysis is a system comprising interrelated constructs/variables forming a network of interrelationships. These interrelationships determine the system's future evaluation based on interconnection metrics (Norton, Buckman, Meadows, & Rable, 2019). Besides, while applying structural analysis, there is a need to structurally identify the associations among the quantitative and qualitative variables in terms of their function in the given system. Simultaneously, the structure analysis's main feature includes identifying the key constructs that influence a system's future evaluation (Luo et al., 2020).

MICMAC Method for Structural Analysis

In cross-impact analysis, the MICMAC analysis technique was applied based on experts' opinions to identify important variables in a system from a diverse set of predictors in a potential direct and indirect influence matrix (Jasiulewicz-Kaczmarek et al., 2021). In every cell of Direct Influence Metrics (MDI), the effect of each" variable on every" variable is presented as"i" (Nematpour & Faraji, 2019). simultaneously different values ranging from zero to three are assigned to these effects. Where"0= no relation between constructs, 1= weak relations, 2= indicates moderate relations and 3= strong relation". There are a few very important steps in the MICMAC analysis technique, i.e., inventory variables collection, demonstration of the interrelationship among variables, and shortlisting key variables. Furthermore, the predictors of the system are ranked according to their influence on each other and the overall system. Thus the MDI matrix elements are formalized in "a kth row and kth column," spawning the following formula (Nematpour, Khodadadi, & Rezaei, 2021);

$$\mathrm{Ik} = \sum_{j=1}^{n} MDI\ (\mathrm{k},\ \mathrm{j})\ and\ \mathrm{I_k} = \sum_{j=1}^{n} MDI\ (\mathrm{j}, \mathrm{k})$$

In addition, a two-dimensional map is presented in the MICMAC chart with vertical and horizontal axis reflecting the impact and dependencies, respectively, as depicted in Figure 1 (Chen, 2018; Villacorta, Masegosa, Castellanos, & Lamata, 2014).

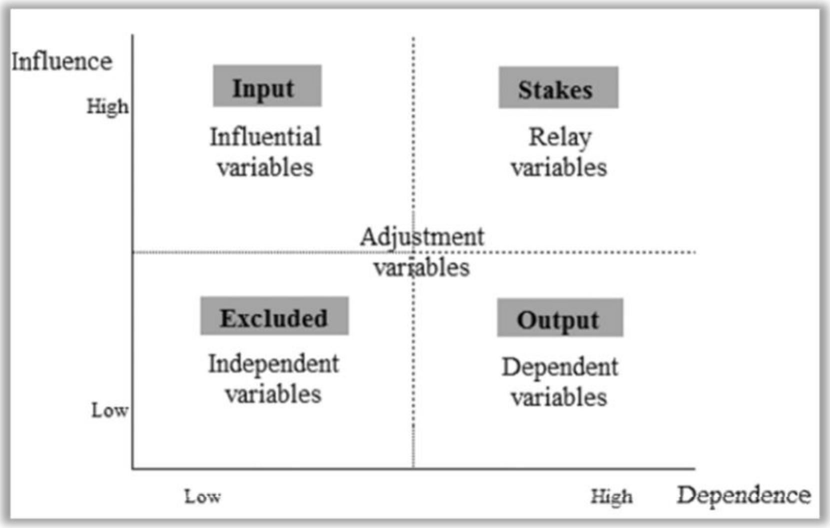

Figure 1. Influence–dependence chart, adapted from Chen (2018)

Additionally, five important zones of each MICMAC chart include input/influential variables (presenting the higher level of projected influence on other constructs and are named as key drivers of a system), intermediate variables (reflecting an unstable nature of being either dependent or influential construct), output/dependent variables (regarded as highly sensitive to change under the impact of intermediate or influential variables), clustered/neuter variables (lying in the center with the tendency to join any group of other variables with an unpredictable nature), excluded variables (having zero influence on the system with low influence or dependence)

