From Protection to Resilience

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Abstract

Past and recent experiences have shown how likely is that protection policies, sooner or later, may fail. For this reason, and being aware of the fact that the efforts put in place for the protection of Critical Infrastructures (CIs) supporting Communities life can be easily bypassed, all of the stakeholders involved in the protection of such delicate and vital infrastructures have reached a level of awareness that strongly suggests to put more emphasis on Critical Infrastructure and Community resilience instead of protection.

It can be affirmed that the adoption of resilience measures seems to be justified by the same variables that a long time ago have suggested the adoption of protection measures and from the awareness that there's no resilience without protection and vice-versa. At the same time, it's necessary to highlight that the adoption of resilience measures shouldn't in any case divert or reduce the focus from protection, as these approaches are complementary and cannot be equally missing from the management and security lifecycle of modern infrastructures.

The paper proposes a methodology for modelling and evaluating Community Resilience.

Introduction

Humanity has become remarkably adept at understanding how to mitigate countless conventional risks that can be relatively easily isolated and managed with standard risk management approaches. But we are much less competent when it comes to dealing with complex risks in systems characterized by feedback loops, tipping points and opaque cause-and-effect relationships that can make intervention problematic[1]

Societies, ecosystems, economies and the global financial system are all examples of such complex systems, and they have various intersections. When a risk cascades through a complex system, the danger is not of incremental damage but of "runaway collapse"—or, alternatively, a transition to a new, suboptimal status quo that becomes difficult to escape.

Though infrastructure / community *protection* and infrastructure /community *resilience* represent complementary elements of a comprehensive risk management strategy, the two concepts are distinct. **Infrastructure / community protection** is the ability to prevent or reduce the effect of an adverse event. **Infrastructure /community resilience** is the ability to reduce the magnitude, impact, or duration of a disruption. The spread in the continuous discovery of new threats that target CIs and entire Communities, stress the importance of a whole rethinking around the concept of protection. That's where resilience emerges from and becomes an important part of the playing field. A resilient approach is a holistic set of procedures and measures that encompasses the entire structure of an institution/business/infrastructure, from the physical parts to the

[1] World Economic Forum - The Global Risks Report 2018

management, to ensure the ability to **prevent, absorb, adapt,** and **recover** to an undesirable event, either natural, man-made, physical or cyber.

The paper is a summary of two Guidelines published by the Italian Association of Critical Infrastructures Expert's (AIIC)[2,3]

World at Risk

Today, unfortunately, Community Resilience Managers have to deal with a landscape characterized by constantly evolving hazards, mostly due to climate change.

"We cannot eliminate disasters, but
We can mitigate risks,
We can reduce damage, and
We can save more lives"
Ban Ki-moon
Former UN Secretary General

- During 1995-2015, weather-related events accounted worldwide for 90% of total disasters, 71% of total economical losses, and 61% of lives lost[4]
- Climate Change may increase the frequency and consequences of such events
- Between 2010 and 2040 the number of people over 65 in less developed countries is expected to nearly triple[5]
- By 2030, 60% of the world's population will reside in cities[6]
- 80 % of the ten largest cities are at risk of being severely affected by an earthquake, and 60% are vulnerable to storm surge and tsunami waves[7]

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[2] *Guidelines for Critical Infrastructures Resilience Evaluation*, ISBN 978-88-9349-090-0 - Published by AIIC, February 2016
http://www.infrastrutturecritiche.it/new/media-files/2017/03/RESILIENCE_Guidelines_AIIC.pdf
[3] *Guidelines for Community Resilience Evaluation*, ISBN 9-78-8893-49-00-30 - Published by AIIC, February 2017
http://www.infrastrutturecritiche.it/new/media-files/2017/03/COMMUNITY_Resilience_AIIC.pdf
[4] The United Nations Office for Disaster Risk Reduction, https://www.unisdr.org/archive/46793
[5] U.S. National Institute on Aging, https://www.nia.nih.gov/research/publication/global-health-and-aging/humanitys-aging
[6] United Nations, https://esa.un.org/unpd/wup/Publications/Files/WUP2014-Highlights.pdf
[7] UN-HABITAT http://mirror.unhabitat.org/categories.asp?catid=690

