Housing Infrastructure Resilience Analysis Against Flood Hazard Using an Intuitionistic Fuzzy DEMATEL Approach

Maryam Garshasbi[1(✉)], Mrinal Kanti Sen[2], Golam Kabir[1], and Subhrajit Dutta[2]

[1] Industrial Systems Engineering, University of Regina, Regina, SK, Canada
maryam.garshasbi76@gmail.com, golam.kabir@uregina.ca
[2] Civil Engineering Department, NIT Silchar, Assam, India

Abstract. Housing is one of the fundamental requirements for people to live and because of natural disasters, several houses are seriously damaged all around the world. Decision-makers and stakeholders need to concentrate on making the infrastructure further resilient toward many kinds of hazards like floods, earthquakes, and landslides. In resilience, dependency is a critical issue; therefore, investigating the resilience factors' dependencies and relationships between the housing infrastructures against flood hazards is essential. The interplay amongst the housing infrastructure resilience factors is assessed by employing an Intuitionistic Fuzzy DEMATEL method in this research. As the findings of this research, by using the Intuitionistic Fuzzy DEMATEL approach, the housing infrastructure resilience essential factors against flood hazard are recognized. The research findings will guide the decision-makers and stakeholders in making the housing infrastructures further resilient.

Keywords: Housing infrastructure · Resilience · Intuitionistic fuzzy DEMATEL · Dependency · Flood hazard

1 Introduction

Infrastructures are vital in the operation of an association. A society includes various infrastructures, like physical and social. The physical infrastructure involves electrical, telecommunication, water, transportation, and housing (Masoomi and Lindt 2019). In contrast, the social infrastructure contains health, income, and education (Cui and Li 2020). The decline in the infrastructure systems' accomplishments depends on factors like life, situation, and dependences with other infrastructures (Bristow 2019). In the current situation, globally and especially in India, natural disasters are becoming further active (EM-DAT 2019). Many types of hazards like floods, earthquakes, landslides, and heavy storms interrupt infrastructures. The influence of these hazards cannot be removed, or the hazards cannot be paused. Therefore, for infrastructure, the notion of resilience can be performed that is trustworthy and retrievable (Hosseini and Barker 2016; Sen et al. 2021; Stead 2014).

J. A. Fonseca de Oliveira Correia et al. (Eds.): ASMA 2021, STIN 19, pp. 194–205, 2022.
https://doi.org/10.1007/978-3-030-98335-2_13

This research proposes a modeling method on the basis of network study in the field of how reliability and recovery factors are interrelated to determine the factors with different priorities. In other words, this study tries to investigate the resilience factors' dependencies and relationships between the housing infrastructures against flood hazards. Knowing those relations gives a vision to policymakers on crucial factors. This data is vital for adequate allocation of resource arrangements, which can make housing infrastructure resilience. The interplay among the housing infrastructure resilience factors is assessed by employing the Intuitionistic Fuzzy DEMATEL method in this research.

This research is described as follows: History and definitions of the Intuitionistic fuzzy set (IFS) and DEMATEL methods are provide in Sect. 2. The submitted complete methodology, which is the Intuitionistic Fuzzy DEMATEL approach, is explained in Sect. 3. Section 4 addresses the outcomes and discussions. In the last section, Sect. 5, the conclusion is discussed.

2 Preliminaries

2.1 Intuitionistic Fuzzy Set (IFS) Algorithm

The fuzzy sets algorithm was launched by Zadeh (1965). In following years, Atanassov (1986) introduced a new method named intuitionistic fuzzy set theory. Nehi and Maleki (2005) suggested that, suppose intuitionistic triangular fuzzy numbers extend, trapezoidal intuitionistic fuzzy numbers can be created.

Some primary descriptions and definitions of IFS theory are summarized below (Nikjoo and Saeedpoor 2014):

Definition 1: Assume X is a non-empty, finite set. Also assume A $\subseteq$ X. *A* is a standard fuzzy set if a membership function $\mu_A(x)$ to the extent that $\mu_A(x) : X \rightarrow [0, 1]$. Whenever $\mu_A(x)$ is a membership function of *x* in *A,* then $A = \{x, \mu_A(x) : x \in X, \mu_A(x) \in [0, 1]\}$ will be a fuzzy set (Ocampo 2018).

