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PROVIDING AN INDICATOR-BASED MODEL FOR QUANTIFICATION OF SEISMIC URBAN RESILIENCE; PILOT STUDY: KISH ISLAND OF IRAN

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ABSTRACT

Resilience is a key concept in disaster risk management. In the recent years enormous efforts have been paid to the development of the concept of resilience. Resilience quantification still remains as a challenge and there are lots of impediments toward it. The process of resilience quantification needs improved knowledge about multiple aspects of resilience concept as well as related reliable data. In this way, utilizing resilience indicator is one of the most applicable way for quantification of resilience. One of the most significant advantages of resilience indicator is its measurability and features which shows the progress or lack of progress of implementation of disaster risk management policies. In this paper a new resilience indicator system is proposed and weighted by conducting an Analytical Hierarchy Process (AHP). Based on this indicator system, a new model proposed for quantification of seismic urban resilience which works on the basis of combination of the importance factors of the indicators (weights) with the value of them in real situation. The model utilizing 37 indicators, 13 thematic areas and 5 sectors has been developed and examined by implementation in the Kish Island in southern part of Iran. Based on the expert's opinions in AHP, the most important part of the urban resilience is physical and the least significant part is managerial, institutional and legal. As a result of the application of a variety of indicators to yield the total resilience, the role of social, economic and physical parameters can be appreciated in the mew model.

Keywords: Seismic Resilience; Indicator System; Urban Fabrics; Case Study; Vulnerability.

1. INTRODUCTION

Population growth and irregular development of the cities, particularly in developing countries, have led to the increased vulnerability and eventually the reduced resilience. Iran is located in a seismic-prone area and occurrence of more than 130 earthquakes with magnitudes greater than 7 in past centuries have been testified this fact. Inefficient performance of infrastructures, high vulnerability of buildings and low-level prevention and preparedness plans are the reasons caused severe damage and loss in the past earthquakes of Iran. Resilience is one of the most essential concepts in Disaster Risk Management (DRM) frameworks. Applying this concept in cities can minimize the extensive damages of earthquakes in urban fabrics as well as can help to better recovery to the normal situation. Perceiving the advantages of implementation of DRM frameworks equipped with quantified resilience, might be time-consuming and costly, but this type of frameworks could be adopted for optimized recovery and reduced impacts of diverse natural disasters. One of the most challenging issues in dealing with resilience is its quantification. Complicated nature of resilience and interaction among its multiple parts, makes the quantification of resilience much harder. Utilization of urban resilience indicators would be an appropriate way to assess the current level of resilience in cities and demonstrates the actions required to be taken in order to improve the resilience.
Application of risk indicators has been introduced by International Strategy for Disaster Reduction (ISDR) and Office for the Coordination of Humanitarian Affairs (OCHA) (2008) as: "Indicators serve as an explicit measure used to determine performance; a signal that reveals progress, or lack thereof; a

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means of measuring what actually happens against what has been planned or anticipated in terms of quality, quantity, and timelines. An indicator can be used to measure performance, change in processes, or outcomes". Indicators are usually proposing in the form of "indicator system" in order to provide a holistic outlook and covering the various dimensions of operating systems in cities. In this regard, several studies have been conducted; for instance: an indicator system for disaster resilience index utilizing 10 indicators for urban resilience have been proposed by Khazai et al. (2015). Disaster Resilience Index (DRI) has been developed as a "self-assessment" tool for tracking the effectiveness of disaster risk management policy. All indicators were evaluated through a participatory modeling process with participation of stakeholders (Khazai et al. 2015). Disaster resilience scorecard method for cities have been proposed to assess the base level of disaster resilience of cities to extreme events. This method is based on UNISDR's "Ten Essential" and evaluates 90 criteria, each single item is cleaved to smaller parts to cover all aspects of disaster resilience according to a 5 level of measurement scale (between 0 to 5).

