EARTHQUAKE RISK PERCEPTION, COMMUNICATION AND MITIGATION STRATEGIES ACROSS EUROPE

Piero Farabollini, Francesca Romana Lugeri, Silvia Mugnano
Editors

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CONTENTS

9. An historical flight and some open questions towards a pluralistic but holistic view of resilience

Maurizio Indirli[*]

Abstract

The term “resilience”, found for the first time in several Latin authors, then passed through medieval culture until intellectuals who strongly contributed to the birth of the modern scientific method (as Francis Bacon), 19th century encyclopedists, the Rankine’s quantitative definition in engineering, and finally to psychology, anthropology, and ecology, with the fundamental Holling's contribution in 1973. In the last decades, the concept expanded quickly into social-ecological systems, disaster/risk assessment, sustainability, and adaptive capacity to cope catastrophic scenarios. Nowadays, multi-disciplinary scientists and representatives of public/private organizations largely use the term “resilience”, but with increasing ambiguity about its properties and attributes. This work presents an *excursus* through the ages and a brief (not exhaustive, of course) *state-of-the-art* regarding “resilience”, pointing out some open questions of the current debate among researchers of different disciplines, working in the fields of hazard mitigation, sustainability, risk assessment, heritage preservation, and so on.Increasing popularity but still scarce unification depict the situation; resilience still necessitates a robust effort of further multi-, inter-, trans-disciplinary research, going beyond the current fragmentation. Impressive tools supplied by Geomatics/Big Data management and extraordinary potentialities available from complex mathematical models give us now the opportunity to create ‘a network of networks’; but the fast run of technology cannot be separated by a slower and shared *Peripatetiké Scholé*, exploring philosophical and scientific theories with a pluralistic but holistic view.

Finally, this work presents open questions and suggestions of some nuclei of future research regarding “resilience” (*safety*, *robustness*, *adaptive capacity*, *sustainability*, *governance*, *anamnesis*) that might be exploited in future studies.

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Keywords: Resilience, Multi-hazard scenarios, Risk management

1. History

1.1 Resilience, origin and evolution of the concept: from the classic age to the end of 19th century

My curiosity about the concept of "resilience" has been stimulated after reading the "*etymological journey*" of Alexander (2013); then, I felt the need of a personal investigation, in order to bring a sharper focus on some crucial historical passages and connections.

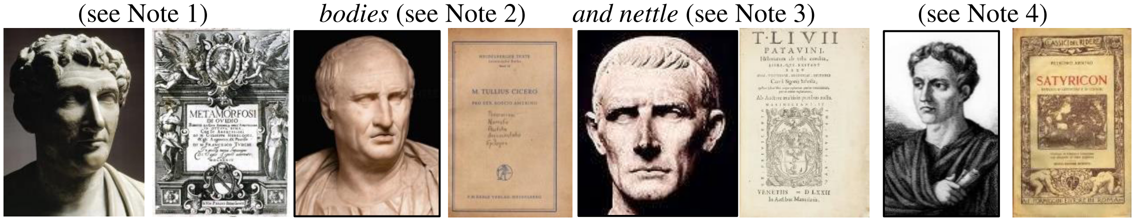
Some authors find captivating links with Ancient Greek Stoicism, Daoism, and Taoism (resilience as interpretation of detachment: Atkinson et al., 2009; Robertson, 2012; Morris, 2004; Wong, 2006; resilience as warrior self-governance, Sherman, 2005). Anyway, I believe that the current term indisputably appears in the Latin writings of Marcus Vitruvius Pollio[1], Titus Lucretius Carus[2], Gaius Plinius Secundus Maior[3], Lucius Annaeus Seneca Maior[4], Lucius Annaeus Seneca Minor[5], Publius Ovidius Naso[6], Marcus Tullius Cicero[7], Titus Livius[8], Marcus Fabius Quintilianus[9], Lucius Enneus Florus[10], Gaius Petronius Arbiter[11], and later Ammianus Marcellinus[12], Flavius Vegetius Renatus[13], among others (Figure 1).

Marcus Vitruvius Pollio, De Architectura: acoustics in theaters (see Note 1)

Titus Lucretius Carus, De Rerum Natura: void and resistance of bodies (see Note 2)

G. Plinius Secundus Maior, Naturalis Historia:fishes, honey and nettle (see Note 3)

Lucius Annaeus Seneca Maior, Controversiae: sentence of the priestess (see Note 4)



Publius Ovidius Naso, Metamorphoses: sailing, swimming, fighting

Marcus Tullius Cicero, Pro Roscio Armerino:

Titus Livius, Ab Urbe Condita:

Gaius Petronius Arbiter,Satiricon: the young slave (see Note 6) *accuse rebounds from own client* (see Note 7) *skittish elephants in Zama battle* (see Note 8) (see Note 11)

Figure 1 - *Appearance of the term resilience in Latin authors.*

In Latin (Liotta et al., 2010), *resilire* (rĕsĭlĭo, rĕsĭlis, resilui, rĕsĭlīre; resilĭens -ĕntis) means the act of rebounding, i.e. to rebound/recoil, from "re-" back + "salire" to jump, leap. It is used in architecture (Vitruvius), natural sciences (Lucretius, Plinius Maior), law and religion (Seneca Maior, Seneca Minor, Cicero, Quintilianus), literature (Ovidius, Petronius), history (Livius, Florus, Marcellinus, Renatus), giving the description of daily experiences in tangible or metaphorical sense (rebounding, leaping, shrinking, drawing back, retreating).

Plutarch (50; after 120 AD; Romanized Greek born at Chaeronea) analyzed the personalities of Lycurgus and Numa Pompilius in his *Parallel Lives* (Plutarch, 2001). He locates the cause for resilience somehow in the traits of the leaders, including virtues both moral and intellectual, and in the specific plans deemed necessary to bring about change to the societies of Sparta and Rome (Cusher, 2015).

Sofronius Eusebius Hieronymus[14] (St. Jerome), Ambrosius Mediolanensis[15] (St. Ambrose), and Aurelius Augustinus Hipponensis[16] (St. Augustine) use the word respectively in their *Epistolae*, *Hexameron*, and *Breviculus collationis cum Donatistis*. Resilire turns out again in *Historia Langobardorum* of Paulus Diaconus Warnefred Barnefridus Cassinensis[17] (Paul the Deacon) and *Legenda Major Sancti Francisci* of Bonaventura Bagnoregis[18] (Bonaventure). The term appears in other medieval authors as Isidorus Hispaliensis[19], Beda Venerabilis[20], Theodulfus Aurelianensis[21], Aelredus Rievallensis[22], Hugo Falcandus[23], and Boncompagnus de Signa[24].

The verb resilire is cited again by Gaufridus Monemutensis[25] (Galfridus Monumotensis, Geoffrey of Monmouth; Hammer, 1951) in his *Historia Regum Britanniae*, it is a popular chronicle originally in Latin, a valuable piece of medieval literature translated into several languages, although historically unreliable. Pietro Alighieri[26] and Guido da Pisa[27] use the word in their commentaries of *Divina Commedia* (by Dante Alighieri, 1265-1321; Alighieri, 1957). By the way, the impressive motto "*PERCUSSA RESILIUNT*" ("*struck they rebound*"; ascribed to Leone X, the Renaissance Medici Pope, as an ingenious allusion to the unstable fortune of his family; Valery, 1839) leaps out in the Hall of Elements, Pitti Palace, Florence, Italy.

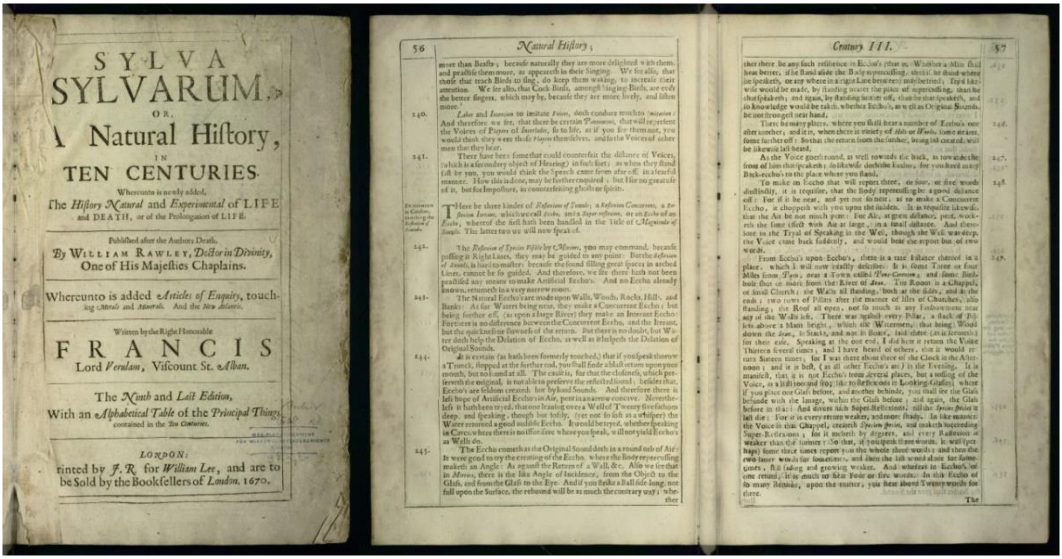
Coming from the sharp philological (pre-scientific) nucleus of the Classic Roman culture (therefore employed infrequently but properly), it seems that resilire, with its derivatives, rebounds from a thinker to another, through subsequent ages: sometimes keeping the original sense until to Giacomo Leopardi (1798-1837; Italian poet, philosopher, essayist, philologist; *Zibaldone di pensieri*, Leopardi, 1832); otherwise becoming ambiguous or capsized.

