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Prioritizing the Components of the Disaster Resilient System Using Dematel and Anp for Urban Areas

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Abstract

Although many research studies have been performed on vulnerability assessment and hazard mitigation, it is extremely hard for communities to cope with disasters appropriately. There are many uncertainties and unanticipated issues in disasters; therefore, coping with disasters and emergencies is not as simple and easy as mitigation and preparedness activities. The concept of disaster resilience has been described as a method to overcome unforeseen problems. This paper aims to discover and prioritize dimensions and components of Disaster Resilient Systems (DRS) in urban areas using Delphi, Decision Making Trial and Evaluation Laboratory (DEMATEL), and Analytic Network Process (ANP). Numerous frameworks and models have been used to define relevant dimensions and components of DRS based on the Delphi method. The relationship between the components has been determined using DEMATEL. Finally, the obtained data has been applied to ANP to define a conceptual model and to obtain a weighted supermatrix for prioritizing the main components of DRS. The results of the study have shown that a Comprehensive Emergency Plan (CEP) is the most important component for earthquake resilience in urban areas.

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Keywords

Analytic Network Process (ANP); Delphi method; DEMATEL; Resilience; Disaster Resilient System (DRS); Earthquake.

1. Introduction

Recent incidents indicate that communities and people are increasingly becoming more vulnerable to disasters, and the risks are globally rising (Mayunga, 2007; Ainuddin and Routray, 2012). However, risk reduction and vulnerability are often ignored until the occurrence of disasters (Cutter et al, 2008b). Under these circumstances in which risks and uncertainties are growing, the concept of resilience has been defined as the managing of disturbance, unanticipated events, and change (Mitchell and Harris, 2012).

Resilience to natural hazards and disasters has been defined as the ability of communities exposed to hazards to resist, absorb, accommodate, and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential structures and functions (UNISDR 2009).

While the concept of resilience has been used in science since 1625 (Alexander, 2013), in the field of ecology; it was first introduced by Holling (1973) and has been applied in disaster risk reduction since 2000 (Alexander, 2013).

In fact, after the presentation of the Hyogo Framework for Action (1995), an evident paradigm shift has occurred from hazard assessment to vulnerability analysis and community resilience creation in recent hazard literature (Ainuddin and Routray, 2012). Although there is a variety of frameworks and models in disaster resilience, there is

no consensus among researchers on the components and standard metrics of resilience. Moreover, the variables that should be utilized to measure resilience have not been determined (Ainuddin and Routray, 2012; Cutter et al., 2008b; Twigg, 2009). Vulnerability and resilience are indeed dynamic processes; however, they are often considered as static phenomena because of their measurement purposes (Cutter et al., 2008b). Recent literature (Norris et al., 2008; Mitchell, 2012) considers resilience as a process rather than an outcome and specifies resilience as a dynamic system.

In addition, various definitions have been presented for disaster resilience. Mayunga (2007) has summarized some selected definitions of the resilience concept published in disaster and hazard literature. A number of recent definitions have also been provided all of which indicate there is no consensus among researchers and practitioners on a common definition of the concept. It is evident that the definitions are diverse, reflecting the complex nature of the concept, and most of them emphasize the capacity to cope with disasters, disturbances, or emergencies. In other words, resiliency is often the flexible capacity of a system to absorb stresses and recover rapidly from emergencies. Accordingly, a resilient community has been defined as one that which can cope appropriately with disasters, has the highest level of flexible capacity, and will not be greatly influenced by disasters. A disaster-resilient community can also be defined as 'the safest possible community that we have the knowledge to design and build in a natural context' (Twigg, 2009).

Two kinds of strategies have been suggested; anticipation and resilience strategies. Anticipation strategies usually operate to resolve known problems, while resilience strategies better resolve unidentified problems (Wildavsky, 1988; Normandin et al., 2011). Resilience concentrates on community resources and methods of strengthening community capacities, instead of focusing on their vulnerability and deficiency (Twigg, 2009). On the other hand, vulnerability, as one of the most common elements of risk that is applied directly or indirectly to risk assessment methods, is often considered as contradictory to resilience (Twigg, 2009). However, resilience goes beyond the capacity component of vulnerability and the combination of these two concepts can lead to a more comprehensive understanding of disasters (Obrist et al., 2010). According to Godschalk (2003), a resilient city is a combination of physical systems and human communities. Resilient systems that can be applied to physical and social systems tend to be redundant, diverse, efficient, autonomous, strong, interdependent, adaptable, and collaborative (Godschalk, 2003).

A resilient community contains a variety of complex issues. Thus, many elements are involved in resilience due to which its description in a clear and organized manner is almost impossible. Therefore, the Disaster Resilient System (DRS) is defined as a resilient system that proposes and prioritizes appropriate dimensions and components of resilience against contingency earthquakes in urban areas based on experts' comments using Delphi, Decision Making Trial and Evaluation Laboratory (DEMATEL), and Analytic Network Process (ANP). It specifies the components that are vital for disaster (especially earthquake) resilience in urban areas with high levels of disaster as a result of earthquakes and should be considered by authorities and managers as their priorities.

Some research has been conducted regarding disaster resilience in urban areas.

The economic and institutional resilience of four different districts of Tehran was evaluated by Rezaei (2014). He assessed institutional resilience (institutional context, institutional relations, institutional efficiency) and economic resilience (loss rate, loss compensation capacity, ability to recover) using Analytic Hierarchy Process (AHP) and Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE). He found that the loss rate indicator (0.383) and compensation capacity indicator (0.281) had the highest importance.

2. Methodology:

2.1 Finding the dimensions and components of DRS using the Delphi method

The first stage was the identification of appropriate criteria for the Disaster Resilient System in urban areas. The Delphi method was suggested for the demonstration of the dimensions and components of DRS. The Delphi method originated from the studies of the RAND Corporation in the 1950s and is known as a method that is applied to a wide variety of fields and a tool for expert problem-solving. The Delphi study is designed to answer questions with high

uncertainty and based on speculation. Hence, only individuals with a high level of relevant knowledge are eligible to respond to these questions (Okoli and Pawlowski, 2004).

In the first step of the Delphi method, a group of relevant experts was identified and selected. For this research, a group of 26 experts in the fields of disaster management, urban planning, civil and environmental engineering, and geography were chosen. After the identification of experts, a relevant questionnaire should be designed. Therefore, in the second step, we selected 16 studies in the field of disaster resilience (Table 1) and classified their selected factors into 6 dimensions as main elements of DRS. Then, based on the obtained dimensions and components, the questionnaire was designed and sent to experts. The experts were asked to respond to the questionnaire and to offer feedback on the position of dimensions and components and consolidation or expansion of components, or to propose other new elements which they thought were important for DRS.

In the next step, the responses of experts were received and analyzed. Then, a new questionnaire was designed for the second round. The respondents were asked to revise their first response and answer other questions based on their responses to the first survey. They could change their responses or maintain their previous opinion. This process was repeated until more than 77% of respondents attained a component identical to that acceptable for DRS. Finally, 41 components in 6 main dimensions were selected (Table 2).

