CITY STRENGTH IN TIMES OF TURBULANCE: STRATEGIC RESILIENCE INDICATORS

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Abstract

Fragility and interdependence have rendered large socio-technical systems, such as cities, vulnerable not only to terrorism but also to natural and technological disasters. Although there have been great innovations in terms of risk analysis and disaster prevention, large events are increasing in size and number throughout the world. These increases are due mostly to an increase in population density in high risk urban zones and to an increase in interdependence of technical and social systems. In order to understand these growing problems, we turn to resilience strategies for the development and governance of cities.

In this paper we identify strategic resilience indicators for cities. Very few authors have developed the concept of urban resilience and none to our knowledge in the specific case to disasters. First, as identified by the Resilience Alliance (2007), we analyze four vectors which are distinct and interdependent: urban metabolism, social dynamics, the environment and network governance. Finally, we compare this analysis with the criteria which are used for sustainable development, commonly called sustainable development indexes. Sustainable development criteria are important to consider because although a city might have developed a high response capacity to disasters it should look into sustainable development factors in order to decrease its vulnerability.

Keywords: resilience, indicators, disaster, strategic management.

1. Introduction

Because society depends on a range of infrastructures and services, preventing their interruption and restoring their operations becomes an important concern for public policies (Comfort, 2002). But the prevention and recovery are two final points of a continuum which also includes intermediate concerns: to ensure the organizational (or system) robustness, or the capacity to fail with elegance rather than catastrophically (La Porte, 2006). This continuum also includes organizational (or system) resilience, or the capacity to recover quickly once an interruption has occurred. Wildavsky (1988) proposes that anticipation strategies work against known problems, while resilient strategies are better against unknown problems. The anticipation strategies can unnecessarily immobilize investments against risks which never materialize, while the resilient strategies include the potential for a certain sacrifice (in the short run) in the interest of a longer-term survival.

Moreover, overconfidence in anticipation can lead an organization to lose its adaption capacity to the changing conditions or threats. This can lead to more vulnerability. Each strategy must adapt to specific conditions. Where uncertainties are large, resilience is probably most suitable. Where the conditions are stable, and where projections about the future are generally right, anticipation will work better, although it must be employed judiciously (Fiksel, 2003). Moreover, risks are various and it is difficult to predict the future. Anticipation strategies require immobilizing resources in a specific or concrete way. Thus anticipation strategies can end up being expensive in the short or the long term. In addition, resilient systems are those which quickly acquire information on their environments, quickly modify their behavior and their structures, even if the circumstances are chaotic. They communicate easily and openly with others, and largely mobilize networks of expertise and of material support (Perrow, 1999). It is thus a question of identifying the structural strategies which allow this organizational flexibility (Therrien, 2005) between anticipation and resilience. The structural strategies are thus internal with each organization. They are also external; therefore each organization should set up a structure which takes into account its participation in an interorganizational network.

For the particular case of resilient strategies, organizations such as cities need to identify strategic resilience indicators to measure their vulnerability level. In this paper we first present our methodology based on 9 studies of vulnerability/ resilience indicators. We then discuss our results by showing the recurrence and

patterns of the 273 indicators, and a classification according to the Resilience Alliance (2007) four vectors. Finally, we compare our classification with the sustainability urban indicator study of Tanguay *et al*. (2009) from which we had adapted our methodology. We then present final comments of these preliminary results.

2. Methodology

2.1 Choice of Studies about Indicators

To find the indicators used for this analysis, we searched for studies that develop indicators for vulnerability and/or resilience of cities. Our selection criteria did not include elements about geographic location of cities (America, Europe, Africa, etc.) and the potential for disaster (earthquake, cyclone, flood, etc.)

After a research with key words (indicators, resilient city, community resilience, community vulnerability, vulnerability indicators, resilient indicators, assessment of vulnerability, and assessment of resiliency), we compiled 9 studies which focus on those issues. These studies establish indicators for different cities and communities (Istanbul, Latin American and Caribbean countries, Bogotá, New Jersey communities, cities in India, districts in Indonesia, Colombia and Switzerland, Mexico city or without specification), and for a variety of disasters or vulnerabilities (earthquake, physical and social risk, coastal hazard, earthquake, cyclone, drought and flood, epidemics, etc.). For the latter, we selected these studies because vulnerability is an essential element in the studies' frameworks used for the creation of the indicators.