Definition 2: If *A* = *(l, m, u)* describes the triangular fuzzy number; then $\mu_A(x)$ will be (Ocampo (Ocampo 2018):

$$\mu_A(x) = \left\{ \begin{array}{cc} 0 & x < l \\ (x-l)/(m-l) & l \le x \le m \\ (u-x)/(u-m) & m \le x \le u \\ 0 & x > u \end{array} \right\} \quad (1)$$

Definition 3: Assume E is a fixed universe. The IFS A is defined as a mapping $E \rightarrow [0, 1] \times [0, 1]$ for *E.* It will be determined by a 2-tuple $\mu_A(x), \nu_A(x)$ which for $x \in E$, $\mu_A(x)$ designates the membership degree of x and $\nu_A(x)$ designates the non-membership degree of x to A. $\mu_A(x)$ and $\nu_A(x)$ fulfill the following circumstance (Angelov 1995):

$$\mu_A(x) + \nu_A(x) \le 1 \quad (2)$$

While $\mu_A(x) + \nu_A(x) = 1$, set B will be a standard fuzzy subset. In here, for IFS, $E = \mathbb{R}$.

Definition 4: Permit A to be an IFS. With Definition 3, consider D_λ as a crispification processor represented with $D_\lambda : [0, 1] \times [1, 0] \to \mathbb{R}$. By $\lambda = 0.5$, the fuzzy set $D_{0.5}(A)$ can be described with a membership function (Anzilli and Facchinetti 2016):

$$\mu(x) = \frac{1}{2}(1 + \mu_A(x) - \nu_A(x)) \tag{3}$$

2.2 The DEMATEL Method

At the end of 1971, DEMATEL method was employed by Fontela and Gabus (1976). It answered several global complicated difficulties in scientific, political, and economical with respecting experts' views. The computational DEMATEL's process is as follows:

1. Find out the elements of the system. This procedure can be done in many ways, including a literature review on the field subject, expert decisions, and concentrate group analysis on the problem. Signify $F_1, F_2, \ldots, F_n$ for those n components.
2. Create a direct-relation matrix. Some experts with members ($H = 1, 2, \ldots, \mathbb{N}$) present pairwise correlations of the causal relations among n components. Therefore, a direct-relation matrix $x^k = \left(x_{ij}^k\right)_{n\times n}$ for the k^{th} member, $k = 1, 2, \ldots, H$ generates. In here, x_{ij} describes the component F_i's casual influence on component F_j. For this causal influence, an evaluation scale of 1, 2, 3, 4, and 5 is utilized. 1, 2, 3, 4, and 5 are showing 'no impact', 'very low impact', 'low impact', 'high impact', and 'very high impact', respectively. The total direct-relation matrix X, $\forall X^k, k = 1, 2, \ldots, H$, with consideration of $w_k \in \mathbb{R}$ is committed to the value of the k^{th} member is defined in the following equation:

$$X = \left(x_{ij}^k\right)_{n\times n} = \left(\frac{\sum_{k=1}^{H} w_k x_{ij}^k}{\sum_{k=1}^{H} w_k}\right)_{n\times n} \tag{4}$$

3. Now the aggregate direction-relation matrix should be normalized. It can be measured with the usage of the following two equations:

$$G = g^{-1}X \tag{5}$$

$$g = \max\left(\max_{1\le i\le n} \sum_{j=1}^{n} x_{ij}, \max_{1\le j\le n} \sum_{i=1}^{n} x_{ij}\right) \tag{6}$$

4. Determine the total relation matrix. When G is reached, a constant reduction in the system's indirect consequences simultaneously as the powers of G confirms convergent answers to the matrix inversion. $T = \left(t_{ij}\right)_{n\times n}$ is calculated utilizing the following equation:

$$T = G(1 - G)^{-1} \tag{7}$$

5. Classify the components into the net effect and net cause. Calculation of R and D can be done by Eqs. 8 and 9, respectively.

$$R = \left(\sum_{i=1}^{n} t_{ij}\right)_{1\times n} = (t_j)_{1\times n} \tag{8}$$

$$D = \left(\sum_{j=1}^{n} t_{ij}\right)_{n\times 1} = (t_i)_{n\times 1} \tag{9}$$

The $(D + R^T)$ vector describes the corresponding value of any component. For relation to the net cause group, the components in the $(D - R^T)$ have $t_i - t_j > 0, i = j$. The components with $t_i - t_j < 0, i = j$ refer to the net effect group.