I neglect here the almost hidden passages (rather difficult to identify) into Romance languages (mention in Alexander, 2013: Middle French: "résiler"; English: "resile"), and remember *en passant* some historicists of the same period (example: Johannes Cluverus[28] or Iohannis Clüver, *Historiarum Totius Mundi Epitome*). In fact, it could be more productive to investigate the work of eminent bilingual (Latin/English; Latin/Romance) intellectuals who strongly contributed to the birth of the modern scientific method. They are Franciscus Baconus de Verulamio[29] (Francis Bacon), Renatus Cartesius[30] (René Descartes), and Galileo Galilei[31].

Bacon uses resilience (and derivatives) both in Latin and English (*Novum Organum*, *Sylva Sylvarum*, Figure 2) to describe physical properties and natural phenomena; the same for Descartes (*Letter 110 to Mersenne* in French, translated into *Epistola CX Ad R.P. Mersennum*). Although Galilei seems to ignore the word, it appears in Latin writings of colleagues involved in epistolary exchanges or debates with him about astronomy and motion of bodies (examples: Honoratus Fabrius or Honoré Fabri, *Tractatus Physicus De Motu Locali*; Fortunio Liceti, 1577-1657, Italian physician, philosopher, scientist, *Liteosphoros, seu de Lapide Bononiensi*).

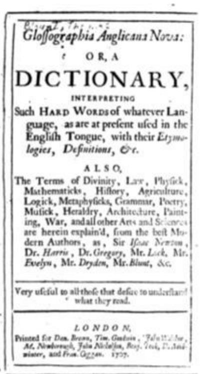
Thanks to the robust basis created by the above said scientists, Ralph Bohun[32] speaks of "resilition" in an important early systematic study of winds (*A Discourse concerning the origine and properties of wind*; Bohun, 1671), after collecting worldwide wind and storm data, including on the land/sea breeze regime, the seasonal Asian monsoonal flow, hurricanes, waterspouts, and tornadoes. The same does James Keill[33] (*An Account of Animal Secretion*; Keill, 1708), and later Thomas Campbell[34] (*A Philosophical Survey of the South of Ireland, in a series of letters to John Watkinson*; Campbell, 1778).

Thomas Blount[35] (Blount, 1656), Edward Phillips[36] (Phillips, 1658), and Ephraim Chambers[37] (Chambers, 1728) employ "resilience/resiliency/resilition/resilient" in their books (respectively: *Glossographia*: RE, Resiliency/Resilition, a leaping back, recoiling, or rebounding; see also Alexander, 2013; *The New World of English Words, or, a General Dictionary*: RE, Resiliency/Resilition, the State or Quality of that which is resilient, Resilient, leaping back, rebounding, or recoiling; *Cyclopaedia, or, an Universal Dictionary of Arts and Sciences*: REC, Recoil/Rebound, the resilition of a body, chiefly a fire-arm; or the motion whereby, upon explosion, it starts or flies backwards; Figure 3).

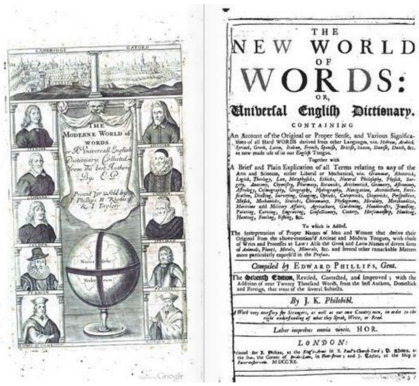


Francis Bacon, Sylva Sylvarum, (see Note 29).

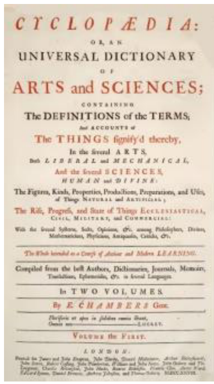
Figure 2 - *The concept of resilience in Francis Bacon.*



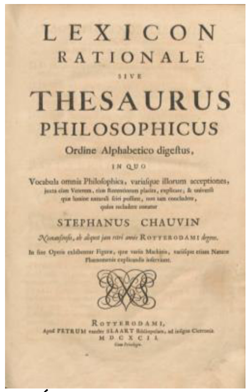
Thomas Blount, Glossographia (see Note 35)



Edward Phillips, The New World of English Words or a General Dictionary (see Note 36)



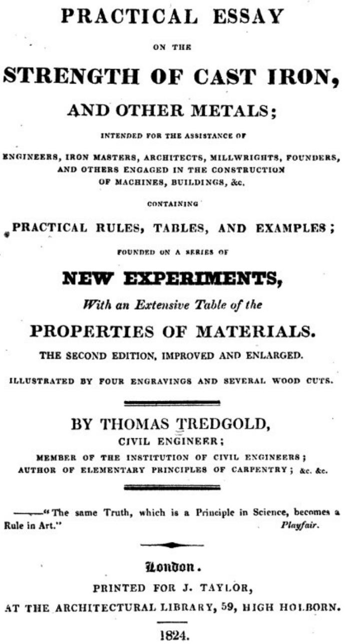
Ephraim Chambers, Cyclopaedia (see Note 37)



Étienne Chauvin, Lexicon Philosophicum (see Note 38)

Figure 3 - *Appearance of the term resilience in English encyclopedists and in Chauvin (Latin).*

Stephanus Chauvin[38] (Étienne Chauvin; Chauvin, 1692) registered the definition of “resilientia” in his *Lexicon Philosophicum*. Denis Diderot[39] and Jean Baptiste Le Rond d’Alambert[39] are co-editors of the *Encyclopédie* (Diderot & Le Rond d’Alambert, 1751-65), inspired by the success of the above mentioned Chambers' volume, but the words "résiliation/résilier" are confined in the field of jurisprudence.



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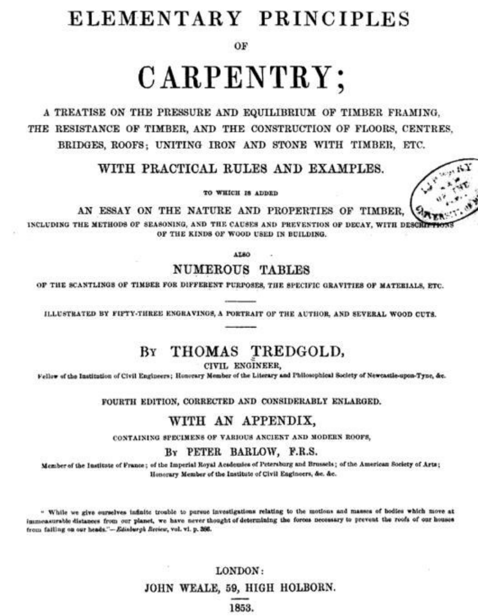

ELEMENTARY PRINCIPLES

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LONDON:

JOHN WEALE, 59, HIGH HOLBORN.

1853.

Thomas Tredgold (see Note 40)
Practical essay on the strength of cast iron, and other metals
Elementary Principles of Carpentry

Figure 4 - *Thomas Tredgold's important books.*

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OF

APPLIED MECHANICS.

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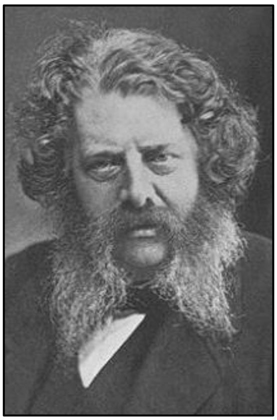
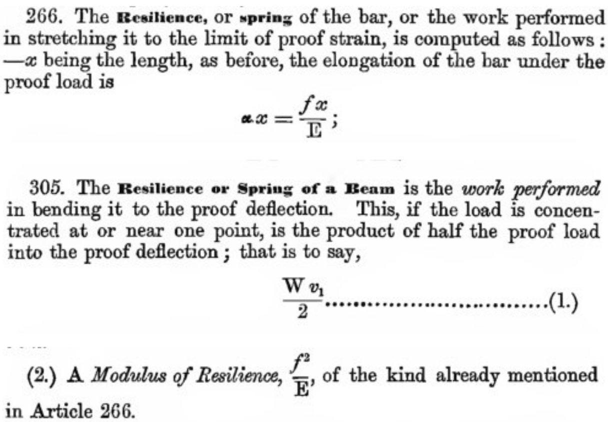




266. The **Resilience**, or **spring** of the bar, or the work performed in stretching it to the limit of proof strain, is computed as follows: —x being the length, as before, the elongation of the bar under the proof load is

$$\alpha x = \frac{f x}{E};$$

305. The **Resilience or Spring of a Beam** is the *work performed* in bending it to the proof deflection. This, if the load is concentrated at or near one point, is the product of half the proof load into the proof deflection; that is to say,

$$\frac{W v_1}{2} \text{..............................} (1.)$$

(2.) A *Modulus of Resilience*, $\frac{f^2}{E}$, of the kind already mentioned in Article 266.

William John Macquorn Rankine (see Note 41)

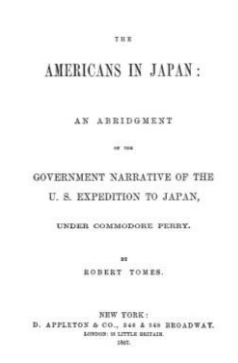
Figure 5 - *First quantitative definition of resilience: relation between force, ductility and resistance of beams.*

In general, advancing the Western scientific culture, resilience - and attributes - focuses on physical properties (rebounding of objects; elasticity of bodies; absorption of energy after impacts; reclaiming the original shape after deformation; sound reflecting; etc.).

The first definitions of resilience in engineering (timber and iron properties) can be found in Thomas Tredgold[40] (*Practical essay on the strength of cast iron, and other metals*; Tredgold, 1824; *Elementary Principles of Carpentry*; Tredgold, 1853; see also references in Haigh, 2015; Figure 4). Later, William John Macquorn Rankine[41] (*A Manual of Applied Mechanics*; Rankine, 1858-64; also reference in Alexander, 2013) provided quantitative formulae linking strength, ductility, and resilience of beams (Figure 5).