2.2 Determination of the intensity of the direct and indirect relationships between DRS components using DEMATEL

DEMATEL is one of commonly used techniques in multiple-criteria decision-making (MCDM) which is suitable for the analysis of the direction and strength of the direct or indirect relationships between defined components (Chen, Hsu, and Tzeng, 2011). The different steps of this method are described below.

Step 1: In this step, the direct relation average matrix should be calculated. The degree of the direct impact that each perspective i exerts on each perspective j is determined by respondents (Chen, Hsu, and Tzeng, 2011) using a scale ranging from 0 to 4 (0: no impact, 1: low impact, 2: medium impact, 3: high impact, 4: very high impact) (Chen, Lien, and Tzeng, 2010). The mean of the same perspective in the various direct matrices of the respondents is used to obtain an average matrix C (eq. 1) (Chen, Hsu, and Tzeng, 2011).

$$C=\begin{bmatrix} c_{11} & c_{1j} & c_{1n} \\ c_{i1} & c_{ij} & c_{in} \\ c_{n1} & c_{nj} & c_{nn} \end{bmatrix} \quad (1)$$

Step 2: The initial direct impact matrix is calculated in this step. Therefore, the average matrix C should be normalized to obtain the initial direct impact matrix D using equations (2) and (3).

$$D=sC \quad (2)$$

$$s=\min\left[\frac{1}{max\sum_{j=1}^{n}|c_{ij}|},\frac{1}{max\sum_{i=1}^{n}|c_{ij}|}\right] \quad (3)$$

Step 3: The total impact matrix is calculated in this step. By obtaining the normalized direct-impact matrix D, the total impact matrix T can be calculated using equation (4) as follows:

$$T = D + D^2 + \cdots . + D^k = D(I - D)^{-1} \quad (4)$$

$T = [t_{ij}]_{n*n}$ i,j=1,2,…,n

$$(I - X)(I - X)^{-1} = I$$

Where I is the identity matrix.

Step 4: In this step, the sum of each row and column of matrix T are obtained using equations (5) and (6).

$$d = \left[\sum_{j=1}^{n} t_{ij}\right]_{n*1} \quad (5)$$

$$r = (c_j)'_{1*n} = \left[\sum_{i=1}^{n} t_{ij}\right]' \quad (6)$$

d_i= the sum of the ith row of matrix T

r_j= the sum of the jth column of matrix T

Therefore, d_i illustrates the sum of direct and indirect impacts of component iIon the other components. On the other hand, r_j shows the sum of direct and indirect impacts that component j has received from the other components (Chen, Hsu, and Tzeng, 2011). Moreover, di+rj indicates the intensity of the relationship between components, and di-rj indicates the intensity of impacts among components (Azizi et al., 2014).

2.3. Applying DEMATEL data to ANP to find weighted supermatrix using Supper Decision software

Finding the intensity and interrelation between the components and dimensions in a complicated system such as DRS is very difficult. DEMATEL is not only used to find interrelation between factors, but is also used to specify the more accurate weights of the pairwise comparison (Chen, Hsu, and Tzeng, 2011). Moreover, due to its nonlinear structure, ANP can manage interdependencies between clusters (dimensions) and nodes (components of each dimension). ANP is one of the MCDM methods, is an extension of AHP, and was introduced by Saaty in 1996 and 2001. A combination of DEMATEL and ANP is increasingly used in different subjects such as equity investment (Lee et al., 2011), environment watershed plans (Chen, Lien, and Tzeng, 2010), hot spring hotel performance (Chen, Hsu, and Tzeng, 2011), brand marketing (Wangand Tzeng, 2012), and entrepreneurship policy (Tsai and Kuo, 2011).

The first step of ANP is defining a conceptual model which determines interconnections among dimensions and components. The second step is a pairwise comparison between components using Super Decisions software. The Super Decisions software is a mathematical theory that applies ANP to find dependence and feedback of dimensions and components. In this step, pairwise comparison is performed through number coding (from 1 to 9) in Super Decisions software (Fig. 1) (Azizi et al., 2014).

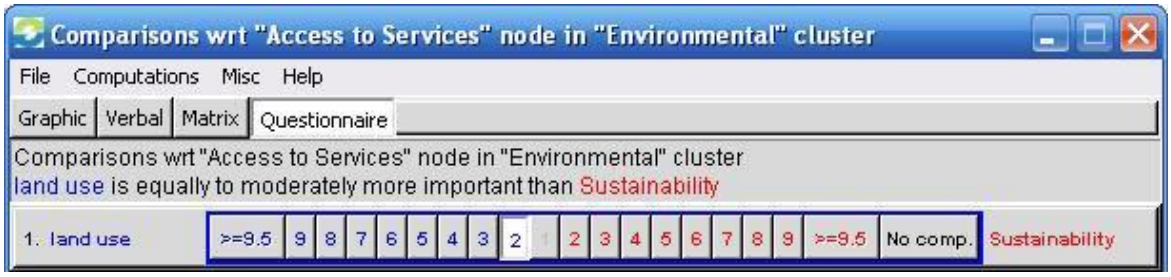

Fig 1: Pairwise comparison in Super Decisions software

The next step is the calculation of the primary supermatrix which is obtained from weights of the pairwise comparison of the previous step. Equation 7 indicates the general form of the supermatrix.

Eq. 7:

$$w = \begin{array}{c} \\ D_1 \\ \\ \\ \\ D_2 \\ \\ \\ \\ D_n \\ \\ \end{array} \begin{array}{c} \begin{array}{c} C_{11} \\ C_{12} \\ \vdots \\ C_{1m1} \\ C_{21} \\ C_{22} \\ \\ C_{2m2} \\ \vdots \\ C_{n1} \\ C_{n2} \\ \vdots \\ C_{nmn} \end{array} \\ \begin{bmatrix} W_{11} & W_{21} & \cdots & W_{1n} \\ W_{12} & W_{22} & \cdots & W_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ W_{n1} & W_{n2} & \cdots & W_{nn} \end{bmatrix} \end{array}$$

This equation has 6 dimensions and 41 components. Therefore, it is a 41*41 supermatrix in which Wij denotes the connection between the ith component and the jth component. In the final step, the dimension weights are calculated

by weighting the primary supermatrix, which is obtained by multiplying the dimension weights matrix by the primary supermatrix (Azizi et al., 2014).

3. Discussion and Results

As mentioned previously, the Delphi method was used to find the relevant dimensions and components of disaster resilience in urban areas. Therefore, the opinions of 26 experts, mostly with experience in disaster management and primary knowledge of resilience, were applied. We tried to include various perspectives in our Delphi process to evaluate the results.

In the first design of the DRS, six dimensions and relevant components were introduced based on the 16 mentioned studies (Table 1). They were used to design a structured questionnaire. The experts were asked to comment on DRS and their components (dimensions and components that are thought to be appropriate for DRS). The structured questionnaire was sent to experts by email, fax, and rarely by mail based on their convenience. In addition to the questionnaire, the main base and origin of each dimension and component were provided to experts for their knowledge. Then, they were asked to modify the classification and the position of components if they had new ideas or comments. These comments were gathered and analyzed by the researchers. Identical responses were removed and other perspectives were consolidated to provide a new questionnaire.

