Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 95 (2016) 491 – 498

Energy Procedia

International Scientific Conference "Environmental and Climate Technologies", CONECT 2015, 14-16 October 2015, Riga, Latvia

Adapting and reacting to measure an extreme event: a methodology to measure disaster community resilience

Fulvio Toseroni[a]*, Francesco Romagnoli[b], Fausto Marincioni[a]

[a]*Università Politecnica delle Marche, via Brecce Bianche, Ancona, 60131, Italy*
[b]*Institute of Energy Systems and Environment, Riga Technical University, Azenes iela 12/1, Riga, LV–1048, Latvia*

Abstract

The 2005 UN Hyogo Declaration introduced the concept of resilience in the field of disaster risk reduction (DRR) unifying environmental sustainability and civil protection concepts. Crucial in this new approach is the development of a new quantitative adaptive strategy, which starting from the risk analysis of a territory, aims at strengthening a symbiotic and adaptive relationship between human communities and their surrounds. This paradigmatic shift needs new analytical and measuring tools in order to describe, evaluate and develop sustainable DRR strategies. Traditional cartographic tools, such as hazard, vulnerability, or risk maps, cannot appropriately represent the overall resilience of a territory (inclusive of its social and environmental dimensions). This article proposes a methodological approach to map such community resilience by assessing energy and resource consumption to maintain the stability of the social-ecological system. Starting from the identification of the complex relations between socioeconomic processes and disasters, this method computes a resilience score or index, integrating hazard and vulnerability factors with emergency management actions (e.g. community planning, mitigation and disaster response capabilities). Such index will enable, inter-alia, the drawing of maps of resilience, necessary to planners and policy makers to assess the effects and sustainability of different DRR strategies and policies.

Peer-review under responsibility of Riga Technical University, Institute of Energy Systems and Environment.

Keywords: resilience index; vulnerability; adaptive capacity; community disaster resilience; map of resilience

* Corresponding author.
E-mail address: fulviotoseroni@hotmail.it

Peer-review under responsibility of Riga Technical University, Institute of Energy Systems and Environment.
doi:10.1016/j.egypro.2016.09.074

1. Introduction

Since the early 1970s extreme events have been growing both in frequency and intensity [1, 2]. The increase of destructive and disruptive extreme events has thus driven the attention of the international scientific community toward a more holistic understanding and study of disasters [3]. The links between traditionally distinct disciplines, such as geology, ecology, economy and sociology, and the field disaster management have been increasingly investigated [4], and an important literature and various schools of thoughts on disasters and emergency management was developed [5–8]. In spite of the different visions and approaches, scientists seem to agree that disasters are the direct consequence of technical failures depending on social, organizational and institutional factors.

1.1. UN International Decade for Natural Disaster Reduction (IDNDR)

In 1989, the UN Resolution 44/236 started a global program aimed at saving human life and reducing the impact of disasters [9]. Such resolution defined the International Decade for Natural Disaster Reduction (IDNDR) program with the aim of reducing the loss of lives, property damage, social and economic disruption caused by natural disasters and other calamities of natural origin (UN, 1989) thanks to a coordinated international action. In 1992 the UN Department of Humanitarian Affairs was established and included in the General Assembly resolution 46/182 [10]. Within this new UN body a novel integrated approach for the management of all the aspects related to disasters was adopted, emphasizing the importance of prevention and preparedness, and thus starting an important process of development of a global culture of prevention mostly focused on vulnerable countries [11]. The first World Conference on Natural Disaster Reduction, held in Yokohama (Japan) in 1994, produced the document: Yokohama Strategy and Plan of Action for a Safer World - Guidelines for Natural Disaster Prevention, Preparedness and Mitigation [12]. The document highlights that environmental protection and poverty reduction became key for the prevention and mitigation of natural disasters. Moreover, the introduction of prevention, mitigation, preparedness and recovery actions, replaced the previous approach mainly based only on disaster response. The World Conference introduced several innovations, such as looking toward the field of anthropic disasters and the introduction of the concept of technical Resilience in the field of DRR. Eventually, the Yokohama declaration became the background for the International Strategy for Disaster Reduction (ISDR), established in 2001 through document 65/195 as a permanent program to continue the work initiated with the IDNDR [12].