Table 1 Summary of the 9 Studies

#	Reference	Territory Covered	Categorization of indicators	Number of indicators
1	Biswanath and Sharma (2004)	Tested in six communities, located in three different states of India.	Indicator for disaster preparedness Framework with ten parameters : physical safety, hazard awareness, Organizational preparedness, Infrastructures and Services, Recovery ability, Physical environment, Social capital, Psychological Preparedness, Cultural capital and Household preparedness.	33 indicators

			Some indicators are related to specific hazards: earthquake, cyclone, drought and flood.	
2	Caliskan et al. (2006)	Two areas in Istanbul	Earthquake Vulnerability Indicators Vulnerability indicators have been classified into three classes: physical, economic and social vulnerability indicators.	16 indicators (included 3 indicators as auxiliary data)
3	Cardona (2005) and IDEA (2005)	Latin American and Caribean countries.	The Index of Physical Risk: the effect of physical risk The Impact Factor: social fragility and lack of resilience	19 variables used to create 2 composites indicators, and a Total Risk Index.
4	Carreño, Cardona and Barbat (2005)	Could be used for different scale: country, subnational region, or city. Used for Bogotá, Colombia	The Risk Management Index measures four kinds of public policies: the identification of risk, risk reduction, disaster management, and governance and financial protection.	24 indicators (six for each category)
5	Cutter (2008)	Coastal Hazard Resilience in New Jersey Communities	The framework is composed of four factors of resilience : Social Vulnerability, Built environment and Infrastructure, Natural System and Exposure, Hazard Mitigation and Planning	104 variables created four factors integrated in GIS
6	Hahn, Villagrán De León and Hidajat, (2003)	Tested in districts in Indonesia, Colombia and Switzerland	Community- Based Risk Indicators Developed by the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) Four factors influence the disaster risk: Hazard (probability, severity), Exposure (structures, population, economy), Vulnerability (physical, social, economic and environmental), and Capacity and Measures (physical planning, social capacity, economic capacity and management)	47 single indicators, aggregation into 4 factor scores and 1 risk index
7	Mayunga (2007)	Framework concept for community disaster	Capital-Based Approach for analyzing Community Disaster Resilience Five forms of capital: Social, Economic, Physical, Human, and Natural. Integrating indicators to create the Community Disaster Resilience Index (CDRi)	16 indicators, aggregation into 5 indices (for each kind of capital), and one Index.
8	Schneiderbauer and Ehrlich, (2006)	Framework used six social levels: individual, household, administrative	Risk is formed by vulnerability, hazards and exposure. The indicators are divided between hazard-independent indicators at different social levels, and the hazard-dependant	56 indicators Hazard-independent indicators: 32

		community, cultural community, national and regional.	indicators (earthquakes, volcanoes, cyclones, floods, droughts and epidemics).	Hazard-dependant indicators: 24
9	Puente, (1999)	Mexico City Vulnerability Index	Socio-economic factors, regional infrastructure, urban spatial structure, natural factors	19 factors 4 indices and one general compound index

2.2 Classification of Indicators

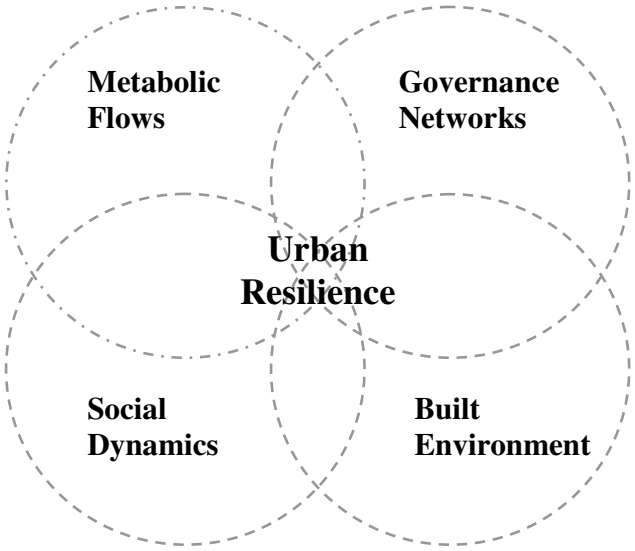
For the classification of the indicators, we followed the methodology used by Tanguay *et al.* (2009) in their study of indicators of city sustainability. First, we compiled indicators developed by studies of vulnerability and city resilience and we observed their frequency. To analyze the indicator recurrence, the description of each indicator was studied with an inclusive approach. For example, we considered the literacy rate and the illiteracy rate as the same indicator because they are both sides of the same issue. This approach allows to underline the different concerns of the risk, vulnerability and resilience in cities, instead of focusing on the different ways to measure the same element with the multiple units, periodicity elements (per month, per year, etc.) or the geographic concentration (km^2, neighborhood, etc.). But, this inclusive method led us to create broad indicators because some of them include more than one element, like television and radio access indicators which aggregate 1) the number of radios per capita, 2) the number of televisions per capita, 3) percentage of population which can hear a warning through radio and television.

Second, to categorize the 273 indicators used in the sample of the 9 studies, we decided to apply a framework developed by the Resilience Alliance (2007) related to the resilience of urban systems and landscapes. In its recent Research Prospectus, this research organization identified four key themes to understand the resilience of urban systems: Metabolic Flows, Governance Networks, Social Dynamics, and Built Environment. Urban resilience is created by the intersection of these four areas. Until now, there is an absence of consensus in the literature on the subjects of resilience and vulnerability (Manyena, 2006). However, the Resilience Alliance's approach provides a useful conceptualization with the identification of the four significant resilience themes.

