Doi: 10.61186/jorar.16.4.236

Modelling the Factors Affecting Disaster Management using Second Order Confirmatory Factor Analysis

Mehdi Nojavan[1], Babak Omidvar[2], Mehdi Sahba[3], Hamid Karimi Kivi[4]

Date of submission: 04Aug.2024 *Date of acceptance: 21 Nov. 2024*

Review Article

Abstract

INTRODUCTION: One of the environmental issues faced by the majority of large human settlements in the world is natural disasters and their effects. Thus, the purpose of this paper is to present a model using Interpretive Structural Modeling (ISM) for explaining the relationship between the factors affecting disaster management in order to improve its effectiveness.

METHODS: In this study, quantitative method were used. For identifying the factors influencing disaster management, thematic analysis and second-order confirmatory factor analysis were used and confirmed through SmartPLS. Then the main model of the study was developed based on ISM using the views of experts in the field of disaster management.

FINDINGS: The findings showed that risk evaluation, risk management, and management actions were the fundamental factors in the disaster management model which consisted of 19 sub-factors. Convergent validity of the study was found to be higher than 0.5 based on Average Variance Extracted (AVE) and reliability was higher than 0.7 based on Cronbach's alpha, also Composite Reliability (CR) was calculated to be larger than 0.6, which showed that the suggested factors completely measure the intended concept in the study.

CONCLUSION: According to the results, the proposed model shows the relation between factors affecting reduction of damages caused by disasters using the ISM. It can be used in different stages of disaster management because it explains the relation between 12 levels of different factors and enables managers and planners to clearly understand what activities need to be taken for more effective disaster management.

Keywords: Disaster management; Interpretive Structural Modeling (ISM); Second order confirmatory factor analysis; SmartPLS; Thematic analysis.

How to cite this article: Nojavan M, Omidvar B, Sahba M, Karimi Kivi H. **Modelling the Factors Affecting Disaster Management using Second Order Confirmatory Factor Analysis.** Sci J Rescue Relief 2024; 16(4): 236-244.

Introduction

As an inevitable aspect of nature, natural disasters have always been a threat to human settlements. In other words, disasters are not new phenomena, but an integral part of human life. (1)

The importance of paying attention to disasters lays in the urban environment and concentration of activities and capitals in the current cities particularly metropolises. In fact, one of the great challenges facing the human communities is reducing the vulnerability of urban areas to natural disasters. (2&3)

On the other hand, due to the increasing rate of urbanization in the countries all over the world (4), as predicted by the UN, about 80% of the world population will be living in the cities by 2050. (5) This means that urban areas will be the place for many of the likely natural disasters. (6)

About 100000 people lose their lives due to natural disasters every year. Furthermore, natural

1 PhD, Department of Environmental Planning, Natural Disaster Management, Faculty of Environment, University of Tehran, Tehran, Iran
2 Professor, Department of Environmental Engineering, Faculty of Environment, University of Tehran, Tehran, Iran
3 MSc, Department of Environmental Planning, Natural Disaster Management, Faculty of Environment, University of Tehran, Tehran, Iran
4 Assistant Professor of Applied Science, Higher Education Institute, Red Crescent Society of Islamic Republic of Iran, Tehran, Iran

Correspondence to: Mehdi Nojavan, Email: nojavan_mehdi@ut.ac.ir

disasters disproportionately threaten the developing countries; about 79% of the deaths caused by natural disasters happen in the developing countries. These disasters can be considered as realities of life over which human has a very limited control and, despite all the developments and the acquired capabilities, human is not able to prevent their occurrence. However, despite the fact that disasters have been always along with humans, disaster management is still a relatively new profession and scientific field. (7)

Sciences and professions are based upon a certain set of principles that change during the time but lay the foundation stone of activities in that field. As a new profession and scientific field, disaster management also needs to develop its principles and foundation to be able to continue as a professional and scientific field. These principles provide the ground for scientific development and will provide guidance to disaster managers in practice. In line with that, researchers and experts have been always trying to find principles for this field and profession in order to base the advances and the consequent measures upon these principles. Although the efforts for achieving this goal have yielded rather positive results, there is an ongoing search and interaction among the intellectuals and the experienced experts in the field about disaster management and planning principles and the need for sustained efforts to reach the desired results is felt.