1.2. UN International Strategy for Disaster Reduction (ISDR) and the Hyogo Framework for Action (HFA)

The UN Millennium Declaration in the year 2000 [12] clarified that the starting point of every DRR action must be a sustainable process that tries to minimize the environmental impact and revert the current unsustainable models of production and consumption. The objective is to protect nature for future generations. The UN reaffirmed its commitment to intensify cooperation and synergies among countries in order to reduce numbers and consequences of natural and manmade disasters [12]. The key concepts of the Millennium document became the basis for the International Strategy for Disaster Reduction (ISDR). In 2005 during the 2nd World disaster conference, held in Hyogo (Japan), the Hyogo Framework for Action (HFA 2005–2015) [13] was presented, the main goal of which was to shift from hazard planning and risk reduction to building disaster resilient communities. Since then the concept of disaster resilience has gained momentum, particularly in the field of emergency management and civil protection. Nevertheless, in the HFA document it was not clearly defined how resilience should be assessed, measured or mapped [14]. This indetermination was carried over to the third UN World Conference on Disaster Risk Reduction (DRR), held in Japan in March 2015, which defined a new set of action for the period 2015–2030. Nevertheless, the close link between extreme events, climate change, consumption of environment, community vulnerability and resilience remains pivotal for the implementation of effective national DRR programs.

2. Resilience in disaster risk reduction

The first documented use of the word resilience in the field of disaster studies dates back to 1854 after the Shimoda earthquake in Japan describing the recovery actions of Shimoda's citizens as resilient. However, only at the beginning of year 2000 the concept of resilience becomes systematically adopted in the field of DRR, also thanks to the above discussed UNISDR and HFA programs. David Alexander, in his etymological analysis of the word resilience [15], highlights three main semantic concepts associated to word resilience: an intrinsic characteristic of materials to survive the application of a force by resisting it with strength (rigidity) and absorbing it with deformation (ductility), from mechanics; the capacity of a social-ecological system to survive disturbance, preserving its integrity and functions, from ecological perspective proposed by Holling [16]; the ability of an individual to adapt and react to abrupt shocks, from psychology [14, 17–19].

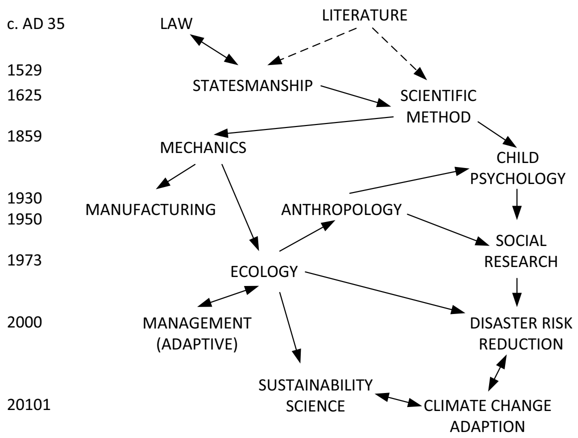

Fig. 1. Meaning of resilience in DRR [19].

According to Alexander the concept of resilience in the field of DRR links back to the definitions developed on the field of ecology and psychology (see Fig. 1). Holling provided an important connection between resilience and DRR, when in 1995 refined his definition of ecological resilience: "A buffer capacity or the ability of a system to absorb perturbation, or the magnitude of the disturbance that can be absorbed before a system changes its structure by changing the variables" [16]. The introduction of magnitude, namely the energy released by a disturbance or extreme event, provided a direct link of the concept of ecological resilience to the field of DRR. Meanwhile, in the field of social science, human geographer Adger [18] first used the term "resilient communities" to describe social systems capable to absorb and recover from extreme events. Since then, various characterizations of resilience had been developed for DRR according to the specific contingencies analyzed. Reported examples include: the ability of a nation, a group of people, a community or a society to face disasters and quickly recover an equilibrium after the impact. This ability of action/reaction is called Community Disaster Resilience; the ability of a system to develop a self-regulatory and reorganization process in case of disturbance. Resilience facilitates and contributes to the community's recovery process [19]; the ability of a system to quickly react to an external stress, and the long term capacity to build a new equilibrium. In this case, resilience is linked both to the timing and to the capacity to reinforce a community after an event; the ability of a system to adapt to changing conditions while preserving its basic structure. From this point of view, the relationship between disasters resilience and sustainable use of natural resources play a major role [20].

