Knowledge management e resilienza dei sistemi urbani e territoriali

SAGGI E PUNTI DI VISTA/ ESSAYS AND VIEWPOINT

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Abstract. Il concetto di resilienza riferito all'ambiente costruito, alle scale della città e del territorio, vede oggi una molteplicità di declinazioni e applicazioni: rispetto a queste scale il paper tratta il ruolo centrale dell'informazione per le analisi di fragilità e vulnerabilità e per lo sviluppo di strategie di resilienza. Assumendo una visione gerarchica della conoscenza e considerando le attuali evoluzioni delle tecnologie dell'informazione, l'obiettivo è di delineare modalità e applicazioni innovative di knowledge management orientate a promuovere forme di resilienza dei sistemi sociali, fisici e infrastrutturali. In questa direzione vengono anche indagate le implicazioni delle attuali innovazioni tecnologiche relative a *big data* e IoT (*Internet of Things*).

Parole chiave: *knowledge management*, gestione urbana, Internet of Things (IoT), sensori, resilienza.

Fragilità, robustezza e resilienza dei sistemi

Il concetto di resilienza è utilizzato da diversi anni in molti ambiti scientifici e operativi (K. Wolter et al., 2012), ma solo in alcuni settori ha assunto un ruolo di primo piano per estendere i concetti di resistenza e robustezza (Roy, 2010) (cfr. Fig. 1). Il riferimento allo stesso concetto nell'ambito di settori disciplinari anche molto diversi tra loro ha portato come conseguenza naturale ad una proliferazione di termini, definizioni e quadri di riferimento per la valutazione della resilienza (Martin-Breen, Anderies, 2011).

Nella prospettiva di migliorare il comportamento dei sistemi in condizioni di elevata incertezza sembra oggi essere vincente la strategia (Fig. 2) che dalla condizione di fragilità evolve verso la robustezza, passa attraverso la resilienza e si conclude nella condizione che alcuni studiosi chiamano anti-fragilità (Johnson, Gheorghe, 2013) (Taleb, Douady, 2013).

Dunque il passaggio da robustezza a resilienza (Fig. 1) è caratterizzato da una risposta dinamica della configurazione del sistema, che cambia in relazione agli eventi che mutano il suo contesto di riferimento (Fig. 3). Un sistema resiliente è capace di intercettare in modo dinamico – attraverso processi di monitoraggio continuo – le modifiche alle condizioni di contesto ed è in grado di attivare cambiamenti alla propria configurazione attraverso un flusso continuo di informazioni in ingresso, che segnalano i cambiamenti, e in uscita per innescare le risposte. La dimensione dinamica della resilienza dei sistemi – e dunque il ruolo delle informazioni – appare un elemento centrale nelle numerose definizioni che vengono fornite dai diversi ambiti scientifici (Wright et al., 2012). Rispetto alla dimensione dinamica è possibile incrementare la resilienza di un sistema attraverso il rafforzamento di tre diversi tipi di capacità (OECD, 2014): capacità di assorbimento, adattativa e trasformativa. Tali capacità sono strettamente connesse con la gestione di flussi di informazioni che permettono a un sistema di leggere la variazione dinamica dei fattori sollecitanti e di attivare processi di modifica per garantire il recupero delle funzioni come schematizzato in Fig. 3.

Resilienza e Informazione

Analizzando la capacità di resistenza e di reazione dei sistemi urbani e territoriali emerge, come molti studi evidenziano[1], che la gestione delle informazioni ha un ruolo di grande rilevanza nello sviluppo di strategie di resilienza. I connotati di tale ruolo, in relazione alla molteplicità delle possibili prospettive di osservazione rispetto alle quali la resilienza può essere considerata, lasciano intravvedere la complessità derivante dalla elevata quantità di dati, afferenti a diversi domini e categorie informati-

Knowledge management and resilience of urban and territorial systems

Abstract. The concept of resilience related to the built environment, thus to urban and territorial scales, counts today a multiplicity of declinations and applications: with respect to these scales, the paper deals with the central role of information for the analysis of fragility and vulnerability and for thedevelopment of resilience strategies. Assuming a hierarchical vision of knowledge and considering the current evolution of information technologies, the purpose is to outline innovative knowledge management methods and applications aimed at promoting forms of resilience of social, physical and infrastructural systems. Hitherward, the implications of current technological innovations related to Big Data and IoT (Internet of Things) are also investigated.

Keywords: knowledge management, urban management, Internet of Things (IoT), sensors, resilience.

Fragility, robustness and resilience of systems

The concept of resilience has been used since several years in many scientific and operational fields (K. Wolter et al., 2012), but there are only few sectors in which the term "resilience" has taken a leading role to extend the concepts of resistance and robustness (Roy, 2010) (see Fig. 1). The reference to the same concept in disciplinary sectors, even very different from one another, has naturally led to a significant proliferation of terms, definitions and reference frameworks for the assessment of resilience (Martin-Breen and Anderies, 2011).

In the perspective of improving the behavior of systems operating under conditions of high uncertainty, nowadays the winning strategy (Fig. 2) seems to be the one that from the fragile condition evolves towards robustness, goes through resilience and ends in the condition that some researchers call anti-fragility (Johnson and Gheorghe, 2013) (Taleb and Douady, 2013).

