Report

A Review of Emerging Technologies for Crisis Management

Social Media, Internet of Things and Big Data

SENSIBLE FUTURE FOUNDATION /
UNIVERSITY OF SALZBURG - CENTER OF GEOINFORMATICS /
MINISTRY OF INFRASTRUCTURE AND ENVIRONMENT (NETHERLANDS)

Colophon

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1 Background

1.1 Project rationale

Over the last 25 years there has been a continuous and growing interest in the use of Information technology in support of Crisis Management (CM). Experience has shown ICT can improve the effectiveness of the work of responders in several areas such as:

- improved decision-making
- better institutional memory and knowledge management
- better information sharing, communication and coordination
- improved situational awareness (SA)

Major IT vendors have an established portfolio of technology for CM, frequently obtained by specializing business applications to the needs of public and private crisis management organizations.

In parallel to established uses of IT in crisis management, recent events have shown how emerging network technologies and business models significantly alter information provision for crisis management in a variety of sectors and for diverse types of crisis, from natural and man-made disasters, to political unrest and riots, to financial and economic crisis.

Examples are:

- Community data-collection efforts based on open-source models have created critical data sources, such as base maps, for assisting international relieve efforts after the Haiti earthquake;
- Bottom-up information provision, facilitated by social networks (e.g. twitter) have represented the de-facto real-time information source during political crisis in the North Africa countries but also after natural disaster crisis such as the Haiti and Japan earthquake;
- RFID tagging of people in evacuation centers has helped coordination centers keep tracking of people in need after hurricane Katrina;
- Global, interconnected networks of sensors are being setup by NASA to monitor evolution of global natural phenomena together with data at high resolution ground level in an attempt to anticipate and manage natural events;
- Data mining (or data analytics, or collective sensing, or machine learning) are used for anticipating or understanding complex patterns of human behavior, for detecting events before they take place (e.g. stock market swings) or for supporting crisis management (e.g. people concentration in a certain area)

These examples point towards the increasing importance of three separate developments:

- social networks and the bottom up information provision enabled by web 2.0 and its evolutions;
- internet of things (IoT) and the increased connectivity between the physical and the digital worlds;

- big data and the ability to disclose patterns from the wealth of information that people or machines (sensors) generate continuously.

The purpose of this project is to explore the role of these three areas for crisis management and to identify trends that may change the way crisis are detected, managed and studied.

This study follows the example of the Strategic Foresight Initiative of the Federal Emergency Management Agency (FEMA) in the United States, which initiated a process of mapping technology developments that can impact the mandate and the operations of the agency in relation to crisis management[1].

The focus of the study is on information provision, although implications for management, regulations, leadership and organization forms also emerge.

1.2 Structure of the report

Chapter two of the report describes the elements of crisis management that serve as a backdrop for the analysis of emerging technologies. This section is not meant to provide an exhaustive analysis of CM but rather to identify areas of the process likely to be mostly impacted by emerging technologies.

Chapter three discusses the nature of the three emerging technologies selected for this study. It articulates their evolution, main features and interest for crisis management. The choice of these specific technology developments is based on empiric evidence of early use to support CM as well on their expected operational and strategic impact on CM once they reach mainstream diffusion.

Chapters four, five and six of the report focuses on early examples of use. For simplicity, each chapter deals with one of the innovation areas defined above, although their evolution indicates a close interlinking.

Chapter sevenlooks at the main trends underlying either the direct evolution of social media, IoT and Big data as well as other main socio-economic trends that appear as relevant in shaping the relationship between emerging technologies and CM.

Chapter eight looks at three hypothetical CM situations and how emerging technologies could impact them. This serves also as a basis for deriving conclusions and recommendations, discussed in Chapter nine.

1http://www.fema.gov/about/programs/oppa/strategic_foresight_initiative.shtm (accessed Nov 12, 2011)

2 Crisis management and emerging technologies

2.1 Crisis management

Crisis management, sometimes indicate also as incident or emergency management, is the process by which an organization deals with a major event that threatens to harm the organization, its stakeholders, or the general public. Three elements are common to most definitions of crisis: (1) a threat to the organization, (2) the element of surprise, and (3) a short decision time[2].

Crisis management, as a discipline, has received an increasing interest in the last decades for a number of reasons, including:

- The effects of population growth, urbanization and the expansion of cities and economic activities in vulnerable areas, which makes entire communities or economies subject to increasing risks of disruption;
- Terrorist and security threats, which can affect critical infrastructures or core business activities anywhere in the world causing massive disruptions and global repercussions;
- The increase in number of large natural events or disasters, and the prospect of a further increase in their frequency and intensity caused by climate change;
- An increased globalization of economic activities which introduces a level of global dependency and imposes a global attention to the prevention and repression of crisis because of their networked impacts well beyond the location where they take place;
- The rapid diffusion of viruses facilitated by global travel and the global supply chain of food, which potentially increases the rapidity and extent of diffusion of illnesses for humans, plants and animals;
- An increased dependence on a growing number of critical infrastructures, which are essential for supporting our lifestyle and economic activities.

In literature there is no general agreement of the definitions and taxonomies on disaster management. In the Netherlands a '*crisis'* is seen as an umbrella term: concepts such as incident, emergency, disaster, serious accident from this perspective are special forms of a crisis. From this perspective '*disaster response*' is a particular form of '*crisis management*'. Under the Act 'Safety regions' a '*crisis*' is defined as '*a situation where the vital interests of society is affected or likely to be affected*'. We can speak of a crisis when national security is at stake because one or more vital interests are affected and which regular structures and / or resources are not sufficient to maintain the stability. In other words, if large parts of Dutch society at risk and therefore a cross-departmental coordinated action by the central government is necessary to eliminate the threat and / or reduce the effect. A disaster is a major accident or other incident involving the life and health of many people, the

[2] http://en.wikipedia.org/wiki/Crisis_management

environment or major material interests are seriously threatened or harmed, and that a coordinated use of services or organization from different disciplines is required to remove the threat take or to limit the adverse effects. A disaster is thus major incident with many casualties and / or extensive damage whose consequences are so great that emergency services (police, fire, ambulance, hospitals) by normal means and normal structure can not handle the incident. We therefore need additional resources and a special organization to be established.

Figure 2.1 illustrates global disaster occurrences over time with their effects in terms of human costs. In spite of modernization, economic growth and development, there seems to be little evidence that disasters and their effects are decreasing, possibly the opposite. They are a continuous and major threat to modern societies.

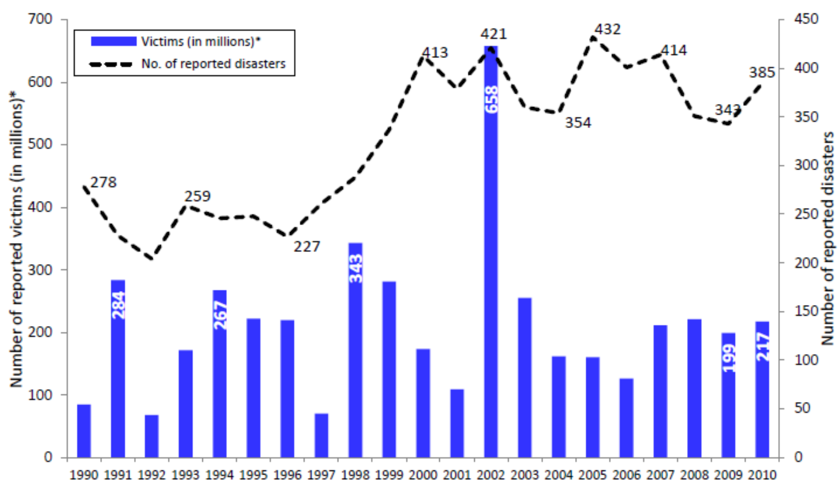

Figure 2.1 Natural disasters (Source: Annual Disaster Statistical Review 2010, WHO - Centre for Research on the Epidemiology of Disasters - CRED)

Mitroff et. al (1987) provides a categorization of crisis affecting an organization as illustrated in Figure 2.2. Lerbinger (1997) provides another categorization of crisis types, based on seven categories of crisis, of which the following four are relevant for this project:

1. Natural disaster, such as earthquakes, volcanic eruptions, storms, floods, hurricanes, droughts etc. that threaten life and property;
2. Man made crisis, such as oil spills, industrial accidents, transportation incidents and the like. They occur when complex technologies fail or when human errors cause technical systems to malfunction or breakdown.
3. Confrontation, such as blockades, acts of resistance to the police, violent demonstrations, occupation of facilities, up to urban riots and revolts. They are usually associated to some form of resistance to public order and established authority.
4. Crime or malevolence, such as terrorism, espionage, product alteration, etc. This occurs when individuals or organizations use extreme means or criminal activities against an organization for the purpose of seeking gain or to destabilize or eliminate the organization itself.

Figure 2.2 Types of crisis (Adapted from Mitroff et al, 1987)

2.2 CM phases

Organizations dealing with CM structure their activities based on some common phases. While different authors suggest slightly different phases and names (see, for instance, Pearson and Clair, 1998), the basis is very similar. A common classification of crises phases distinguishes between:

- Signal detection, the interpretation of signals of an impeding crisis;
- Preparation and prevention, or the measures in place to avert the crisis if possible and to prepare to its impacts in case the crisis cannot be averted;
- Containment, response and damage control. Refers to the set of measures that attempt to isolate the crisis effects and deal with the immediate needs of crisis management to ensure, for instance, safety for people or essential infrastructures. Includes activities that occur during and immediately following a disaster. They are designed to provide emergency assistance to victims of the event and reduce the likelihood of secondary damage.
- Business recovery, or the phase of re-establishing the system to either the previous state or to another stable and acceptable state;
- Learning, or the institutionalization of the lessons learned from a crisis in view of creating the conditions for preventing another crisis or better management one should it occur.

There isn't a pre-defined role of digital technology in any of these phases, nor in any particular class of crisis. Nonetheless, it is evident that any crisis management relies on efficient management of timely, accurate and relevant information, and on the sharing of adequate information across all actors that deal with a crisis.

Figure 2.3 presents the same core phases and distinguishes between the pro-active and reactive parts of the CM workflow. The model can be entered at and exited from any point, and the action can proceed in any direction, in line with the reality of organizations dealing with CM.

Detection stands for the organization's early warning systems. Those systems - including IT process control systems, plant/equipment monitoring systems, management information systems, environmental scanning systems etc. - that monitor the external and the internal environments of an organization for signals of impending crises.

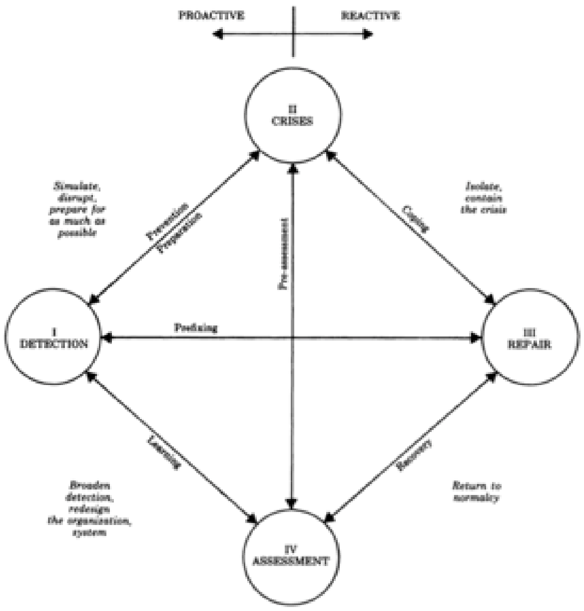

Figure 2.3. Phases of crisis management (Source: Mitroff et al, 1987)

Detection and the line labeled "prevention/preparation" indicate that it is difficult to prevent or prepare for crises that one has not detected. For most people and most organizations, detection logically occurs before prevention. Although one may unintentionally prevent what one has not detected, prevention in such instances is based on luck and happenstance, not on deliberate organization intervention.

No organization can prevent every crisis from occurring: prevention of all crises is not the basic purpose of planning and crisis management, but constant testing and revision of plans should allow an organization to cope more effectively with crises that occur, because such efforts help it learn how to roll out resources when necessary and in the most effective way.

Prevention and preparation takes the form of safety policies, maintenance procedures, environmental audits, crisis audits, emergency planning, and training. Repair represents the major structures and mechanisms an organization has in place for guiding recovery. These include emergency plans, public relations plans, crisis management teams, etc. Learning indicates when the organization asks itself what it has learned from its past crises and how it can use that knowledge in the future. It also assesses the effectiveness of its crisis handling strategies and identifies areas in which better crisis management capabilities need to be developed.

The more an organization denies its vulnerability, the more it will be focused on the right-hand side of the diagram. This corresponds to an organization that focuses on reaction to crises and "clean up" efforts. Conversely, the more crises it anticipates and the more potential crises it prepares for, the more it engages in proactive behavior.

3 Selected emerging technologies: a review

3.1 Emerging technologies for crisis management

The evolution of computing and communication technologies have always represented a source of innovation for crisis management, which has adopted digital technologies at the core of the discipline and evolved along with the availability of better and more sophisticated tools (see, for instance, Zlatanova and Li, 2008; Perry et. al 2003; Taylor and Perry, 2005).

Broadly speaking, any technology that provides opportunities form enhancing detection, assessment and repair through situation awareness, early warning, collaboration between emergency forces, or citizens information has the potential of finding applications in CM. This encompasses a very broad spectrum of technologies, from games to airborne remote sensing, from augmented reality to speech recognition etc.

Some emerging technology trends, however, have both a close affinity to the discipline and are also likely to create radical disruptions and innovation in the way CM evolves. The Internet of Things, social networks and the resulting phenomena of big data are among the most striking examples of this radical innovation potential.

These three terms share a strong affinity to Situational Awareness (SA). SA is most commonly used in the field of Human-Computer Interaction (Endsley and Garland, 2000). "Situation awareness is the perception of environmental elements with respect to time and/or space, the comprehension of their meaning, and the projection of their status after some variable has changed, such as time. It is also a field of study concerned with perception of the environment critical to decision-makers in complex, dynamic areas from aviation, air traffic control, power plant operations, military command and control, and emergency services such as fire fighting and policing; to more ordinary but nevertheless complex tasks such as driving an automobile or bicycle" [3].

3.2 Social networks and web 2.0

3.2.1 The nature of social media

A social network is a social structure made up of individuals (or organizations) called "nodes", which are tied (connected) by one or more specific types of interdependency, such as friendship, kinship, common interest, financial exchange, dislike, sexual relationships, or relationships of beliefs, knowledge or prestige.[4]

Social networks have been studied in many diverse areas (psychology, medicine, innovation, politics etc., see Scott, 1991), but the main trigger for the interest of social networks in CM is the evolution of bottom-up networks facilitated by web

[3] http://en.wikipedia.org/wiki/Situation_awareness
[4] http://en.wikipedia.org/wiki/Social_network

communication and specific tools such as Facebook, Flickr, YouTube, Twitter and the like.[5]

A key feature of the so-called Web 2.0 is the ability of essentially everybody equipped with very standard tools (a computer, a phone, some form of internet connection) to contribute to content generation through publishing text, images, video or voice, as well as collaborating to the creation of content by means of remote collaboration and coordination between informal groups. This phenomenon has developed to a phase whereby the amount and reliability of user-generated content is comparable if not superior to professionally generated content.[6].

Social networks are relatively recent phenomena: Facebook was launched in 2004, Twitter in 2006, FourSquare in 2009. The diffusion has been so rapid and viral that some of these sites are larger than most nations in the world.

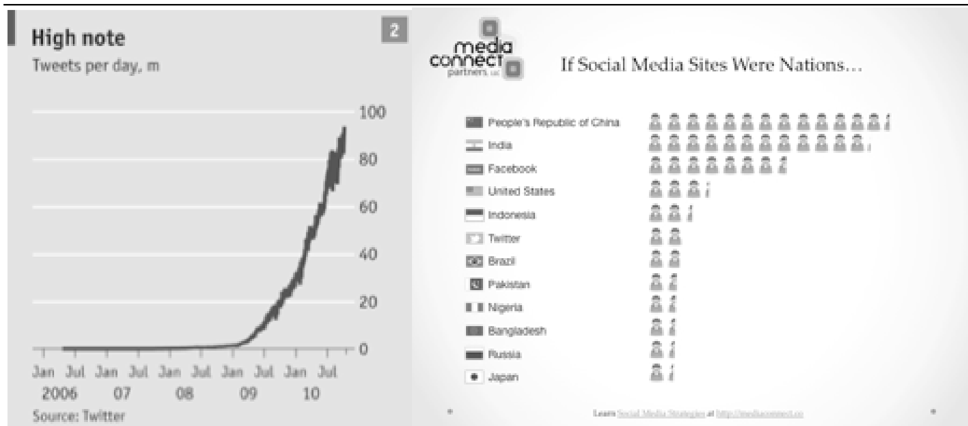

Figure 3.1 Twitter growth (Left - Source: Twitter, The Economist); If Social media sites were nations (Right - source: Media Connect, 2010).

Social media was not developed for CM purposes. Nonetheless, social media creates new channels to collect, generate, share, circulate, and exploit information, as well as generating a different type of information (personal comments and insights). The role of social media in CM is frequently associated to the so-called Government 2.0, and examples of social media for incident and crisis management are predominant in the Government 2.0 movement[7].

3.2.2 Social media and crisis management

While in a simplistic way we can consider social media as just a new source of information for crisis management, it can be argued (White, 2011) that social media changes the game for CM, in particular in anything that refers to information collection, validation, communication and sharing, between all actors of a crisis situation.

To illustrate this, let's elaborate on an example of crisis communication. In the traditional world, an incident would be followed by the creation of a crisis response team. This team gathers information and evidence about the incident and, usually

[5] http://en.wikipedia.org/wiki/Web_2.0
[6] http://123management.nl/0/051_informatie/a510-informatie-12-informatieperspectief-web-2-0.html
[7] http://shareable.net/blog/the-worlds-top-10-gov-20-initiatives (accessed 27 Nov 2011)

supported by a specific PR function, provides the most relevant information to the media. The media gathers this information and establishes a dialogue with the crisis response to create an information channel to the public. In this model, the crisis response team as well as the media provide two filters of information before news are provided to the public. This is a linear, organized, controllable, although not necessarily efficient or complete, communication mechanism.

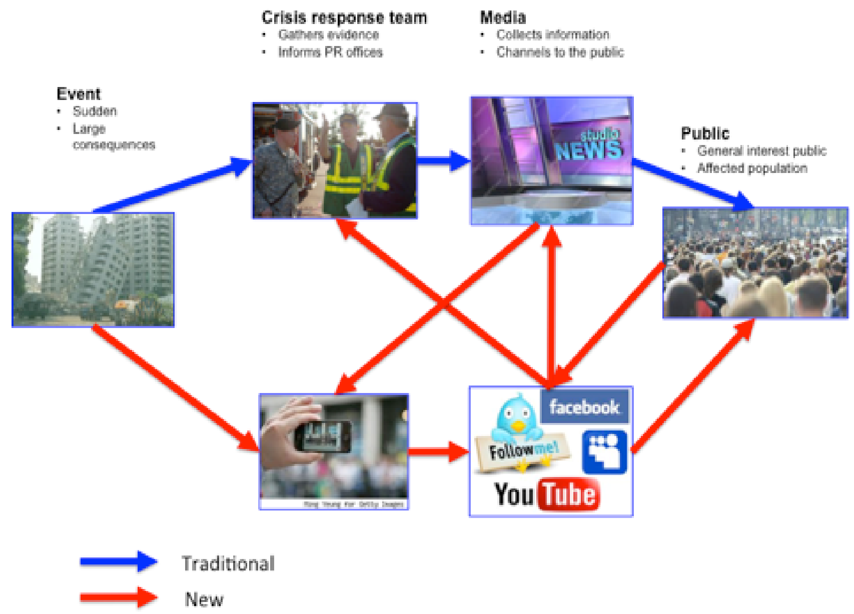

Figure 3.2 Crisis information before and after social media availability.