6. Create the prominence-relation map. It displays the $(D + R^T, D - R^T)$ of the components (Ocampo and Yamagishi 2020).

3 Methodology: The Intuitionistic Fuzzy DEMATEL Approach

In the current division, the IF-DEMATEL method is performed for assessing the interplay of the Barak valley North-East India's housing infrastructure resilience against flood dangers. The subsequent sections show the IF-DEMATEL approach steps.

3.1 Identify the Housing Infrastructure Resilience Factors

Ten experts from various fields were chosen to determine impacting factors and generate initial direct-relation matrixes. The experts' details are mentioned in Table 1. Table 2 highlights the selected factors.

Table 1. Details of experts

Numbers of experts	Affiliation	Years of experience
1	Field officer from District Disaster Management Authority (DDMA)	>3 years
1	Assistant engineer	>8 years
1	District project officer	>10 years
2	Assistant professor	>3 and 10 years
5	Catastrophe modeler	>3, 4, 5, 7, and 16 years

3.2 Establish the Direct-Relation Matrix

The mentioned ten experts contrasted the factors pair-wise based on their information and experience with the impacts. Two initial direct relation matrixes were generated for each expert (for reliability and recovery factors) using the impact range shown in Table

Table 2. Housing infrastructure resilience's reliability and recovery factors

Factor ID	Reliability factor	Reference	Factor ID	Recovery factor	Reference
F1	Classification of the house	(van de Lindt et al. 2020)	F7	Income	(van de Lindt et al. 2020)
F2	Wall thickness	(van de Lindt et al. 2020)	F8	Insurance	(De Iuliis et al. 2019)
F3	Age of the house	(De Iuliis et al. 2019)	F9	Availability of resource	(Sen et al. 2020)
F4	Depth of the flood	(Sen et al. 2020)	F10	Relief received	(Pham et al.2010)
F5	House plinth level	(Sen et al. 2020)	F11	Approachability	(Sen et al. 2020)
F6	Availability of drainage	(Sen et al. 2020)	F12	Education	(Sen et al. 2020)

Table 3. The intuitionistic fuzzy linguistic scale

Linguistic Variable	Impact score	Corresponding IFNs
Very low impact	2	(0.1,0.9)
Low impact	3	(0.35,0.6)
No impact	1	(0.5,0.45)
High impact	4	(0.75, 0.2)
Very high impact	5	(0.9,0.1)

3. For generating the direct-relation matrixes, intuitionistic triangular fuzzy numbers have been used (Table 3).

Since the number of experts is more than one, therefore, the average was used to create the direct-relation matrix. Tables 4 and 5 illustrate the direct-relation matrixes of reliability and recovery factors, respectively. Any of the components are expressed as a 2-tuple (as in Definition 3), that is $x_{ij} = \mu_A(x), v_A(x)$.

3.3 Get the Equivalent Standard Fuzzy subset's Corresponding Membership Function

The two-step defuzzification method of Anzilli and Facchinetti (2016) was selected to defuzzify the IFS values. The primary step is to transform the IFS into corresponding standard fuzzy subsets with the use of Eq. (3). The reliability and recovery factors' initial-direct relation matrix in standard fuzzy subsets are shown in Tables 6 and 7, respectively.

Table 4. Direct-relation matrix of reliability factors

Factors	ID	F1	F2	F3	F4	F5	F6
Classification of the house	**F1**	(0.50, 0.45)	(0.65, 0.26)	(0.54, 0.42)	(0.61, 0.38)	(0.70, 0.26)	(0.69, 0.28)
Wall thickness	**F2**	(0.46, 0.49)	(0.50, 0.45)	(0.48, 0.49)	(0.50, 0.48)	(0.34, 0.64)	(0.40, 0.57)
Age of the house	**F3**	(0.72, 0.25)	(0.53, 0.43)	(0.50, 0.45)	(0.61, 0.35)	(0.46, 0.50)	(0.65, 0.32)
Depth of the flood	**F4**	(0.57, 0.40)	(0.57, 0.39)	(0.66, 0.29)	(0.50, 0.45)	(0.37, 0.60)	(0.49, 0.48)
House plinth level	**F5**	(0.67, 0.28)	(0.32, 0.65)	(0.46, 0.50)	(0.87, 0.12)	(0.50, 0.45)	(0.63, 0.35)
Availability of drainage	**F6**	(0.44, 0.53)	(0.48, 0.49)	(0.36, 0.62)	(0.83, 0.16)	(0.69, 0.28)	(0.50, 0.45)