Hence, the transition from robustness to resilience (Fig. 1) is characterized by a dynamic response of the system configuration, which changes in relation to the events that alter its reference context (Fig. 3). A resilient system is able to dynamically intercept – through continuous monitoring – changes to the context conditions and it is able to activate changes to its configuration through a continuous flow of incoming information, which reveals changes, and output information to trigger the answers. The dynamic dimension of systems resilience - and therefore the critical role of information – seems to be a key element in the several definitions provided by various scientific fields (Wright et al., 2012). With re-

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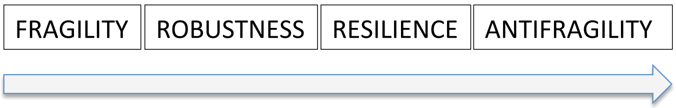
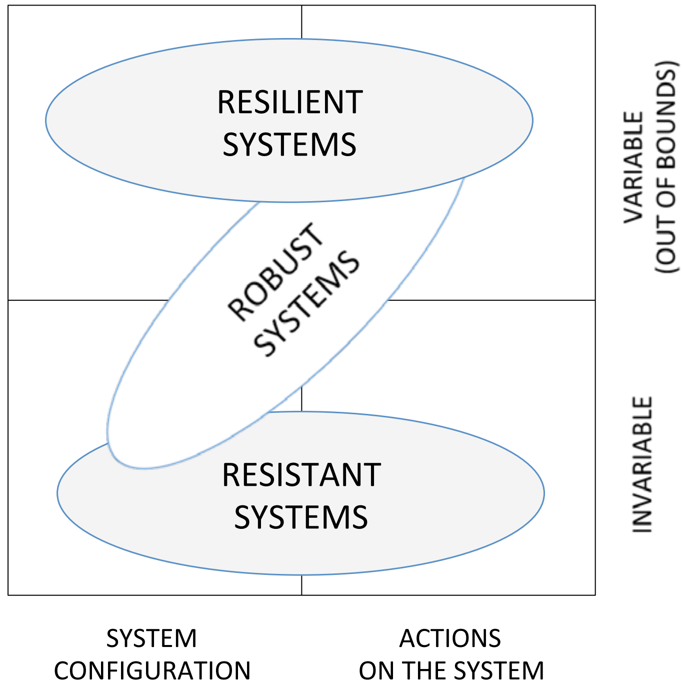


01 | Resistenza, robustezza e resilienza dei sistemi in relazione alla variabilità della configurazione e del quadro di sollecitazioni agenti sul sistema.
Resistance, robustness and resilience of systems in relation to configuration variability and actions on the system



02 | Da fragilità a antifragilità nei sistemi complessi. Adattamento da (Johnson, Gheorghe, 2013)
From fragility to anti-fragility in complex systems. Adapted from (Johnson, Gheorghe, 2013)

ve, provenienti da più fonti, da raccogliere, selezionare e dirigere a una pluralità di soggetti attraverso modalità di elaborazione diversificate a seconda dei contesti e delle finalità.
I sistemi complessi e interagenti, quali quelli urbani e territoriali, formano network, caratterizzati da legami non lineari; in presenza di eventi perturbativi, si generano, spesso in modo repentino, modificazioni nella quantità e nella velocità degli scambi informativi, creando nuove interconnessioni e nuovi canali di comunicazione. In queste condizioni (Internews, 2009) le prestazioni generali dei sistemi interconnessi, e stressati da eventi perturbanti, tendono a diminuire al crescere di complessi fenomeni dissipativi riguardanti materia ed energia (Bhamra et al., 2011), difficilmente controllabili senza un adeguato apparato[2] (infrastrutture e organizzazioni) capace di sostenere e gestire i flussi informativi (Bharosa et al., 2009). A tale proposito uno studio su casi di collasso dei sistemi di gestione dell'emergenza in situazioni di disastri naturali (Comfort, 2007) analizza le quattro funzioni fondamentali per la gestione di situazioni di crisi dei sistemi – cognizione, comunicazione, coordinazione e controllo – ed evidenzia come la cognizione, ossia la corretta interpretazione dei fenomeni in corso, sia condizione essenziale per l'attivazione dei conseguenti processi di comunicazione, coordinamento e controllo. Tale corretta interpretazione, considerata la complessità delle interconnessioni dei sistemi e la repentinità dei fenomeni, non può che dipendere da processi dinamici basati sull'acquisizione in continuo di dati, che devono poter essere rapidamente validati e contestualizzati rispetto ai molteplici livelli organizzativi e operativi. Il fine è quello di generare, a livello di sistema, capacità condivisa di imparare, di interpretare correttamente i fenomeni, di attribuire priorità, di innovare e di rispondere ai cambiamenti, in ultima analisi di giungere ad un sapere collettivo.
Dall'insieme di queste riflessioni sul rapporto tra informazioni e gestione della risposta dei sistemi in condizioni anomale emergono tre considerazioni tra loro correlate, che delineano possibili scenari di ricerca e sperimentazione. Una prima questione riguarda le modalità più efficaci per la raccolta delle informazioni nel momento in cui le si vuole finalizzare alla resilienza dei

spect to the dynamic dimension it is possible to increase the resilience of a system by strengthening three different types of capability (OECD, 2014): Absorption capability, Adaptive capability, Transformative capability. These capabilities are strictly connected with the management of information flows that enable a system to read the dynamic variation of the stressing factors and to activate modification processes in order to guarantee the recovery of the functions as shown in Fig. 3.

Resilience and information
Analyzing the resistance and reaction capacity of urban and territorial systems, as many studies show[1], it is clear that Information Management plays a major role in the development of resilience strategies. The features of this role, in relation to the multiplicity of possible observation perspectives of resilience, outline the complexity arising from the large amount of data, belonging to different domains and information categories and coming from multiple sources, that has to be collected, selected and directed to a plurality of entities through processing methods diversified according to contexts and purposes.
Complex and interacting systems, as urban and territorial systems, build networks, characterized by non-linear bonds: in presence of perturbation events, changes in quantity and speed of information exchanges are generated, often in a sudden way, creating new interconnections and new communication channels. In these conditions (Internews, 2009) the general performance of interconnected systems, stressed by disturbing events, likely decrease as complex dissipative phenomena - concerning matter and energy – grow (Bhamra et al., 2011). Moreover, these phenomena are difficult to control without a proper apparatus[2] (infrastructures and organizations) able to support and manage information flows (Bharosa et al., 2009). In this regard, a study on cases of collapse of emergency management systems in situations of natural disasters (Comfort, 2007) analyzes the four fundamental functions for the management of system crisis situations – cognition, communication, coordination and control – and it highlights how cognition, i.e. the correct interpretation of ongoing phenomena, is an essential condition for the activation of the consequent communication, coordination and control processes necessary for systems response. This correct interpretation, considering the complexity of systems interconnections and the suddenness of phenomena, can only depend on dynamic processes based on the continuous acquisition of data, which have to be quickly validated and contextualized with respect to the various organizational and operational levels. The aim is to generate, at the system level, the shared ability to learn, to correctly interpret phenomena, to prioritize, to innovate and to respond to changes and, at last, to attain a collective knowledge.
From all these reflections on the relationship between information and management of system response under anomalous conditions, three interrelated considerations emerge, which outline possible scenarios of research and experimentation. A first question concerns the most effective methods for data collection with the purpose of contributing to the resilience of territorial and urban systems. On the basis of previous considerations, it is clear that the collection regards both data