With the advent of social media, the entire logics of communication has changed. While the institutional channels remain in place, a series of autonomous and unstructured channels have appeared. The first source of information is usually eyewitnesses that share images or text almost immediately with web sites and social networks. This can be much faster than any other form of communication. In the recent earthquake in Virginia-USA (August 2011), the first Tweet from people at the epicenter was sent almost immediately after the quake. The messages arrived in New York 40 seconds ahead the first shock wave!

This information is the source for the public as well as for the media, which implements ways to capture and organize bottom up sources and comments to create reports as well as to ensure a real-time information feed. The same source is used by the emergency management forces that rely on a diffuse data capture network (eye witnesses, people on the ground) to create a better basis to organize response and management.

Social media do not represent a new source of information: they are a game changer in the way information is collected, shared and structured during a crisis. Clearly this raises both opportunities and challenges, from the way to best organize and exploit these new flows of information, to assessing the validity and reliability of bottom up information.

3.3 Internet of Things (IoT)

3.3.1 The nature of IoT

In most organizations, public and private, information flows along familiar routes. Proprietary information is stored in databases and analyzed in reports and then rises up the management chain. Information also originates externally, from public sources, the Internet or information suppliers.

But the predictable pathways of information are changing: the physical world itself is becoming a type of information system. In what's called the Internet of Things, sensors and actuators embedded in physical objects - from roadways to cattle - are linked through wired and wireless networks, often using the same Internet Protocol that connects the Internet.

When objects can both sense the environment and communicate, they become tools for understanding complexity and responding to it swiftly, something which appears as essential in any circumstance where time criticality is a fundamental attribute of a situation. What's revolutionary in all this is that these physical information systems are now beginning to be deployed, and some of them work largely without human intervention.

Table 1: Defining the Internet of Things

THINGS	CONNECTED TO	THE INTERNET
Consumer Products: Pill box/bottle, Car/keys, Locks, Groceries, TV, Utility meter, Appliances, Grandma's shoes, purse or necklace Commercial Products: Construction equipment, Vending machines & kiosks, Farm animals, Smart Grid equipment Government Products: Toll collection, School books and busses, Environmental monitoring, Wastewater management, Offender tracking, First Responder, Homeland Security & Defense	Small and mid-range wireless networks Wide area cellular and satellite networks Wired and fixed wireless broadband networks	Applications, services and information in the Cloud: - Remote applications - Data repositories - Messaging - Real-time human interaction - Software & firmware updates, device management

Source: Lamberth & Associates, 2010

Figure 3.3 Internet of things (Source: Lamberth and Associates, 2010)

While there is an abundance of definitions for the Internet of Things (Fleish, 2010; Kopetz, 2011, Atzori et al. 2010), the basic idea is simple are relies on the connection between physical objects and the network through some form of computing device associated or embedded to the object.

In this world, physical objects become integrated into the information network and can become active participants in business processes, with or without human intervention.

The IoT as a network of sensors not new and there are dozens of sensor networks implemented in industry and transportation, for many years already. A non exhaustive list of typical applications include (see also RFID Journal[8]and Sundmaeker et al., 2010):

[8]http://www.rfidjournal.com/article/purchase/8730

- Agriculture. Feed water systems can be monitored to detect water tank levels and implement automated irrigation.
- Air pollution monitoring. Wireless sensor networks have been deployed in most cities to monitor the concentration of potentially dangerous gases and particles for citizens.
- Area monitoring. Used to detect intrusion in a certain installation (e.g. pipeline). Sensors may detect heat or pressure and report this information to base stations.
- Environmental sensing. Deployed to monitor the status of volcanoes, oceans, glaciers, forests, etc. And designed to detect early warnings of eruptions, dislodgments, fires etc.
- Greenhouse monitoring. Used for instance to control temperature and humidity levels inside greenhouses and activate misting systems, vents, fans, or other responses.
- Industrial process monitoring and machine health monitoring. Sensors are deployed to measure pressure, temperature or vibrations to control process status and the health of the machines and systems involved.
- Landslide detection systems. Makes use of wireless sensor networks to detect the movements of soil and changes in other parameters that may indicate risk of landslide.
- Structural monitoring. Used to monitor movements within buildings and infrastructure such as bridges, tunnels etc.
- Vehicle detection. Used to detect presence of a vehicle (car, train, etc.) on an infrastructure. This is frequently based on magnetic sensors.
- Water/wastewater monitoring, to control volumes (e.g. in rivers) or quality of water (e.g. in fresh water sources for drinking).

ARC advisory group, a consulting firm, estimates that almost 70 million field devices (pressure, temperature, level, valve, position, etc.) are installed worldwide[9]

What has become particularly relevant in the recent past, however, is the progress in hardware and network technologies:

- The decrease in the size, cost, power consumption and size now allows the production of extremely small and cheap low-end computers and sensors (Payne and MacDonald, 2004).
- The increasing availability of ubiquitous wireless communication creates the conditions for a rapid diffusion by reducing the complexity of deployment.
- Advances in energy management, battery capacity as well as energy harvesting enable remote devices to operate longer or, in some cases, indefinitely without traditional power sources.

All these developments reduce the complexity of equipping objects with computing capabilities and enable a degree of diffusion which is orders of magnitude larger that any sensor deployment that has been done so far[10].

[9] http://www.hartcomm.org/hcf/news/whats_new/ARC_Advisory_Group_Study.html
[10] See EU project Casagras, FP7

There are various estimates of the growth of the Internet of things. Intel, the largest chip manufacturer in the world, estimates that over 30 billion devices will be deployed by 2020. This implies a double-digit growth rate in the next decade (Table 3.1)

Table 3.1Growth forecasts (source: Gigaom, 2010)

Category	Forecasted Units, in millions					CAGR	Source
	2008	2009	2010-2012	2013	2014		
Connected CE products/U.S.	6				86	56.0%	Strategy Analytics, "U.S. Connected Device Forecast," Jan. 2010
M2M/Global	73			430		42.6%	Harbor Research, "2009-2013 M2M/Pervasive Internet Market Forecast Report," Feb. 2009
M2M/Global	46				412	44.1%	Juniper Research, "Embedded Mobile and M2M Strategies, 2009-2014," Jan. 2010
M2M/Global		71			225	26.0%	ABI Research, "Maximizing Mobile Operator Opportunities in M2M," 1Q 2010
Mobile Phones	286				364	4.3%	IE Market Research Corp, "2Q10 United States Mobile Operator Forecast, 2009 – 2014," May, 2010

3.3.2 The Internet of Things and the "regular" Internet

Fleisch (2010) describes the main differences between the IoT and the regular Internet by looking at five main dimensions:

Invisible vs. flashy hardware. A peculiar feature of the IoT is that computing capabilities will disappear inside the fabric of objects of daily use, creating a sort of invisible computing layer. This is the opposite of the current Internet, where humans initiate the interactions with the network though dedicated objects (computers, tablets, phones etc.).

5. Trillion vs. Million nodes. With about 2B Internet users[11] there are about 3B mobile phones and over 1B computers in operation today. These numbers are very small compared to the number of things/objects we constantly create (e.g. consumer goods produced are about 84B). While it is impossible to estimate how many will be connected to the internet and have some form of sensing capability, these estimates suggest that there will many computer- enabled things around us, many more than us.
6. Light sensor identification vs. heavy Internet protocol. The Internet-based identification and addressing schemes require too much capacity to become part of low-end smart things. Academic and industrial communities are searching for alternative technologies and standards (e.g. EPC, ucode, 6LoWPAN etc.) to number and address the physical world. So far, this has been resolved through proprietary or closed-loop vendor specific schemes. The IoT will likely develop along the path of the classical Internet, whereby any computer on the net could in principle access any tagged object.
7. Machine centric vs. user centric. While the vast majority of current Internet services are designed for humans, the attributes of the IoT almost completely exclude humans from direct intervention. This is sometimes called silent computing or transparent computing.
8. Focus on sensing vs. focus on communication. The economic success of the Internet is largely based on the ability to distribute and access content. The nature

[11] Source: The Economist

of IoT is different and focuses on smaller amounts of sensing data that refer to specific contexts and objects, which require some other instrument for interpretation.

At a technical level, the implementation of the IoT revolves around the implementation of a sensing edge and the implementation of a service layer that can take advantage of the instrumentation of the physical world. At a high level the implementation can be usually described by (see Figure 3.4):

1. The entity of interest or the "Thing". This can be a vehicle, box, place, animal, fridge, etc. The need to understand the identity, location or condition of the entity of interest is the reason why we are interested in the IoT;

9. The sensors or (micro) computing devices associated to the objects of interest. These devices capture information about the entity and/or it's surrounding. These devices usually take care of communicating information to the service layer, and are indicated as "edge" devices, as they exist at the edge between the physical objects and the digital world. While many sensors will be dedicated and logically simple (an ambient temperature sensor that enables remote heating), some can be extremely complex computers. The electronics embedded in modern cars, providing vehicle control as well as remote communication for assistance or to enable congestion charging, has the level of complexity of a enterprise server and many of its functions.

10. The communication between the sensors and the service layer. This communication can take place in various forms or protocols, proprietary or open standards. The bearer can be wired or wireless, and increasingly exploits the ubiquitous nature of Wi-Fi and 2G/3G/4G communication.

11. The service layer. This is the layer where the utilization of the sensor information and main computations take place. At this level the interaction may be between machines or between machines and humans and can take a variety of forms, such as enabling ERP systems.

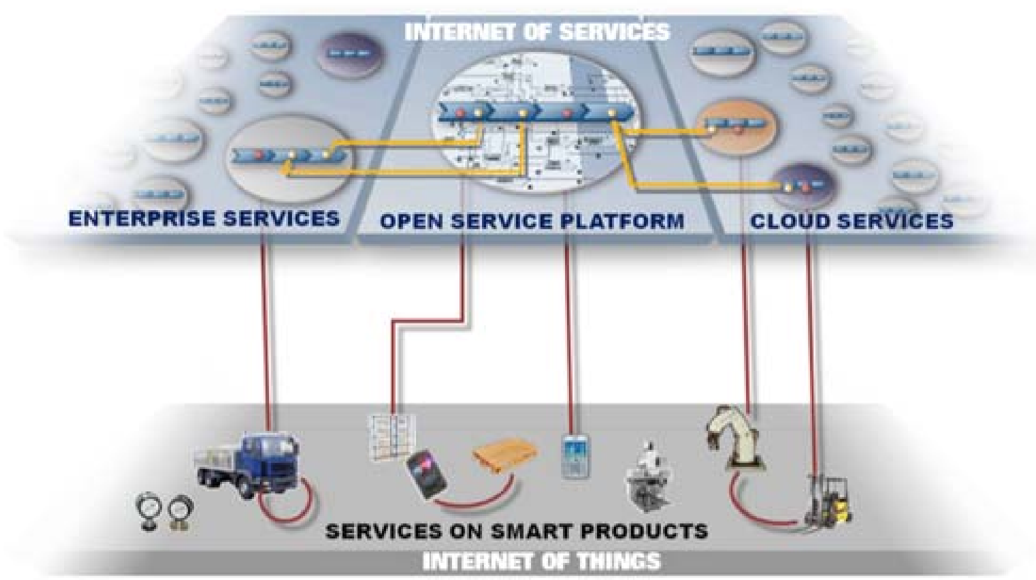

Figure 3.4. Internet of Things and Services. Source: Stephan Haller, SAP Research.

3.3.3 Examples of IoT

Chui et al. (2011) use a simple framework to articulate the utilization of emerging applications of IoT. They use six different types of applications divided in two basic categories. **Information and Analysis** contains applications such as:

- *Tracking Behavior*, i.e. monitoring and tracking movements and even interaction of individual. Examples are:
  - Tracking shoppers
  - Monitoring supply chain
  - Detecting car accidents automatically
- *Enhanced Situational Awareness*, i.e. supporting decision maker and manager with condensed information from a large amount of sensor data reflecting real-time events. Examples are:
  - Detect soil, humidity and harvest condition
  - Detect unauthorized entry through the combination of sensors and videos
  - Detect structural health of buildings, bridges etc.
- *Sensor-Driven Decision Analytics*, or the support of more complex and far-reaching human planning and decision-making (for instance in health-care). Examples are:
  - Continuous remote monitoring of health conditions
  - Analysis of shoppers behavior for improving points of sale

Automation and Control include:

- *Process Optimization*, i.e. improving added-value chains in production processes. Examples are:
  - Adjusting industrial processes based on fine-grained monitoring of process parameters (temperature, flows, etc.)
  - Automating quality control in supply chains
- *Optimized Resource Consumption*, i.e. efficient management of scarce resources like water and energy according to demand and support. Examples are:
  - Smart meters to control home electricity consumption
  - Data center power optimization
- Complex Autonomous Systems, i.e. intelligent mechanisms by means of automated systems that mimic human reactions in a time-critical decision making process. Examples are:
  - Automatic driver for consumer vehicles
  - Robots manipulating waste and other dangerous substances

The widespread adoption of the Internet of Things will take time, but the timeline is rapidly advancing thanks to improvements in underlying technology and the greater standardization of communications protocols. Massive increases in storage and computing power, some of it available via cloud computing, make it also possible to crunch numbers at very large scale and at declining cost.

3.3.4 Internet of Things and Crisis Management

Crisis management authorities extensively rely on data sources, which are collected by local and national authorities, frequently as continuous monitoring programs (see, for instance, Timmermans et al. 2010). Besides reference data such as population records, maps, utility location and the like, real-time data collected before, during and after an event are essential to guide decision making for crisis management.

There is a wealth of sensor data collected by public authorities. In recent years there has been a continuous effort to open up this data and favor re-utilization and break through the variety of data silos created over time by bureaucracies and inefficient IT systems. The UK Government offers an example of data openness[12]. Nonetheless, most of this data is static and, although provides historical data with high time granularity, it does not provide real-time feeds, with the exception of traffic data. This seems to be common of most government data sets: there is plenty of data, frequently open, sometimes collected in real-time but rarely available real-time. This poses a great challenge to effective crisis management: understanding the environmental parameters within witch a crisis unfolds is a critical asset for allocating resources, deriving priorities and in general creating a context within which to operate.

The existing sensor data collection networks (weather, pollution, traffic, radiations, images and video feeds, etc.) can be described as "Intranet of things". They are deployed by specific organizations that manage them as part of their core activities. The data is available within a walled garden, usually the organization network. Even if the data was released as real-time feed and made available to other organizations, proprietary data collection schemes would make it hard to re-use and share.

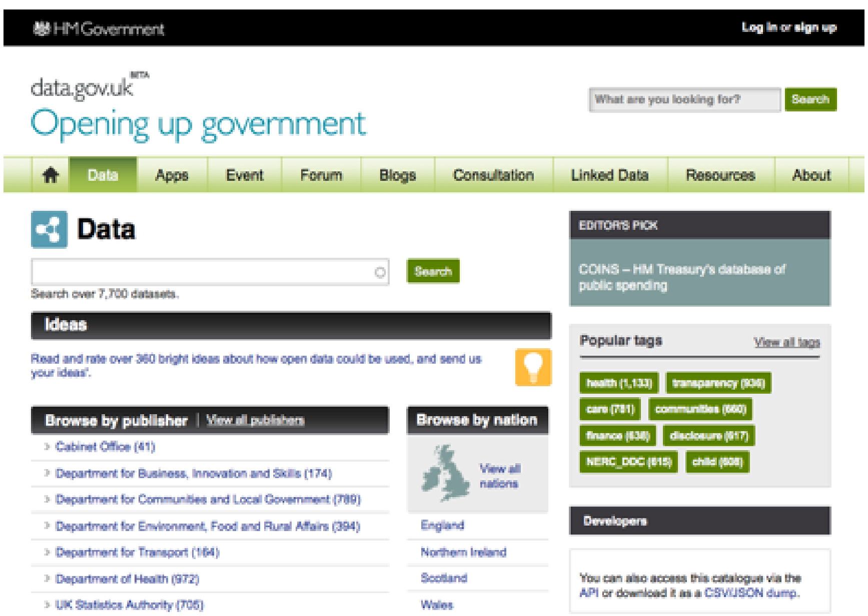

Figure 3.5 UK Open data initiative (http://data.gov.uk/data, accessed 26 November 2011)

This is the main promise of the Internet of things. In spite of the on-going efforts to share information across organizations especially during crisis (see Grothe et al. 2005), the premise of the IoT is that this access to multiple data feeds is possible by design. To simplify, it can be said that traditional data access has been designed for being closed and protected and then engineered for allowing some selected form of sharing. The Internet of Things is designed to allow openness and data mashing up, then it will

[12] See http://data.gov.uk/

be engineered to implement the level of protection/closeness required by an organization.

In these terms, IoT creates an opportunity of accessing, sharing and mashing-up sources of information on the physical environment, and doing so based on a far higher level of standardization that has been the case so far.

Furthermore, government and citizens have traditionally had distinct roles in terms of data collection: authorities collect, package and share information, while citizens utilize it for personal or business purposes. The Internet of Things changes this paradigm in that households, business and individuals become both consumers as well as producers of information, and at the same time government becomes a consumer of information generated by individuals.

To illustrate this, let's elaborate on an example of crisis data collection. In the traditional world, crisis management would start by collecting the facts about the area affected as available to the crisis organization or to the crisis management parties (e.g. police, fire department, civil protection etc.). This is usually complemented by information collected on the ground by the staff on the incident, by video feeds from e.g. helicopters and other ad-hoc data collection schemes that are deployed to improve situation awareness. The data assets are usually identified in advance as part of crisis preparation and complemented by data collection during the crisis, largely as a closed-loop data collection effort. CM actions and information to the citizens follows largely from the evidence collected in this way.

Now let's consider the situation in which people, vehicles, home appliances, streets and commercial buildings are equipped with various types of sensors dedicated to specific purposes such as:

- home automation and energy consumption reduction;
- eCall, insurance management or preventive maintenance;
- security improvement, waste management and energy reduction;
- street safety, street maintenance, efficient lighting and pollution monitoring.
- health monitoring for elderly people;

Consider also the possibility of standardizing access to telecom data traffic or utility measurements.

For practical and convenience reasons all this information will generally be available within specific application contexts and be protected from non-authorized utilizations. However, in a crisis situation it could be opened up to authorities and provide a real-time view of an area far more detailed and accurate that any other information available to CM organizations. It could provide:

- Real-time indications of where people are and how many need to be evacuated;
- Detection of people with health conditions that may need priority attention;
- Measurements of temperature and/or radiation,
  indicating the on-set of fires in non-accessible locations;
- Traffic situation and flows towards and away the incident area;
- Imagery of building to assess damage of explosions or other structural damages;
- Presence of electricity leaks, water leaks etc.