- Vulnerability introduced by local conditions such as poverty, government corruption, poorly planned development, and environmental degradation are adding to the risk

Cost of Disasters[8]

- In the 10 years since Hurricane Katrina, the world has seen an annual average of 260 major natural disasters, with average annual economic losses of US$ 211 billion, insured losses of US$ 63 billion, and 76,000 lives lost
- In 2014, 72 percent of global disaster losses were caused by extreme weather events
- In 2015 the devastating Nepal earthquake resulted in close to 9000 lives lost alone
- In 2016 the central Italy earthquake resulted in close to 300 lives lost
- In 2017 the 7.3 magnitude earthquake that hit western Iran resulted in close to at least 407 lives lost
- In 2018 1459 death toll caused by extreme rainfall and floods across India
- These figures do not include any of the many smaller-scale floods, storms, earthquakes and other localized disasters

What does Community Resilience mean

Figure 1. Community Functions supported by Community Infrastructures
(source NIST SP1190)

The paper makes reference to the definition of Community *Resilience* developed by the Community and Regional Resilience Institute (CARRI)[9]:
Community resilience is the capability to anticipate risk, limit impact, and bounce back rapidly through survival, adaptability, evolution, and growth in the face of turbulent change.
This definition contains the core concepts making resilience:

[8] AON Report on "Annual Global Climate and Catastrophe Report"
[9] http://www.resilientus.org/wp-content/uploads/2013/08/definitions-of-community-resilience.pdf

- Prepare for anticipated hazards
- Adapt to changing conditions
- Withstand and recover rapidly from disruptions

and can enable communities to determine how resilient they are and to take actions to improve their resilience.

Characteristics of a Resilient Community

The six *characteristics* of a resilient community that emerged from the Report "*Community Based Disaster Risk Reduction Study: Characteristics of a Safe and Resilient Community*" International Federation of Red Cross and Red Crescent Societies, Geneva, 2012[10] are summarized below. They are fully endorsed by this paper.

A safe and resilient community...

1. …**is knowledgeable and healthy**. It has the ability to assess, manage and monitor its risks. It can learn new skills and build on past experiences
2. …**is organized**. It has the capacity to identify problems, establish priorities and act.
3. …**is connected**. It has relationships with external actors who provide a wider supportive environment, and supply goods and services when needed.
4. …**has infrastructure and services**. It has strong housing, transport, power, water and sanitation systems. It has the ability to maintain, repair and renovate them.
5. …**has economic opportunities**. It has a diverse range of employment opportunities, income and financial services. It is flexible, resourceful and has the capacity to accept uncertainty and respond (proactively) to change.
6. …**can manage its natural assets**. It recognizes their value and has the ability to protect, enhance and maintain them.

These *characteristics* recognize the importance of human health and well-being and also individual knowledge and awareness as central to the ability of community members individually and collectively to be able to prepare, prevent, respond to and recover from shocks and stresses. Secondly, they acknowledge the importance of assets and access to wider resources beyond the immediate control of the community.

Community Resilience Model

The proposed Community Resilience Model is based on the following three assumptions:

- A Community is made of people, technological key infrastructures and organizations supported and regulated by processes. Any Resilience Evaluation activity must take in consideration all these components, including cultural background, in view to be complete and successful. (Figure 2).