The same concepts, recalled in following technical-scientific books (Ewart Sigmund Andrews[42]; Andrews, 1908; 1913), spread immediately to the construction practice and industrial processes (Charles Frederick T. Young[43], *The fouling and corrosion of iron ships*, Young, 1867; William John Gordon[44], *Foundry, Forge and Factory*, Gordon, 1890; Andrew Wynter[45], *Subtle Brains and Lissom Fingers*; Wynter, 1869).

Furthermore, resiliency is found in Medicine (Robert Bentley Todd[46], *The Cyclopaedia of Anatomy and Physiology*; Todd, 1836-59; David James Hamilton[47], *A text-book of pathology systematic & practical*; Hamilton, 1889-94; Thomas Clifford Allbutt[48], *A System of Medicine by Many Writers*; Allbutt, 1901). The word also describes the ability to recover from adversity (Robert Bell[49], *Eminent literary and scientific men, English poets*; Bell, 1839; also reference in Alexander, 2013).



THE

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AN ABRIDGMENT

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U. S. EXPEDITION TO JAPAN,

UNDER COMMODORE PERRY.

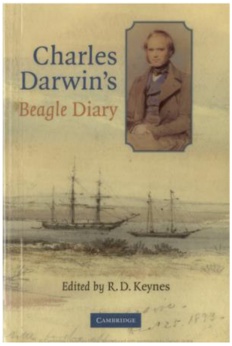
BY

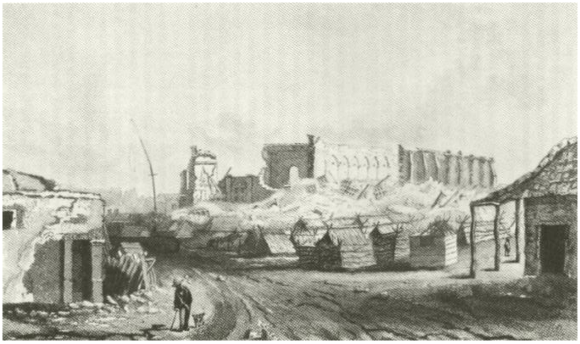
ROBERT TOMES.

NEW YORK:
D. APPLETON & CO., 346 & 348 BROADWAY.

Robert Tomes, The Americans in Japan (see Note 50)

Figure 6 - *Tomes's description of the earthquake/tsunami occurred in Shimoda, December 23rd, 1854.*



Book cover *Principal expeditions* *Remains of the cathedral of Concepcion, Chile*
Charles Darwin (see Note 51)

Figure 7 - *The Charles Darwin's Journey reported by his Beagle Diary.*

Robert Tomes[50] (*The Americans in Japan*, Tomes, 1857; also reference in Alexander, 2013; Figure 6) gives a sharp and astonishing description of the earthquake/tsunami sequence occurred in Shimoda, near Tokyo, on December 23rd, 1854, highlighting the adaptive capacity of Japanese people as resiliency and energy in their character.

Although Charles Darwin[51] does not mention explicitly the term resilience, he was quite shocked (Darwin, 1988, Figure 7) when he experienced a seismic event (earthquake and tsunami of Concepción/Talcahuano, Chile; February 20th, 1835, 11:30 local time, 15:30 UTC; estimated magnitude M_s=8.2, M_L=8.1). Furthermore, Charles Darwin and Robert Fitzroy witnessed the volcanic phenomena of Mount Osorno in Chiloe (November 26th, 1934). Darwin's observations about volcanos, earthquakes, and fossils contribute greatly to develop his thinking about the long-lasting age and transformation of the earth (but approximately only 6,000 year old for the Bible dogma in the dominant creationism of that period!). Consequently, also thanks to the study of the coral reefs growth, Darwin moved to the concept of 'coral of life' instead of 'tree of life', more appropriate for him to formulate the theory of the origin of species by natural selection (Darwin, 1859). *"Changes in the land created new environments and fostered adaptations in life forms that could lead to the formation of new species. Without the demonstration of the accumulation of multiple crustal events over time in Chile, the biologic implications of the specific species of birds and tortoises found in the Galapagos Islands and the formulation of the concept of natural selection might have remained dormant*" (Lee, 2010). Finally, the exceptional discontinuity marked by Darwin has been fundamental, more than one century later, for Crawford Stanley Holling, studying invading species and species in danger of extinction, to stress the separation of ecological resilience from stability, as different concepts and processes.

At this stage of our historic *excursus*, it is quite evident that the resilience flow, at the end of the 19th century, already presents, although in an embryonic state, the terms of future problematic conflicts, which will be emphasized by the growing up of multi-, inter-, trans-disciplinary approaches. A delimited and quantitative definition, born in applied contests of hard sciences, is going to be transferred to themes involving significantly social disciplines, until disaster assessment and civil protection, due to its undeniable metaphoric strength. The following direct quotation (Alexander, 2012; and 2013) summarizes perfectly the question: "*A resilient steel beam survives the application of a force by resisting it with strength (rigidity) and absorbing it with deformation (ductility). By analogy, the strength of a human society under stress is its ability to devise means of resisting disasters and maintaining its integrity (coherence), while the ductility lies in its ability to adapt to circumstances produced by the calamity in order to lessen their impact.*" Powerful and charming, the word resilience, acting as a prism scattering rapidly its original background into different directions, will catch the forthcoming and transversal attention of scientists, institutions, and citizens.

1.2. Resilience, origin and evolution of the concept: from the 20th century until today

The concept of resilience, built around the original nucleus belonging to the Latin culture, then renovated by the birth of the modern scientific method, offered broad description of phenomena in medicine, while engineering provided first quantitative formulae. In the second half of the 20th century, it spreads its complex potential towards different directions: again manufacturing (studies related to properties of yarn and woven fabrics: Hoffman, 1948; Beste & Hoffman, 1950), but especially psychology/anthropology (first), and ecology (later).

Donald A. Bloch (and colleagues) starts to analyze the effects of a disaster experience (December 5th, 1953 tornado of Vicksburg, Mississippi) on children in the community: "*A motion picture theatre, filled with children attending a Saturday afternoon movie, was particularly affected. For this reason, the Committee on Disaster Studies of the National Research Council felt that an unusual opportunity existed to study selectively the effects of the* *disaster experience on children in the community*" (Bloch et al., 1956). Then, the research develops towards competence/resilience in psychopathology (Garmezy, 1971 and 1973; Garmezy et al., 1984) and life experiences affecting resistance to psychiatric disorder (Rutter, 1985). Finally, continuity/change in competence/resilience over the transition to adulthood is interested, where: "*[...] resilience refers to the process of, capacity for, or outcome of successful adaptation despite challenging or threatening circumstances*" (Masten et al., 1990 and 2004; also: Alexander, 2013; Olsson et al., 2015; and references therein).

To summarize, resilience in psychology is "*a dynamic process of positive adaptation within the context of significant adversity, trauma, tragedy, threats, or significant sources of stress. [...] More recently, resilience [...] shifted the focus from individual resilience to include the role of social capital in communities in which individuals are embedded. Research on community resilience includes insights on health and human development, and can potentially be seen as an example of co-development with resilience theory in the context of socio-ecological systems (SESs)*" (Olsson et al., 2015; references therein).

In fact, the concept will expand in the following years until the definition of social resilience as the ability of: "*communities to withstand external shocks to their social infrastructure*"; "*a system to absorb perturbations*"; "*groups or communities to cope with external stresses and disturbances as a result of social, political and environmental change*" (Adger, 2000).

The term resilience appears in an anthropology work regarding West African cultures, speaking about their greater mental resilience to shocks through conservation and adaptation (Herskovits, 1952). Other studies are between anthropology/psychology (Kagan, 1975) and anthropology/ecology (Lasker, 1969).

A couple of decades after the publication of *Outline of General System Theory* (von Bertalanffy, 1950), Crawford Stanley "Buzz" Holling[52] (Figure 8) worked on ideas originally proposed by Darwin[51] (1988 & 1859), reiterated by MacArthur (1955), modeled by May (1973) that species richness produces ecological stability (Peterson et al., 1998, and references therein). Holling, analyzing forest budworms, is the first scientist who adopts and defines precisely resilience in the field of ecology, making a clear distinction from the concept of stability (Holling, 1973; also Pimm, 1984; Gunderson et al., 1997 and 2009; Alexander, 2013; and references therein).

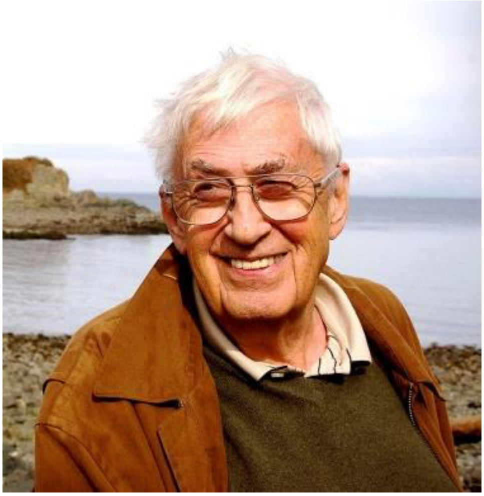
"*It is useful to distinguish two kinds of behaviour. One can be termed stability, which represents the ability of a system to return to an equilibrium state after a temporary disturbance; the more rapidly it returns and the less* *it fluctuates, the more stable it would be. But there is another property, termed resilience, that is a measure of the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables*". Further, speaking about random events (affecting ecological systems considered non-deterministic), Holling says: "*they suggest that instability, in the sense of large fluctuations, may introduce a resilience and a capacity of resist*"; and finally in the synthesis, with definitions: "*I propose that the behaviour of ecological systems could well be defined by two distinct properties: resilience and stability. Resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and persist. In this definition, resilience is the property of the system and persistence or probability of extinction is the result. Stability, on the other hand, is the ability of a system to return to an equilibrium state after a temporary disturbance*" (quotations: Holling, 1973).

