Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 212 (2018) 198–205

Procedia Engineering

www.elsevier.com/locate/procedia

7th International Conference on Building Resilience; Using scientific knowledge to inform policy and practice in disaster risk reduction, ICBR2017, 27 – 29 November 2017, Bangkok, Thailand

# Necessities and challenges to strengthen the regional infrastructure resilience within city clusters

S. Thomas Ng[a]*, Frank J. Xu[a], Yifan Yang[a], Mengxue Lu[a], Junjie Li[b]

[a]*Department of Civil Engineering, The University of Hong Kong, Pokfulam, China*
[b]*College of Computer Science & Software Engineering, Shenzhen University, China*

**Abstract**

Building resilient infrastructure and making cities and human settlements inclusive, safe, resilient and sustainable are the important elements making up the goals of the 2030 Agenda for Sustainable Development. Economic development and population growth have brought diverse needs of citizens for urban mobility resulting in various forms of urbanization including suburbanization, urban sprawl, and local or cross-border city clusters, and this has generated greater citizens' demands for quality, resilient, safe and secure infrastructure services. As infrastructures of different cities within a cluster are highly interdependent and interconnected, any minor disruptions of a single infrastructure component within a city could lead to unpredictable knock-on effects on its neighbors. Despite great research efforts being attributed to community and city resilience, there are limited studies focusing on regional infrastructure resilience within the city clusters, in particular those cross-border city clusters like the Pearl River Delta city cluster of China.

This paper aims to investigate the necessities and challenges of strengthening regional infrastructure resilience within the city clusters by applying and extending an integrated framework for resilience management of internetwork city infrastructures developed by the authors. The necessities, gaps and challenges will be explored from multiple perspectives not least the organizational structure, people, policy, management process, technology and supporting system, as well as the decision-making and performance management perspectives. Two typical city clusters in China are selected for case studies. Programs and practices of the cities within the two clusters pertinent to sustainable development, climate change, urban planning, built environment management and hazard management are critically examined and analyzed to produce a panoramic view on the necessities and challenges. The findings of this research shall invoke more innovative researches and solutions to enhance national, regional and city resilience, as well as building regional sustainability.


Peer-review under responsibility of the scientific committee of the 7th International Conference on Building Resilience.

* Corresponding author. Tel.: +852-28578556; fax: +852-25595337.
*E-mail address:* tstng@hku.hk

1877-7058 
Peer-review under responsibility of the scientific committee of the 7th International Conference on Building Resilience
10.1016/j.proeng.2018.01.026

*Keywords:* Infrastructure resilience; regional resilience; city cluster; resilience management; sustainable development

## 1. Introduction

Urbanization is one of the most transformative drivers for economic growth as well as social and cultural development in modern society. Well-planned and properly managed infrastructures *viz*. buildings, transportation, water and energy are crucial to underpin sustainable urban development. Nowadays, cities account for over 70% of global GDP and consume over 60% of global energy. It is estimated that by 2050, two thirds of world's population will be living in cities with 41 mega-cities expected to emerge [1].

Over the last century, dramatic and rapid changes of our society including the geographic, economic, social, physical, governance and technological aspects have given rise to the emergence of a variety of spatial patterns of cities such as urban agglomerations, city clusters, city-regions, urban corridors, polycentric cities, regional networked cities, and cross-border metropolitan regions [2]. Well-known examples include the Pearl River Delta and the Yangtze River Delta regions in China and the Singapore–Johor Bahru–Bintan growth triangle [3]. While these diverse urban configurations play vital roles in promoting economic growth, the cities within these patterns are facing unprecedented demographic, environmental, economic, social and spatial challenges to meet the greater citizens' demands for quality, resilient, safe, secure and sustainable infrastructure services.

In recent years, city-region and cluster-based economic development approaches have resurged as a promising way to help cities and regions' enhance competitiveness, stimulate innovation, conserve and share public resources, reduce business transaction costs, and tackle environmental and social problems towards sustainable development. In China, an acceleration of city cluster development has been formulated as the government's national strategy to implement the National New-type Urbanization Plan targeting to improve its urbanization ratio to 60% by 2020 [4].