[10] http://www.ifrc.org/PageFiles/96986/Final_Characteristics_Report.pdf

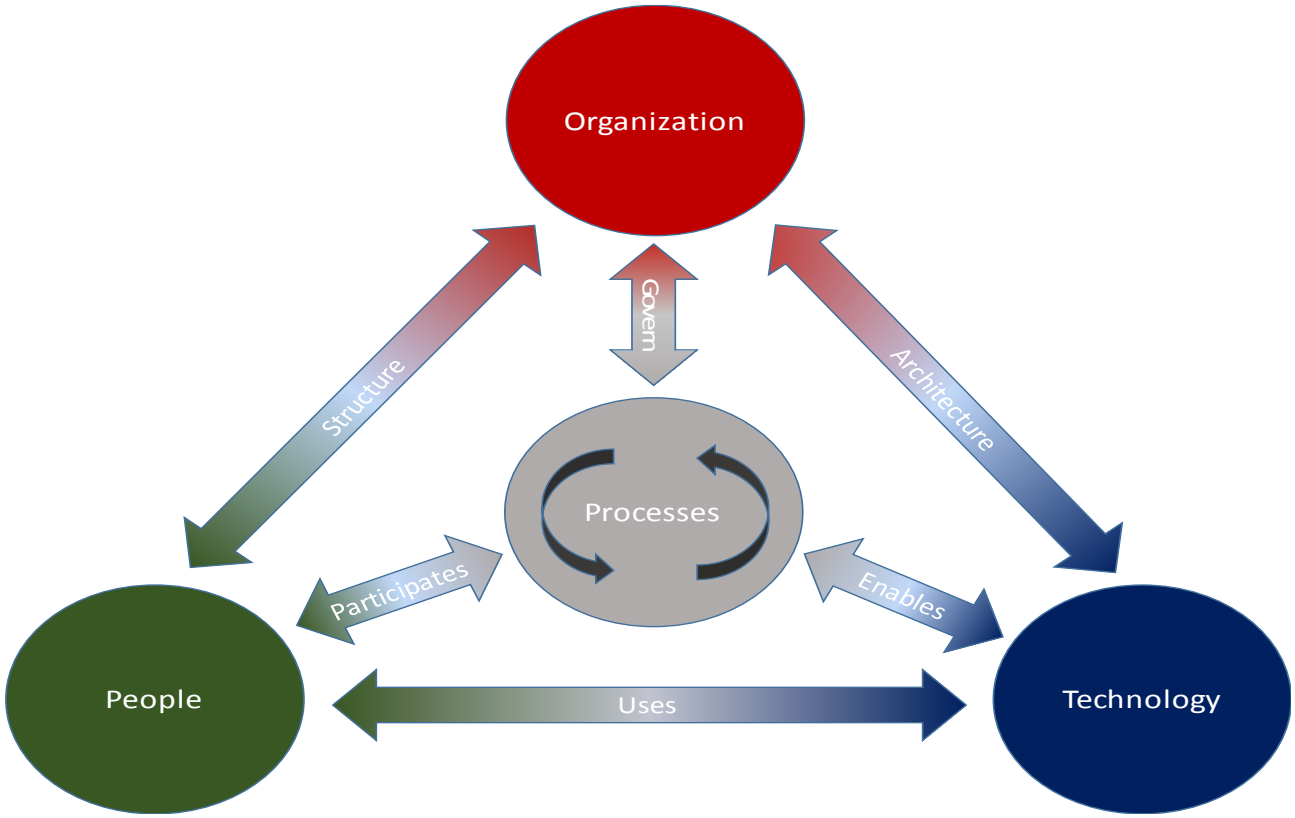

Figure 2. Basic components of a complex systems

(Source: USC Marshall School of Business Institute for Critical Information Infrastructure Protection)

- A Community Environment, referred in the NIST SP1190 with the term "*built environment*", is made of *Community Key Infrastructures*, *Community Key Functions*, *Community Key Organization's Capacities*. The full meaning of these three Community Elements that contribute to Community Resilience will be given in the following sections. Figure 3[11] gives a pictorial representation of the Community Elements that contribute to Community Resilience. The built environment in any community includes its buildings and infrastructure systems. When a hazard event occurs, damage to the built environment can make it difficult for a community's institutions to function and meet members' needs. While some social institutions rely more heavily on the built environment than others, there are linkages between the social and built environments that need to remain strong for a community to thrive. This paper is based upon the foundation that *the community key functions and the community key organization's capacities drive the requirements of the community key infrastructures*, based on their importance in supporting key functions and key organization's capacities in the community.