Using Cross-impact Balance to Build Scenarios

"Cross-impact Balance (CIB)" is a modern analysis technique used in qualitative systems of multidisciplinary studies. Scenario wizard is among the most commonly applied field of CIB. Disaster resilience has been conceptualized based on various dimensions and steps. Whereas focusing on its physical dimension, the current study aims to develop several scenarios related to the disaster resilience system's four steps: preparedness, absorption, self-organization, and adoption. Various scenarios must be established to identify the key determinants of the liquefaction disaster resilience system. Developing these scenarios further requires the know-how of interrelated variables, including satisfactory, moderate, and unfavorable variances. Hence, researchers apply the peer interaction system approach in CIB analysis. During this analysis, in the first step, descriptors being the key variables or determinants of the system are identified using the MICMAC analysis technique (Jasiulewicz-Kaczmarek et al., 2021). The association among different predictors can be understood with the help of Figure 2. This figure reflects the interconnectivity of all key variables with reciprocal relationships managed by a consolidated internally consistent configuration system for keeping balance among the key constructs.

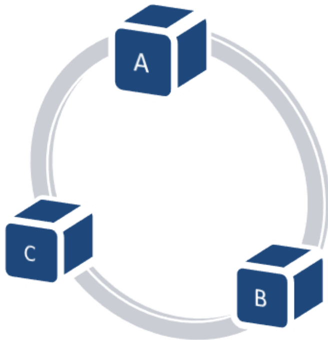

Figure 2. A simple CIB networks

Moreover, the steps to build scenarios in the CIB process include;

i. Application of MICMAC technique to identify important predictors. For instance, X1, X2….. Xn.
ii. Defining several alternatives characterizing the probable states of the descriptors. For instance,
    a. "X1 {xa, xb, xc}
    b. X2 {x, xy, xz}
    c. X3 {xi, xj} Xn {x1 … xn}"
iii. A decision-making "-3 strongly restricting influence to +3 strongly promoting influence" for the impact of "state xa of descriptor X1" on "state xx of descriptor X2".

Sampling Procedure

To identify the most important factors impacting public policy development regarding the liquefaction disaster resilience system linked with the public health in Indonesia, a cross-impact analysis was conducted via the MICMAC analysis technique to identify the best scenarios for future system development utilizing Scenario Wizard. For that purpose, we applied a 6-phase process of structural analysis, including problem identification and analysis, the conceptualization of the variables, analysis among the relationships, chart analysis, selection of the key constructs, and writing of the probable scenarios for the future disaster management system development. This study was conducted from September 2021 to April 2022. The experts were selected based on their knowledge and quality information linked with the study context by applying a purposive sampling methodology (Devers & Frankel, 2000). The recommended size for future projection studies applying scenario-based analysis is between 10-100 participants organized into two to three groups of experts (Chen, 2020; Jasiulewicz-Kaczmarek et al., 2021). Thus, based on the available guidelines, we approached 30 academicians, administrators, professionals, and area experts and requested them to participate in the current study. However, 23 agree to take part in this study. Therefore, they were provided with a self-administrative questionnaire and cross-impact analysis metrics form. Self-administrative questionnaires were developed based on the variables collected from a detailed literature review in phase two of the cross-impact analysis procedure. The panel of experts identified the various variables based on their knowledge and expertise. This whole process resulted in two a diverse set of 33 variables belonging to four broader categories (macro indicators). Table one presents a detailed description of all the macro indicators and predictor variables.

