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Comparative-Analytical Assessment of Urban Disaster Resilience Models

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ABSTRACT

In the present century about the growing of economic, human, ecological and social resources, and they're centralized in the cities and their importance has caused excessive attention to Disaster result from natural and man-made comes. It reduces the cost of the damage to structure and function of cities to quickly retrieve. The present century is a turning point in the disaster management approaches and attitudes from Disaster management to risk management and urban resiliency that several models over these years have been developed. The goal of this study was to find urban resilience models and their comparative assessment to meet their structural differences and integrated analysis to offer an suitable urban resiliency framework. to meet these goals, 10 urban resiliency model in the face of disasters among 2009 and 2015 have been found and evaluated in the analytical framework. The findings show that these models often have differences in form and substance. Some of these models have taken steps to expand concepts of resiliency and others have focused on resiliency components, criterions, indicators and how to show and measure the resiliency.
KEYWORDS: Resiliency; Disasters, Models, Hazard

1. INTRODUCTION

More than a decade after starting attempts for quantifying community resilience, endeavors are still ongoing to refine and develop more applicable resilience models [1].There exist a number of centers which are investigating urban resiliency in different scales, mostly based in the US. They have developed a few disaster resilience models of varying degrees of comprehensiveness and sophistication, some of which have been and are being applied to real-life communities and places for purposes of research and/or policy analysis and/or education[2, 3]

This paper offers an overview of current disaster resiliency models. It starts by examining the general definitional issues of the concept and then presents eight resiliency models which will be evaluated later by criterions such as comprehensiveness, models structure and components, methods, scale and unit of analysis, dynamics, data requirements, validation and operationally, and actual and potential applications. The paper shows that most of the existing frameworks have not been fully operationalized and validated with real data yet, and ends with speculating about the most capable avenues to further develop effective and implementable planning and design strategies for increasing the resiliency of cities to the potential future shocks.

2. RESEARCH METHODOLOGY

The methodology of this study is based on studying scientific documents and analysis of them so that getting specific the dimension of resilience models in order to comparative assessment. In accordance with the main objectives, there are there steps involved in writing this research paper.

Figure 1 displays the research methodology.

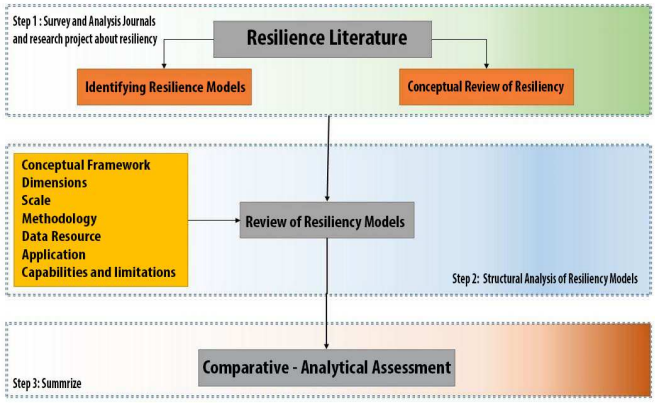

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Figure 1.Research Methodology

In the first step in order to verify the concept of resilience and identify models of resilience has done a wide search in scientific sites. Because of the objective of this study is process analyzing and evaluate new models of urban disaster resilience so resilience models made between 2009 and 2015 has surveyed. In the second step in order to verify the models and the definition of the appropriate framework to comparative assessment, the models were studied in seven aspects. Model Capability and limitation

- This aspect survey model capabilities and limitations
- In the final step, all models based on these asp 503 e placed comparative analytical assessment Resilience Models

3. Resiliency Models

In order to identify indicators and to develop the final urban resilience assessment framework addressed and analyzed resilience models to identify their conceptual framework. In the last 50 years due to the resilience of communities in urban systems is growing day by day, but most models have been devised and proposed a coherent and strong in the current century[4]. generally this paper aims to survey and analysis resilience models and tries to have an analytical – comparative assessment with each other. Each model tries to develop a new framework for assessing resilience. With this approach, some of them tried to complete earlier models and some others presented a new aspect of urban resiliency. For this purpose, eight resilience model that are most cited was selected. At first describe the model framework and after that these model was compared with each other's based on some axis.