[11] http://cip.gmu.edu/2016/11/29/human-landscape-functional-bridge-physical-economic-social-elements-community-resilience/

Figure 3. System Elements that contribute to Community Resilience

(Source: "The Human Landscape – The Functional Bridge between the Physical, Economic, and Social Elements of Community Resilience" The CIP Report, George mason University, November 2016)

- AIIC Community Resilience Model is built by grouping all the *item to be measured* (Features) with the *indicative measurements* (Resilience Indicators) into four community resilience dimensions: Technical Dimension (Infrastructure & Environment), Organizational Dimension (Leadership & Strategy), Cooperative & Societal Dimension (including Health & Wellbeing), Economic Dimension, and it is represented by the following Figure 4.

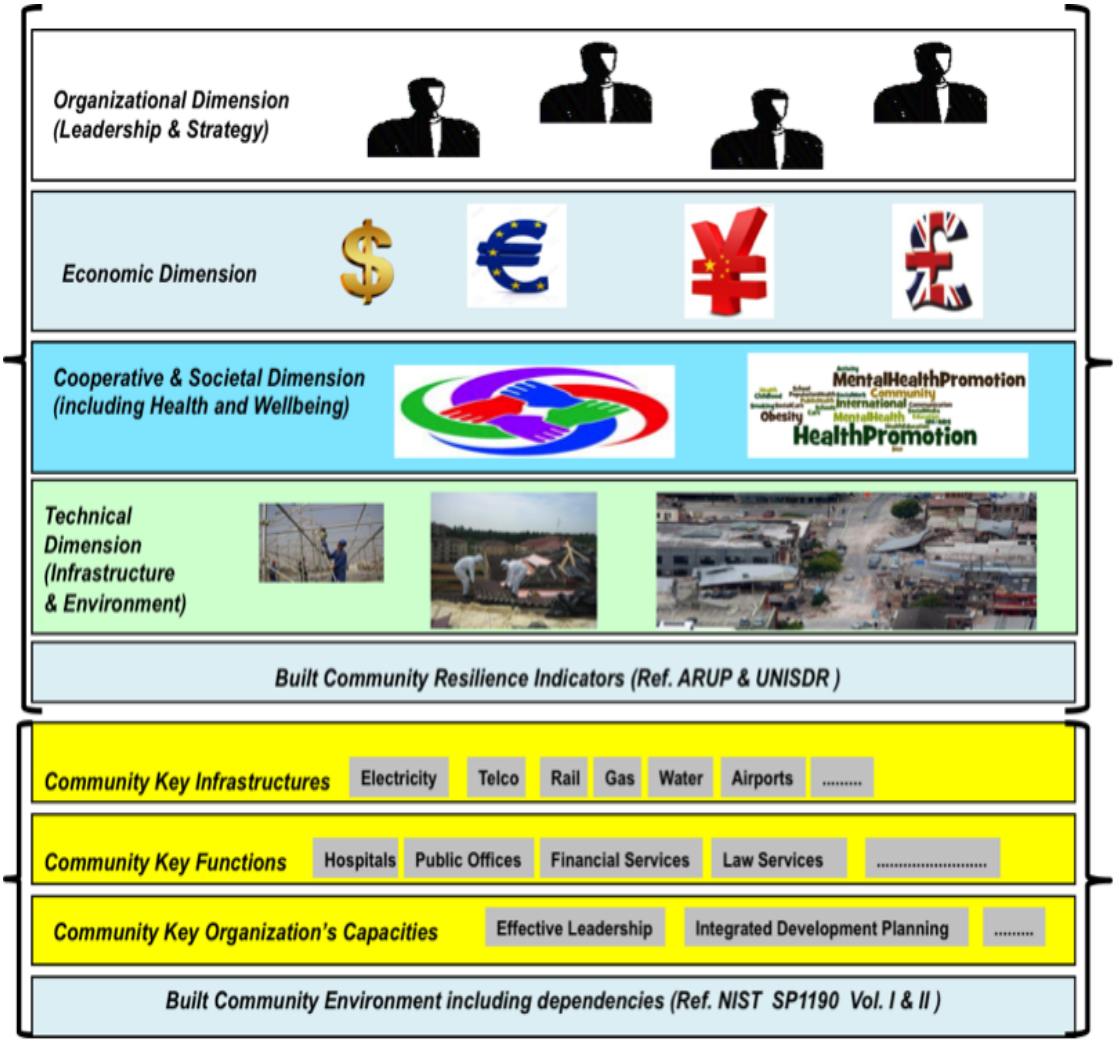

Figure 4. AIIC Community Resilience Model

The AIIC Community Resilience Model reported in the Guidelines published in the year 2017[12], starts from the results of the previous "Guidelines for Critical Infrastructures Resilience Evaluation" published in the year 2016[13], by introducing the concepts of social and economic aspects as well as "dependencies, interdependencies and cascading effects" aimed at identifying dependencies and potential cascading failures among the Infrastructures serving the Community, through the implementation of combinations of societal, organisational and technological resilience concepts. **Its objective is to allow a territorial Community to understand its standing towards the risk of some specific catastrophic events and its shortcomings, should they exist.**

The Model involves the following steps:

1. Identify the boundary and the constituents of the Community (Built Community Environment)