For the Resilience Alliance approach (2007), cities are represented as a socio-ecological system which is characterized by four categories defining resilience. First, the concept of Metabolic Flows (Resilience Alliance, 2007) refers to the production, supply and consumptions chains in an ecosystem, which exceed the limits of the city (Floke et al. 1997). This represents the productive capacity for energy, material goods, and services required for the well-being of the population and the quality of life of the community (Floke et al. 1997). Moreover, the elements of interconnection, interdependency, diversity and efficiency of production systems are important to understand their resilience. Second, Social Dynamics (Resilience Alliance, 2007) regroup the demographic characteristics, human capital and inequity of the population. Third, the category of Governance networks (Resilience Alliance, 2007) is composed of institutions and organizations which lead and manage the city. The networks between them could exist at the regional, national and international levels. Governance is also characterized by the management of budget, services (sewer, water, education, etc.) and emergency structures (police and fire departments). Finally, Built environment (Resilience Alliance, 2007) category represents different ecologic and urban landscapes, and habitats. Ideologies, policies, building codes and transports facilities influence the development of the built environment.

In this model, these four levels are in interaction. For example, the city council (governance) could influence the Built Environment by creating a new building code or a new transportation plan (Metabolic flow). Moreover, the schematization of the model shows that these categories are not mutually exclusive.

Figure 1: Representation of the Four Vectors of Urban Resilience



Source: Reproduction of the Figure 1: « Four interconnected research themes for prioritizing urban resilience research» (Resilience Alliance, 2007, p. 10)

However, the Resilience Alliance (2007) did not name and characterize the overlapping points between two or three categories. For the categorization, this absence of conceptualization increases the difficulty of classification, because some indicators seem to belong to more that one vector. However, we decided to classify the indicators only in one vector and subsequently analyze and discuss this question.

3. Results

3.1 A Large Variety of Indicators

Table 2 shows a great variety of indicators from the 9 studies on city vulnerability. 273 indicators were revealed, and only 31 of them were present in two studies or more. This means that only 11% of the indicators are used in two studies or more. If we turn to indicators found in three studies or more, the result decreases to 11 indicators which represent 4%. The comparison of the studies demonstrates that there exists different ways to measure the risk, vulnerability and/or resilience of cities, which results in a large variety of indicators.

Table 2 Summary of Frequency of Use of Indicators in 9 studies

			# of indicators used		
Resilience Community Dimension	**Categories**	**# indicators in category**	**1 time**	**2 times**	**3 times of more**
Social Dynamics	Age	4	3	1	0
	Population (density, growth, number)	8	6	1	1
	Education	3	1	2	0
	Gender	2	1	1	0
	Health conditions	6	6	0	0
	Housing conditions (cost)	3	3	0	0
	Awareness about probable hazards	8	8	0	0
	Labour force	7	7	0	0
	Origin (ethnic or cultural)	5	5	0	0
	Ownership	2	2	0	0
	Poverty / Income	8	7	0	1
	Social conflicts	6	6	0	0
	Community participation	2	2	0	0
	Other	1	1	0	0
	Sub-total	65	58	5	2
Metabolic Flows	Agriculture	4	4	0	0
	External aid	2	2	0	0
	Business	8	7	1	0
	Economic development	8	8	0	0
	Education	4	4	0	0
	Energy	4	1	2	1
	Finance	4	4	0	0
	Health	6	5	1	0
	Insurance	3	2	0	1
	Sewers	2	2	0	0
	Telecommunication	3	2	0	1
	Water	3	1	1	1
	Others	3	3	0	0
	Sub-total	54	45	5	4
Environment Built	Environment conditions	25	22	1	2
	Housing conditions	14	10	3	1
	Zone at risk	5	5	0	0
	Safety standards and codes	11	9	1	1
	Transportation	13	12	1	0
	Urban planning	9	8	1	0
	Others	3	3	0	0
	Sub-total	80	69	7	4
Governance Networks	Budget / Funds	8	8	0	0
	Community involvement about hazards	7	6	1	0
	Coordination	6	6	0	0
	Emergency Services	5	5	0	0
	Law for prevention	6	6	0	0
	Emergency planning	7	6	0	1
	Mitigation plan	2	2	0	0
	Training for emergency	4	3	1	0
	Other types of preparation	3	3	0	0
	Public information/education about hazards and risk	4	4	0	0
	Risk assessment	14	13	1	0
	Others	8	8	0	0
	Sub-total	74	70	3	1
Total		**273**	**242**	**20**	**11**

First, this could be explained by the specific elements of each study. As explained above, the studies were created to assess the situation of different cities located in developed and developing countries, which could potentially face different hazards such as earthquakes, cyclones or floods. In fact, some indicators are specialized in the evaluation of the vulnerability to specific hazards such as "Seismic zones with high amplification", "Number and intensity of the regional conflicts" or "Dune management districts". These examples illustrate the influence of local particularities of the development of indicators. However, this does not affect all indicators, and the majority of them are not too specific. They could be applied to a large variety of situations.