These definitions are certainly robust landmarks summarizing the research in rising ecology that followed the activity of Odum[53], 1971 (see also Thorén, 2014; and references therein).

Dynamic equilibrium and homeostatic reaction proper of ecosystems, captured by Holling's resilience, migrate quickly into other disciplines and attract researchers interested in sustainability/sustainable development and socioeconomic systems (Perrings, 1998; Levin et al., 1998; Batabyal, 1998).

The concept is used as a diagnostic indicator (Thorén, 2014; and references therein), informing analysis of change in economy-environment systems. In fact, some years later, "*the key point is that resilience is a measure of stability in the face of shocks […] in joint economy-environment systems*" and "*offers a helpful way of thinking about the evolution of social systems partly because it provides a means of analyzing, measuring and implementing the sustainability of such systems*" (quotation: Perrings, 1998).

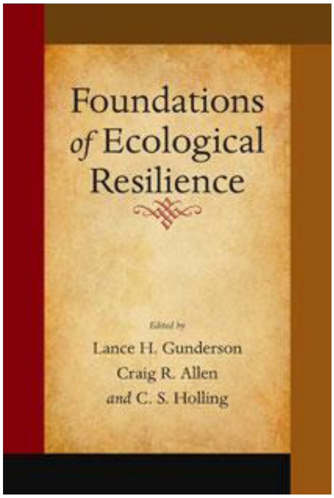
Starting from a sentence contained in a declaration of the World Climate Conference ("*natural environments […] especially vulnerable or especially resilient to climatic variability and change*", WMO, 1980), Timmermann (1981; and references therein) speaks about resilience, analyzing the vulnerable society and reviewing some basic models/paradigms of social systems under stress. Same approaches are already used after Holling (1973) by other authors (Burton et al., 1978) and agencies (CSRG, 1979). Resilience is conceived "*as a concept describing the ability of a society to bounce back from severe stress*" and as "*the measure of a system's, or part of a system's capacity to absorb and recover from the occurrence of a hazardous event*" (quotation: Timmermann, 1981).



RESILIENCE AND STABILITY OF ECOLOGICAL SYSTEMS

C. S. Holling

INTRODUCTION



Crawford Stanley 'Buzz' Holling (see Note 52)

Figure 8 - *Adoption and definition of resilience in the field of ecology.*

The widespread impact of the Holling's work is quite impressive; anyway, in ecology and social sciences,"*although there is always a strong link to Holling's resilience, variation in the way different authors use the concept is considerable*" (Thorén, 2014), as shown by Table 1 (adapted from Brand & Jax, 2007).

In fact, some years later, Holling feels the need to clarify (Holling, 1996; and references therein). He distinguishes (quotations from Holling, 1996):

(i) *engineering resilience*, focusing on "*maintaining efficiency of function*", concentrating on "*stability near an equilibrium steady state, where resistance to disturbance and speed of return to the equilibrium are used to measure the property*";

(ii) *ecological resilience*, focusing on "*maintaining existence of function*", where its measurement, in conditions far from any equilibrium steady state, "*is the magnitude of disturbance that can be absorbed before the system changes its structure by changing the variables and processes that control behavior.*" Therefore, "*ecological resilience decreases even though engineering resilience might be great*", and "*there are different stability domains in nature, […] thus, a near-equilibrium focus seems myopic*".

Table 1 - *Definitions of resilience in ecological and social sciences (adapted from Brand & Jax, 2007).*

Categories and classes	*Definitions*	*References*
	(I) DESCRIPTIVE CONCEPT	
	(Ia) ECOLOGICAL SCIENCE	
1) original-ecological	measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables	Holling, 1973
2) extended-ecological	magnitude of disturbance that can be absorbed before the system changes its structure by changing the variables and processes that control behavior	Gunderson & Holling, 2002
	and	
	capacity of a system to experience shocks while retaining essentially the same function, structure, feedbacks, and therefore identity	Walker et al., 2006
	2a) three characteristics: *i)* to absorb disturbances; *ii)* for self-organization; *iii)* for learning and adaptation;	Walker et al., 2002
	2b) four aspects *1)* latitude (width of the domain); *2)* resistance (height of the domain); *3)* precariousness; *4)* cross-scale relations;	Folke et al., 2004
3) systemic-heuristic	quantitative property that changes throughout ecosystem dynamics and occurs on each level of an ecosystem's hierarchy	Holling, 2001
4) operational	resilience *of* what *to* what?	Carpenter et al., 2001
	and	
	ability of the system to maintain its identity in the face of internal change and external shocks and disturbances	Cumming et al., 2005
	(Ib) SOCIAL SCIENCES	
5) sociological	ability of groups or communities to cope with external stresses and disturbances as a result of social, political, and environmental change	Adger, 2000
6) ecological-economic	transition probability between states as a function of the consumption and production activities of decision makers	Brock et al., 2002
	and	
	ability of the system to withstand either market or environmental shocks without losing the capacity to allocate resources efficiently	Perrings, 2006
	(II) HYBRID CONCEPT	
7) ecosystem-services-related	underlying capacity of an ecosystem to maintain desired ecosystem services in the face of a fluctuating environment and human use	Folke et al., 2002
8) social-ecological system		
8a) social-ecological	capacity of a social-ecological systems to absorb recurrent disturbances so as to retain essential structures, processes, feedbacks	Adger et al., 2005
8b) resilience-approach	perspective or approach to analyze social-ecological systems	Folke, 2006
	(III) NORMATIVE CONCEPT	
9) metaphoric	flexibility over the long term	Pickett et al., 2004
10) sustainability-related	maintenance of natural capital in the long run	Ott & Döring, 2004

Some years later, the concept of resilience enters sustainable hazard mitigation, thanks (among others) to the contribution of Graham A. Tobin (1999), with the aim to provide innovative policies to construct resilient communities. Assuming "*the state of Florida, USA, […] as a microcosm of […] global concerns*", Tobin conjugates ecological/socio-political approaches to build up a framework (flowchart in Figure 9), as a dynamic system, adapting three separate models: mitigation (from Waugh, 1996); recovery (from Peacock & Ragsdale, 1997); structural-cognitive (from Tobin & Montz, 1997). His "*ultimate goal is to achieve community sustainability and resilience in the face of prevailing natural and technological hazards*" and "*facilitate recovery processes*". Moreover, "*sustainable and resilient communities are defined as societies which are structurally organized to minimize the effects of disasters, and, at the same time, have the ability to recover quickly by restoring the socio-economic vitality of the community*" (quotation: Tobin, 1999).

Always in 1999, Holling and a small group of scientists/practitioners found the Resilience Alliance (RA[52]), an international multidisciplinary network that explores the dynamics of social-ecological systems. RA members "*collaborate across disciplines to advance the understanding and practical application of resilience, adaptive capacity, and transformation of societies and ecosystems in order to cope with change and support human well-being*" (quotation: RA[52]). The concept, extended to social-ecological systems, is described as 'panarchy' (Gunderson & Holling, 2002).

Starting from the work of McEntire et al. (2002; and reference therein), tracing the evolution of disaster paradigms and their drawbacks, Manyena (2006) affirms that resilience helps "*to obtain a complete understanding of risk and vulnerability*", both of them "*have not been conceptualized in a comprehensive manner*" and "*fragmentation has been common*". After giving a summary of resilience definitions, swinging between outcome and process, he concludes: "*the goal of any 'disaster resilience' programme will be to enhance the fundamental values, assets, and resources that can be applied to the process of adapting to adverse circumstances*". Furthermore, he discusses about the relationship among resilience and vulnerability, concluding in this way: "*resilience and vulnerability, although often viewed as opposites, are two distinctly separate constructs*". Finally, "*disaster resilience could be viewed as the intrinsic capacity of a system, community or society predisposed to a shock or stress to adapt and survive by changing its non-essential attributes and rebuilding itself. This definition has consequences for disaster risk reduction and development practice*" (quotation: Manyena, 2006).

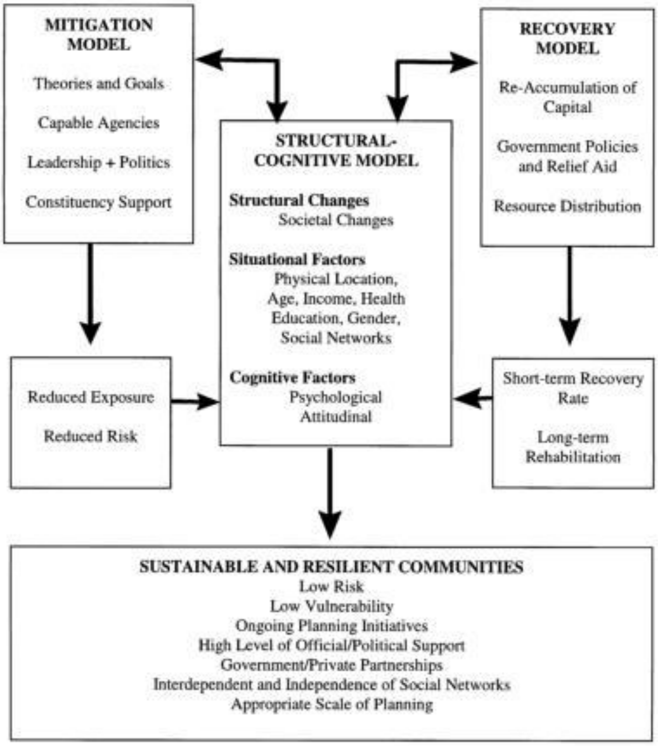


Figure 9 - *Sustainable and resilient communities in hazardous environments: a framework for analysis (Tobin, 1999, adapted from: Waugh, 1996; Peacock & Ragsdale, 1997; Tobin & Montz, 1997).*

Now important International agencies and institutions are ready to incorporate resilience in their declarations, documents and programmes. The International Federation of Red Cross and Red Crescent Societies (IFRC), the world's largest humanitarian organization founded in 1919, focuses on community resilience its World Disaster Report in 2004 (IFRC, 2004). The United Nations deliver the Hyogo Framework (UN-ISDR, United Nations-International Strategy for Disaster Reduction, 2005) one year later. In 2009, UNISDR (United Nations Office for Disaster Risk Reduction) publishes its terminology (UNISDR, 2009), including the definition of resilience ("*The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management*"). The same year, the UNISDR "Making Cities Resilient" campaign begins, addressing issues of local governance and urban risk.