[12] *Guidelines for Community Resilience Evaluation*, ISBN 9-78-8893-49-00-30 - Published by AIIC, February 2017
http://www.infrastrutturecritiche.it/new/media-files/2017/03/COMMUNITY_Resilience_AIIC.pdf
[13] *Guidelines for Critical Infrastructures Resilience Evaluation*, ISBN 978-88-9349-090-0 - Published by AIIC, February 2016
http://www.infrastrutturecritiche.it/new/media-files/2017/03/RESILIENCE_Guidelines_AIIC.pdf

- Identify and characterize infrastructure systems, location, and dependencies between and among them
- Identify and characterize community facilities serving the community functions, location, and dependencies between and among them
- Identify stakeholders key contacts/representatives for evaluation, coordination, and decision making activities
- Identify and characterize functions and dependencies of social institutions, including business, industry, and financial systems, based on individual/social needs met by these institutions and social assets and vulnerabilities

2. Identify Catastrophic Events and their prioritization based on the possible impact on the Community

3. Assess (perform or acquire) Resiliency of Basic Critical Infrastructures relevant to the Community

4. Evaluate Resilience Indicators for the Community in the four dimensions of:
    a. Technical
    b. Cooperative & Societal
    c. Economic
    d. Organizational

5. Built in a Radar Chart for each Community Resilience Dimension, to get a pictorial and immediate idea of what is weak and to compare with possible solutions

Built Community Resilience Indicators and Metrics

Based on the Community Resilience Model described in the previous section, and AIIC Guidelines for Critical Infrastructures Resilience Evaluation (2016), the following Tree Model has been adopted for the definition of Resilience Indicators and Metrics (Figure 5).