Also, we considered that vulnerability, risk and resilience are concepts still in development. Thus, the frameworks used by the authors of the 9 studies are not the same. Table 3 identifies definitions and categories developed by each study to support the indicators. First, we observe that the studies use one or two concepts to develop indicators. Risk is characterized by impact, probability, severity, exposure, vulnerability or types of hazards. For vulnerability, there is a recurrent concern about economic, physical, and social vulnerability (or fragility). The environment and the built vulnerability are also presents, but less frequent. We also note a relation between vulnerability and resilience. In a study, vulnerability is influenced by a lack of resilience, and in a second one, social vulnerability, and natural system and exposure are factors of resilience. This conceptualization is not surprising if we consider that authors present vulnerability and resilience as the two faces of the same coin.[1] For the concept of resilience, it describes as process or an inherent quality of the city. Thus, indicators reflect the steps taken previously to the disaster to mitigate hazards reduce vulnerabilities or prepare an emergency plan. Post-disaster actions are taken into account by recovery capacity. In other studies, resilience is presented by the community's assets that favor a recovery capacity after a disaster such as human, social, economic, physical, natural or managerial assets. These two resilience definitions - the process and the inherent quality - are present in the literature and demonstrate the large conception of this concept (Sutcliffe and Vogus, 2003). In general, the conceptualization of the risk, vulnerability and resilience are based on a wide variety of elements, which is reflected in the development of indicators.

[1] In his literature review, Manyena (2006) present height definitions of vulnerability related to disaster resilience, p. 441

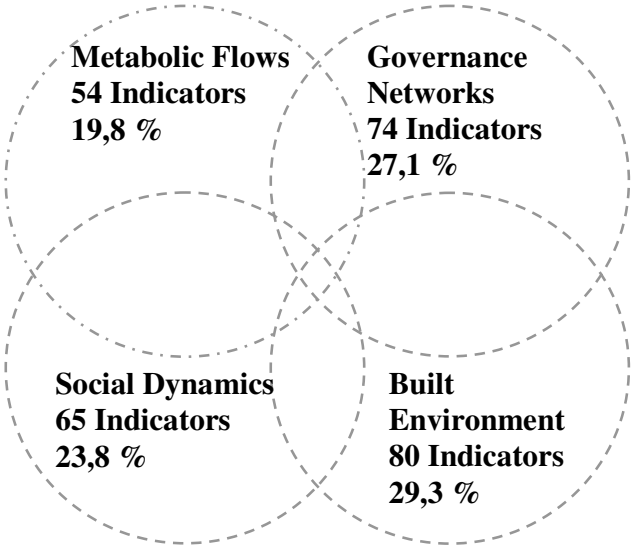
Table 3: Conceptualization of Risk, Vulnerability and Resilience by the 9 studies

Reference	Risk	Vulnerability	Resilience
Caliskan, et al. (2006)	-------	Physical vulnerability (spatial), social vulnerability (non-spatial), economic vulnerability (non-spatial)	-------
Cardona et al. (2005)	Physical risk impacts	Impact factor: social fragility and lack of resilience	-------
Risk Management index Carreño et al. (2005)	-------	-------	The indicators reflect actions taken to reduce vulnerability and losses, to prepare for crisis and to recover efficiently from disasters.
Cutter, (2008)	-------	Four factors of resilience : 1. Social Vulnerability 3. Natural System and Exposure	Four factors of resilience : 2. Built environment and Infrastructure, 4.Hazard Mitigation and Planning
Biswanath and Sharma (2004) Disaster preparedness	Indicators related to specific hazards: earthquake, cyclone, drought and flood.	-------	Indicator for disaster preparedness
Hahn, et al. (2003) Community-Based Risk Indicators	Hazard (probability, severity)	Exposure (structures, population, economy), Vulnerability (physical, social, economic and environmental)	Capacity and Measures (physical planning, social capacity, economic capacity and management)
Mayunga (2007) Community Disaster Resilience	-------	-------	Five forms of capital for the resilience: Social, Economic, Physical, Human, and Natural.
Schneiderbauer and Ehrlich, (2006)	Risk is formed by vulnerability, hazards and exposure. Hazard-dependant indicators (earthquakes, volcanoes, cyclones, floods, droughts and epidemics).	hazard-independent indicators at different social levels	-------
Puente, (1999) Mexico Vulnerability Index	-------	Socio-economic factors, regional infrastructure, urban spatial structure, natural factors	-------

3.2 Equity Representation of the Four Dimensions

The categorization of the 273 indicators into the four dimensions of resilience developed by the Resilience Alliance (2007) shows that all studies do not focus only on one or two aspects of urban resilience. In fact, the indicators covert equally Metabolic Flows (19,8% of the indicators), Social Dynamics (23,8%), Governance Networks (27,1%), and Built Environment (29,3%) dimensions (see Figure 2). Thus, this model is reflected by the indicators, despite that none of the 9 study used it namely.