It is clear that multiple cross-disciplinary transfers, among various disciplines, contribute to the polysemous concept of resilience. It is seen "*as an outcome, a state, a property or a process*". It refers to terms related one each other, but never completely overlapping; "*everyone* [pulls] *resilience towards its own meaning to adapt it to its own*" purpose. Furthermore, "*authors recall earlier concepts and rely on them, drawing some sort of circle where every term is linked to the other but without enough information to know just how they relate to one another*" (see Figure 10, Table 2; quotation: Reghezza-Zitt et al., 2012; and references therein).

In a system at risk, resilience: if a process, it should be seen in a diachronic perspective; if a property, it is a-chronic; if a quality, it can be innate or acquired (again from Reghezza-Zitt et al., 2012).

An intense debate whirls around "*change and resistance to change*" (Olsson et al., 2015). It generates two main polarized couples:

(i) *resilience vs resistance* (engineering: resilience occurs by recovering towards a previous or an improved stable state; Bruneau et al., 2003; from Cimellaro et al., 2016);

(ii) *resilience vs stability* (ecology: resilience is achieved by moving towards a different system state; Handmer & Dovers, 1996; from Cimellaro et al., 2016).

Figure 10 - *The multidisciplinary aspect of resilience (Reghezza-Zitt et al., 2012).*

In addition, another "*major point of [...] discussion in resilience circles is whether resilience is a normative concept or not*" (Olsson et al., 2015): i.e. a good, neutral or bad attribute (Olsson et al., 2015), with a varying range of application - global/local resilience - (Thorén, 2014).

Table 2 - *Synthesis of definitions/approaches of resilience (adapted from: Reghezza-Zitt et al., 2012).*

	definitions/approaches			
	Theoretical - heuristic /Practical	*Stability (equilibrium) /Persistence*	*Property /Process*	*Antonym vulnerability /Continuity or complementarity*
theoretical	Holling, 1973; Provitolo, 2012;	Pimm, 1984; Handmer & Dovers, 1996; Sheffy, 2007; O'Rourke, 2007;	Klein et al., 2003; Pelling, 2003;	Folke et al., 2002; Handmer & Dovers, 1996; UN-ISDR, 2005;
operational	Folke et al., 2002; Godschalk, 2003; UN-ISDR, 2005;	Holling, 1973, 1996; Berkes et al., 2002; Walker & Salt, 2006;	Manyena, 2006; Mc Entire et al., 2002;	Provitolo, 2012; Gallopin, 2006;
	Resistance/Adaptation	*Social/Material*	*System/Analytical*	*Positive/Neutral*
theoretical	Mileti, 1999; Alwang et al., 2001;	Mc Manus et al., 2008; Handmer & Dovers, 1996; Vale & Campanella, 2005;	Berkes et al., 2002; Carpenter et al., 2001; Gallopin, 2006;	Godschalk, 2003; Folke et al., 2002;
operational	Gordon, 1978; Comfort, 1999; Dovers & Handmer, 1992; Fiksel, 2003	Cimellaro et al., 2010a; Sheffy, 2007; O'Rourke, 2007; Bruneau et al., 2003	Cardona, 2003; Dauphiné, 2004; Mc Manus et al., 2008	Perrow, 1986; Klein et al., 2003; Comfort et al., 2010

Table 3 - *Typology of resilience definitions in ecology and social-ecological systems (Olsson et al., 2015).*

Meanings	*Attributes*			
	Descriptive-neutral (N)	*References*	*Prescriptive-good (G)*	*References*
Bounce Back (BB)	**BB-N** resilience and stability of ecological systems	Holling, 1973	**BB-G** resilience and sustainable development	Perrings, 1998
Bounce Back and Transform (BB-T)	**BB-T-N** a handful of heuristic and some propositions for understanding resilience in social-ecological systems	Walker et al., 2006	**BB-T-G** resilience thinking: integrating resilience, adaptability and transformability	Folke et al., 2010

Table 3 (adapted from Olsson et al., 2015) gives an interesting summary of these resilience definitions in ecology and social-ecological systems (SESs). Thorén & Olsson (2017; and references therein) conclude that resilience ("*definition: the ability of a system S to absorb some disturbance D whilst maintaining property P*"):

- "*should be considered [...] a descriptive concept*";

- “*the assumption that resilience is a kind of natural property of systems gives the concept a sheen of scientific objectivity that is in certain contexts unwarranted or even outright dangerous*”.

Evidently, in this increasing ambiguity, “*with regard to research on disasters and crises, the overlap between*” different disciplines, driving to diverse definitions of resilience (from Zhou et al., 2010; Cimellaro et al., 2016) “*has not always produced harmonious views of the same phenomena*” (from Alexander, 2013). Furthermore, “*new approaches to resilience*” look *“for new equilibrium conditions in the future than in the past [...] implementing uncertainty and adaptation*” towards the definition of a “*‘ductile’ resilience [...]. Accordingly to Chandler’s interpretation, it could be possible to define the ‘bounce-back’ or ‘elastic’ approach as homeostatic, while the evolutionary or ‘ductile’ resilience can be recognized in the autopoietic one*” (from Cerè et al., 2017; Chandler & Coaffee, 2017; and reference therein).

But meanwhile, the supporters of quantitative resilience based on functionality are digging deeply, analyzing and grouping technical, organizational, social, and economic patterns (TOSE; Table 4 from: Bruneau et al., 2003; Tierney & Bruneau, 2007) of communities prone to hazards/disasters (Figure 11: NRC, 2006). The study starts from the measure of the seismic resilience, characterized by *4R*: *Robustness*, *Redundancy*, *Resourcefulness*, *Rapidity*; when an event happens, the quality of the infrastructure immediately decreases (vertical line); then, it gradually restores until normality (Figure 12; Bruneau et al., 2003).

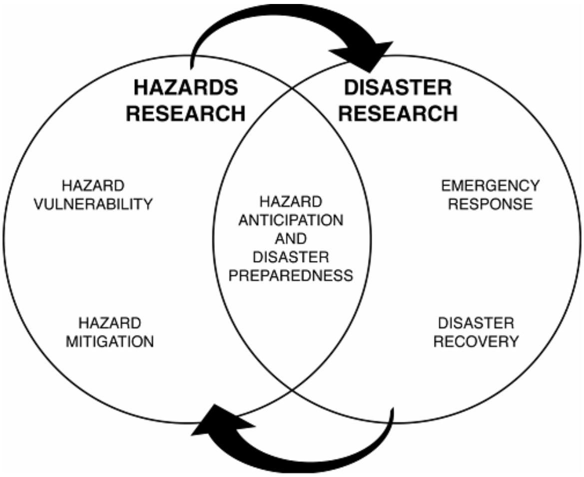


Figure 11 - *Hazards and disaster research (from NRC, 2006).*

CARRI[54] (Community and Regional Resilience Initiative) Reports (i.e. Cutter et al., 2008; Moser, 2008; Colten et al., 2008; Morrow, 2008; Gunderson, 2009; Tierney, 2009; Wilbanks, 2009; Rose, 2009; Colten & Sauer, 2010; Norris, 2010), provides a robust amount of reference materials. Resilience focuses on "*a community or region's capability to prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to public safety and health, the economy, and national security.*" For CARRI[54], the dimensions of a resilient community are: *it anticipates* problems, opportunities, and potentials for surprises; *it reduces* vulnerabilities related to development paths, socioeconomic conditions, and possible threats; *it responds* effectively, fairly, and legitimately; *it recovers* rapidly, safely, and fairly (quotations: CARRI[54]).

$$R = \int_{t_0}^{t_1} [100 - Q(t)]dt$$

t_0: time instant when the hazardous event happens; $Q(t)$: quality of infrastructure in function of time.

R: community earthquake loss of resilience (100% pre-event; reduced, as an example, to 50% immediately after the event).

Figure 12 - *Measure of seismic resilience; conceptual definition (adapted from Bruneau et al., 2003).*

Table 4: TOSE dimensions of resilience (adapted from Bruneau et al., 2003).

TOSE	*Dimensions of resilience (in case of an earthquake event)*
Technical	*The technical dimension of resilience refers to the ability of physical systems (including components, their interconnections and interactions, and entire systems) to perform to acceptable/desired levels when subject to earthquake forces.*
Organizational	*The organizational dimension of resilience refers to the capacity of organizations that manage critical facilities and have the responsibility for carrying out critical disaster-related functions to make decisions and take actions that contribute to achieving the properties of resilience outlined above, that is, that help to achieve greater robustness, redundancy, resourcefulness, and rapidity.*
Social	*The social dimension of resilience consists of measures specifically designed to lessen the extent to which earthquake-stricken communities and governmental jurisdictions suffer negative consequences due to the loss of critical services as a result of earthquakes.*
Economic	*The economic dimension of resilience refers to the capacity to reduce both direct and indirect economic losses resulting from earthquakes.*

Figure 13 (adapted from Cerè et al., 2017) gives a summary of the various methodologies used for the quantitative resilience assessment. It classifies approaches, with/without a targeted attention on specific domains, as (see Cerè et al., 2017):

(i) single-hazard;

(i_a) indirect performance-based (resilience evaluation through subjective consultations to experts, useful for a quick evaluation, but with non-negligible margins of error);

(i_b) direct expert-based (more precise, relying, for example, on fragility curves for resilience assessment at the building scale, but still with a fragmented perspective);

(ii) multi-hazard.