Indeed, the multitude of interpretations and usages to which the term resilience has been subjected has led to confusion. Help came once again from the UNISDR, which in 2009 provided a definition of resilience that has become widely accepted in the field of DRR. Such definition reads as follow: "The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions" [16].

3. Need for resilience metrics

Researchers and practitioners, governments and NGOs as well as UN organizations, have undertaken the quest for a shared method to measure resilience, and various metrics focusing on different aspects of resilience have been developed. However, resilience analysis is still in its infancy, and no single method has yet received the authority of consensus approval. One organization, the Resilience Alliance, has developed guidelines for applying resilience analysis to socio-ecological systems [Resilience Alliance, Assessing resilience in social-ecological systems: Workbook for practitioners. Version 2.0, 2010, Resilience Alliance], but the socio-ecological systems framework cannot be applied to every context. From a qualitative point of view, the key indicators of system resilience can be defined using system dynamics modelling; the thresholds of certain characteristics/variables before a system stability is disrupted define the systems' resilience. Examples of such indicators are listed in Table 1.

Table 1. Characteristics of system resilience.

Characteristic	**Description**
Diversity	Existence of multiple resources and behaviors within the system.
Adaptability	Capacity of a system to change in response to new pressures.
Cohesion	Strength of unifying forces, linkages, or feedback loops.
Latitude	Maximum amount of change a system can absorb while still functioning.
Resistance	Capacity of a system to maintain its state in the face of disruptions.

Certainly, once we find the right indicators and the right calculations, we will have major progress in enhancing and quantifying resilience. The purpose of this article is to foster discussion on the following aspects of resilience: How far are we in the process of making resilience principles less theoretical and more contextual? How to overcome information sharing barriers to circulate and test good practices of resilience metrics? What is the status of measuring resilience in the specific field of emergency planning? How to create maps of resilience and how can they be linked to maps of risk? Can maps of territorial resilience encourage the development of adaptive human systems, and increase preparedness for unknown future extreme events? And finally which type of holistic methodology can be applied.

3.1. Classifying adverse events

In this paper the word "event" means every phenomena that affect the dynamic equilibrium of a system, causing loss of life, injuries, health, economy and environmental damages. An event can be classified according to: Source of disturbance (hazard); Energy released (magnitude); type of impact (slow or fast onset, localized or diffuse, etc.); type of consequence/damage; Methodology to cope with, respond and recover from an event.

The UN identifies three main categories of primary hazards [18]: natural hazards (originating from natural phenomena - i.e. earthquakes, landslides, volcanoes, etc.); technological hazards (originating from technological or industrial processes – i.e. accidents, dangerous procedures, infrastructure failures or specific human activities); socio-natural hazards, originating from the interaction of natural hazards with overexploited or degraded land and environmental resources. The term highlights circumstances where human activity is increasing the occurrence of certain hazards beyond their natural probabilities.

Quarantelli classified four different levels of events: accidents, major incident, disaster, catastrophe [21]. If we adopt this classification, we can describe every event in terms of disruptive energy release unmanageable and uncontrollable from the societal systems. The disruptive event in terms of energy released depends from the magnitude, intensity, the period, and the velocity of propagation of the affected area [22].

3.2 Methodologies for assessing and measuring community resilience

There is a common understanding that resilient systems are less vulnerable to hazards and threats than places with lower level of resilience. Nevertheless the way how resilience is quantified (covering assessments, determinations, measurements, enhancements) is still a matter of question. Specifically, it is not obvious what drives to a higher level of resilience within interconnected systems (e.g. human, environment and technological) and thus what are most consistent and robust variables or indicators that should be used within the measurement process.