Notice here the duality of the data access structures in the traditional and IoT words. In the traditional world what can be acquired in terms of data is largely predefined and complemented ad-hoc. In the IoT world this will remain the case but there will be an additional, possibly much larger, data stream provided by individuals and organizations that open up their data assets and sensor networks to contribute to minimizing the disaster consequences, enhance their safety and that of others at the same time. It is clear that this requires some high level of standardization, comparable to the level of standardization used by the Internet to access any web site. The analogy to the Internet is in this case perfectly valid.

3.4 Big Data

3.4.1 The nature of Big Data

IBM estimates that everyday, we create 2.5 quintillion bytes of data - so much that 90% of the data in the world today has been created in the last two years alone. This data comes from sensors used to gather climate information, posts to social media sites, digital pictures and videos posted online, transaction records of online purchases, cell phone GPS signals and thousands of additional sources[13].

As for any emerging term, there isn't a unique and universally accepted definition of Big Data, although it is common to refer to it as "datasets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyze". It is also common to describe Big Data through three Vs (three dimensions):

- **Variety.** Big data extends beyond structured data, including unstructured data of all varieties: text, audio, video, click streams, log files and more.
- **Velocity.** Often time-sensitive, big data must be used as it is streaming in to the organization in order to maximize its value to the business.
- **Volume.** Organizations are awash with data, easily amassing terabytes and even petabytes of information.

Big data is an opportunity and a challenge. While it is clear that many data management tools are inadequate to handle heterogeneous, real-time massive data quantities, there are clear opportunities to find insight in new and emerging types of data, to make organizations more agile, and to answer questions that, in the past, were beyond reach.

Big Data is characterized by an exponential growth of data production and this growth can be seen in a variety of diverse and unrelated sectors. IDC estimates that in the last five years[14]:

- Digital information has more than doubled every 2 years (approximately following the Moore law);
- The number of files created grows faster than the overall information flow, indicating replication/duplication of content and fragmentation;
- 70% of information is created by individuals, for instance by uploading videos or pictures on the web, instead of organizations or institutions;
- Data continues to outpace storage, meaning that lots of data generated is not stored (e.g. TV programs that are watched but not recorded)

[13] http://www-01.ibm.com/software/data/bigdata/

[14] http://www.emc.com/collateral/demos/microsites/emc-digital-universe-2011/index.htm

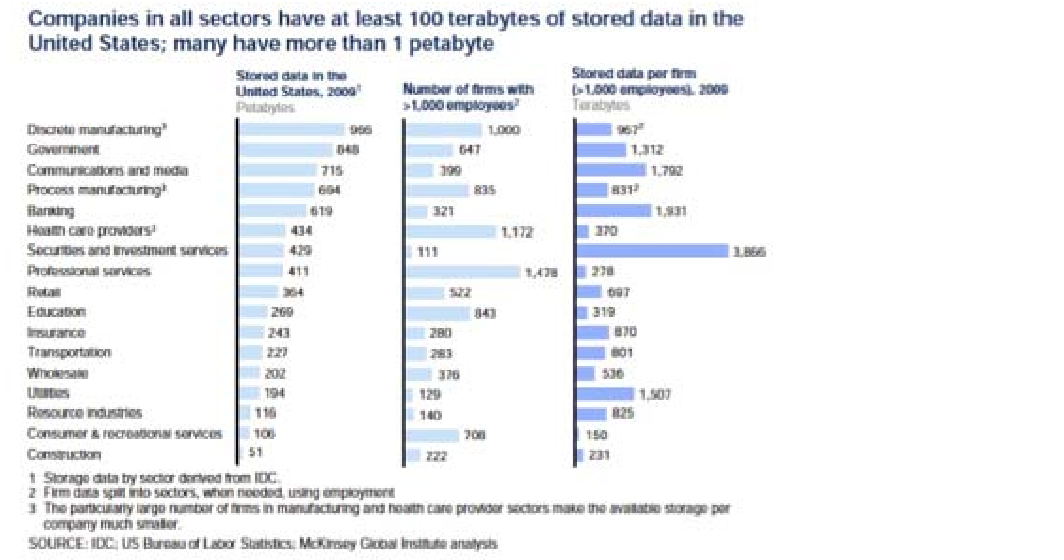

Figure 3.6. Size of data in industry.(Source:Maniyka et al., 2011)

McKinsey estimates that "in 15 of the US economy's 17 sectors, companies with more than 1,000 employees store, on average, over 235 terabytes of data - more data than is contained in the US Library of Congress" (Manyika et al. 2011).

But where does all this data come from? Here are some examples:

- RFID and barcode systems
- Sensor networks
- Social networks
- Blogs
- Media sites and news
- Internet text and documents
- Internet search indexing
- Call detail records
- Astronomy and satellite feeds
- Genomics and bio sciences
- Scientific research
- Financial transactions
- Payments and commercial transactions
- Military surveillance
- Medical records
- Photography archives
- Video archives
- Human generated files
- Surveillance cameras
- ECommerce transactions
- etc. ....

3.4.2 What is the advantage of big data?

While there are intuitive advantages to the availability of large data quantities, the premise of the "Big Data" movement is that these advantages are not linearly related to data volume, but exponentially increase once the availability of data exceeds a certain level and cuts across boundaries or silos that prevented earlier exploitation. The main game changes for big data are the following:

- **Radical transparency**. As information becomes more readily available within and across sectors, business models and decision practices based on proprietary closed data assets tend to become obsolete and be replaced. In real estate, for instance, brokers always exploited an information asymmetry between buyer and seller. Data analytics can now help create alternative sources of property value and valuations, undermining the power of brokers in favor of more open exchanges. Healthcare institutions spend vast sums of money to run medical trials and population studies. Data collected from individuals that monitor their health parameters and share the data anonymously provides an alternative and potentially much vaster source of data that augments or replaces traditional experimental settings.
- **Simulating decisions, anticipating changes**. Many important decisions cannot be tested ahead and their outcomes can only be measured after some time, usually after effects cannot be reversed. This is the case for government, cities or businesses. Big data may offer the opportunity of testing outcomes small scale first. The city of New York, for instance, tested the effects of large art installations on tourism patterns by mining telecom data on selected first sites. The impacts serve to assess city regeneration capabilities of these installations and measure their effectiveness before full deployment. At the same time, financial decisions can already by affected by mining social media trends. The first Edge Fund that invests only based on twitter data has already been launched and proven more successful than average stock indices[15].
- **Personalization and customization.** Pattern analysis and segmentation can be far more granular and real-time. Besides the obvious example of customer segmentation and personalization in retail, this can be applied to many sectors. In advertisement, for instance, mining social media or telecom traffic can measure the popularity of advertisement and adapt as a result of this. Utilities can analyze individual and organization consumption patterns and optimize their offers.
- **Automating decision-making**. Algorithms applies to data streams collected in real-time can be more effective at some decision making tasks than humans. Manufacturers can use this to streamline production and carry out preventive maintenance without human intervention. Retailers can anticipate on purchase patterns and re-stock accordingly. Traffic authorities can use bottom up travel data collection to automate traffic communication as well as adapt speed limits or re-direct flows in peak hours. Farmers can plan harvest a decision based on analytics that capture the entire data stream of a season and transforms it in optimal harvest time based on weather forecasts.
- Not all organizations are positioned in the same way to capture the benefits of big data. Brown et al. (2011) ranks economic sectors based on the potential of big data and the ease of acquiring data. Government and financial institutions are ranked among those that can benefit most from big data, with government been the sector where big data capture is the hardest. (see Figure 3.8).

[15]http://www.derwentcapitalmarkets.com/

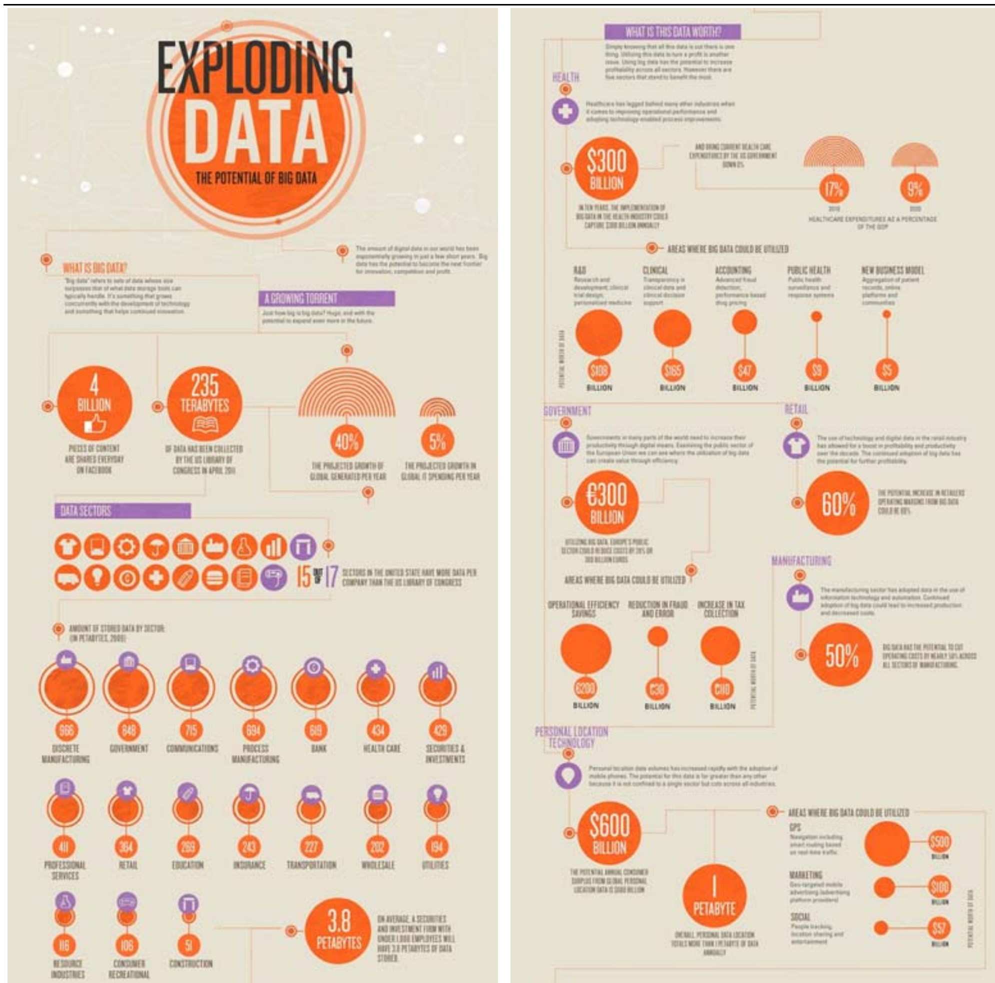

Figure 3.7.Big data infographics[16]

3.4.3 Big data and Crisis Management

Big data is largely the result of the increased digitalization of our lives and workplaces. The role of big data in CM has already been discussed as part of the roles of social media and the Internet of Things in CM, but there are also some very specific advantages of big data that deserve attention, specifically:

- ability to anticipate and predict a crisis
- availability of data analysis tools
- pre-defined data analytics

The increased capability of sensing utilities, transportation, weather, people behavior or flows underpins an ability to anticipate conditions that may lead to a crisis. Sensors will be able to detect little problems, like blocked sewer lines, and data analytics can serve to combine them with other data in near real-time, like weather forecasts, impending rain or traffic density to provide a mechanism to alert of a crisis before it

[16] http://datarecoverynewjersey.info/2011/future-amazing-business-the-growing-big-data/

takes place. The potential is that of connecting diverse and apparently un-related data to detect risks in a way that would be very hard otherwise, providing responders with an important time advantage.

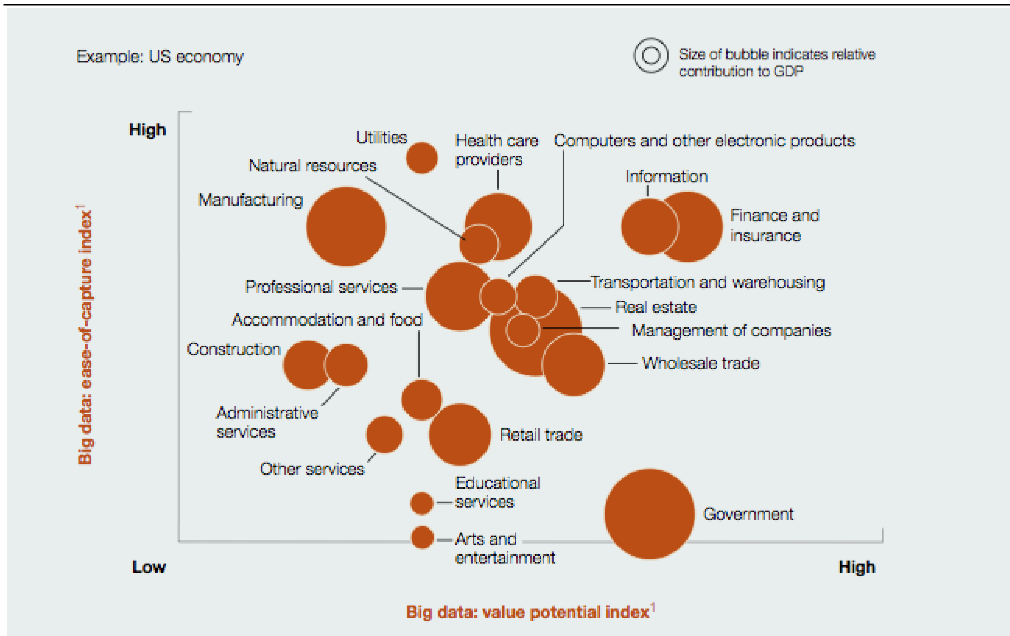

Figure 3.8. Ease of data capture and potential of big data (Source: Brown et al. 2011)

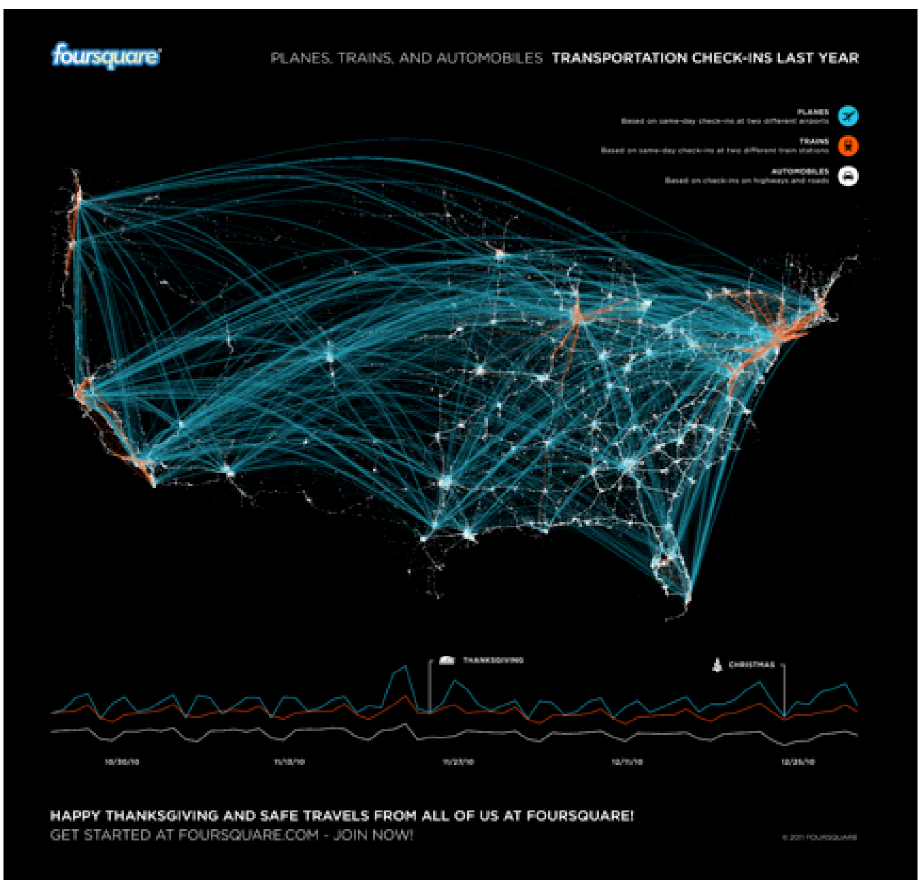

Figure 3.9.Collective travel patterns based on Foursquare check ins (Source: Foursquare)

Companies and institutions worldwide are producing big data tools for gathering, mining, visualizing and interpreting large data sets. These tools are becoming part of the regular set of assets of organizations and will be essential in CM situations. While the data available in a crisis is only in part known upfront, the main advantage of the availability of sophisticated analytics tools is the short amount of time that will be necessary to ingest new data sources and the range of tools available for fast analysis. This makes it much more realistic to implement ad-hoc analysis on new data streams, something which is aligned with the rapid pace of decision making during a crisis.

Furthermore, analytical models that are designed for other purposes that CM but can be critical during a crisis. Examples are real-time population models, sentiment analysis based on twitter, image recognition and pattern analysis based on social media pictures and the like. All these data analytics informs business and government for planning, marketing, safety etc. They can be rerouted to CM organizations and provide enhancements to situation awareness.

4 Case studies: social media

4.1 Selected case studiesfor social media

This chapter illustrates examples of social media in relation to crisis management. The literature in this area, in spite of the relatively recent development of social media, is already vast and there are dozens of case studies described in literature (see, for instance, White, 2010). Examples are:

- The airplane crash in the Hudson River in 2009
- The earthquake in Haiti in 2010
- The closure of European airports during the Island Volcano explosion in 2010
- The earthquake, tsunami and nuclear disaster in Japan in 2011
- The Arab Spring - political unrest in North Africa 2010/2011
- The floods in Queensland, Australia in 2010/2011
- The earthquake in North Carolina in 2011
- The earthquake in Christchurch (NZ) in 2011
- The earthquake in Turkey in 2011
- The Thailand floods in 2011

The case studies selected below are indicative of the main role of social media in CM as it evolved in the last 2-3 years.

4.2 Social media: the earthquake in Haiti in 2010

On Tuesday January 12th, 2010, at about 5 PM local time, a massive earthquake struck the island of Haiti. The quake was measured as magnitude 7.0M, which makes it one of the severest earthquakes in the last century of Haiti's history. Its epicenter being only 25 km away from the capital Port-au-Prince caused massive damage to buildings, infrastructure and the people themselves. The earthquake caused death to more than 316.000 people, injured about 300.000 and made 1.3 million Haitian citizens homeless. The first quake lasted about 40 seconds, followed by eight smaller aftershocks that were still measured between 4.3 and 5.9M in the first two hours after the disaster. In total, the United States Geological Survey measured 52 aftershocks within 12 days after the first quake.

Many countries from all over the world responded to the appeals for humanitarian aid. Funds and donations were made, and goods that were needed most were sent to the area - medicine, water, lifting machinery etc. but also personnel like doctors and nurses, disaster relief teams and many more.