Table 1. Study Variables and Sub-Indicators

Sr. #	Macro-Variables	Sub Indicators	Labels
1	**Preparation**	Efficiency	VAR1
		Resourcefulness	VAR2
		Creativity	VAR3
		Foresight Capacity	VAR4
		Connectivity	VAR5
		Communication	VAR6
		Public Awareness	VAR7
		Education and Training	VAR8
		Ensuring safety and Security	VAR9
		Community Assistance	VAR10
		Emergency Supplies	VAR11
		Disaster Plan	VAR12
2	**Absorption**	Diversity	VAR13
		Facilities	VAR14
		Rehabilitation Capacity	VAR15
		Multifunctionality	VAR16
		Modularity	VAR17
		Independence	VAR18
		Robustness	VAR19
3	**Self-organization**	Adaptability	VAR20
		Adequate Knowledge	VAR21
		Self-belief	VAR22
		Nerve Control	VAR23
		Trust in system	VAR24
		Coordination	VAR25
		Social Responsibility	VAR26
4	**Adoption**	Helpfulness	VAR27
		Collaboration	VAR28
		Agility	VAR29
		Flexibility	VAR30
		Resource Utility	VAR31
		Redundancy	VAR32
		Copping Abilities	VAR33

Findings and Data Analysis

Application of Cross-impact Analysis to Identify Key Variables/Constructs

A detailed literature review was conducted to identify the key predictors impacting the government's measures of public policy in developing the liquefaction disaster resilience system. Also, interviews were conducted among the administrative experts', academicians, and professionals of public health policy and disaster management institutions. All these procedures resulted in a diverse set of 33 variables. Out of those 33 variables, the experts' panel was requested to evaluate and filter these diverse sets of variables and place them into four broader categories, i.e., preparedness, absorption, self-organization, and adoption. After assigning the most appropriate categories to all the 33 constructs across impact analysis, 33X 33= 1089 was performed. In the end, a group of domain experts evaluated and validated this structure analysis by applying the MICMAC technique (Patidar, Soni, & Soni, 2017). The matrix filtration amount was 72.63, showing approximately 72.63% influence of the variables on each other. Out of 1089 metrics-based associations, 251 (23.05%) showed"no association" 268 (24.61) presented"weak associations" 245 (22.50%) showed"moderate associations" and 325 (29.84%) reflected "strong associations" among each other (see Table 2).

Table 2. Matrix of Direct Influence MDI

Indicators	Values
Matrix' size	33
Number of iterations	2
Number of zeros	251
Number of ones	268
Number of twos	245
Number of threes	325
Total	1089
Filtrate rate	72.63%

The cross-impact analysis results applying MDI presented in Table 2 depict that most of the shortlisted variables significantly impacted developing public policies regarding the liquefaction disaster resilience system in Indonesia. It is also evident from the results that almost two-thirds of the variables (29.84%) are identified as key predictors of a disastrous resilience system in a developing nation. Simultaneously, Table 3 presents the results of a cross-impact matrix divided into five different categories of the constructs, i.e., "key, input, clustered, output, and excluded variables." It also presents the key predictors of developing public policy related to the liquefaction disaster resilience system linked with public health in Indonesia. These determinants include foresight capacity, connectivity, public awareness, ensuring safety and security, emergency supplies, disaster plan, facilities, multifunctionality, trust and system resource utility, and coping abilities. Simultaneously, efficiency, resourcefulness, creativity, education and training, self-belief, and helpfulness were regarded as input constructs of the study. In addition, communication, community assistance, diversity, modularity, and adequate knowledge were regarded as clustered variables reflecting these constructs' complex and unpredictable nature. These constructs can switch their place and either move towards the input or the output variables for future scenarios. At the same time, robustness, adaptability, nerve-control, coordination,

Croatian International Relations Review
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CIRR
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XXIX (92) 2023, 171-195

social responsibility, redundancy, and flexibility were identified as output/dependent variables in developing Indonesia's disastrous, resilient system. Finally, rehabilitation capacity, agility, independence, and collaboration were found to be the least impactful in devising the public policies to strengthen the liquefaction disaster-resilient system in Indonesia; hence were regarded as excluded variables in the current study.