Table 5. Direct-relation matrix of recovery factors

Factors	ID	F7	F8	F9	F10	F11	F12
Income	**F7**	(0.50, 0.45)	(0.70, 0.29)	(0.47, 0.51)	(0.39, 0.59)	(0.56, 0.40)	(0.84, 0.14)
Insurance	**F8**	(0.87, 0.12)	(0.50, 0.45)	(0.42, 0.55)	(0.49, 0.48)	(0.34, 0.65)	(0.60, 0.37)
Availability of resource	**F9**	(0.80, 0.18)	(0.32, 0.66)	(0.50, 0.45)	(0.44, 0.53)	(0.70, 0.29)	(0.46, 0.53)
Relief Received	**F10**	(0.48, 0.49)	(0.49, 0.48)	(0.57, 0.39)	(0.50, 0.45)	(0.59, 0.39)	(0.48, 0.49)
Approachability	**F11**	(0.50, 0.46)	(0.50, 0.45)	(0.81, 0.16)	(0.76, 0.21)	(0.50, 0.45)	(0.36, 0.62)
Education	**F12**	(0.77, 0.19)	(0.62, 0.34)	(0.39, 0.58)	(0.45, 0.51)	(0.64, 0.33)	(0.50, 0.45)

Table 6. Initial-direct relation matrix of reliability factors

Factor ID	F1	F2	F3	F4	F5	F6
F1	0.525	0.697	0.560	0.613	0.720	0.705
F2	0.486	0.525	0.493	0.508	0.350	0.415
F3	0.733	0.548	0.525	0.630	0.480	0.665
F4	0.588	0.590	0.685	0.525	0.385	0.505
F5	0.695	0.333	0.483	0.875	0.525	0.638
F6	0.453	0.495	0.373	0.835	0.705	0.525

Table 7. Initial-direct relation matrix of recovery factors

Factor ID	F7	**F8**	**F9**	**F10**	**F11**	**F12**
F7	0.525	0.703	0.480	0.400	0.578	0.850
F8	0.875	0.525	0.433	0.508	0.345	0.613
F9	0.810	0.333	0.525	0.453	0.705	0.465
F10	0.495	0.508	0.588	0.525	0.598	0.495
F11	0.523	0.525	0.825	0.773	0.525	0.373
F12	0.788	0.640	0.405	0.470	0.658	0.525

3.4 Defuzzify the Standard Fuzzy Subset Values

Last step of the defuzzification procedure of Anzilli and Facchinetti (2016) is selecting a defuzzification function f that can outline $f : \mu(x) \rightarrow \mathbb{R}$. The membership function numbers are allocated to the triangular fuzzy number, which is (0, 4, 4). By employing Eq. (1) which $l = 0$, $m = 4$, $u = 4$, the subsequent equation will be established (Ocampo and Yamagishi 2020):

$$\mu(\tilde{x}) = \frac{\tilde{x} - l}{m - l} \Rightarrow \tilde{x} = l + \mu(\tilde{x})(m - l) \quad (10)$$

where l, m, u are a triangular fuzzy number's parameters, $\tilde{x}$ is defuzzified value or the corresponding crisp, and $\mu(\tilde{x})$ is the membership function value given.

3.5 Gain the Normalized Direct-Relation Matrix

By employing Eqs. (5) and (6), the normalized direct-relation matrix for reliability factors is calculated with $g = 15.94$ and for recovery factors is computed using $g = 16.06$.

3.6 Create the Total Relation Matrix

Tables 8 and 9 illustrate the total relation matrixes of reliability and recovery factors, respectively, which are collected employing Eq. (7). They also present $\left(D + R^T\right)$ and $(D - R^T)$ vectors for reliability and recovery factors, respectively. Moreover, in these two tables, the factors' categorization based on net effect or net cause is displayed. These vectors are calculated using Eqs. (8) and (9).

3.7 Create the Prominence-Relation Map

Based on $\left(D + R^T, D - R^T\right)$ coordinates, the prominence-relation map can be built. The created maps are shown in Figs. 1 and 2.