Table 1: Models and frameworks of resilience

Model or Study	Factors
EMA (2001)	**personal attributes** (health, income, age, gender, skills, network, and lifestyle choices); **infrastructure status** (coverage, accessibility, and reliability); **community attributes** (networks, amenities, and facilities); **economic status and trends** (growth or decline, employment levels, and innovation); **demographic status and trends** (age structure, immigration, and gender balance); **environmental status** (sustainability, diversity, and pollution); **geographic attributes** (remoteness, topography, and weather)
Buckle (2006)	shared community values, knowledge of hazards, established social infrastructure, positive socioeconomic trends, partnerships, resources, and skills.
CSIRO(2007)	metabolic flows (production, supply, and consumption chains); governance networks (institutional structures and organizations); social dynamics (demographics, human capital, and inequity); built environment (ecosystem services in urban landscapes)
Mayunga (2007)	Social capital (trust, norms, and networks); economic capital (income, savings, and investment); human capital (education, health, skills, and knowledge/information); physical capital (housing, public facilities, and business/industry); natural capital (resource stocks, land and water, and ecosystem)
Twigg (2009)	Governance (policy, planning priorities and political commitment, legal and regulatory systems, integration, institutional mechanisms, capacities and structures, allocation of responsibilities, partnerships, and accountability and community participation); risk assessment (hazards/risk data and assessment, vulnerability and impact data and assessment, and scientific and technical capacities and innovation); knowledge and education (public awareness, knowledge and skills, information management and sharing, education and training, cultures, attitudes, motivation, and learning and research); risk management and vulnerability reduction (environmental and natural resource management, health and wellbeing, sustainable livelihoods, social protection, financial instruments, physical protection, structural and technical measures, and planning regimes); disaster preparedness and response (organizational capacities and coordination, early warning systems, preparedness and contingency planning, emergency resources and infrastructure, emergency response and recovery, participation, voluntarism, and accountability).
Cutter et al. (2008a)	social vulnerability (race and ethnicity, age, socio-economic status, gender, employment, education, household structure, access to services, occupation, housing, and special needs); built environment and infrastructure (residential, commercial and industrial development, lifelines, transportation infrastructure, and monuments and icons); natural systems and exposure; hazards mitigation and planning (emergency response plans, building standards and codes, hazard mitigation plans and vulnerability assessments, comprehensive plan, COOP, interoperable communication, recovery plans, and etcetera)
Cutter et al. (2008b)	Ecological (wetland acreage and loss, erosion rate, impervious surface, biodiversity, and coastal defense structure); social(demographics, social network and social embeddedness, community values-cohesion, and faith-based organization); economic (employment, value of property, wealth generation, and municipal finance); institutional (participation, hazard mitigation plans, emergency services, zoning and building standards, emergency response plans, interoperable communications, and COOP); infrastructure (lifelines and critical infrastructure, transportation network, residential housing stock and age, and commercial and manufacturing establishments); community competence (local understanding and risk, counseling services, absence of psychopathologies, health and wellness, and quality of life).

Model or Study	Factors
Norris et al. (2008)	economic development (risk and vulnerability to hazards, level and diversity of economic resources, and equity in resource distribution); social capital (received social support, perceived social support, social embeddedness (informal ties), organizational linkage and cooperation, citizen participation, leadership and roles (formal ties), sense of community, and attachment to place); community competence (community action, critical reflection and problem-solving skills, flexibility and creativity, collective efficacy empowerment, and political partnership); information and communication (narratives, responsible media, skills and infrastructure, and trusted sources of information)
Normandin et al. (2011)	income; water; emergency planning; population; energy; insurance; telecommunication; environment condition; housing condition; safety standards and codes; age; education; gender; business; health; transportation; urban planning; community involvement; training; risk assessment
Lo´pez-Marrero and Tschakert (2011)	Suggested focusing on community-level disaster prevention supporting local authorities and civic organizations, building cooperative partnerships, strengthening disaster prevention knowledge and capabilities, and encouraging the expression of relevant thoughts or opinions on disaster prevention issues through the implementation process to ensure consensus building for key disaster management issues
Smith et al. (2011)	Suggested that community-based disaster prevention measures should provide resident participation and transformational approaches, including disaster management implementation plans, expert assistance and analysis, and capability assessment models and experience transfer, thus increasing public disaster prevention awareness and improving emergency and crisis response capabilities
McGee (2011)	Proposed supporting community-based disaster prevention by localizing disaster and emergency management responsibilities and capabilities. Recommended government support of community organizations and residents in implementing community-based disaster prevention, along with the establishment of public-private partnerships for disaster prevention and rescue work
Ainuddin and Routary (2012)	leadership and politics, structural and societal changes, physical location, age, attitudinal factors, health, income, gender, long-term commitment, social networks, government policies, short-term recovery, capable agencies, reaccumulation of capital, and long-term rehabilitation
Wilson (2013)	Proposed the use of government channels to promote community-based disaster prevention, coordinate the timing of policy implementation, define the rights and responsibilities of various stakeholders, and control funding to ensure proper implementation of community-based disaster prevention measures
Parsons et al. (2016)	absorptive capacity was social character, economic capital, community capital, emergency services, planning, infrastructure, information, and engagement. On the other hand, adaptive capacity included themes such as governance, policy, leadership, social engagement, and community engagement
Mohammed Hamidul Hasan et al. (2020)	Demographic structure, Economic capital, Social capital, Community engagement, Plan and Policies, Infrastructure, Existing resources, Knowledge of hazards

In the second round, experts provided their comments on the modified questionnaire. Finally, after 4 rounds, an agreement was reached by experts and more than 77% of participants accepted the dimensions and components of Table 2 as the elements of DRS. Although some of these components such as land use can belong to different dimensions, they were placed in only 1 dimension based on experts' comments.

Table 2: Proposed dimensions and components of DRS

Conception	Dimensions	Components	Explanation
Disaster Resilient System	Economic dimension	Access to services (C1)	availability, diversity, frequency, and distance from services
		Economic diversity (C2)	income and occupational resources in the community
		Economic growth (C3)	
		Economic safety (C4)	security and safety in national and international investment and production
		Economic stability (C5)	stability in international deals and exchanges, and stability in national currency exchange rate
		Individual economic condition (C6)	Employment, income, savings, investment, value of property, housing, and occupation
		Municipal finance (C7)	role of governmental-based assistance during and after disasters
		Sustainable livelihoods (C8)	occupational security, unemployment security, and distribution of wealth and livelihood assets
	Environmental dimension	Biodiversity (C9)	
		Geographic attributes (C10)	remoteness, topography, and weather
		Land use (C11)	urban open spaces such as parks and green spaces for settlement operations, commercial and residential use, and their distance to open spaces