Table 3. Direct Dependence and Influence of Variables

				Matrix of Direct Influence (MDI)	
Sr. #	**Role**	**Variables**	**Items**	**Direct Influence**	**Direct Dependence**
1	Key	VAR4	Foresight Capacity	623	501
2	Key	VAR5	Connectivity	609	478
3	Key	VAR7	Public Awareness	597	423
4	Key	VAR9	Ensuring safety and security	621	419
5	Key	VAR11	Emergency Supplies	567	379
6	Key	VAR12	Disaster Plan	601	370
7	Key	VAR14	Facilities	588	361
8	Key	VAR16	Multifunctionality	523	359
9	Key	VAR24	Trust in system	514	332
10	Key	VAR31	Resource Utility	506	320
11	Key	VAR33	Copping Abilities	480	391
12	Input	VAR1	Efficiency	487	399
13	Input	VAR2	Resourcefulness	417	368
14	Input	VAR3	Creativity	440	360
15	Input	VAR8	Education and Training	409	332
16	Input	VAR22	Self-belief	391	330
17	Input	VAR27	Helpfulness	378	219
18	Clustered	VAR6	Communication	369	223
19	Clustered	VAR10	Community Assistance	365	250
20	Clustered	VAR13	Diversity	270	210
21	Clustered	VAR17	Modularity	201	376
22	Clustered	VAR21	Adequate Knowledge	189	234
23	Dependent	VAR19	Robustness	140	364
24	Dependent	VAR20	Adaptability	127	290
25	Dependent	VAR23	Nerve Control	124	228
26	Dependent	VAR25	Coordination	112	190
27	Dependent	VAR26	Social Responsibility	106	198
28	Dependent	VAR32	Redundancy	92	132
29	Dependent	VAR30	Flexibility	81	129
30	Excluded	VAR15	Rehabilitation Capacity	56	97
31	Excluded	VAR18	Independence	42	82
32	Excluded	VAR28	Collaboration	29	167
33	Excluded	VAR29	Agility	13	153

Using CIB to Build Consistent Scenarios

After identifying the important variables to strengthen the liquefaction disaster-resilient system in Indonesia utilizing cross-impact analysis, scenario wizard was used to generate several scenario assumptions with different combinations for attaining the authenticity of the key variables identified. Simultaneously, the coded rule in the CIB method was applied to identify the possible scenarios of the 11 key variables extracted in the cross-impact algorithm. For that purpose, 11 extracted key descriptors were organized systematically and distributed to the expert groups. In addition, a 33x33 matrix was formulated to review the key descriptors to check their significance for strengthening Indonesia's liquefaction disastrous resilience system. It helps us identify the changes the descriptor variables brought to the overall system. Finally, scenarios were built by using associations, interactions, and forthcoming judgments regarding the constructs and their impact on the system. We also defined the qualitative variance after compiling the key descriptors list. This helped us identify the key variables' characteristics, presenting their various states to strengthen Indonesia's liquefaction disaster resilience system. In literature, such states are considered "strategic drivers" of the system under study. Furthermore, the key variables and their three best possible descriptive states are presented in Table 4.

Table 4. Descriptors' Possible States

Descriptors	Variables		
A. Foresight Capacity name	A1. Foresight the capacity of the infected area and anticipate a list of alternatives by visualizing multiple possible situations and their solutions	A2. Shortlisting the characteristics and drawbacks of the area and infrastructure along with medical facilities before disasters	A3. No preparation or estimation of the capacity to deal with the natural disasters
B. Connectivity	B1. Ensuring connectivity between different elements of the region	B2. Easy movement of the people and goods within the physical structure of the areas under critical situation	B3. Rapid evacuation and provision of timely medical and emergency assistance
C. Public Awareness	C1. With a clear communication system, the people should be trained and guided about the projected situations and the ways to deal with such situations	C2. Initiation of training centers and disaster preparedness programs	C3. No awareness regarding projected earthquakes and the consequences brought by such disasters
D. Ensuring safety and security	D1. Surety of physical safety to the public with adequate health facilities	D2. Availability of a consolidated disaster management plan to secure the valuables and lives of the people	D3. Lack of medical facilities and infrastructure to ensure the safety and security of the people during and after natural hazards