Table 8. Total relation matrix and the prominence and relation vectors of reliability factors

Factor ID	F1	F2	F3	F4	F5	F6
F1	1.067974	1.040169	0.989098	1.227315	1.034685	1.105997
F2	0.802583	0.764733	0.742717	0.903528	0.708086	0.780283
F3	1.067158	0.960123	0.935386	1.170297	0.93123	1.046962
F4	0.954971	0.898562	0.904948	1.052241	0.832861	0.929271
F5	1.057137	0.904176	0.925582	1.229561	0.940031	1.038649
F6	0.946022	0.89295	0.850957	1.161562	0.933162	0.956614
D	6.4652	4.7019	6.1112	5.5729	6.0951	5.7413
R^T	5.895846	5.460714	5.348688	6.744504	5.380057	5.857776
$\left(D + R^T\right)$	12.3611	10.1626	11.4598	12.3174	11.4752	11.5990
Rank $\left(D + R^T\right)$	1	6	5	2	4	3
$(D - R^T)$	0.5694	−0.7588	0.7625	−1.1716	0.7151	−0.1165
Rank $(D - R^T)$	3	5	1	6	2	4
Category	Net cause	Net effect	Net cause	Net effect	Net cause	Net effect

Table 9. Total relation matrix and the prominence and relation vectors of recovery factors

Factor ID	F7	F8	F9	F10	F11	F12
F7	1.091567	0.95989	0.893473	0.844419	0.958003	1.018932
F8	1.108784	0.866198	0.827492	0.816331	0.847068	0.914015
F9	1.088094	0.814998	0.860447	0.809613	0.939136	0.870992
F10	0.986746	0.831598	0.851017	0.805589	0.88673	0.850397
F11	1.076948	0.900978	0.979083	0.931289	0.94265	0.890302
F12	1.137327	0.935129	0.868313	0.852801	0.96589	0.931287
D	5.7663	5.3799	5.3833	5.2121	5.7212	5.6907
R^T	6.489466	5.308791	5.279824	5.060042	5.539476	5.475924
$\left(D + R^T\right)$	12.2558	10.6887	10.6631	10.2721	11.2607	11.1667
Rank $\left(D + R^T\right)$	1	4	5	6	2	3
$(D - R^T)$	– 0.7232	0.0711	0.1035	0.1520	0.1818	0.2148
Rank $(D - R^T)$	6	5	4	3	2	1
Category	Net effect	Net cause	Net cause	Net cause	Net cause	Net cause

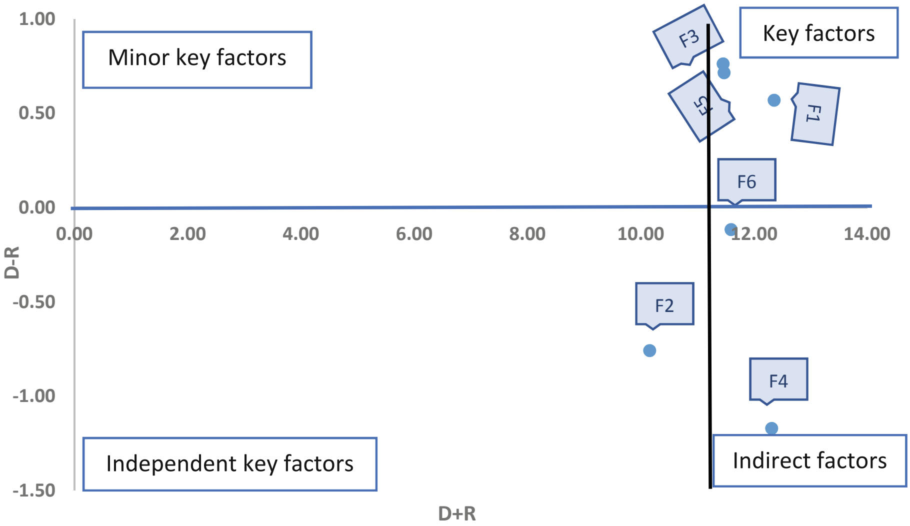

Fig. 1. Reliability factors' Prominence-relation map.