This paper presented an indicator-based model for quantification of seismic urban resilience considering the localized indigenous features of developing countries such as Iran. This study can be considered as one of the first–defined studies in Iran following the quantification of seismic urban resilience. Therefore, the main purpose of this study, i.e., quantification of resilience, can be considered as the "first step" toward quantification of seismic urban resilience. The followings are set as the specific objectives of the study:

- To provide a resilience indicator system compatible with localized features;
- To define the relative importance of the indicators (weighting process);
- To model the quantitative urban resilience;
- To evaluate seismic urban resilience in Kish Island in Iran to test the model applicability

1.1 The Background of Urban Resilience and Indicator Systems

Definition and inclusion of the resilience concept in cities in the face of natural hazards do not have a long background. The urban resilience concept have been reviewed from different perspectives such as: resilient cities against climate change, resilient cities against extreme natural hazards, resilient cities against energy shortage and resilient cities against terrorism activities. Mileti (1999) states that a resilient city can stand on its own feet in the occurrence of disasters and experiences the least amount of damages and reduction in quality of life, focused on its own capacity. A city composed of physical systems and human communities; physical systems like roads, buildings, infrastructures and natural systems operate as "the body of the system" and must withstand to extreme events. While, human communities such as associations in schools, neighborhoods and organizations operate as "the brain of the city" and organize non-engineering parts of the city; a city with poor communities cannot sustain and manage catastrophic events (Godschalk 2003). Lamond and proverbs (2009) have considered the urban resilience as the ability of the city to recover as fast as possible from different kinds of disasters. Lhomme et al. (2011) have identified a resilient city as a city with absorptive capacity of perturbations and ability to regain its functions. The Rockefeller foundation and ARUP have proposed the definition of city resilience, under the program of 100 resilient cities, as: city resilience points to functional capacity of the city, so livelihood of citizens – especially vulnerable groups – won't be influenced by any kind of disasters (Index 2014). Campanella (2006) mentioned, a resilient city is able to return to the condition prior to destruction easily. Urban resilience is the capability of the city to keeping on the principal livelihood-related functions against catastrophe (Hamilton 2009). Community seismic resilience is the ability of the system (communities, organizations) to relieve the hazards, while some activities to decrease social effects of earthquake have been taken for the system and it is ready to reduce the effects of incoming earthquakes; in summary, the main objective of improving the seismic resilience is to make the least of the quality of life reduction due to earthquakes (Bruneau et al. 2003).

The Resilience Measurement Index (RMI) is a new indicator system of resilience developed by Argonne National Laboratory; this index provides a holistic approach to critical infrastructure resilience by considering operational elements as well as response and recovery elements of resilience. To provide a distinction among subjects, this index takes into account the issue of resilience in four main parts as level 1 and some sub-level indicators. Level 1 includes: preparedness, mitigation measures, response capabilities and recovery mechanisms. After that, through definition a five-levels of attainment scale, all needed parts were quantified (Petit et al. 2013). Kusumastuti et al. (2014) have proposed an indicator-based approach to resilience against natural hazards in Indonesia, in which, they have considered the resilience in two main parts as preparedness and vulnerability; then suggested social, community capacity, economic, institutional and infrastructure as the dimensions for preparedness. Besides all mentioned dimensions for preparedness, hazard was also considered as a dimension for vulnerability. For each dimension, some sub-dimensions and indicators were proposed, totally a set of 67 indicators describing the resilience. Finally by a scorecard approach as well as weighting process of the indicators, all indicators were quantified. An indicator system for the measurement of community resilience against seismic hazard has been proposed by (Ainuddin and Routray 2012) in Pakistan; this model considers the resilience as four major parts, namely: social resilience, economic resilience, institutional resilience and physical (shelter) resilience; for each category, some variables have been provided. The model has been implemented amongst 200 household in two different earthquake risk zones in Pakistan. Subsequently, weighting process and quantification of each variable have been conducted for each indicator. Finally the overall value for community resilience index in two districts has been estimated.