Quarantelli (1994) made a good attempt for developing the principles of disaster management under the term ‘disaster planning and management principles’. To him, principles of good and efficient disaster planning have certain characteristics that can be used as general principles. These principles were, first, presented by him, who believed that these principles can be applied in many of the planning activities and measures in disaster management. (8)

Gaillard (2007) believed that the capacity of resilience of traditional societies and the concurrent degree of cultural change rely on four factors, namely: the nature of the hazard, the pre-disaster socio-cultural context and capacity of resilience of the community, the geographical setting, and the rehabilitation policy set up by the authorities. These factors significantly vary in time and space, from one disaster to another. (9)

Kasdan (2016) explored the relationship between factors of socio-cultural contexts and disaster risk. Multiple correlation analysis was employed to find significant relationships between two sources of socio-cultural data and the World Risk Index scores in this research. (10)

Alexander (2016) also reviewed the modern-day challenges facing researchers, scholars and practitioners who work in the field of disaster risk reduction. He stated that there is a need for a major revision in the body of disaster theory so that it can take account dynamic changes in the modern world. On the other hand, disaster theory must adapt to new conditions if it is to remain the road-map that clarifies complex realities and enables disasters to be managed and abated. (11)

Scott et al., (2016) developed a unique monitoring and evaluating framework for use by disaster risk management programs to track the outcomes of their interventions and ultimately raise standards in this area. In this study they discussed and noted a weakness in relation to monitoring and evaluating of disaster risk management and highlighted that disaster risk management capacity development programs typically need help to develop and implement robust monitoring and evaluating systems. (12)

Given the weaknesses of previous models, despite their effectiveness in some places and under certain conditions, disasters remain a major challenge to sustainable development. Therefore, disaster management requires a systematic system with an appropriate approach to greatly reduce the likelihood of negative consequences of the crisis.

In short, today and in the current situation, most developing countries such as Iran are having problems in planning for disaster management due to specific political, economic and social conditions. The problems of disaster management and planning are so serious that they have faced these countries with challenges. These problems indicate weakness in planning, inappropriate management and the use of new methods and very effective programs and the lack of strong theoretical foundations for warding off disaster.

In the present study, an attempt has been made to formulate the general principles and criteria of disaster management and planning. Accordingly, considering the importance of this issue and citing expert views in this field, an attempt was made to identify and classify, based on a review of the conditions, the most important measures and criteria for disaster management and planning before, during and after disasters, according to the studies conducted so far in the field of disaster and crisis management and the factors affecting it.

Methods

The present study is a strategic research in terms of the purpose and the theoretical part is based upon documentary methods and systematic analysis. Data were collected using thematic analysis. In addition, statistical analyses were used for confirming the components or factors, which were obtained by thematic analysis of about 40 disaster and crisis planning and management models proposed by different researchers from 1941 to 2016 in different countries. Accordingly, data were collected through a questionnaire. Then, the determined factors were validated using SmartPLS software based on library studies and a Likert scale questionnaire to measure the impact of these factors on the desired concept. The sample population of the study included 15 experts in the field of disaster and crisis who, besides experience, were fully familiar with the mentioned terms for inclusion in the study. Accordingly, highly experienced and well-known researchers and professors in different countries were selected for the study. The study is summarized in four main stages in Figure 1.

In the first stage, thematic analysis was used to identify factors affecting disaster management. Then, using typology, classification was performed and based on previous studies, three factors were obtained. Subsequently, the identified factors were sent to experts for final approval. It should be noted that in the second and third steps, substantial and the constructs of questionnaire validity were also confirmed.

The instruments used at this phase are a questionnaire including three main factors and 19 sub-factors, which are presented in Tables 1-3. In this questionnaire, which consisted of pair-wise comparisons, the participants (i.e., 15 experts in disasters and crisis management) were asked to make a two-by-two comparison between the factors (no relationship, one-way relationship, two-way relationship) and, accordingly, determine the relationship between them. The different phases of ISM include the following: (13)
a) developing the structural self-interaction matrix; b) developing the initial reachability matrix; c) developing the final reachability matrix; d) level partitioning; e) developing the interpretive structural model.