Building resource-efficient, reliable, well-connected, safe, smart and resilient infrastructures and making cities and human settlements inclusive, safe, resilient and sustainable have become the core elements making up the objectives of the 2030 Agenda for Sustainable Development and the Habitat III New Urban Agenda (NUA) [5]. The NUA also calls for member states to implement sustainable urban and territorial planning, build resilience, foster mitigation of and adaptation to climate change by using the integrated city region or city-cluster concepts.

With a growing frequency and severity of natural disasters and man-made hazards, various programs and initiatives have been launched by different governments and organizations to improve the resilience of critical infrastructure systems and develop pragmatic strategies to ensure a community can *"plan for, absorb, respond to, recover from, and more successfully adapt to new adverse events*" [6]. Examples of influential resilience initiatives include the Making Cities Resilient Campaign [7]; Rockefeller Foundation's 100 Resilient Cities Network (www.100resilientcities.org); and other national initiatives in the US, UK and Australia [8].

Building the regional infrastructure resilience of city clusters appears more challenging than uplifting the resilience of a single city. On one hand, infrastructures of different cities within a cluster are highly interdependent and interconnected at uncertain spatial and temporal scales. On the other hand, city-cluster resilience operation and management practices involve substantial complexities in terms of policy formulation, urban planning, integrated management of built infrastructure assets, and performance monitoring and evaluation for continuous improvement.

To address the research and practice gap, this paper aims to investigate the necessities and challenges of strengthening the regional infrastructure resilience within the city clusters. This study applies and extends an integrated framework for resilience management of internetwork city infrastructures developed by the authors. Drawing on published resilience literatures, government plans and published reports, Section 2 of this paper firstly reviews the previous related works of city cluster, city region, community and urban resilience. Data sources and methodology for conducting this research are then presented in Section 3. To explore the necessities, gaps and challenges, two representative case studies are discussed in Section 4 from multiple perspectives. In Section 5, the necessities and challenges are highlighted to provide relevant stakeholders an overall picture of the necessities and issues. Finally, the authors deliberate the open questions and the future direction for devising a generic regional resilience framework in order to facilitate deriving suitable resilience solutions reconciling with the profiles of different city clusters.

## 2. Related works

### *2.1. Concepts of city cluster, city region and urban agglomeration*

City cluster, city region and urban agglomeration are complementary and evolving concepts widely spreading in a variety of research disciplines, e.g. geographical economics, urban planning and regional studies. The origin of these concepts can be traced back to the seminal studies of Howard's work on *'town cluster'*; Geddes' research on the internal dynamics of cities and the process and sprawling patterns of urbanization; Christaller's central place theory; and Gottmann's prestigious and pioneering contribution to *'megalopolis'*, just to name a few [9].

A *city cluster* can be defined as a group of closely spaced, though physically discrete, towns and/or cities which share access to common infrastructure, geo-spatial proximity for supply chains and networks, and concentrations of human resources and skills, and thus help lower the production and transaction costs [10]. The concept of cluster is also utilized by Porter to explore the competitive advantage of industries and nations [11]. The *city region* has been considered as a 'chaotic' concept used for conceptualizing the transformation of metropolitan economic, political, technical and social landscape of global urbanization [2]. The *urban agglomeration* concept is coined by the United Nations to refer to a contiguous territory inhabited at the urban density levels without regarding to the administrative boundaries, which could consist of high-density metropolises, small cities, as well as some rural areas [9].

Besides the aforementioned three concepts, there are also many other similar terms depicting the spatial patterns of a cluster of cities, such as urban regions, urban clusters, concentrated urban areas, metropolitan areas, expanded metropolitan areas, urban-rural integrated regions, metropolitan regions, megalopolis, new urban cluster belt, and others. The comprehensive literature review by Fang and Yu reveals that a general concept of *'urban agglomeration'* can be used to summarize all the relevant concepts, which is defined as *'a highly integrated cluster of cities'* [9]. Throughout this paper we adopt this definition and use the terms *'urban agglomeration'*, *'city region'* and *'city cluster'* interchangeably. The various cities within a city cluster function as an integrated community to provide their residents with a full range of food, products, trading, manufacturing, as well as infrastructure and social services by sharing coordinated master plans, supply chains, urban and rural development projects, urban infrastructure networks, information flows, financial and marketing practices, science and technology knowledge, etc.