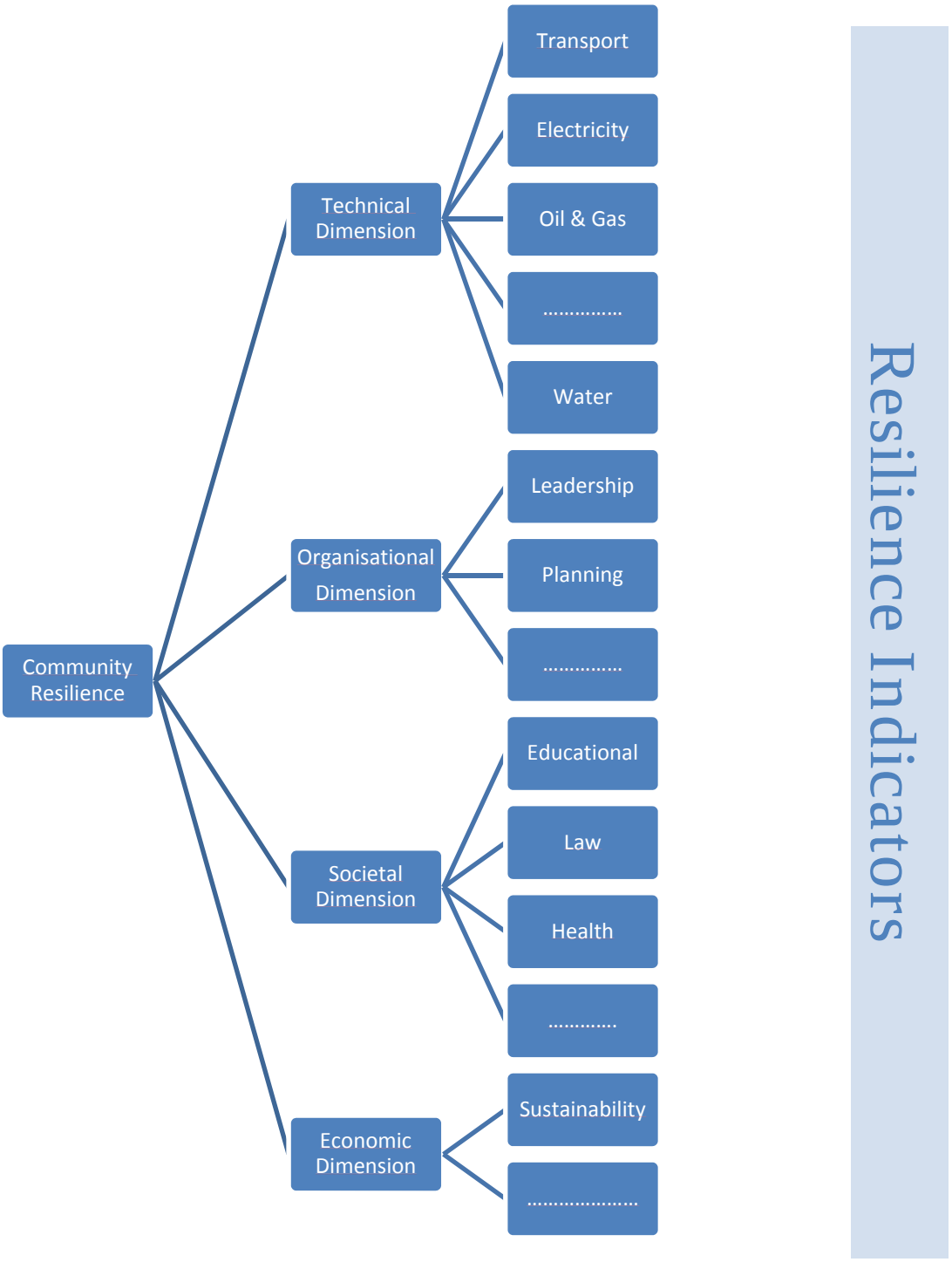

Figure 5. Community Resilience Tree

In total, the Community is represented by: 4 Dimensions, 34 Features, and 77 Resilience Indicators that contribute to the Community Resilience Evaluation

Explaining Resilience Indicators

Resilience Indicators (RIs) are quantified properties of the dimensions, and features characterizing the community subject to evaluation. Evaluating the resilience indicators means to evaluate the adoption of resilience solutions at the bottom level of the implementation used to implement features, acting in the four dimensions, with the goal to build a more resilient community. Resilience indicators are the basic tools for the evaluation process.

Resilience Indicators are edited in cards sharing a common template whose components are hereunder explained. Such cards are grouped in each of the four dimensions referred in the general model. During the evaluation process, each card can be customized and eventually applied to the Community subject to evaluation. If needed, additional Resilience Indicators can be defined by the Community Resilience Manager. **The number and the type of RIs used for the Resilience Evaluation of a specific Community will very much depend from the type of Community, as defined during the phase indicated by the name "community built". The evaluation criteria supporting each RI must be clear and defendable.**

A Template is proposed to answer to the question "What is being evaluated?". The Template shall be used to define specific Resilience Indicators and is general enough to be adapted case by case to the resilience dimensions and features of the community under evaluation (see Fig. 6).

