BuildERS

D2.4 CATALOGUE OF TOOLS, TECHNOLOGIES AND MEDIA OPPORTUNITIES FOR DISASTER MANAGEMENT

Project acronym: BuildERS

Project title: Building European Communities' Resilience and Social Capital

Call: H2020-SU-SEC-2018-2019-2020/H2020-SU-SEC-2018

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Executive Summary

This report is focused to capture the results achieved in the BuildERS project Task 2.5. Catalogue of tools and technologies for disaster management. The objective has been to survey of technologies and tools for preparedness and disaster management, and to survey of essential opportunities arising from recent technological advances in tracking the location of people, use of drones, use of social media, artificial intelligence and machine learning, communications over 5G, interaction with IoT assets and sensors.

The analysis of technologies and tools (T&T) covered 118 tools, developed within ~52 European research collaboration projects, potentially applicable for disaster management. Essential gaps were found especially related to the level of use, because only 27 of the tools were estimated to be in real use in disaster management. Therefore, it is recommended to investigate into transferring and further developing especially the TRL-7 level tools towards real use. The tools helping application of satellite images have good potential to trigger real advances in natural disasters. The tools supporting use of location information, drones, more real-time communications over 5G, and interaction with IoT assets and sensors, are estimated to trigger real opportunities in advancing immediate responses in disasters. For example, location information is essential in Covid19 virus pandemic tools, which are needed to find the people that have had possibility to get the infection from the infected people. Use of positioning with identities looks important in following epidemic chains, however, there is serious trust and privacy related challenges due to risk for illegal use.

The opportunities arising from recent technological advances in positioning, use of social media, satellite imaging, internet of things, use of drones, 5G, AI and blockchain technologies are here discussed. The role of smart phones in capturing locations, enabling use of social media and crowdsourcing, public safety warnings and emergency communications seem very essential, however, the challenge is that these require smart actions from people. The IoT solutions can enable more rich information via use of different kinds of sensors enabling totally new level of situation awareness. In addition, controlling of CPS devices (e.g. drones and robots) can enable more rich information details obtained from the disaster areas. Trustworthy information sharing via heterogeneous communication channels in uniform way, use of social media and advanced AI means could open possibilities for improving the situation awareness among authorities, NGOs, communities and even ordinary people in disasters. The positioning, use of social media, satellite imaging, internet of things, use of drones, 5G, AI and blockchain technologies have good potential to improve disaster management in future. The cost of using satellite pictures may hamper the application of them in disaster management.

The digital divide between people related to unequal distribution of skills, access to technological means and tools cause challenges especially with vulnerable people in crisis. Finding vulnerable people in disaster area is very challenging issue if the vulnerable people do not have e.g. smartphone or any other IoT device as well as some preceding actions related installation, configuration and skills to use the referred assets and applications. The use of location aware services became easier with these required capabilities, however, then the trust, security, privacy and ethical issues cause challenges. Thus fairness and inclusivity need great attention in the application of these technologies in crises or disasters in order not to oversee the vulnerable population groups. It is very essential that these issues are considered and included in the monitoring radar of the emergency planners and responders. Furthermore, the fragility of critical electricity and communication infrastructures may cause risks for operation of the technologies and tools and thus also for vulnerable people in hazards situations. However, the potential of the discussed technical opportunities for improving operation in different disaster life-cycle phases is so essential that significant investment on research and development actions is recommended, however, consideration of trust, security, privacy and ethics related challenges is important. There are also essential ethical arguments against surveillance because human rights to privacy are very important in democracies.

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List of Acronyms

AB	Advisory Board
BuildERS	Building European Communities Resilience and Social Capital project
D	Deliverable
DoA	Description of Action
ICT	Information and communication technologies
NGO	Non-Govermental organization
TRL	Technology readiness level
T&T	Technologies and tools
VTT	VTT Technical Research Centre of Finland
WP	Work Package

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1. Introduction

1.1. Content and structure of D2.4

The overall focus of the BuildERS project is to help improve government policies aimed at enhancing the disaster resilience of European populations, with a focus on disadvantaged groups and the effects of false information. This report contributes mainly towards reaching the BuildERS project's Objective 3 Analyse and provide foresight on how new technologies and media will develop and what could be their role in improving disaster resilience of societies.

This report presents the results of Task 2.5 in WP 2 (Comparative assessment of institutional aspects of resilience management). The work in WP2 aims among others to:

• assess the institutional functioning (organisations, processes, resources, tools/assets, guidelines) for resilience management in sample countries and clarify the determinants of effective disaster-resilient systems. In this objective, Task 2.5 contribution is related to aspects of technological tools for resilience management and disaster-resilient systems.

• Catalogue the most relevant current tools, technologies, and media and communication channels for preparedness and disaster management. Task 2.5 contributes especially towards realizing this objective.

• Describe the practices of government social media campaigns and how they are received and spread by audience and provide good practices and recommendations on effective responses in cases where disinformation interferes with official messages. In this objective, Task 2.5 contribution is related to analysis of emerging opportunities from advances in the use of social media tools.

All the results of this WP will be utilised in the co-creation activities in WP 6 "Co-design and co-development with stakeholders" where cross-fertilisation of concepts will be done taking into consideration all the experiences and new opportunities. WP2 also feeds into WP 5 "Recommendations to improve resilience and risk awareness" where recommendations for organisational innovation for disaster resilience, including operationalisation of volunteer communities, technologies, and communication channels for preparedness and disaster management will be elaborated.

The Task 2.5. Catalogue of tools and technologies for disaster management is defined as follows:

"Lead: VTT; contributions: UTA, POS, GEO

Technologies and tools are and will be available to support preparedness and disaster management. This task will produce a survey of most important opportunities, such as the creation and use of location-based information, use of drones, automatic analysis of texts and images using machine learning and artificial intelligence, communication platforms and services as well as 5G, and IoT / sensor technologies. The focus will be on supporting tasks like communication, decision making, location-based predictions and alerting (storms, floods, avalanches).

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European H2020 and preceding Framework Projects are here an important source of information. These projects have extensively listed, reviewed, developed and tested different technologies. The catalogue includes indexing of tools and technologies based on their maturity (TRL level), and the level of use (if deployed in practice). In Task 6.3, the tools' potential of usability and applicability will be evaluated by end users."

This deliverable report is organised as it follows: chapter 2 provides a view to technological landscape for crisis/disaster management to help readers to understand the surveys of tools and technologies and -emerging opportunities arising from recent technological advances. In chapter 3, a survey of tools and technologies including analysis of past projects, indexing of resulting tools, considering their maturity (TRL level), and the level of use (if deployed in practice). Chapter 4 consist of survey on most important emerging opportunities. Finally, Chapter 5 represent the conclusions from this work.

1.2. Discussion on the objectives, scope and terms

The task description speak about "The catalogue includes indexing of tools and technologies based on their maturity (TRL level), and the level of use (if deployed in practice)." Making such a catalogue of tools and technologies requires survey of available technologies and tools for preparedness and disaster management, which have been created e.g. in European H2020 and preceding Framework Projects. The challenge in this kind of action is definition of the scope, because there are huge amount of tools and technologies available for disaster management. The selected strategy is iterative starting from the EU projects mentioned in the Builders description of the action and proceeding towards tools supporting the most important opportunities mentioned in the task description[1]. In addition, when a big number of heterogeneous tools are analysed, it is important to consider some common classification and categorization for enabling proper estimation of the maturity of tools that have been developed for some specific purpose, for some specific stakeholder, for some specific user group, and for some specific phase of disaster life cycle.

The task description speaks about "produce a survey of most important opportunities, such as the creation and use of location-based information, use of drones, automatic analysis of texts and images using machine learning and artificial intelligence, communication platforms and services as well as 5G, and IoT / sensor technologies. The focus will be on supporting tasks like communication, decision making, location-based predictions and alerting (storms, floods, avalanches)". The challenge in this kind of action is arising from the very wide technological scope included in the referred terms and large amount of aspects included when discussing about opportunities. Therefore, our decision has been to add a specific chapter for this report discussing on the technological landscape for disaster management to provide a bit more background information for readers to understand the rest of the

[1] When making the actions for this tasks, during the survey process, there were several difficulties to obtain the data from the tools due to the availability of the information, limited access and language barriers. Some of the websites were not any more active and therefore it was challenging to find the required information on the capabilities and maturity of the tools. Some of the tools were not publicly available to be tested and explored, and the applied language in documents slowed the study. In addition, the available time for analyzing details of the tools was limited, and therefore the survey had to be limited to very basic capabilities only, level of use and estimation of maturity level.

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deliverable. In addition, special attention is refined to opportunities arising from the location-based services, use of social media, satellite imaging, and internet of things (IoT).

The term emerging opportunity has been a bit challenging during this work, because there are multiple viewpoints included. First of all, there are technologies that may or may not enable something new, we call them here as technical enablers. For example, capability to detect position, location of person or physical device is such a technical enabler. Then the question is what they can enable? In this task we speak about enabling some function or service supporting disaster management. For example location based service can support disaster management when finding vulnerable people in the disaster area. The term opportunity refers to importance of the related possibility for someone in future, because otherwise it cannot be defined to be an opportunity. In this task, we came into conclusion that therefore the potential importance of the technical enablers for the involved stakeholders and the applicability of the technical enablers for different phases of disaster management is inherently considered in the task description. The selected strategy is relying on the contributions of the project partners for estimation of the importance and applicability of the emerging technologies in different phases of disaster life cycle.

1.3. Method of the task

The applied method for the task has been iterative: we focused first on a rapid analysis of the technologies and tools related to results from EU projects listed in the BuildERS Description of Action. Based on the quick pilot analysis, a possible way for classification and categorization was developed. After this phase, the categorization was evaluated by taking into account more EU projects. This categorization was adjusted into the final form according to the following categories: Technologies and Tools (T&T) type, Purpose, Owner, Potential users, Level of use, TRL level and Crisis/disaster lifecycle. Then, the list of the EU projects was divided between partners to analyse according to the categorization. Simultaneously, the key disaster management stakeholders of the BuildERS project described their most essential needs, requirements and gap areas related to the technological areas mentioned in the task 2.5 description. After this phase, selected emerging opportunities were described in a preliminary way: location-based services, use of social media, satellite imaging, internet of things (IoT), use of drones/robots, 5G, artificial intelligence and machine learning, and blockchain technology. The subsequent phase consisted in using keywords from these opportunities for a new project search from Cordis database. The most relevant projects focused on the areas of specific opportunities were analysed and the tools were updated into the catalogue with the categorization. The finalization phase of the report has been very demanding due to the huge amount data about the T&T potentially applicable for disaster management. In addition, the emergence of the COVID-19 pandemic has highlighted the importance of tools for such disaster management especially from the point of view of ordinary citizen and citizen with limited social capabilities. Therefore, some attention has also been given to the status of the potentially applicable tools for this kind of crisis.

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2. Technological landscape for disaster management

2.1. A technological landscape

The technological landscape of crisis/disaster management system is visualized in the Figure 1. [1]. The system can be divided to two parts: disaster management related organizations and their capabilities (yellow rounding rectangle), and capabilities of technological ecosystems (dashed red rounded rectangle). People are usually connected into these technologically enabled systems via various physical asset devices such as smart phones etc. The disaster management organizations, e.g. official responders, NGOs, critical infrastructure and other ICT service providers, apply the referred technological capabilities for enabling understanding disaster risk or risk mitigation, preparedness to disaster, immediate response to disaster and recovery disaster management functions for realizing and improving their disaster resilience. Such technological capabilities are usually strongly established around information sharing and communications happening between multiple organizations and their assets, which usually requires commonly agreed specifications and standards to be operational in technical sense in the real world. Some of the key rule setters and contributors for the commonly agreed specifications and standards are shown in the Figure 1 (related to dashed black rectangle), and in Table 1 [2, 9]. Critical areas for standardization, identified by the Resistand project, are related to critical infrastructure and resource protection, continuity and organizational resilience, hazardous materials and devices, emergency management, community resilience, and IT security technologies (see Figure 2). For example, ISO/TC 292, 224, 262, 493, ISO/IEC JTC 1/SC 27, CEN/TC 164, 162, 391, 493, CEN-CENELEC SF-SEC and ETSI SC EMTEL are working in the related technical standardization in practice. Enabling such technical capabilities can be and has been done by developing the required technical solutions separately for disaster management and emergency communications or by applying the technological solutions developed also for other industrial/commercial purposes. Examples of such separate solutions or systems are e.g. public warning systems (PWS) [3, 4] and emergency calls (112) [5, 6, 7], which are visualized in Figure 3.

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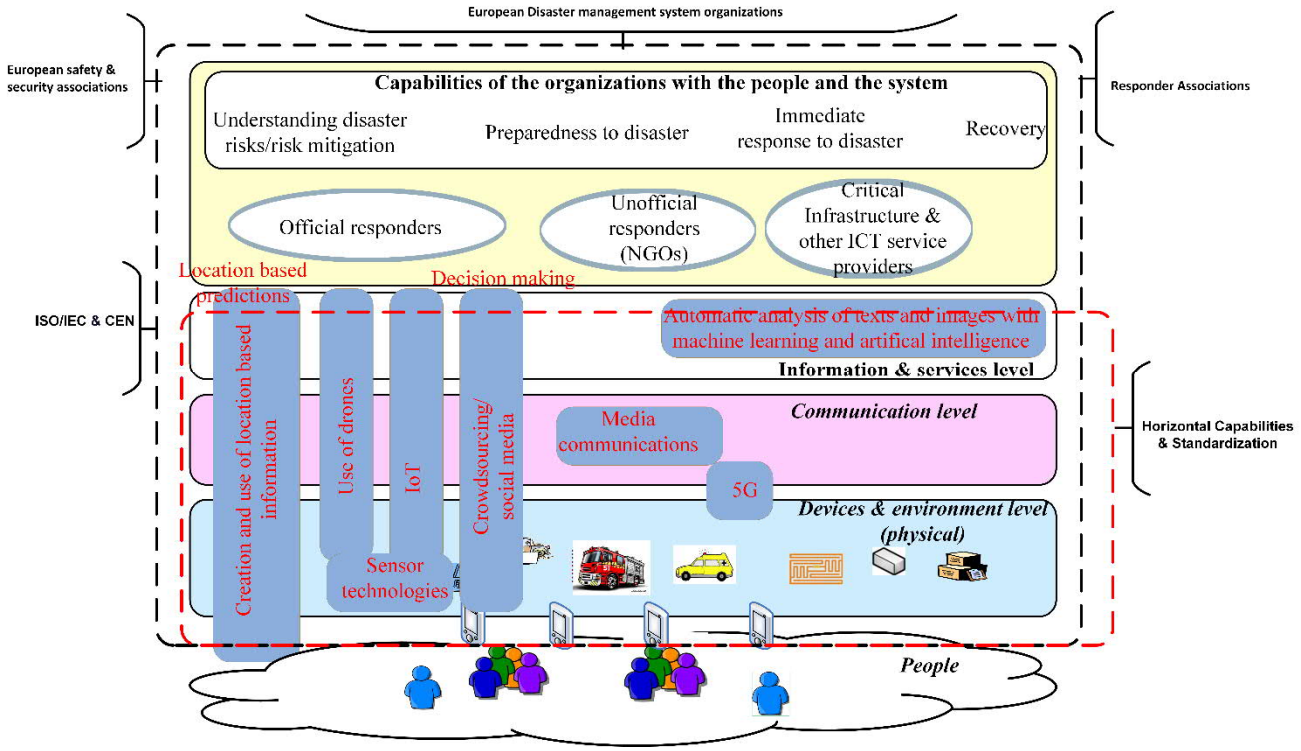

Figure 1. A view to technological landscape of disaster management, adopted from [1] and updated to consider the key terms of this report.