Figure 2: Classification of the 273 Indicators



3.3 Discussion about the Most Widely Used Indicators

If we analyze the 31 most used indicators identified in table 4, we note they describe 1) tools for prevention, mitigation or crisis management, 2) characteristics of the situation, and 3) critical infrastructures, regardless of the four dimensions of resilience.

First, we notice that a variety of indicators are related to crisis management tools which could reduce damages, contribute for preparation or help to recover. It is the

case for: 3- Having an emergency plan; 6- Insurance coverage; 11- Application of building codes; 26- Earthquake resistant building; 28- Land use planning; 29- Committee with public representatives; 30- (Emergency) Drill; and 31- Mapping risk. These indicators are within three of the four resilience dimensions (Governance networks, Built environment and Metabolic Flows). These specific indicators show that managerial or governance actions related to hazard management contribute to reducing vulnerability or are a source of resilience. If we compare these indicators to the Policy Responses to Natural and Human-Made Disasters identified by the United Nations Human Settlements Program (2007, p. 195-218), it appears that all policies are not covered. In fact, the height indicators concern the disaster risk assessment, land-use planning, building code and regulation, and response capacity, but they fail to take into account Planning to protect Critical Infrastructures, Financing Urban Risk Management, pro-active view of Strengthening Local Disaster Resilience by improving the local capacity-building, and aspects of the Early Warning like risk detection system and risk communication.

Second, fifteen indicators are characteristics of Social Dynamics, Built Environment or Metabolic Flows. They are: 1- Income; 4- Population growth; 8- Erosion; 9- Land cover; 10- House Material; 12- Age average; 13- Density of the population; 14- Education level; 15- Literacy rate; 16- Sex ratio; 17- Small business; 22- Forestation; 23- Housing density; 24- Number of houses; 25- Building Height. This multitude of indicators is not surprising. In fact, it is coherent with knowledge about community vulnerability. On human perspective, the vulnerability is partly determined by obstacles to effective response related to poverty, education or health (United Nations Human Settlements Program, 2007, p. 34). By considering these elements, the indicators assess the social weaknesses or strengths of the community and which aspects the government should target and work on to improve the population-capacity. For the Built Environment, environmental degradation could increase the vulnerability of the population (Renaud, 2006, p. 117-127), including by the process of deterioration of the quality, quantity and availability of resources necessary for the community. Also, the modifications of natural protections generate weakness as the effects of deforestation on floods in Haiti for example (Renaud, 2006, p. 117-127). Moreover, an uncontrollable urban expansion and growth, which could be evaluated by density, can create and exacerbate vulnerabilities (United Nations Human Settlements Program, 2007, p. 183)

Third, several most used indicators address the issue of critical infrastructures: 2- Access of water; 5- Oil and gas; 7- Radio and TV access; 18- Dams; 19- Electric power; 20- Hospital beds; 21- Water network; and 27- Transportation network. The President's Commission on Critical Infrastructure Protection (PCCIP) in United States defines infrastructures as: « The framework of interdependent networks and systems comprising identifiable industries, institutions (including people and procedures), and distribution capabilities that provide a reliable flow of products and services essential to the defense and economic security of the United States, the smooth functioning of government at all levels, and society as a whole » (Executive order, 1996, p. 37347). Because of their importance, the disturbance or the destruction of critical infrastructures would destabilize society, and have important economic, safety and health effects. Also, interrelation and interdependence between infrastructures are likely to create a domino effect. Following these characteristics, the presence of indicators related to critical infrastructures is coherent with the fact that they represent essential lifelines for communities. However, the majority of them do not assess the robustness of the critical infrastructures or their capacity to bounce back after a crisis (resilience).

Table 4: Indicators used two times or more in the 9 studies

Frequency	Indicator	Description	Vector	Category
5	1. Income	Income (per capita, per capita per month, household income)	Social dynamics	Poverty / Income
4	2. Access of water	Access to drinking water, % of homes with piped drinking water, Availability and quality of drinking water	Metabolic flows	Water
	3. Having an emergency plan	Preparedness/emergency planning, Disasters/emergency response plans, Availability and circulation of emergency plans or Emergency response planning and implementation of warning systems	Governance Networks	Emergency planning
3	4. Population growth	Population growth rate	Social dynamics	Population
	5. Oil and gas	Oil and natural gas facilities, oil network, gas network	Metabolic flows	Energy
	6. Insurance coverage	Insurance coverage (housing and private coverage, % of population with insurance coverage, etc.)	Metabolic flows	Insurance
	7. Radio and TV access	Number of radios per capita, Number of TVs per capita, % of population can access warning through radio and television	Metabolic flows	Telecom-munication
	8. Erosion	Erosion rates or degraded land: % of area that is degraded/eroded/desertified	Environment Built	Environment conditions
	9. Land cover	Land cover classification or land cover	Environment Built	Environment conditions
	10. House Material	Main building material, material conditions of housing, or Building Material	Environment built	Housing conditions
	11.Application of building codes	Updating and enforcement of safety standards and construction codes, Building standards, codes and enforcement, Building codes: Applied building codes	Environment built	Safety standards and codes
2	12. Age average	Age average of the population	Social dynamics	Age
	13. Density of the population	Population density in the city	Social dynamics	Population
	14. Education level	Education level	Social dynamics	Education
	15. Literacy rate	Literacy rate or illiteracy rate	Social dynamics	Education
	16. Sex ratio	Sex ratio or % female	Social Dynamics	Gender
	17. Small business	Number and % of small business	Metabolic flows	Business
	18. Dams	Number of dams	Metabolic flows	Energy
	19. Electric power	Electric power facilities, electric network and power stations	Metabolic flows	Energy
	20. Hospital beds	Hospital beds	Metabolic flows	Health
	21. Water network	Potable water facilities, Water supply network.	Metabolic flows	Water