E. Emergency Supplies	E1. An emergency supply of necessary equipment, medical facilities, food, and other necessities	E2. Enhanced level of networks for a continuous supply of basic necessities to mitigate the impacts of disastrous hazards	E3. Lack of emergency supply system
F. Disaster Plan	F1. Effective and efficient disaster plan and communication of the same with the public and disaster management units	F2. A consolidated disaster plan, keeping in view the projected level of intensity of the disasters, i.e., earthquakes	F3. Poorly structured disaster plan with no rehabilitation activities
G. Facilities	G1. Modern medical facilities with low cost and high quality along with solid infrastructure, i.e., equipped hospitals	G2. Quick medical facilities with trained and patriotic medical staff and doctors who can handle the disaster situations with self-responsibility	G3. Poor- and low-quality medical facilities and infrastructure to deal with natural hazards
H. Multifunctionality	H1. The use of infrastructure for multiple purposes during the disastrous situations, i.e., parks and recreation places as rehabilitation centers and temporary shelters	H2. The use of hospital wards as emergency centers to facilitate the infected people on an immediate basis	H3. No planning for using infrastructure for multi-purposes
I. Trust in system	I1. Need for good governance practices to establish and enhance the level of the citizens' trust in the system to deal with emergencies and natural disasters	I2. Communication of the government concerns regarding citizens' lives and valuables to establish trust among them to psychologically deal with disaster situations	I3. Lack of good governance practices and limited connectivity with the public
J. Resource Utility	J1. Efficient and effective use of the available resources to cope with the disasters' after effects	J2. The infrastructure and professionals, including hospitals and medical staff, and doctors, should be efficiently and effectively utilized	J3. Inefficient add extravagant utilization of the resources
K. Copping Abilities	K1. Problem-focused coping strategies should be implemented with necessary medical aids	K2. Resources must be utilized to stand back and cope with the disastrous situations with subsidies, etc.	K3. Poorly structured coping mechanism, causing damage to the mental and physical health

The next steps dealt with the judgments about descriptor "X's state x's" impact on descriptor "Y's state y's" based on literature review and the opinions and interviews of the experts. This resulted in a "cross-impact matrix in Scenario Wizard Software" with 33 states for 11 key constructs impacting the government measures in developing public policy regarding strengthening the liquefaction disaster resilience system in Indonesia. From these possible states' numbers, we extracted 78,732 possible combining scenarios (3x2x3x3x3x2x3x3x3x3x3). These scenarios were loaded in scenario wizard. Finally, we extracted four scenarios with strong consistencies, 1,910 with weak consistencies, and 621 with mild consistency. Furthermore, the three highly occurring scenarios for strengthening the liquefication disaster resilience system in Indonesia in the future as the forecast to mitigate the disastrous effect of the natural hazards, i.e., an earthquake with specified categories, are presented in Table 5.

Table 5. Scenarios with Strong Consistencies

Scenario 1	Scenario 2	Scenario 3	Scenario 4
A1	A3	A1	A3
B3	B2	B1	B2
C2	C1	C1	C3
D2	D2	D3	D3
E2	E1	E3	E2
F1	F2	F1	F1
G1	G2	G3	G3
H1	H3	H2	H2
I2	I3	I2	I2
J1	J1	J3	J2
K2	K1	K3	K2
L2	L1	L3	L1
M1	M3	M2	M2

Moreover, Table 5 depicts that scenario 1 showed desirable and ideal conditions and is named the "driving scenario." Scenarios 2 and 3 presented the intermediate status with appropriate states of the selected key variables impacting the liquefaction disaster management system. In contrast, scenario 04 was critical, mostly reflecting undesirable status with the least projections of strengthening the liquefaction disaster resilience system. Moreover, Table 6 presents the level of consistency for each possible state of the key predictors to strengthen this system.