Table 1. European stakeholders that have impact on the standardization around disaster management, [2, 9].

European Policy making Organizations working around Disaster management and related system
EU Agency for Law Enforcement Cooperation EUROPOL (https://www.europol.europa.eu)
European Border and Coast Guard Agency FRONTEX (http://frontex.europa.eu/)
Committee for Civilian Aspects of Crisis Management (CivCom) of the European Council (http://www.consilium.europa.eu/en/council-eu/preparatory-bodies/committee-civilian-aspectscrisis-management/#)
Copernicus Emergency Management Service (http://emergency.copernicus.eu/)
European Flood Awareness System (https://www.efas.eu)
European Forest Fire Information System (http://effis.jrc.ec.europa.eu)
European Reference Network for Critical Infrastructure Protection (https://erncipproject.jrc.ec.europa.eu)
European Disaster Responders Associations
Federation of the European Union Fire Officer Associations (http://www.f-e-u.org)
European First Responder Innovation Managers Platform (http://efrim.org)
Confederation of Fire Protection Associations Europe (http://cfpa-e.eu/)
European Emergency Number Association (http://eena.org)
European Association of Competent Authorities (http://www.euraca.eu/)
Association of European Police Colleges (https://www.aepc.net/)
Red Cross EU Office (https://redcross.eu/)
European Safety and Security industrial communities
European Safety Federation (http://eu-esf.org)
AeroSpace and Defence Industries Association of Europe (http://asd-europe.org)
Confederation of European Security Services (http://www.coess.org/)
European Organisation for Security (http://www.coess.org/)
European Cyber Security Organisation (ECSO) (https://ecs-org.eu/)

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European Biosafety Association (http://ebsaweb.eu)
Euralarm (https://www.euralarm.org/)

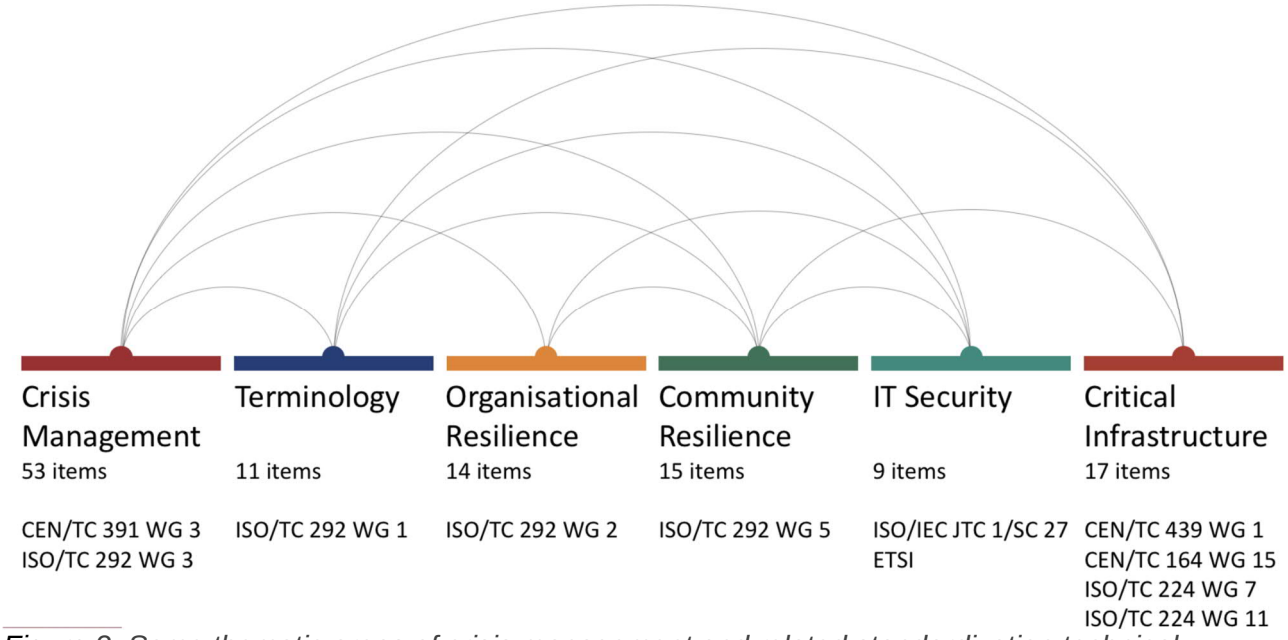

Figure 2. Some thematic areas of crisis management and related standardization technical commitees [8].

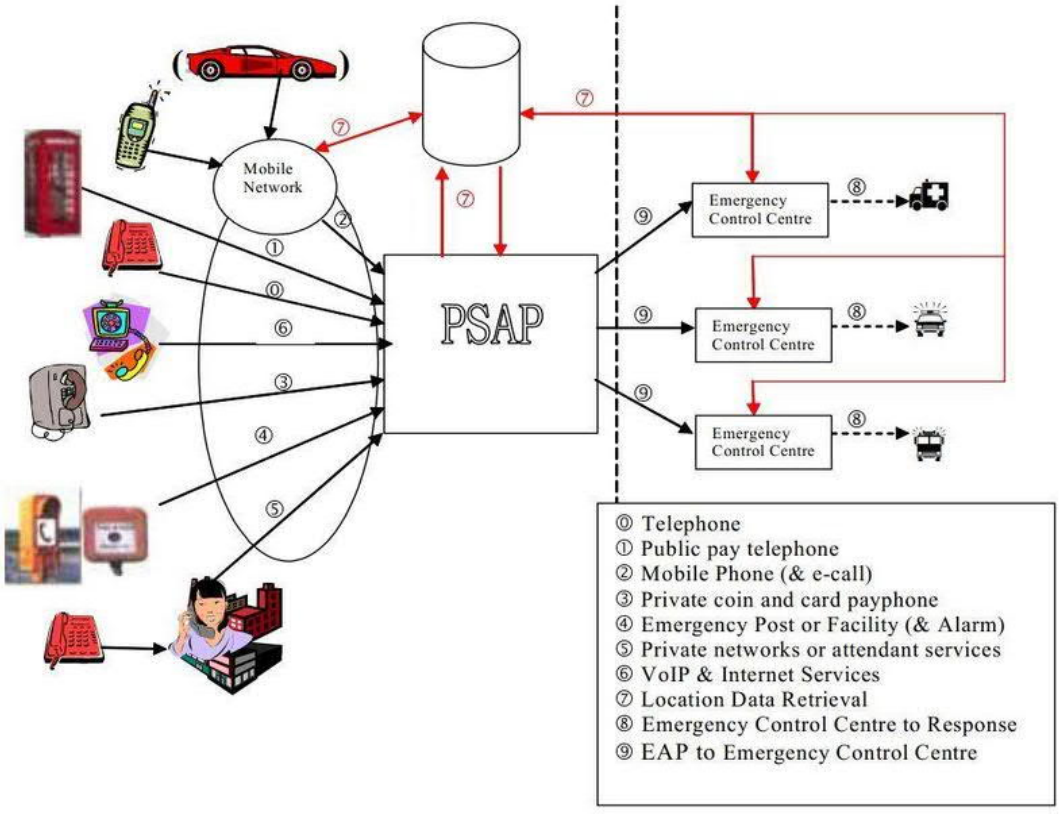

Figure 3. Functional architecture of PSAP (Source: EENA, 2015) [5].

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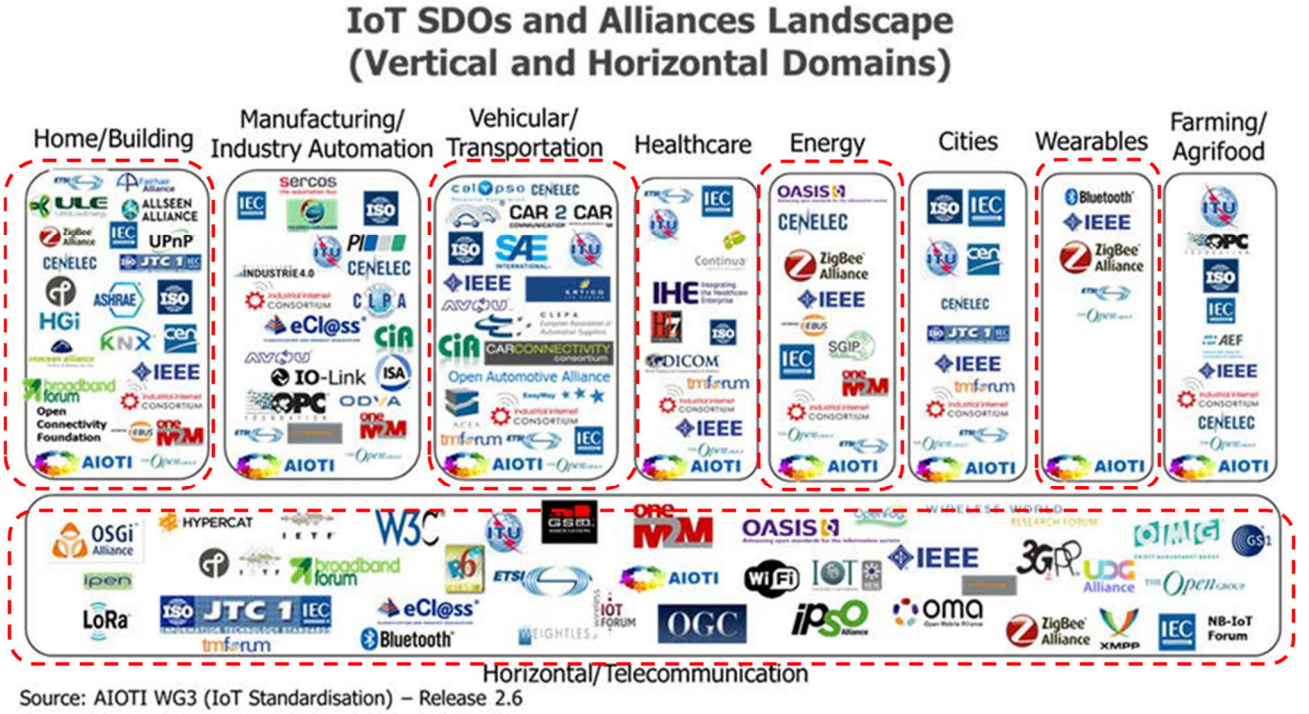
The central role in the emergency call has so called Public Safety Answering Point (PSAP), which is provided by the PSAP service provider on behalf of public authorities (Figure 3). It takes the caller information from trusted sources and ensure that it is provided to the correct PSAP [6, 7], so that it is possible to respond to the emergency of the caller. The PWS differs from emergency call in the sense that they are applied by the authorities to warn people for example in tornados, tsunamis, hurricanes, floods, natural volcanic, releases of deadly gas or terrorist attacks. Requirements for communications from authorities and organizations to individuals, groups or the general public during emergencies has been defined by ETSI [3]. The main means for PWS message distribution for Mobile phones are cell broadcast (CB), location-based alerting using Short Message Service (LB-SMS), instant messages service (IMS), email, push IP to smartphones, and mobile apps based solutions. In addition, fixed phones, TV, radio, sirens and long-range acoustic devices, variable-message signs and public address systems and internet (web, email, PC notifications, social media) can be used.

In addition, there are safety related capabilities under standardization within CEN TC 278 related to intelligent transport systems (ITS). ITS systems utilise data communication and computing technologies in transport related applications to improve traffic safety, increase efficiency of transport system and reduce the impacts of transport on environment. Some of the ITS systems capabilities are relevant also to disaster management, for example, the European in-vehicle emergency call system (eCall), technologies used to communicate real-time traffic information to road users (RDS-TMC and TPEG) and traffic signal priority for emergency vehicles.

When speaking about the resilience of society and industries, communities of people and individual people themselves, the application of the technological solutions developed for other industrial/commercial purposes looks feasible e.g. because of cost of the infrastructures, communication and physical assets perspectives. A view to the standardization landscape for such technological fields both from vertical (e.g. healthcare, energy, transportation etc.) and horizontal (e.g. telecommunications) domains perspectives is visualized in the Figure 4.



Source: AIOTI WG3 (IoT Standardisation) – Release 2.6

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Figure 4. Standardization landscape of Alliance of Internet of Things Innovation (Source: AIoTI).

The position of the creation and use of location based information, use of drones, automatic analysis of texts and images using machine learning and artificial intelligence, crowdsourcing/social media, media communications, IoT, sensor technologies, and 5G is presented in the context of standardization landscape by the blue rounded rectangles in the

. The location based predictions are an information and services level function which is relying on the positioning of entities in physical level and use of that location based information for making more or less smart predictions what is the status now in the system and what can happen in the coming future. Decision making is an activity under responsibility of the authorities and responders, and it can be supported by all the technical capabilities of the system. Alerting needs to consider the information about the situation of the physical devices and the environmental conditions (e.g. storms, floods, avalanches), feeding them into the decision-making process, and creating alerts to the required stakeholders, communities and people.

2.2. State of the practice view to the technological landscape

The resilience of the society in disasters requires e.g. continuous operation capabilities from vital basic technological services (Figure 5). The communication channels (such as radio, TV, mobile access network) are important in enabling delivery of warnings and information related to the disasters (public warning systems (PWS)). The emergency call (112) services are important for people for announcing the event to authorities. The rescue groups need information technological services for various real-time actions in disaster field. Supply of goods and treasury needs technological means for transportation via air and via roads in disaster conditions. It is obvious that such vital technological services depends on the local circumstances, - authorities and - legislation framework.

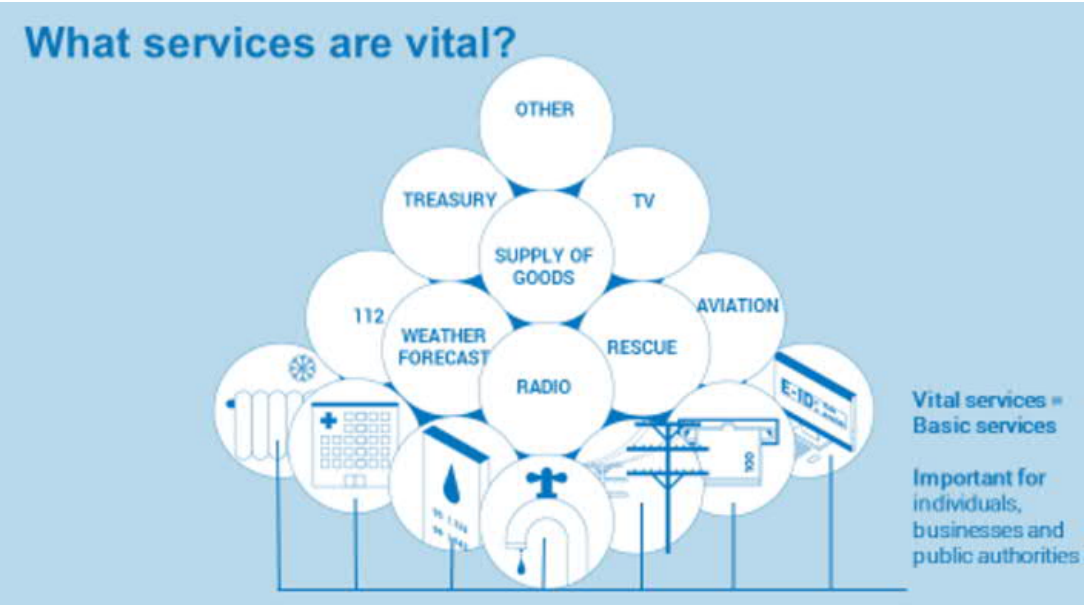

Figure 5. A view to the vital basic services of a society from disaster management perspective in Estonia.