Conception	Dimensions	Components	Explanation
		Natural capital (C12)	resource stocks, land and water, and ecosystem
		Pollution (C13)	Extension and kind of produced pollution
		Potential hazards and exposure (C14)	
		Sustainability (C15)	
	Infrastructural dimension	Critical infrastructure (C16)	national public media, nuclear facilities, internet networks, emergency centers, government organizations, and military sites
		Coverage, accessibility, and reliability (C17)	coverage of, accessibility to, and reliability of critical infrastructures, lifelines, and public facilities
		Lifelines (C18)	electric power facilities, water and wastewater facilities, oil and natural gas facilities, telecommunication, and transportation
		Public facilities (C19)	police stations, hospitals, fire stations, schools and universities, and nursing homes
	Institutional and planning dimension	Comprehensive emergency plan (C20)	response plans, Continuity of Operation, recovery plans, preparedness and contingency planning, urban planning, hazard mitigation plans and vulnerability assessments, and infrastructure protection plan
		Early warning systems (C21)	
		Governance networks (C22)	connections between governmental organizations and agencies
		Hazard insurance (C23)	acceptance and coverage of hazard insurance by the public, and the existence of scientific-based insurance
		Institutional mechanisms, capacities, and structures (C24)	institutional mechanisms, capacities, and structures to respond to disasters and emergencies, and the role of NGOs and related organizations in disasters
		Legal and regulatory systems (C25)	existence of emergencies and disasters laws, and law enforcement actions
		Responsible media (C26)	role of media in disasters
	Socio-cultural dimension	Attachment to place (C27)	dependence on location, and neighborhoods
		Community competence (C28)	local understanding and risk, counseling services, absence of psychopathologies, health and wellness, quality of life, community action, critical reflection and problem-solving skills, flexibility and creativity, collective efficacy and empowerment, and political partnership
		Demographics(C29)	age structure, gender balance, populations with special needs, and immigration
		Education and training (C30)	level of education, level of public information about disasters, level of disaster training among people, and public knowledge
		Household structure (C31)	number of children, family network and connections, distance between family and their relatives, health, and age
		Sense of community (C32)	
		Social network (C33)	social cohesion, individual and public participation, race and ethnicity, beliefs, social embeddedness (informal ties), and leadership and roles (formal ties)
		Social protection (C34)	social mutual assistance systems, access to social services, and social information channels
	Structural and physical dimension	Hazardous facilities (C35)	locations, amount, kind, and preservation activities
		Historic landmarks(C36)	locations, importance, age, usage, and popularity
		Industrial and commercial units (C37)	number of employees, structural conditions, kind of activity, and access to services
		Physical protection (C38)	civil engineering activities for physical empowerment and strength
		Residential units (C39)	structural condition, number of residents, and access to services
		Standards and codes (C40)	
		Structural and technical measures (C41)	

In the second step, the experts were asked to specify the extent of the impact of each component on other components through the numbers 0 to 4 (0: no impact; 1: very low impact; 2: low impact; 3: high impact; 4: very high impact) regarding the earthquake condition and resources of urban areas. Therefore, based on the obtained data, DEMATEL techniques, and programming by MATLAB software, the intensity and direction of the relationship between

components were calculated. The outcomes were applied to introduce a conceptual model in ANP. Figure 2 illustrates the overall defined conceptual model of DRS in Super Decisions software. It shows how dimensions are connected and therefore impact each other. As mentioned previously, connections and intensity among components (connected to or from each component) were computed by importing DEMATEL outcomes data and defining user formulas to this software.

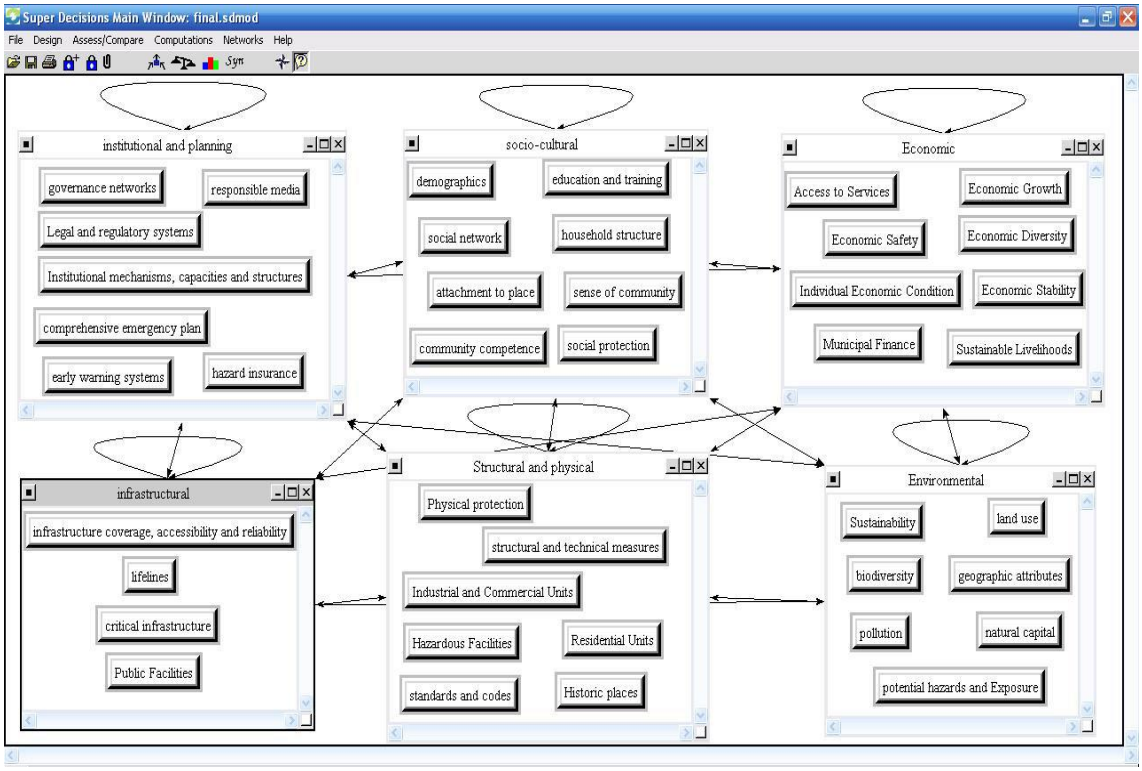

Fig 2: The conceptual model of DRS in Super Decisions software

In the next step, pairwise comparisons were performed between dimensions and components to specify the importance of dimensions and components to each other for urban areas. Finally, the results of the model were obtained as a weighted supermatrix, normalized components, and overall synthesized priorities for alternative dimensions in the following charts and tables.