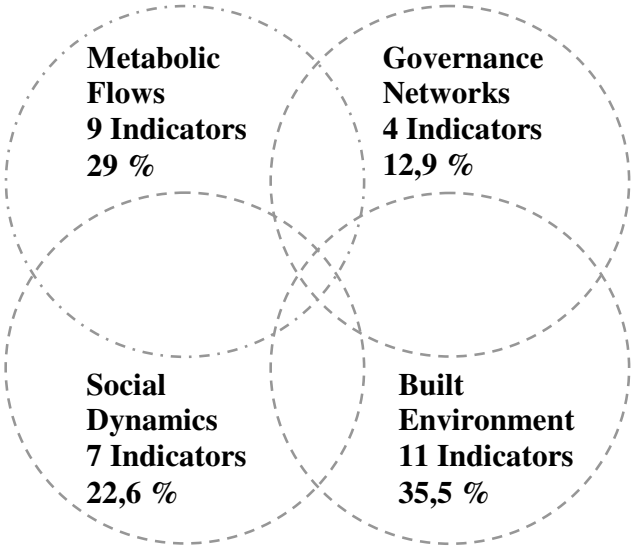
	22. Forestation	Area under forest: % of area of the commune covered with forest or Deforestation rate	Environment Built	Environment conditions
	23. Housing density	Density of housing units or Density and type of housing	Environment Built	Housing conditions
	24. Number of houses	Number of housing units (living quarters) or Number of families/residential building	Environment Built	Housing conditions
	25. Height	Building Height or Number of floors	Environment Built	Housing conditions
	26. Earthquake resistant building	Percentage of earthquake resistant built houses or Earthquake: Percentage of houses in the community that are earthquake-resistant	Environment Built	Safety standards, codes
	27.Transportation network	Trafic infrastructure/road network or Transportation and communication network	Environment Built	Transpor-tation
	28. Land use planning	Comprehensive plans (Land use and growth management) or Land use planning: Enforced land use plan or zoning regulations	Environment Built	Urban planning
	29. Committee with public representatives	Public participation: Emergency committee with publics representatives or Existence of disaster committee and how well different social groups e.g. minorities and women etc. are represented in such committee	Governance networks	Community involvement
	30. Drill	Emergency response drills: Ongoing emergency response training and drills or Tabletop and mock-exercises and drills for disaster response	Governance Networks	Training
	31. Mapping risk	Hazard evaluation and mapping and Availability and circulation of risk maps	Governance Networks	Risk assessment

3.4 Disparity about the Most Widely Used Indicators Four Dimensions

If the four urban resilience dimensions are generally equally represented by all indicators, the situation is different when we only focus on the most widely used indicators. The results shown in the figure 3 demonstrate an under-representation of Governance Networks, with only four indicators used in two or more studies, compared to eleven indicators for the Built Environment dimension. Therefore, the large number of indicators present for the dimension does not indicate the existence of recurrent indicators between different studies. In general, this is consistent with the lack of consensus discussed in the first part of the analysis. We showed above that 11 % of the indicators are used in two studies or more, and 4 % in three studies of more. For Governance Networks, this inconsistence is more important than the

three others, because only 4 of the 74 its indicators (5 %) appear in more than one study.

Figure 3: Classification of the Most Widely Used Indicators (two or more)



3.5 Comparison between sustainability indicators and vulnerability/resilience indicators

This comparison summarized by the table 5 indicates that a minority of sustainability and vulnerability/resilience indicators are the same. Nonetheless, authors argue for the necessity to link sustainable development to vulnerability or resilience. For example, Pelling (2003) presents the necessity to place mitigation policies in the context of sustainable urban development. Adger considers that « resilience, in both its social and ecological manifestations, is an important aspect of the sustainability of development and resource utilization» (Adger, 2000, p. 357). To reduce the impact of hazard, Mileti (1999) proposed a model of sustainable hazard mitigation, while McEntire (2001) suggests implementing invulnerable development to address vulnerabilities. In general, the close relationship between vulnerability/resilience and sustainable development is developed in scientific literature, but our analysis shows a lack of transposition of this idea in the indicators.