Community Resilience Dimension	
Community Resilience Feature	
Community Resilience Indicator Name	
Description	Description of the specific Community Resilience Indicator for the goal / subject under assessment
Scenario Relevance	Relevance for the specific scenarios (earthquake, windstorm, flooding, tsunami, etc.);
Evaluation method(s)	Method used for ranking the specific community resilience indicator, based on "prompt questions" formulated by the expert in charge for the resilience evaluation
Indicator's score	A numerical value between 1 and 5 attributed by the expert in charge for the resilience evaluation, adopting the CMMI (Capability Maturity Model Integration) levels indicator
Sources / References	For more details and information

Figure 6. Template for Resilience Indicator Cards

How to compose the quantified resilience indicators in a number of "composite indicators" or a unique Resilience Index characterizing the overall Community is not covered by the present state of the art and shall be the target of a future research work and/or project.

Community Technical Dimension Resilience Indicators

The Resilience Indicators for the Technical Dimension are the way for the Assessor to evaluate the status of the Resilience of each of the Critical Infrastructures serving the Community.

The evaluation is done assessing an "indicator parameter", one for each Critical Infrastructure – CI, that is representative of the preparedness of the CI in the occurrence of one of the Catastrophic Events prioritized in the Resilience Model (natural or human-made).

As mentioned before, Critical Infrastructures are either

- in support of a Primary Need (like water and electric power)
  or
- providing Key Assets to a Community Key Function

In some instances, the infrastructure will have a prior resilience assessment done by the provider of the specific service.

In case this assessment is not available, the Community Resilience Assessor should evaluate the effectiveness of the disaster resilience plans for this infrastructure system vs. characteristics of the location, relationships between critical assets, the population they serve, and any documentation that may predict the damage that can be expected from the emergency scenario under consideration.

The evaluation of the Resilience Indicator itself is subjective, i.e. based on the experience and knowledge of the Assessor, who is also responsible to factor in the evaluation inter-infrastructure dependencies.

The expectation of severe impacts from the unavailability of other infrastructures which are a dependency for the one under evaluation (e.g. a "brittle" road network which is likely to fail under emergency, will expose to failure also the emergency-response infrastructure) will result in a lower RI for the infrastructure under consideration.

Community Cooperative and Societal Dimension Resilience Indicators

The definition of boundaries of the Societal dimension is quite difficult because it reflects the variety of human and political organizations. It is a shared consensus that a "highly cohesive " community is more resilient, but definition of parameters for community cohesion is not unique.
The extensive study known as City Resilience Index (CRI)[14] made by ARUP on behalf of Rockefeller Foundation is particularly focused on societal aspects and their relation with the resilience of a community (in their case a city). We have tried to synthesize and make more easily applicable their complex and complete approach on the assumption that resilience is a characteristic very useful for a community of every size. Small communities are usually understaffed and do not have the resources to hire specialized teams, on the contrary they do not need a very complex and articulate approach to resilience and can use a reduced set of instruments. For large communities our approach can also be useful to have a first evaluation of the most relevant indicators that contribute to resilience and the gaps to a sufficient condition.
Other studies have been considered for educational and law enforcement: namely those of International Federation of Red Cross and RED Crescent (IFRC)[15], National Institute for Standard

[14]The Rockefeller Foundation/ARUP *City Resilience Index – understanding and measuring city resilience*
[15]IFCR Report *Community Based Disaster Risk Reduction Study: Characteristics of a Safe and Resilient Community* International Federation of Red Cross and Red Crescent Societies, Geneva, 2012

and Technology (NIST)[16] and the United Nation International Strategy for Disaster Reduction (UNISDR)[17].
Every community has to select its set of indicators, there are many indicators that are generally applicable but resilience cannot be generalized. A possible approach to the choice of the indicators useful for a particular community starts from the risk analysis and then proceeds to elicit the aspects that are relevant in case of possible emergencies, prioritization is also an important and difficult task. A long term vision is desirable but if it is not present a short program of study and intervention is much better than none.