### *2.2. City cluster development in China*

Over the last three decades, China has been on its journey towards industrialization; and developing city clusters has recently become the national strategy of China to realize new-type urbanization. From 1978 to 2013, China's urbanization ratio has risen from 17.9% to 53.7%, with the number of urban residents in China risen from 170 million to 730 million and the number of cities increased from 193 to 658 over that period of time [12].

By 2013, three urban agglomerations have been formed in China, which include the Beijing-Tianjin-Hebei (BTH) Bohai Rim city cluster, the Yangtze River Delta (YRD) city cluster, and the Pearl River Delta (PRD) city cluster. These three clusters altogether contribute to 36% of China's GDP, with about 18% of China's population inhabiting on the mere 2.8% of the national territorial area. The clusters have already evolved into regional networks of cities which are linked together by the increasingly sophisticated urban infrastructures and the integrated industrial chains. This provides China with the major platform to participate in the global economic system and promote rapid economic growth [4].

According to the National New-type Urbanization Plan, China is actively establishing a hierarchical urban agglomeration system to achieve the goals of the people-centered sustainable urbanization. The urban agglomeration system is to be built irrespectively at the national, regional and local levels through sound coordination mechanisms in economic structure optimization and upgrades, infrastructure development, ecological conservation and environmental improvement. The 'Plan' proposes optimizing and enhancing the BTH, YRD and PRD regions to be the global urban agglomerations; nurturing Chengdu-Chongqing, Central Plain, Middle Reach of Yangtze River, and Hachang urban agglomerations in the central, western and north-eastern regions; and piloting the establishment of cross-border urban agglomerations, e.g. the Guangdong-Hong Kong and Macao Bay area urban agglomeration. Meanwhile, building city corridors is one key components of China's *'One Belt, One Road'* initiative [13].

### 2.3. Community, urban and regional infrastructure resilience

Community resilience researches broadly emphasize the integrated capacities of a community to mitigate and adapt to disturbance or adversity originating from climate change, natural hazards, or man-made threats without detrimental resultant manifestation in population's wellness, levels of mental and behavior health, functioning, and quality of life [14]. Agarwal *et al.* examined the diverse definitions and interpretations of community resilience, as well as how it relates to vulnerability, risk and adaptability [15].

How to measure community resilience currently remains a hot and challenging research topic, and there is still no consensus on the general measurement methods and standards for community resilience metrics. Currently, there are prevailing methods to measure community and urban resilience, ranging from multi-dimensional [16] and multi-stage assessment framework [17], to analytical function, and resilience index [18]. Underpinned by these approaches, the current trend evolves to analyze the temporal-spatial variation of community and urban resilience [19].

As for infrastructure resilience, current studies mainly focus on those engineering systems pertinent to defining and quantifying resilience. Approaches similar to community resilience analysis like resilience index, multi-dimension [20], multi-stage framework, dynamic inoperability input-output model (DIIM) [21] and probabilistic modeling approach [22] are adopted in some specific infrastructure sectors. Due to the network features and complexity of infrastructures, a network theory is also adopted for resilience analysis in road transportation, water and gas distribution, electricity transmission, and telecommunication systems [23,24].

### 2.4. The inter-network infrastructures resilience management framework

The authors have recently developed an ICT-driven inter-network infrastructures resilience management (ICT-IN-IRM) framework. This framework can be employed and extended to investigate the necessities and challenges of strengthening the regional infrastructure resilience within the city clusters. Figure 1 demonstrates the seven major components of the ICT-IN-IRM framework. Detailed interpretation can be found in [25].