Hazus-MH[55] (a GIS-based software model which produces loss estimates for earthquakes, floods, hurricanes, and tsunamis, developed by the Federal Emergency Management Agency, FEMA) is situated apart in Figure 13, because "*resilience is taken into account in a non-explicit way*" and other "*geo-environmental hazards*" are considered "*as an indirect aftereffect of the primary seismic event*" (from: Cerè et al., 2017).

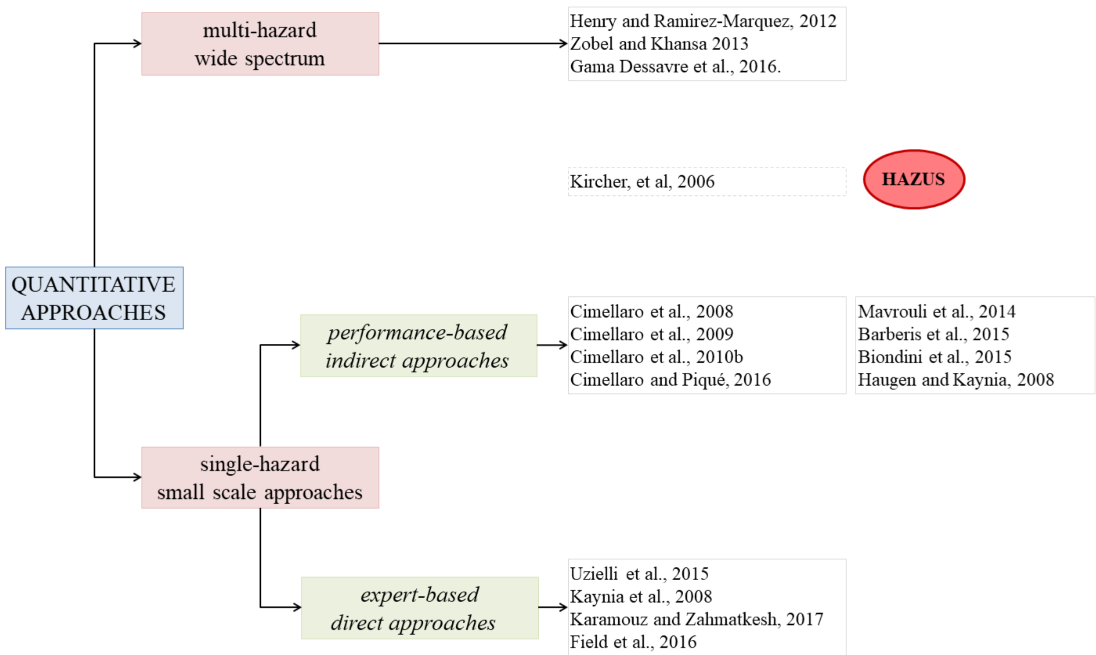


Figure 13 - *Classification of resilience quantitative approaches (adapted from Cerè et al., 2017).*

After some initial frameworks proposed by several authors (Bruneau et al., 2003; Chang & Shinozuka, 2004; Rose & Liao, 2005; Miles & Chang, 2006; Cagnan et al., 2006; see also Cimellaro et al., 2016; and references therein), "*the resilience concept as input to decision support methodologies has been applied to hospitals, lifeline structures, and cities*"; "*several methods for the quantification of infrastructures' resilience have been proposed that can be grouped in probabilistic methods, graph theory methods, fuzzy logic methods, and analytic methods*" (from: Cimellaro et al., 2016; and references therein).

Among a current wide literature, but still missing a comprehensive model quantifying resilience of communities/infrastructures, an advanced example of an interwoven framework "*to evaluate resilience […] taking into account the influence of the human behaviour, societal, organizational, and economic issues*" is given by PEOPLES, built up at MCEER (Multidisciplinary Center for Earthquake Engineering Research, University of Buffalo). PEOPLES establishes a resilience index, proposes resilience performance levels (*RPLs*) based on a finite number of parameters (Renschler et al., 2010; Cimellaro et al., 2016; Table 5), and develops "*a community hybrid model combining network models to simulate the physical infrastructures […] with agent-based models to simulate the sociotechnical networks […]. Furthermore, special attention is given to human behaviour and emotions*". In PEOPLES, the extreme earthquake scenarios are defined through probabilistic seismic hazard assessment (PSHA) and ground motion selection; only some performance indicators might be valid on a multi-hazard approach.

Table 5 - *PEOPLES framework for resilience-based design (RBD) (adapted from Renschler et al., 2010; Cimellaro et al., 2016).*

Acronym *PEOPLES*	*Framework groups*
P	Population and demographics
E	Environment and ecosystem
O	Organized government services
P	Physical infrastructure
L	Lifestyle and community competence
E	Economic development
S	Social-cultural capital

A heuristic effort, trying to obtain a certain consensus between different approaches in order to provide vulnerability assessment in the context of natural hazards and climate change, is given by MOVE (Methods for the Improvement of Vulnerability Assessment in Europe). It is a project sponsored by the European Commission within the framework of the FP7 programme. MOVE (Figure 14) considers four key factors: (a) exposure to a hazard or stressor; (b) susceptibility (or fragility); (c) societal response capacities or lack of resilience; (d) adaptive capacities. The framework does not provide a specific assessment method (qualitative or quantitative) or a pre-defined list of indicators; rather, it outlines key factors and different dimensions of vulnerability that can serve as a basis for a systematic operationalization of vulnerability (Birkmann et al., 2013). The framework has been already applied in several contexts (examples: Romieu et al., 2010; Papathoma-Köhle et al., 2012; Depietri et al., 2013; Papathoma-Köhle et al., 2015).

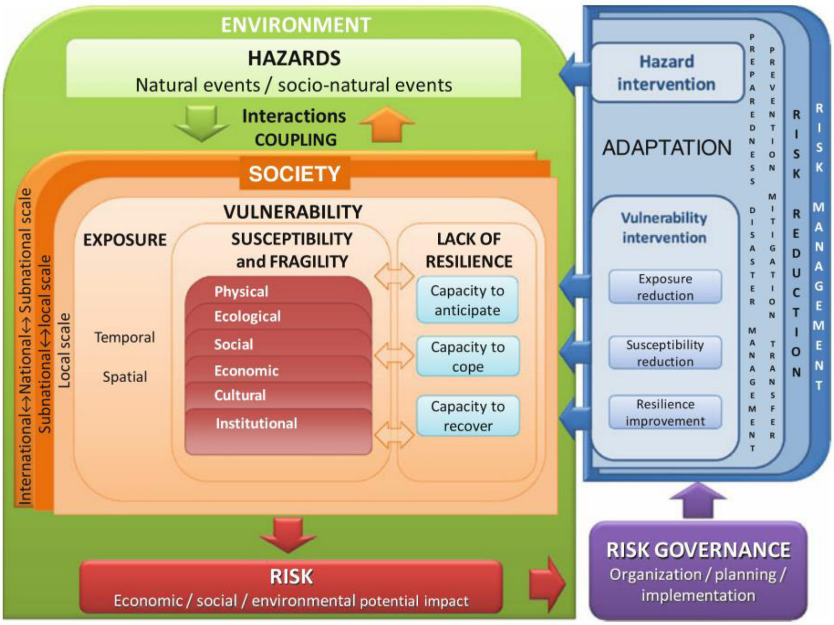


Figure 14 - *The MOVE framework (from Birkmann et al., 2013 and references therein).*

Other researches are analyzing resilience in supply chains *SCs* (a *SC* is "*a system of organizations, people, activities, information, and resources involved in moving a product or service from supplier to customer*", see: Wikipedia[56]) and supply chain networks (*SCNs*), by using structured or unstructured Big Data. Big Data can be defined "*as a holistic approach to manage, process and analyse the "5 Vs (i.e. volume, variety, velocity, veracity, and value) in order to create actionable insights for sustained value delivery, measuring performance and establishing competitive advantages*" (Wamba et al., 2015). An example of "*a theoretical framework to explain* *resilience in supply chain networks for sustainability using unstructured Big Data*" is proposed by Papadopoulos et al. (2017; and references therein), applied to the context of Nepal after the April 25th, 2015 earthquake.

Far from exhausting the discussion with our contribution, and aware of the need to go beyond the use of the term resilience as a fashionable buzzword or just an attempt of a full-scale paradigm (Alexander, 2013; and references therein), we want to conclude this *excursus* introducing, in the next section, some crucial questions requiring focused insights.

2. Some open questions

2.1. System ontology and system boundaries in the definition of resilience

A structured resilience ontology is still lacking in the scientific literature. Without a solid theoretical background, the use of resilience as an integrated framework can create tensions if system ontology and system boundaries are not well defined. Starting from some widely accepted definitions of ontology (*philosophy*: the most general branch of metaphysics concerned with the state of being, its essence and existence; *computer science*: attempt of formulate an exhaustive/rigorous conceptual schema into a given domain, with artifacts providing data representation structure in terms of concepts/relations expressed through the use of logic), ontology might be considered a method of formally representing high-level knowledge as a set of concepts within a domain. More specifically, key components of a formal ontology are: classes (taxonomies), relationships, axioms, and instances (Guarino, 1998, Levine, 2014).

For scientists involved into natural disciplines, "*the system is self-organising […] and non-linear in outcomes*", where "*the effects of a simple interaction in one part of the system can produce large and complex effects in other parts of it*". "*It is the adaptive capacity of such systems […] that characterizes the*[ir] *relative resilience*" (Welsh, 2014).

On the other hand, researchers belonging to social sciences "*are reluctant to use systems as an ontological description of society*", but "*they may use 'system' analytically to study a specific aspect*" (Olsson et al., 2015). Although "*some early social system theories emanated from physics and biology*" (Olsson et al., 2015; references therein: Pareto, 1935; Parsons, 1970), "*this early view of social systems inspired by natural sciences […] is now highly controversial*" (Olsson et al., 2015; references therein: Baecker, 2001).