2. METHODOLOGY

2.1 Proposed Indicator System

The proposed indicator system has been developed based on the related parts of Sendai Framework for Disaster Risk Reduction (2015-2030) – as the newest adopted international strategy for disaster risk reduction – as well as other proposed indicator system for urban resilience, especially which proposed by (Khazai et al. 2015) as well as considering the local situation of Kish Island. Proposed indicator system has a hierarchical structure and has been extended according to a rational lookout to cover all operating and contributing parts of a city. In this regard, major parts of the city have been divided into five sections, named “Sectors”; then as for each sectors coverage, some smaller portions have been provided, namely “Thematic areas”; as the final step, for each thematic area, its relevant “Indicators” have been presented. Indicators have been considered as the smallest part of the indicator system that operates in a city. Main parts of the proposed indicator system have been shown in Figure 1 which presents “sectors” of the proposed resilience indicator system.

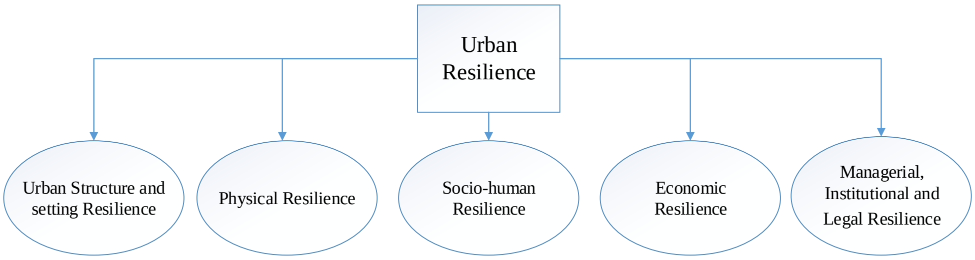

Figure 1. Main components of the proposed resilience indicator system

The process of “indicator selection” has been done with high care, because each selected indicators must be quantifiable and the required data should be available; another considerable point in the indicator selection process was the relevancy and effect of chosen indicators to urban resilience, this process carried out carefully as well. It should be mentioned that the proposed indicator system looks at the whole city generally and does not go into the detail of the components (Ghafory-Ashtiany and Atrachali 2016). Proposed resilience indicator system is shown in Table 1.

2.1.1 Components of the Resilience Indicator System

- Urban structure and setting resilience: the overall “urban structure” plays an important role in increasing the resilience of the city. This significant factor has been considered as the “urban structure resilience”. In fact, the first sector of the proposed resilience indicator system looks at the city from an urban design and considers the development activities of the city and its compatibility to seismic hazard as well. However, a city with a comprehensive development plan and also compatible construction with the level of hazard, will be more ready for incoming earthquakes. Meanwhile, wide street and well-organized accessibility to open and safe spaces, would facilitate the recovery process after an earthquake.

- Physical resilience: second sector of the proposed resilience indicator system is “Physical resilience”, which contains buildings and infrastructures totally. Existing robust buildings is a critical need to reduce the destructive impacts of earthquakes and infrastructures play a supportive role in pre, during and post disasters. In order to cover all aspects of infrastructures, it has been divided into two different parts, namely: “disaster management infrastructures” and “urban infrastructure”; the reason behind such division is to make a distinction between available infrastructure in cities to have a much clear perceive about them. Disaster management infrastructure has been considered in the sector of physical resilience due to the investigation of the structures and facilities of the responsible organizations for disaster management and response. The urban infrastructure is composed of the five basic facilities in a city that must operate well during the abnormal situation. The thematic area of “buildings” is one of the most important part of the proposed indicator system, because lots of the post event efforts would be eliminated by existing robust buildings. Therefore, this part has been proposed to assess vulnerability and usage as two most effective parts of the role of the physical resilience.
- Socio-human resilience: third sector of the indicator system devoted to study socio-human components of a city; which has been widely emphasized as a priority for action in Sendai framework for disaster risk reduction (Aitsi-Selmi et al. 2015). A city with aware and sensitive people to hazards will be more ready for confronting an earthquake and the impacts of earthquakes will decrease. Developed cities with high quality of living are more resilient against natural hazards and especially earthquakes, so the development index is surveyed in the proposed indicator system. Social contribution is used to assess the social connectivity and group activities of different communities in a city; hence, it considers the cooperation of the communities within a city as well as the level of citizen’s skill and training. The last thematic area of this sector is elaborates on the vulnerability of the people and the population density rate as one of the most important indicators in the context of socio-human resilience.
- Economic resilience: it is considered as the forth sector of the resilience indicator system, which contains economic potential and income as two thematic areas. Financial capacity plays an important role in the pre and post occurrence of the disasters; thus, financial capacity for policies implementation and economic recovery has been considered for the first thematic area as well as the ability to make job opportunity. A community with high financial welfare will respond better to disasters and it can bounce back earlier to the original situation.
- Managerial, Institutional and Legal resilience: the fifth and the last sector of the proposed indicator system is “managerial, institutional and legal resilience”, composed of a thematic area for existence and enforcement of laws and another thematic area which considers the management of emergency situation. The existence and enforcement of laws is a necessity for a resilient city, without which, management of the city and consequently the managerial and legal resilience will be deficient. Early warning systems has been considered in this sector, because with benefits of an early warning systems, primary and secondary impacts of an earthquake will be reduced; so that is a kind of preventive tool. During a disaster, it is vital to establish an organized process in order to deliver essential assistance to vulnerable people. So, an indicator is provided to quantify that.