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Let us take an example related to the technologies and tools applied in PWS practice in different countries.

An analysis of technologies applied in the public warning systems in Finland, Sweden and Italy is presented in the Table 2. The overview demonstrates the heterogeneity of the applied communication channels and specific tools developed for each channel and for different purposes. It seems that several channels are applied in order to reach as many people as possible in the disaster area. However, full population coverage is still challenging to reach even if multiple communication channels are applied in parallel to deliver warning events or information. It is estimated that one reason for this is arising from the fact that most of the communication means and tools of PWS requires ownership of a physical device (e.g. smart phone, radio, TV) and previously done configuration, set-up and installation actions from people. This may be difficult for children, older people, people with disabilities or people that have little economic resources.

Table 2. An overview of of technologies applied in the Public Warning Systems in Finland, Sweden and Italy (BuildERS D2.3).

Responsible stakeholders	Technical service provider/system	Communication channels	Tools of public warning systems (PWS)
Emergency Response Centre Agency (Fin)	Finnish Broadcasting Company (YLE)	radio; TV; web; teletext; mobile apps; social media;	112.fi website, teletext, emergency text messaging via SMS 112 to preregistered numbers, YLE uutisvahti mobile application[2], 112 Suomi application[3], Secapp application[4], social media: Facebook, Twitter, Instagram, YouTube
Swedish Civil Contingencies Agency (MSB). Authorities mandated to request sending IPC	Important public announcement (IPA) warning system, Krisinformation.se web site (MSB). Regional SOS centre.	radio; TV; Web, mobile apps; social media; voice and text messages to mobile phones; via outdoor warning signal; cell broadcast as an option to send EU electronic alarm code (still under clarification).	Krisisinformation.se website, app[7] and social media; Swedish radio play app; SOS Alarm 112 app;

[2] https://play.google.com/store/apps/details?id=fi.yle.uutisvahti
[3] https://play.google.com/store/apps/details?id=fi.digia.suomi112&hl=en
[4] https://www.secapp.fi/en/home/
[7] Krisinformation (2019c). Mobilapp för Krisinformation.se. Retrieved from https://www.krisinformation.se/om-krisinformation/mobilapp-for-krisinformation.se

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warning messages[5], - information messages[6].			
In Italy, Mayors of Province, as an institution closest to the citizen, are civil protection authorities and are primarily responsible for responding to the emergency	Regions and the Autonomous Provinces to issue alerts for local civil protection systems	Web; social media (Facebook, Twitter, Instagram); IM applications (Whatsapp, Telegram); the press releases (newspapers, TV, press, radio); smartphone applications; message panels; bells or megaphones	*Alert System*[8]; *AllertaLOM* or *Cittadino Informato;* IT-alert new system[9]; Twitter (as @DPCgov) Facebook (as @DPCgov) YouTube (Civil Protection Department) Flickr (Civil Protection Department)

5

Rescue commander/rescue leader for municipal rescue service
Rescue leader for state emergency services Swedish Radiation Safety Authority
Swedish Police Authority
Infectious Disease Physicians
Operators of dangerous plants, in accordance with Chapter 2, 4 §, Act (2003:778) on protection against accidents
SOS Alarm

6

The Government and the Government Offices
All government agencies with responsibility and obligations in crisis management (authorities with an official in standby)
Municipalities and County Councils
Svenska Kraftnät (Swedish power grid) and the largest electricity distributors
Telecom operators with their own networks
Government agencies and companies that may request the transmission of a warning message

[8] https://www.alertsystem.it
[9] Web site: http://www.it-alert.it/ accessed 8 February 2020

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3. Survey on tools and technologies for disaster management

3.1. Classification and indexing methodology

An objective of the task has been to analyse the technologies and tools related results achieved in the past European H2020 and preceding Framework Projects for preparedness and disaster management. During the analysis of project contributions and especially the tools of preparedness and disaster management related results, it came clear that some classification of projects and their resulting tools related contributions are needed. Several projects were identified that have contributed technologies and tools (T&T) related to guidelines, methods, organizational development, training and education. Several projects have contributed T&T related to risks of natural disasters and their mitigation, and several ones have contributed T&T related to response phase of disasters. In addition, there were group of projects that have contributed T&T related to more specific technological enablers such as cyber-physical systems, advanced internet of things (IoT) solutions, specific industrial sector solutions and ecosystems, and even standardization related tools. In order to facilitate more smooth discussion on the resulting tools and technologies, we have here defined separate classes for the resulting tools of the projects (see Table 3).

The indexing methodology is needed to help referring into the specific T&T, and binding them into the parent project where the T&T has been developed. We use the following indexing in this deliverable:

The [x.y] indexing refers into the project and into the T&T results of it as follows.

x defines the sequential order number of the project (x). The list of the projects with their sequential order numbers are provided in the annex A of this report. The identities of the resulting T&T are also included in the annex A.

y is the identifier of the technology or tool (T&T). The full list of the T&T are provided in the annex B of this report.

Thus **[x.y]** indexing refers to the specific technology or tool ***y*** that has been created as the result from the project ***x.***

Table 3. The classes of tools as the main contributions from past European H2020 and preceding Framework Projects for preparedness and disaster management. The [x.y] with the project names refers to the T&T that has been developed within the referred project (see annexes A and B)

Technologies & tools related to guidelines, methods, organizational development, training and education (class 1)	
Contribution area	References to the projects, technologies and tools
Guidelines or methods for helping organizations, stakeholders, decision makers etc. to analyse risks, analyse their maturity,	SMR [1.1-5], DARWIN [2.1-4], IMPROVER [3.1-5], RESILENS [4.1-3], RESOLUTE [5.2], EDUCEN [7.1-4]

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learn and improve their resilience related capabilities.	
Analysis of community resilience, or increasing the awareness of communities for better preparedness for natural hazards	emBRACE [10.1], CapHaz-Net [18.1]
Tools supporting training, education of people and organizations for increasing preparedness for disasters	CAST [17.1-3], KOPHIS [23.1], BRTE [26.1]
Collaborative training for improving inter-organizational response capacity	IN-PREP [27.1]
Tools for impact assessment	Driver+ [54.1]
Technologies & tools related to risks related to natural disasters (class 2)	
Contribution area	References to the projects, technologies and tools
Tools supporting risk and situation analysis related to various natural disasters	RISC-KIT [8.1-5], ENHANCE [11.1], CORFU [14.1], SMARTEST [16.1-5], Syner-G [19.1-3], Anywhere [25.1], NAIAD [28.1], ESA Copernicus [43.2]
Tools supporting analysis of slower environmental processes, like climate change	BASE [15.1-3]
Tools for detecting, collecting, storing, processing, validation etc. of satellite imaging data	EPOS IP [41.1], ASSIST [42.1], ESA Copernicus [43.1], USGS [44.1], I-REACT [49.1]
Technologies & tools related to standardization, multiple ecosystems, cyber-physical systems and advanced IoT solutions in disaster management (class 3)	
Contribution area	References to the projects, technologies and tools
Standardization and architectures supporting development of services for disaster management	RESISTAND [6.1], M2MGRIDS [31.1]
Means for smooth application development, with horizontal solutions for trustworthy information sharing and communications in cyber-physical context	M2MGRIDS [31.1]
Advanced situation awareness system using UAV:s, sensors and surroundings.	BRIDGE [13.1-3], INACHUS [32.1], MOBNET [36.1]
Holistic situation awareness with blockchain, ML, UAV, IoT etc. in critical infrastructures	RESISTO [30.1]
Advanced IoT solutions	CUBE [37.1], Quakebots [38.1], AdvIoT [39.1]
Mapping and advanced connectivity	HOTOSM [52.1]
Technologies & tools enabling more or less real-time operation during the crisis or disaster events (class 4)	

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Contribution area	References to the projects, technologies and tools
Tools for helping in information sharing and communication of disaster-responders	BRIDGE [13.1-3], HEIMDALL [22.1], Anywhere [25.1]
Tools for enabling and helping collaborative training of practitioners and first responders in real-time like situations.	IN-PREP [27.1], RESOLUTE [5.3], Other [33.8]
Tools for helping in preparedness for attacks, e.g. terrorist, towards the resilience	PRACTISE [12.1]
Tools for taking care of critical infrastructures and critical organizational collaborations in disasters	Safeway [29.*], RESISTO [30.1], Other [33.6]
ICT Applications and tools to support emergency services and public safety warnings	RESOLUTE [5.1, 5.3], NEXES [24.1], Anywhere [25.1], Other [33.1,33.4-5, 33.12, 33.15], I-REACT [49.2]
Situation aware services for information sharing to public audience	Other [33.2-3, 33.13-14], INACHUS [32.4], Knowage [40.5]
Tools for enabling information sharing related emergency real-time situations, helping search and rescue teams in location, situation awareness and events	RESOLUTE [5.3], INACHUS [32.3], Other [33.6-7, 33.9-11, 33.13, 33.16, 33.18]
Tools for information collection and analysis, storing, verification. Ex. social media use related tools.	INACHUS [32.2], beAWare [35.1], Knowage [40.1-4], E2mC [45.1], Comrades [47.1-2], Super [48.1], Emergent [50.1]
Applications and tools for people in disasters (e.g. pandemic such as Covid19)	Other [33.16-17], ESRI [51.1], EU-VRI [53.1]

3.2. Categorization of tools and technologies

The provided overview of the technological landscape for disaster management demonstrates the wide scope, heterogeneity of the applied technologies and number of tools developed separately for each communication channel and for different purposes. Because of the heterogeneity of tools, it is challenging to compare them with each other unless relevant categories is not defined. Reasoning of the applied categories is provided in the following.

Some of the tools are related to physical systems such as a specific device like a drone for example. Some tools are focused to support communications such as e.g. message based communications. Some tools are done to take care of information processing, some for providing guidelines or ICT services for disaster management stakeholders. Some tools have been developed to help the research and development process or improving of the disaster management processes. Therefore, we have defined here, **tool or technology type** category to clarify the type of the tool. There are tools which have been developed to enable for example information services based on location of people, warning to big amout of people or help processing of big amount of data to help authorities to decide

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the actions to be done. Thus the purpose in which the tool has been developed varies, and therefore the **purpose** category have been defined.

Some of the tools are more or less strictly bound to the operation of authorized stakeholders, who can be the only owners of the related service process. It is essential to know who is expected to own the rights to host the service, whether it is some authorized stakeholder or non governmental organization or whatever company or people. Therefore, the **owner** category has been defined.The possible users/customers of the tools may also vary, for example, the only allowed user group can be authorities or the usage can be more open and allowed also for non-governmental organizations, companies or even ordinary people. Thus it is essential to know who is expected to be the potential user group of the service, whether it is authorities, NGOs, communities or individual people or so, and therefore the category **potential users/customers** have been defined.

The level of use in which the tool is today varies, for example, a tool can be in prototype level use, or in piloting or already in real use in disaster management. Therefore, the category **level of use** has been defined. The technology readiness level (TRL) are usually applied for definition of respective maturity level, and therefore it needs to be considered. It is essential to know the maturity level of the technology or tool accordingly, and therefore the category **TRL level** has been defined.
In addition, it is essential to know into which of the disaster life-cycle phases [58]: risk mitigation, preparedness to disaster, response, or recovery, the tools are applicable. Therefore the category **Crisis/Disaster lifecycle** has been defined.

The more detailed clarification of the referred main categories, and definition of their sub-categories have been provided in the Table 4.

Table 4. The main categories of the tools and technologies (T&T).

Main category: Tool or technology type **Clarification:** The tool or technology type category defines the basic focus of the technology or tool.
Definition of Sub categories: Sub-category: Technology - physical system related Definition: The tool/technology is mainly related to physical system and/or devices. Sub-category: Technology - communication related Definition: The tool/technology is mainly related to communications systems and/or exchanging of messages or information streams without considering the content of the information so much. Sub-category: Technology - information or knowledge related Definition: The tool/technology is mainly related to information sharing with considering the content of the information mainly. Sub-category: Tool - guideline or method Definition: Guideline or methodology type of tool. Sub-category: Tool - application, software solution or ICT service Definition: Application, software solution or ICT service type of tool

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Sub-category: Tool - physical materialized product
Definition: Physical materialized product

Sub-category: Process Tool - can be applied in Research & Development process
Definition: Process related tool that can be applied in (e.g. tool) research & development process

Sub-category: Process Tool - can be applied in guiding/continuous improving of processes related to disaster management
Definition: Process related tool that can be applied in guiding/continuous improving of processes related to disaster management.

Sub-category: Process Tool - can be applied in the actual real-time operation process of disaster mgt
Definition: Process related tool/service that can be applied in actual physical real-time operation process in disaster management.

Main category name: Purpose
Clarification: The purpose defines the main operation in which the tool or technology has been developed and intended to be applied.

Definition of Sub-categories:
Sub-category: Communication oriented
Definition: Communication and messaging between various stakeholders in the crisis/disaster situations

Sub-category: Information/data oriented
Definition: Information/data related processing to be applied in crisis/disaster management. E.g. Aggregation, mining and processing of information from different social media sources.

Sub-category: Decision making / operational actions oriented
Definition: Decision making / operational actions related assets & services in crisis/disaster management

Sub-category: Location detection based services related
Definition: The location based information technological services are applied e.g. to predict what is happening next in the system

Sub-category: Warnings and Alerting
Definition: Means needed for informing on warnings or alerting (e.g. storms, floods, avalanches)

Main category name: Owner
Clarification: This category defined the hosting stakeholder, who can be the owner of the service

Definition of Sub-categories:
Sub-category: Unofficial civil society organization
Definition: Non-governmental, civil society organizations (NGOs) such as e.g. Red Cross and various other associations

Sub-category: Authorities, usage limited to authorities only
Definition: Official responders such as e.g. fire & rescue, police, emergency medical. Clients targeted only for authorities.

Sub-category: Authorities, usage allowed also for other stakeholder

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Definition: Official responders such as e.g. fire & rescue, police, emergency medical. Clients targeted also for other groups than authorities

Sub-category: Service integrator/provider
Definition: Stakeholder that is providing information technological services

Sub-category: Tool developer
Definition: Stakeholder that is developing the tool

Sub-category: Individual persons or communities
Definition: Whoever individual person or community can be the owner

Main category name: Potential users/customers
Clarification: This category defines the potential targeted user/customer group of the tool or technology.

Definition of Sub-categories:
Sub-category: Unofficial response system with civil society organizations
Definition: Non-governmental, civil society organizations (NGOs) such as e.g. red cross and various other associations

Sub-category: Official response systems with authorities
Definition: Official responders such as e.g. fire & rescue, police, emergency medicals.

Sub-category: Communities of people
Definition: Communities of ordinary people

Sub-category: Individual ordinary people
Definition: Ordinary people

Sub-category: Individual people with limited capabilities/low social capital
Definition: People with limited capabilities and low social capital (most vulnerable people)

Sub-category: Tool product developer or service integrator/provider
Definition: Stakeholder that is developing physical product, integrating or providing information technological services

Main category name: Level of use
Clarification: This category describes the use level of the technology or tool today.