03 | Effetto di una corretta gestione delle informazioni sulla vulnerabilità e sulle modalità di recupero di un sistema.
Effect of proper management of information on vulnerability and recovery of a system

sistemi territoriali e urbani. Dalle considerazioni svolte appare evidente che la raccolta riguarda sia dati acquisibili secondo modalità tradizionali e riferibili a situazioni essenzialmente stabili (per esempio dati statistici demografici, macroeconomici, descrittivi delle caratteristiche fisiche dei territori, ecc.), sia dati da acquisire in tempo reale, da fonti multiple e in grandi quantità, in particolare in situazioni di emergenza. Queste considerazioni aprono al tema attuale dei Big Data e agli approcci più adeguati per la loro gestione (criteri e metodi di selezione e validazione).
Una seconda questione riguarda le modalità organizzative innovative per la gestione dei dati, al fine della attivazione dei processi necessari per la composizione della piramide «*from data to wisdom*» (Ackoff, 1989). Tale questione apre a molteplici domande, per esempio: come relazionare e contestualizzare dati provenienti da fonti tradizionali e dati acquisiti secondo logiche Big Data? Quali modelli di governo dei flussi informativi e quali piattaforme operative utilizzare? Quali modalità di interoperabilità tra sistemi informativi tradizionali e applicativi a rete? Quali metodi e quali strumenti per il *knowledge management*? Quali strategie e tattiche di coinvolgimento (fornitura, scambio, utilizzo, interpretazione dei dati) della collettività?
Infine un'ultima questione riguarda i manufatti costituenti i contesti territoriali e urbani, poiché il tema resilienza-informazione non si esaurisce sul piano organizzativo e relazionale tra individui e collettività. Anche gli oggetti dei territori e delle città sono in grado di partecipare allo scambio informativo, secondo due livelli di lettura. Uno è quello del loro patrimonio informativo. I manufatti, se dotati di informazioni, sia di progetto sia di feed back circa i

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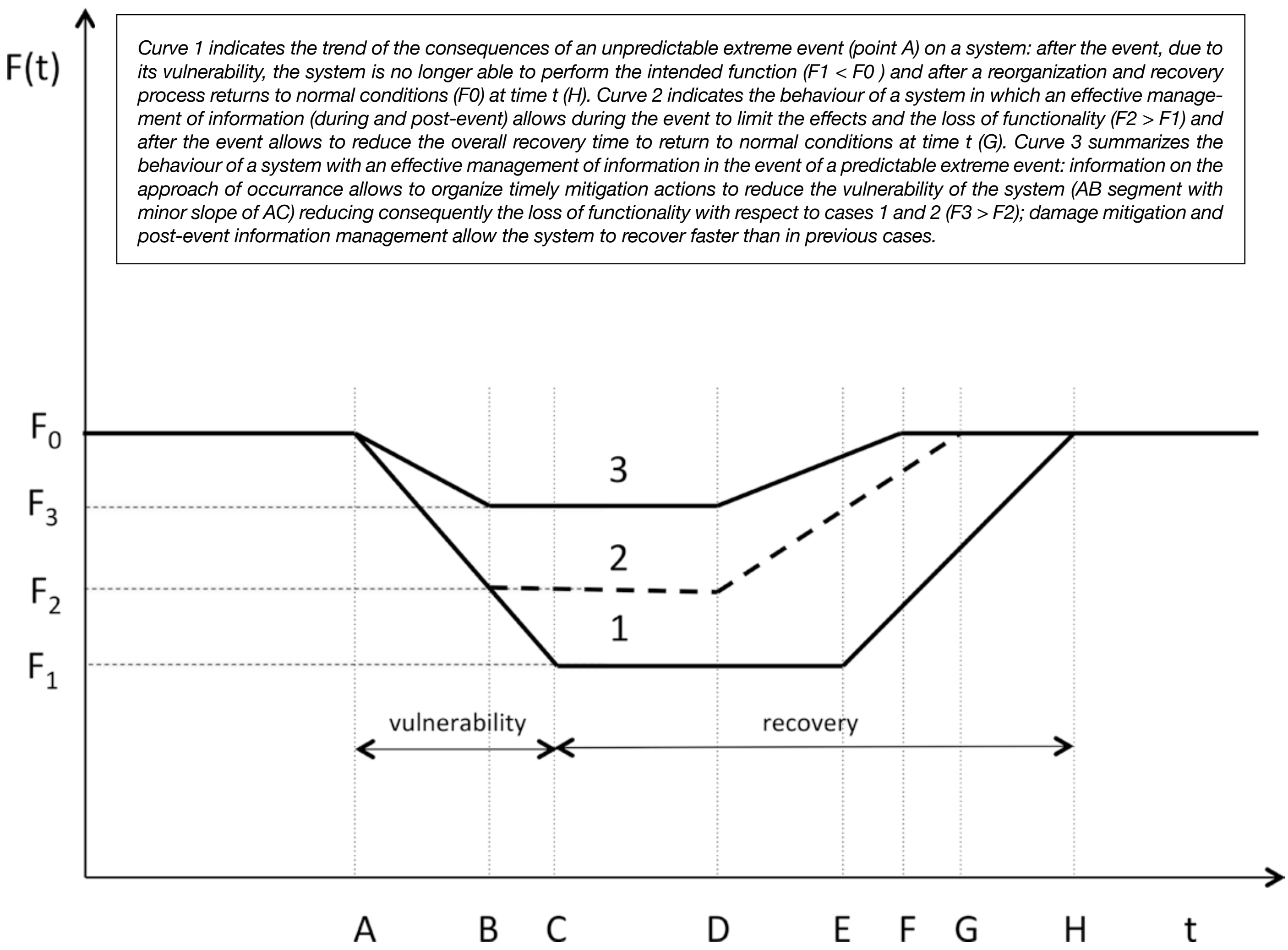