Community Economic Dimension Resilience Indicators

Economic sustainability extends to household level, the city level and beyond. The private sector also must be ready to cope with calamity through risk management and business continuity plan setting up.
The primary short-term focus is the re-establishment of a viable supply chain for primary staples as food, carburant, drinking water, but immediately after, the focus shifts to the restart of all local economic activities, returning people to their normal work routine.
This will also contribute to safeguard the wellbeing of human resources. Besides these actions are recommended preventive interventions to acquire the integration of local economy at regional, national and international level.
Fundamental to a resilient economy is that the communities have a degree of financial independence, so they can invest in infrastructures and respond quickly to shocks and stresses; in the same time they must be able to quickly obtain funding by government in case of major disaster.
According to a study, four questions could be addressed: *resilience of what* (to which community does resilience apply?), *to what* (what disturbances is the community experiencing?), *for whom* (who are the beneficiaries?) and *for what* (for what identity or goal does resilience aim in the future?)[18]. In our model we consider only the first three questions when the answer to the forth one is more accurately declined into Functions and Objectives. The first question (*resilience of what?*) can be solved by reference to resilience of the community economy as a system of production, distribution and consumption of supplies and services within a border line. The second question (*resilience to what?*) can be answered by resilience to disturbances that are essential in their scope of sound effects, abrupt, like disaster or economic crises, or gradually, like demographic transformation. The third question (*resilience for whom?*) can be referred to resilience for the community economy as a whole, maintaining the functioning of the overall local economy. To help answer these questions, indicators of the Community Economic Sustainability have been considered.

Community Organizational Dimension Resilience Indicators

The organizational resilience indicators are based on the ARUP-Rockfeller Foundation indicators[19] and on the ISO proposals for management system standards "High Level Structure"[20].

[16]NIST Special Publication 1190 *Community Resilience Planning Guide for Building and Infrastructure Systems* Volume I and II
[17]UNISDR Working Document *Disaster Resilience Scorecard for Cities*
[18] Huong Dinh, Leonie Pearson "*Specifying community economic resilience – a framework for measurement*" Australian Journal of regional Studies, Vol. 21, No. 3, 2015
[19] City Resilience Index - The Rockefeller Foundation - ARUP

In order to measure how satisfactory is the treatment of the organizational dimension of resilience, we adopt the CMMI (Capability Maturity Model Integration) levels indicator[21]. Maturity levels provide a method that enables to compare the organization's capability to others and to itself over time. CMMI, as shown in the Figure 7 below, provides 5 maturity levels: *Initial, Managed, Defined, Quantitatively Managed and Optimizing.*

Figure7. CMMI Maturity Levels
(Source: ISACA-CMMI Maturity Levels)

Conclusions

The paper shows a way of modelling a Community and a possible approach for evaluating the Community Resilience based on Resilience Indicators defined for each dimension of the Community Resilience Model. Both Community Resilience Model and Indicators have to be customized case by case.

[20] ISO/IEC Directives, Part 1. Consolidated ISO Supplement 2015 —Procedures specific to ISO- Annex SL- Proposals for management system standards - Appendix 2- High level structure, identical core text, common terms and core definitions;
[21] http://www.isaca.org/knowledge-center/blog/Lists/Posts/Post.aspx?ID=667

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While working at ENEA his main research topics have been on system safety and reliability, decision support systems, risk analysis and risk management. Recent main research activities deal with Critical Infrastructure Protection and Resilience, with a special emphasis to vulnerability and interdependencies modeling, simulation and analysis.
Past President of the Italian Association of Critical Infrastructure Experts (AIIC) and present Board Member, at the present he is independent researcher and freelance expert for the participation to National and International Research Projects in the field of Critical Infrastructure Protection and Resilience, Community Modeling and Emergency Management .