Table 6. Value Consistency of Each Possible State

Descriptors	Possible sates	Value Consistency
Foresight Capacity	A1	540
Connectivity	B3	512
Public Awareness	C2	490
Ensuring safety and security	D2	477
Emergency Supplies	E2	434
Disaster Plan	F1	362
Facilities	G1	321
Multifunctionality	H1	280
Trust in system	I2	223
Resource Utility	J1	101
Copping Abilities	K2	69

The findings present the highest consistency value of foresight capacity of the most vulnerable areas to strengthen the liquefaction disaster resilience system as an early preparedness approach to minimize the damage caused by earthquakes. Simultaneously, connectivity and public awareness are also considered to be important factors in strengthening the liquefaction disaster resilience system. At the same time, reserves revealed the significance of ensuring the safety and security of the public to keep them mentally relaxed during disasters. It also helps to enhance their willpower and minimize the physical damage caused by disasters. At the same time, emergency supplies, disaster plans, and facilities in terms of infrastructure, hospitals, medicines, and paramedical staff were the key predictors with high consistencies in strengthening the liquefaction disaster management system. Furthermore, multifunctionality, trust in the system, resource utilization, and coping abilities were found to be moderately affecting government policies in developing and strengthening the liquefaction disaster resilience system linked with the public health in Indonesia.

Discussion and Conclusion

The statistics and forecast present a tremendous increase in natural hazards in recent years. These hazards can become disasters with terrifying consequences without hazard mitigation plans and strategies (Parizi, Taleai, & Sharifi, 2021). Hence, dealing with and preparing for such hazards and their damaging impacts is one of the greatest challenges of today's era all over the globe (Aydin, Duzgun, Wenzel, & Heinimann, 2018). Therefore, to deal with such hazards and their disastrous impact, scholars and planners have introduced resilience to mitigate the impact of such disasters (Ainuddin & Routray, 2012; Fan et al., 2019; Ma, Guo, Deng, & Xu, 2021). At the same time, the main focus of the current study remains the physical resilience in terms of infrastructure and public health and the future projections of how the government can formulate public policies in strengthening the liquefaction disaster resilience system in a developing nation, i.e., Indonesia with the help of future study methodology.

Nowadays, future study methods are valuable to identify the important predictors of a system based on scenario building so that strategies can be formulated to deal with various factors in such systems (Nematpour, Khodadadi, & Rezaei, 2021). Simultaneously, "Cross-impact Analysis (CIA)" (Khademi-Jolgehnejad, Ahmadi Kahnali, & Heyrani, 2021) and "Cross-impact balance (CIB)" (Stankov et al., 2021) are also employed as the future study technologies to highlight the key predictors and their characteristics and rule in a system. It also presents the interrelationship among the variables and their nature as an influencer or dependent variables with the help of possible scenarios (Weimer-Jehle et al., 2020). This study evaluated the contextual association of 33 constructs identified via literature review, expert opinions, and interviews using a "CIA-based systematic framework". Moreover, "MICMAC analysis based on CIA findings" was utilized to develop an integrated model to evaluate interrelationship among the variables important for strengthening the liquefaction disaster resilience system.

After a detailed analysis, 11 key constructs were identified and shortlisted with the stronger impact on government measures in devising a public policy to strengthen Indonesia's liquefaction disaster resilience system. Later, utilizing scenario wizard, all possible scenarios of the 11 key constructs were generated. Furthermore, following the CIB technique using scenario wizard, four scenarios with stronger consistencies were found. Out of these four scenarios, scenario 1 was identified as desirable with ideal features for strengthening Indonesia's liquefaction disaster resilience system. Simultaneously, this scenario was found more suitable in the public health context during natural disasters. Although scenarios 2 and 3 also included the stable and desirable characteristics, however, they were not appropriate to devise the best policies for strengthening the liquidation disaster resilience system sustainably. In contrast, no appropriate or determinantal characteristics linked with the liquefaction disaster resilience system were identified in scenario 4.