The model was developed based on the determined levels and the final reachability matrix.

Findings

As mentioned in steps 1 and 2 of the study, the factors affecting disaster management were identified and classified using thematic analysis, and then second-order confirmatory factor analysis was used for quantitative and qualitative evaluation based on this classification to find answers to the hypotheses formulated on the SmartPLS software.

The Average Variance Extracted (AVE) was utilized to assess convergent validity of the study and as it was higher than 0.5, was considered appropriate (14). A Cronbach's Alpha value of 0.6-0.7 is appropriate or considered acceptable for Composite Reliability (CR) respectively. (Table 1)

The main factors identified and derived from thematic analysis were tested using PLS and SmartPLS software. T-values for all the paths was above than standard absolute value of 1.96, indicating that the initial constructed factors will play an effective role in disaster management. (Figure 2).

The path coefficient value shows the strength of the relationship between the two variables. The numbers on the paths represent the path coefficient values and the numbers within the circles represent R^2 and the numbers on the latent variable arrows represent factor loadings. The coefficient of determination (R^2) shows what percent of the dependent variable is explained by the independent variable. For R^2, values approximate to 0.67 are considered as appropriate, values close to 0.33 are normal, and values lower than 0.190 are regarded as weak. (Table 2 and 3 & Figure 3)

Based on the results as presented in Figures 2 and 3 and Tables 1-3 all the hypothesized factors were confirmed. In other words, these factors could well measure the main construct of the study, i.e., disaster management.

Table 1. Validity and reliability of the research hypotheses

Factors	No. of questions	Cronbach's alpha	AVE	CR	R Square
Hazard Assessment	6	0.920	0.725	0.939	0.916
Risk Management	7	0.923	0.702	0.943	0.928
Management Actions	6	0.892	0.651	0.918	0.929
Disaster Management	3	0.968	0.640	0.971	-

[DOI: 10.61186/jorar.16.4.236]

Table 2. Main hypotheses of the study

Hypothesis	Correlation			Correlation direction	Path coefficient	Test result
1	Hazard Assessment	_	Disaster Management	direct	0.957	Desired/ confirmed
2	Risk Management	_	Disaster Management	direct	0.963	Desired/ confirmed
3	Management Actions	_	Disaster Management	direct	0.964	Desired/ confirmed

Table 3. Subordinate hypotheses of the study

Hypothesis	Correlation			Correlation direction	Path coefficient	Test result
1	Exposure Analysis	_	Hazard Assessment	direct	0.928	desired/ confirmed
2	Hazard Identification	_	Hazard Assessment	direct	0.902	desired/ confirmed
3	Forecast Hazard	_	Hazard Assessment	direct	0.903	desired/ confirmed
4	Hazard Analysis	_	Hazard Assessment	direct	0.870	desired/ confirmed
5	Vulnerability Assessment	_	Hazard Assessment	direct	0.576	desired/ confirmed
6	Resource Assessment	_	Hazard Assessment	direct	0.878	desired/ confirmed
7	Risk Context	_	Risk Management	direct	0.801	desired/ confirmed
8	Risk Communication	_	Risk Management	direct	0.818	desired/ confirmed
9	Risk Identification	_	Risk Management	direct	0.838	desired/ confirmed
10	Risk Analysis	_	Risk Management	direct	0.769	desired/ confirmed
11	Risk Evaluation	_	Risk Management	direct	0.908	desired/ confirmed
12	Treat Risk	_	Risk Management	direct	0.879	desired/ confirmed
13	Monitoring and Revising the Risk Control Plan	_	Risk Management	direct	0.855	desired/ confirmed
14	Prevention/ Warning	_	Management Actions	direct	0.840	desired/ confirmed
15	Mitigation	_	Management Actions	direct	0.782	desired/ confirmed
16	Preparedness	_	Management Actions	direct	0.810	desired/ confirmed
17	Response	_	Management Actions	direct	0.746	desired/ confirmed
18	Recovery (Reconstruction/ Rehabilitation)	_	Management Actions	direct	0.828	desired/ confirmed
19	Learning/ Development	_	Management Actions	direct	0.829	desired/ confirmed