The first two sectors have been considered as the technical and engineering part of resilience, and three remaining sectors have been considered as non-technical aspects of urban resilience. Complexity and dependence of the proposed sectors and indicators can be considered as the most impediments to achieve the best possible resilience indicator system.

2.1.2 AHP Analysis for Assigning Weight to the Indicators

Since the proposed model to assess the urban resilience is based on the combination of weights and values of the indicators, so the weighting process should be done systematically. Due to different role and importance of indicators in an urban area, different weights have been assigned to them. There isn't any consensus in the best way to assign weight to indicators and it depends on the different factors and situations of where the method is implemented (Mayunga 2007). However, any selected method to assign weight to indicators must be valid and demonstrate the correct contribution of each indicator to final urban resilience. There are lots of methods for assigning weight and selection a method depends on the situations. By considering current features of Iran and lack of data, the authors decided to use the Analytical Hierarchy Process (AHP), which is proposed by (Saaty 2008). AHP can illustrate the privilege of each options by each decision maker as well as display the most important alternative (Sato 2009). AHP is a kind of empirical method that based on the expert judgment, it can prioritize alternatives by making pairwise comparison via expert opinion (Saaty 2008). In this regard, the special questionnaires of AHP have been designed and more than 80 interviews with specialists and experts in the context of resilience and related fields have been conducted. Interviewees were included faculty members, experts in earthquake engineering field, sociologists, economists, urban planners, senior managers, decision makers, policy makers, and experts who are familiar with the concept of resilience and disaster risk management. The data for assigning weight to the indicators were collected from several organizations and institutions such as: International Institute of Earthquake Engineering and Seismology (IIEES), National Disaster Management Organization (NDMO), Tehran Disaster Mitigation and Management Organization (TDMMO), Tehran Municipality, Sharif University of Technology, Iranian Red Crescent Society, Institute of Natural Disasters, etc. After the extraction of opinions from the questionnaires, statistical analysis have been performed to assign the weight to each indicator. In order to eliminate the comparison error, all weights are expressed as a percentage. The average of all extracted weights were considered as the final weight for each indicator. AHP has the ability to eliminate inconsistencies among opinions and this process can be conducted by a small change to the comparison matrix arrays (Saaty 2008). Proposed resilience indicator system is shown in Table 1.

2.2 Seismic Urban Resilience Model

The proposed model is an indicator-based model used for quantification of seismic urban resilience. This model is based on the combination of the indicators weights and their values. Weighting process is described in the previous section. In order to quantification of indicators, a five level of attainment has been defined, then, based on the available data and procedures, each indicator has been quantified according to a pre-defined measurement scale. One of the advantages of the new model is to eliminate the overlapping effects of the existing sectors and thematic areas. The logic behind the development of the present model is based on the simulation of the different sectors of a city to serial springs which means the final effect of an earthquake on a city can be considered as the summation of individual effect of different sectors of a city (Atrachali 2017). The presented model for quantification of urban resilience is shown as the equation 1:

$$\textbf{Total Resilience} = (\mathbf{W'_F} \,.\, \mathbf{R_F}) + (\mathbf{W'_P} \,.\, \mathbf{R_P}) + (\mathbf{W'_S} \,.\, \mathbf{R_S}) + (\mathbf{W'_E} \,.\, \mathbf{R_E}) + (\mathbf{W'_M} \,.\, \mathbf{R_M}) \tag{1}$$