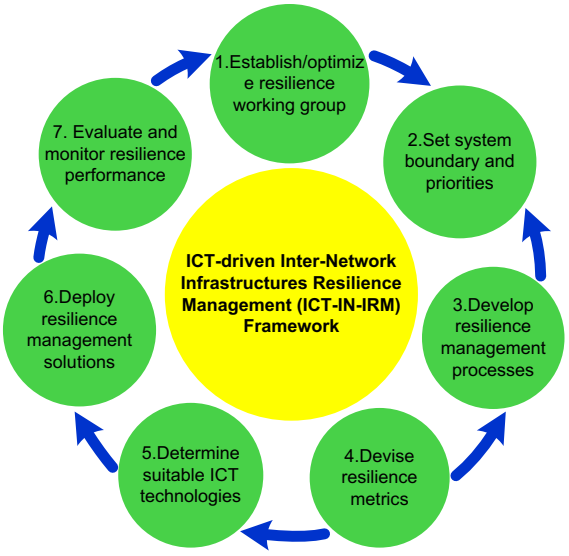


*Figure 1. The ICT-driven Inter-network Infrastructures Resilience Management (ICT-IN-IRM) Framework*

## 3. Data and methodology

A set of methods were adopted in this research, and these include desktop study, focus group meetings, interviews, and inductive qualitative content analysis of policies and strategies issued by governments pertaining to building resilience for infrastructures within predefined city clusters (see the two city clusters below). Interviews were conducted to clarify certain ambiguous issues and contents in such policies and strategies. Similarly, categories of

disturbances, threats, disasters, incidents, stresses, infrastructure service failures, hazard events, and countermeasures to dealing these hazards facing infrastructure systems were collected from authoritative media sources or incident reports disclosed on official websites. Existing management practices in infrastructure asset management, risk management, security and safety management and smart city management were also examined to clarify the practices related to emergency or hazard management, which should be treated as an initial step towards a resilient infrastructure system.

The collected data were investigated through the seven dimensions *viz*. (i) organization structure; (ii) people engagement; (iii) policies, strategies and pilot initiatives; (iv) management process; (v) performance metrics formulation and management; (vi) technology and supporting systems; and (vii) decision-making and monitoring. Notably, the current study pays more attention to the cooperation and collaborative efforts of cities within the same city cluster and relevant to infrastructure resilience when scrutinizing through the above dimensions. As a demonstration, two case studies were conducted for two city clusters, the Guangdong-Hong Kong-Macao Greater Bay Area and the YRD region, respectively.

## 4. Case studies

### *4.1. Guangdong-Hong Kong-Macao Greater Bay Area*

Infrastructure sector serves as the main contributor to energy consumption and carbon emissions, giving rise to climate change and adversely jeopardizing the resilience capacity. Hong Kong has initiated an Inter-department Steering Committee on Climate Change recently to steer and coordinate the climate actions of various organizations. Apart from those organizational arrangements, various strategies and guidelines like the Energy Saving Plan for Hong Kong's Built Environment 2015~2025+, Hong Kong 2030+: Towards A Planning Vision and Strategy Transcending 2030, Energy Audits and Energy Saving Practices for Government and Public Buildings, Contingency Plan for Natural Disasters, Landslip Prevention and Mitigation Program, etc. have been proposed to enhance Hong Kong's resilience from the policy end. As for the technology and supporting systems, notable examples in Hong Kong are the advanced weather warning and alert system and the early storm surge system, which support decision-makers to make informed proactive measures to mitigate and prevent damage caused by extreme weather. From the process management perspective, different fund schemes including the Green Transport Fund, Building Energy Efficiency Fund Scheme, etc. are launched to encourage early trials towards resilience. Guangdong and Macao governments respectively attempt to build up resilience capacity within their administration boundary from similar aspects ranging from organizational arrangement, seed funding support, and issuance of preliminary guidelines. However, there is still a lack of a set of consistent processes, systems and metrics to help evaluate, monitor, track and improve infrastructures' performance towards adaptation and resilience. In additional, education, engagement, collaboration and partnership among the community, government departments and private sectors are crucial to pursue a holistic and effective resilience scheme.

A Greater Bay Area development plan, which comprises 9 cities of Guangdong province plus Hong Kong SAR and Macao SAR, is proposed by the National State of Council in early 2017 to build cross-border city cluster and enhance cross-border collaboration, technology innovation, as well as optimize and integrate resources allocation in order to promote economic prosperity. Within such regional context and close connections between infrastructure systems across the border, different governments need to collaborate to face the challenges pertaining to infrastructure resilience joint-handedly. As a result, a regional, mutually agreed and holistic resilience management framework is indispensable. Great efforts have been attributed to constructing an integrated cross-border transportation system with pilot projects like the Hong Kong-Zhuhai-Macao bridge and the Guangzhou-Shenzhen-Hong Kong Express Rail Link. At the Guangzhou / Hong Kong Cooperation Joint Conference, a *Framework Agreement on Hong Kong/Guangdong Cooperation* was signed as basic guidance. Subsequent endeavors should be focusing on formulating consistent infrastructure asset management process and enacting common specification standards for reference. Moreover, a consistent set of adaptation and resilience metrics for assessment and monitoring along with a data scheme for encoding information on infrastructure resilience would be the foundation to achieving coordinated resilience management within the Great Bay Area. Based on these consistent standards and schemes, an information technology