4.2.1 How were social media used?

Both citizens and disaster recovery helpers faced several problems after the earthquake. The landline telephone network went down, which caused the mobile phone network to deal with a massive overload of telephone traffic. The phone stations could not put through the calls that were coming in, so the citizens could not get in contact with their relatives by phone. Some of them found another solution, though, and started exchanging information through text messaging. They stayed in touch via SMS, and since the Internet was still sporadically running, they were able to send Twitter messages as well. (White, 2011)

Twittergradually became one of the main information channels after the disaster. Since traditional means of communication and information were disabled, the traditional media abroad had to rely on the text messages that were distributed online. This worked very well - media like the Guardian or CNN gathered their news online via Twitter, and lists of twitter users that were on-site were collected.

Disaster relief was hampered by the fact that the vast majority of the infrastructure had been destroyed by the quake itself or by collapsed buildings. Since there were no recent maps of the area available. Much time was wasted through following a dead end and finding a way through the rubble on the streets. Many government agencies and commercial providers of satellite imagery made some high-resolution satellite images of the area available to the public and the helpers. This was the starting signal for another public participation effort. Many active users of **OpenStreetMap** spent their time to digitize the satellite images and thereby provide a detailed map of the island. It took no more than 26 hours until Port-au-Prince was mapped in high detail, including devastated buildings, blocked roads and provisory shelters.Another mapping service, **Ushahidi**, provided the helpers with an information exchange platform. With this application, the citizens themselves could report specific events directly. Volunteers, mainly students, who were already involved in the development of the open source software, verified the reports. Among the mapped reports were emergencies, vital logistics lines, public health issues, security threats, natural hazards and services available for help. Furthermore, a free iPhone GPS application (Gaia GPS for Haiti disaster relief) was provided, which facilitated navigating through the streets with the help of a mobile device. In order to make it easier for citizens to search for relatives and friends, Google set up a service named "Google person finder for Haiti earthquake" for the Haitian population.

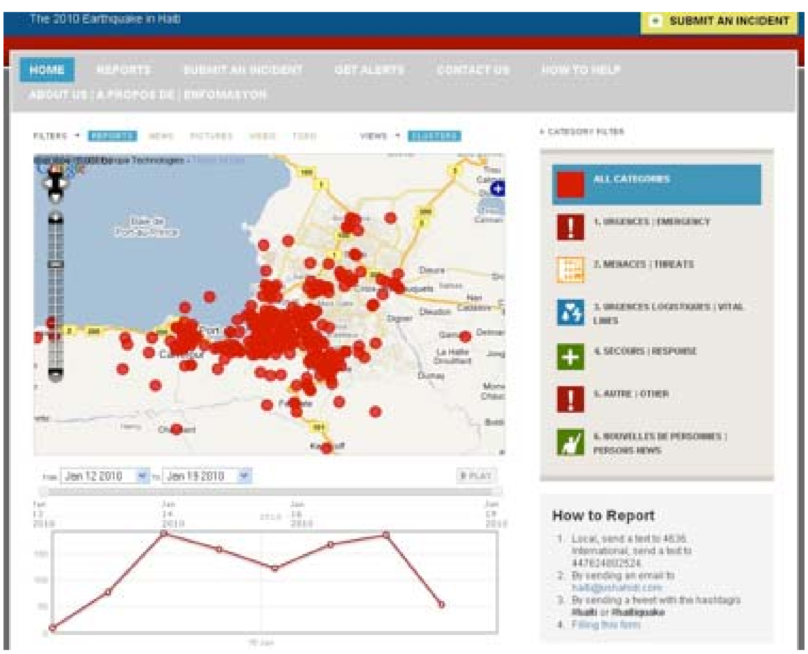

Figure 4.1 Ushaidi Haiti map(Source: http://geoserver.isciences.com/DataBlog/?p=1244)

An application named **Sahana Eden** also proved to be useful during the emergency. It provides out of the box applications for different areas of use in emergency management, like for example requests management, shelter registry, and mapping or hospital management. Sahana was mainly used for maintaining a huge database with information from different sources like health organizations, which then could be geocoded and mapped (White 2011). The different applications and media were used by many helpers and rescue organizations, among these the Red Cross, FEMA and the Coast Guard.

4.2.2 Social media's impact on the situation

The help of many volunteer mappers made OpenStreetMap one of the most important tools during the disaster relief. The map is now "the most complete digital map of Haiti's roads, hospitals, triage centers and refugee camps currently available"[17]. By relying on this map, rescue helpers and citizens were able to find their way through the chaos, and even identify the areas where their help was needed.

Twitter facilitated the communication between the Haitian citizens. It helped them to bypass other means of communication, which were not available and enabled them to stay in touch with each other, call for help and provide their neighbors with information. The Twitter messages fed three vital emergency functions:

- assessment (What is happening?)
- coordination (What is needed?)
- response (What must be done?)

By following the Twitter messages from Haiti, many civilians who could not help directly were nonetheless able to contribute to the disaster relief without much effort - e.g. by making a donation, translating messages from Créole to English and other languages or by mapping the region. This encouraged the people to contribute and therefore made the community of helpers much bigger than it would have been without "distant" helpers.

Ushahidi and Sahana are both applications that are highly dependent on the collaboration of many volunteers. Their information content grows with the number of entries that are made and with the quality of the data that is provided. Since there were many entries made by the people on site and since many volunteers verified them, false entries could be avoided and the tools proved to be very useful on site.

Ushahidi ("testimony" in Swahili) was initially developed to map reports of violence in Kenya after the post-election of 2008. The original website was used to map incidents of violence and peace efforts throughout the country based on reports submitted via the web and mobile phones. This website had 45,000 users in Kenya and was at the basis of the platform, offered as open source project to others around the world. The company itself is non-profit and specializes in developing free and open source software for information collection, visualization and interactive mapping.

[17]http://issuu.com/mla_rmit/docs/schwabe_niki_mla_concise_adr

4.3 The earthquake in Christchurch in 2011

On February 22nd, around lunchtime, a massive earthquake struck in the area around Christchurch, the second-most populous city in New Zealand. The quake had a magnitude of 6.3M and occurred 5km beneath the surface. It killed 181 people[18] and caused extensive damage to the city of Christchurch. Since there had already been an earthquake a few months before, the building fabric was already weakened. Many buildings collapsed, burying the victims beneath the rubble.

4.3.1 How were social media used?

Shortly after the earthquake, Google launched their person finder for the Christchurch earthquake. In addition to that, they set up a crisis response page with emergency numbers and an interactive map with different layers for shelters, places where the citizens could fill up their water supplies with clean drinking water etc. The Google person finder tracked up to about 5200 records shortly after the disaster[19].

People were cut off both the power network and the Internet shortly after the quake. With no power available, they kept in touch with neighbors and friends rather than wasting battery power on phone calls. Written notes were fixed on lampposts to exchange information. As soon as power was sporadically available, mobile devices with Internet access were the main tool for staying in touch with friends and family abroad. Facebook profiles were updated regularly to let friends and family know what was happening[20].

In Twitter, popular hashtags like #eqnz or #chch were used to search for missing people, but also for exchanging information. NGOs (non-governmental organizations) used their Twitter accounts for information distribution, like for example the New Zealand Red Cross. Active Twitter users posted pictures of the situation outside on the streets. YouTube was used to spread videos of the quake and the damage over the Internet[21]. Traditional news resources like the New Zealand Herald or ABCNews created a social media collection on Storify, which works like a book marking page for different media formats[22].

Ushahidi launched a mapping service called "Christchurch Recovery Map", which was used to collect geo-located information on the current situation. The page could also be used to request help and it provided useful information like links, advice and suggestions where to help. In addition to Ushahidi, many other mapping services came to use after the quake. Google created a map of the earthquake destruction, and ESRI published a social media map with geo-located Ushahidi posts and filtered social media content like YouTube videos, Flickr photos, Tweets and many[23].

4.3.2 Social media's impact on the situation

According to those involved, social media had a sizable measurable impact on the situation. Facebook proved to be a key tool for friends and family to post what they

[18]http://en.wikipedia.org/wiki/2011_Christchurch_earthquake
[19]http://www.google.org/crisisresponse/christchurch_earthquake.html
[20]http://www.gottaquirk.com/2011/03/08/interview-christchurch-quake-survivor/?qpv=dsk
[21]http://socialmedianz.com/opinion2/2011/02/22/the-christchurch-earthquake-told-on-social-media-platforms/
[22]http://socialmedianz.com/news/2011/02/23/storify-shows-its-true-value-in-the-christchurch-earthquake/
[23]http://blogs.esri.com/Support/blogs/arcgisonline/archive/2011/02/22/new-zealand-earthquake-social-media-map.aspx

need and what they can offer (accommodation, other supplies). It also involved people from outside as messengers when Internet access was not available in the area. The Twitter messages provided a detailed damage report and thereby allowed people to focus on relatives who might more likely be in danger. For instance, the Twitter accounts of different companies became a platform for relatives to inform about the condition of employees if the building had collapsed.

Other media content like photos and videos were also distributed by traditional media. This way, citizens who were not using social media could also inform about the current situation. The many mapping services online were a good information source for the people in Christchurch as soon as the power went on again.

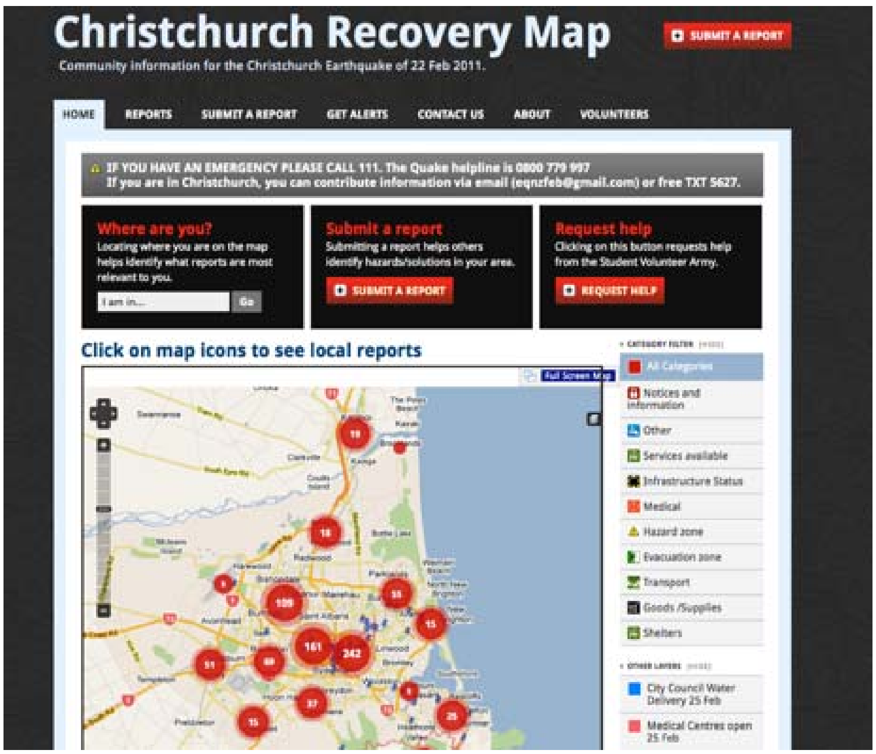

Figure 4.2 Christchurch Recovery Map (http://eq.org.nz/): Ushahidi Community (http://community.ushahidi.com/index.php/deployments/deployment/christchurch-recovery-map)

4.4 The Arab Spring - political unrest in North Africa 2010/2011

4.4.1 Information and facts

From December 2010 until present, a revolutionary wave of protests and demonstrations has been taking place in large parts of the Arab world. The uprisings started in Tunisia and took over to other North African and Arab countries, among these Egypt, Lybia, Syria, Algeria, Iraq and many more. In Tunisia and Egypt, the protests have led to a revolution with the authoritarian governments being overthrown. The first demonstration in Egypt took place on January 25th and sparked the revolt. After 18 days of protest, the Egyptian president Hosny Mubarak resigned. In Lybia, the protests led to a civil war, which caused the death of at least 20.000 people. The Libyan leader, Col. Muhammar el-Qaddafi was killed during the civil war.

The following sections describe both the developments and the use of social media in the countries of Egypt and Lybia, which stand for many other countries joining the political unrest in 2011.

4.4.2 How were social media used?

The organizers of the uprisings were a network of liberalists, socialists and members of the Muslim Brotherhood, an important opposition movement in Egypt that has been banned by the government[24]. Most of them did not know each other personally, but just communicated online.

One third of Egypt's population is younger than 30 years old. They are educated, frequently unemployed and angry at the circumstances in their country. Originally, they wanted to raise the minimum wage, fire the interior minister (which stood under suspect of torturing Egyptians) and stop police brutality against citizens.

When a young Egyptian businessman was tortured and murdered by two policemen in 2010, a Facebook page was launched anonymously to commemorate him. The name of the page is *"We are all Khaled Said"*, and its founder is Wael Ghonim, a young Egyptian who was working as executive for Google and who would later be one of the key figures of the revolution. "We are all Khaled Said" spread over the Internet in a flash. Many Facebook users contributed to the page by sharing other material of abuse and mistreatment of Egyptian citizens by policemen. After a few months, the number of followers had grown to half a million[25]. The page became a central platform and information channel for a campaign against police brutality, being supported by hundreds of thousands of Facebook users[26]. Silent demonstrations were planned on the page, giving instructions for silent protest.

A few days before the protest on January 25th, a group member posted a note to ask for "marketing help". January 25th is a state holiday in Egypt: Police Day, which is meant to honor the security forces. A Facebook event was planned for this date, which would turn out to be the starting signal for the revolution.

A revolution is not managed behind keyboards and monitors, though. The Internet penetration and the Facebook usage in Egypt are very low: in order to reach the poor and the worker families, members of the group had to go on the streets to spread their message. They went to the slums in Cairo and split up into two parts. The first part was shouting from the roofs, the second part went from door to door (especially shops, bars etc.) to tell the people why they are here. More and more people followed them. The crowd called for a change of government - a decision that did not came from the organizers, but from the people themselves. A few days later, the organizers again went to a worker neighborhood and knocked on doors. They started with 20 people, and within two hours, they were already 3.000. The next day, a massive demonstration took place, with hundreds of thousands of people on the streets. That day, January 28th, would later be called "the day of anger"[27]. Flickr was used to share high-quality photos of the demonstrations, videos were shared on YouTube.

[24]http://video.nytimes.com/video/2011/02/09/world/1248069625583/the-road-to-tahrir-square.html
[25]http://www.cbsnews.com/video/watch/?id=7346812n
[26]http://www.huffingtonpost.com/2011/02/08/wael-ghonim-freed-activis_n_820290.html
[27]http://video.nytimes.com/video/2011/02/09/world/1248069625583/the-road-to-tahrir-square.html

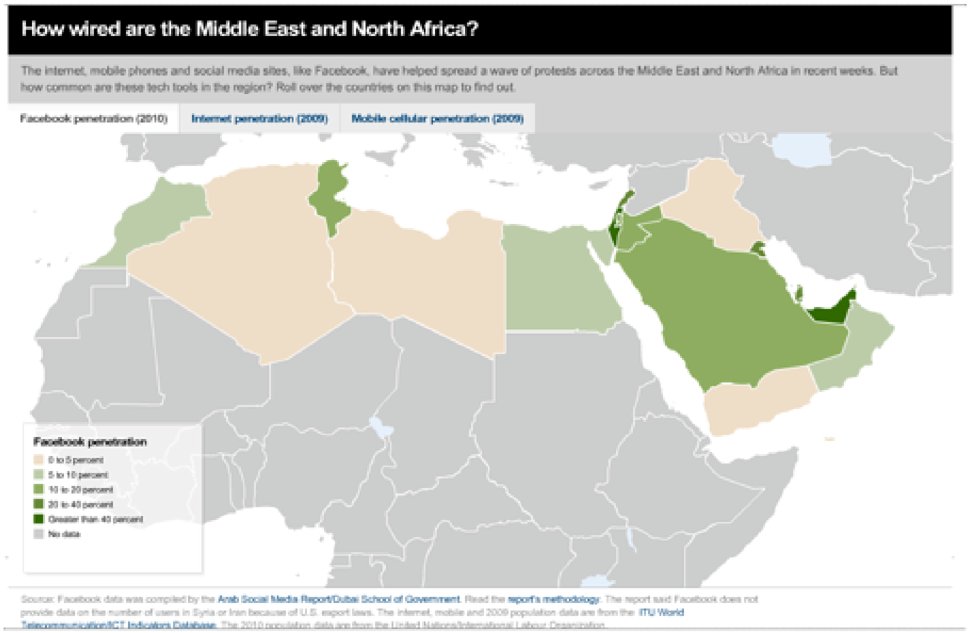

Figure 4.3. North Africa Internet penetration and Facebook usage: CNN (http://edition.cnn.com/interactive/2011/02/tech/map.mideast.tech/index.html)

The participants of the revolution must be split into two groups: the ones who were networking online and organizing the protests, and the ones who went out on the streets, exposing their lives to danger. When Wael Ghonim and the other organizers started posting dates and locations of protests, they did not expect so many followers to show up[28]. The protests were organized in a weekly schedule. To draw off the police forces, the protest movement leaked false leads to the officials. After the January 28th protest, the government shut down the Internet for 5 days in order to cut off the online connection of the protestors. Not being able to read the news on Facebook anymore, the people were even more motivated to go on the streets and see what was happening. In addition to that, cutting down the Internet was a clear sign of fear for the government.

The country of Lybia had been far more suppressed by its leader than Egypt had. Col. Muhammar el-Qaddafi controlled the television and radio broadcasts in the country, and after more than 40 years of leadership also had a lot of - willing or unwilling - followers. Nonetheless, the majority of Libyan citizens were angry with the government. Very few Libyan citizens use social media like Facebook and Twitter, since Internet penetration is very low in Lybia and the amount of control is very high. There have been some, though, that posted information on the on-going protests online, and others who posted pictures and videos of the demonstrations. This information was mainly useful for the world outside Lybia, to know what was going on inside the country. One web page called "Lybia 17th February 2011" was highly frequented as information platform by the Libyan citizens with Internet access. The page collects Twitter messages, videos, photographs and news from all over the world about the Libyan revolution[29].

[28]http://www.cbsnews.com/video/watch/?id=7346812n
[29]http://libyaFeb17.com/

The demonstrations led to a civil war between Qaddafi's loyal followers and the revolutionists. Many Libyan citizens fled out of the country, and many were killed. The UN Office for the Coordination of Humanitarian Affairs (OCHA) activated the Standby Volunteer Task Force for Lybia. They set up an Ushahidi application for the country to monitor reports on armed confrontations, attacks, explosive remnants of war, needs and many more[30]. The Lybia Crisis Map was used to gain an overview on the developments inside and along the borders of Lybia.