loro comportamenti nel ciclo di vita, sono in grado di comunicare le loro caratteristiche e le loro attitudini; si tratta in questo caso di caratteristiche e prestazioni "stabili", rappresentanti situazioni pre-crisi. L'altro è quello del loro stato attuale, le prestazioni erogate in tempo reale, che può evidenziare le "prestazioni residue contingenti" in situazione di crisi. Quest'ultimo aspetto apre agli approfondimenti sul ruolo della sensoristica applicata agli oggetti edilizi e alle infrastrutture (Talamo et al., 2016): i sensori diventano fonti di dati in continuo e possibili generatori di Big data.
Da questi due livelli di lettura emerge un collegamento stretto con l'ambito delle applicazioni IoT (*Internet of Things*) capaci di rendere i manufatti dei veri e propri terminali informativi in grado di comunicare e di ricevere dati appropriati rispetto a comportamenti resilienti, sia in situazioni normali che in condizioni di perturbazione.

Resilienza, big data e infrastrutture IoT

Il territorio può essere, dunque, inteso come una rete di infrastrutture digitali in cui le infrastrutture fisiche (edifici, strade, ecc.) sono nodi (IoT) che raccolgono e scambiano dati (Big Data), contribuendo ad aumentare i livelli di conoscenza e il controllo dei processi di gestione della città e dei fenomeni che la interessano.
Questa visione della città apre interessanti considerazioni circa l'entità e le caratteristiche del patrimonio informativo da essa sviluppato, poichè la mole di dati che il territorio può generare ha ordini di grandezza che superano gli Exabyte (1 EB=10^18 Byte) (IBM, 2017). Le infrastrutture ICT, tra cui l'IoT, sono fondamentali al fine di gestire tali quantità di dati ed elaborarli per generare informazioni da dirigere opportunamente laddove necessario (Gòmez et al., 2017). L'IoT può essere intesa come un'infrastruttura di rete globale dinamica, basata su protocolli di comunicazione standard e interoperabili, in grado di interconnettere oggetti fisici e virtuali, dando loro identità uniche e possibilità di interazione attraverso interfacce intelligenti tra loro e con gli utenti (ITU-T, 2012; Vermesan, Friess, 2013). L'infrastruttura IoT è un'infrastruttura caratterizzata da interconnettività, varietà, scalabilità, dinamismo e articolata secondo tre componenti (Haas et al., 2015): (i) sistema di dispositivi e sensori che donano proprietà di comunicazione agli oggetti fisici; (ii) software, piattaforme o sistemi informativi che raccolgono, elaborano e utilizzano i dati raccolti; (iii) rete di comunicazione che consente l'interazione tra tutti gli elementi coinvolti.
L'aspetto innovativo – e interessante in relazione alle strategie di resilienza – è rappresentato dal fatto che i diversi componenti del sistema città hanno la possibilità di imparare ad essere consapevoli del contesto in cui sono collocati (consapevolezza situazionale) (Ghimire et al., 2017), a rilevare, raccogliere, trasmettere, archiviare ed elaborare in tempo reale Big Data in modo integrato al fine di comunicare tra loro e con le persone (Bandyopadhyay et al., 2011; Giusto et al., 2010). Si tratta di dati (Urban Big Data) di varia natura relativi a una molteplicità di aspetti – clima, mobilità, grado di affollamento, ecc. (Tab. 1) – capaci di diventare informazioni utili per i processi di gestione in situazioni di eventi perturbanti sia prevedibili (gestione del rischio), sia non prevedibili (gestione delle emergenze).
Se si considera come campo di applicazione la scala urbana è facilmente intuibile come l'implementazione di un sistema distribuito e disseminato di sensori e di device dell'IoT conduca a scenari caratterizzati da una elevata complessità informativa relativamente

that can be acquired with traditional methods, referable to essentially stable situations (for example demographic, macroeconomic, descriptive data about physical characteristics of territories, etc.), and data to be acquired in real time, from multiple sources and in large quantities, especially in emergency situations. These considerations open up to the hot topic of Big Data and to the most appropriate approaches for their management (selection and validation criteria and methods).
A second consequent consideration concerns the innovative organizational methods for data management, in order to activate processes necessary for building the pyramid «from data to wisdom» (Ackoff, 1989). This topic opens to many questions, for example: how to relate and contextualize data from traditional sources and Big Data acquired by innovative devices? Which governance models of information flows and which operating platforms to use? How to assess the interoperability between traditional information systems and network applications? What methods and tools for knowledge management? What strategies and tactics (supply, exchange, use, interpretation of data) for community inclusion and participation?
Last of all, a consideration about the artifacts constituting the territorial and urban contexts, since the resilience-information topic does not end on the organizational and relational level between individuals and the community. Even the objects of territories and cities are able to participate in the information exchange, according to two reading levels. The first one regards their information assets. The artifacts, if embedded with information, both from design projects and from feedbacks about their behavior during their life cycle, are able to communicate their features and their aptitudes, thus "stable" characteristics and performance representing pre-crisis situations. The other level concerns their current state, so the real time performance that can highlight the "contingent residual performance" in crisis situations. This last aspect opens to insights about the role of sensing technology applied to buildings and infrastructures (Talamo et al., 2016): sensors become continuous data sources and possible Big Data generators.
From these two reading levels, it comes out a close connection with the field of IoT (Internet of Things) applications, able to convert artifacts into information terminals able to communicate and receive proper and suitable data with respect to resilient behavior, both in normal and perturbation conditions.