Already a large number of studies have tried to described the overall aspects of resilience like Berkes et al. [23] and Plummer and Armitage [24], but due to its multi-disciplinary nature a holistic model of resilience has not yet been tested and approved. The study of Duijnhoven and Neef [25] highlights how there is not a large number of frameworks and studies aiming to build conceptual and theoretical models of community and societal resilience based on the theory of adaptive and thus complex systems. The same concept is also highlighted in the work of Cutter [25] and Jordan Javernick-Will [26].

Within the study of Schneiderbauer and Ehrlich [27] is described the importance of assessing resilience in terms of indicators instead of absolute resilience quantification. The proper and consistent selection of a set of indicators would offer the possibility of quantification among different places and over time [28] even if in this aspect the dynamic and non-linear perspective is still missing.

The study proposed by CSS [29] identifies the resilience evaluation methods through quantitative approaches (mostly associated to an index based evaluation), qualitative approaches (based on a descriptive evaluation), and mixed-methods. The mixed methodology is suitable and related to community resilience specifically focused on the evaluation of social links among communities, their environment and the structural aspects on which they are based and rely on.

In the study proposed by Cutter et al. [25] is stressed the link of resilience with the concept of adaptive capacity as well as the interconnections among resilience, adaptive capacity and the concept of vulnerability. The author defines resilience as a system's capacity to absorb disturbance and re-organize into a fully functioning system. As mentioned in the study of Klein et al. [19] the framework on how determine, measure, enhanced, and maintain a resilient community is essential in order to decrease its vulnerability to hazards and disasters.

Based on this assumption and how previously described general frameworks have been proposed during the last decade looking toward different key aspects (e.g. PEOPLES, CDRF, DROP).

PEOPLES [30] framework is based on the identification of seven dimensions (i.e. population, environmental, governmental, physical infrastructural, community, economic, social). The method merges exposure to hazards with the social dimensions that make the community vulnerable to a particular hazard. The purpose is to describe the socio-economic status of the community. The method provides a frame to include metrics for measuring economic resilience in term of loss estimation models (i.e. property loss and the effects of business disruption after disasters). PEOPLES framework integrates current economic activity and dynamic growth of the economic development.

CDRF (Community Disaster Resilience Framework) developed by Mayunga [31], is focused the main management phases of an occurring disaster (i.e. mitigation, preparedness, response, and recovery on the one hand and on the other involving community capital in terms of social, economic, physical, and human resources to be implemented during the disaster management phase. CDRF is a consistent, robust and validated method merging the community capitals with the disaster management phases based on a structured platform of indicators. This operates more extensively at the national level, lacking in community resilience at smaller scales.

DROP (Disaster Resilience of Place) [25] describes the relationship among vulnerability and resilience in a framework open to empirical testing. Within DROP the time frame within the evaluation of communities' resilience is focused in two main components: i) an antecedent condition to the disaster (i.e. inherent resilience) - defined as the link (space and multiscale dependant) among natural systems, built environment, and social systems; ii) a post-disaster condition focused on the ability to cope and respond during and after the disaster (i.e. adaptive resilience). Within this structure is integrated the social vulnerability index proposed by Cutter [32–34]. The DROP model is frequently referred to as an evaluation approach, the main concern is its lacking experimental tests (i.e. more theoretical frame), the several assumptions made and the focus on the social resilience of places.

A common aspect for all the previous mentioned frameworks is the concept to define the community resilience to disaster under two main important components: the disaster management phase activities and the overall community capitals. Moreover, the quantitative evaluation of the community resilience to disaster is referred to the use composite indicators [25] as a quantitative tool. This foresees the following systematic steps: general platform for the definition of the indicators, selection of the relevant indicators, and comparability of the indicator though standardization and weighting, final evaluation of the consistency and robustness of the set of indicators selected through an overall validation and testing. Thus one of the main research directions is oriented toward the need to identify consistent metrics to evaluate (and support) policy action in order to develop a set of holistic metrics applicable to hazards in different infrastructural, economic, geographic, social and cultural dimensions. The next section of this paper will thus propose a community resilience evaluation framework integrating several aspects of the previously mentioned approaches.