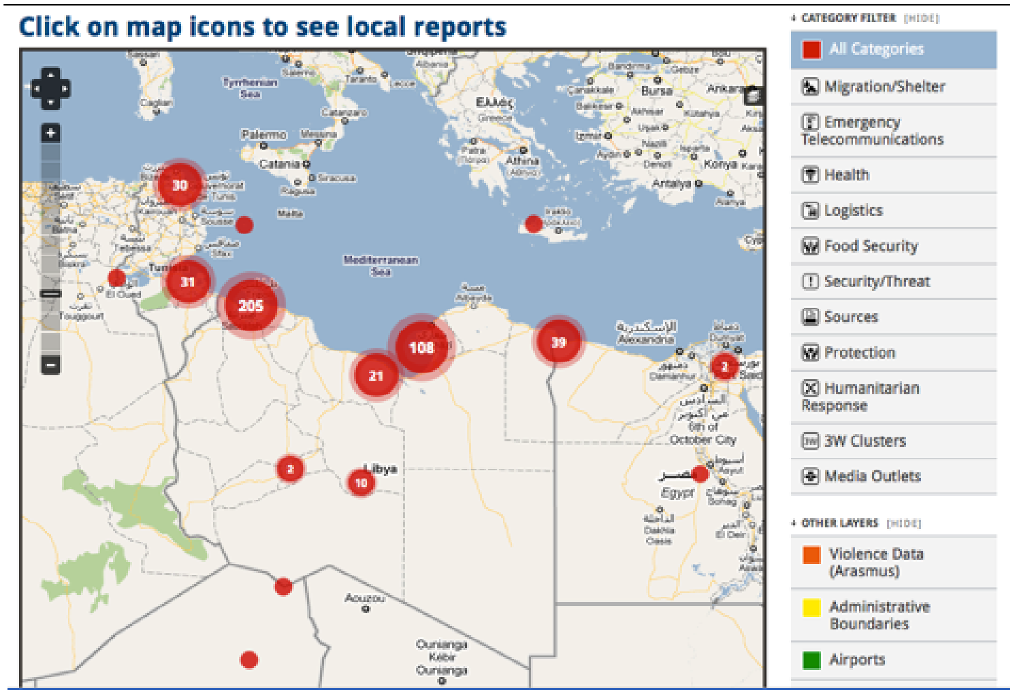

Figure 4.4. Libya crisis map (Source: http://www.flickr.com/photos/ushahidi/5703376329/sizes/o/in/photostream/)

4.4.3 Social media's impact on the situation

When asked what Facebook did contribute to the revolution, Wael Ghonim said:

> *"This revolution started online. This revolution started on Facebook. This revolution started [...] in June 2010 when hundreds of thousands of Egyptians started collaborating content. [...] I've always said that if you want to liberate a society just give them Internet."*

The media adopted this enthusiasm. Egypt's revolution was often named "Facebook revolution" by different sources. Nonetheless, one must not forget that it takes more than a few youths in front of a keyboard to start a radical change. The most important contribution of social networks in this political unrest is a feeling of community - seeing that thousands of people are interested, as angry and as willing to change their situation as oneself. As an organization tool, social media may be useful but it is easily overtaken by the mosques: less than 25% of the Egyptian citizens have Internet access,

[30]http://blog.ushahidi.com/index.php/2011/03/06/using-new-ushahidi-map-libya/

only 5.5% have a Facebook account - but nearly every Muslim in Egypt can be found in a mosque during Friday prayers. Where if not there does word of mouth make sense?

For Egyptians and journalists outside of Egypt, social media proved to be a highly important tool. With the help of Facebook, Twitter, Flickr and YouTube, they were able to get information from places where it was too dangerous for foreign news reporters to get[31]. One problem here is that this information is highly dependent on a working Internet connection. As soon as the Egyptian government cut the network down, the people could no longer provide the world with information nor could they continue organizing further protests online.

The Ushahidi crisis maps, which were launched for Egypt and especially for Lybia, proved to be useful information for both the outside world and the people inside the country. One fact that cannot be neglected is that Internet penetration in these countries is not very high, especially in Lybia. Therefore, the crisis maps were not accessible for everyone who could have needed them.

[31] http://edition.cnn.com/2011/WORLD/africa/01/27/egypt.protests.social.media/index.html

5 Case studies: Internet of things

5.1 Selected case studies for the Internet of Things

This chapter illustrates examples of uses of Internet of Things relation to crisis management. The experience and literature in this area is fragmented and poorly articulated, primarily because the term Internet of Things is used in a loose sense to encompass virtually any application of automatic identification, location and sensing.

In some area, such as water or environmental management, earthquake detection, dykes monitoring, sensor data collection is an established discipline (see, for instance, Timmerman et al. 2010 for water management). Similarly, process industries rely on extensive sensor networks to operate the plants and for safety purposes. These, and many others, are closed-loop applications designed for specific sensing needs (see for instance Figure 5.1 and Figure 5.2) and have developed over a long period of time, to become main stream in certain sectors or industries. They are to some extent the precursors of the Internet of things and have already obvious and estblished applications in CM.

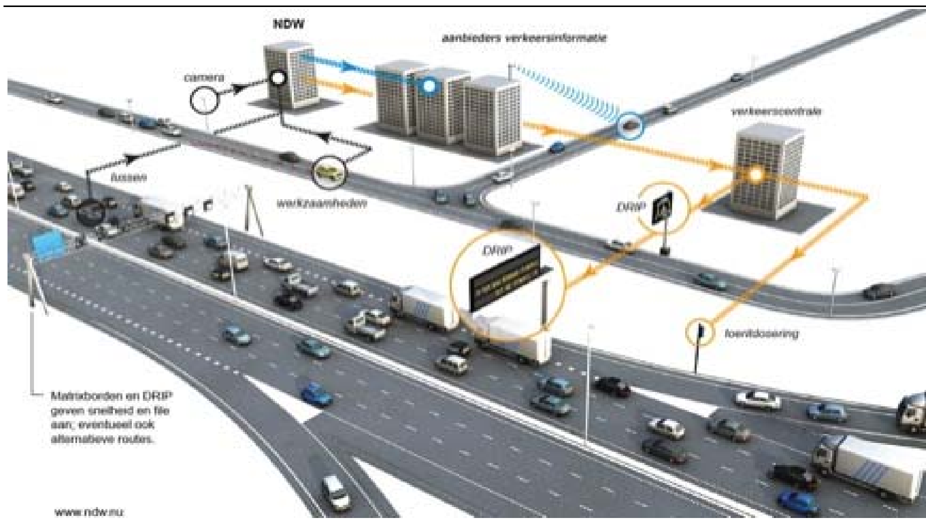

Figure 5.1. National data bank for traffic data in the Netherlands and the interplay of multiple sensors (Source: www.ndw.nu).

A new wave of applications is however emerging. They:

- exploit sensor networks specifically for CM, including ad-hoc deployments during prevention and crisis management;
- extend the use of sensor networks beyond the traditional domains or applications;
- leverage the increasing availability of sensor capabilities in consumer devices
- leverage the increasing interoperability of sensor networks and technologies, to create "systems of systems"

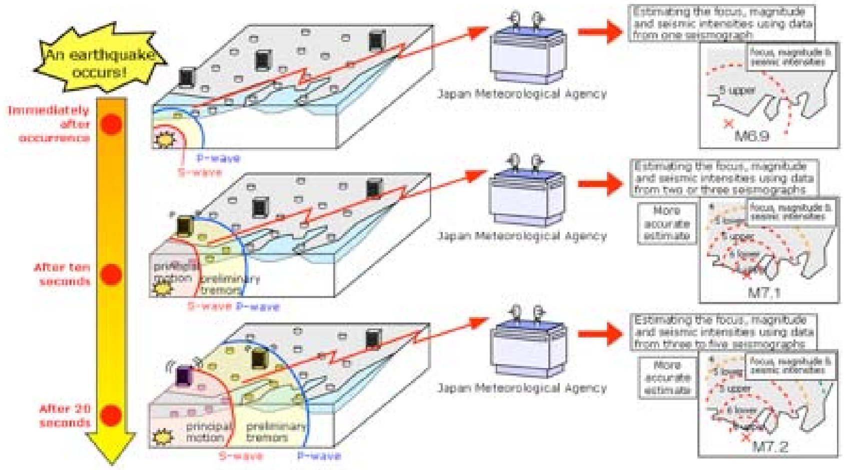

Figure 5.2. Earthquake Early Warning system in Japan. The system provides advance announcement of the estimated seismic intensities and expected arrival time of principal motion. (Source: http://www.jma.go.jp/jma/en/Activities/eew.html)

The examples below provide some examples of recent applications of sensor technologies to crisis and disaster management and of some ongoing large-scale developments that will leverage the IoT for large scale events and emergencies.

5.2 Ensuring clean water availability

The system developed by Deep Springs International (DSI) and Nokia Research Centre ensure the supply of clean drinking water in Haiti by making use of near field communication (NFC) technology in combination with a mobile phone application.

Families in the most rural areas in Haiti will have one water treatment kit consisting of a five-gallon (19 liter) plastic bucket with a lid and spigot. RFID tags are attached to buckets for storing the treated drinking water, which are delivered to families together with a chlorine solution and written instructions for using the kit. When DSI's water technicians visit their homes, they check whether they are using the kits properly and provide additional chlorine solutions. The technicians will read the tags using NFC cell phones loaded with software guiding them to ask relevant questions about the water being tested. They then send the data to DSI's headquarters via SMS.

This fast and cost-efficient system enhances fresh water supply system during natural catastrophes or serious outbreaks of infectious disease. Using RFID, the report information is current, more reliable and properly detailed. The system also verifies that control visits have actually been done, and thus ensures complete documentation. Taking time-consuming paperwork out of the process means the technicians can visit many more households. With the help of this system the organization is currently reaching 35,000 families throughout Haiti and aims to reach even more by directing its resources more efficiently.

Figure 5.3. NFC checks (Source: http://washtech.wordpress.com/)

5.3 Evacuation Planning

The evacuation coordination following Hurricane Katrina and Rita in southern Louisiana and Texas 2005 involved almost three million people. Thousands of special-needs citizens lost connection to their families and relatives because of sparely documented evacuation activities.

The Texas Special Needs Evacuation Tracking System (SNETS) has been established in 2008 to streamline verification of people location during large scale emergencies.

The first use of the system was for Hurricanes Gustav and Ike, monitoring the evacuation of about 30,000 people. Once an evacuation ordered is issued, residents that require assistance are directed to meet at pre-designed mustering centers where they are registered and equipped with RFID wristbands (see Figure 5.3). Busses equipped with GPS take them to evacuation hubs, where they are scanned on entry-exit. This allows for a full visibility of the evacuation process, and provides real-time information of who and where has been evacuated and where people is in the evacuation hubs.

Figure 5.4 Texas Evacuee Tracking System Wristband (Left - Source: www.geoplace.com); Preparing for Hurricane Ike (Right - Source: http://www.beaumontenterprise.com)

A similar system, the City Assisted Evacuation Plan (CAEP), is in place for the City of New Orleans. Upon an evacuation order, the City's Emergency Operation Centre would deploy busses across the city to pick up evacuees at their predetermined pickup stops. The busses take evacuees to an evacuation center, where they would receive an RFID wristband that is automatically registered to Evacuation Tracking System (ETS).

The principle of the system is to know who is where at all times. Technologies involved include RFID identification, GPS tracking, mobile phone networks and spatial databases. Information is used to allocate transportation resources (such as busses), to provide information to relatives, to manage hospitality resources and capacity and for comprehensive online situation monitoring.

5.4 Safety and Security of CM personnel

CM and safety personnel have usually a high degree of autonomy in deciding activities and operations on an site either for prevention and monitoring purposes or in response to an incident. In some circumstances this may be exploited by others, for instance to grant access to areas where they would be otherwise denied access to.

During large events, manifestations, concerts or the like, which attract vast crows, ensuring a clear distinction between those that have access everywhere as part of their job and the rest of the participant can be challenging and in most cases far from water tight. Security breaches can represent a threat to event and its participants.

Safety organizations have started adopting real-time sensing technologies to improve this situation, frequently with ad-hoc implementations. An example is the 2009 Boston Pop's Fourth of July concert. The safety of 500,000 audience members and 20 federal, state and local agencies during the event has been ensured by RFID tagging. Passive RFID tags embedded in staff members' pendants allowed only them to enter the secured command center quickly where they monitored the event. The system was enhanced to provide a long RFID read range and integration with other security solutions including video cameras, pressure sensitive floor mats, and red and green stack lights used to indicate whether a person entering the room was authorized or not.

Figure 5.5. Event picture (Right - Source: www.thinkmagic.com); command center (Right - Source: http://radio-frequencyidentification.blogspot.com/2009/07/rfid-protection-used-recently.html)

Prior to this technology, an authorized person using paper lists did this verification. With the system, the negotiation of about 6,000 movements in and out of the command center and other restricted area during that event has been managed much more efficient and more secure. These presence data could be analyzed to help determine how often specific agencies or individuals accessed the center or other areas of interest. This enhanced situational awareness of the security personnel as well as the collaboration between different agencies, besides the ability to reconstruct violations should they be subject to analysis or investigations.

5.5 Detecting forest fires

Forest fires destroy every year millions of hectares of land, damaging natural resources and economies as well as putting people and properties at risk. In summer of 2007 alone more than 80 people lost their lives in Greece and forest fires destroyed over 2000 km2. The situation is not different elsewhere in the world.

Number of fires (thousands)	PT	ES	FR	IT	GR	CY	EU-Med
Average 1980-1989	6.8	9.5	4.9	11.6	1.3		34.0
Average 1990-1999	22.3	18.2	5.5	11.4	1.7		59.0
Average 2000-2005	28.6	21.6	4.3	7.7	1.8	0.3	64.3
Average 1980-2005	17.8	15.6	5.0	10.6	1.6		50.6
Total 1980-2005	462.0	406.0	130.0	276.0	41.0		1316.0

Burnt area (1000 ha)	PT	ES	FR	IT	GR	CY	EU-Med
Average 1980-1989	74.5	244.8	39.2	148.5	52.4		559.3
Average 1990-1999	102.2	161.3	22.7	108.9	44.1		439.2
Average 2000-2005	214.0	141.8	29.9	71.9	31.6	3.4	492.5
Average 1980-2005	117.3	188.9	30.7	115.6	44.4		497.7
Total 1980-2005	3050.7	4911.8	797.7	3005.1	1154.7		12940.6

Figure 5.6.Forest fire statistics for European Mediterranean countries, most affected by forest fires. (Source: Eurostat Forestry Statistics)

The U.S. Forest Service and the Los Angeles County Fire Department tested the ProxFire Detection System[32] that uses RFID temperature sensors to provide early-warning signals in the event of a fire: if the temperature reaches 170 degrees Fahrenheit (77 degrees Celsius), the sensor activates and uses its battery power to transmit a unique ID up to a 9843 foot (3000 meter) distant gateway. This gateway then adds its GPS position and time stamp to the signal and forwards it via mobile telecom networks or Wi-Fi to a server, which can then be accessed via the Internet at a central location, such as an operations center for forest-fire response and management. In the absence of a fire, the sensor remains dormant and functions as a passive RFID tag.

Since most wildfires are already out of control by the time fire fighters can detect them, this RFID-based system enables early and rapid response. Self-diagnostic tests of the system continuously ensure its correct function. Thus, fire fighters but also other institutions can access the data via the Internet and will get automatically alerted in the case of fire. Till now fire fighters are stationed at watch sites and looking through binoculars to monitor what is taking place in and around the coastal community. Due to the advantage of fast and reliable detection of fire, this application greatly reduces the potential for damage to the environment and property, loss of wildlife and its habitat, and loss of human life.

[32]http://www.firehouse.com/taxonomy/term/86/proxfire-detection-system-proves-successful-controlled-burn

Figure 5.7. California fires (Source: http://worldlywise.pbworks.com/w/page/26474623/)

A similar concept has been developed in Spain to coveran area of about 210 hectares in the North Spain region, comprising the Communities of Asturias and Galicia[33]. The aim was to provide to different organizations of an environmental monitoring infrastructure, with capability to have alert management and to deliver early warning alarms.

The solution has three components:

1. the Wireless Sensor Network
2. the Communications Network
3. the Reception Centre

Detection sensors are deployed in strategic locations and measure temperature, humidity, carbon monoxide and carbon dioxide and several other parameters every 5 minutes. Sensors are located at specific known places and can be powered by long-lasting batteries or solar power. Energy management capabilities ensure that the sensors can operate autonomously for a long time. Long-range wireless communication ensures that a sparse network of sensors can be used, limiting the installation costs.

Once certain parameters exceed predefined thresholds, the system alerts of a fire risk and the data can be used to construct a map of the likely fire outbreak and other areas at risk.

[33]http://www.elpais.com/articulo/portada/Libelium
/reyes/sensor/elpepisupcib/20100204elpcibpor_4/Tes

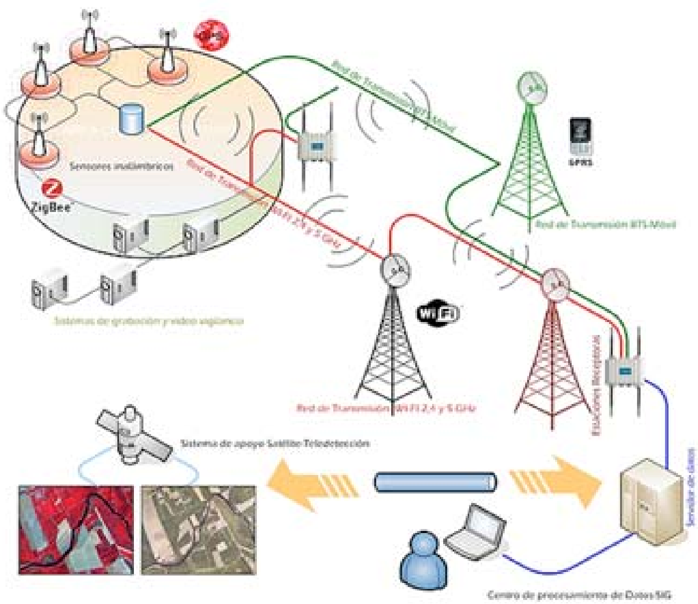

Figure 5.8. Example of forest fire detection system (Source: http://www.libelium.com/wireless_sensor_networks_to_detec_forest_fires/)

5.6 Planetary skin

While many examples of sensing applications are local or vertical in nature, institutions globally realize the need for global sensing capabilities.

Risk Skin is one of six areas of activity of the Planetary Skin Institute (PSI; http://www.planetaryskin.org) that harness ICT for managing scare resources and risks on a global level. It focuses on addressing the prevalence of frequent and increasingly high intensity weather extremes, which will lead to increasing frequency/intensity of natural disasters.

The plug-and-play nature of the platform will allow other players in the public, private, and NGO sectors, and in the research community, to contribute their expertise at different layers of the architecture. Planetary Skin takes a “system of systems” approach with common architectural components. This approach enables a combination of regional, national, and local “skins” focused on different capabilities and themes. For example, “Rainforest Skin” will focus on tropical rainforest deforestation, while “Urban Skin” will focus on enabling citywide aggregation of energy service companies, integrated renewable energy supply chain risk management, and seamless connection to—and integration with—carbon markets (Castilla-Rubio and Willis, 2009) .

The Institute is collaboration between partners from public sector (e.g. NASA) and private sectors (e.g. CISCO) as well as universities (e.g. University of Minnesota).

Figure 5.9. Planetary Skin user interface (Source: http://www.planetaryskin.org) applied to land-change detection.

6 Case studies: big data

6.1 Selected case studies

This chapter illustrates examples of uses of big data in relation to crisis management. While all examples of Social Media and IoT relate one way or another on forms of data mining, technology and models for big data applications for CM are still in development. The cases below are early examples of pure big data modeling exercises, in the sense that they exploit vast amounts of data generated for other purposes to detect emergencies or to inform CM organizations.