Table 4. Final reachability matrix

I \ J	Exposure analysis	Hazard identification	Forecast hazard	Hazard analysis	Vulnerability assessment	Resource assessment	Risk context	Risk communication	Risk identification	Risk analysis	Risk evaluation	Treat risk	Monitoring and revising the risk Control plan	Prevention/ warning	Mitigation	Preparedness	Response	Recovery (reconstruction / rehabilitation)	Learning/ development
Exposure analysis	1	0	0	1*	0	0	1*	1*	1*	1*	0	0	0	0	0	0	0	0	0
Hazard identification	1	1	1	1	0	0	1	1	1	1*	0	0	0	0	0	0	0	0	0
Forecast hazard	1	0	1	1	1*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hazard analysis	0	0	0	1	1	1*	0	0	0	1	1*	0	0	0	0	0	0	0	0
Vulnerability assessment	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0
Resource assessment	0	0	0	0	1	1	0	0	0	0	1	1*	0	1*	1*	1*	0	0	0
Risk context	1	1	1*	1*	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
Risk communication	1	1	0	0	0	0	1	1	1	1*	0	0	0	0	0	0	0	0	0
Risk identification	1	1	1*	1*	0	0	1*	1*	1	1	1*	0	0	0	0	0	0	0	0
Risk analysis	0	0	0	1	1*	0	0	0	0	1	1	1*	0	1*	1*	1*	0	0	0
Risk evaluation	0	0	0	0	0	0	0	0	0	0	1	1	1*	1	1	1	1*	1*	1*
Treat risk	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1*	1*	1*
Monitoring & revising the risk control plan	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1*	1*	1*
Prevention/ warning	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1*	1
Mitigation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1*	1*	0
Preparedness	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1*
Response	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1*
Recovery (reconstruction/ rehabilitation)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Learning/ development	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1

[DOI: 10.61186/jorar.16.4.236]

Table 5. The results of level partitioning

Factors	Reachability set	Antecedent set	Intersection set	Level
Exposure analysis	1, 7, 8, 9	1, 2, 3, 7, 8, 9	1, 7, 8, 9	10
Hazard identification	2, 7, 9	2, 7, 9	2, 7, 9	12
Forecast hazard	3	2, 3, 7, 9	3	11
Hazard analysis	4, 10	1, 2, 3, 4, 7, 9, 10	4, 10	9
Vulnerability assessment	5, 6	3, 4, 5, 6, 10	5, 6	8
Resource assessment	5, 6	4, 5, 6	5, 6	8
Risk context	2, 7, 9	2, 7, 9	2, 7, 9	12
Risk communication	1, 2, 7, 8, 9	1, 2, 7, 8, 9	1, 2, 7, 8, 9	10
Risk identification	7, 9	2, 7, 9	7, 9	12
Risk analysis	4, 10	1, 2, 4, 7, 9, 10	4, 10	9
Risk evaluation	11	4, 5, 6, 9, 10, 11	11	7
Treat risk	12, 13	6, 10, 11, 12, 13	12, 13	6
Monitoring & revising the risk control plan	12, 13	11, 12, 13	12, 13	6
Prevention/ warning	14	6, 10, 11, 12, 13, 14	14	5
Mitigation	15	6, 10, 11, 12, 13, 14, 15, 16	15	3
Preparedness	16	6, 10, 11, 12, 13, 14, 16	16	4
Response	17	11, 12, 13, 14, 16, 17	17	2
Recovery (reconstruction/ rehabilitation)	18, 19	11, 12, 13, 14, 15, 16, 17, 18, 19	18, 19	1
Learning/ development	18, 19	11, 12, 13, 14, 16, 17, 18, 19	18, 19	1