4. Novel resilience community assessment framework

The framework for the assessment of the community resilience proposed in this study is based on an holistic approach of the resilience able to provide a comprehensive measure involving all phases of disaster's cycle within the different overall community systems (i.e. social, economic, infrastructural/physical, environmental/ecological, institutional).

The method is implementing the classification of Quarantelli to identify benchmarking to better evaluate how the resilience is estimated with reference to the coping capacities thresholds of community. The overall framework, here called the Holistic Community Resilience Assessment Method, is proposed in Fig. 2.

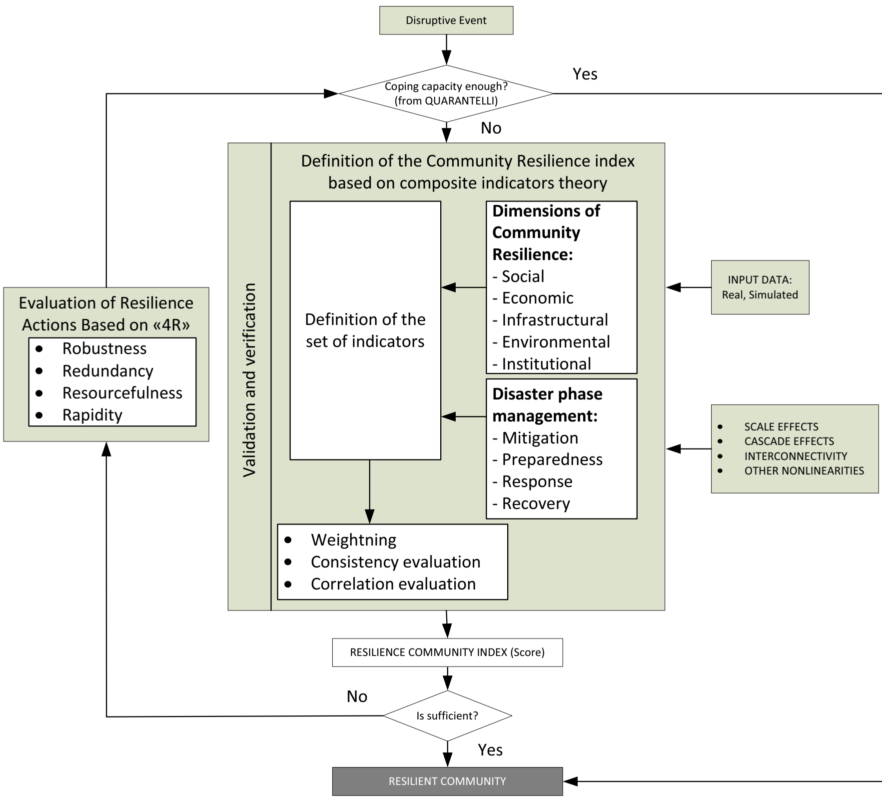

Fig. 2. Holistic community resilience assessment method.

The processes related to the definition of a final evaluation score takes into account the implementation of a composite indicator approach. This approach includes: data transformation into comparable scales, exclusion of correlated indicators, a further weighting and a final validation and testing. Within this approach a set of composite indicators which are representative, relevant and robust must be guaranteed. With this approach it would be possible to investigate how the effect of potential measure enhancing resilience on different dimensions will provide an overall increase within the score. The potential implementation of supporting actions to define scenarios aiming to enhance resilience will be implemented trough the based concept of 4R developed by Bruneau [35] and Cimellaro [36]. According to the scheme of Fig. 2 this aspect will be beneficial to evaluate in a second round the community resilience based on a composite indicators platform to evaluate the overall benefit looking toward a final aim of a resilient community.