Where:

$\mathrm{W'_F}$: *the weight of urban structure resilience sector*; $\mathbf{R_F}$ *is the final resilience value of this sector*
$\mathrm{W'_P}$: *the weight of physical resilience sector*; $\mathbf{R_P}$ *is the final resilience value of this sector*
$\mathrm{W'_S}$: *the weight of socio − human resilience sector*; $\mathbf{R_s}$ *is the final resilience value of this sector*
$\mathrm{W'_E}$: *the weight of Economic resilience sector*; $\mathbf{R_E}$ *is the final resilience value of this sector*
$\mathrm{W'_M}$: *the weight of Manegerial resilience sector*; $\mathbf{R_M}$ *is the final resilience value of this sector*

2.3 Quantification of Indicators

One of the most significant and difficult parts of the current study is the quantification of indicators, because of complicated essence of indicators as well as lack of verified data that makes the quantification process much harder. Five level of attainment scale has been used to quantify indicators as shown in Table 2. Each indicator has a value between 0 to 1. This range is divided into five equally separated levels. If there were reliable data for any indicators, it has been used; otherwise, indicators were quantified by field visit, interview with local stakeholders and expert judgment. A sample form which is completed for quantification of indicators in the fourth zone of Kish Island is shown in Appendix A.

3. PILOT STUDY: KISH ISLAND

Kish Island has about 37000 population in an area of 91 km^2, about 43 kilometers beach and the overall elliptical shape, is located in the Persian Gulf. Kish is located in the first quarter of 1359 km along the coast in southern Iran at the mouth of the Persian Gulf and near the end part of the waterways around the Strait of Hormuz. Its north latitude is 26 ° 32 ' and its east longitude is 58° 53' and in the West Bank - the east coast, it has 45.15 km long. The maximum width of the island on the southern coast to the northern coast is 7.5 km. The Island has no special topographic features such as mountains and high hills. The maximum slope of the Island is from the north of the airport to the beach (Kish Free zone website). In the northern part of the Kish Island in the main land, the potential of seismic hazard is high and occurring lots of destructive earthquakes testifies this fact. Generally, it can be said that according to the recorded figures describing history of occurred natural hazards in Iran, the most source of massive losses would be earthquakes (Ghafory-Ashtiany, 2009). Kish Island is considered as one of the most significant recreational Islands in Iran. Besides the recreational places, hotels and facilities for tourists, native people are living in the western part of the Island. Furthermore, the commercial port of the Kish Island is considered as one of the main trading centers for import and export of goods. The strength of the Island can be categorized as follows:

- The appropriate ratio of buildings height to streets width
- Good transportation access and being nearby to the main traffic lifeline
- Proper access to large open spaces
- Relatively high level of financial welfare
- The provision of comprehensive awareness and education for residents

On the other hand, the weak points and identified shortcoming of the Island can be categorized as follows:

- Inharmonious and uneven development in some parts
- Low level of social contribution
- Lack of adequate urban facilities and services
- Complexity and difficulty of provision of urban services due to inappropriate urban development
- High level of social difficulties

In order to facilitate the data collection process, the study area has been divided into seven zones. Final value of urban resilience has been estimated as the average of calculated values for five zones. Results obtained from model implementation in each zone have been shown in Figure 2.
Results for each sector and zone are shown in the Table 3. As mentioned before, the proposed model utilize the combination between indicators value and corresponding weight factors.