Definition of Sub-categories:
Sub-category: Idea, concept or method
Definition: Idea, concept or method type of tool, which can be applied e.g. as a guideline

Sub-category: Research prototype
Definition: Tool, technology or method, which maturity is estimated to be in a prototype level.

Sub-category: End user evaluated research prototype
Definition: Tool, technology or method, which is evaluated by some end user group

Sub-category: Preliminary product or service
Definition: Tool, technology or method, which is developed, supported and provided by a company or organization

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Sub-category: Product or service in pilot use of end users
Definition: Tool, technology or method, which is developed, supported and provided by a company or organization, and it is in pilot use of the owner/end users/customers

Sub-category: Product or service in real use of end users
Definition: Tool, technology or method, which is developed, supported and provided by a company or organization, and it is in real end use of the owner/end users/customers

Main category name: TRL level
Clarification: The technology readiness level (TRL) definition is applied here according to the H2020 definitions clarified in https://enspire.science/trl-scale-horizon-2020-erc-explained/.

Definition of Sub-categories:
Sub-category: TRL-1
Definition: Basic principles observed

Sub-category: TRL-2
Definition: Technology concept formulated.

Sub-category: End user evaluated research prototype
Definition: Experimental proof of concept

Sub-category: TRL-3
Definition: Tool, technology or method, which is developed, supported and provided by a company or organization

Sub-category: TRL-4
Definition: Technology validated in lab

Sub-category: TRL-5
Definition: Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)

Sub-category: TRL-6
Definition: Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)

Sub-category: TRL-7
Definition: System prototype demonstration in operational environment

Sub-category: TRL-8
Definition: System complete and qualified

Sub-category: TRL-9
Definition: Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

Main category name: Crisis/Disaster lifecycle
Clarification: This category is here defined according to the applied according to Sendai framework definitions into disaster life-cycle.

Definition of Sub-categories:
Sub-category: Understanding disaster risk (risk mitigation)

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Definition: Identification and understanding exposure, vulnerability and hazard characteristics of disaster and risk

Sub-category: Preparedness to disaster
Definition: Pre-event preparation phase, including monitoring of the situation, warnings and alerting (e.g. emergency notification, setting the criteria for triggering alarm event to happen).

Sub-category: Immediate response to disaster
Definition: Disaster management during the alarm, e.g. response from official responders (e.g. situation awareness, decision making, command, control), civil society organizations, communities of people, ordinary people or people with limited capabilities

Sub-category: Recovery
Definition: Recovery phase after the disaster, may be executed in parallel with preparedness phase

The detailed categories of each T&T is clarified in the annex C.

3.3. Key findings from the survey

The analysis covered 118 tools developed within ~52 European research collaboration projects revealed large heterogeneity and wide variance in the maturity of tools. The number of tools in different classes of technologies and tools are shown in the Figure 6. Most of the tools were related to response to disasters (53 tools of class 4), a little bit less for the guidelines, methods or training (31 tools of class 1), risk mitigation (26 tools of class 2) and standardization, cyber-physical or IoT (12 tools of class 3). An objective of the task has been the analysis of the maturity (TRL level), and the level of use (if deployed in practice). Therefore, we focus especially in discussing these issues related findings of the survey in this section. The maturity level of the analysed tools varied for full scale from TRL-1 to TRL-9. 33 of the tools are estimated to be in TRL1-3 levels, 27 in TRL4-6 and 97 in TRL7-9 levels (see Figure 6 also annex C).

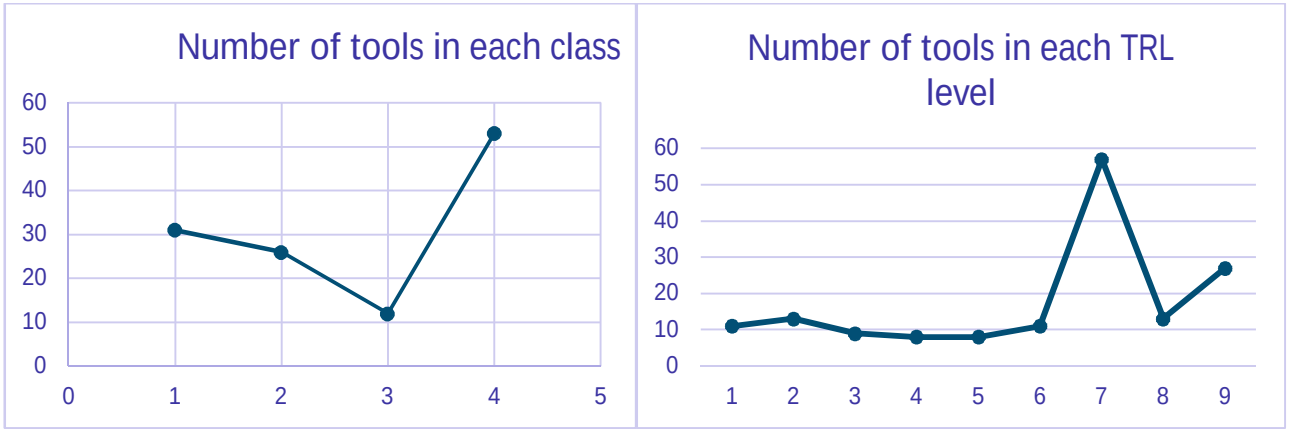

Figure 6. Number of tools in different classes of technologies and tools. Number of tools in each TRL level.

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The tools,their maturity and the level of use (if deployed in practice) are discussed in the following focusing on each class separately.

CLASS 1 - guidelines, methods guidelines, methods, organizational development, training and education.

Most of the class 1 tools could be regarded either as guidelines or tools that help stakeholders assimilate them. Both the information itself and the way it is represented is important, so that the potential users could benefit from it. This was well understood and implemented by SMR [1.1-5], whose Resilience Management Guidelines are thorough, but easy to understand and marketed through an attractive platform. Both theoretical insights and empirical examples are used in that tool. In addition, several educative simulators and serious games have been developed. These help decision-makers and crisis responders prepare and practice for real action under controlled circumstances. A prime of example of such tools was SimEnv developed under DARWIN [2.3], that enables responders and decision-makers cooperate in a multiplayer simulation environment. SimEnv had great potential, but it was not implemented fully, reaching only TRL 4. Another approach was used by EDUCEN, whose Games to Foster Empathy [7.4] were quite simple, but targeted to wide audiences and is estimated to be in TRL 9 maturity level.

It is estimated that the field of class 1 tools has been covered quite well, however there is un-balance in the achieved maturity levels. Let's have a look at the number of class 1 tools in each TRL level in the Figure 7. It can be seen that most (**26**/**53**) of the class 1 tools are estimated to be TRL-7 level, however, only 4 that are in pilot use or real use of end users (TRL-8 and TRL-9).Therefore, it is recommended now to look for possibilities to investigate into transferring and further develop the TRL-7 level tools towards taking them into real use.

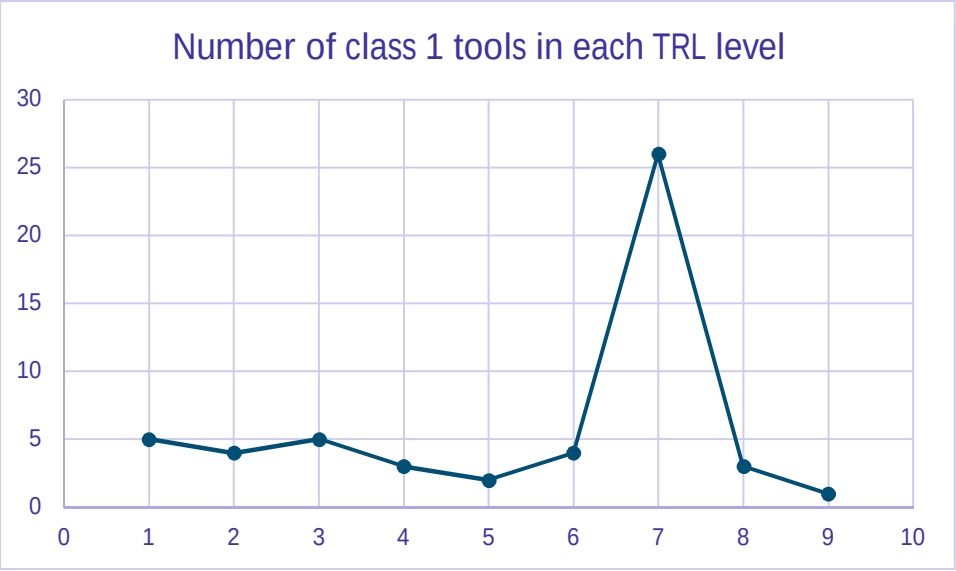

Figure 7. Number of class 1 tools in each TRL level indicating their level of use.

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CLASS 2 - Technologies & tools related to risks related to natural disasters and their mitigation.

There are several tools having important capability to take into account multiple variables while conducting damage assessment or prediction to infrastructure from disaster, e.g. Prototype software OOFIMS [19.1], Fragility Manager Tool [19.2], MCDA software [19.3], Multi-Hydro [16.1], HOWAD - Prevent [16.2], RAINS [16.4], FVAT [16.5], and A4EU platform [25.1]. The Prototype software OOFIMS [19.1], Fragility Manager Tool [19.2], MCDA software [19.3] provide a comprehensive package of software that provides a wide range of analytical tools such as hazard computation, structural damage analysis, cost repair estimations, Shelter Needs, Social Vulnerability, Temporary Housing etc. The A4EU [25.1] is a rich platform that collect weather and climate related information and provides early warnings, emergency management and response to extreme weather and climate events. In addition, there are essential tools supporting application of satellite images for help in natural disasters, e.g. EPOS system [41.1], CSW [42.1], EMS rapid mapping [43.1], EMS risk and recovery [43.2], Earthquake mapping [44.1], I-REACT value added services [49.1] and I-REACT Core components [49.2]. When discussing about the maturity of tools (*Figure 8*), it can be seen that there are quite many tools which are/have been in pilot or real use of end users (22 from the total number of 30). It is estimated that this field has good potential to trigger real advances in preparedness to disasters. In order to boost this it is recommended to take action towards taking the TRL-7 level tools (13) into real use.

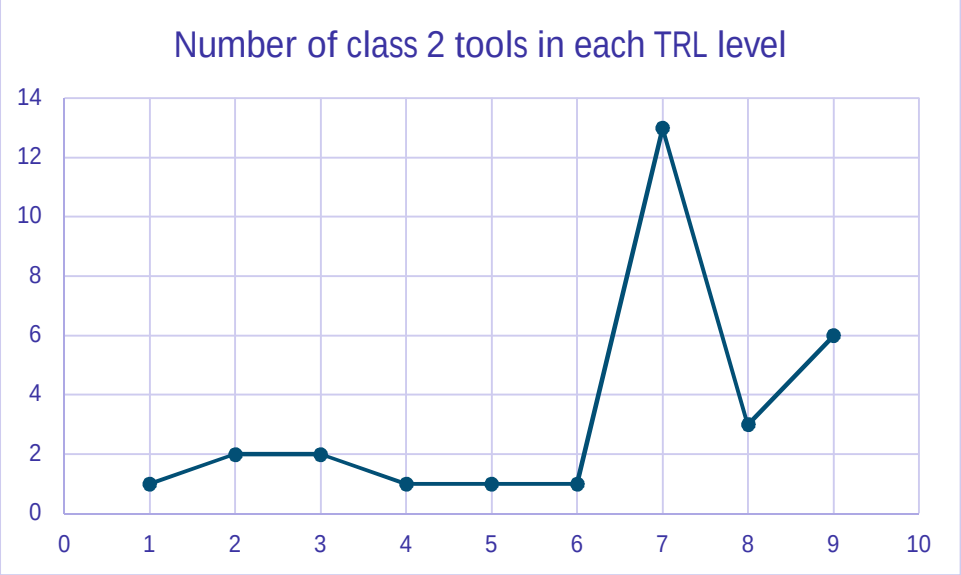

Figure 8. Number of class 2 tools in each TRL level indicating their level of use

CLASS 3 - Technologies & tools related to standardization, multiple ecosystems, cyber-physical systems and advanced IoT solutions in disaster management.

The class 3 tool set was the most heterogeneous one in terms of the maturity level, see Figure 9. The tools were splitted for the full scale from TRL-1 to TRL-9, and an essential part of the tools were still in prototype levels (8 tools were in TRL levels 1-3). When discussion about individual tools, the early stages of development is obvious. Resistand [6.1] has been essential to establish standardization roadmap for disaster management. M2MGrids highlighted smooth application development with horizontal solutions for trustworthy information sharing and communications in cyber-physical systems context [31.1]. There are several tools enabling use of robot like equipment for help in disasters, such as UAVs in real-time video delivery (ASA [13.1]), snake-like robot for detecting (INACHUS robot [32.1]) and UAVs for detecting victims in the rubble (BTS [36.1]). Tools for helping in location and situation aware views for responders into the disaster area, such as Dynamic tagging [13.2] and Swarm [13.3], and enabling connectivity in critical

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disaster conditions Resisto platform [30.1] and HOTOSM [52.1]. Tools for helping in energy producing [37.1] and measuring seismic events on buildings [38.1]. There is essential innovation potential in the class 3 tools area relying on specific technical capabilities, however, consideration of horizontal approach is recommended for helping smooth application development with new technologies and application of heterogeneous cyber-physical assets of different vertical sectors for help in disaster management.

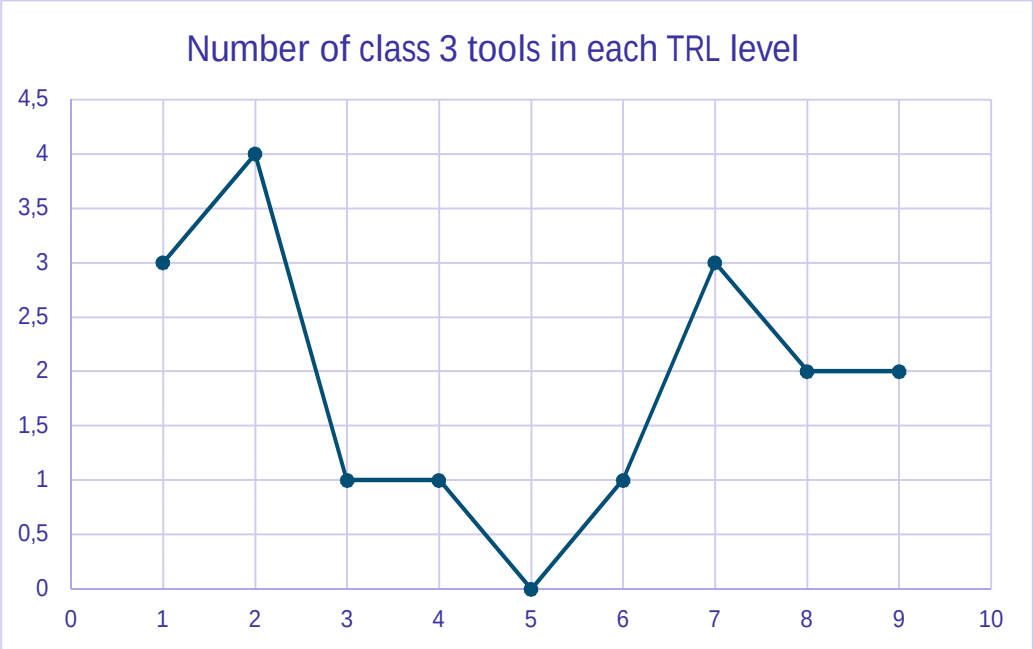

Figure 9. Number of class 3 tools in each TRL level indicating their level of use.