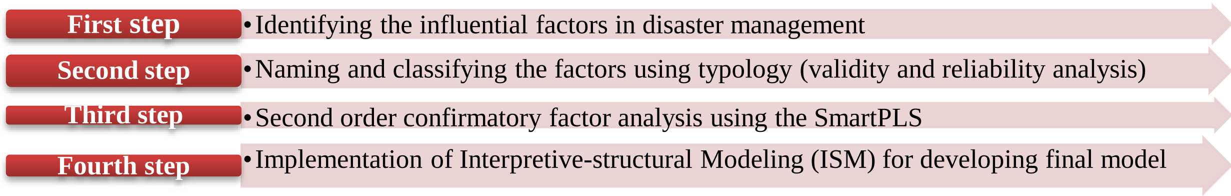

Figure 1. Research process for modeling of disaster management

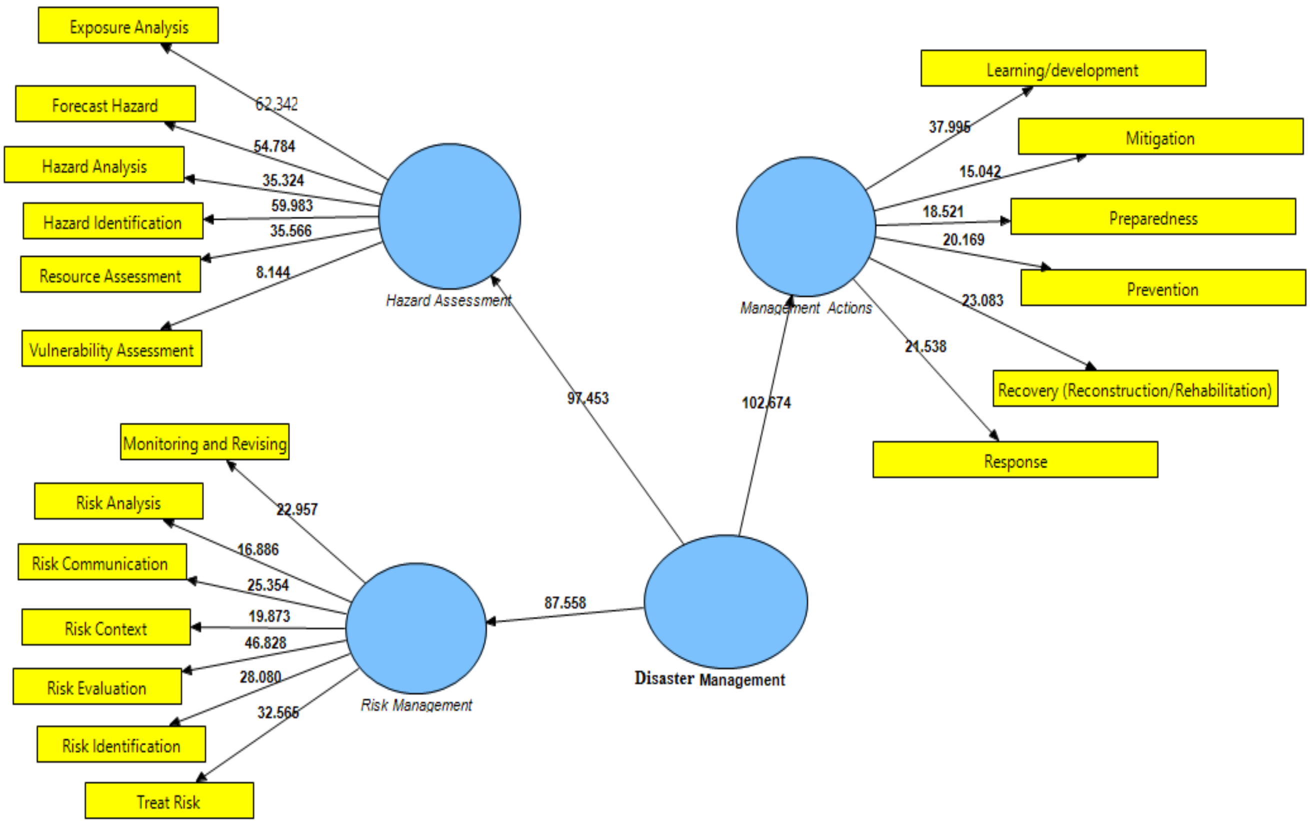

Figure 2. T-values

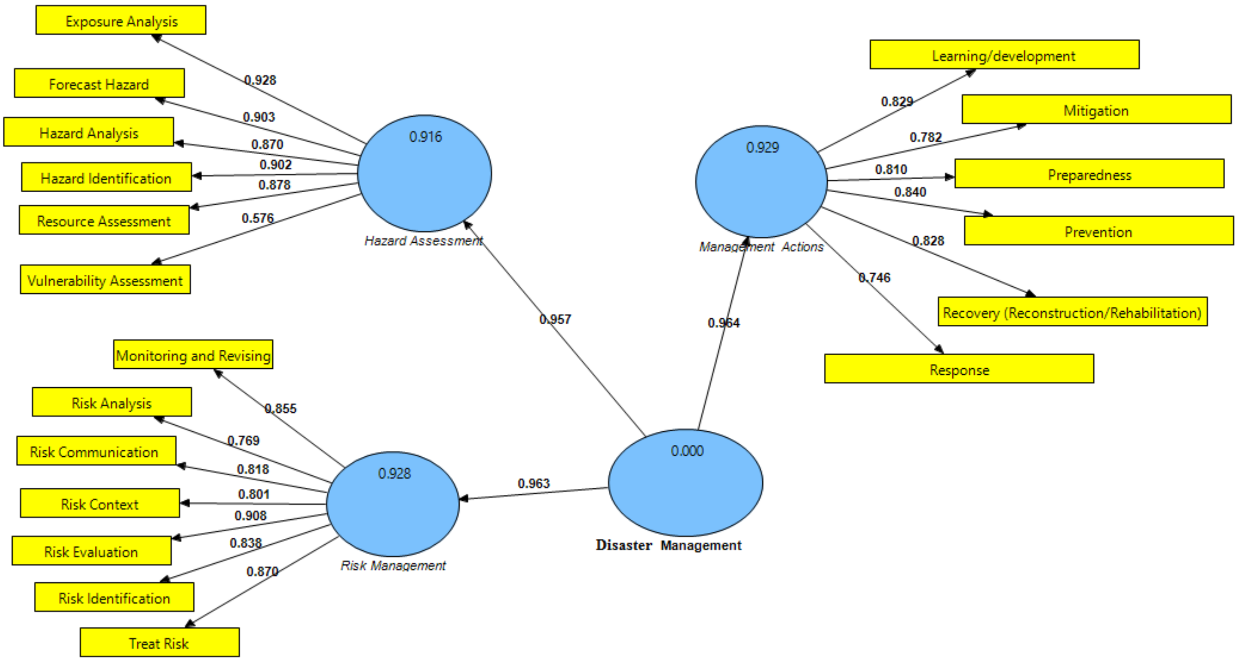

Figure 3. Path coefficient values and factor loadings

The results of the present study can be divided into two parts. In the first part, considering the fact that planning and management requires systematic identification of the factors that can play a considerable role in disaster management and planning, an attempt was made to specify the factors influencing disaster management by combining the two methods of thematic analysis, which is qualitative, and confirmatory factor analysis, which is quantitative. To achieve this goal, the most important factors were identified and classified using thematic analysis and typology respectively. Accordingly, they were divided into three major categories that could, overall, be examined under 19 factors. Based on this classification, the research hypotheses were formulated and were tested by second order confirmatory factor analysis which is the method of testing hypotheses and is based on what you think about these latent variable factors.

Considering the limited number of participants in the present study, the SmartPLS was used for testing the hypotheses. The results indicated that the initial classification mentioned in the previous section can be effectively used in disaster management and planning. This conclusion is presented in Tables 1, 2, and 3 and Figures 2 and 3, which provide an evaluation of the validity of the initial classification. Since the hypotheses were automatically tested on the software at a significance level of 95%, a t-value of greater than 1.96 indicates confirmation of the hypothesis. As shown in Figures 2 and 3, all the t-values were higher than 1.96, which means that all the 19 initial hypotheses have been confirmed. Furthermore, based on the path coefficient values in Figure 3, the factors of 'exposure analysis' (0.928) and 'risk evaluation' (0.908) have the highest effect on the intended construct. The 19 identified factors were considered as input for ISM, based on which a questionnaire was prepared, then using the questionnaire and summarizing the experts' opinions, an interactive-structural matrix was formed based on the highest frequency. After that, the initial achievement matrix was formed using the interactive-structural matrix, and finally, the final reachability matrix was formed following the initial reachability matrix (Table 4).