The proposed methodological approach would like to integrate the effects related to changes of resilience due to scale, cascade effects and interconnectivity within the community resilience composite indicator evaluation. For example the link among the physical dimension (i.e. physical infrastructures) and the social dimension is a key issue within the scientific arena, Jackson [37] recognized that "Regarding the resilience of technological systems, the point is usually made that the people and infrastructures surrounding the technological systems also are involved in ensuring resilience".

Nevertheless, the interpretation of indices can bring misleading conclusions. Thus the implementation of a system dynamic modelling methodology [38–40] would represent an integration to be considered to evaluate the non-linearity of the interaction among the dimensions considered. In this way the interaction between and among physical activities, information flows and policy measures can be identify thus revealing the dynamical nature of the variables.

5. Conclusion

This paper provides a preliminary attempt to develop a methodological approach for measuring and monitoring the disaster resilience of community defined as Holistic Community Resilience Assessment Method. The proposed approach provides the baseline to correctly implement quantitative metrics of resilience that can be well understood as thus implemented in policy and decision making processes looking toward enhancing resilience of communities. This paper is thus moving toward the DRR management beyond the concept of risk and proposed a quantitative assessment framework of responding capacity of a territorial system and thus its resilience. Within the proposed framework the concept of Quarantelli related to the classification of an event from accident to disaster is considered in order to identify territorial threshold benchmarking and thus capacity to cope the impact of an extreme event. The framework integrates the DROP and CDRF framework, the concept expressed by Bruneau within the definition of resilience under the 4R view (Rapidity, Robustness, Redundancy, Resourcefulness) and the use of composite indicators within the definition of a resilience index. The proposed methodological approach is in fact providing the opportunity to map community resilience by assessing energy and resource consumption to maintain the stability of a socio-ecological system. The final results from the proposed approach should look toward the drawing of maps of resilience, necessary to planners and policy makers to assess the effects and sustainability of different DRR strategies and policies. The methodology can be generalized and expanded to emerging hazards rather than only natural disasters. Still the overall framework needs a refining aimed to define the effects of interaction, cascading effects and scale effects among and within the dimensions of the community resilience. Moreover, real application and test on a case study must be explored.

References

[1] Natural Catastrophes 2012, Munchen, Münchener Rückversicherungs-Gesellschaft; 2013.
[2] Il cambiamento climatico. Milano: Muenchener Ruck Italia; 2009.
[3] Intergovernmental Panel on Climate Change, The IPCC Special Report on managing the risks of extreme events and disasters to advance climate change adaptation. New York: Cambridge University Press; 2012.
[4] United Nation. Environment and Development conference, 1992.
[5] White G, Burton I, Kates R. The environment as hazard. New York: The Guilford Press; 1997.
[6] White GF. Natural hazards, local, national, global. New York: Oxford University Press; 1974.