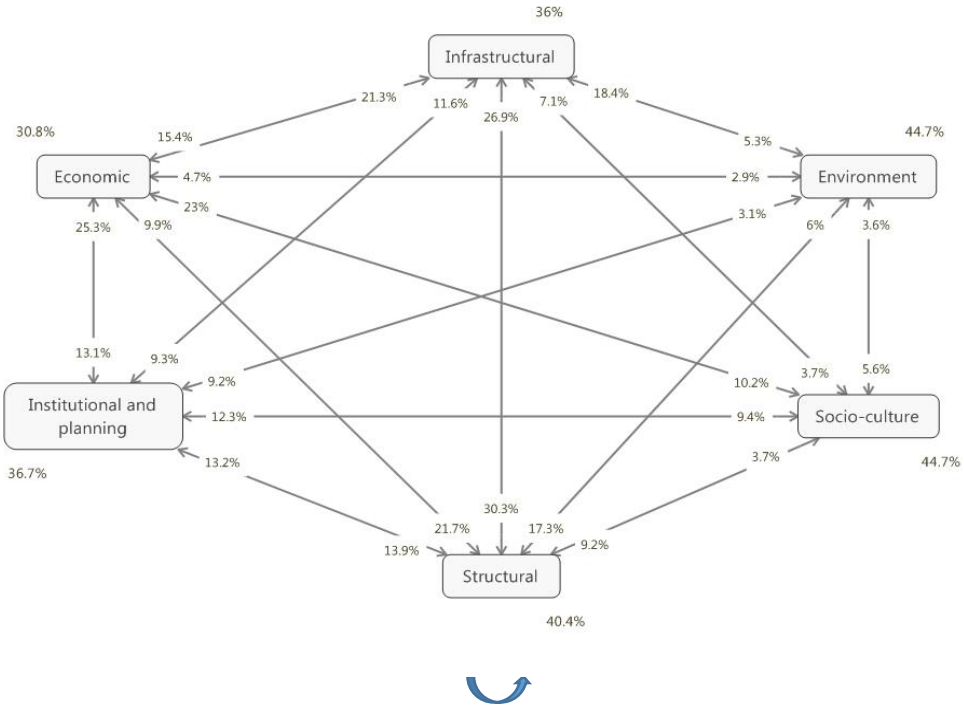

Figure 3: Urban areas dimension matrix

The intensity between dimensions is shown in Figure 3. Data in columns indicate the impact of each dimension on others. It can be seen that the economic dimension of urban areas has the most impact on structural and infrastructural dimensions (0.21837, 0.213053), and then, on the institutional and planning dimension (0.130875). This means that a strong economic dimension results in powerful and resistant infrastructural and structural dimensions in urban areas. It also illustrates the impact of the economic dimension on other dimensions which is relatively high in comparison with other dimensions. The environmental dimension also has a high impact on structural and infrastructural dimensions (0.17263, 0.184595). Obtained data indicate that the infrastructural dimension is more influential on structural resilience (0.303017) and economic resilience (0.153694) in urban areas. The high impact of planning and socio-cultural dimension on economic dimension can also be seen in urban areas. However, in the next rank, planning is more influential on structural and infrastructural dimensions. It should be noted that the socio-cultural dimension has a reasonable impact on planning. Finally, the structural dimension also has a high impact on the infrastructural dimension, and then, with a significant difference, on the planning dimension.

Table 3: Urban areas weighted supermatrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
C1	0	0	0.03539	0.04204	0.05216	0.02155	0.0616	0.01298	0	0.02226	0.01185	0.00838	0	0.01068	0.00242	0.00658	0.04131	0.00801	0.02562	0
C2	0	0	0.0498	0.01498	0.04062	0.05661	0	0.03363	0.00833	0.00471	0	0.00205	0	0.00288	0.0022	0	0.01071	0	0	0
C3	0	0.13965	0	0.14147	0.11516	0.14236	0	0.10607	0.04806	0.01031	0	0.00651	0	0.00661	0.01354	0.04199	0.06573	0.04864	0	0
C4	0	0.07782	0.06237	0	0.08765	0.06106	0	0.03573	0	0	0	0.00205	0	0.00178	0.00452	0.01552	0.01797	0.01641	0	0
C5	0	0.08074	0.07165	0.07716	0	0.06106	0	0.03573	0	0	0	0.00205	0	0.00183	0.00452	0.01552	0.01797	0.01641	0	0
C6	0	0.01907	0.011	0.042	0.02744	0	0	0.08387	0	0	0	0.00479	0	0.00361	0.00471	0	0	0	0	0
C7	0	0.04947	0.04465	0.03809	0.03594	0.01733	0	0	0	0.00505	0.03554	0.01678	0	0.01577	0.00652	0.07408	0	0.06422	0.12808	0
C8	0.30801	0.02465	0.03315	0.03567	0.03243	0.03143	0.24641	0	0.01733	0.00505	0	0.00479	0.06552	0.00424	0.00894	0	0	0	0	0.30801
C9	0	0	0	0	0	0	0	0	0	0.05921	0.02586	0.04879	0.05028	0.02221	0.03968	0	0	0	0	0
C10	0	0	0	0	0	0	0	0	0.23356	0	0.0807	0.15884	0.31963	0.2	0	0	0	0	0	0
C11	0.01935	0	0.00177	0	0	0	0.00312	0	0.03402	0.09315	0	0.10598	0	0.10165	0.18251	0	0	0	0	0.01935
C12	0	0	0.01129	0	0	0.03074	0	0	0.08363	0.15195	0.0807	0	0.16085	0.06253	0.11979	0	0	0	0	0
C13	0	0	0.00342	0	0	0.00615	0.00153	0	0.12058	0.06084	0.02303	0.02072	0	0.01503	0.02547	0	0	0	0	0
C14	0	0	0	0	0	0	0.00849	0	0.05123	0.0382	0.18064	0.03231	0	0	0.07996	0	0	0	0	0
C15	0.00968	0.03689	0.01255	0.03689	0.03689	0	0.01589	0.02903	0.17301	0.04405	0.05647	0.08076	0.08782	0.04598	0	0.05292	0.05292	0.05292	0.05292	0.00968
C16	0	0	0.06087	0	0	0	0.06653	0	0	0.05869	0	0.05538	0	0.06831	0.06153	0	0.17984	0.16683	0.15415	0
C17	0.11716	0	0.03044	0	0	0	0.01792	0	0	0.01694	0	0.01846	0	0.0184	0	0.05138	0	0.10105	0.05138	0.11716
C18	0.05119	0	0.06087	0	0	0	0.06653	0	0	0.05448	0.1846	0.05538	0	0.06372	0.06153	0.15415	0	0	0.15415	0.05119
C19	0.0447	0	0.06087	0	0	0	0.06207	0.21305	0	0.05448	0	0.05538	0	0.03416	0.06153	0.15415	0.17984	0.0918	0	0.0447
C20	0	0	0.03539	0.04204	0.05216	0.02155	0.0616	0.01298	0	0.02226	0.01185	0.00838	0	0.01068	0.00242	0.00658	0.04131	0.00801	0.02562	0
C21	0.01828	0.12473	0.02182	0.0467	0.04463	0.12473	0.02834	0.09816	0.14336	0.01434	0.00861	0.01684	0	0.0274	0.06297	0.02743	0.00844	0.0104	0.0147	0.01828
C22	0	0	0.01387	0	0	0	0.0222	0	0	0.03598	0.02809	0.02564	0	0.02518	0	0.04331	0.0441	0.02369	0	0
C23	0.06908	0	0.0378	0	0	0	0.02892	0	0	0	0	0	0	0.01011	0	0	0.02622	0.03804	0.05554	0.06908
C24	0	0	0.00782	0.02245	0.01949	0.04158	0.02777	0.03272	0	0.00555	0.0132	0.00884	0	0.01466	0.01841	0	0	0	0	0
C25	0.04352	0.04158	0.04957	0.09715	0.10218	0	0.02364	0	0	0.02618	0	0.04083	0	0.00693	0.01077	0.01581	0.0148	0.01524	0.02333	0.04352
C26	0	0	0	0	0	0	0	0	0	0	0.04226	0	0	0.00339	0	0	0	0	0	0
C27	0	0	0	0	0	0	0	0	0	0.0101	0	0	0	0.00448	0	0.007	0	0.00619	0	0
C28	0	0	0	0	0	0.00424	0	0.00353	0	0.01214	0	0.00376	0.01054	0.0028	0	0	0	0	0	0
C29	0.01739	0.08197	0.03819	0.0448	0.06064	0.01324	0.08144	0.02459	0	0.00515	0	0.01287	0.04826	0.02067	0.01945	0.01074	0.03714	0.01182	0.00952	0.01739
C30	0.03853	0.02483	0.02307	0.01896	0.01767	0.00773	0	0.00689	0.08689	0.02273	0.04468	0.02209	0	0	0.00479	0.01702	0	0.01668	0.01855	0.03853
C31	0.009	0	0.00841	0	0	0.01613	0.02036	0.01263	0	0	0	0	0	0	0.00801	0	0	0	0	0.009
C32	0	0.02255	0.00415	0.01091	0.00779	0.02301	0	0.00755	0	0	0	0	0	0.00783	0.00223	0	0	0	0	0
C33	0	0	0	0	0	0.00436	0	0.00309	0	0.0113	0.01117	0.0026	0	0.00229	0	0	0	0	0	0
C34	0.03077	0	0.0171	0	0	0.03288	0	0.02359	0	0	0	0.00891	0	0.01503	0.01553	0.00643	0	0.00577	0.00619	0.03077
C35	0.00611	0	0.01088	0.05468	0.04326	0.02777	0	0.01992	0	0.00454	0	0.00564	0.01842	0.00723	0.00585	0.00294	0	0.00288	0.00287	0.00611
C36	0	0	0.01066	0	0	0	0	0	0	0.01278	0.02849	0.06601	0	0.01982	0.00671	0.08132	0.03528	0.03823	0.04759	0
C37	0	0.13803	0	0	0	0	0	0	0	0.01133	0.048	0.01026	0	0.00582	0.00977	0	0	0	0	0
C38	0	0.13803	0.10797	0.20704	0.18403	0.01704	0.01484	0.11017	0	0.01278	0	0.03346	0	0.01008	0.02942	0.18618	0.08493	0.07913	0.17988	0
C39	0	0	0.02347	0	0	0.03635	0.07955	0.04428	0	0.04467	0.01449	0.01428	0	0.05176	0.05917	0	0	0	0	0
C40	0.02848	0	0.04905	0	0	0.15776	0.01484	0.01851	0	0.01278	0	0.03346	0.23868	0.01439	0.0202	0.03552	0.02648	0.02708	0.07555	0.02848
C41	0.04521	0	0	0	0	0	0.0343	0	0	0.03363	0.06514	0	0	0.02915	0	0	0	0	0	0.04521