After forming the final reachability matrix, the factors could be level partitioned. In line with that, first, the reachability set, the antecedent set, and the intersection set were determined and, by comparing the reachability set of each factor with the intersection columns, the factors that were exactly the same were selected as the first level. After determining the first level, the factors in this column including all the reachability, antecedent, and intersection sets were removed and again the similarity between the column related to the reachability set and the intersection column was examined to determine the second level. This was repeated as many times as necessary to determine the level of all the factors. As it was already mentioned, after determining the level of the factors, the related factor was eliminated from the sets and again the reachability and the antecedent sets were formed and the next level was obtained. By continuing this process, the level of criteria was determined and, the final level partitioning was achieved after 12 stages (Table 5). Hazard identification, risk context and risk identification are at the first level of the model, and learning/development and recovery (rehabilitation and reconstruction) are at level 12 of the model.

In the second part, using ISM the experts examined the factors identified in the previous stage (i.e., three main factors and 19 sub-factors) for developing the disaster management model. Hazard identification, risk context and risk identification are the most important factors and the foundation of the model. In fact, these factors should be considered by disaster management and planning officials as the first step for achieving the goals. Paying attention to these factors facilitates access to the subsequent levels. In addition, based on Figure 4, it can be stated that any change at any level and any factor will lead to changes in the next levels. Overall, in line with drawing a general plan for a promising future, all the independent factors affecting future events should be predicted and a harmonious combination of all these factors should be presented within the framework of scenarios. One of the concerns of organizations to use the tacit knowledge of managers and experts is to ensure a clear mind for decision makers to plan for an uncertain future.

Today, one of the most important methods of prediction is modeling. In fact, models play a very special role in gaining a better understanding of the issues and controlling them by simplifying the existing complexity in the environment. The final model developed in the present study using ISM will enable managers and planners to clearly understand what measures and activities need to be taken for more effective disaster management and planning. In other words, the developed model will not only help the managers to set their priorities of action, but will also help them imagine the different scenarios that are likely to occur as a result of changes in factors. Furthermore, creating a systematic approach towards the issue under study can provide the basis for planning and allocation of organizational resources and considerably decrease the national and organizational costs.

Based on the findings, it is suggested that, future studies use multi-criteria decision-making methods to prioritize factors affecting disaster management under fuzzy environment. After determining the priority and level of the factors, the results can be compared with the findings from the present study. In addition, a comprehensive model can be developed by considering the factors in the present study and using System Dynamics (SD) methods.

Discussion and Conclusion

In the present study, factors affecting disaster management were identified through a thematic analysis of the models presented in this topic. Then, the factors were labeled and classified, and the validity and reliability of the research were examined. Subsequently, SmartPLS was used to confirm these factors or test and confirm the research hypotheses for second-order confirmatory factor analysis. Since the hypotheses were automatically tested by the software at a significance level of 95%, a t-value of more than 1.96 indicated confirmation of the hypothesis. Based on the findings, all 19 hypotheses were confirmed. In other words, the initial constructed factors or variables do have an influential role in disaster management.

Furthermore, based on the values of the path coefficients, it can be stated that ‘exposure analysis’ and ‘risk evaluation’ have the greatest impact on disaster management. Also, according to the calculated path coefficient values and factor loadings, which indicate intensity of the relationship, all the hypothesized factors were confirmed. That is, these factors can properly measure the main construct of the study, namely disaster management. The results of the study showed that the initial classification under hazard assessment, risk management, and management actions, can effectively help in disaster planning and management. At the final stage, ISM was utilized to design the final model of the study.

Based on the proposed model, hazard identification, risk context and risk identification are the most important factors that form the foundation of the model. Thus, these factors need to be considered by the authorities as the first step for effective planning and efficient disaster management as the goal of the present study Because paying attention to them can facilitate access to subsequent levels. Also based on the proposed model, it can be predicted that following

[DOI: 10.61186/jorar.16.4.236]

changes in each level or factor, what changes will occur in the next levels or factors.

Therefore, all the considered stages and levels in this study are essential for effective disaster management and need to be implemented. If the initial stages of the model are not passed, the subsequent stages will also change and disaster management will not be operational and will not yield the desired results.