3.1. CDRI

Climate Disaster Resilience Index (CDRI) has developed about climate change in Tokyo University by Shaw (2009).this model presented five dimensions for urban resiliency and for each dimension developed its indicators. CDRI also assess the urban resiliency in nine Asian countries including Indonesia, Thailand, Sri Lanka, Vietnam, Philippine, India, and japan. Table 1 shows the dimensions and indicators of this model[5].

Table 1. Dimensions and indicators of CDRI Model[5]

Dimensions	Variable considered
Physical	Electricity, Water supply, Sanitation, Solid waste disposal, Internal road network, Housing and land use, Community assets, Warning system and evacuation
Social	Health status, Education and awareness, Social capital
Economic	Income, Employment, Households' assets, Access to financial service, Savings and insurance, Budget and subsidy
institutional	Internal institutions and development plan, Effectiveness of internal institutions, External institutions and networks, Institutional collaboration and coordination
Natural	Hazard intensity, Hazard frequency

Data collected from questionnaire surveys were computed in excel. To better describe Climate Disaster Resilience Index (CDRI), prime goal of this model, some weights were assigned. Aggregate Weighted Mean Index or AWMI (for each dimension) was calculated by using Weighted Mean Index (WMI) method. The calculated AWMI of one dimension is the CDRI of that dimension[5].

Initially, rating scale has been constructed and weight has been assigned subjectively based on how the city officials perceive the vulnerability of each variable by comparing them one by one. Each dimension (natural, physical, social, economic, institutional) correspond to various variables (Table 1) through which their respective scores are calculated.

Rating scales are given the numbers 1, 2, 3, 4 corresponding to very low, low, high and very high respectively. Therefore, WMI was calculated by summing the product of the weights (given by city officials) to the index of each variable (obtained from the sum of rating scales under any given variable divided by the number of elements) and finally dividing the whole by the number of variables in each dimension. Overall CDRI values are obtained after averaging each of the five dimensions' resilience values. Figure 2 show the Resilience mapping for Iloilo city, in Philippine[5].

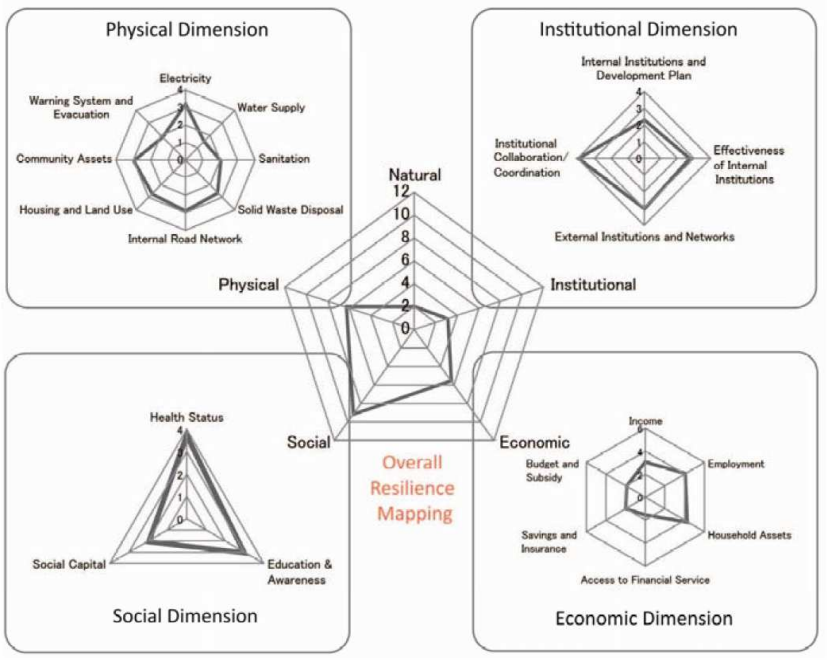


Figure 2. Resilience mapping for Iloilo city [5]

3.2. URF

Urban Resilience Framework (URF) is a model was developed by Stephen Tyler and Marcus Moench in 2010. From the perspective of this model, resiliency is maintaining system function in the face of pressure and changes. So the three basic characteristics for resilient systems is [6]:

- Flexibility and diversity: The ability to perform essential tasks under a wide range of conditions, and to convert assets or modify structures to introduce new ways of doing so. A resilient system has key assets and functions physically distributed so that they are not all affected by a given event at any one time (spatial diversity) and has multiple ways of meeting a given need (functional diversity).
- Redundancy, modularity: Spare capacity for contingency situations, to accommodate increasing or extreme surge pressures or demand; multiple pathways and a variety of options for service delivery; or interacting components composed of similar parts that can replace each other if one, or even many, fail. Redundancy is also supported by the presence of buffer stocks within systems that can compensate if flows are disrupted (e.g. local water or food supplies to buffer imports). .
- Safe failure: Ability to absorb sudden shocks (including those that exceed design thresholds) or the cumulative effects of slow-onset stress in ways that avoid catastrophic failure. Safe failure also refers to the interdependence of various systems, which support each other; failures in one structure or linkage being unlikely to result in cascading impacts across other systems

Based on URF framework for promoting urban resilience, training and organization capacity (responsible and participatory) and visualization capacity and expedient execute the strategies must put on the agenda. This model focuses on climate change and the disaster resultant from it and definite its territory in the city and the local community. Figure show URF conceptual framework [6].

Unlike earlier models that focus on how to assess their resilience, URF emphasis on process and planning and intend to offer a module and framework for preparation and implementation a comprehensive plan for urban resilience to deal with climate changes. URF design its process based on 4 main steps include: shared learning multiple stakeholders, Vulnerability Assessment, Sector studies and Pilots and Resilience Planning [7].

This cycle suggests preparation and implementation of resilience plan based on partnership module that is continuous and incessant process need to comment on all matters. It is in fact URF is the result of extensive studies by ACCCRN (Asian Cities Climate Change Resilience Network) and this model was applied in the cities of these countries (India, Vietnam, Bangladesh, Indonesia, etc.).Figure 4 shows URF planning cycle.

Figure 3. Resilience Planning Cycle [7]

URF typically means resiliency as reducing vulnerabilities against climate change. Identifying vulnerabilities is also a collaborative process with use of geographical analysis tools. Another significant point is this model has a lot of emphasis on the capabilities of Non-Governmental Organizations (NGOs). In general URF has Common aspects with Community-Based Disaster Risk Management (CBDRM) concepts [7, 8].

3.3. BRIC

Baseline Resilience Index (BRIC) has developed by cutter and et al (2010) based on DROP model, and the main goal was to introduce criterions and indicators for measuring resiliency. This is a regional model and applied in eight south-east states of US. BRIC presented resiliency criterions and indicators in five essential dimensions:

- Social Resilience
- Economic Resilience
- Institutional and Organizational Resilience
- Infrastructure Resilience
- Community Capital

BRIC didn't present any method for weighting criterions and indicators and make same weight for all of them in layers overlapping. Output was resilience map in each dimension and summarized in comprehensive resiliency map. This model was measured resiliency in also local and regional level and presented a visualized resiliency map.

3.4. P.E.O.P.L.E.S

This model has developed by Chris Renschler (2010) and presented in 9th national conference seismic engineering in Toronto, Canada and published in "A Framework for Defining and Measuring Resilience at the Community Scale: The Peoples Resilience Framework" in 2010[3, 9].PEOPLES introduce seven resiliency dimensions and presented massive resilience assessment framework. Figure 4 shows dimensions and criterions for measuring resiliency used by PEOPLES.