system for the appraisal and management of infrastructure resilience can be established. Experiences can be accumulated from the East River-Shenzhen Water Supply Project which is a representative cross-border infrastructure system operated for 50 years, especially for the risk and benefit sharing arrangement. Water resources from Guangdong enhance the diversity of water supply and thus releasing the burden of relying solely on precipitation in Hong Kong which allows reservoirs to dynamically adjust the level of reserve. Such diversity essentially enhances the resilience capacity of the Hong Kong community to extreme drought conditions. On the energy transmission side, nuclear power from Guangdong gradually converts the energy production structure in Hong Kong, and help contribute to creating a cleaner society and help combat climate change. Notably, Hong Kong government should also consider the operational capacity of inner-city transportation infrastructure systems as the demand instigated by cross-border infrastructure connection would inevitably cause accelerated aging problem, frequent breakdown and even overcapacity problems of the existing transportation infrastructure systems.

### *4.2. Yangtze River Delta Region / Beijing–Tianjin–Hebei mega-city region*

The Yagtze River Delta region collaborative development strategy has been running for many years in China. The basic transportation infrastructure network, especially the cross-provincial expressway and high-speed railway, is formulated which laid down a strong foundation for cross-provincial resource allocation and economic development. Besides transportation infrastructure, collaborations are also witnessed in the water and energy supply sectors. Through such collaborative effort, strengths of relevant cities are evidenced and the weaknesses can be compensated by the strengths of neighboring cities to achieve holistic efficiency of resource allocation and avoid homogeneous competition in the region. Moreover, provinces and cities in this region are collaborating in terms of emergency responses and disaster risks reduction, including but not limited to flood hazard and air pollution governance.

However, collaboration should be further proceeded to formulating the unified management objectives, processes and integrated systems for infrastructure asset management, consistent specification standard for infrastructure planning, and consistent performance indicator systems or resilience metrics for timely monitoring and continuous improvement of the city cluster infrastructures. From the perspective of organization structure, a high-level steering board would be beneficial for cross-provincial collaboration. Technically, a data scheme for encoding and exchanging information is essential for establishing an integrated IT-driven infrastructure management platform with cutting-edge information and communication technologies, such as the internet-of-things, big data and cloud computing, which is yet to be explored.

## 5. Necessities and challenges to strengthen regional infrastructure resilience within city clusters

### *5.1. Necessities*

The preliminary results of our study have demonstrated the necessities to strengthen the regional infrastructure resilience within city clusters as follows:

- Different city clusters / urban agglomerations and different cities within one city cluster need to coordinate and cooperate to build resilience capability against all forms common hazards they may face.
- Growing integration, interconnectedness and interdependencies of infrastructures and economies of cities within the city clusters generates increasing complexity for regional resilience building and improvement.
- Strengthening the regional infrastructure resilience needs to consider the diversity and evolutionary dynamics of infrastructure configurations over different lifecycles and across different sectors, cities and city clusters.
- All organizational and individual actors of a city cluster, not least the governmental departments, non-profit communities, urban planners, infrastructure operators, city mayors and managers, etc. shall examine their existing policies, strategies, plans, operational practices and processes and information systems through an integrated and regional resilience lens in order to come up with a tailored approach to improve resilience that could reconcile the infrastructure characteristics and profiles (i.e. types, density, ages, and capabilities to withstand various hazards, shocks and stresses) of the city cluster.