Scenario 1 was considered the driving scenario for strengthening the liquefaction disaster resilience system in Indonesia linked with public health for early preparedness for natural hazards to minimize the damage caused by such disasters and mitigate their impacts to rehabilitate the area with efficient utilization of the available resources. Simultaneously, the 11 states of the key variables identified in scenario one are very important and stable to help the government develop policies to strengthen the liquefaction disaster resilience system. One of the most influential states in scenario 1 included the A1 (Foresight the capacity of the infected area and anticipate a list of alternatives by visualizing multiple possible situations and their solutions). This reflects the significance of analyzing all the resources available in an area to formulate the best protective measures to deal with natural hazards before and after occurring such hazards. It also reflects the analysis of the area's infrastructure and the medical facilities to utilize such resources in the best possible way. These results can be related to the prior studies, which reflected the significance of the foresight capacity of the available resources in the most vulnerable areas to deal with natural hazards and environmental issues efficiently (Alikhani, Torabi, & Altay, 2021; Cook et al., 2014).

Secondly, the most influential state of the key predictors was identified as B3 (Rapid evacuation and provision of timely medical and emergency assistance). This state presents the significance of rapid evacuation from the infected areas and the provision of emergency assistance and timely medical facilities so that physical and mental health damages can be controlled and minimized. Previously, researchers highlighted the importance of providing medical facilities to the infected people so that they can trust the system and recover quickly with minimal psychological and mental health damages (Li et al., 2021). Researchers also reported that during the natural hazards, i.e., earthquakes, the most damaging part is not the disaster itself but the mental illness and insecurity among the people regarding the system and coping mechanisms to deal with such disasters (Liu, 2022). Hence, by providing the people of such areas with the best medical facilities and evacuation plans, their mental health during disasters can be restored; as a result, physical losses can be minimized.

Another most influential state of the key predictors impacting the government policies to strengthen the liquefaction disaster resilience system linked with public health was C2 (Initiation of training centers and disaster preparedness programs). It reflects the importance of spreading awareness among the people regarding forthcoming natural hazards and early preparation to deal with such hazards. This can be related to the fact that when people are aware of bad incidents, they prepare themselves physically and mentally to deal with such hazards; as a result, the damages can be minimized (Lestari et al., 2021; Toyoda, Muranaka, Kim, & Kanegae, 2021). Hence, the government should focus on developing training centers where people should be briefed about the forthcoming natural hazards and strategies to deal with such hazards. The next important state of the key predictor was D2 (availability of a consolidated disaster management plan to secure the valuables and lives of the people) also reflects the significance of a disaster management plan. This can be based on the early preparedness strategies so the people of more vulnerable areas are already aware of the future need for natural disasters and prepared for such disasters in the best possible way to reduce the lethal consequences of such disasters in the long and short term (Florentin et al., 2021; Kumar, 2022).

Another important variant found in the current study results is E2 (enhanced level of networks for a continuous supply of basic necessities to mitigate the impacts of disastrous hazards). This state presents the significance of strengthening networks regarding infrastructure, personnel, professionals, and trained people to quickly rehabilitate the infected areas. Previously, researchers have demonstrated the importance of connectivity and communication among various tiers of government and disposable divisions and groups to coordinate with the people to deal with such disasters and their consequences (Pribadi et al., 2021; Zhuang, He, Deng, & Xu, 2021). This further reflects the significance of quick recovery based on highly professional and organized networks.

Hence in this context, the government should invest in strengthening the infrastructure and training the professionals along with the best networks for connecting with the people. Nowadays, social media is one of the best networks to connect people all over the globe (Mansoor, 2021). The significance of social media has been seen during the COVID-19, where the governments of various nations communicated with the people to highlight the destructive impacts of the COVID-19 and persuade them to follow SOPs, ensuring the safety and security of their people (Hartanto, Agussani, & Dalle, 2021). Thus various social media channels can be utilized during the natural hazards, i.e., earthquakes, to connect the people and speak the timely and accurate information to deal with such disasters and avail the medical facilities on a timely and immediate basis.