In sociology, Luhmann (1982), making use of the functionalist method, says that "*a social system consists of nothing but communication [...] characterized by autopoiesis, meaning that the system creates its own basic elements that make up the system*", where "*its boundaries are determined by the system itself*". Furthermore, environment and society are in Luhmann reciprocally unconnected and functionally autonomous (Olsson et al., 2015). After Luhmann, this assumption becomes less rigid, but the effort to build up a common framework is still problematic "*to justify the translation of theory and models between them*" (Welsh, 2014).

At this point of the discussion, the importance to define the system's boundaries is clear, but "*the boundaries of the social system may be considerable harder to describe than those of the ecological systems*" (Alexander, 2013). Because the description of a system "*is from the perspective of an observer*" (Collier and Cumming, 2011), theories, systems and boundaries pertinent to the definition of resilience are broadly subjective; researchers and institutions "*would treat the aspects of society and nature and their dynamics [...] differently*" (Olsson et al., 2015).

Other crucial concepts of the resilience theory in social-ecological sciences are: multiple equilibria, thresholds, feedback mechanisms, and self-organization (Olsson et al., 2015). The different approaches of homeostasis (elastic) and autopoiesis (ductile), i.e. engineering and ecological resilience (as already discussed before), put in the center the quality of the system transformations: are they oscillations around a 'bouncing-back' position (temporary altered) or an 'irreversible shift' towards a new equilibrium (without any turn back after exceeding a critical threshold)? Indeed, "*after a transition, the society, or a subsystem, operates according to new assumptions and rules, thus indicating a range of new practices and not just an altered function*" (Jerneck & Olsson, 2008).

The binary definition of feedback given in cybernetics (negative: stabilization of the system; positive: exponential change) is too simplistic if applied to social phenomena, due to its less predictability and great complexity. In fact, feedback mechanisms in social-ecological systems "*are primarily determined by [...] structured agency* [individual and collective], *rather than by structural forces"* (Olsson et al., 2015; reference therein: Davidson, 2010). Finally, also the principle of self-organization is quite debated; being unproblematic in ecology (seen as the overriding organizing principle in the resilience theory), "*in the social sciences [...] it is mainly understood as a reaction to power asymmetries and structural inequality such as the formation of social movements*" (Olsson et al., 2015; and reference therein).

2.2. Criticism to functionalism theories

A theoretical framework for modeling societal phenomena, based on the functionalism general theory, has been elaborated by Talcott Parsons[57] (1951; 1966; 1970; 1971). It provides a model (acronym: AGIL) with a tetradic structure ordered hierarchically (Table 6; Zwick, 2014; Olsson et al., 2015). To the Parsons' AGIL hierarchy, Gunderson & Holling (2002) prefer the neologism 'panarchy' (from the Greek god Pan, god of chaos and play) to describe the adaptive cycle model (Figure 15).

Table 6 - *AGIL scheme (Parsons, 1951; 1966; 1970; 1971); definitions taken from Olsson et al. (2015).*

A	*Adaptation* a system must adapt to the physical and social environment as well as adapt the environment to its needs
G	*Goal Attainment* a system must define and achieve its primary goals
I	*Integration* a system must coordinate and regulate interrelationships of its components and strive toward a cohesive whole
L	*Latency* a system must furnish, maintain, and renew itself and its individuals to perform their roles according to social and cultural expectations

Anyway, the resilience approaches originating from functionalism have been later criticized, being inadequate "*for overemphasizing consensus, conformity, stability, and reification*". They drives to "*a conservative approach to social change*", where "*the existence of malfunctioning institutions is difficult to explain*". If resilience is conceived as "*the equivalent of stability and harmony*", it does not take into account that "*consensus theories have declined dramatically since the 1960s […], giving more space to conflict theory and issues of diversity, inequality, and power*" (Olsson et al., 2015; and references therein). Therefore, a static concept of resilience can justify and endorse (consciously or not) "*particular policies, projects, and practices […] increasily adopted by influential global organizations such as the United Nations Development Program and funding institutions such as the Rockfeller Foundation as a basis for policy-making and deployment of funds*" (Olsson et al., 2015; and references therein). A similar attitude seems to be also adopted by the European Commission in the framework of recent research programmes.

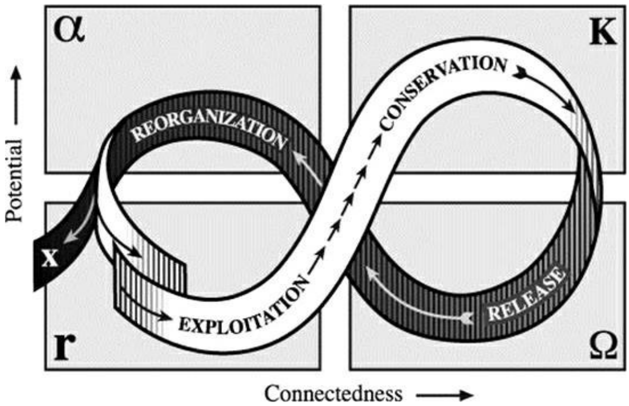


Figure 15 - *Panarchy adaptive cycle, with a stylized representation of the four ecosystem functions r, K, Ω, α and the flow events among them (from Gunderson and Holling, 2002).*

2.3. Underestimation of key factors in disaster risk reduction

As a consequence of the above said point, official provisions of International Agencies (UN-ISDR, 2005; UNISDR, 2012; UNDRR, 2015) should be updated, putting in place "*new arrangements* [with] *a period of consultation during which suggestions and observations* [are helpful to] *identify five 'priorities for action'* ", as specified below by Alexander & Davis (2012; and references therein):

- the human right to hazard information;
- explosive population growth;
- corruption;
- how people are placed at risk by the actions of governments;
- discrimination against women.

This effort is fundamental to fill the existing gap, highlighted by researchers belonging to social sciences/humanities, in the definition of resilience, and *"to challenge publicly any social, economic, political, religious or cultural obstacles to risk reduction*" (Alexander & Davis, 2012).

3. Final remarks

After my personal flight over the historical evolution of the resilience concept (summary in Figure 16), stimulated by the reading of the Alexander's work (2013), I tried to point out some open questions about the different approaches to resilience across various disciplines, analyzing a huge amount (but non exhaustive, of course) of scientific literature. Four leading threads can be pulled out from the mess:

(i) first, originating from the early Rankine's and later Bruneau formulations, several methods for the quantification of the 'engineering resilience', with special focus on structural and infrastructural domains, have been implemented, until to very articulated networks; this 'bounce-back' or 'elastic' approach (oscillations around a steady state) can be considered as '*homeostatic*';

(ii) second, the 'ecological resilience', commonly used in this field after Holling and colleagues of Resilience Alliance (RA), regards a possible 'irreversible shift' towards a new equilibrium, i.e. with a 'ductile' or '*autopoietic*' essence;

(iii) third, resilience does not currently engage the core of social sciences, where functionalism (and subsequent neofunctionalism) models are judged inadequate, with conflict theories gaining more audience; thus, increasing popularity but still scarce unification depict the situation, where resilience still necessitates a robust effort of further multi-, inter-, trans-disciplinary research, going beyond the current fragmentation;

(iv) four, impressive tools supplied by Geomatics/Big Data management and extraordinary potentialities available from complex mathematical models give us now the opportunity to create 'a network of networks'.

Anyway, the fast run of technology cannot be separated by a slower and shared '*Peripatetiké Scholé*' (Περιπατητική Σχολή), exploring philosophical and scientific theories with a pluralistic but holistic view.

At this point of the discussion, a proposal of a rigid frame regarding the resilience concept is far from my purpose. Hence, I only suggest some nuclei of future research (Table 7) that might be exploited in future studies. Furthermore, the presence of the concept of resilience, coming from other cultures and countries worldwide, should be more extensively investigated; to this goal, additional contributions are strongly encouraged.