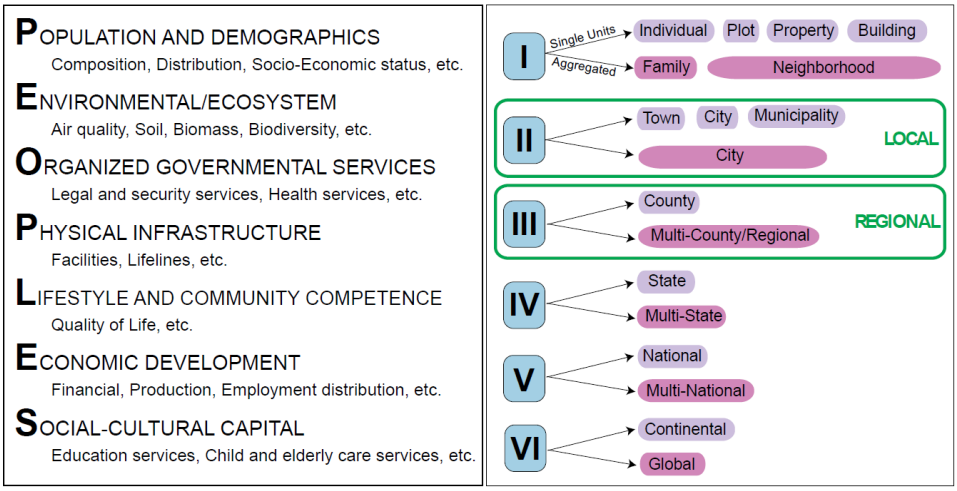


Figure 4 the PEOPLES Resilience Framework and associated Geographic Scales [9-12]

PEOPLES in criticizing earlier models that often refer to the concept of technological and technical resiliency, trying to strengthen social components in assessing and suggested the framework of the resilience components and indicators. Finally to measure urban disaster resiliency, provide decision support software. This model defines its role in local (urban and rural) and regional level [12].

3.5. CCaR and ST-DRM Theory

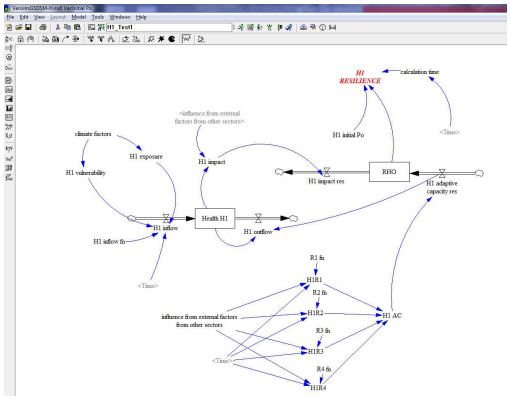
Simonovic and Peck (2013) developed CCaR based on a research project in Ontario University. This model intended to design a simulation model for coastal cities at risk and main goals were to:

- present an original systems framework for quantifying
- resilience and introduce a space-time dynamic resilience measure (ST-DRM)
- discuss ST-DRM theory and calculations introduce Generic System Dynamics Simulation Models (GSDSMs) and provide implementation example
- present a high-level structure of the City Resilience Simulator (CRS);
- provide current state of modeling progress for the CCaR project and outline future work

CCaR classified the resilience dimension to space and time. These resiliency simulations were based on GSDSMs in Vensim Software. GSDSMs applied in economic, health, organizational, physical and social.

Figure 5 shows GSDSM-H simulation and final output of CCaR. This model finally presented simulation of all dimensions of resiliency and measure the resiliency during disaster[13].

In general, this model is one of the advanced models in the modeling and simulating in the area of resiliency that provides the proper software to measure the resiliency. But this model didn't present the resilience indicators as well as other models in this area and just only a lot of emphasis on the model implementation by using special software and trying to find the causes of the damage and identify the potential capability and their impact on the resilience.



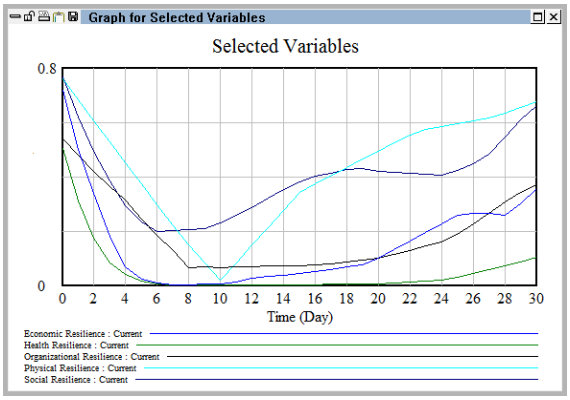


Figure 5 left GSDSM-H; Health generic model structure and right GSDSM-C simulation results for economic, health, organizational, physical and social resilience measures; an illustrative example[14]

Simonovic (2014) applied this model in three subsystems environmental, economic and management in Vancouver, Canada[15]

3.6. CCRAM

Conjoint Community Resiliency Assessment Measure is an initiative tools for multi-dimension assessment of community resilience and Cohen and et al (2013) deve 507 his model includes two steps:

- Local survey and demographic data collection
- To provide suitable data about urban infrastructu.. by questionnaire

The CCRAM population survey was conducted in nine small to medium size towns in Israel, including three types of communities: (1) midsize urban towns, (2) villages and planned communities and (3) collective communities. The self-reported questionnaire asks participants to report on a 5-point Likert scale, the extent to which they agree with each statement (1—strongly disagree to 5—strongly agree) related to six domains: leadership, collective efficacy, preparedness, place attachment, social trust and social relationship. Items also enquire about general and socio-demographic information, including: gender, type of settlement, duration of residence in the community, age, family status, number of children, physical disability, dependence of others on the participant's care, level of education, religion, level of income, and employment status. Other items deal with history of exposure to emergency situations, involvement in volunteering activity, belonging to an emergency response team in their place of residence and availability of emergency preparedness equipment such as shelters at home. Two final questions asked about perceived individual and CR after defining resilience as "the ability to quickly return to routine after an emergency event".

The CCRAM survey data analysis included 31 items from the self-report assessment which yielded six factors: leadership (α=0.95), collective efficacy (α=0.84), preparedness (α=0.83), place attachment (α=0.78), social trust (α=0.85) and social relationship (α=0.72). 0.83), place attachment (α=0.78), social trust (α=0.85) and social relationship (α=0.72) .According to the type of variables, Pearson and Spearman correlation coefficients were calculated and used to examine the association between CCRAM (

Table 2) [16].

Table 2 CCRAM factors: Pearson product-moment correlations

variables	α	1	2	3	4	5	6
1. Leadership	0.95	–					
2.Collective efficacy	0.84	0.62	–				
3. Preparedness	0.83	0.45	0.56	–			
4. Place attachment	0.78	0.60	0.42	0.37	–		
5. Social trust	0.85	0.36	0.51	0.42	0.34	–	
6. Social relationship	0.72	0.36	0.49	0.51	0.22	0.41	–

3.7. SERV

Spatially Explicit Resilience-Vulnerability (SERV) was developed by Frazier et al. (2013) and applied in a large in Sarasota, Florida state. SERV assumes resiliency as reducing vulnerability and emphasis on inharmonic spread social and economic dimension that promote vulnerability and applied in urban and regional level. There distinctions of SERV are :

- Vulnerability assessment in urban and regional level
- Spatial data Assessment
- To provide coefficient for criterions and indicators
- Assessment based on Exposure, Sensitivity and Adaptive capacity

In order to determine the distribution of vulnerability, block scores were then calculated using the following static vulnerability equation:

$$V = [E+S] - AC$$

Where V = vulnerability, E = exposure, S = sensitivity and AC = adaptive capacity.

In order to create the final block-level vulnerability scores, each of the equation's raw component scores (exposure, sensitivity, and adaptive capacity) were calculated [17].

SERV developed 21 indicators for adaptive capacity (such as literacy, employment, poverty and etc.) and 34 indicators for exposure and sensitivity. After that with using factor analysis provided the coefficient of indicators and classified indicators in limited factors (

Table 3) .finally with using GIS analysis tools, SERV has calculated the vulnerability in the regions (Figure 6).

Table 3 Adaptive Capacity and sensitivity factors [17]

Adaptive Capacity	Sensitivity
Age and employment	Population
Population and utilities	Business and development

Economic base, social services, infrastructure **Traditionally vulnerable populations and housing capital** **Higher education and equality**	Traditionally vulnerable populations Critical and medical facilities Low to medium development Income and economic base Tourism and agriculture

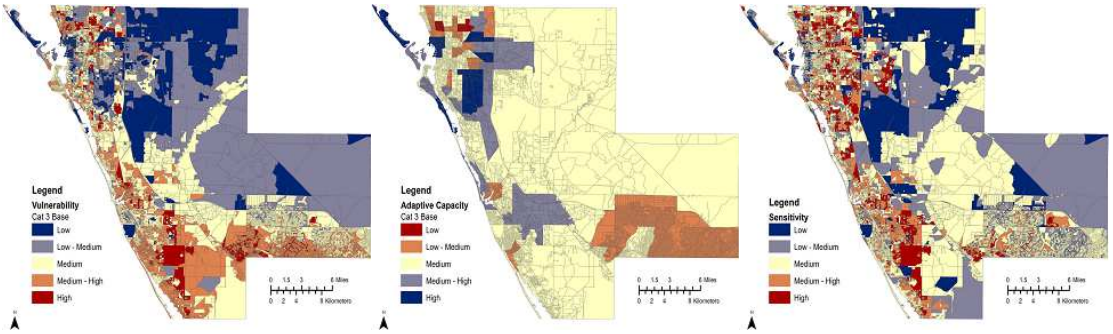


Figure 6. SERV Output; right Sensitivity, middle Adaptive Capacity and left Vulnerability [17]