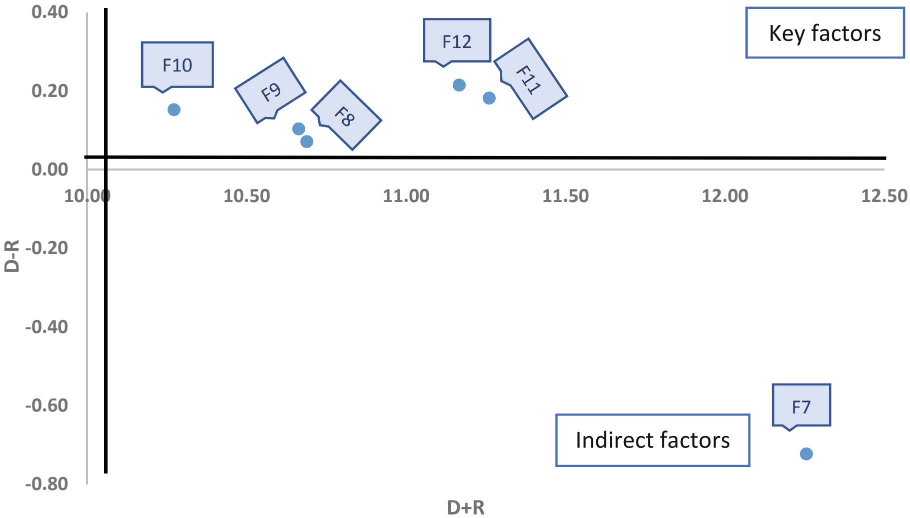

Fig. 2. Recovery factors' Prominence-relation map.

4 Results and Discussions

The results reveal that the Classification of the house (F1), Age of the house (F3), and House plinth level (F5) are classified into a net cause group in reliability factors. On the other hand, Insurance (F8), Availability of resource (F9), Relief Received (F10), Approachability (F11), and Education (F12) are classified into a net cause group in recovery factors. These factors affect the whole set of guidelines, and their accomplishment or nonaccomplishment involves the housing infrastructure resilience administration. Therefore, these factors require more attention. In the net cause group, these factors have a less influenced impact, which is R, than influential impact, which is D.

The net effect group includes Wall thickness (F2), Depth of the flood (F4), and Availability of drainage (F6) in reliability factors and Income (F7) in recovery factors. As the $(D - R^T)$ of net effect factors are negative, they are simply affected by other factors. It means that their influenced impact is more than their influential impact of these factors.

$\left(D + R^T\right)$ numbers represent the relative importance or influence of the factors. In our study, Classification of the house (F1) in reliability factors, and Income (F7) in recovery factors got the highest $\left(D + R^T\right)$ numbers; therefore, these factors should be taken into account as essential for the housing infrastructure resilience strategy. This outcome can mention that these two factors hold the most significant influence.

Recognizing the essential factors should respect both $\left(D + R^T\right)$ and $\left(D - R^T\right)$ vectors. For reaching this, all factors were categorized into four different divisions (Ocampo and Yamagishi 2020):

- Key factors (high eminence, high association)
- Indirect factors (high eminence, low association)
- Minor key factors (low eminence, high association)
- Independent factors (low eminence, low association)

The main focus should be on the key factors classification and recognize the most important factors. In reliability factors, the Classification of the house (F1) is the most important one. In recovery factors, the most important one is Approachability (F11). Therefore, the government and related associations should focus their resources and attempting to guarantee that these two factors are stringently observed.

5 Conclusions

As housing is one of the basic necessities for people to live in and because of natural disasters, several houses are seriously damaged worldwide. Decision-makers and stakeholders have to concentrate on making the infrastructure further resilient toward many kinds of hazards like floods, earthquakes, and landslides. By employing an Intuitionistic Fuzzy DEMATEL method in this research, the interplay amongst the factors of the housing infrastructure resilience is estimated. The findings show the essential factors of housing infrastructure resilience toward flood hazards. This research's findings will lead the decision-makers and stakeholders in making the housing infrastructures notably resilient.

Like other studies, this study is also not free of limitations. The initial limitation is the limited experts' number. For future studies, various stakeholders, decision-makers, and policymakers can participate. Next, the suggested technique is pliable if new factors added or excluded from the current factors' group. Future studies can discuss the connections between the quantity and types of factors while modifications are offered for answering hazards more properly. Next, another network modeling methods like interpretative structural modeling and system dynamics modeling can be used. Finally, the usage of different fuzzy DEMATEL expansions like hesitant fuzzy sets, and type-2 fuzzy sets can be investigated and contrasted to this research's outcomes.