CLASS 4 - Technologies & tools applicable in response phase of disaster, supporting more or less real-time operation during the crisis or disasters.

There are very many technologies & tools estimated to belong to class 4 (52 all together). There are tools helping in taking information out from various sources, -sharing and communications: UAV enhanced situation awareness services [13.1-3], means for combining the data from various sources for responders and location populations (Heimdall [22.1]), and means for integrating several tools with geolocalization (A4EU[25.1]]; Tools targeted for collaborations and training of responders in real-time like situations, e.g. In-Prep [27.1] and Trasim [33.8]; Tools for helping in preparedness for attacks, e.g. Practise [12.1]; Tools for taking care of infrastructures and critical collaborations in disasters, e.g. Resisto [30.1] and Cobra [33.6]; Tools supporting emergency services and public safety warnings for wider audience, e.g. collaborative workspace CRAMSS [5.1], Mobile app for emergency responders and civilians [5.3], Nexes system with e.g. a Mobile Emergency Application for the citizens [24.1], European in-vehicle emergency call system eCall [33.1], traffic announcement service [33.4], public emergency announcement service [33.5], weather forecast and warnings [33.12], watershed forecast and warnings [33.15]; Tools for providing situation aware information for public audience, e.g. traffic information services [33.2-3], Tilannehuone [33.13], Radiation today [33.14], common operational picture [32.4], and city-wide sensor network for sharing social and sensor data in smart cities [40.5]; Tools for enabling situation awareness for responders, e.g. SaR-ESS [32.3], DMA [33.7], sharing information to group of people via messaging SITMAN [33.9], a web dashboard for estimating different population types by municipality from past mobile positioning data Temporary population [33.10], and web based situational awareness solution Insta Blue Aware [33.11]; Social media related tools for

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information collection, analysis, storing, verification, e.g. multi-source data fusion information engine [32.2], gathers and analyses data from sources such as social media, drones, weather databases [35.1], analysis toolbox for reporting and visualizing [40.1], repository for information storing BigClouT Data Lake with related capabilities [40.2-4], tools for analyzing social media data, localization and crowdsourcing [45.1], tools for analyzing messages [47.1], classification tool [47.1] and natural language processing [48.1], and guidelines for using social media [50.1]. The analysed class 4 tools were quite mature in general, which is indicated by the TRL levels, 6 of the referred tools are in TRL1-TRL3 levels, 13 in TRL4-6, and 38 in TRL7-9 (see Figure 10). This class demonstrates good progress in the sense that there are many tools already taken into real use. It is important to continue this process, especially because most of the opportunities arising from e.g. use of location awareness information, use of drones, more real-time communications over 5G, interaction with IoT assets and sensors, are estimated to trigger real advance opportunities in immediate respond processes to disasters.

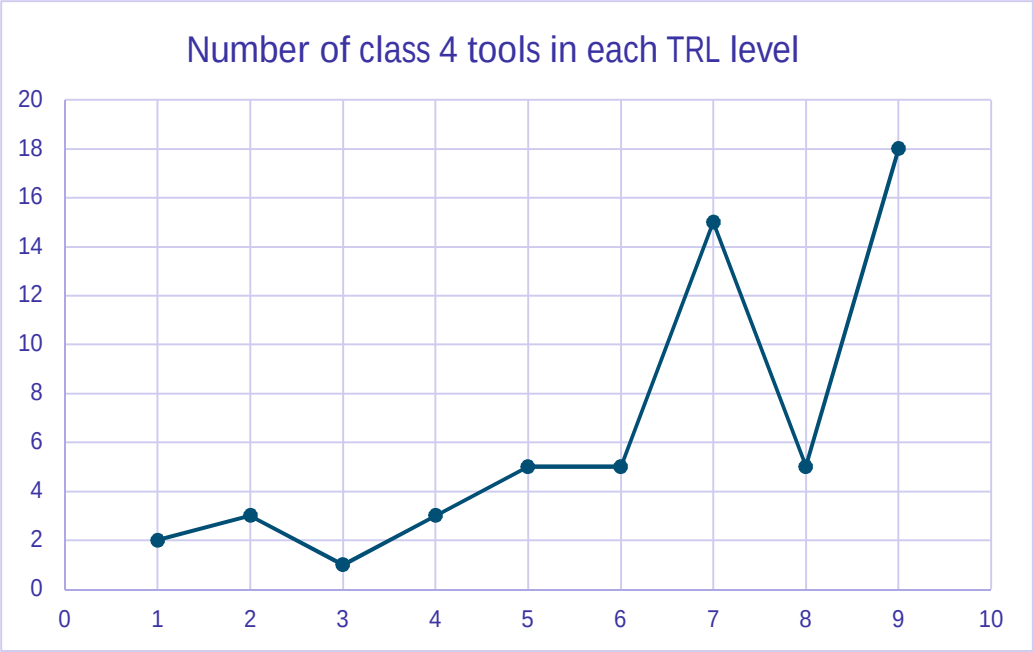

Figure 10. Number of class 4 tools in each TRL level indicating their level of use.

During the work for this task, the COVID-19 global pandemic occurred. As the result, some attention was taken to look for applicable tools for citizen and authorities in case of epidemics/pandemics. For example, there are ESRI COVID-19 GIS hub for representing global epidemic situation [51.1], with geographical information relying on ArcGIS platform for location aware services [33.16]. The hub with its related continuous update process enables establishing better understanding of the disease spread trajectories, situation and basis for planning, decisions and response actions and measuring the impact. There are also several studies related to disease spread calculations[10],[11], epidemiologists are using global travel data to understand global spread of the disease[12] and countries are relying on

[10] https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(20)30260-9/fulltext
[11] https://www.worldpop.org/events/COVID_NPI
[12] https://spectrum.ieee.org/the-human-os/biomedical/devices/predicting-the-coronavirus-next-moves

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location services of mobile operators[13] to find out moving patterns of individuals[14]. The BuildERS project is also studying positioning data access with specific tools, such as Temporary population [33.10] and DMA [33.7] to detect people who are travelling in disaster struck areas and those who might travel there soon, and determine the proper course of action. The Covid19 applications have rapidly arised to be a hot topic for industries and research all over the world, which has increased the amount of new development actions such as e.g. COVID19 Risk radar [53.1] studying most relevant links from Web sources, informing and guiding young people[15], tools for following epidemic chains[16], tracing of contacts using decentralized proximity logging [17],[18],[19], use of digital QR codes with smart phone application to control access of people out from home, taking a subway, going to work, entering cafes, restaurants and shopping malls[20], e.g. using Wechat mobile app of Alipay and Tencent. These applications can be useful in following the possible epidemic chains, however, there seems to be *serious trust and privacy related challenges* because the location of individual persons with their contacts may also be applied for other illegal purposes. There are essential ethical arguments against surveillance because there are human rights to privacy that is very important for the functioning of democracies. Thus surveillance is an interference with fundamental rights, and it is manifested distrust. This is because when surveillance technology is used for one purpose, it does not mean that the technology will not be used for other purposes (without the knowledge of citizens)[21].

4. Survey of emerging opportunities for disaster management

An objective of the task has been to survey on emerging opportunities arising from recent technological advances in tracking the location of people, use of drones, use of social media with artificial intelligence and machine learning, communications over 5G, interaction with IoT assets and sensors. For example, the referred emerging technologies may provide new kinds of means in supporting tasks like communication, decision making, location-based predictions and alerting (storms, floods, avalanches) for helping disaster management stakeholders to improve the operations related to preparedness and disaster management. Therefore, we focus here on discussing the emerging opportunities from three viewpoints: technological, importance and applicability perspectives. The technological perspective can be considered as the enabler. The importance focuses on the needs of the involved key disaster management stakeholders: different types of

[13] https://techcrunch.com/2020/03/08/telecom-operators-in-india-warn-people-of-coronavirus-outbreak-share-tips/
[14] https://www.ohtuleht.ee/994890/valitsus-tahab-telefonifirmadelt-teada-kui-klient-on-kainud-koroonapiirkonnas
[15] http://dy.fi/4g2
[16] http://dy.fi/4g9 , http://dy.fi/4gn
[17] https://bluetrace.io/
[18] https://siliconcanals.com/news/poland-protego-app-slow-down-coronavirus/
[19] https://github.com/DP-3T/documents
[20] https://edition.cnn.com/2020/04/15/asia/china-coronavirus-qr-code-intl-hnk/index.html
[21] www.cnet.com/health/covid-19-could-set-a-new-norm-for-surveillance-and-privacy www.technologyreview.com/2020/04/12/999186/covid-19-contact-tracing-surveillance-data-privacy-anonymitywww.nytimes.com/2020/03/23/technology/coronavirus-surveillance-tracking-privacy.html

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authorities and NGOs. The applicability focuses on the analysis of the potential meaning of the enabler for the disaster or crisis management cycle.

4.1. Enabling technologies of the emerging opportunities

This section discusses about selected enabling technologies of the emerging opportunities such as location-based services, use of social media and crowdsourcing, satellite imaging, internet of things (IoT), use of drones and robots, 5G, artificial intelligence and machine learning with big data, and blockchain technology.

4.1.1 Location based services

Location based services (LBS) emerged in 1990s but became a fast-developing field only in the last 20 years after precise GPS positioning was made commercially available [10]. Raper et al. [11] discussed about LBS and computer applications that deliver information depending on the locations of the device and the user, and highlighted that it is hard to find a consensus on a more precise description, as the field is quite diverse and complex.

There are several ways to use LBS in disaster management, which can be divided into two bigger clusters [12]. Firstly, information can be sent from disaster managers and responders to the people in need of help. Secondly, information from people in danger situation can be sent to disaster managers. This can be done through both passive and active systems. Different LBS and types of mobility data can be used in all cycles of disaster management, and it offers great potential to improve decision-making, communicate information regarding impacted areas and potential evacuation trajectories and thus, relieve the scope of disaster impact [23]. A number of solutions have been proposed in this field.

Applications in which authorities send information to people potentially endangered by the crises is perhaps the most widespread use of LBS in disaster management [12]. One of the simplest examples is a Location Based Alert System used to send SMS to alert people about an upcoming natural hazard – one of such was used in India [71]. Some of similar, but more sophisticated systems, initiatives and prototypes include:

HelpMe, solution for aid requests in crisis situations when Internet connection has been disabled. The system exchanges information between smartphones in close proximity, which enables information to spread from people in need of help to disaster responders [13];

MyMapVolunteers, a mobile and web application prototype developed in Indonesia with a purpose of enabling disaster management coordinators share information with volunteers. The coordinators can see the locations of the volunteers and give them fast broadcasting messages etc. [72];

A subproject of GSMA's Big Data for Social Good initiative in Sao Paulo, in which information from mobile phone positioning, weather stations and traffic sensors is combined to estimate and map dangerous NO_2 levels and warn people in potential harm 24 to 48 hours prior to the pollution reaching dangerous levels [24].

LBS with the focus on communicating information to people in danger have the greatest impact in the early response cycle of disaster management. Challenges regarding such tools include the danger of smartphones running out of battery in the receiver hand, often the apps do not work without a 3G

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connection, the systems are concentrated to only certain types of phones (e.g Android or iPhone) [72]. In addition, there are also other challenges related to the capabilities of people, who are often in great need of help during disasters might not have a smartphone and apps, e.g. children, old people, homeless people. Or they are not able to use some technologies because they have disabilities or difficulties seeing or hearing. Or people with limited economic capacities that might share a phone with others or who don't have a smartphone at all.

The second method to use LBS is to gather mobile positioning data and use it in decision-making of disaster planning and emergency situations, often combining it with other data. Mobile positioning data can be divided into active (the system operator is tracking the phone at all time) and passive (the system operator is tracking the phone only when it is used for calling, texting etc.) positioning [14]. Passive mobile positioning data (also known as call data records or in short, CDR) usually has to be acquired from mobile phone operators. The data includes pseudonymized IDs, timestamps and type of phone activity, the ID of the cell tower that the phone was connected to and the origin country of the SIM-card can also be identified. Although passive mobile positioning data does not offer quite the same spatial and temporal resolution to analyze human mobility as can be done through active mobile positioning, it has several pros, such as it does not need any extra activities from the phone user and it does not drain the battery of the phone.

One of the first disasters where CDR was used was the Haiti earthquake in 2010 [18]. After the Christchurch earthquake in 2011 the statistics board in New Zealand concluded, that cellphone data provides information regarding the districts with greater inflow of people, patterns of rapid movement, relative inflows of people compared to ordinary ones and information regarding the regions which receive more people because of a nearby emergency [27]. CDR data has also successfully been used in flood management [28], humanitarian crises caused by political changes [15], and probably most widely to investigate potential spatial spread and epicenters of disease outbreaks [16], [73], 19].

One of the cutting-edge initiatives of using mobile phone data in disaster management is the Flowminder Foundation, what was created by the same group of scientists who contributed in the aforementioned Haiti earthquake. They have also estimated the numbers of displaced people after the Nepal earthquake in 2015 and Hurricane Matthew in Haiti using CDR data, releasing reports within few days after the disaster has struck. (flowminder.org) [25, 26]

Flowminder has also released an open-source toolkit called FlowKit, with which potential stakeholders can create origin-destination matrices, analyze commuting patterns and the placement of people, all of which can be used in disaster response [25, 26]. Besides Flowminder, who releases data briefly after the disaster, StreetLight Data used anonymized location data derived from smartphones and navigation devices in USA to identify limited evacuation routes, thus, generating information before the disaster to be used in crisis situation.

Projects funded under European Commission have not heresofar focused deeply to mobility data from location based services, through which disaster management programmes could benefit. Still, there are examples of widespread disaster area detecting and short-range detecting of locations of people.

Some of more outstanding programmes detecting and forecasting disaster-affected areas include ANYWHERE (2019) and beAWARE (2019), both of which are focused on the effects of extreme climate events. ANYWHERE models and assesses disaster-prone areas before the effects of extreme events themselves start taking place, thus enabling decision-makers and people to take preventative action. beAWARE created a platform which gather and analyses data from several different sources

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– weather sensors, social media, photo and video detection etc. This data is then processed with machine-learning algorithms and the outcome is sent to disaster responders.

A good example of short-range detection of people is provided by MOBNET (2018), who have created a device, that can be carried by a drone or a helicopter and detects mobile phones which are up to 5 meters deep in collapsed rubble.

The main challenges regarding the use of LBS comprise of privacy and ethical issues, problems with international cooperation, insufficient agreements regarding the privacy laws [20]. These have been recently addressed by [21], who proposed four models for the privacy-conscientious use of mobile data; and [22], who created a relative risk model of different aggregation levels of data to be used on a case-by-case basis.

Additionally, there are challenges regarding situations with power outages, disruption of internet connection possibilities or cellular networks not working [18]. This is a substantial methodological gap, because this means that in major disasters the LBS may be not working - insofar most of the services may not be usable in the culmination of the crises. One solution would be to use historical data prior to the crises to estimate the numbers of people in potential danger.