Resilience, Big Data and IoT infrastructures

The territory can be understood as a network of digital infrastructures in which physical infrastructures (buildings, roads, etc.) are nodes (IoT) that collect and exchange data – Big Data – contributing to increase the levels of knowledge and control of management processes of the city and its affecting phenomena.
This vision of the city opens up interesting considerations about the entity and characteristics of the information assets generated by the city itself, as the amount of information that the territory can generate has orders of magnitude exceeding the Exabytes (1 EB = 10 ^ 18 Bytes) (IBM , 2017). ICT infrastructures, including IoT, are fundamental in order to manage such data volume and process them in order to generate information to be opportune-

Tab. 1 | Descrizione delle principali categorie di Urban Big Data, evidenziando alcuni esempi di dati e informazioni, alcune fonti e la velocità di aggiornamento. Adattata da Thakuriah et al. (2014) e Pan et al. (2016).

Description of main categories of Urban Big Data, highlighting some examples of data and information, sources and updating speed. Adapted from Thakuriah et al. (2014) and Pan et al. (2016).

Category	Sources	Types of data	Update Rate
Data from sensors (on urban infrastructure, environment and mobility)	Connected Systems of sensors (e.g. WSN) and other IoT Networks: (mobile and fixed) device networks and sensor networks in urban areas (e.g. public utility control units, environmental parameters detection networks, smart grids, etc.); Public utilities sensor systems; Building Management Systems (BMS); Smart Grids; Surveillance System; Geographic Information Systems (GIS); Satellite Earth observation service (Earth Observation Satellites System & Land Observations System)	Environmental data (Temperature, Humidity, etc.); Seismic data; Hydrological data; Geological data; Data on mobility (timetables and possible delays in public transport, data on the movements of people in the city - including origin, destination, itinerary and time spent, data on the real-time traffic situation); Data on public utilities (energy and electricity distribution, water, gas); Data from monitoring of use and consumption (heating, lighting, power supply)	High
Data generated by users	Participatory sensing systems; social media; access and log ins; Global Positioning System (GPS); Global Navigation satellite systems (GNSS); on line social network; mobile application; Blogging & web 2.0	Users' position; Users' preferences; Online activities; Socially-generated or shared data (posts, links, etc.)	High
Administrative data (public and confidential)	Administrative portals, regional and municipal portals of the Government (open and confidential microdata on population)	Data of the public administration on transactions, taxes and revenues, payments and registrations; basic public data on population, traffic, land, housing and geography; confidential micro-data on personal employment, medical care and social assistance payments, on welfare and education, education registers, etc.	Low
Business data	Records, memory cards and company documents; workforce management system; data on public services and financial institutions; product purchase register and terms of service agreements	Data on customer transactions; customer data; customer preferences; number of purchases / contracts	Low

ai volumi di dati, alle sorgenti di dati ed alle modalità di raccolta. Pertanto, se da un lato la disponibilità e l'accessibilità a tale ricchezza informativa aprono a inedite possibilità di incrementare la capacità adattativa dei sistemi urbani per renderli più resilienti, dall'altro una tale complessità di dati richiede nuove forme di gestione per poter trasformare questo patrimonio informativo in concreti strumenti, strategici ed operativi, che contribuiscano a rendere maggiormente resilienti i sistemi urbani.

Rispetto ad alcune azioni capaci di innalzare la resilienza – ossia rilevamento real-time dei dati ed elaborazione di previsioni, comunicazione e allerta, rilievo e gestione post-evento – ad oggi è possibile delineare alcuni approcci possibili (Tab. 2), basati sulle applicazioni IoT, per esempio (Tab. 3):

– definizione di soglie di accettazione per parametri ambientali critici, unita al monitoraggio ambientale degli stessi in tempo reale e all'analisi dei dati raccolti per elaborare previsioni e

ly directed where necessary (Gomez et al., 2017). IoT can be understood as a dynamic global network infrastructure, based on standard and interoperable communication protocols, capable of interconnecting physical and virtual objects, giving them unique identities and the possibility to interact with each other and with users through intelligent interfaces (ITU-T, 2012; Vermesan and Friess, 2013). The IoT infrastructure is characterized by interconnectivity, variety, scalability and dynamism, and it is constituted by three components (Haas et al., 2015): (i) system of devices and sensors that gives communication abilities to physical objects; (ii) software, platforms or information systems that collect, process and use the collected data; (iii) communication network that allows interaction between all the involved elements.

The innovative aspect – interesting in relation to resilience strategies – is represented by the fact that the different components of the city system learn to be aware of the context in which they are located (Situational Awareness) (Ghimire et al., 2017) and to detect, collect, transmit, store and process Big Data in an integrated way in order to communicate with each other and with people (Bandyopadhyay et al., 2011; Giusto et al., 2010). The Urban Big Data includes data of various kinds relating to a variety of aspects – climate, mobility, degree of crowding, etc. (Table 4) – capable of becoming useful information for management processes in situations of disruptive events, both in the cases they are predictable (risk management) or non-predictable (emergency management).

Considering as scope of application the urban scale, it is easily understandable how the implementation of a distributed and disseminated system of sensors and other IoT devices leads to scenarios characterized by an information complexity with regard to data volumes, sources and methods of collection.

Therefore, if on one hand the availability and accessibility to this wealth of information open up novel possibilities to increase the adaptive capability of urban systems to make them more resilient, on the other hand such a complexity of data requires new forms of management in order to transform this information assets in real strategic and operational tools that contribute to make urban systems more resilient.