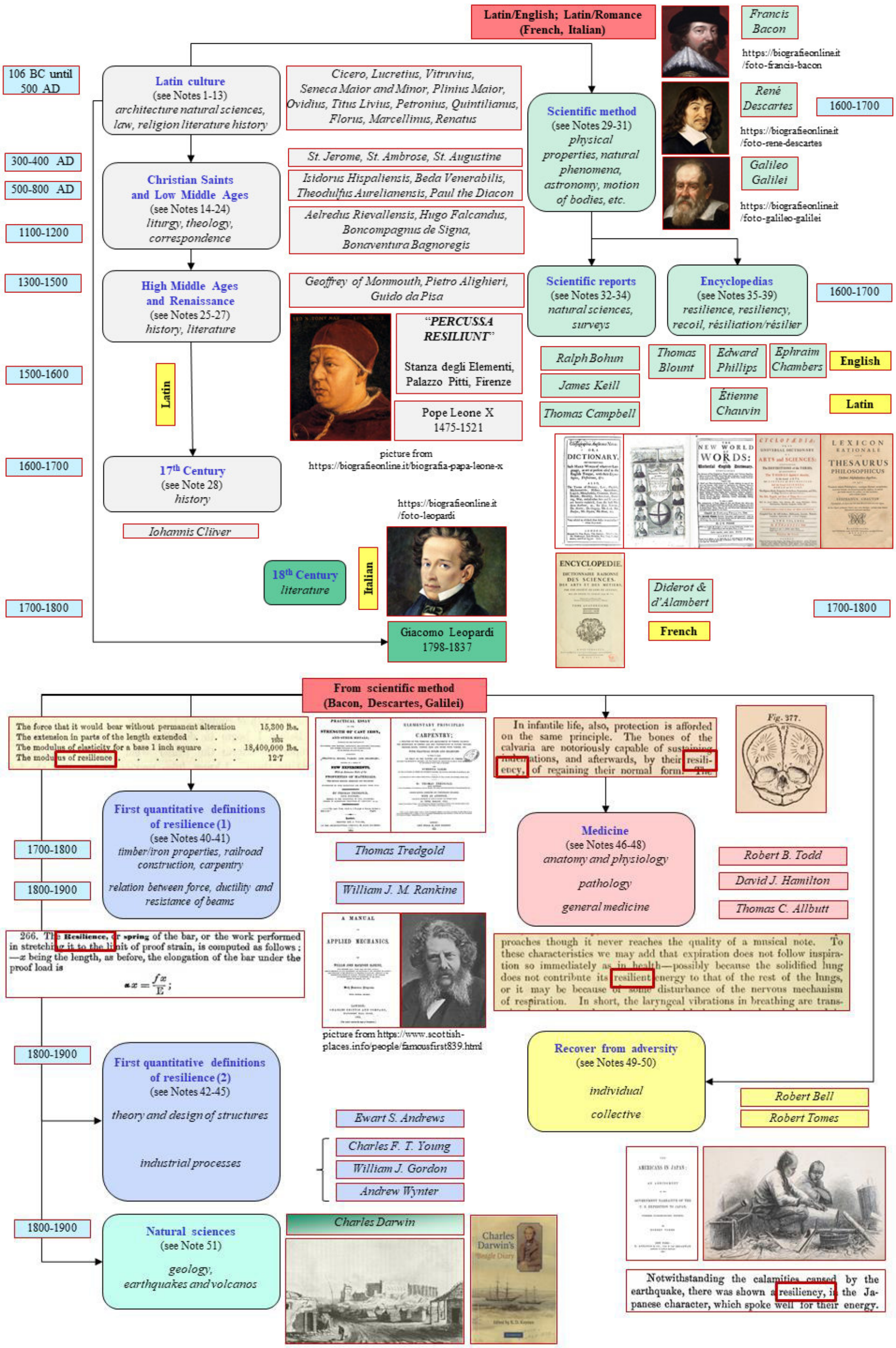


Figure 16a - *Evolution of resilience; from the classic age to the end of 19th century.*

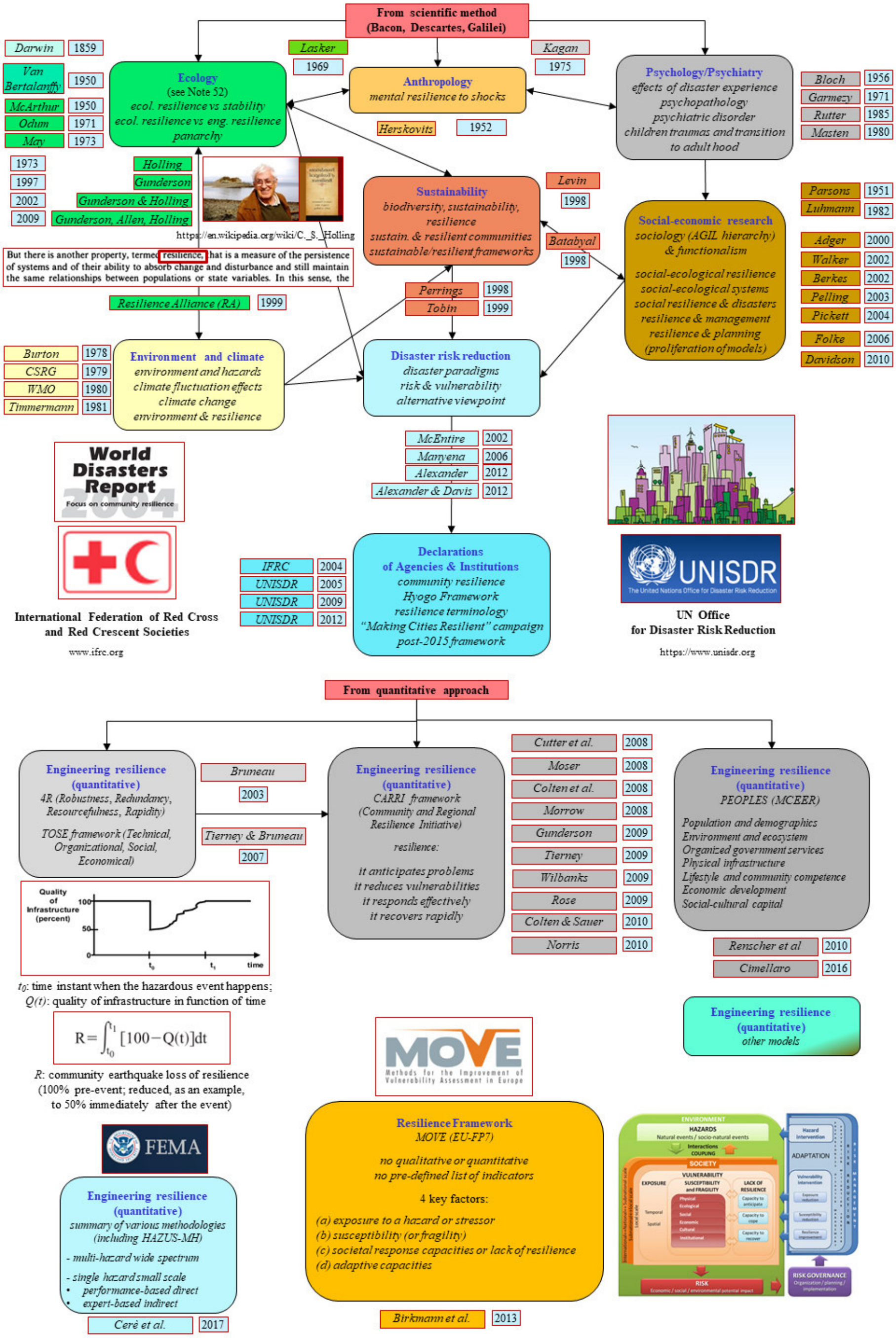


Figure 16b - *Evolution of resilience; from the 20th century until today.*

Table 7: nuclei for a pluralistic but holistic view of resilience.

attributes	description	target
safety	*protection of life, heritage, assets from natural/human-made disasters across climate/social changes*	*multi-hazard combinations and maps*
robustness	*adequacy of structural/infrastructural systems to withstand actions related to their function/exposure*	*multilevel networks*
adaptive capacity	*ability to respond successfully to new changes and recovery with acceptable consequences after catastrophic events*	*social-ecological models*
sustainability	*maintaining the natural/anthropogenic capital and fostering mature self-balanced environments*	*sustainability models*
governance	*consensual and shared management of conflicts towards a new equilibrium before/throughout/after traumas/disasters*	*risk management*
anamnesis	*safe-guarding and transmitting collective memory and cultural identity intact to posterity as a drop anchor for democracy*	*preservation of tangible/intangible heritage*

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& lying down in the wood to rest myself. It came on suddenly & lasted two minutes (but appeared much longer). The rocking was most sensible; the undulation appeared both to me & my servant to travel from due East. There was no difficulty in standing upright; but the motion made me giddy … An earthquake like this at once destroys the oldest associations; the world, the very emblem of all that is solid, moves beneath our feet like a crust over a fluid; one second of time conveys to the mind a strange idea of insecurity, which hours of reflection would never create ..."; March 3rd, 1835 at Conception: "… *As soon as the ship entered the harbor of Concepcion, I landed on the island of Quiriquina, & there spent the day, whilst the ship was beating up to the anchorage. The Major domo of the estate rode down to tell us the terrible news of the great Earthquake of the 20th: - That not a house in Concepcion or Talcuhano (the port) was standing, that seventy villages were destroyed, & that a great wave had almost washed away the ruins of Talcuhano - ... The Island itself showed the effects of the Earthquake, as plainly as the beach did that of the consequent great wave. Many great cracks which had a North & South direction traversed the ground; some of these near the cliffs on the coast were a yard wide; & many enormous masses in every part had fallen down; in the winter when the rain comes, the water will cause greater slips. The effect on the underlying hard slate was still more curious; the surface being shattered into small fragments. If this effect is not confined, as I suppose it is, to the upper parts, it appears wonderful that any solid rock can remain in Chili. For the future when I see a geological section traversed by any number of fissures, I shall well understand the reason. I believe this earthquake has done more in degrading or lessening the size of the island, than 100 years of ordinary wear & tear … Many compared the ruins to those of Ephesus or the drawings of Palmyra & other Eastern towns; certainly there is the same impossibility of imagining their former appearance & condition ... The earthquake alone is sufficient to destroy the prosperity of a country; ... what a horrible destruction there would be of human life. England would become bankrupt; ... To my mind since leaving England we have scarcely beheld any one other sight so deeply interesting. The Earthquake & Volcano are parts of one of the greatest phenomena to which this world is subject…*". Among the final considerations, he says that earthquakes and volcanos "*...possess for me a higher interest, from their intimate connection with the geological structure of the world. The earthquake must however be to everyone a most impressive event; the solid earth, considered from our earliest childhood as the very type of solidity, has oscillated like a thin crust beneath our feet; and in seeing the most beautiful and laboured works of man in a moment overthrown, we feel the insignificance of his boasted power ...*".
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Increasingly, socio-natural risks and disasters represent the result of an unsustainable interaction between human beings and environment. The current scientific debate has generally agreed on the idea that the impact of natural hazards needs to take into account the social vulnerabilities and exposures to risk of the affected population. The most recent earthquakes have unequivocally shown the complexity of the phenomena and their multi-scale dynamics. Indeed, the territory is the combination of natural, social and cultural environment and only by exploring its anatomy and physiology, it will be possible to manage and protect it in the best way.
This volume collects a quite wider range of national and international case studies, which investigate how socio-natural risks are perceived and communicated and which strategies the different communities are implementing to mitigate the seismic risk. This publication has been possible thanks to a fruitful discussion that some scholars had at the 36th General Assembly of the European Seismological Commission held in Malta from 2 to 7 September 2018.

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