6.2 EpidemicIQ

Pandemics are one of the greatest threats to humanity. While the frequency and intensity of outbreaks appear to have diminished dramatically compared to the past, many unidentified pathogens are probably hiding out in the open. For some epidemics like HIV, SARS, and H1N1, the microbial triggers were anonymously in our midst for many years. With new infections, viruses and bacteria can mutate and evolve into more harmful strains. Because of the intrinsic dangerousness of some of these new sources of epidemics, and of their ability to mutate and defeat traditional responses, there is a great attention to the ability to identify and isolate new pathogens as quickly as possible, before they trigger large scale epidemics.

Researchers are studying the relationship between mobility patterns and diffusion of the epidemics (see for instance Brokmann, 2009) using proxies of mobility, such as the travel patterns of dollar bills. Similar analysis can be carried out with any other proxy of mobility, stemming from physical (e.g. aviation) or social media. Researchers have estimated for instance that the peaks of hospitalization for flu and related complications follow about two weeks after Google records a peak of searches for terms like "flu symptoms" or "flu complications".

Increasingly, the initial outbreaks are reported in local online media as sudden clusters of ‘influenza-like’ or ‘pneumonia-like’ cases, many months or even years before tests confirm a new microbial threat. The task of tracking global outbreaks and epidemics early on in the development phase has defeated virtually every organization so far because of the spread of information sources, multiple languages or formats of information. Early signals may be buried in blogs, emails, tweets, in different countries, in different languages and formats.

The project EpidemicIQ[34], the Global Viral Forecasting Initiative, is meant to detect and track outbreaks globally. Field surveys are carried in 23 countries with an initiative that leverages large-scale processing of outbreak reports across a myriad of formats, utilizing machine learning, natural language processing and micro tasking coupled with advanced epidemiological analysis.

[34]http://epidemiciq.com/

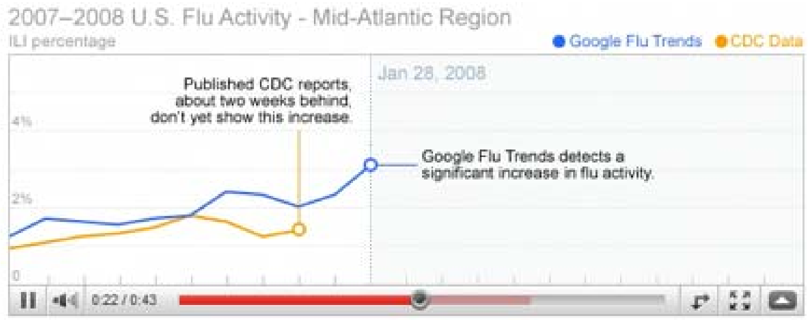

Figure 6.1. Flu trends detected by Google Flu Trends. (from Robert Munro, presentation at Strata Conference, 23/09/2011)

EpidemicIQ mines a variety of web sources: open web-based reports, social media, transportation networks and direct reports from healthcare providers globally. Machine-learning and natural language processing sifts through the data and detects epidemic-related information across orders of magnitude more data than any prior health efforts, across multiple languages.

Complemented by a workforce of micro askers, the system can adapt to new sources, languages and even diseases of unknown origin.

While the system is still in testing phase, the use of big data to mine early signals and weak signals offers the possibility to create some defenses from otherwise extremely scary prospects of uncontrollable global epidemics.

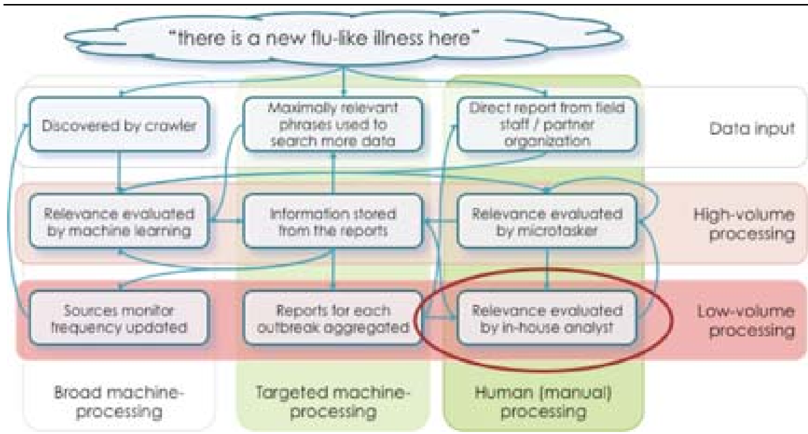

Figure 6.2. EpidemicIQ workflow (from Robert Munro, presentation at Strata Conference, 23/09/2011)

6.3 Crowd management and big events

Studies in crowd behavior, urban and mobility dynamics and urban space utilization usually rely on traditional data collection methods, such as surveys, phone calls, and pedestrian or vehicle counts. Some of these measurements can be automated, usually requiring significant upfront investments for instance to install road sensor networks. Other methods may be expensive or cumbersome to execute, thus limiting the frequency of updates that can be reasonably obtained. There are important areas of urban dynamics where surveys cannot reach or where automatic sensor infrastructures cannot be reasonably deployed based on cost-benefit analysis.

As a consequence, only a very small amount of data on people presence, flows or transportation volumes is available in near real time and at high spatial granularity. This hampers the decision-making ability of public and private organizations. Issues like planning for evacuations, verification of progress of a large-scale evacuation, flows taken by people and vehicles are hard and expensive to measure. It is not surprising therefore that in the past few years a number of innovative approaches have emerged to fill a clear gap and satisfy a growing demand for precise, timely and accurate spatial-temporal information, especially on urban dynamics (see Becker et al, 2011). These approaches seek to exploit new technology based on mobile devices and sensor networks as a way to collect spatio-temporal data on people and mobility in real-time.

The Currentcity project[35], a spin-off project of MIT and University Salzburg, focuses on modeling anonymous digital traces from telecom operators or social media to measure presence and flows of people in near real-time. The models developed have been tested in collaboration with CM actors (e.g. Police, traffic management authorities such as Rijkswaterstaat in the Netherlands).

The models derive estimates of presence (how many people are on average in a certain area during a certain time interval) and flows (how many people have moved from one area to another area in a certain time interval). Telecom traffic data (anonymized), as well as social media data (Foursquare check-ins, geolocated twitter posts, Flickr public pictures) can be used to model and to cross validate models across sources.

The figure below (Figure 6.3) illustrates the estimates of people presence for the Sail 2010 event in Amsterdam[36], for Saturday August 21, 2010. Over 1M people visited the event over three days. The diagram shows the count of visitors in an area of about 60,000m2 computed in near real-time between 10am and 10pm. The diagram shows that the maximum number of people measured in this are is about 60,000 people at about 3pm, with a resulting density of ± 1person for m2, well below the safety limit of 4 people per m2. The system provides these indications in near real-time, including a rate of increase-decrease which serves to assess if the people density is likely to be higher or smaller in the near future.

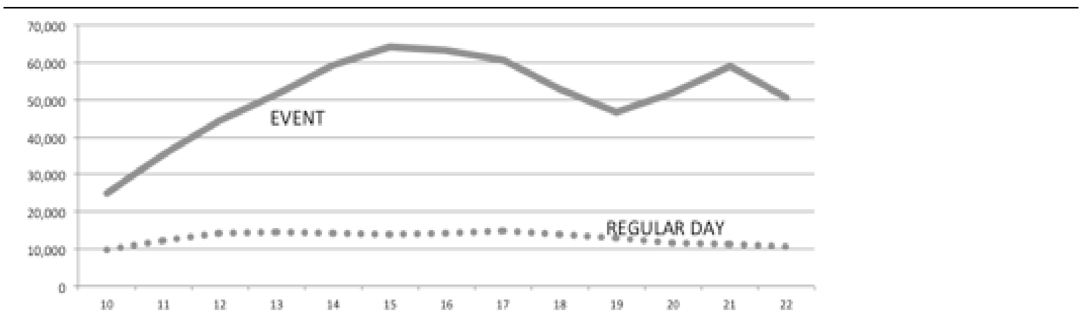

Figure 6.3. Estimates of people presence in a section of the Sail Area (Source: Currentcity Foundation).

The same methods and data can be used to estimate people flows, independent of their transport mode. Figure 6.4 shows flows estimates for a section of the area discussed above and for the same day. In this example flows are relative volumes of

[35] www.currentcity.org

[36]http://www.sail2010.nl/

people that - within a certain time interval (here fixed at 1 hour) - go from one location to another independent of the path taken. The paths shown in the figure, therefore, are not necessarily the route travelled but simply an indication of the start and end of the flow.

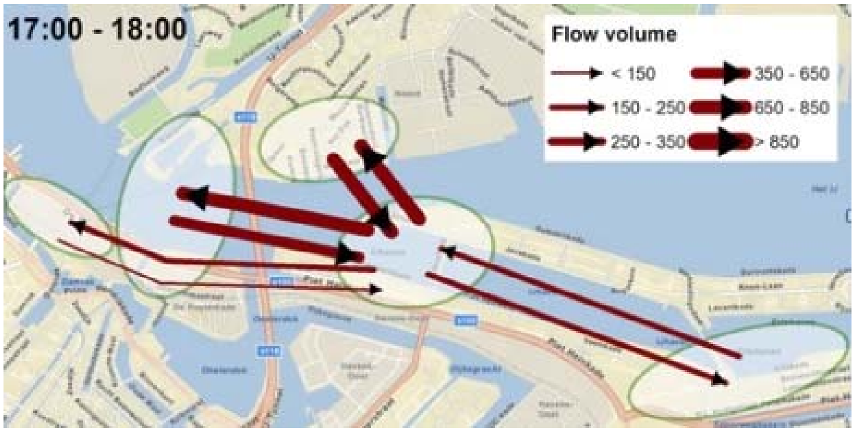

Figure 6.4. Estimate of people flows (Source: Currentcity Foundation)

6.4 Anomaly detection in urban environments

One of the biggest challenges of emergency management is the ability to detect events before they happen and/or understand the spatial implications of their unfolding. The most common methods rely on some form of predictive modeling or statistical assessment of normal situations[37]. The definition of anomaly is particularly attractive if statistical tests infer that a certain phenomena have a well-defined statistical distribution, for which normality (e.g. average value) can be estimated. Telecom data is a particular case that received significant attention (see for instance, Reads et al., 2007, 2009; see also Steenbruggen and Sitko, 2011). In the project Currentcity, the definition of anomaly depends on thresholds applied to telecom traffic levels. The thresholds separate random traffic fluctuations from actual anomalies once the traffic distribution is known. Statistical properties of telecom traffic (e.g. SMS, originated and terminated calls) are first determined to understand which statistical distribution better describes telecom traffic. Based on telecom traffic for one year, the project has defined the concept of normality for single telecom cells, for each hour of the day, for each day of the week.

Once anomalies are known it is usually necessary to disambiguate them and understand the relationship between a telecom traffic anomaly and an urban anomaly. A telecom traffic anomalymay well be detected but be the result of some an irrelevant physical phenomena (e.g. SMS voting for a popular TV program).

A recent study has looked at a series of urban anomalies in the city of Amsterdam and focused on the ability of telecom anomalies to identify incidents, fires, concerts, violence events, and urban gatherings. The system of anomaly detection is successful

[37] See, for instance, Urbanflood for applications to flooding in urban areas (http://urbanflood.eu/default.aspx)

in 74% of cases. In other words, just by looking at telecom traffic there is a 3/4 chance of detecting when and where something is taking place in the city, in real-time.

The success rate is 100% for big public events and for other human gathering, while it drops to about 50% for disruptions in the transportation networks and/or sudden small local events.

An interesting, but not yet fully explored, use of the concept of anomaly detection is the potential of anomalies to provide early warnings. Similar to the concept developed by Bollen (2011) for predicting Dow Jones variations from twitter moods, the concept of anomaly can be potentially used to anticipate large events. The figure below shows the telecom traffic and the anomaly status at the Schiphol Amsterdam airport before, during and after the Icelandic volcano explosion of 2010.

The telecom traffic started becoming very anomalous several hours before the closure, when there was no evidence of a possible airport shut down.We believe that people at the airport started communicating much more than usual in view of the closure of airports in the UK and thus assessing the likelihood of being affected, or simply reacting to the growing concern of air traffic being possibly affected. At some point the traffic dropped, around airport closure and remained negatively anomalous (=much less than normal) for the duration of the closure, with the exception of many areas in the airport during the night where people was likely stuck for the night. Once re-opened, the telecom traffic went back to normal after ±4 days, the time it took to the airport to restart operations.

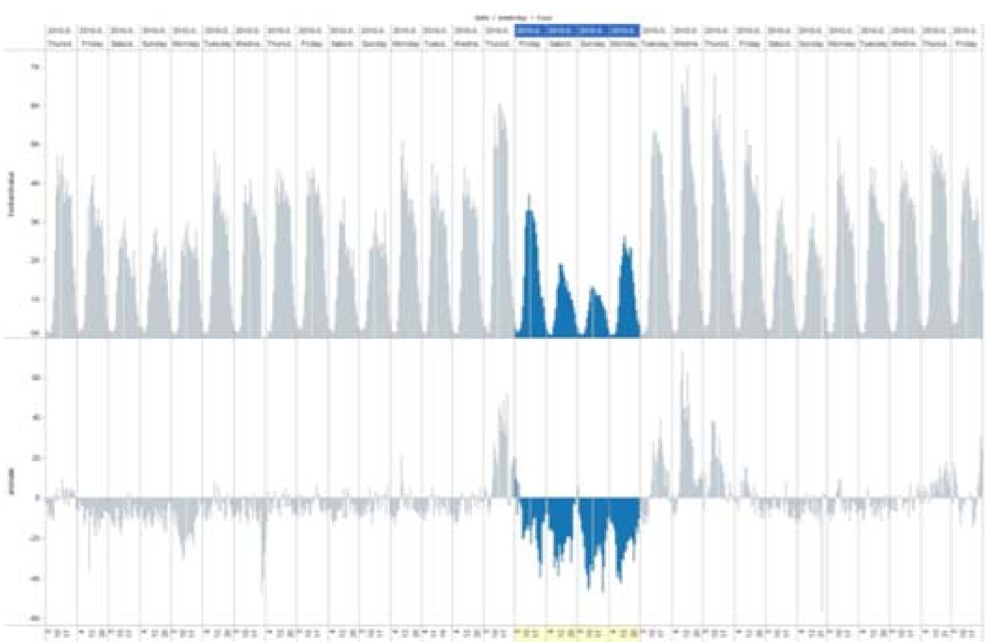

Figure 6.5. Index of human activity computer from telecom traffic (top) and anomaly status (bottom), before, during and after the closure of Amsterdam Schiphol airport caused by the Island volcano explosion in 2010. Source: Currentcity Foundation.

Similar behaviors have measured during the Lehman Brothers collapse: a series of telecom traffic anomalies affected the financial centers of the city, well ahead of the event when there wasn't any public information on the event taking place. Both examples seem to indicate that we can possibly crowd source weak signals of large events and detect them ahead of time by interpreting collective behaviors. While the foundation of this phenomena is far from clear and the reliability of estimates is to be proven, apparently there is wisdom in our collective behavior and the possibility of detecting important changes before they take place.

7 Understanding trends and implications

The case studies and examples illustrated above underline a series of trends that will likely unfold in the next years. They may represent opportunities for better CM, but also new sources of potential risks and vulnerabilities, which challenge CM practice and methods. In any case, they have implications that need to be addressed by CM actors. The table below summarized the major trends and their implications for CM.

7.1 Technology trends

Trend	Description	Implications
Wireless everywhere. Mobile devices will be the primary connection tool to the internet for most people in the world.	It is predicted there will be 6.9 billion mobile phone subscribers worldwide by 2020. The vast majority of people, of all ages, will carry one, and increasingly more mobile devices, all the time. Most devices will have internet connectivity and smart functions;they will be capable of running applications. Devices will appear in all forms and shapes, and increasingly be embedded in objects of daily use, such as clothes.	Everybody will have access to information, communication and data, all the time. Responders and authorities need to factor in the expectation that citizens will require precise, accurate, relevant, personalized, real-time information, location and context based information as part of incident response. Otherwise they will take autonomous decisions based on bottom up information sources, bypassing or interfering with CM.
Things affected by an emergency are connected. Vehicles, buildings, public spaces will be connected and be capable of "sensing"	A variety of trends align towards the instrumentation of the physical world. Industrial mandates for supply chain visibility, cold chain monitoring or eCall obligations to connect all cars/vehicles to the network represent good examples. The Chinese Government has launched a 5 years plan to foster the sensor industry with an initial investment of 5B Yuan (close to 1B USD)	Information on buildings, vehicles, structures, people, networks etc. will be available in near real time at a very fine granularity. While a lot of this will be closed and protected, CM organizations need to capture the potential availability and at least prepare to access critical sources of data when necessary. Most of this data will neither be collected nor orchestrated by CM.
Personal data and objectdata are commonly available. People and things will share large amounts of data on the internet,generally accessible.	Factual (e.g. location, demography, place of residence etc.) as well as behavioral data will be largely available from social media sites. Things will share features about themselves in closed environments but also increasingly in an open way, as part of the open data movement.	Situation awareness can be created based on digital resources, in a much better way that was the case in the past. However, the complexity of capturing the essential data from a flood of digital resources will defeat the capabilities of CM players. They need to start developing strategies to participate in social networks, understand

		their structures and potential.
Social network platforms dominate communication. Social media and application-based internet access will dominate the web.	Facebook, Twitter, Foursquare, Google+, Thumbler and similar platforms provide communication capabilities within an application context, rather than on the open internet. Whatever new service will appear aside the dominant ones in 2011, or perhaps replace them, it is likely that closed application environments will be the main communication platforms for internet users.	Access to information will in part be mediated by applications. Anticipating on methods to participate within communities or anticipating methods to open them up under specific circumstances will be a new task for CM and will in part define the level of preparedness.
Predictive capabilities will increase exponentially	The combination of big data, machine learning and analytic tools together with more access to open real-time data will give rise to a new generation of tools that can predict events with increasing advance notice.	Disaster management will need to shift resources and attention to interpreting early signals of events, and focus on preventive actions. This may require a re-allocation of resources, new competencies and a new set of tools. This will also increase the risk of false positives and create the need to manage expectations and warnings.
Telemedicine and Electronic Health Records will change patient care and treatment.	Telemedicine, or the use of medical information exchanged from one site to another via electronic communications to improve a patient's health, will complement traditional health care provision. Thanks to > electronic health records > personal sensing devices > remote, continuous connectivity between patients and service providers, Patients will enjoy a greater degree of freedom and activity without compromising health supervision, especially for the elderly and for chronic illnesses.	By providing responders with quick, easy access to medical information, these capabilities could also assist in treatment and tracking of patients during emergencies and in particular in setting priorities and addressing specific rather than generic needs..