With respect to some actions able to raise resilience – i.e. real-time data collection and forecasts processing, communication and alert, relief and post-event management – nowadays it is possible to outline some promising approaches (Table 5), based on IoT applications, for example (Table 6):

- definition of acceptance thresholds for critical environmental parameters, together with their real time monitoring and the analysis of collected data, in order to elaborate forecasts and action plans aimed at mitigating the risk associated to the event occurrence. A reference case study is represented by the Municipality of Can Tho in Vietnam;
- integration of monitoring infrastructures with the communication and alert system both to promptly notify and inform critical infrastructure managers and, if necessary, to implement appropriate adaptation actions (e.g. train and air block), both to activate emergency services (police, police fire, etc.) and to alert the population through mass media. The Great East Japan Earthquake

piani d'azione per mitigare il rischio legato al verificarsi dell'evento. Un caso studio di riferimento è la municipalità di Can Tho in Vietnam;
- integrazione delle infrastrutture di monitoraggio con il sistema di comunicazione e allerta sia per avvisare tempestivamente i gestori delle infrastrutture critiche ed, eventualmente, implementare opportune azioni di adattamento (es. blocco treni e aerei), sia per attivare servizi di emergenza (polizia, vigili del fuoco, ecc.) e allertare la popolazione attraverso i mass media. Il Great East Japan Earthquake del 2011 è uno dei casi rappresentativi di questo approccio;
- utilizzo dei dati derivanti dai sistemi georeferenziati di monitoraggio in tempo reale delle risorse dispiegate/disponibili come strumento informativo di supporto ai soggetti decisori per pianificare e coordinare, nel minor tempo possibile, le operazioni di assistenza e soccorso post-evento. Un caso di riferimento è l'approccio seguito dal Governo indiano;
- implementazione e utilizzo di piattaforme di crowdsourcing per comunicazioni di emergenza, nonché come strumento di categorizzazione e mappatura informazioni. Un caso rappresentativo in questo senso è quello del Pakistan che ha implementato Pakreport, piattaforma di crowdsourcing per la segnalazione di emergenze e la raccolta di informazioni;
- impiego delle ICT per la realizzazione di sistemi di Early Warning aventi lo scopo di fornire tempestivi, affidabili ed economici avvisi di disastro di massa. Un esempio rappresentativo di questi sistemi è il Disaster Early Earning Network - DEWN implementato in Sri Lanka.

Conclusioni

Nella costruzione di strategie di resilienza il tema dell'informazione è di fondamentale importanza e si può delineare nei suoi connotati attraverso lo sviluppo di due piani di lettura connessi. Uno è quello, di carattere teorico e interpretativo, riguardante le varie pro-

Tab. 2 | Scenari di utilizzo dei servizi ICT per lo svolgimento delle funzioni di resilienza a scala urbana. Adattata da ITU-T (2015) e APCICT (2016).
Scenarios of ICT use for the development of urban-scale resilience functions. Adapted from ITU-T (2015) and APCICT (2016).

Attribute of Urban system	Actions	Key objectives	
Reliability	Data collection and preparation of forecasts	Monitoring	- Risk mitigation by monitoring environmental parameters - Identification and tracking of resources available on the territory
		Predictive methods ans tools and Intervention strategies	- Descriptive and predictive analysis to predict potential disasters and evaluate related impacts - Predictive maintenance of critical infrastructures - Enabling Early Warning Monitoring systems - Identification of appropriate locations for resource storage, rest areas, evacuation routes and emergency operations centers - Solving of any vulnerabilities of the ICT infrastructure - Improving alert strategies by identifying appropriate channels, sources and messages - Improving evacuation planning by identifying potential areas, shelters, routes and location of populations with special evacuation needs - Conducting public education campaigns, including the integration of disaster risk awareness into school curricula - Conducting emergency drills and evacuation simulations
Vulnerability	Communication and Warning	Real-time monitoring	- Real-time monitoring of the supply of stocks and supplies - Real-time tracking of resources - Monitoring of rescue vehicles and civil vehicles - Monitoring the progress of response activities
		(Early) Warning	- Reception of reports and requests - Broadcasting of warning and mass alert messages - Broadcasting of useful information on recovery units and locations, location of resources, safe points, etc.
Recovery	Survey and post-event management	Real-time monitoring	- Real-time monitoring of the supply of stocks and equipments - Real-time tracking of resources
		Assessment and post-event management	- Assessment of damage and provision of information for planning and coordination of rescue activities - Interaction between rescue teams for appropriate allocation of resources - Creation of a virtual logistics network to facilitate communication between all the involved parties, as well as real-time monitoring of feedback information system

Tab. 3 | Approcci al potenziamento della resilienza con il supporto delle reti informativi: casi rappresentativi

Approaches to strengthening resilience with the support of information networks: representative cases

Approaches	Case Studies	Tools, potentialities and criticalities
Definition, monitoring and management of acceptance thresholds for critical parameters	The Can Tho municipality in Vietnam has developed a project aimed at enriching existing databases and providing accurate and reliable real-time information about water salinity levels to identify critical salt thresholds. The objective of the project is, therefore, to identify the saline intrusion thresholds and the potential response actions in order to develop an information tool for local communities and decision-makers to support the participatory elaboration of policies and action plans. Source: ISET (2012), "Climate Resilience Case Study. Can Tho, Vietnam. Real-Time Monitoring for Responding to Saline Intrusion" available at: http://Training.I-S-E-T.Org/ (accessed 13 November 2017).	Condition-based intervention tool based on predictive and descriptive analysis as a part of an information support tool. It represents a participatory and inclusive program that allows the various stakeholders to support experts and technicians in the management of the project, from the data acquisition phase up to the last phase of action plans definition. In addition to the development of a real-time data management and visualization system, the project involved: the construction of a website on which real-time data updates are published, the creation of systems for analyzing and processing raw data in order to create a dynamic database about salinity values and the preparation of saline intrusion alarm systems.
Integration of monitoring infrastructures with the communication and warning system	During the Great East Japan Earthquake of 2011, the monitoring system was able to detect in real time the first shock wave (P waves). Thus, it gave a useful timeframe of few seconds, before the occurring of the second wave of impact (S waves), to Tokyo Metropolitan Government and to Japan Meteorological Agency to: notify the three main mobile network operators which - as a result of an alert - sent a message in five languages to all users warning them of the earthquake; mobilize the mass media to broadcast a warning on all their channels, showing the epicenter and indicating the exposed areas; send the arrest command to railway and airport systems, as well as to nuclear reactors; mobilize emergency services and forward requests to the main medical facilities for increasing levels of preparedness. Sources: GSMA. (2013), "Smart City Resilience Learning from Emergency Response and Coordination in Japan", available at: www.gsma.com (accessed 13 November 2017); Cheng, J. W., & Mitomo, H. (2016), "Effects of ICT and media information on collective resilience after disasters–from a virtual crowd to a psychological crowd–Part 1-ICT and media information and collective resilience in an emergency situation", available at: https://www.econstor.eu/ (accessed 13 November 2017).	Collaboration and coordination between research centers, municipalities and private operators of mobile networks as an enabling element for the entire project. The project is based on the use of existing technologies which were fundamental for the success of the entire project, as well as for achieving the objectives of cost limitation. Therefore, the repeatability and applicability of this project in other cities inevitably depend on the availability of a pre-existing technological infrastructure that ensures an extensive and widespread dissemination of warnings on the entire urban territory.
Use of data from geo-referenced real-time monitoring systems of deployed / available resources	The Indian government has launched the India Disaster Resource Network (IDRN), a project that was created with the aim of mitigating the risks associated with the lack of information on the resources available in case of a disaster. The project involves the development of a dynamic database of resources, updated in real time, able to collect and transmit information about the availability of equipments, critical supplies and human skills, so that decision-makers can mobilize the appropriate resources in the least possible response time. This database is centrally managed at the national level by the National Institute of Disaster Management - NIDM. Source: MAIT Digital India Action Group (2016), Internet of Things (IoT) for Effective Disaster Management, Whitepaper, New Delhi, India, available at: www.mait.com/ (accessed 13 November 2017).	The IDRN has a double value, on one hand it allows decision-makers to find answers about the availability of equipment and human resources necessary to counteract emergency situations of different nature, on the other it can be used as a tool for assessing the level of preparation for specific disasters. It is a resource mapping tool developed through open source GIS software and real-time monitoring solutions that feeds the database by transmitting geolocalized data. The dynamic database could evolve into an information system or an information platform that allows to manage the detected measurements, performs statistical analyzes and display the collected information in the form of an interactive dynamic map connected to the communication systems, requesting mobilization and / or resource supply.