	C21	C22	C23	C24	C25	C26	C27	C28	C29	C30	C31	C32	C33	C34	C35	C36	C37	C38	C39	C40	C41
C1	0	0.02679	0.06635	0	0	0	0	0	0	0.02076	0	0	0	0	0	0.09862	0	0	0.01233	0	0.01409
C2	0	0	0	0	0	0	0	0	0	0.007	0	0	0	0	0	0	0.01263	0.00274	0	0	0
C3	0.10049	0.07364	0	0	0	0	0	0	0.12755	0.05198	0.02235	0	0	0	0	0	0.03773	0.02475	0	0	0
C4	0.01819	0.01721	0	0	0	0	0	0	0	0.01285	0	0	0	0	0	0	0	0.00727	0	0	0
C5	0.01819	0.01721	0	0	0	0	0	0	0	0.01285	0	0	0	0	0	0	0	0.00727	0	0	0
C6	0	0	0.01639	0.09332	0	0.0633	0	0	0.01857	0.08023	0.16468	0.18577	0	0.24769	0.27495	0	0	0.00495	0	0.04437	0
C7	0.07604	0.11839	0.14028	0.2091	0.34002	0.18993	0.3548	0	0.06757	0	0	0	0	0	0	0	0.08455	0.03623	0.08629	0.10158	0.08453
C8	0.04033	0	0.03021	0.03123	0	0	0	0	0.03401	0.04438	0.06067	0.06192	0	0	0	0	0	0.0154	0	0.01938	
C9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C11	0.00881	0	0.00776	0	0	0	0	0	0	0.0018	0	0	0	0	0	0	0.08168	0	0	0	0.01194
C12	0	0	0	0	0	0	0	0	0	0.01489	0.01011	0.03103	0	0	0	0.0361	0	0	0.03687	0.08342	0
C13	0.00219	0	0	0	0	0	0	0	0	0.00356	0.00321	0.00776	0	0	0	0.00626	0	0	0.00511	0.01668	0
C14	0.0159	0.02661	0	0	0	0	0	0	0.00646	0.00958	0	0	0	0.0097	0	0	0	0	0	0	0
C15	0.00414	0.00443	0.02328	0	0.04168	0.02661	0	0	0.03232	0.00619	0.02547	0	0	0.02909	0.04305	0.01735	0	0.05971	0.01773	0	0.04777
C16	0.03318	0.05036	0.02323	0	0	0.03871	0	0	0	0.02375	0	0	0	0	0	0.05095	0	0.08966	0.04483	0	0.0807
C17	0.01659	0.01029	0.04646	0	0	0	0	0	0	0	0	0	0	0	0	0.13874	0	0	0.13449	0	0.0269
C18	0.03318	0.02774	0.02323	0	0	0.03871	0	0	0	0.02375	0	0	0	0	0	0.05095	0	0.08966	0.04483	0.22548	0.0807
C19	0.03318	0.02774	0.02323	0	0	0.03871	0	0	0	0.02375	0	0	0	0	0	0.02835	0	0.08966	0.04483	0.22548	0.0807
C20	0	0.0983	0.255	0.48306	0.13768	0.08908	0.06021	0.13979	0.03519	0.03088	0.09974	0.09974	0.18638	0.02063	0.14762	0.01357	0.18005	0.09871	0.03767	0.22066	0.03021
C21	0.06593	0	0	0	0.04609	0	0.31561	0	0	0	0	0	0	0.00949	0	0.07625	0	0	0.00792	0	0
C22	0.12696	0	0	0	0.30851	0.17036	0.13786	0	0	0	0	0	0	0.03248	0	0	0	0	0	0	0
C23	0.01747	0.02508	0.02765	0	0	0.05243	0	0.0466	0.00719	0	0.03325	0.03325	0	0.00627	0	0.03507	0	0	0.06569	0	0.01538
C24	0.08051	0.04921	0.08397	0	0	0.03626	0	0	0.02664	0.09264	0	0	0	0	0	0.00673	0	0.0329	0.02034	0	0.00833
C25	0.04559	0	0	0	0	0	0	0	0.05083	0	0	0	0	0	0	0	0	0	0	0	0.0777
C26	0.03016	0.19403	0	0	0	0.0185	0	0	0.01315	0	0	0	0	0.06412	0	0	0	0	0	0	0
C27	0	0	0	0	0	0	0	0	0	0.04661	0.02033	0.10733	0.29054	0.14267	0.04284	0	0.01378	0	0	0.00788	0
C28	0.06448	0.02519	0.02396	0	0.09452	0.09386	0.03288	0.0497	0	0.01809	0.07498	0.03254	0.05434	0.02233	0.05273	0.03004	0	0	0	0	0.03755
C29	0	0	0	0	0	0	0	0.10411	0.04516	0	0.04106	0.06005	0.12311	0.11447	0.10233	0	0	0	0	0.03444	0
C30	0.01188	0	0	0	0	0	0	0	0.22293	0.04763	0	0	0	0.017	0	0	0	0	0	0	0
C31	0	0	0	0	0	0	0	0	0	0.14114	0.16298	0	0	0.06828	0.08704	0	0	0	0	0.01636	0
C32	0	0	0	0	0	0	0	0.18442	0.02227	0.04526	0.02033	0.12967	0	0.08599	0.03041	0	0.00602	0	0	0.00427	0
C33	0	0.05767	0.06039	0	0.03151	0	0.09864	0.25437	0.12749	0.10304	0.10896	0.12716	0.16151	0	0.21902	0	0.03156	0.03004	0	0	0
C34	0.0175	0.011	0.00951	0	0	0	0	0.08209	0.06355	0.04534	0.05277	0.02465	0.04518	0.03065	0	0.00751	0	0.00751	0.03755	0	0
C35	0.03782	0.03991	0	0	0	0.01869	0	0	0	0.01104	0	0	0	0	0	0	0	0	0.07812	0	0.05828
C36	0.00547	0.00565	0	0	0	0	0	0	0	0.00667	0	0	0	0	0	0.03641	0	0	0.01584	0	0
C37	0.02136	0.03544	0.0754	0	0	0.00648	0	0	0	0.02467	0	0	0	0	0	0.26827	0	0	0.05284	0	0.03714
C38	0.00899	0.00768	0	0	0	0.02358	0	0	0.02478	0	0.04957	0	0	0.04957	0	0	0	0	0	0	0.14222
C39	0.03275	0.02709	0.01902	0.18329	0	0.00979	0	0.13894	0	0.04968	0	0.09913	0.13894	0	0	0.09883	0	0.40352	0.03001	0	0.02366
C40	0.01377	0.01445	0	0	0	0.05384	0	0	0	0	0	0	0	0	0	0	0.4416	0	0	0	0
C41	0.01895	0.00887	0.03588	0	0	0.02673	0	0	0.07435	0	0.04957	0	0	0.04957	0	0	0.1104	0	0.22671	0	0.14222