7.2 Organization and governance trends

Increased expectation of transparency of Government and 24/7 access to information from and about government activities will increase. Open data will be the norm.	Technology will continue to alter the relationships and communications between individuals and their government. The public may become more involved in response and recovery efforts by helping authorities sift through large amounts of data provided by sensory devices.	People may seek guidance and assistance from their virtual communities rather than from the government. The role of government as primary source of information will change and decrease. Public authorities may retain a central role as long as they retain authority in terms of quality and reliability

	Continuous pressure to open up public data, combined with a growing number of examples of open data from virtuous governments, will result into a significant release of data to the public.	of information and in particular as authoritative sources of interpretation. CM organizations are expected to make use of the wider data availability and to prepare their structures to the utilization of an extremely wide data asset.
Data rich, information poor organizations will be the norm	The proliferation of data will be independent of the ability of organizations to take advantage of it and to identify useful data from noise. Vast amounts of data, largely irrelevant, possibly wrong or contaminated by, for instance system malfunctions, will be generated. Duplication of information and bottom-up data conflation will contribute to the data cacophony.	One of the riskiest prospects of an emergency situation is the incapacity of sifting through inconsistent or useless data, and the loss of direction caused by wrong inputs and sources. CM organizations need to start developing management strategies to cope with bad data, and to create filters and/or validation strategies to prevent data pollution to contaminate decision processes.
The distinction between information producers and consumers disappears.	Technological advances and public preference for and dependence on the internet may increase present expectations that responders will use the internet, social media and mobile phones in emergency response situations. Technology and preferences may also make the public less dependent on government as people turn to their virtual communities for information and assistance. Community-generated information to help citizens navigate their city is becoming an increasingly important replacement for traditional local information sources (e.g., community radio/TV stations and newspapers).	Crowd sourcing collects meaningful real-time data actively, supplementing data collected by government and allowing better decisions than would otherwise be made. CM organizations will need to introduce organizational forms that allow them to openly collaborate with citizens and with bottom up initiatives during crisis. Non-government organizations may gain an important or essential role in crisis, thanks to their ability to mobilize data collection.
Technological dependence will provide benefits while potentially increasing vulnerabilities. Terrorist threat will evolve.	The reliance on technology may make infrastructure more vulnerable to cyber attacks, natural disasters, electromagnetic pulse events or solar flares. These types of events can knock out the power grid and disable electric/electronic devices. As reliance on the internet and mobile devices continues to grow, terrorists may conduct denial-of-service attacks to disrupt or take down internet and cell phone network access.	The effect is dual. On the one hand, a new type of technology disasters needs to be managed, which threaten the basic functioning of our societies. On the other hand, the need to address the implications of large scale telecommunications and IT failures on the ability of managing disasters effectively.

Demographic shifts change the needs of emergency management and evacuations	Biotechnology could significantly increase life expectancy leading to a larger share of ageing population. Immigrants and minorities will represent a sizable percept of the population. The digital divide will remain across generations, and across social layers.	Some sections of the population will be less likely to use new, or emerging technologies. Emergency managers must continue to combine more traditional technology such as radio and television to reach out to citizens while capitalizing on the popularity of the new technologies to reach all citizens.
Government budgets will continue to be under pressure	Governments at all levels must consider budgeting for the growth, maintenance and protection of electronic infrastructure as well as traditional infrastructure (e.g. roads, bridges, dams, levees). At the same time, Governments will be under pressure to reduce investments and CM will compete against a growing number of demands.	A reallocation of spending within CM will be necessary to take advantage of new digital capabilities. A less likely scenario is the reallocation of spending across Government funding to increase CM funding. It is reasonable to anticipate that, instead of a pure public function, CM will need to evolve as a Public-Private-Citizen partnership to share responsibilities and limit costs of the CM organization.

8 Illustrations and simulations in hypothetical cases

8.1 Simulation cases

The following simulations illustrate the implications of a growing adoption of Internet of things, social media and big data. The table below guides, in part, the choice of cases studies, putting priority on the events that have occurred most frequently in the last years. For the simulations we have chosen:

- Fires and explosions
- Water floods and extreme events

To extend the simulation to events that have not yet occurred but are considered as possible by a growing number of experts, we have added the case of the diffusion of a virus.

Table 8.1 Frequency and intensity of incidents in the Netherlands

	Number of events	Casualties	Injured	Evacuated
Airplane crash	8	206	158	0
Train disaster	2	117	54	0
Traffic disaster	3	42	49	0
Ship disaster	1	11	0	0
Extreme weather	1	7	32	0
Water flood	3	1,836	unknown	350,000
Mine disaster	1	13	0	0
Fire	10	149	197	0
Explosion	7	81	1,127	0
Legionella	1	32	0	0
Total	**37**	**2,494**	**1,617**	**350,000**

8.2 Explosion and fires

8.2.1 Case description

In the Netherlands, companies that store more than 10,000 kg of hazardous substances are listed and located on the risk map. The hazardous materials may include poisonous, flammable or explosive substances. The danger occurs when a hazardous substance is released and, depending on the type of substance, the hazard can be related to direct contact with the substance or to the consequences of a fire or explosion.

The government sets rules for the quantity of a hazardous substance that a company may store and imposes minimum distances from homes, hospitals, schools, etc. In case of accidents authorities also suggest some very basic precautionary measures to the general population, such as:

- Do not go to the accident

- Call 1-1-2
- Stay at least 500 meters away from the accident area
- Walk across the wind away from the accident, and
- Follow instructions of emergency services (police, fire, ambulance).

In reality, people during large incidents behave in a far from rational way. Panic sets in and even basic common-sense suggestions like the above may be ignored.

In this hypothetical case study we assume a case of a toxic release caused by an explosion that also sets in a large fire at the incident site. Predominant winds disperse the substance to a vast surrounding area, which becomes subject to evacuation and other protection measures.

Safety and emergency response regards the site itself, to rescue workers and secure the site, as well as the general population and area affected by the incident and the toxic release.

8.2.2 The role of emerging media

The table below illustrates some of the issues faced by CM with the current management methods and information sources, together with the potential role of emerging technologies in support of CM.

Table 8.2 Issues for CM and potential contribution of emerging technologies

Issues for CM	Potential contribution of emerging technologies
Inside the plant	
The number of people on site at the time of the incident is usually only approximately known, depending on how watertight the access control procedures of the company are.	Intelligent badges replace the current access control cards. They provide physical access control (e.g. open-close gates) and virtual access control through real-time location of workers and virtual geo-fences. Real-time location and counting of workers across the facility is a standard feature of real-time location systems.
Mustering, the process of reporting to a specific location during an evacuation, is manual and imprecise. During emergencies workers may disregard mustering procedures and seek for safety independent of evacuation rules. Reconciling counts of people may take hours, making it difficult to know if workers need attention of otherwise.	Real-time identification and location systems provide continuous visibility of where anybody (and anything) is within a plant. People reporting to a mustering station are automatically counted, without requiring them anything different that they would otherwise do. A full and accurate count of who is inside and who has left the facility is always available.
The number of people that need to be rescued/helped is not known precisely in real time. It may take minutes or hours to assess who is missing, where they are and what type of help they need.	By comparing people that have mustered and/or left the facility with the facility counts, it is immediate to identify who's missing and where they have been seen last. Rescuers can proceed to the exact locations without wasting time or risking their lives in empty areas.
Actual concentrations of substances after the release may be hard to measure if the explosion damages sensors. Even when this is not the case, the concentrations to which rescuers are exposed are known to the individuals in the field that wear gas detectors, but not to the central command post.	Workers will increasingly become situation sensors as they carry digital equipment (location sensors, wearable gas detectors, cameras etc.). Each worker or rescuer on site will generate localized information that is aggregated at the central management post.
Directing rescuers to those that need help is hampered by the lack of precise location information on rescuers and injured workers.	Real-time location and identification, as well as other context information such as smoke or gas, allows rescuers to identify where they need to go to

Because of this rescuers may be exposed to unnecessary dangers and injured workers are helped much later than otherwise possible.	provide assistance as well as the situation they will likely find once there.
Sealing off of dangerous areas is based on physical measures or through on site instructions. Rapid situation changes cannot be addressed in real time (e.g. the need to seal off another area due to high temporary concentrations). This may expose local teams to unnecessary risks or, at the other end, implement too strict/loose precautionary measures.	Mobile sensors can be deployed across the facility and augment the sensing capabilities of workers wearable instrumentation. Zones that represent dangerous environments for rescue operations, that need to be sealed off for ongoing activities and or for changes on the ground situation may be virtually sealed off and managed as virtual fences, that can change at any time following the evolution of the operations.
Outside the plant / general population	
The number of people affected by the emergency is not known. Models that overlap diffusion plume and population estimates are at best an approximation of the number of people affected by the event.	Collective sensing solutions, based on telecom probes, utility probes or social media probes, can estimate in near-real time the number of people present in any area. The granularity is at present limited to perhaps areas of minimum 100x100 meters, but can cover large areas in real time.
Evacuation orders, which can be dispatched by a variety of means including Cell Broadcast (NL-Alert) lack any feedback mechanism: it is simply not known in real-time how many people have complied to the order and how many have not.	Real-time location of people provides the real-time feedback for large evacuation exercises. By measuring how many people are where now it is possible to assess the degree to which evacuation are unfolding and the degree of completeness.
The dynamics of people moving to and from the site is at best an approximation. Real-time people presence and their location are essential to manage evacuations and/or site sealing.	The same mechanisms that allow real-time people presence can be used to estimate the flows to and from the sites. By measuring the variation of these flows, e.g. every 15 minutes, CM actors can estimate the dynamics of people potentially affected by the incident and or the evacuation flows.
Local emergencies, such as people needing help, incidents or violence escalations are hard to detect and may fall under the radar of larger emergencies. It may be hard to allocate resources to where they are effectively needed.	Social media provide the mechanism to create fine-grained granularity visibility. Inputs from people close to a situation of need reports to social media the case and the location. Monitoring multiple media streams and geo-locating their content creates localized journals that can be used to monitor or respond to specific situations.
Official forms of information to citizens are slow and usually with insufficient precision to assess if, for instance, relatives or friends are safe or affected.	People will rely on bottom up sources to acquire information and assess their situation and of those that they hold dear. Public sources will be consulted to the extent to which they will provide additional value, and in many cases public sources will be accessed indirectly through social media diffusion.
Situation awareness gathered with usual mechanisms and existing technologies will rapidly appear as non-adequate in comparison to what citizens will have available and/or what firms and sites have created within their domains.	Big data analytics is increasingly used to support decisions and in part to create autonomous systems. Deriving consequences from facts (such as closing a road to traffic, remaining closed inside a building, avoid using cars etc.) can be automated and taken much faster by computers that sift through all information available in near real-time and apply tested models. Only this level of relevance and immediacy will provide the edge that separates unstructured bottom up information from controlled and verified top down sources.

8.3 Floods and extreme weather events

8.3.1 Case description

Min et al. (2011) and Pall et al. (2011)looked at the increase in the frequency of extreme rainfall events documented across much of the Northern Hemisphere between 1950 and 2000.There are variations from year to year and from place to place, but intense downpours have become more common over the period. The researchers suggest there is nothing that can explain this trend except the slow steady increase in temperatures caused by greenhouse gas emissions. While scientists have always believed that on a global scale, a warmer world should be a wetter one, this is the first formal identification of the link between emissions and intense rains. Combined with the expected increase in the likelihood of extreme weather events, this is likely to indicate an increased risk of flooding.

In the Netherlands flood risk management has been addressed since the 12th century as a conditions to safeguard lives and economic activities. The strength of the dikes is higher than ever before and the probability of flooding has been reduced. Nonetheless the risks of casualties and economic damage have become higher in the past decades due to increasing population and density of economic activities.

The three pillars of flood risk management considered for "Water Safety for the 21st Century" policy (WV21, See Rijkswaterstaat, 2008) are as follows (see Leuwsen, 2008):

- prevention
- limiting the consequences of a flood disaster
- increase the awareness within society of the possibility of flooding

Translated into the whole safety chain, they include:

- pro-action (protection vital infrastructure, etc.)
- prevention (heightening of the dikes, etc.)
- preparedness (early warning systems, etc.)
- response (alarming and warning systems, evacuation, etc.)
- after-care (insurance, restoration, psycho-social help, etc.)

CM, as intended in this document, focuses essentially on preparedness and response, although the information assets necessary to support these phases support also the other phases.

In this simulation we assume the combination of extreme rainfalls combined with an anomalous river discharges causing the flooding of areas in the southern part of the country (similar to the 1993 and 1995 events). In this example we look at CM as concerns information provision ahead of a possible evacuation and the evacuation management.

8.3.2 The role of emerging media

The table below illustrates some of the issues faced by CM with the current management methods and information sources, together with the potential role of emerging technologies in support of CM.

Table 8.3 Issues for CM and potential contribution of emerging technologies

Issues for CM	Potential contribution of emerging technologies
Authorities struggle to provide highly detailed, accurate and current information on the status of the rivers and dykes before, during and after the flood event. People tend to create alternative information channels that run parallel and independently from official channels.	Cooperation between CM and social media channels can provide a consolidated information source that includes CM sources as well as bottom up, localized sources of information.
Ability to predict water levels with large advance notice is hard. Ability to precisely identify when and where overflow or dyke breaches may occur with large advance notice is complex and addressed through scenarios.	At a general level, this will be improved by advances in prediction models, weather forecasts and sensors placed along the levies and dykes. High-resolution aerial photographs and thermal/spectral image recognition will support better assessments of the water protection lines. Furthermore, the possibility of easily installing mobile sensors across the areas, possibly with very high spatial granularity, will increase the predictability of the event.
Status of properties, local issues, issues with evacuation orders etc. are hard to know unless CM respondents are on the site.	Bottom up information collection provides a source of localized high granular information that can be consolidated and mined to assess where to best deploy resources to deal with what issues. Crowd sourced situation awareness complements official models.
Number of people potentially affected by flood is only known through census. Number of animals affected is also at best an approximation.	Collective sensing methods can provide accurate estimates of people presence in the area, in near real-time. This can support a better assessment of resources needed to support evacuation. Widespread tagging of animals, adopted for field-to-fork visibility, will provide a mechanism to count animals in near real-time and assess the needs of animal evacuation (size, type, feed, etc.)
Number of people evacuated and number of people that still need to be evacuated are known only approximately, and based only on ground surveys and observations. Progress of evacuation is hard to measure in real-time: not clear when evacuation is completed, where bottlenecks occur and how actual flows compare to predicted/mandated flows of people/vehicles.	Collective sensing methods provide feedback on people presence and flows, and can serve to measure progress of evacuation and feedback to Evacuation Coordinators. A real-time census of the area can be achieved. The same models that provide real-time census and flows information can be used to measure progress of evacuation, percentage complete and pockets of difficulties. Plan adaptation can be made as a result of the information available. Social media - such as Foursquare for CM - could provide a bottom up mechanism for positive confirmation of evacuation completed.
Flows of people within the area potentially affected are not known in detail: can interfere with evacuation measures and movement of equipment.	Flows of people/vehicles within the area affected, caused by self-organized initiatives (e.g. voluntary early evacuations), can be measured and quantified in near real-time.
Information on the state of the buildings, bridges, roads, homes, schools and other facilities is not known during the flood or the evacuation.	Instrumented facilities, as well as ad-hoc sensor connected facilities, provide status information. Once accessed by CM the information can be used to detect facilities that require immediate attention.
Cattle/animal evacuation is complicated by the lack of precise number of animals, real-time status of roads	Widespread tagging of animals for field-to-fork visibility will provide a mechanism to count animals

to and from the barns, and availability of feed supplies at collect points.	in near real-time. Progress of evacuation can be supported by detection of animals at the designated temporary areas.
People with special needs or elderly people may not receive a special treatment in case of evacuation because of lack of information to carry out separate or special planning.	Combination of personal information disclose together with location information allows respondents to plan and cater for special needs, as part of the overall response operation.
Damage assessment is carried out at the end of the emergency. Recovery planning follows emergency response completion.	Information on status of buildings, roads, utilities, structures etc. is collected in real-time and can be used to plan for recovery while the emergency is still unfolding. This will reduce the total time it will take to return to normality.

8.4 Diffuse, network events: virus

8.4.1 Case description

Like all influenza A viruses, H5N1 viruses continue to evolve. The Centers for Disease Control and Prevention (CDC) and other organizations, such as World Health Organization (WHO) or the Food and Agriculture (FAO), conduct routine surveillance to monitor influenza viruses for changes that may have implications for animal and public health. Changes in H5N1 viruses that WHO and CDC look for specifically are those that could increase the threat to human health. Over time, H5N1 viruses have evolved into different groups: since early 2008, 20 different clades (types of virus) of H5N1 viruses have been identified.

In this simulation, public health authorities suspect that a new form of virus, possibly a variant of H5N1 has developed and could potentially spread and affect people in various parts of the world. The exact nature of the virus, as well as its origin, is not yet known. The search for patient # one has not yet started, the extent of the virus diffusions are not yet known, neither the exact biological nature of the virus.

8.4.2 The role of emerging media

The table below illustrates some of the issues faced by CM with the current management methods and information sources, together with the potential benefits obtained by introducing emerging technologies in support of CM.

Table 8.4 Issues for CM and potential contribution of emerging technologies

Issues for CM	Potential contribution of emerging technologies
Signs collected in other areas around the world that could indicate an "early warning" are not available until after the epidemics has started. The assessment of the dangerousness of the epidemics is known after it has already reached a certain level of diffusions.	Signals and clues may be hidden in various forms of media, reports, blogs and social media. The detection of these signals, as well as their interpretation may provide a substantial time advantage.
Reconstructing the source of the virus requires a tedious investigation-like activity in support of biochemical analysis.	Access to a growing source of data on animal life-cycle, transportation networks and end-to-end supply chains offers a new opportunity for reconstructing how, for instance, animal and human interaction has taken place and how the virus initiated.

Identifying patient #1 may require the reconstruction of a vast social and activity networkthat may take months or even years to bear results.	Information stored in social media and the timeline of activities may represent a fast and accurate way of reconstructing the lives and habits of early victims, leading quickly to the origin of diffusion.
Alerting potentially infected people from known cases may require the reconstruction of activity and network of connections.	Social networks provide a natural connectivity source. Together with information on whereabouts of people and their work lives it can provide a map of potentially at-risk individuals.
Quarantine areas are defined based on very rough criteria, usually triggered by precautionary principles.	Identification of networks of infection and location and severity of cases can help identifying precisely single households or areas for quarantine, without the need of sealing off large areas.
Samples of substances for analysis may be lost or misrouted on their way to the analysis labs, delaying diagnosis.	End-to-end visibility of the supply chains reduces the chance of misrouting samples and reduces the time for returning diagnosis.
Doctors and nurses dealing with emergencies may not be aware of the risks they are facing, for lack of proper information	Information on patient potential exposure to the virus, thanks to network analysis, can be used to take the adequate precautions while dealing with otherwise unaffected patients.
Panic related to poor information, approximate cause-effect diagnosis or community scares may impact the ability of authorities to deal with the crisis as well as undermine their suggestions.	Ability to data mine large amounts of bottom up information can be used to detect bad information, counteract to its diffusion, balance its impact by offering facts, and reduce the chance of data and information pollution.