Table 1. Resilience indicator system provided

Sectors	**Weight factors**	Thematic areas	**Weight factors**	Indicators	**Weight factors**
Urban Structure and setting Resilience	**0.19**	Urban development commensurate with the level of hazard	**0.63**	I_{F1} = Compatibility of development and construction with the level of hazard	**0.57**
				I_{F2} = Comprehensive urban development plan	**0.43**
		Form and overall structure of the city	**0.37**	I_{F3} = Ratio of buildings height to streets width	**0.14**
				I_{F4} = Access to outdoor	**0.24**
				I_{F5} = City pattern	**0.25**
				I_{F6} = Time-worn area	**0.37**
Physical Resilience	**0.34**	Buildings	**0.39**	I_{P1} = Vulnerability (structure type, age, No. of floors)	**0.80**
				I_{P2}= Usage	**0.20**
		Disaster management related infrastructures	**0.30**	I_{P3}= Fire stations	**0.28**
				I_{P4}= Hospitals	**0.36**
				I_{P5}= Rescuers access	**0.36**
		Urban infrastructures	**0.31**	I_{P6}= Water conveying network	**0.19**
				I_{P7}= Gas transmission system	**0.23**
				I_{P8}= Power distribution system	**0.21**
				I_{P9}= Telecommunication system	**0.12**
				I_{P10}= Road network	**0.25**
Socio – human Resilience	**0.18**	Understanding the disaster risk	**0.22**	I_{S1} = Level of people's awareness and sensitivity	**0.61**
				I_{S2} = Local risk management / emergency response team	**0.39**
		Human development index	**0.22**	I_{S3} = Trust and communication among people, officials and experts	**0.21**
				I_{S4} = Level of health	**0.17**
				I_{S5} = Level of education and training	**0.29**
				I_{S6} = Age	**0.16**
				I_{S7} = The relative welfare and hope to life	**0.17**
		Social contribution	**0.21**	I_{S8} = Collaboration	**0.38**
				I_{S9} = Existence and activities of NGOs	**0.32**
				I_{S10} = Holding emergency response drills	**0.30**
		Human vulnerability	**0.35**	I_{S11} = Vulnerable population in disasters	**0.45**
				I_{S12} = Population density	**0.55**
Economic Resilience	**0.15**	Economic potential	**0.63**	I_{E1} = Financial capacity to implement policies and responding to the effects of the crisis	**0.37**
				I_{E2} = Ability to physical and economic recovery	**0.37**
				I_{E3} = Job	**0.26**
		Income	**0.37**	I_{E4} = Economic welfare	**0.69**
				I_{E5} = GDP per capita	**0.31**
Managerial, Institutional and Legal Resilience	**0.14**	Administrative and legal capacities of city	**0.57**	I_{M1} = Existence of laws	**0.28**
				I_{M2} = Enforcement and rule of laws	**0.72**
		Emergency management	**0.43**	I_{M3} = Early warning systems	**0.49**
				I_{M4} = Ability to manage delivery of resources to the most vulnerable populations and optimum use of existing resources	**0.51**

Table 2. Defining measurement scale for quantification of resilience indicators

Value	Description
0.2	There is very little awareness about the importance of the indicator among officials and stakeholders, so, any special effort has not made to promote the value of the indicator in the city. Different parts of the city are not ready in the domain of the indicator and high level of vulnerability as well as low level of resilience can be seen.
0.4	The relative importance of the indicator is somewhat perceived by citizens and officials, therefore, some efforts have been done to improve it, but, those are not enough. A safe performance of the city against an earthquake is not expected.
0.6	The importance of the resilience indicator has been determined, but the mechanisms and procedures to attain high resilience level have not been fully established yet. The functional level of the city against natural disasters is in a medium level and plenty of preventive tasks in order to reduce the impacts of an earthquake are required.
0.8	The importance of the indicator has largely been determined, but the implementation procedures have not been fully developed. An acceptable performance of the city against an earthquake is expected, but this performance can be improved to achieve ultimate goal of a resilient city.
1	The importance of the indicator has been fully determined by citizens, officials and decision makers. Illustrative procedures have been conducted to attain the best level of the indicator and there is a full integration between the responsible organizations to do their duties. It should be noted that although the city is resilient, further effort is required to achieve higher level of safety and resilience.