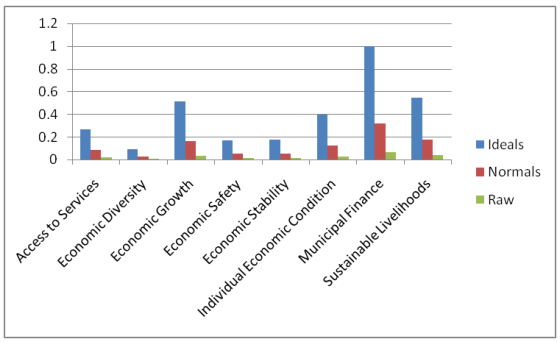

Chart 1: Overall synthesized priorities for the economic dimension

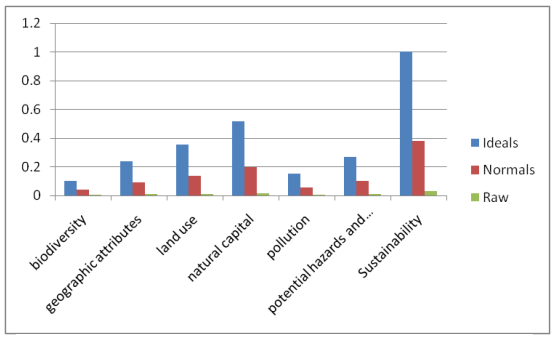

Chart 2: Overall synthesized priorities for the environmental dimension

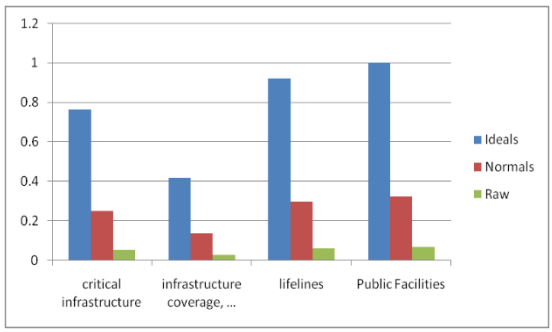

Chart 3: Overall synthesized priorities for the infrastructural dimension

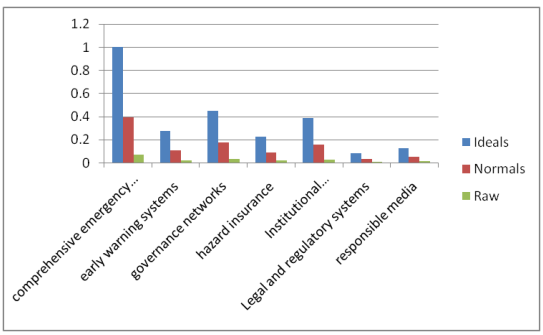

Chart 4: Overall synthesized priorities for the institutional and planning dimension

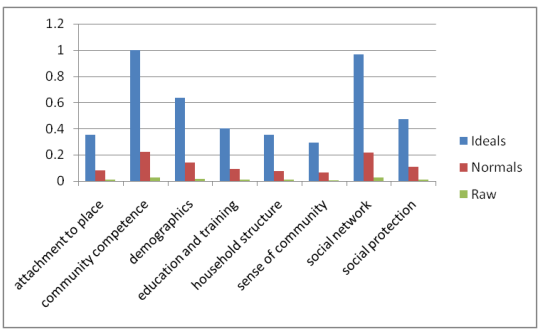

Chart 5: Overall synthesized priorities for the socio-cultural dimension

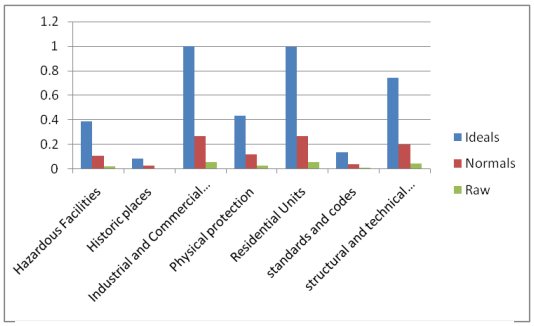

Chart 6: Overall synthesized priorities for the structural and physical dimension

Table 3 illustrates the weighted supermatrix which is the result of pairwise comparison of components. This table also represents the connection or disconnection of components with each other and the impacts of each component on the other components. The impact of each component on the other components is shown in each column. It can be seen that potential hazards and exposure, natural capital, and geographic attributes of urban areas have the highest impacts on the other components. The comprehensive emergency plan (CEP) is also one of the vital components of urban areas, which is under the influence of most components.