4.1.2 Use of social media

Social media emerged about 20 years ago as did mobile phones that later became smart phones with internet access and cameras. In some form or other, social media use has become part of everyday life of most Europeans. Smart phones have enabled people to use social media and contribute their own opinions and observations as well as photos, videos and audio clips even in mobile conditions. Social media has been studied and used in connection to crisis management throughout the crisis management cycle from improving preparedness, to supporting and informing during a crisis and to support in the recovery phase [29].

The five main use opportunities of social media in crisis management, their main benefits and challenges are described in the Table 5. Five main use opportunities, benefits and challenges of social media in crisis management . The first three opportunities deal with communicating and informing through social media services. Here, the main challenges deal with practises, skills, access and resources for communication. There are tools that help in managing communication and even automate it for some parts, but active human participation and genuine communication are needed for building networks that will be useful in crisis situations. During actual crisis situations, the volumes of data may be huge and with pressure and need to act quickly, ways to work need to be well defined in advance. Systems with capabilities to automatically analyse text, photos and videos are useful.

Table 5. Five main use opportunities, benefits and challenges of social media in crisis management

Opportunity	Benefits	Challenges
Communicating and building networks	Connecting directly to people in the affected areas Building trust. Builds the foundation to communication during crisis.	Takes time and long-term commitment to build networks and trust that are needed for successfully using social media in emergencies.. Requires skills to communicate and network. Many social media services with different user groups and cultures.

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		In acute crisis, difficult to follow and identify relevant messages.
Informing and warning	Quick spreading through networks.	Users with large networks need to share the message. Also rumours and misinformation spread quickly. Understanding and monitoring the spread of information.
Identifying needs and opportunities for helping	Quick. Opportunity for volunteers to offer and organise help.	Wrong expectations of authorities' responses to social media messages. Difficulties to organise help with many unexperienced volunteers.
Crowdsourcing for situational mapping	Gathering data quickly and with low cost from the affected areas. Familiarity with the tool. Little extra effort needed for learning.	Requires tools to capture data in structured form and analyse it efficiently. Data may be messy Extracting the data can only be done in ways and formats that the service provider allows. Installation of extra apps, and privacy issues
Monitoring data	Obtaining data quickly and with low cost from the affected areas. Spontaneous data, for example of the sentiment of affected communities.	Filtering relevant data out of the mass: - Location detection - Sentiment analysis - Event detection - Damage assessment Accessing to social media data sources. Multiple data format and unstructured data

Crowdsourcing and monitoring deal with using social media to gather data from locations. Crowdsourcing refers to actively asking people to act and co-operate, for example by sending specific data, photos or videos relating to the situation of interest. Monitoring refers to gathering and analysing existing data that can help in assessing the current situation or to detect information.

Poblet, García-Cuesta & Casanovas [69] divide crowdsourcing and monitoring into four layers (Figure 11). The bottom two layers deal with monitoring and the top two with crowdsourcing. The bottom level requires only that the users have their mobile phones on, so-called social sensing. The next level consists of utilising the data that people produce to public channels without intending to produce data for other than the immediate purpose. Reporters refer to the shared data being including some metadata, particularly hashtags that support harvesting relevant data. Microtaskers refers to using specific apps that help carrying out small task and gathering information.

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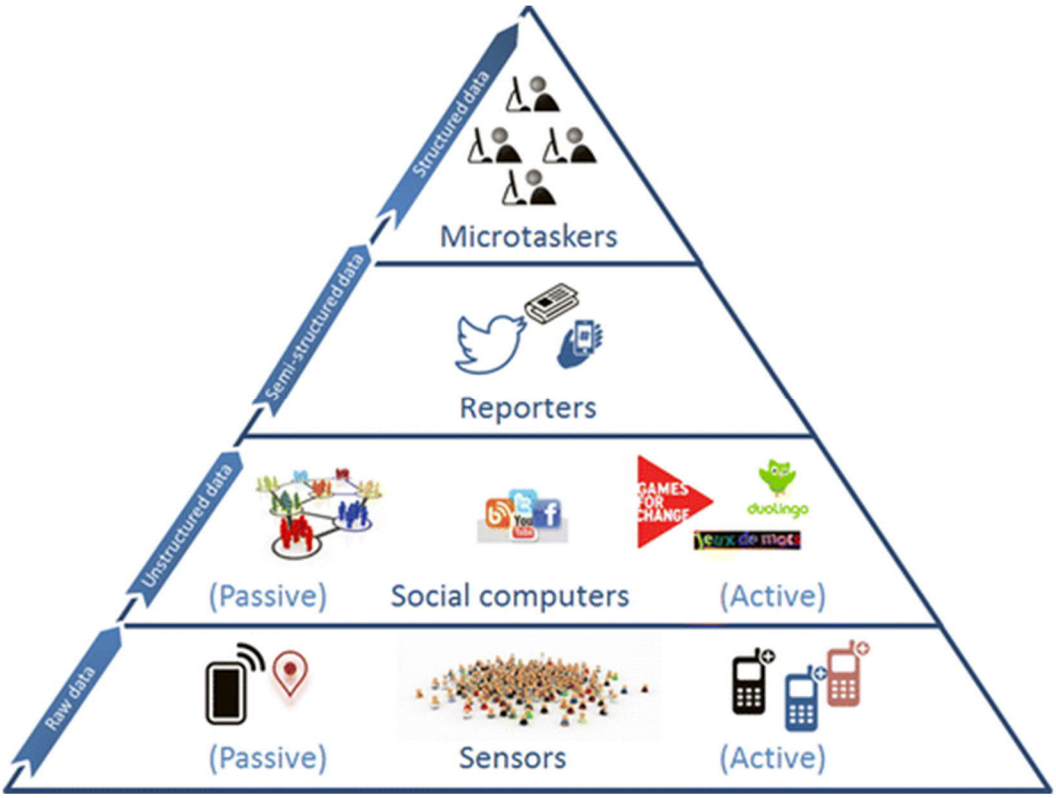

Figure 11. Four layers of crowdsourcing according to Poblet, García-Cuesta & Casanovas [69].

Crowdsourcing may be done using available social media services and using the opportunities they offer for describing and structuring data, or a special application may be used for gathering the data. Using hashtags in Twitter and Facebook, or groups in Facebook for gathering data are examples using the social media tools for crowdsourcing.

Poblet, García-Cuesta & Casanovas [69] analysed 38 tools for crowdsourcing for crisis management, out of which 25 were web platforms and 13 mobile apps. They describe what type of crowdsourcing the applications support and which phase of the crisis management cycle they cover. The most frequent use case for these applications was data collection in connection to a single developing event. The majority of the web platforms were open source or have open source components; several were powered by PyBossa[22], an open source software designed for microtasking applications. Uploading and sharing geo-tagged pictures was a common feature of the mobile apps.

Ushahidi[23], one of the applications included in the survey, is an example of a widely used app. It was originally developed to map reports of violence in Kenya after the post-election violence in 2008, and the system has been developed further to support gathering and visualising observations. By 2018[24], 150 000 deployments had been made to gather data for different purposes; 35 % of the deployments have been set up in connection to humanitarian and crisis response. Pánek & al. [30] report of Czech

[22] https://pybossa.com/
[23] https://www.ushahidi.com/about
[24] https://www.ushahidi.com/uploads/case-studies/ImpactReport_2018.pdf

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experiences of using Ushahidi to gather crowdsourced data in connection to floods in 2013. The COMRADES project (https://www.comrades-project.eu/) has developed tools on top of the Ushahidi platform to speed up and automate the analysis of user contributions.

The following includes some examples of available tools and recent research papers presenting crowdsourcing tools. I-react was a H2020 project[25] that produced software that is available[26] as open source or free software. A mobile application, web frontend for control room, back-end, and I-REACT Data Interface are available. Currently the I-React app is available in Google Play tuned to mapping and following weather-related events. The design process of the app is described in [31].

Felice & Iessi [32] introduce an app that can be used to upload structured messages to Twitter to report earthquake damages. The mobile application guides the users to give the essential information in a way that will be easy to extract making the processing of data, and the input gathered through Twitter. This way the Twitter infrastructure can be utilised.

Several papers report on research and development relating to combining social media data and data from other sources. Shah & al. [33] present an architecture for combining a variety of datasets (i.e., smart buildings, city pollution, traffic simulator, and twitter) to detect and generate alerts of a fire in a building, pollution level in the city, emergency evacuation path, and the collection of information about natural disasters. Fang & al. [34] analysed Wuhan 2016 rainstorm by comparing social media data with precipitation data, and found the social media information consistent with the storm events and correlation was found between social media activities and precipitation intensity.

Rossi & al. [35] take weather forecasts as the starting point that focuses the social media data collection and analysis to detect weather related events and problems. The beneficiaries of the system would be weather forecasters and first responders. Barker & Macleod [36] take risk areas as identified in their national geodata as the starting point and present a pipeline with state-of-the-art processing technology to filter flood-related tweets.

Surakitbanharn & al. [37] compared the images found on Instagram and Twitter with what could be seen through surveillance cameras to evaluate the usefulness of social media images. Their finding was that 10% to 13% of Instagram images were useful. Filter and automatic methods to analyse images are needed to scale up the approach.

[25] http://project.i-react.eu/
[26] https://mobilesolutionsismb.bitbucket.io/i-react-open-core/

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The H2020 project beWARE (https://beaware-project.eu/) is an example of a recently completed EU project that built a platform that combines multiple data sources and processes them to support emergency personnel in assessing the emergency situation and make decisions. In addition to using texts from social media, the platform includes automatic analysis of images either form social media or for example supplied by drones.

Social media is a potential data source to detect quickly unusual events, such as natural and man-made disasters. Suprem & Pu [38] present a framework for weak-signal event detection by combining sensor data with social media data. The signals from sensors help in identifying real events from the data where terms, such as the word landslide, may be used with many different meanings. Arachie & al. [70] present an approach for detecting sub-events, in other words, events within a big event like a bridge collapsing during a flood. The H2020 project E2mC (https://www.e2mc-project.eu/) created the Copernicus Witness Service Component to place social media data to Copernicus satellite images.

High level Natural language processing (NLP) is needed for tasks like text classification, sentiment analysis and topic extraction. These can be used in extracting information from social media feeds. Machine learning and AI solutions based on deep neural networks have improved the performance of these tasks. One drawback of deep learning technology is the need for large training sets, but the latest development in creating and using pre-trained models may help there. Pre-trained models represent transfer learning and they reduce the need of training data because only the specific features relevant in an application need to be taught and the general language knowledge comes with the pre-trained model. Google AI's BERT, Allen AI's ELMo, Open AI's GPT-2 and Fast-ai's ULMFiT are some of the available pre-trained models. Considerable improvement has been achieved in tasks like entity recognition, question answering, classification and sentiment analysis when using transfer learning [39, 40].

Fan, Wu & Mostafavi [41] propose and demonstrate a pipeline for detecting locations and disaster events. Despite of service support on location awareness, only few tweets seems to have location coordinates. To address this challenge, the pipeline integrates "Named Entity Recognition for detecting locations mentioned in the posts, location fusion approach to extract coordinates of the locations and remove noise information, fine-tuned BERT model for classifying posts with humanitarian categories, and graph-based clustering to identify credible situational information".

Monitoring the population sentiment is relevant in crisis management throughout the recovery process. Shibuya & Tanaka [42] showed multiple correlations between sentiment on social media and the socio-economic recovery activities involved in restarting daily routines. This offers a quicker way to monitor recovery than official statistics which are produced with considerable delay.

Singh, Roy & Gangopadhyay [43] present the use of sentiment analysis with the latest technologies for capturing the sentiment and particularly the changes in sentiment in connecting to events like the Las Vegas shooting in Oct. 2017. Sarkar & al., [44] report the use of NLP and sentiment analysis to extract people views on who was to blame for the Chennai water crisis.

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4.1.3 Satellite imaging

Satellite imaging provides the way to monitor large areas in a hazard situation. Both earth orbiting remote sensing satellites and meteorological satellites provide information both for hazard risk mapping and for hazard detection, monitoring and mapping. Their passive optical instruments measure the reflected or emitted visible and infrared radiation, thermal instruments the temperature, and active SAR or radar instruments measure the distance and the backscattering intensity.

Typically floods and wildfires can be mapped accurately from optical images, landslides and earthquakes from SAR images, and heat waves and storms from meteorological satellites.

The critical parameters of satellite images are the spatial resolution, or pixel size, and the timeliness. The spatial resolution spans from 0.3 m to several kilometers. The timeliness of the satellite images is usually max few days, but with the programming possibility of the instruments, the imaging can be directed toward the hazards area from several satellites and orbits to increase the timely imaging.

Applications of satellite imaging

Hazard monitoring, delineation and mapping

Several services provide global data on hazards and extreme weather events based on satellite imaging:

1. International Charter on Space and Major disasters https://disasterscharter.org/web/guest/how-the-charter-works, https://cgt.disasterscharter.org/
2. Copernicus emergency service https://emergency.copernicus.eu/mapping/list-of-activations-rapid
3. European severe weather database (https://www.eswd.eu/, https://www.essl.org/cms/european-severe-weather-database)
4. National Meteorological Institutes
5. NASA earth observatory https://earthobservatory.nasa.gov/images/
6. USGS earthquake events https://www.usgs.gov/natural-hazards/earthquake-hazards

The International Charter on Space and Major disasters provides satellite images for free in disaster situations from several satellite image providers. In the service27, a specific country can be selected for looking images of hazards in that area. It also allows selection and focusing on the satellite specific material in the charter, among most relevant the SPOT-, Sentinel- , Landsat- , ALOS- and RadarSAT-series satellites.

The Copernicus emergency service seems to be the most active and up-to-date service. It lists and delineates all hazards for which a satellite imaging request has been sent by the national accredited

27 https://disasterscharter.org/web/guest/library

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authority. It contains hazards globally since 2012, but in practice, European hazards are dominating. Figure Number shows, as an example, the hazards in Europe in 2019. Wildfires and floods are the dominating hazard types. In some cases, for instance the Italian Amatrice earthquake, also detailed maps and statistics on damaged buildings is available. The delivery times of impact assessment, delineation of the impact area and detailed damage mapping are from 3 hours to 12 hours in urgent cases, and 1-5 working days in less urgent cases (https://emergency.copernicus.eu/mapping/ems/rapid-mapping-portfolio).

Figure 12. Hazards in Europe with Satellite Imaging Request in 2019[28].

Humanitarian support

Natural and man-made crises and disasters force people to move from their homes, and they often end up in camps. To estimate the need for food and equipment, an estimate of the number of refugees is needed. This can be done from very high-resolution satellite images, like GeoEye and QuickBird [74]. The geohydrological situation around the camps can be mapped from high-resolution satellite images to identify possible well sites, which could decrease the need for water transport from long

[28] *Source: Copernicus Emergency Management Service (© 2019 European Union).*

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distance. Here high-resolution Sentinel or Landsat series satellites with spatial resolution between 10m – 30m are suitable. These activities are being developed for instance at the Z_GIS of the Universtity of Salzburg (http://zgis.at/research/)

HOT (Humanitarian OpenStreetMap Team) is an international team dedicated to humanitarian action and community development through open mapping. Anyone can participate in this team. In case of disasters, satellite and other imagery are provided to the team to analyze the impact area and map the damages (https://www.hotosm.org/).