In addition to above mention best-predicting states of key predictors, F1 (effective and efficient disaster plans and communication of the same with the public and disaster management units is also vital to developing the tourism sector), G1 (modern medical facilities with low cost and high quality along with solid infrastructure, i.e., equipped hospitals), H1 (the use of infrastructure for multiple purposes during the disastrous situations, i.e., parks and recreation places as rehabilitation centers and temporary shelters), I2 (communication of the government concerns regarding citizens' lives and valuables to establish trust among them to deal with disaster situations psychologically), J1 (efficient and effective use of the available resources to cope with the disasters' after effects) were also found to be significantly impacting the government measures of devising policies regarding the strengthening of liquefaction disaster resilience system in a developing nation, i.e., Indonesia.

Theoretical and Practical Implications

The current study is a valuable addition to the existing body of literature. It offers several theoretical and practical implications for academicians, policymakers, and governments to deal with natural hazards and minimize the damage caused by such hazards as earthquakes. This study presented some key determinants linked with strengthening the liquefaction disaster resilience system in a developing nation. Previously, the liquefaction disasters resilient system has been assessed based on the non-physical dimensions, including economic, organizational social, and environmental dimensions (Ainuddin & Routray, 2012; Aydin, Duzgun, Wenzel, & Heinimann, 2018; Parizi, Taleai, & Sharifi, 2021). In contrast, the current study has focused on the physical dimension of the disaster resilience system especially linked with public health. Besides, it has been established based on the future projections where MICMAC technique and scenario wizard were applied to device several scenarios which best fit in strengthening the disaster resilience system in Indonesia in the coming days.

The current study also revealed the significance of focusing on the physical dimension of resilience in the form of infrastructure, hospitals, and connectivity among the people, paramedical staff, and management teams to avoid this heavy damage to the people's mental and physical health. Simultaneously, as discussed earlier, the key constructs identified as the major drivers are developing a significant liquefaction disaster resilience system should be considered at the government level to prepare the people of more vulnerable areas for such disasters in advance and provide them with an opportunity to deal with such disasters and come out of such situations as quickly as possible with minimal damage. In that context, the current study has uniquely presented the significant role of public awareness and ensuring their safety and security based on good governance practices.

This can further help strengthen the people in the most vulnerable areas mentally and physically to deal with such hazards. Simultaneously, the result has reflected the significance of foresight capacity and connectivity among various groups and individuals so that a highly efficient system before natural hazards can minimize the management caused by such disasters. Previously, research depicted that natural hazard, i.e., earthquakes affect the mental and psychological health of the people more than their physical damages (Lestari et al., 2021; Li et al., 2021; Xu et al., 2020). Hence, utilizing the current study findings, an early preparedness system with good governance practices is needed, which can motivate the people of the most vulnerable areas to such disasters to feel safe and secure with the trust in government and its security and health measures. A disaster management plan can also help mitigate the facts of earthquakes and quick recovery with minimal losses.

Future Directions

In addition to identifying the key factors important to dealing with natural hazards, the current study has some limitations that future researchers should consider. The current study is based on the MICMAC and scenario wizard analysis which is considered very efficient in identifying the factors impacting a system in the future and highlighting the complex relationships between the constructs. However, the knowledge of the expert panel can be critical and variable depending upon the knowledge and skills. Therefore, there is a possibility of dominant group members influencing others, and biased results are probable. Hence, for future researchers, it is recommended to organize multidisciplinary teams so that a more authentic and diverse set of key variables can be identified that help to control and minimize the damages caused by natural disasters.

Moreover, the technique applied in the current study cannot project the time for which the projected key variables are valuable in the system based on the ambiguities and uncertainties in the future. In addition, the current study mainly focused on the physical dimension of the resilience linked with public health; however, the other dimensions, i.e., economic, organizational social, and environmental, can also be integrated with public health to find out the factors that are valuable to strengthening the system. Finally, the current study is based on only projecting the key variables important in strengthening the liquefaction disaster resilience system in the future. Whereas the measures and policies available at the national and international level regarding disaster management systems or ignored. Therefore, in the future, a comparative study can be conducted analyzing the available procedures, policies, and laws and the gap available to identify the factors that can add value to the disaster resilience system for a sustainable time.

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