Charts 1 to 6 illustrate overall synthesized priorities of urban areas for the dimensions which have been represented in 3 forms; ideal, normal, and raw which are based on three different methods by idealzing or normalizing the values. The first normal priority in the economic dimension is municipal finance. Sustainable livelihood and economic growth are, respectively, in the second and third rank (Chart 1). Sustainability, natural capital, and land use are the priorities of the environmental dimension (Chart 2). As can be observed in Chart 3, the infrastructural priorities are critical infrastructure, lifelines, and public facilities which are close to each other. The CEP is the priority of the planning and institutional dimension. Governance networks and institutional mechanisms, capacities, and structures are the

next priorities (Chart 4). Community competence and social network are also close in socio-cultural dimension and demographics are the subsequent priority (Chart 5). Chart 6 illustrates that industrial and commercial units and residential units are in the highest normal priority.

Table 4: Prioritized components of resilience in urban areas

Dimensions	Components	Score*	Dimensions	Components	Score*
Economic (20.2%)	Access to services (C1)	1.7209	Institutional and planning (17.7%)	Comprehensive emergency plan (C20)	6.9827
	Economic diversity (C2)	0.5676		Early warning systems (C21)	1.8935
	Economic growth (C3)	3.3122		Governance networks (C22)	3.1218
	Economic safety (C4)	1.0929		Hazard insurance (C23)	1.5451
	Economic stability (C5)	1.1122		Institutional mechanisms, capacities, and structures (C24)	2.709
	Individual economic condition (C6)	2.5234		Legal and regulatory systems (C25)	0.5647
	Municipal finance (C7)	6.4238		Responsible media (C26)	0.877
	Sustainable livelihoods (C8)	3.4959	Socio-cultural (12.3%)	Attachment to place (C27)	0.9722
Environment (7.8%)	Biodiversity (C9)	0.301		Community competence (C28)	2.7394
	Geographic attributes (C10)	0.7003		Demographics(C29)	1.7455
	Land use (C11)	1.056		Education and training (C30)	1.1045
	Natural capital (C12)	1.5296		Household structure (C31)	0.9598
	Pollution (C13)	0.4467		Sense of community (C32)	0.8087
	Potential hazards (C14)	0.7953		Social network (C33)	2.6542
	Sustainability (C15)	2.9616		Social protection (C34)	1.3013
Infrastructure (20.1%)	Critical infrastructure (C16)	4.953	Structural (21.9%)	Hazardous facilities (C35)	2.2482
	Coverage, accessibility, and reliability (C17)	2.7038		Historic landmarks(C36)	0.4567
	Lifelines (C18)	5.968		Industrial and commercial units (C37)	5.8221
	Public facilities (C19)	6.4885		Physical protection (C38)	2.4908
*				Residential units (C39)	5.7727
				Standards and codes (C40)	0.7692
				Structural and technical measures (C41)	4.3084

The next analysis of the DRS was the analysis of normalized components by dimension which has been illustrated in table 4. This table represents the components that should be noticed for resilience in urban areas and illustrates the prioritized components of urban areas. It has been shown that the CEP is the priority of urban areas and the most effective component of the system. This means that experts believe there are some deficiencies in the CEP for urban areas. This also shows the role of emergency plans in resilience in urban areas. With minor differences, sustainability stands in second place. The next 8 important components for urban areas are, respectively, public facilities, municipal finance, lifelines, industrial and commercial units, residential units, critical infrastructure, community competence, and social network. It is evident that the majority of priorities are related to structural and infrastructural resilience in urban areas. Among the final 10 priorities, the outstanding role of social components can be observed in urban areas resilience.

4. Conclusion:

Since the use of the resilience concept in disaster risk reduction (Alexander, 2013), various models and frameworks have been proposed by scholars and scientists. Moreover, resilience has been analyzed in different fields, from environment to engineering and disasters. Although there is a variety of frameworks and models in disaster resilience, there is no consensus among researchers on components and standard metrics of resilience and the variables that should be used to measure resilience have not been determined (Ainuddin and Routray, 2012, Cutter et al., 2008b, Twigg, 2009). In this article, the physical and nonphysical dimensions of resilience were examined for urban areas Disaster Resilient System and the relationship between selected components and dimensions was specified using DEMATEL and ANP.

Whenever an emergency occurs, communities in urban areas are confronted with disturbances and interruptions; therefore, destruction and entropy are created based on community vulnerability. The community system of urban areas is resilient and has the capacity to cope with disasters if DRS is performed and implemented accurately. The selected elements, which consisted of 6 dimensions and 41 components, were determined using the Delphi method. ANP and DEMATEL were used to find the interactions between components in addition to their weights. Although ANP determines interactions between components, it cannot specify the weights of the components (Azizi et al., 2014). Therefore, the application of DEMATEL was suggested in combination with ANP to increase accuracy. As a result, the direction and the intensity of the relationship between selected dimensions and components were calculated using DEMATEL. Finally, the weight and importance of the components were obtained through ANP. It should be mentioned that due to the time-consuming process of responding to the questionnaire, it was very difficult to convince participants to take their time to complete it.

One of the key findings of this research is dimensional interrelationships. According to the findings, structural and infrastructural dimensions have the most impact on each other. Furthermore, the institutional and planning dimension and socio-cultural dimension have the most impact on the economic dimension. Furthermore, the economic dimension also has a noticeable impact on structural and infrastructural dimensions.

According to experts' comments and the analysis conducted using ANP and DEMATEL, the first prioritized component for contingency earthquake of urban areas is a CEP. This is mostly due to the lack of existence of a CEP for urban areas which should contain response plans, continuity of operation plans, recovery plans, preparedness and contingency plans, urban plans, disaster risk reduction plans, and infrastructure protection plans. These are pieces of a puzzle that should be defined with respect to each other. It is suggested that the TDMMO, as a responsible organization in disaster management in urban areas, provide a CEP for urban areas as one of the vital criteria in responding to this devastating disaster in urban areas. For the second priority of urban areas resilience, the sustainability indexes of urban areas should be recognized and defined. Moreover, in the first 10 prioritized components, the important role of public facilities resilience, lifelines resilience, industrial and commercial resilience, residential resilience, and critical infrastructural resilience was noticeable. This finding indicates that, besides other responsible organizations and agencies, TDMMO should implement projects to improve the resilience of the mentioned components.

Finally, experts believe that community competence and social networks are in a reasonable condition in urban areas; however, they have not been well-implemented in the CEP for urban areas. Therefore, it is suggested that authorities and managers consider these components as nonphysical components of resilience in their programs and decisions.

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Ethics approval:

Not applicable.

Conflict of interest:

The authors declare that there is no competing interest.

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