Table 5: Comparison between the vulnerability/resilience indicators and the sustainable development indicators for city

List of sustainable development indicators for city (Tanguay et al, 2009)	**Indicator present or not in the list of vulnerability/resilience indicators**
1. Unemployment rate	No
2. Users of mass transit (MT)	No
3. Density of urban population	Yes, # 13. Density of the population
4. Quantity of waste	No
5. Crime rate	No
6. Mean or median household income per year	No, but it is related to # 1. Income (per capita, per capita per month, household income)
7. Job creation for all sectors combined	No
8. Citizen participation in public affairs	No, but it is related to # 29. Committee with public representatives
9. Low income households	No
10. Concentration of PM10 particles	No
11. Businesses with environmental certification	No
12. Quantity of waste recycled	No
13. Daily water consumption per person	No
14. Households spending 30% or more of income on housing	No
15. GHG emission (excluding transport)	No
16. Quality of waterways	No
17. SD policies or strategies	No
18. Rate or participation in municipal elections	No
19. Participation rate for all sectors	No
20. Ratio, population with high-low-income	No
21. Population receiving social assistance	No
22. Population aged 18 and over less than a high school diploma	No, but it is related to # 14. Education level
23. Space allotted to nature conservation relative to area of territory	No, but it is close to # 9. Land cover, and # 22. Forestation
24. Average distance travelled per capita for all means of transport combined	No
25. Victims of traffic accidents	No
26. Green space per 1000 inhabitants	No
27. Playground (parks) per 1000 inhabitants	No
28. Cultural events	No
29. Average capacity of primary and secondary school classes	No
30. Diversity of new housing built	No
31. Premature mortality rate	No
32. Ecological footprint	No

4. Conclusion

In this study, we first adapted a methodology to categorize 273 indicators from 9 studies of resilience/vulnerability indicators specific to cities or urban areas. Our findings show that these studies rendered a large variety of indicators which shows a lack of consensus. We also noted that indicators were often difficult to be used at an operational level by urban managers. However, because of this large number, indicators covered well the four vectors we borrowed from the Resilience Alliance (2007) to present a classification. This classification should be developed as we noticed that intersections between the vectors were un-named and therefore could represent more specific areas related to interdependence between indicators. Also, when we took the most widely used indicators (31), our results show a lack of representation in the Governance Networks vector. However, this is not present when we look at the 273 indicators divided in the four vectors. One of our most important finding is linked to the fact that the 31 most widely used indicators belong in cross categories. These cross categories show the importance of interdependence between indicators linked to critical infrastructures. They also help to describe elements linked to characteristics of disaster situations and crisis management tools. Finally, we compared our results with the sustainability indicators which showed a complete lack of similitude. This result was surprising as many authors link sustainable development to vulnerability or resilience.

Bibliography

Adger, Neil W. (2000), « Social and ecological resilience: are they related? », *Progress in Human Geography*, Vol. 24, No. 3, p. 347–364

Birkmann, Joern (2007), Risk and vulnerability indicators at different scales: Applicability, usefulness and policy implications, Environmental Hazards 7, p. 20–31

Biswanath, Dash and V. K.Sharma (2004), *Indicators for disaster preparedness*. (ProVention Consortium working paper). Online: http://www.proventionconsortium.org/themes/default/pdfs/AG/biswanath.pdf

Cardona, Omar D. (2005), «Indicators of disaster risk and risk management. Main technical report», National University of Colombia – Manizales, Institute of Environmental Studies, Inter-American Development Bank. 43 p. Online: http://idea.manizales.unal.edu.co/ProyectosEspeciales/adminIDEA/CentroDocumentacion/DocDigitales/documentos/MaintechnicalreportIDEA1.pdf

Carreño, M. L. O. D. Cardona, and A. H. Barbat (2005), « Evaluation of the risk management performance », Presented for 250th Anniversary of the 1755 Lisbon Earthquake. Online: http://www.unisdr.org/HFdialogue/download/tp1-Evaluation-risk-management-performance-m1.pdf

Caliskan, Semiha, Hannes Taubenböck, Stefan Hinz, Achim Roth (2006), « Earthquake vulnerability indicators and vulnerability assessment using remote sensing, Istanbul», 1st EARSeL Workshop of the SIG Urban Remote Sensing Humboldt-Universität zu Berlin, 2-3 March 2006

Comfort, L.K. (2002). "Governance Under Fire: Organizational Fragility" in Complex Systems. Symposium on Governance and Public Security, 18 Janvier 2002, Campbell Public Affairs Institute, Maxwell School of Citizenship and Public Affairs, Université de Syracuse

Cutter, Susan L. (2008), «A Framework for Measuring Coastal Hazard Resilience in New Jersey Communities», White Paper for the Urban Coast Institute. Online:

http://www.monmouth.edu/urban_coast_institute/articles/SusanCutterFrameworkforMeasuringCoastalHazardResilientCommunitiesNJ.pdf

Cutter, S. L., B. J. Boruff, and W. L. Shirley. 2003. Social vulnerability to environmental hazards. *Social Science Quarterly* 84 (1):242-261.