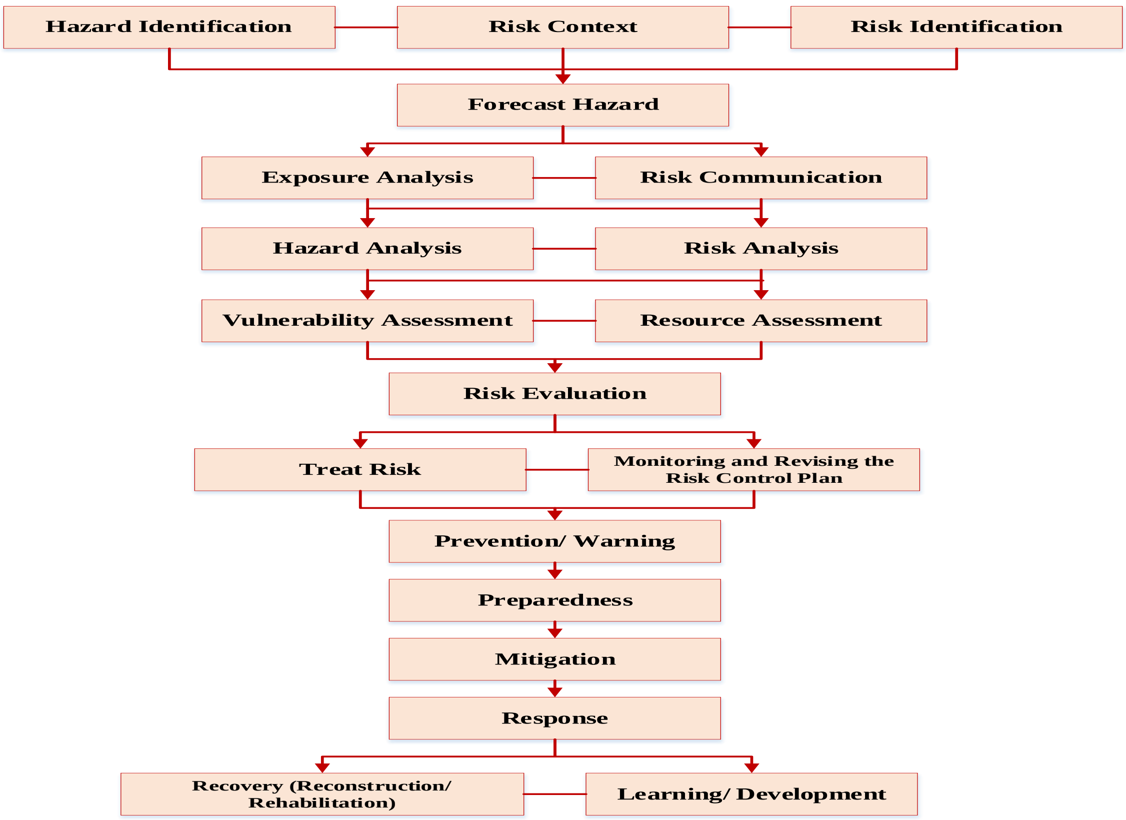

Figure 4. Modeling of disaster management using ISM

Compliance with Ethical Guidelines

All ethical principles have been considered in this article, and participants were informed of the purpose of the research and its implementation steps.

Funding/Support

This article is extracted from Mehdi Nojavan PhD thesis entitled "Modelling the Factors Affecting Disaster Management using Second Order Confirmatory Factor Analysis" without any financial support at the Department of Environmental Planning, Natural Disaster Management, Faculty of Environment, University of Tehran in 2024.

Author's Contributions

This article is based on Mehdi Nojavan PhD thesis at Faculty of Environment, University of Tehran, who was responsible for conducting the research, collecting, and analyzing the data and methodology; and the second author, Babak Omidvar, was responsible for the design and supervision, and Mehdi Sahba and Hamid Karimi Kivi were responsible for collecting, and analyzing the data. However, Mehdi Nojavan was responsible for correspondence and editing the final manuscript submitted to the journal.

Conflict of Interests

The authors declare no conflict of interest.

Acknowledgments

None

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[DOI: 10.61186/jorar.16.4.236]

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[DOI: 10.61186/jorar.16.4.236]