However this model denote two limitations (i) weighting method and (ii) not to consider hazard type [17].

3.8. WISC

Miles(2015) suggested Well-Being, Identity, Services, And Capitals (WISC) and entire emphasis on local communities. Based on its dimensions, WISC definite 29 indicators and design an assessment framework of community resilience (Figure 7). In general WISC just has introduced indicators and didn't present any method for Collecting and analyzing data and finally measuring community resiliency [18].

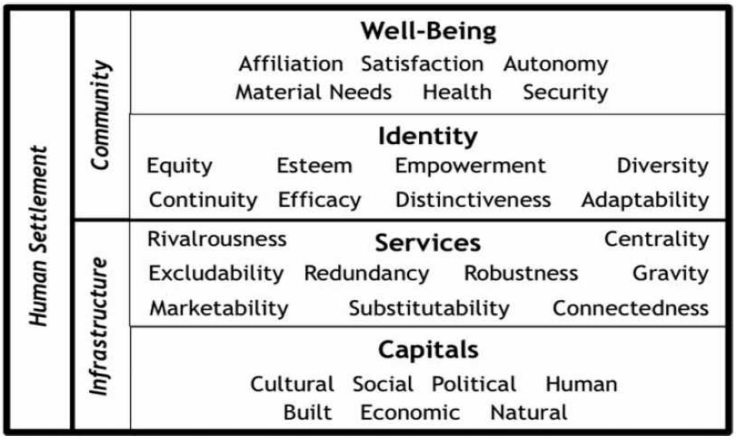


Figure 7 Conceptual model of static community resilience for the theoretical framework WISC, showing relationships between the concepts of community and infrastructure, constructs of well-being, identity, services, capitals, and 29 collective variables for the 4 constructs[18].

4. Analyzing Resiliency Models

Analyzing model based on research methodology is done in seven dimensions. This analyzing make a context for comparative assessment of models. These dimensions are:

- The conceptual framework of model

From this aspects, the fundamental approach of the models to the concepts of resilience, their attitude to the vulnerability and disaster management, the comparative assessment will be placed.

- Dimensions, criterions and indicators

In order to comparative assessment of the comprehensiveness of the resilience models, their dimensions, criterions and indicators will be discussed. It should be noted that the vast dimensions of resilience does not mean comprehensiveness and sometimes the multiplicity dimensions and criterions will be caused to complexity.

- Scale

Each model has described its framework between the community and national level the scale of the models and their dimension can directly affect each other.

- Methodology

How to analyze data and provide resilience assessment method is another important issue in evaluating the performance of urban resilience models.

- Data collecting

Data collection methods depending on the size, components and indicators of resilience in various models has a lot of essential different. The numerous dimensions and indicators in models, make various forms of data collection.

- Model usage

Each model with the emphasis in its framework, in the one or more dimensions of resiliency, can be used more effectively. So, according to their actual or potential application, models will be placed the comparative assessment.
Table 4 shows the comparative –analytical assessment of the resiliency models.