9 Discussion and Conclusions

9.1 Review of the work

Early applications and examples indicate that CM will be significantly impacted by the diffusion of social media, the internet of things and big data. The experience so far is primarily the result of spontaneous utilization of information tools that appeared as useful in a crisis situation. There is very little in the way of organized exploitation of emerging technologies from institutional CM organizations yet, something that can be explained with the different speed at which government organizations and new media develop. Nonetheless there is substantial evidence of changes that can be attributed to emerging technologies:

1. Vast amounts of real-time information are becoming available. The amounts and granularity of this information is unprecedented and can support CM in many different ways, from preparedness, to response and recovery.
2. Tools for self-organization and for information generation in case of a crisis are widely available. People increasingly rely on autonomous information sources for decision-making in a crisis.
3. Instrumentation of the real world continues at a growing speed and affects a variety of physical assets (houses, buildings, vehicles, animals) that are not traditionally the target of sensor networks.
4. Widespread real-time information on identity, location and status of assets and people will - at least in principle - be available during crisis and emergencies.
5. New forms of collaboration, that mimic open source communities, can rapidly create information sources and tools that are comparable or even more effective than traditional CM tools.
6. Data mining and modeling promises to increase advance notice and/or create far better situation awareness than present.
7. Access to digital information and communication during a crisis becomes essential: it is part of the lifeline of those affected and of those responding to the crisis.
8. The roles of information producer and information consumer disappear. Government and citizens are both information producers and information consumers.
9. Bottom-up data generation and crowd sourcing can integrate responders and help assessing local needs in a much more rapid and precise way.
10. The reliance on technology for CM will create a new type of emergencies, linked to technical meltdowns.

9.2 Discussion, challenges and implications

9.2.1 Data quantity and quality dilemmas

The large amount of data pumped into the information stream from the public, the media and government sources leads to questions regarding its accuracy and reliability.

Data generated bottom up by individuals are inherently subjective or subject to personal interpretation. At a minimum, it is necessary to validate and tag it (see the Ushaidi approach, for instance) to establish some form of data reliability.

There are already examples of the impact of bad information or intentionally misleading information. As an example, reports of violence in areas affected by the Haiti earthquake had at times the effect of delaying aid delivery to survivors. Aid workers later discovered that several reports were false[38]. New media can also be vulnerable to fraud or malevolent use. In 2010, a hacker accessed the Twitter account of the disaster management advisor to the Indonesian president and sent out fake tsunami warning messages[39]. This creates, on the one hand, unnecessary alarm, and on the other hand undermines the credibility of the information channel.

Besides cases of misleading or wrong information, social media generates also rumors, partial, poor or biased data, which can be replicated and magnified within social networks. Combatting misleading or simply bad information will be a specific task of the CM authorities, to prevent that a strategic information asset will turn into a source of unmanageable noise. This will require that CM authorities develop a specific social media strategy to ensure that CM will be at least capable of understanding, decoding and assessing the information produced bottom-up.

The issue of data and information quality (IQ) applies also to the Internet of Things. The diffusion of "consumer grade" sensor data (frequently of lower quality compared to those used in traditional environmental monitoring networks), for instance, will provide a great additional source of data but of unknown quality in many circumstances. Also, the availability of sensor data at a particular point in space and time cannot be guaranteed, since many sensor networks are designed for purposes different than CM.

For both social media and IoT data, CM organizations will need to develop ways to assess data quality before it feeds the decision making process. At this point in time there is very little evidence and experience that can be used to guide CM in this task.

9.2.2 Privacy and security of data

Privacy rules limit the collection and sharing of real-time data from consumers, the access to commercial datasets, the sharing data among government agencies and so on. They are designed for regular situations and are essential for the adoption of emerging technologies and for trust in digital transactions. They are also an impediment in effective use of information during crisis. The same holds for company data security policies, which in regular situations ensure that information assets of organizations are protected but in emergency situations may decrease effectiveness of rescue operations.

For instance, firms will increasingly adopt automatic location and identification systems for assets or workers. This can be because of safety regulations or because best practice in the industry will put pressure on laggards to level to the safety technologies adopted by industry leaders. Emergency teams, especially those that support site teams (e.g. fire fighting team of chemical plants or deposits) and are not familiar with the site situation, will need to have full access to digital safety systems usually secured under company firewalls. Accessing this information will reduce

[38] http://www.usip.org/publications/crowdsourcing-crisis-information-in-disaster-affected-haiti.

[39] http://www.wired.co.uk/news/archive/2010-11/26/indonesia-tweet-tsunami.

unnecessary risks to the rescue teams and increase chance of rescuing people in need in time. Nonetheless, systems will be designed for being closed and protected, not open and accessible.

This will be the case for industrial sites, commercial estates, buildings, infrastructures and private properties. They will hold vast amounts of information critically important for CM, but not automatically accessible for CM.

CM organizations will need to establish ahead of the need arrangements for accessing proprietary or closed information for support during emergencies. The institutional arrangement may be complex, and include contractual provisions, technical arrangements, liability and confidentiality clauses, many of them not yet designed or even conceived at any level needed close to practical needs.

9.2.3 Transparency and the role of Government

With constant access to information, citizens will expect that government will be able to provide open and ongoing access to information as well as use the same tools that society increasingly uses for information access and sharing.

Data openness will be part of government accountability and emerging technologies will continue to transform the communications environment. Crowd sourcing of information and bottom-up validation could lead people to relying more on themselves and their virtual communities and less on government. Many people seek affirmation of information from multiple sources independent of the fact that the information is provided by Government or other organization. Virtual communities will exert a growing influence on the acceptability and credibility of government information and challenge it based on alternative sources. Virtual communities will possibly act as Government controllers and information validation mechanisms.

CM authorities should be equipped to understand this phenomenon and develop strategies to leverage transparency and collaborate with virtual communities as a standard component of CM.

9.2.4 Risk-aversion in times of rapid changes

City governments and government agencies are frequently risk-averse organizations when it comes to emerging technologies. They tend to rely on proven, even if surpassed, technologies, frequently assisted in bad decisions by companies that benefit from the status quo.

Experimentation with emerging technologies, when done at all, is subject to the roles ad times of government decision making, rather than those of innovation. Concepts like "beta testing" or "fail fast, forward", common in the IT world are virtually absent in CM and in government.

They would need to be introduced to experiment and gradually adopt technologies that change much faster than traditional government can deal with. The impact on governance will be much greater than many CM organizations anticipate.

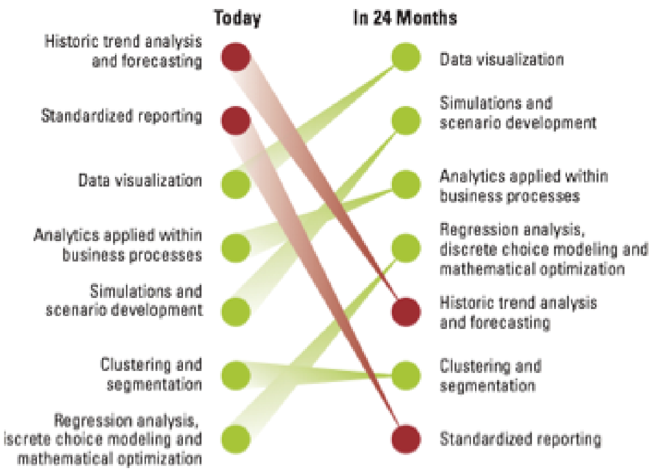

Figure 9.1. Techniques creating value for organizations for data analytics: changes in priorities in 24 months (Source: MIT-IBM). Respondents were asked to identify the top three analytic techniques creating value for the organization now (2011) and 24 months from now.

9.2.5 Technology as a strategic asset

Many organizations believe that technology is only an operational asset. They do not place a high priority on CM information technology and lack relevant policies for instance to manage open data or to ensure that it is useful and used, not only available.

Policies for dealing with information assets, information access, federation of information sources, linking to social media platforms, or presence in social media forums should be part of the strategic vision of an organization.

Frequently, this is addressed in a superficial manner. It not uncommon that, for instance, organizations simply display twitter messages on a map and expect that this will produce better information. Without filtering, modeling, de-duplication, and bulk analysis this will hardly produce any benefit.

9.2.6 Human resources challenges, awareness limitations

CM organizations or local governments lack leadership and staff with the combination of design, planning and technology expertise needed for true innovation and successful utilization of emerging technologies. The lack of competencies such as social media analysis, big data experts, social media brokers, data journalists and similar will affect the ability of government and local authorities to leverage emerging technologies for CM.

At the management level, a lack of awareness of the true potential and challenges of emerging technologies could significantly delay the experimentation and adoption of these technologies.

9.2.7 Technology-initiated side emergencies

Real-time estimates of people presence, check-ins and/or evacuation-completed status may lead to the disclosure of information that can be used for theft, vandalism or other crimes. Securing this information will be essential to reduce the chance of side emergencies emerging along the main one. Misleading information designated to distort response efforts can be used to create the conditions for criminal activities that combine physical and digital crime.

This balance between openness and protection needs to be explored and articulated, and the side effects of disclosing critical information need to be included in scenario analysis of CM.

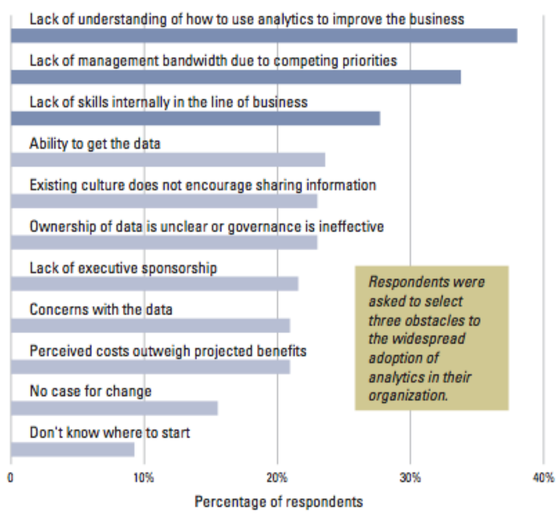

Figure 9.2. Adoption barriers for data analytics (Source: MIT-IBM). Factors that prevent the widespread adoption of analytics in organizations.

9.2.8 Technology meltdowns

In 2009, to keep communication with Iran protesters, the US Department of State asked Twitter to delay a scheduled maintenance which could have affected communication between protesters and to the outside world[40].

With the growing reliance on mobile communication, social media sites, network-based cloud computing and diffuse networks of sensors the chance of major effects of a technology unavailability or meltdowns during a crisis will increase. The pressure on these networks will be much higher than normal and it is unclear to which extent they will be able to withstand a crisis situation. Should a technology meltdown take place, CM will be in a situation of dual emergency. On the one hand, it has lost a vast array of tools on which the response is predicated. On the other hand, people used to instant communication and pervasive connectivity will be unable to cope to information black out situations, possibly generating erratic behaviors or panic.

Technology resilience assessments will be necessary as part of preparedness policies. They will need to identify which systems could be affected in which case and assess the range of system reliability and the impacts of system unavailability.

[40]http://www.cbsnews.com/8301-503544_162-5092668-503544.html

9.2.9 Bottom up development of CM tools

Crisis management has proven a test-bed for new ways of collaboration in technology development. Besides Ushaidi[41], tools like Crisis Mappers[42]and CrisisCommons[43]are good example of open source, crowd sourcing, volunteer organizations and NGOs meeting with the international community to develop CM tools.

CM organizations should increasingly become structural parts of part of these movements; contribute resources to their development and/or finance part of their activities.

Crisis Mappers leverage participatory maps, crowd sourced data, geospatial platforms, visual analytics, and computational models for early warning and rapid response. The International Network of Crisis Mappers is the largest international community of experts, practitioners, policymakers, technologists, researchers, journalists, hackers and skilled volunteers engaged at the intersection between humanitarian crises, technology and crisis mapping. Launched in 2009, the Crisis Mappers site accessed from 191 different countries. The Network catalyzes communication and collaboration between and among crisis mappers with the purpose of advancing the study and application of crisis mapping worldwide[44].

CrisisCommons seeks to advance and support the use of open data, volunteer technology communities to catalyze innovation in crisis management. CrisisCamp began in 2009 as a barcamp event to connect crisis management and development practitioners. CrisisCommons has coordinated crisis event responses such at the Haiti, Chile and Japan Earthquakes and the floods in Thailand, Nashville and Pakistan. Over 3,000 people have participated worldwide in over 30 cities across 10 countries[45].

9.2.10 Command and control and digital escalation

The command and control structures will be put to extreme test by the availability of massive amounts of real-time information that can affect coordination. This information will provide a far better basis to create situation awareness, but the flood of data will defeat the ability of any human being to make sense of it. Automation of decision-making and delegation of coordination to machines will be a necessity, especially for non-critical, routine tasks.

Commanders and managers will gradually develop a role of supervisors/auditors of decisions made by machines. While they will remain the ultimate escalation and decision authorities, part of their operational role will need to be delegated to digital command and control, with all ethical and legal implications. The cultural implications of these shifts are widespread.

9.3 Reccomendations

9.3.1 Experimenting with Information Quality

Information quality (IQ) can be seen as an important constrain for improving CM. The concept of ‘quality’ is often defined in terms of ‘*fitness for use*’ (Juran *et al.*, 1974),

[41]http://ushahidi.com/
[42]http://crisismappers.net/
[43]http://crisiscommons.org
[44]From: http://crisismappers.net/)
[45] From http://crisiscommons.org

'*fitness for intended use'* (Juran and Godfry, 1999) or '*fitness for purpose*' which has been a widely used approach by quality agencies, usually based on the ability of an institution to fulfill its mission (Harvey and Green, 1993).

IQ is difficult to observe, capture or measure (Singh *et al.*, 2007). Literature paid a lot of attention to attributes of IQ that are important for end users (Miller, 1996, Evans and Lindsay, 2005). Data quality is established during the information manufacturing cycle, which evolves through a sequence of stages: data collection, organization, presentation and application (Strong *et al.*, 1997).

There is a wealth of literature on information system success in profit-oriented business environments and research regarding information quality dimensions. However, literature in the public sector on emergency services regarding information quality and sharing across different agencies, and the quality of information sharing, is scarce and empirical support is almost nonexistent.

This is even more the case for information sources such as social media, which have developed extremely rapidly in a very short amount of time and for which there is a clear need for providing systematic data/information assessments for CM.

Several CM organizations have started experimenting with social media as part of developing policies and methods in anticipation of use in operations. In many cases this has involved simple uses, such as filtering and mapping twitter messages, but fall short of clear and structural assessments of the information content and quality of the channel

There is a need to qualify social media information streams for emergency, incident or disaster management to make sure that we can build upon them and derive models to extract useful information from the vast flow of data which also contains useless, skewed, biased, misleading or simply wrong data.

Sources of data such as twitter, Panoramio, foursquare or flickr need to be qualified and assessed to understand the typical information content and its semantics but also the profile of each of these sources in terms of their intrinsic attributes (e.g.: What is the tweet feed for a certain area? What is the regular volume? Is it compatible with the needs of CM? What does it contain? Which section of population uses it? What is its spatial distribution? To what extent does it reflect other information sources? etc.).

Following methods such as those developed by Bollen and Mao (2011), it is possible to validate information contents and information classifications of e.g. Twitter messages, by constructing models which include automatic semantic analysis of the data feed and manual human validation for selected samples. Similar classifications and validations can be carried out for any other social media feeds.

Experimenting with data quality and data relevance for CM should logically precede the operational adoption of Social Media in CM. The essence of these experiments and studies is to understand in detail what information we can count on, what are its features, volume, reliability, noise etc. providing realistic expectations to the future use of social media for disaster management.

9.3.2 Experimenting with Big Data

In spite of the increasing awareness of Big Data, and of the supporting technology and policy movements (such as Open Data) there is a pressing need to experiment with the factual implications of Big Data and with its implications for decision making for all phases of CM. This experimentation should account for a few aspects:

- There is an increasing **amount of data** which is collected and never exploited, which potentially contains important evidence in support of CM. Datasets collected by, for instance, telecoms, utilities, municipalities, in addition to the social media feeds, are still largely untapped. This holds in general, across industries and government, and in specific for their implications for CM for preparedness and for supporting decision making during crisis.
- Experience in **correlating** evidence from multiple, large-scale datasets is at an even more embryonic stage. The complexity here is arguably higher, given the additional implications of data ownership, privacy and confidentiality of datasets, lack of policies for exchanging data etc. However, behind these tactical and practical problems there is a general lack of understanding of the potential and a gross underestimation of the benefits of assessing this potential ahead of need.
- Managing Big Data has implications for the **data policies** of organizations. There are many examples of organizations that archive or simply remove vast amounts of data because they find it hard to cope with huge data sizes and because they do not have any specific utilization beyond the initial core use of the data. Valuable resources are therefore ignored or wasted for lack of knowledge or polices. Given the increasing availability of tools and the low data storage costs, the business or practical rationale for wasting so much potential value is rapidly vanishing, and will eventually become an organization liability.
- In the current setup, the information available to **decision makers** in CM situations is, in terms of type, amounts or availability, known in advance. CM organizations have a good understanding of what they can count on and what it can be used for, especially when data sources are numbered, well known, stable over time and part of the shared understanding of CM information assets. Faced with information such as "real-time presence of people in a certain area", or "expected flows of people in the next 10 minutes" or "crowdsourcing of incident impacts" it is unclear if and how they could benefit and adapt policies, decision making structures and practices or resource allocations to leverage this information.

Given these premises, it seems pertinent to stimulate explorations of the impacts of big data in a systematic way, in terms of tools, organization arrangements, information assessment and decision processes. This exploration should also be intended to assess the skills and competences of CM organizations, as they extend to areas such as information design, data analytics, information management and the like, frequently missing as core competencies of CM.

9.3.3 Facilitating thought leadership

It is reasonable to expect that industry and government will increasingly leverage automatic identification and sensing technologies, social media and big data, and that this adoption will accelerate in the next 3-5 years.

These technologies have a transformational power and call for re-thinking the way we manage people and assets, implement safety and structure governance. They impact accountability, affect work organizations and possibly the form of leadership. In spite of their clear potential, it is far from easy to map the full scope of impacts and to imagine the medium to long-term implications, as they articulate in a variety of areas, such as safety, technology, privacy, management, or law. Several organizations therefore prefer to focus on immediate utilization but in doing so they and fail to capture the deeper impacts and the long-term effects, and do not prepare adequately for them.

Aside from experimentation, it is important for CM and government organizations to develop instruments for understanding the role of emerging technologies from multiple perspectives and articulate meaningful mid- to long-term scenarios. The key difficulty is to balance the discussion about immediate possibilities with mid-term transformations based on the conceptual understanding of the Internet of Things, Social Media and big data.

Several instruments can be conceived from this purpose, from forums, to advisory boards, to dedicated studies, blogs and many more. Some common features need to be stressed, however, and include:

- A focus on the medium-to long term, to create forums for strategic thinking;
- A focus on concepts (such as user-generated content, large scale-human presence feeds) rather than instruments, which are subject to a more rapid change;
- To engage multiple perspectives and disciplines, to facilitate the elaboration of comprehensive views of change rather than sectorial perspectives;
- A continuity of engagement, to reflect the need to adapt and reflect changes in particular for an evolving landscape of technologies, concepts, players.

A thought leadership platform in this area could support CM and the institutions behind CM in exploring, framing, understanding and communicating these developments as a contribution to organizational and policy choices. It would need to engage "experts with vision" as well as organizations sensitive to technology innovation. It would need to explore this area from multiple perspectives to understand the intersection between CM and emerging technologies and articulate meaningful mid- to long-term scenarios. It would also need to balance the discussion about immediate possibilities with mid-term transformations based on the conceptual understanding of emerging Internet could alter management, operations and labor relations.

Such platform could be an opportunity to capture what are believed to be priority areas for policy and analysis, to identify the stakeholders that need to be part of this debate as well to understand views on trends and challenges that underpin the evolution of the Internet of Things, Social Media and Big Data for CM.

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