### *5.2. Challenges*

Strengthening the regional infrastructure resilience within the city clusters encounters the same challenges as a single city is facing for the resilience management of inter-network infrastructures [25]:

- Incomplete, incorrect and inconsistent understanding and awareness on resilience principles and types across multiple stakeholders, sectors and disciplines;
- Accelerated interdependencies between infrastructure systems and between the services being provided;
- Co-existence of various types of aging and deteriorated built infrastructure assets and facilities and a growing number of new mega infrastructures in particular in Asian countries;
- Increasing types and frequencies of adverse events, as well as the ranges and scales of negative impacts brought by those events;
- Lack of unified methodology, processes and metrics to assess and measure resilience performance;
- Fragmented, vague and untraceable resilience management activities;
- Lack of quality data to optimize the resilience improvement processes based on relevant performance indicators;
- Lack of supporting tools and systems for data collection, data analysis and resilience decision-making;
- Lack of integrated framework and information technology solutions to support resilience management;
- Lack of proven best practices for benchmarking; and
- No long-term roadmap and strategy for launching large-scale and cross-scale resilience management initiatives.

Besides, there are other essential challenges that need to be tackled in particular when building regional infrastructure resilience as follows:

- How to determine responsible organizations and persons for leading the regional infrastructure resilience;
- How to identify suitable infrastructure sectors, boundaries, criticalities and priorities for improving regional infrastructure resilience;
- How to orchestrate and streamline the resilience improvement efforts of different cities to achieve overall regional resilience that could reconcile the specific infrastructure configurations of a city cluster;
- How to engage governmental agencies, business sectors, social communities and individuals, and build a strong public-private partnership for co-producing regional resilience;
- How to leverage the power of those top-down state-driven strategy for city cluster development (e.g. in China) and the advantage of any bottom-up whole-community resilience building approaches (e.g. by FEMA of the US) for achieving long-term and sustainable regional resilience;
- How to make better use of emerging information and communication technology (e.g. social media and mobile applications) and solutions (e.g. smart infrastructure and smart city platforms) to collect, integrate, communicate, share and utilize the relevant data and knowledge to support resilience decisions of different stakeholders; and
- How to establish and implement consistent city cluster public policy across the local administrative boundaries and multiple sectors for achieving sustainable regional resilience.

## 6. Discussions and Future Work

The development of city cluster and urban agglomeration has recently received increasing attention by developing countries like China with a desire to implement a sustainable and new-type urbanization, and the concepts and principles of resilience and adaptation have been adopted by more developed countries and international organizations to tackle a wider range of natural and human-made hazards and foster mitigation of and adaptation to climate change. Despite the large volumes of research, news and policy reports attributed to resilience, limited research has been conducted on how to strengthen the regional infrastructure resilience within the city clusters.

By using an integrated framework for resilience management of internetwork city infrastructures developed by the authors as a tool, the present paper investigates the necessities and challenges for improving the regional infrastructure resilience within the city clusters, through comprehensive literature review, deep analysis of reported incidents and accidents and government plans and guidelines, focus group meetings with experts and case studies. The preliminary results reveal that each city cluster may need a tailored approach that fits the spatial, temporal and technical profiles

of the infrastructures in the city clusters to achieve sustainable resilience, which is expected to be developed through collective efforts, coordination and innovation across multiple jurisdictions and sectors and by active engagement of various organizations and communities.

The future work would include but is not limited to the development of an integrated framework for building regional infrastructure resilience within the city clusters, a study on the methodology for evaluating the infrastructure resilience of the city clusters, designing the regional infrastructure resilience metrics, exploring the resilience hotspot analytical techniques, and prototype development of a regional infrastructure resilience management and collaboration service platform which is enabled by such information and communication technologies as cloud computing, internet-of-things, crowdsourcing, social network, mobile applications, data science and big data analytics.

## Acknowledgements

The authors would like to thank the Research Grants Council of the HKSAR Government for funding this work under the General Research Fund (Project No.: 17202215 & 17248216). The financial support of The University of Hong Kong through the CRCG Small Project Fund (Project No.: 201409176107) is also gracefully acknowledged.