[7] Alexander DE. The study of natural disasters, 1977–97: some reflections on a changing field of knowledge, in Disasters 21(4). 1997;284–304.
[8] Turner B. Man-made disasters. London: Wykeham Pubblications; 1978.
[9] UN–General Assembly. International Decade for Natural Disaster Reduction, resolution act 44/236. New York; 1989.
[10] UN–General Assembly. Strengthening of the coordination of humanitarian emergency assistance of the United Nations, resolution act 46/182. New York; 1991.
[11] UN. Yokohama Strategy and Plan of Action for a Safer World - Guidelines for Natural Disaster Prevention, Preparedness and Mitigation. World Conference on Natural Disaster Reduction. Yokohama; 1994.
[12] UN–General Assembly. UN Millennium Declaration. New York; 2000.
[13] UN-ISDR. Hyogo Declaration, in World Conference on Disaster Reduction. Kobe; 2005.
[14] Mayunga JS. Understanding and Applying the Concept of Community Disaster Resilience: A capital-based approach. Munich; 2007.
[15] Alexander DE. Resilience and disaster risk reduction: an etymological journey. London: Natural Hazards Earth System Science; 2013.
[16] Holling CS. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics 1973;4:2–23.
[17] Fiksel J. Designing Resilient, Sustainable Systems. Environ Sci. Technol 2003;37:5330–5339.
[18] Adger WN. Social and ecological resilience: are they related? Progress in Human Geography September 2000;24:347–364.
[19] Klein RJT, Nicholls RJ, Thomalla F. Resilience to natural hazards: how useful is this concept? Environmental Hazards 2003;5(1–2):35–45.
[20] Smith K. Environmental Hazards: Assessing Risk and Reducing Disaster. 3rd edition. London; 2001.
[21] Quarantelli EL. Emergencies, disaster and catastrophes are different phenomena, Disaster Research Center - University of Delaware; 2000.
[22] Berkes F, Colding J, Folke C. (ed). Navigating social–ecological systems: building resilience for complexity and change. Cambridge: Cambridge University Press; 2003.
[23] Plummer R, Armitage D. A resilience-based framework for evaluating adaptive co-management: Linking ecology, economics and society in a complex world. Ecological Economics 2007;61(1):62–74.
[24] Duijnhoven H, Neef M. Framing Resilience. From a model-based approach to a management process. Procedia Economics and Finance 2014;18:425–430.
[25] Cutter SL, Barnes L, Berry M, Burton CG, Evans E, Tate EC, Webb J. A place-based model for understanding community resilience to natural disasters. Global Environmental Change 2008;18:598–606.
[26] Jordan E, Javernick-Will A. Measuring Community Resilience and Recovery: A Content Analysis of Indicators. Construction Research Congress 2012;2190-2199.
[27] Schneiderbauer S, Ehrlich D. Social levels and hazard (in) dependence in determining vulnerability. Birkmann J. (ed.) Measuring vulnerability to natural hazards: Towards disaster resilient societies. Tokyo: United Nations University Press; 2006.
[28] Birkmann J. Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies. New York: United Nations Publications; 2006.
[29] Risk and Resilience Research Group Center for Security Studies (CSS), ETH Zürich Commissioned by the Federal Office for Civil Protection (FOCP). Zurich; 2012.
[30] Renschler CS, Frazier AE, Arendt LA, Cimellaro GP, Reinhorn AM, Bruneau M. A Framework for Defining and Measuring Resilience at the Community Scale: The PEOPLES Resilience Framework, New York: Multidisciplinary Center for Earthquake Engineering Research (MCEER), 2010.
[31] Mayunga JS. Measuring the measure: A multi-dimensional scale model to measure community disaster resilience in the U.S. Gulf Coast region. PhD. 3370760, Texas, A&M University; 2009.
[32] Cutter, SL. Vulnerability to environmental hazards. Progress in Human Geography 1996;20(4):529–539.
[33] Cutter, SL, Finch C. Temporal and spatial changes in social vulnerability to natural hazards. PNAS 2008;105(7):2301–2306.
[34] Cutter SL, Burton C, Emrich C. Disaster Resilience Indicators for Benchmarking Baseline Conditions. Journal of Homeland Security and Emergency Management 2010;7(1).
[35] Bruneau M, Chang SE, Eguchi RT, Lee GC, O'Rourke TD, Reinhorn AM, Shinozuka M, Tierney KT , Wallace WA, Von Winterfeldt D. A framework to quantitatively assess and enhance the seismic resilience of communities. Earthquake Spectra 2003;19(4):733–752.
[36] Cimellaro GP, Fumo C, Reinhorn AM, Bruneau M. Quantification of seismic resilience of health care facilities. MCEER technical report-MCEER-09-0009. Buffalo (NY): Multidisciplinary center for earthquake engineering research; 2009.
[37] Jackson S. A multidisciplinary framework for resilience to disasters and disruptions. Journal of Integrated Design and Process Science 2007;11(2):91−108.
[38] Forrester JW. Industrial dynamics: a major break through for decision makers. Harvard Business Review 1958;36(4):37-66.
[39] Sterman JD. Business Dynamics: Systems Thinking and Modelling for a Complex World. New York: McGraw-Hill; 2000.
[40] Blumberga A, Timma L, Romagnoli F, Blumberga D. Dynamic modelling of a collection scheme of waste portable batteries for ecological and economic sustainability. Journal of Cleaner Production 2015;88:71−82.