The role of satellite images will most probably increase in disaster mapping and also the dissemination of physical impact maps to all citizens by LBS and mobile phones. More in general, the role of spatial information and GIS in epideomologic surveys and maps is shown in this Covid-19 situation, see for instance ESRI covid-19 HUB (https://coronavirus-resources.esri.com/) . Satellite images, like Sentinel 5P, have also shown probable associations between air pollution and deadly Covid-19 cases (https://www.nationalgeographic.com/science/2020/04/pollution-made-the-pandemic-worse-but-lockdowns-clean-the-sky/).

4.1.4 Internet of Things (IoT)

The use of sensors for monitoring conditions that could trigger disasters dates back several years. Improvements in cloud computing, broadband wireless networks, the sensors themselves and data analysis have led to the emergence of powerful, integrated and real-time systems referred to as the Internet of Things (IoT). Multiple definitions can be found online on what IoT is, however, the term generally refers to world-wide network of interconnected objects having unique identity and communicating using standard protocols [47]. Disaster management is an ideal place for IoT applications, since sensors can send alerts about potentially dangerous situations. Tree sensors can detect if a fire has broken out by testing temperature, moisture and carbon dioxide levels. Ground sensors can detect earth movements, which might signal earthquakes. River levels can be monitored by sensors for possible flooding [57]. From an implementation point of view, IoT is utilized by establishing a system that connects and feeds data to a main server or center. The collected data in that aspect is then transformed and easily accessible by first responders and government officials. As timing is a crucial component in disaster response, utilizing IoT data provides a real time information for the crisis on the ground.

The utilization of IoT is massive and the numbers continue to grow. For example the number of IoT connections within the EU is estimated to increase from approximately 1.8 million in 2013 to almost 6 billion in 2020, leading to the EU IoT market being higher than one trillion euros by 2020 [48]. The wide distribution and availability of IoT based protocols and applications enable a fruitful ground for the development of disaster management solutions. A brief overview of a selection of IoT based disaster protocols will be presented below as well as market available solutions.

There are several varieties of IoT protocols that can be used in disaster management. Ray et al. [49] separate them in: infrastructure, discovery, data, communication, semantic, multi-layer framework, and security. The categorization is needed because each disaster requires a customized approach due to the specific characteristics and obstacles it brings.

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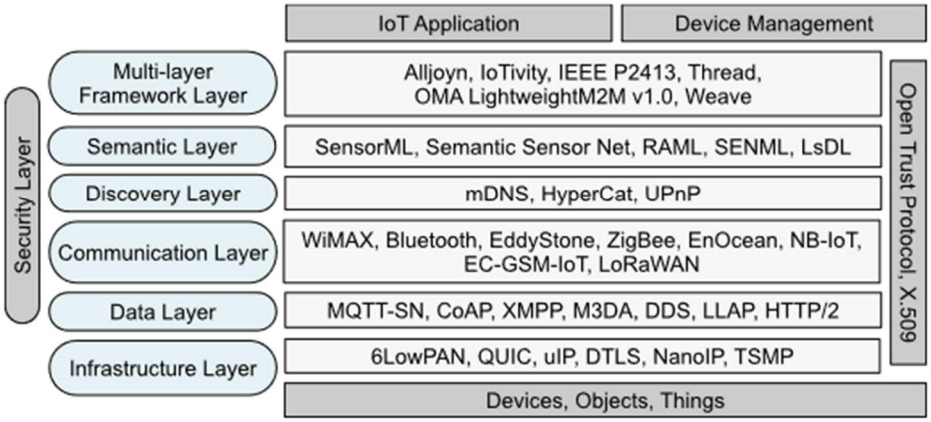

Figure 13. *Stack-supported reference model for IoT-based disaster management [49]*

Figure 13 shows how these protocols can be connected and utilized to connect data, access information, discover data etc. (. These protocols are used widely to develop disaster mitigating solutions. Full exploration of these protocols and their potential application can be found in Ray et al ([49]. Aside of the IT protocols there are multiple 'off-the -shelf' IoT solutions available for usage in the market either as a service or product. Here we present several examples:

- Grillo [50] is an smart hazards alarm that can be installed in homes connected via an mobile app which alerts users of imminent earthquakes.
- MyShake [51] utilizes a crowd source quake monitoring system that is monitored by the Berkley Seismological Laboratory. The app detects seismic activities via the phone accelerometer and notifies the user if it is an earthquake.
- BRCK [52] is an IoT enabled device that provides connectivity in remote and poor areas. The advantage of BRCK is that it can work on solar energy thus being a suitable device to be used in disaster affected areas.
- Firecity [53] uses a system that connects fire alarms to an app via the Internet of Things (IoT) tech.
- SymbloTic [54], which uses sensors to monitor strategic, high-risk flood areas and alert municipalities in the event of a disaster
- Wellcheck [55]**,** provides a solution to help authorities and impacted consumers monitor and prevent pollution in drinking water.

Analysis of EU funded projects on IoT

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With regards to the current IoT funded projects from the European Commission, research on the Cordis portal was done using the keywords: “IoT”, “Internet of Things”, “disaster”. The research results returned several projects that are focused specifically on disaster prevention/ management, and in addition to this, also the application of their IoT product in disaster prevention/management.

The research revealed several important tools that were developed in this context. For example, the CUBE project refers to an autonomous and plug-and-play solar-powered system, able to create supply points in electricity, clean water and internet in IoT cubes of 585 x 585 x 585 mm.[29] As such the cubes can be deployed in disaster affected areas to provide the population quickly with water, energy and mobile network.

Quake Engineering proposes a distributed sensor network (QUAKEBOTS) that is capable of automatically detect the occurrence of primary waves during a seismic event, and acting as a distributed IoT P2P neural network, propagate an alert to all the other nodes in the network in cascade. This “signaling” wave propagates much faster than the harmful secondary waves, providing the users with a local acoustic and visual alert, giving them a small time frame in the magnitude of tens of seconds for taking safety critical actions.[30]

BigClouT platform, was developed as a tool for providing a modular framework to build customised solutions for today’s smart city challenges including concerns in interoperability and big data. BigClouT is composed of various parts, each one contributing to provide main features that are implemented through corresponding tools developed within the project such as:

1. KNOWAGE-an open source business intelligence suite providing different analytical tools to create reports, charts, graphs and interactive cockpits, in order to visualise data on maps, to perform multidimensional analysis, to extract knowledge.
2. The BigClouT Data Lake- a shared repository that is used to manage both static and real-time data from BigClouT partners. Based on the popular CKAN open data platform, the BigClouT project enabled its extension with a real-time capability allowing it to provide high performance queries over real time (streaming) data from city sources.
3. sensiNact- an open IoT platform dedicated to the smart city domain. It provides support for various IoT protocols and platforms to provide a homogenous access over heterogeneous city data sources.
4. ECA Verifier- an open source plugin which implements the functionality of self-aware conflict resolution for service composition. It improves the degree of dependability of the platform by automatically detecting and resolving conflicts among applications developed and deployed in sensiNact.
5. SOXFire- a multi-community city-wide sensor network for sharing big, social, sensor data in smart cities. The goal of SOXFire is to provide practical distributed and federated infrastructure for IoT sensor data sharing among various[31]
6. AdvIOT is a project aiming at strengthening research partnerships through staff exchanges and networking activities between eight worldwide organizations, addressing scientific issues related to Advanced Methods for Analyzing and Improving the Reliability and Security of Novel Environmental-friendly Wireless Devices for Internet of Things. The programme of exchange is focused on novel RFID- and WSN-based green IOT devices with renewable materials that were developed for different applications by using additive manufacturing methods. As a result of the AdvIOT, novel tool for testing, analyzing, and

[29] https://cordis.europa.eu/project/id/827152
[30] https://cordis.europa.eu/project/id/806911
[31] https://cordis.europa.eu/project/id/723139/results

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improving the reliability and security of these new devices in various demanding applications and environments, such as in healthcare, disaster prevention, and intelligent transportation, was achieved.[32]

Most essential challenges

IoT is a constantly evolving area that brings forth a lot of opportunities for disaster management. However, three challenges can be identified:

1. Data-various developed systems in this field use different format, sizes and semantics of how and in what way data is collected, processed and utilized from disastrous events.
2. Cost:in lower income countries, development of such IoT devices would come with a set of financial and resource connected challenges. Reduction of the costs for components and services to host IoT applications will ease the development and dissemination.
3. Fault tolerance refers to the ability of a system to be resilient and continue to work without any interruption when one or more of the components are damaged or stop working. Usually the fault tolerance shall ensure that there are enough resources to replace the damaged component and that the system continues to operate.

A discussion on future opportunities, challenges and ideas for their solution

With the identified issues above, several recommendations can be made for the future development of IoT solutions in disaster management. For example, when using data, an effort can be made to provide a framework that will specify the format and structure on how data should be standardized. Secondly, the reduction of the cost of IoT devices and communications can have positive effect on the development of IoT solutions. Lastly, the Internet-of-Robotic-Things (IoRT) is another novel area that should be explored in the area of disaster management. The Internet-of-Robotic-Things (IoRT) is an emerging paradigm that brings together autonomous robotic systems with the Internet of Things (IoT) vision of connected sensors and smart objects pervasively embedded in everyday environments [56].

Though several advancements have been made in this field, such as the development of highly specialized robots to be used in rescue operations and post disaster response, still this field is in an early stage to properly identify its applications.

4.1.5 Intelligent transport systems and other data sources in transport system

The transport system provides a number of data sources, which have potential to contribute to disaster management. Some transport operators, transport authorities or infrastructure managers may also be able to inform their users or travellers about an imminent danger or to initiate traffic control actions.

In case of urban transport, the public transport authority or an individual transport operator (e.g. operator of the metro system) may be operating a security control room with access to cameras in public transport vehicles and at public transport stations and terminals. The security control centre may also be able to inform travellers and public transport staff of an imminent danger, e.g. via loudspeakers installed at stations and terminals or via passenger information systems.

[32] https://cordis.europa.eu/project/id/611606/reporting

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The main links of the road network or special locations such as tunnels and bridges may be equipped with roadside traffic monitoring equipment such as magnetic loops, cameras or radar detectors. The information collected with monitoring equipment installed on the road network is typically communicated to the traffic control centre of the road operator (e.g. national road authority or city authorities). The use of this information in various disaster scenarios would be an interesting research topic. In case of incidents, the traffic control centre may disseminate real-time traffic information to warn road users, e.g. via RDS-TMC (radio data system - traffic message channel) messages, radio broadcast stations or variable message signs installed on the road network. In some cases, the traffic control centre may also be able to initiate traffic control actions facilitating disaster management, if appropriate roadside systems are available (e.g. to close entrance to a tunnel where an accident has occurred).

4.1.6 Use of drones/robots

The drones are basically unmanned vehicles that usually have no human occupant on board. They can also be classified as robots, which can be autonomous, semi-autonomous and/or remote controllable cyber-physical entities. The drones can be applied e.g. in aerial, underwater or on ground vehicular way.

Unmanned aerial vehicles (UAVs) have initially been developed for military use [57]. They have also applied to aerial photography and package delivery. UAVs can fly in places where manned aircraft cannot fly. In addition, they can also fly at low altitudes, and therefore the images from drones are of higher resolution than satellite images. Drones have been used for example after Hurricane Katrina in the US in 2005 [61]. Because roads were blocked by trees, small drones were deployed to search for survivors and assess river levels. Currently UAVs are used for preparedness, response and recovery. For example, monitoring volcanic activity in order to determine when warnings should be created can improve preparedness for volcanic disasters. UAVs can be applied also for delivery of goods to locations where ground-based transportation has been disrupted, which can improve rapid response actions. They can also be applied to record video/picture material depicting damages in disaster areas, which can help planning of recovery actions. They have also potential to collect information in locations that would be unsafe for human user due to hazardous chemicals (e.g. gas), radiation, risk of fire or explosion, imminent threat of violence etc.

Unmanned underwater vehicles (UUV) can measure e.g. storm intensity and direction [57]. The positioning under water is challenging and therefore the use range is limited [62]. For example, UUV that carry sensors to measure ocean heat, salinity and density has been applied in hurricane status detection during Hurricane Florence in the US in 2018. Sensors measured the ocean heat fueling the hurricane and transmitted the data to the National Weather Service. The data fill in gaps left by satellite images improving hurricane modelling. The data also enhance forecasting the intensity and route of the hurricane, and the sensors measure salinity levels to determine how much water from rain and rivers is mixing into the ocean.

Robots have become more sophisticated through integration with microprocessors and sensors [57]. Their growing dexterity makes them suitable for disaster situations that are too dangerous for humans or rescue animals. Search-and-rescue robots were first used following the September 2001 terrorist attack in New York City to assess the wreckage of the demolished World Trade Center. Since then, more than 50 deployments of robots for disaster use have been reported. Breakthroughs are being achieved in Japan, where there is the possibility for commercialization of robots designed specifically for disasters.

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Examples of UAV use for different disaster phases include (e.g.): Preparedness such as videoing volcanic activity in order to determine when warnings should be issued [63]. Response such as delivering equipment to locations where networks have been affected by a disaster: For example, China has been using drones to deliver mobile gear to affected areas as well as a virtual tower functioning as a base station. Drones are already used to deliver blood in several countries, and this could be expanded to include other medical supplies and equipment needed during a disaster [64]. Another example is the use of drones to assist Australian firefighters at night. A Lockheed Martin Indago drone (Figure 2.2) streamed live video to operators on the ground, who used the images to determine fire location and intensity, and find people and property that were at risk. The drone helped save an estimated 100 homes, worth more than USD 50 million. Assisting with recovery efforts by photographing disaster areas for damage assessments. The Pacific Drone Imagery Dashboard uses data from satellites and now drones for creating maps for disaster preparedness, response and recovery.

4.1.7 5G

The so called 5G has been under development since year 2012 within wireless communities around the world (International Telecommunication Union (ITU), World Radio Conference (WRC), 3rd Generation Partnership Project (3GPP), Global Mobile Suppliers Association (GSMA)). The target of the 5G has been to facilitate broadband-connected society via high-capacity optical networks for the backbone of 5G (virtual networks, network function virtualization and network slicing), allocation of additional spectrum for wireless communications and specification of the new 5G radio interface using the referred spectrum. In practical level, actions related to detailed specifications for the new 5G radio interfaces, strategies to increase the use of radio spectrum and efficiency of emerging 5G systems and their realization in companies in the field have been addressed. There are today many countries that are deploying 5G, telecom operators in ~50 countries are working and targeting to providing services for 5G before end of 2022 [57].

From the technological capabilities perspective, 5G technology has higher capacity, is faster and has lower latency compared with previous generations [60]. Therefore, it seems to be essential enabler for the more real-time communications with mobile assets such as e.g. vehicles, robots, drones, cameras and other sensors etc. which produces big amount of data and require low latencies in interaction with infrastructures. Multimedia type of camera sensors generate vast amounts of data that need to be shared rapidly. Drones can be more effective if high definition images can be transmitted in real-time, instead of having to wait until they return to their base. In addition, the drones may even be controlled remotely based on the referred information streams. This means that 5G can provide essential novel opportunities especially in increasing situation awareness and real-time on-site operation of first responders in disaster situations.

4.1.8 Artificial Intelligence (AI) and machine learning with big data

Software algorithms are increasingly generating valuable insights about a variety of phenomena, which allows computers to imitate human intelligence, called as artificial intelligence (AI) [57]. Examples of AI are already operational, such as voice and facial recognition, and commercialized by

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products such as the IBM Watson33 computer system, which integrates AI into the analysis of Big Data (see Figure 14. Watson has been applied to disaster scenarios by having it analyse weather and census data to help organizations prepare for a crisis and optimally allocate resources.