Table 4 . The Compa[illegible] nalytical of Resiliency Models

Model	*Developer*	*Conceptual Framework*	*Dimensions*	*Scale*	*odology*	*Data Resources*	*Application*	*Capabilities and limitations*
CDRI	Rajib Shaw 2009	----	Physical Social Economic Organizational Natural	County Region	Non spatial Spreadsheet – based Questionnaire Survey	Surveys Secondary data	Information gathering Priority setting and Policy recommendations Based on level of resiliency in each dimension.	Applied in 9 Asian cities Concentrated on climate changes Nominate the scoring to the indicators Application of simple data analyze model
URF	Stephentyler Marcus Moench Jo da Silva ARUP + ISET/ 2009	Three characters of resilient systems: Flexibility Redundancy Failure	Urban Systems (ecosystem,]infrastructure institutions, knowledge) Social agents	City/ Wards (communes)	Shared Learning Dialogues(SLD) workshops; GIS enabled sampling and aggregation method; Hazard, Capacity and Vulnerability Assessment(HCVA)	Identification of homogeneous socioeconomic clusters by satellite imagery verified with rapid ground survey; Secondary data	Information gathering; Interpretation; Collaboration; Implementation	Based on climate changes To present how to reach resiliency objectives To present a participatory module to get resilient Not to provide indicators Not to present resiliency Assessment model Applied in Asian cities
P.E.O.P.L.E.S	Renschler et al. MCEER University at Buffalo/2010	It is a manual for determine the capacity of urban function and structure to absorb shocks	Population &demographics Environment Organized governmental Services Physical infrastructures Lifestyle & community Competence Economic development Social cultural capital	Community (can be adapted to multi scale) County	Spatial (time dependent community functionality maps); Visual inspection of RS imagery; Quantitative and qualitative models for any or a combination of dimensions. E.g. SoVI for social resilience.	Census ; Quality of life surveys; Utility usage; Mortgage rate; Voter registration; Home price indices; Unemployment rates; SEC filings; Content Ground trothing interviews; Pre/post disaster detection analysis; Object oriented classification; Change detection analysis	Information gathering; Comparison of resilience between Counties; Empowerment of people; After complete development, it can be used as a geospatial and temporal decision support software tool	Emphasis on social and economic dimensions To provide a decision support software
BRIC	Cutter et al. HVI- University of South Carolina/ 2008	Based on DROP	Social resilience Economic resilience Institutional resilience Infrastructure resilience Social capital	Community County	Spatial mapping; Weighting; Aggregation; Multivariate analysis; Sensitivity Analysis	Census; American community Survey	Information gathering Comparison of the resiliency of different Counties	Not to provide weighting method Inattention to hazard type Using geospatial analysis tools
CCaR	Slobodan Simonovic Angela Peck 2013	Resilience dimension: Space and time	Economic Health Organizational Physical Social	Community County	Application of Vensim Software	Spatial map Census data	Ability to detonate cause of resiliency Ability to simulate urban resiliency in various scenarios	Emphasis on coastal cities Provide a resiliency simulator model Limited indicators Applied in Vancouver, Canada
CCRAM	Cohen et al 2013	Based on communities and social structure	Leadership Collective efficacy Preparedness Place attachment Social trust Social relationship	Communities	Local survey Inferential statistic	Local survey Gathering data from administrator Questionnaire	Ability to measure effective dimension on urban resiliency	Making indicators for social dimensions Not to provide spatial map Applied model
SERV	Frazier et al 2014	Resiliency is as reducing vulnerability and promoting adaptive capacity.	Sensitivity Exposure Adaptive capacity	County	Factor Analysis GIS Spatial analysis tools	Census data Spatial map	Compare the resiliency Ability to measure effectivity of dimensions	Based on statistic and GIS Simultaneous attitude to vulnerability and resiliency Not to pay attention to hazard type
WISC	Miles 2015	Social Resiliency	Welfare Identify Social services Social Capitals	Communities	-----	----	Measuring resiliency in local community	Emphasis on social dimension of resiliency Limited indicators Not to provide data collecting method

5. Comparative Assessment of Resiliency Models

Each model have been studied meet the attributes on resilience turn opened a new vision in the disaster management literature. But in terms of content and extent there are significant differences with each other, so none of them is not top of each other. Hence, these models are comprised based on four axes and using DELPHI. This method is a systematic approach or method to extract expert's comments in the study of an issue or a question [19, 20].according to this, all models described for some disaster management administrator and experts and based on bellow indicators, all models was scored between 0 to 10 :

Comprehensiveness: This indicator points out that these models have denoted to what extent the various aspects of resilience and disasters. For example, such models like WISC proposed four dimensions (welfare, identify, social service, capital) and some other add others dimension like PEOPLES. The comprehensiveness of disaster resilience models can be assessed based on different dimensions of resiliency included in the models such as built environment, economic, social, organizational and different temporal phases of disaster (mitigation, prep 510 response, recovery) for different types of disasters (such as geological, climatic,…). Yet it doesn't mean that the sive model is necessarily better and more useful for policy making and planning purposes as it may result in too much complexity and serving too many purposes at one time.[21]