E.O.1310. 1996. Critical Infrastructure Protection. URL: Executive Order 13010—*Critical Infrastructure Protection*. Federal Register, July 17, 1996. 61(138), 37347-37350.

Fiksel J. (2003). "Designing Resilient, Sustainable Systems", *Environmental Science and Technology,* Vol. 37, No. 23, p. 5330-5339.

Folke C., Jansson, A., Larsson, J., and Costanza, R. (1997). «Ecosystem appropriation by cities», *Ambio*, 26, p. 167-172.

Hahn, Herwig, Juan Carlos Villagrán De León, and Ria Hidajat (2003), « Component III: Indicators and other disaster risk management instruments for communities and local governments», Study of phase III on Comprehensive Risk Management by Communities and Local Governments, Study coordinated by Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Online: http://www.gtz.de/de/dokumente/en-report-component-iii.pdf

Instituto de Estudios Ambientales (IDEA), National University of Colombia-Manizales, *Indicators of Disaster Risk and Risk Management: Program for Latin America and the Caribbean. Main Technical Report.* Washington, DC: Inter-American Development Bank, 216 p. Online: http://idea.manizales.unal.edu.co/ProyectosEspeciales/adminIDEA/CentroDocumentacion/DocDigitales/documentos/MaintechnicalreportIDEA1.pdf

La Porte, Todd (2006), «Organizational Strategies for Complex System Resilience,Reliability and Adaptation », In Auerswald, Philip E, Lewis M. Branscomb, Todd M. La Porte and Erwann O. Michel-Kerjan (Eds), *Seeds of Disaster, Roots of Response How Private action can reduce Public Vulnerability*, Chapter 10, p. 135-156, Cambridge University Press, 554 p.

Manyena, Siambabala Bernard (2006), «The concept of resilience revisited», *Disasters,* Vol. 30, No. 4, p. 433–450 .

Mayunga, Joseph S. (2007), « Understanding and Applying the Concept of Community Disaster Resilience: A capital-based approach», (Draf working paper), Academy for social vulnerability and resilience building, 22-28 July 2007, Munich, Germany. Online: http://www.ehs.unu.edu/file.php?id=296

McEntire, David (2001), «Sustainability or invulnerable development? Proposals for the current shift in paradigms», *Australian Journal of Emergency Management*, Vol. 15 No.1, p. 58-61.

Mileti D. (1999), *Disasters by Design: A Reassessment of Natural Hazards in the United States*, Joseph Henry Press, Washington, D. C.

Pelling, Mark (2003), *The Vulnerability of Cities: Natural Disaster and Social Resilience*, Earthscan, London, 212 p.

Perrow, C. (1999). "Organizing to Reduce the Vulnerabilities of Complexity", *Journal of Contingencies and Crisis Management*, vol. 7. no.3:150-155.

Puente, Sergio (1999), « Social vulnerability to disaster in Mexico City : An assessment method», chapter 10, p. 295 – 334, in James K. Mitchell (eds), *Crucibles of Hazard: Mega-Cities and disaster in transition*, Tokyo, New York, Paris: United Nations University Press, 535 p.

Resilience Alliance (2007), A Research Prospectus for Urban Resilience: A Resilience Alliance Initiative for Transitioning Urban Systems towards Sustainable Futures, (Feburary), Online: http://www.resalliance.org/files/1172764197_urbanresilienceresearchprospectusv7feb07.pdf

Renaud, Fabrice G. (2006), «Environmental components of vulnerability», in Jörn Birkmann, *Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies*, Hong Kong, United Nations University Press, Chapter 5, p. 117-127, 524 pages.

Schneiderbauer, Stefan and Daniele Ehrlich (2006) «Social levels and hazard (in)dependence in determining vulnerability». In: Birkmann, J. (Ed.) *Measuring*

Vulnerability to Natural Hazards – Towards Disaster Resilient Societies, United University Press, pp 78-102.

Sutcliffe, Kathleen M. and Timothy J. Vogus (2003), «Organizing for Resilience». In K. Cameron, J.E. Dutton, & R.E. Quinn (Eds.), *Positive Organizational Scholarship*, San Francisco: Berrett-Koehler Publishers, chapter 7, p. 94-110.

Tanguay, Georges, Juste Rajaonson, Jean-François Lefebvre and Paul Lanoie (2009), «Measuring the Sustainability of Cities : A Survey-ased Analysis of the Use of Local Indicators», (Online: http://www.cirano.qc.ca/pdf/publication/2009s-02.pdf)

Therrien, M.C. (2005). "Modeling Systemic Learning of Complex Events: a case study of forest fires*", International Journal of Emergency Management*, Vol.2, No.3: 203-217.

United Nations Human Settlements Programme – UN-Habitat (2007), «Global report on Human Settlements 2007. Enhancing Urban Safety and Security», Earthscan, London, 448 pages.

Wildavsky, A. (1988). *Searching for Safety*. New Brunswick: Transaction Books.