## References

[1] UN, World urbanization prospects (2014 revision) (2015), United Nations, New York.
[2] J. Harrison, The city-region: in retrospect, in snapshot, in prospect, in: K. E. Jones, A. Lord, R. Shields (Eds.), City-regions in prospect? : exploring points between place and practice, McGill-Queen's University Press, Montreal & Kingston, 2015, pp. 20-52.
[3] UN-Habitat, World cities report 2016 – urbanization and development: emerging futures, UN-Habitat Programme, Nairobi, Kenya, 2016.
[4] The State Council, National New-type Urbanization Plan (2014–2020), The People's Republic of China, http://www.gov.cn/zhengce/2014-03/16/content_2640075.htm, accessed on May 18, 2017.
[5] United Nations General Assembly, New Urban Agenda: Resolution adopted by the General Assembly on 23 December 2016 (2017).
[6] NRC, Developing a framework for measuring community resilience, National Research Council, USA, 2015.
[7] UNISDR, Making development sustainable: The future of disaster risk management, Geneva, Switzerland, 2015.
[8] NIST, Community resilience planning guide for buildings and infrastructure systems - volume I & II, National Institute of Standards and Technology, Gaithersburg, MD, USA, 2015.
[9] C. L. Fang, D. L. Yu, Urban agglomeration: An evolving concept of an emerging phenomenon, Landsc. Urban Plan. 162 (2017) 126–136.
[10] S. Krakover, Cluster of cities versus city region in regional planning, Env. Plan. A 19 (1987) 1375-1386.
[11] M. E. Porter, The competitive advantage of nations, Harvard Business Review 68(2) (1990), 73-93.
[12] SDPC, The 13th Five-Year Plan for Economic and Social Development of The People's Republic of China (2016–2020), http://www.sdpc.gov.cn/, accessed on May 18, 2017.
[13] The State Council, New guidelines to further promoting new-type urbanization, The People's Republic of China, http://www.gov.cn/zhengce/content/2016-02/06/content_5039947.htm, accessed on May 18, 2017.
[14] F.H. Norris, S.P.Stevens, B. Pfefferbaum, K.F.Wyche, R.L. Pfefferbaum. Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. American journal of community psychology, 41(1-2)(2008), 127-150.
[15] J. Agarwal, Improving resilience through vulnerability assessment and management, Civ. Eng. Environ. Syst., 32(1-2) (2015), 5-17.
[16] G.P. Cimellaro, C. Renschler, A. M. Reinhorn, L. Arendt, PEOPLES: a framework for evaluating resilience, Journal of Structural Engineering, 142(10) (2016), 04016063.
[17] K. Fischer, I. Häring, W. Riedel, G. Vogelbacher, S. Hiermaier, Susceptibility, vulnerability, and averaged risk analysis for resilience enhancement of urban areas, International Journal of Protective Structures, 7(1) (2016), 45-76.
[18] S. Yu, S. W. Kim, C.W. Oh, H. An, J.M. Kim, Quantitative assessment of disaster resilience: An empirical study on the importance of post-disaster recovery costs, Reliability Engineering & System Safety, 137 (2015), 6-17.
[19] S. L. Cutter, C. G. Burton, C. T. Emrich, Disaster resilience indicators for benchmarking baseline conditions, Journal of Homeland Security and Emergency Management, 7(1) (2010).
[20] J.C. Matthews, Disaster resilience of critical water infrastructure systems, Journal of Structural Engineering, 142(8) (2015), C6015001.
[21] H. Baroud, K. Barker, F. Hank Grant, Multiobjective stochastic inoperability decision tree for infrastructure preparedness, Journal of Infrastructure Systems, 20(2) (2013), 04013012.
[22] P. Franchin, F. Cavalieri, Probabilistic assessment of civil infrastructure resilience to earthquakes, Comput. Aided Civ. Inf., 30(7) (2015), 583-600.
[23] W. Zhang, N. Wang, Resilience-based risk mitigation for road networks, Structural Safety, 62 (2016), 57-65.
[24] E. Levenberg, E. Miller-Hooks, A. Asadabadi, R. Faturechi, Resilience of Networked Infrastructure with Evolving Component Conditions: Pavement Network Application, Journal of Computing in Civil Engineering, (2016), 04016060.
[25] S. T. Ng, F. J. Xu, An integrated framework for resilience management of inter-network city infrastructures, Proceedings of the 5th International Conference on Building Resilience, Newcastle, Australia, 15-17 July 2015, pp. 564-1:13.