Figure 2. Results obtained from model implementation in Kish Island

Table 3. Results for each zone from model application

	W'_F	R_F	W'_P	R_P	W'_S	R_S	W'_E	R_E	W'_M	R_M	Final Value
Zone 1	0.19	0.497	0.34	0.401	0.18	0.380	0.15	0.418	0.14	0.312	0.406
Zone 2	0.19	0.371	0.34	0.365	0.18	0.397	0.15	0.418	0.14	0.412	0.386
Zone 3	0.19	0.212	0.34	0.310	0.18	0.347	0.15	0.359	0.14	0.364	0.313
Zone 4	0.19	0.511	0.34	0.523	0.18	0.402	0.15	0.562	0.14	0.517	0.504
Zone 5	0.19	0.511	0.34	0.421	0.18	0.513	0.15	0.541	0.14	0.465	0.479
Zone 6	0.19	0.418	0.34	0.451	0.18	0.475	0.15	0.456	0.14	0.489	0.455
Zone 7	0.19	0.476	0.34	0.452	0.18	0.434	0.15	0.412	0.14	0.333	0.430
$\text{Total Resilience} = (W'_F . R_F) + (W'_P . R_P) + (W'_S . R_S) + (W'_E . R_E) + (W'_M . R_M) = \mathbf{0.425}$											

4. CONCLUSION

In this paper a new indicator-based model for quantification of seismic urban resilience against earthquake hazard is proposed. The model has been implemented in the Kish Island of Iran. Authors have tried to cover the most significant part of operating system in an urban fabric in the indicator system, as well as the process for quantification of indicators have been conducted with high care. In case of existing reliable data, they have been used in quantification process, otherwise, the expert judgment used for determination of indicators value. The results show that physical indicators with the highest importance factor play a crucial role in the final value of urban resilience. As a result of the application of a variety of indicators to yield the total resilience, the role of social, economic and physical parameters can be appreciated in the new model. The indicator-based approaches to measure the urban resilience against earthquake must be localized to include indigenous features of urban fabrics; this study is the first step toward proposal of a comprehensive integrated DRR framework for developing countries like Iran. Further studies must be performed to implement and verify proposed model in different pilot situations.

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Appendix A

Table A-1: Indicator’s Value for the zone 4 in Kish Island

Indicator’s Value	0.2	0.4	0.6	0.8	1
Urban Structure and Setting Resilience					
I_{F1} = Compatibility of development and construction with the level of hazard		✓			
I_{F2} = Comprehensive urban development plan			✓		
I_{F3} = Ratio of buildings height to streets width		✓			
I_{F4} = Access to outdoor				✓	
I_{F5} = City pattern			✓		
I_{F6} = Time-worn area				✓	
Physical Resilience					
I_{P1} = Vulnerability (structure type, age, No. of floors)				✓	
I_{P2}= Usage of buildings		✓			
I_{P3}= Fire stations				✓	
I_{P4}= Hospitals				✓	
I_{P5}= Rescuers access				✓	
I_{P6}= Water conveying network	✓				
I_{P7}= Gas transmission system	✓				
I_{P8}= Power distribution system	✓				
I_{P9}= Telecommunication system	✓				
I_{P10}= Road network	✓				

Socio – human Resilience					
I_{S1} = Level of people's awareness and sensitivity	✓				
I_{S2} = Local risk management / emergency response team	✓				
I_{S3} = Trust and communication among people, officials and experts		✓			
I_{S4} = Level of health			✓		
I_{S5} = Level of education and training			✓		
I_{S6} = Age				✓	
I_{S7} = The relative level of welfare and hope to life				✓	
I_{S8} = Collaboration	✓				
I_{S9} = Existence and activities of NGOs	✓				
I_{S10} = Holding emergency response drills	✓				
I_{S11} = Vulnerable population in disasters			✓		
I_{S12} = Population density				✓	
Economic Resilience					
I_{E1} = Financial capacity to implement policies and responding to the impacts of the crisis			✓		
I_{E2} = Ability to physical and economic recovery			✓		
I_{E3} = Job			✓		
I_{E4} = Economic welfare				✓	
I_{E5} = GDP per capita				✓	
Managerial, Institutional and Legal Resilience					
I_{M1} = Existence of laws		✓			
I_{M2} = Enforcement and rule of laws	✓				
I_{M3} = Early warning systems	✓				
I_{M4} = Ability to manage delivery of resources to the most vulnerable populations and optimum use of existing resources	✓				