References

Angelov, P.: Crispification: defuzzification of intuitionistic fuzzy sets. BUSEFAL **64**, 51–55 (1995)

Anzilli, L., Facchinetti, G.: A new proposal of defuzzification of intuitionistic fuzzy quantities. In: Atanassov, K.T., Castillo, O., Kacprzyk, J., Krawczak, M., Melin, P., Sotirov, S., Sotirova, E., Szmidt, E., De Tré, G., Zadrożny, S. (eds.) Novel Developments in Uncertainty Representation and Processing. AISC, vol. 401, pp. 185–195. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-26211-6_16

Atanassov, K.: Intuitionistic fuzzy sets. Fuzzy Sets Syst. **20**, 87–96 (1986)

Bristow, D.N.: How spatial and functional dependencies between operations and infrastructure leads to resilient recovery. J. Infrastruct. Syst. **25**(2), 04019011 (2019)

Cui, P., Li, D.: A SNA-based methodology for measuring the community resilience from the perspective of social capitals: take Nanjing, China as an example. Sustain. Cities Soc. **53**, 101880 (2020)

De Iuliis, M., Kammouh, O., Cimellaro, G.P., Tesfamariam, S.: Downtime estimation of building structures using fuzzy logic. Int. J. Disaster Risk Reduct. **34**, 196–208 (2019)

EM-DAT. EM-DAT (2019). http://www.emdat.be/

Fontela, E., Gabus, A.: The DEMATEL Observe, Battelle Institute, Geneva Research Center (1976)

Hosseini, S., Barker, K.: Modeling infrastructure resilience using Bayesian networks: a case study of inland waterway ports. Comput. Ind. Eng. **93**, 252–266 (2016)

Masoomi, H., van de Lindt, J.W.: Community-resilience-based design of the built environment. ASCE-ASME J. Risk Uncertainty Eng. Syst. Part A Civ. Eng. **5**(1), 04018044 (2019)

Nehi, H.M., Maleki, H.R.: Intuitionistic fuzzy numbers and it's applications in fuzzy optimization problem. In: Proceedings of the 9th WSEAS International Conference on Systems, Athens, pp. 1–5 (2005)

Nikjoo, A.V., Saeedpoor, M.: An intuitionistic fuzzy DEMATEL methodology for prioritising the components of SWOT matrix in the Iranian insurance industry. Int. J. Oper. Res. **20**(4), 439–452 (2014)

Ocampo, L.A.: Applying fuzzy AHP–TOPSIS technique in identifying the content strategy of sustainable manufacturing for food production. Environ. Dev. Sustain. **21**, 2225–2251 (2018). https://doi.org/10.1007/s10668-018-0129-8

Ocampo, L., Yamagishi, K.: Modeling the lockdown relaxation protocols of the Philippine government in response to the COVID-19 pandemic: an intuitionistic fuzzy DEMATEL analysis. Socio-Econ. Plan. Sci. **72**, 100911 (2020)

Pham, T.M., Hagman, B., Codita, A., Van Loo, P.L.P., Strömmer, L., Baumans, V.: Housing environment influences the need for pain relief during post-operative recovery in mice. Physiol. Behav. **99**(5), 663–668 (2010)

Sen, M.K., Dutta, S., Kabir, G.: Development of flood resilience framework for housing infrastructure system: integration of best-worst method with evidence theory. J. Cleaner Prod. **290**, 125197 (2020)

Sen, M. K., Dutta, S., Kabir, G.: Evaluation of interaction between housing infrastructure resilience factors against flood hazard based on rough DEMATEL approach. Int. J. Disaster Resilience Built Environ., 1–28 (2021)

Stead, D.: Urban planning, water management and climate change strategies: adaptation, mitigation and resilience narratives in the Netherlands. Int J Sust Dev World **21**(1), 15–27 (2014)

van de Lindt, J.W., et al.: Community resilience-focused technical investigation of the 2016 Lumberton, North Carolina, flood: an interdisciplinary approach. Nat. Hazard. Rev. **21**(3), 04020029 (2020)

Zadeh, L.A.: Fuzzy sets-information and control. Inf. Control **8**, 338–353 (1965)