Tab. 3 |

Approaches	Case Studies	Tools, potentialities and criticalities
Crowdsourcing platforms for emergency communications	After the massive flood of 2010, Pakistan decided to use a technological platform based on crowdousrcing - Pakreport - as a real-time monitoring and reporting tool for climate disasters to overcome the sense of isolation felt by the affected citizens and to overcome the limited quality of information received from the responsible subjects that have to provide answers and aid interventions. Pakreport allows to: a) create a report line, based mainly on text messages, which allows affected parties to communicate and provide useful information about their position and situation; b) after the translation, categorization and geolocalization of messages coming from users, Pakreport processes and publishes online an open access geographical map containing all the information received and c) simultaneously connects this information with control centers, operational teams and other persons responsible for response, in order to improve decision-making and assistance efforts. Source: Chohan, F., Hester, V., & Munro, R. (2012), "Pakreport: Crowdsourcing for Multipurpose and Multicategory Climaterelated Disaster Reporting". CTs, Climate Change and DisasterManagementCase Study.	Crowdsourcing is an effective tool for collecting input data from the model, which otherwise would have been based on much more limited input from the individual operators of the rescue teams. The project exploits existing communication technologies and infrastructures provided by the country's mobile telephone system. Therefore the implementation of the project did not require new infrastructure investments. However, in order to be repeatable in other countries, it is necessary to certify the operational continuity of existing digital infrastructures in a crisis situation. One of the main challenges of this mass reporting project is the validation of the accuracy and authenticity of input data and messages received. The use of mobile phones and SMS allows the project to reach a very large user population. However, there are still problems of digital division, related both to the ability to use, and to the linguistic diversity. For example, Pakreport recognizes, understands and translates only three languages and, by requiring the sending of a text message, it could potentially exclude some members of the population.
ICT for Early Warning Systems	The Disaster Early Warning Network (DEWN) was implemented in Sri Lanka with the aim of providing timely, reliable and convenient emergency warning messages through the use of ICT. The DEWN server is located in the Sri Lanka Disaster Management Center (DMC). The DMC is responsible for verifying the emergency situation and for issuing warnings. These notices are multi-modal, i.e. they use multiple technologies to disseminate information with the aim of reaching even the most isolated areas of the country. DEWN can generate mass, personal or localized warning to end devices using two of the most widely used and reliable mobile communication technologies: cell broadcast - CB and short message service - SMS. Source: Wickramasinghe, K. (2011), "Role of ICTs in early warning of climate-related disasters: A Sri Lankan case study", Proceedings of International Forestry and Environment Symposium, Vol. 16.	The project is based on the use of existing infrastructures that were of fundamental importance for the success of the entire project, as well as for achieving the objectives of cost limitation. However, the repeatability and applicability of this project in other countries must be verified by testing the availability and reliability of the pre-existing digital infrastructure. Early Warning System is suitable for dealing with the growing threat of natural disasters. It releases the early warning immediately after the detection of a potentially dangerous event and before it occurs. However, this tool can also be used, for example, to disseminate information on post-disaster operations. The use of CB and SMS allows the project to reach a very large user population, however it is not free from digital division problems related to the ability to use such technologies. The repeatability and applicability of this project must be verified, testing the availability and reliability of the pre-existing digital infrastructure. Mass alarms could generate panic and chaos among receivers, making the tool counterproductive.

prietà che è possibile riconoscere ai sistemi (fragilità, resistenza, robustezza), che si relazionano in vari modi al concetto di resilienza e che concorrono a divenire i bisogni conoscitivi per la gestione di sistemi complessi sottoposti ad eventi perturbativi. L'altro, di carattere applicativo, riguarda le strategie e le modalità attraverso le quali dalla raccolta dei dati e gestione delle informazioni è possibile giungere a forme di conoscenza condivisa, fondamentali per sostenere le azioni di riconoscimento dei fenomeni, comunicazione, coordinamento delle risorse sui territori e controllo.