Validity and operationally: Many researches in developing composite indices in resilience studies, fail to empirically validate the measures especially in terms of incremental validity. This is one of the major flaws of using composite indexes as there is no simple way to get scientific validation of a particular index. The absence of validation is a major concern. In many circumstances, the index relies on empirical data that is far from perfect. Many assume that because numbers have been derived using some basic statistical procedure, the overall results of the index is valid and reliable. However, some qualitative methods such as in-depth surveys and case studies can be used to validate the index. Actually the best way that any sort of metrics related to the disaster field could be validated would be to continually test them after major events and refine them accordingly. This would take a considerable amount of time [22]. For example, CDRI has applied in nine Asian cities but some other hasn't applied and hasn't presented any method for model validity.

The development of new concepts: This index is used to measure the resiliency model innovation. Resilience model to what extent the concepts, components and indicators and new data analysis methods is used. For example, WISC, have presented new processes of resilience or CCaR offer a new method for analyzing and making resilience scenarios.

Measurement: The criterion shows the quality of resilience measurement method, such as the WISC with no clear method to measure resilience. Some models like CCaR even offer the software simulator and the new method for effective measures, such as advanced statistical analysis and spatial analysis tools.

Figure 8 shows Delphi based measurement of the resilience model. According to this, the highest rank is assigned to PEOLES and CDRI.

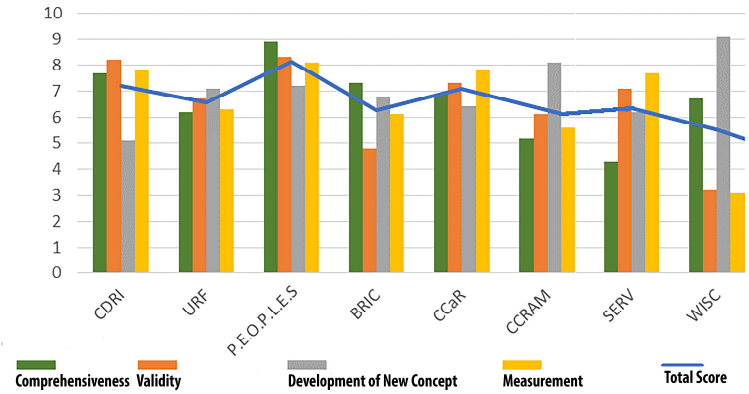


Figure 8 DELPHI based assessment of Resilience Model

6. Conclusion

This paper has analyzed some of the most well cited and prominent resiliency models. Resiliency is a broad and complex concept which is very difficult to define and measure comprehensively. This review revealed that most of the frameworks for measuring disaster resilience are generic and broader in the context of environmental hazards. Defining a proper context and scale for resiliency models seems necessary to take the most useful and applicable output of the model and also to provide a consistent basis for data development required for assessment. More specifically the variables and attributes of some of the frameworks are very broad and often not workable at the community level for measurement purposes. Therefore, their application becomes clumsy at this level, particularly where availability of data for certain indicators at the local level is a great challenge. The existing indicators can also be criticized for the difficulty of meaningful interpretation or the lack of causal linkages between the indicator values and the policy relevance of outcomes.

According to this the concept of resilience is essentially a complex, multifaceted to understand and it makes its evaluation complicated it. The results show that generally whole models studied were found on natural hazards. Some refer to only one natural hazard such as climate change others, regardless of hazard, provide the framework to develop it. Hence, the definition of hazard and fields, as well as scale models and components is vital in the development indicators. Some variables have meaning only at the regional level and the city and others in the local community.

On the other hand note that the development of framework and determine the of indicators should be done in such a way that in addition to availability of information can provide comprehensiveness, validity and for measuring the dimensions and variables.

To sum up, for making our communities disaster resilient we need tools for evidence-based policy making, analysis and evaluation of a large variety of issues and criterions. Existing experience shows that developing indexes, typology approaches and benchmarking can be of great help in research as well as for practitioners for making our communities resilient.

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