Rispetto alla questione della gestione delle informazioni deve essere considerato che oggi lo sviluppo delle infrastrutture digitali ha le potenzialità per cambiare il rapporto dei cittadini con l'acquisizione di beni e servizi e con esso le modalità di comunicazione, di apprendimento, di collaborazione e decisione. *Big data* e *Internet of Things* pongono nuovi interrogativi sulle modalità di acquisizione e utilizzo delle informazioni. Le città stanno entrando in una nuova fase di sviluppo tecnologico, guidata da servizi a banda larga e *cloud-based*, dai dispositivi mobili e dalle reti di sensori: nel futuro prossimo la realtà urbana potrà risultare sempre più definita dalle nuove infrastrutture digitali e dalle interazioni che esse consentono.

Rispetto a questi scenari è possibile evidenziare e analizzare alcuni possibili contributi delle nuove tecnologie all'incremento delle capacità di resilienza dei sistemi urbani e territoriali, quali per esempio:

- la raccolta dati attraverso reti di sensori a diverse scale e il successivo uso di tecniche di modellazione e analisi di scenari per la valutazione e la gestione dei rischi, la mappatura delle vulnerabilità e per la definizione di nuovi indicatori dinamici capaci di monitorare il mutare nel tempo dei fenomeni urbani;
- l'utilizzo di applicazioni satellitari e mobili per la lettura delle dinamiche di adattamento in atto nella città;
- lo sviluppo di piattaforme di condivisione delle conoscenze per facilitare la comunicazione, l'autoapprendimento e lo scambio informativo tra governi locali, comunità, organizzazioni e ricercatori che lavorano nei programmi di sviluppo urbano, rafforzando la trasparenza, la responsabilità e il sostegno pubblico.

Si aprono molteplici ambiti di ricerca e sperimentazione, finalizzati alla definizione e applicazione dei possibili approcci, riguardanti la gestione delle informazioni relative alla resilienza nei diversi momenti della vita di un sistema urbano in relazione alle condizioni di sollecitazione (situazione ordinaria pre-evento, situazione di vulnerabilità legata al verificarsi di un evento perturbante e situazione di recupero post-evento). Approcci che, al di là della diversità delle modalità adottate, dovranno sicuramente essere accomunati da una consapevolezza: le infrastrutture fisiche e digitali e l'applicazione della tecnologia a diverse scale saranno valide e utili nella misura in cui parteciperanno alla costruzione di modelli volti all'inclusione, al coinvolgimento e alla partecipazione collaborativa delle amministrazioni, dei soggetti decisori e di tutti i cittadini.

NOTE

1. Si veda: Bhamra et al., 2011; Bharosa et al., 2009; CSIC, 2017; Comfort et al., 2001; Arup, 2014).

2. Internews, nel suo studio supportato dalla Rockefeller Foundation, evidenzia come nonostante la riconosciuta importanza della informazioni nella definizione dei sistemi resilienti, raramente le politiche e programmi per la resilienza affrontano in modo diretto il tema dei network informativi nelle loro molteplici possibili applicazioni.

of 2011 is one of the representative cases of this approach;

- use of data coming from real time geo-referenced monitoring systems of deployed / available resources as an informative tool to support decision-makers to plan and coordinate the post-event assistance and rescue operations in the shortest possible time. A reference case is the approach followed by the Indian Government;
- implementation and use of crowdsourcing platforms for emergency communications, as well as a tool for categorization and information mapping. A representative case in this sense is Pakistan which has implemented Pakreport, a crowdsourcing platform for reporting emergencies and gathering information;
- use of ICT for the implementation of Early Warning systems with the aim of providing timely, reliable and low-cost mass disaster warnings. A representative example of these systems is the Disaster Early Earning Network - DEWN implemented in Sri Lanka.

Conclusions

In the creation of resilience strategies, information is a crucial topic.

This topic can be described and analyzed in its connotations through the development of two connected reading plans. The first one has a theoretical and interpretative nature, it concerns the various properties of systems (fragility, resistance, robustness), which deal in various ways with resilience and which contribute to becoming the cognitive needs for the management of complex systems affected by perturbation events. The second plan has an applicative nature, it concerns strategies and methods through which from data collection and information management it is possible to reach forms of shared knowledge, fundamental to support actions for recognition of phenomena, communication, resources coordination on territories and control.

Regarding the issue of information management, it should be take into consideration that today the development of digital infrastructures has the potential to change the relationship between citizens and the acquisition of goods and services, as well as the methods of communication, learning, collaboration and decision. Big data and IoT bring out new questions on how to acquire and use information. Cities are entering a new phase of technological development, driven by broadband and cloud-based services, mobile devices and sensor networks: in the near future, urban reality could be increasingly defined by new digital infrastructures and the interactions that they allow.

With respect to these scenarios, it is possible to highlight and analyze some possible contributions of new technologies to increase the resilience of urban and territorial systems, such as:

- data collection through sensor networks at different scales and subsequent use of modeling and scenario analysis techniques for risk assessment and management, for vulnerability mapping and for the definition of new dynamic indicators able to monitor the change over time of urban phenomena;
- use of satellite and mobile applications for reading the adaptive dynamics that happen in the city;
- the development of knowledge sharing platforms to facilitate communication, self-learning and information exchange between local govern-

ments, communities, organizations and researchers working in urban development programs, strengthening transparency, accountability and public support.

There are many areas of research and experimentation aimed at defining and applying possible approaches regarding the management of information related to resilience at different moments in the life of an urban system in relation to the solicitation conditions (ordinary pre-event situation, situation of vulnerability linked to the occurrence of a disturbing event and post-event recovery situation). Approaches that beyond the diversity of the adopted modalities, will surely have to share an awareness: the physical and digital infrastructures and the application of technology at different scales will be valid and useful insofar as they will participate in the construction of models aimed at inclusion, involvement and collaborative participation of administrations, decision-makers and all citizens.

NOTES

1. See: Bhamra et al., 2011; Bharosa et al., 2009; CSIC, 2017; Comfort et al., 2001; Arup, 2014.

2. Internews, in its study supported by the Rockefeller Foundation, points out that despite the acknowledged importance of information in defining resilient systems, policies and programs for resilience rarely directly address the issue of information networks in their multiple possible applications.

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