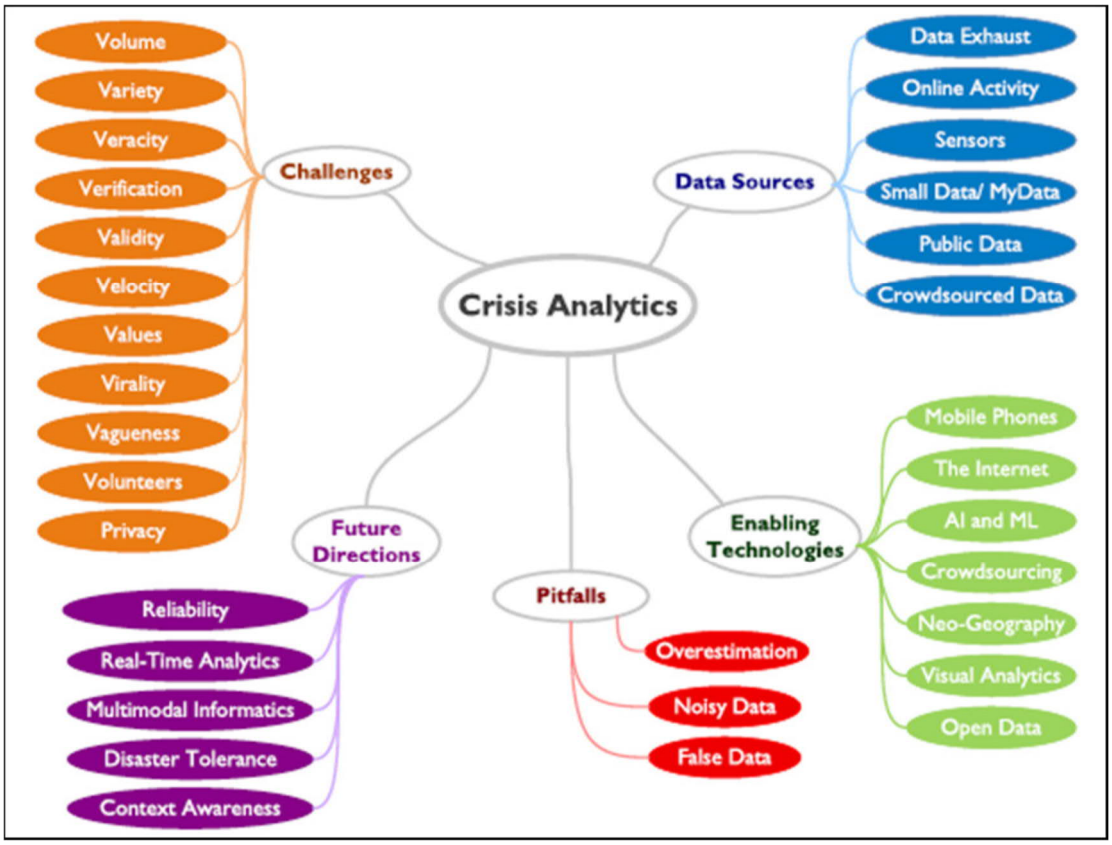

Figure 14. Artificial intelligence (AI) as the part of the Big Data and crisis analytics [65]

AI could have tremendous impact for disaster management, from potentially predicting earthquakes to quickening recovery and response times. Humanitarian groups are hoping to speed up map creation by using machine learning in computer software to extract objects such as buildings and roads from aerial images. Considerable research effort is currently being devoted to the use of AI for detecting and maybe one day predicting earthquakes. AI does not need to be costly, as shown in research by the Tanzania Meteorological Agency on weather and climate monitoring. The Agency used the PHP programming language to execute equations regarding meteorological observations, with the software refining its calculations to make better predictions. The cloud-based system features a user-friendly web-based interface and utilizes the free open source MySQL database management software.

Artificial intelligence (AI) and machine learning have advanced means and thus also good potential to be applied for help in making predictions and in identification and classification. **Processing information:** AI is used for image recognition of satellite photos to identify damaged buildings, flooding, impassable roads, etc. Multiple data streams can be combined with unreliable data removed and heat maps generated. For example, DigitalGlobe (https: //www.digitalglobe.com) provides open

33 https://www.ibm.com/watson

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source software for disaster response that learns how to recognize buildings on satellite photos. Following the Nepal earthquakes in 2015, humanitarian and relief groups used pre- and post-disaster imagery and utilized crowdsourced data analysis and machine learning to identify locations affected by the quakes that had not yet been assessed or received aid.

Emergency calls: During a crisis, call centres are often overwhelmed. In addition to voice calls, emergencies are increasingly reported by text messages and social media. AI and machine learning are being applied to cope with the volume and different types of calls. In the United States of America, Watson, developed by IBM, is being used for speech-to-text recognition at emergency call centres. The text is input to analytical software that guides operators on how to respond to the call.

Social media analysis: Real-time information from social media sources, such as Twitter and discussion boards, can be analysed and validated by AI to filter and classify information and make predictive analysis. Artificial Intelligence for Disaster Response (AIDR) was created to process the large number of tweets generated during a crisis.1 AIDR uses machine learning to automatically process tweets in real time. The software collects tweets based on hashtags and keywords, and then uses AI to further classify them by topic. The open software is free for those who work in crisis response.

Predictive analytics: AI is being used to analyse past data to predict what is likely to happen in the event of a disaster. Optima Predict software processes information from emergency response systems to optimize ambulance routes. The data can be integrated with online dashboards so that emergency personnel can respond in real time.

It is obvious that AI provides potential for advances in disaster management, however there are challenges arising from ethical and privacy issues34. In addition, AI can make mistakes just as humans can, so they should not be the only base for analysis, predictions and emergency plans.

4.1.9 Blockchain technology

An essential challenge in disaster management is related to the quality and reliability of the information exposed from disaster area [57]. More specifically, how to co-ordinate and verify the information that is shared by other stakeholders to be enough high quality level for the use in disaster management. For example, the United Nations found that, in the wake of the 2010 Haitian earthquake, assistance efforts were hampered by too many data sources among the some 20 relief groups [66]. A potential solution approach is provided by Blockchain technology. The Blockchain distributed ledger system and chain of verified information records could play a significant role in improving control of information sources/validity.

In the US, the Center for Disease Control and Prevention is planning a pilot test of blockchain for a more rapid and reliable collection of data during a crisis, in order to reduce the spread of disease [67]. This has relevance for disaster management, since similar to public health, agencies offering relief (e.g. government, assistance agencies, telecom operators, food suppliers, transporters, health workers and the public) need to share trusted data quickly to collaborate effectively.

34 https://kambria.io/blog/the-7-most-pressing-ethical-issues-in-artificial-intelligence/
https://plato.stanford.edu/entries/ethics-ai/

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Another way blockchain technology is already indirectly used for disaster relief is for fundraising activities that accept cryptocurrencies [68]. Several organizations – including Direct Relief, Humanity Road and Save the Children – currently accept cryptocurrencies such as Bitcoin in their fundraising activities.

4.1.10 A discussion on maturity of enabling technologies for the opportunities

A maturity estimation of the enabling technologies for the opportunities is presented in Table 6. We use the following maturity stages of technologies in the estimation: research, concept, prototype, demonstration, validation in a real use case, deployments in use cases, or applied in disaster management. In addition, the Table 6 shows also in which phases of disaster or crisis management, the technologies described above can be applied.

It is estimated that the analysed enabling technologies can be applied mostly in all disaster life-cycle phases. However, for example use of drones, 5G, and use of social media can be more applicable in immediate response to disaster, and blockchain in the recovery phase. The maturity of the technologies is a bit fuzzy to estimate, because some details of the technology can still be in research stage even if some basic features are simultaneously applied in disaster management of real world cases. Our current estimation is that the IoT and blockchain technologies are still mainly in the research, concept and prototype stage. Use of drones, AI/ML with big data and 5G is proceeding towards real use cases. Location based services, use of social media, and satellite imaging are in validation or are already applied in use cases in disaster management.

Table 6. A maturity estimation and application of the enabling technologies

	location based services	use of social media	satellite imaging	Internet of things (IoT)	use of drones /robots	5G	AI/ML, big data	Blockchain
Disaster management cycle35	all	immediate response to disaster, recovery	all	all	Immediate response to disaster	Immediate response to disaster	all	Recovery
Maturity stage	deployments in use cases, applied in disaster management	deployments in use cases, applied in disaster management	deployments in use cases, applied in disaster management	research, concept, prototype	demonstration / validation in real use cases	validation in real use cases	demonstration / validation in real use cases	research, concept, prototype

35 The disaster or crisis management cycle consists of phases such as preparedness, mitigation, response and recovery.

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The discussed enabling technologies provide essential basis for the advances in the disaster management operations, however, even basic real-time communication/information sharing between multiple stakeholders, multiple vertical domains, and people demonstrate several barriers before the full potential of the referred enabling technologies can be properly applied in disaster management. Such barriers can be, for example, heterogeneity of communication means, multiple information syntax and semantics, and recent regulations related to privacy.

The heterogeneity of communication means cause challenges with public warning systems (PWS). The number of technologies and communication channels for delivering PWS messages are continuously increasing, e.g. Hybrid Broadcast Broadband TV, DAB+, and satellite, which may be used together with the legacy channels clarified in the section 2.1-2 and [5]. Therefore, the problem of the emergency managers may be a complex mix of different technologies for delivering PWS messages, which makes it difficult to determine which technologies are best suited for the specific emergency. Therefore, some common format for composing warning messages sent out using multiple channels is clearly needed. One such specification is Common Alerting Protocol (CAP), which is a general format for exchanging all-hazard emergency alerts and public warnings over all kinds of networks. CAP allows a consistent message structure for every warning message to be disseminated simultaneously over many different warning systems, thus increasing warning effectiveness while simplifying the warning task. For example, Multiple Alert Messages Encapsulation over Satellite (MAMES protocol) can carry CAP messages efficiently over a Galileo/EGNOS (the European navigation satellite programmes) satellite link. In addition, a tendency for including more rich media delivery in public warnings is emerging.

The recent General Data Protection Regulation (GDPR) cause essential challenge for sharing any information that may possibly be connected to an individual person [59]. It is estimated that this challenge is related to, for example, location of people and their IoT or CPS assets, the information shared in the social media, detailed entities and objects in the satellite and drone based images, IoT assets, 5G subscriptions, and cryptographical identities in the blockchain applications. This means that there are still future research to be done before the full potential of the discussed technical enablers can be deployed in full scale in disaster management.

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4.2. Importance of emerging opportunities for disaster management stakeholders

The technological perspective discussed in section 4.1 is the enabler of the emerging opportunities to improve disaster management operations. In this section we speak about the importance and capability of the selected technical enablers to support the needs of the disaster management stakeholders. Especially, the estimations of the different disaster management stakeholders belonging to the BuildERS consortium are focused. Their estimation of importance of emerging opportunities arising from recent technological advances (emerging technological opportunities) is presented in the Table 7, and shortly discussed in this section. The importance is estimated using priorities (1-6), so that the number 1 represent the highest priority and number 6 the lowest priority in the Table 7.

Table 7. Importance (priorities) of emerging opportunities for disaster management stakeholders.

Organization type (name of the organization)	**Crowdsourcing/social media**	**Media/communication related opportunities**	**creation and use of location based information**	**Use of drones**	**Automatic analysis of texts and images with machine learning and artificial intelligence**	**New technological opportunities (ex. 5G, IoT, sensor technologies, blockchains etc.)**
Priorities of Official responders - fire & rescue (ERB)	5	1	2	4	6	3
Priorities of Official responders - police (PUC)	4	1	3	2	5	6
Priorities of Official governmental - area civil protection (PAT)	5	6	4	2	1	3
Priorities of Non-governmental, civil society organization - prior collaboration with authorities in the area (DRK)		2	1		(3 - linked with 1 and 2)	
Priorities of Non-governmental, civil society organization - no prior collaboration with authorities in the area (SAL)		1	2		(3 - linked with 1 and 2)	
Average priorities	4.7	2.2	2.4	2.7	3.6	4

Official responder - fire & rescue (ERB - Estonia):

The first priority is to use the location based quick public warning system that allows reaching to all people (sms warning, warning apps, social media warnings etc.). It is obvious that these instruments may have challenges to reach all people, e.g. children, old people, homeless people, people who

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have difficulties to see or hear, people with disabilities. However, adequate information that reaches people in time makes them more resilient and reduces their vulnerability. Additional opportunities of messaging or using social media within or between communities makes the community more resilient, and reduces the need for help from outside. Adequate information in the beginning and during the crisis is crucial and in addition to different possible sources of information (social media, on-line news etc.) it is important to have a trustful official source of information (e.g. official crisis website).

The second priority is the creation and use of location based information. Knowing the endangered area and vulnerable people in this area helps to prioritize the interventions and information sharing. It is important to be able to create the on-line information of the endangered area by using and combining the available databases, mobile positioning, different kind on sensors and cameras from this area, satellite pictures, drone pictures, crowdsourcing of social media etc.

The third priority is to look for the new technological opportunities that support planning and execution of interventions. The aim of these technologies is to support the first and second priorities (adequate and quick warning; creating information based on the position of the population, e.g. causalities and subjects at risk). So far it is already possible to use the information of the public security cameras, fire alarms from the public buildings, and various types of event reporting etc.

The fourth priority is to widen the use of drones. That gives the additional opportunities for collecting information and executing interventions in the areas that are hard to reach or that are dangerous for people. They also give an additional dimension for getting the overview of the endangered area (including the information from added sensors – infrared, radiation, chemical etc.).

The fifth priority is crowdsourcing. Collecting information straight from the people in the endangered area by using the two-way communication or analysing social media gives often the useful information of the dangers and vulnerabilities. At the same time, it is important to be able to analyse the risk of misinformation and misinterpretation of information. Often, in the disclosure of information relating to a disaster, there is a natural and psychological tendency to expand the news and its effects.

The sixth priority is the use of machine learning and artificial intelligence for analysing the text and images. There is need for prototypes for estimation of benefits and usefulness of these technologies.

Official responders - police (PUC - Finland):

Overall, the police could use technology to better observe and analyze the working environment so that they can forecast negative side effects and phenomena. The approach of the police has traditionally been reactive and there is a need to direct more focus on preventive measures when considering technological innovations and their usefulness.

Police would benefit from a comprehensive strategic view regarding the use of technology and tool development; it should also pay attention to understanding the requirements of technology in the different phases of the disaster or crisis management cycle. Furthermore, as development of technology is mainly market driven in Europe, the market should be closely followed; most of the patents come from Asia.

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Overall, there are often budgetary restrictions to what technology can be incorporated into the police. Nonetheless, the internal security aspect should be in the focus when developing and incorporating new technologies. As a final point, misinformation is a significant threat. If the authorities do not respond quickly or there is confusion as to who is responsible for crisis communication, someone else will occupy that communicational space.

Accessibility/alerting - communication to citizens during the disaster

The main purpose of the police is to ensure the safety of citizens. Therefore, effective alerting and communication towards citizens is a priority for the police. In the acute phase of the crisis, alerting is vital. The ability to warn citizens with a localized message that could reach all devices regardless of any pre-existing application would be helpful. At the same time, such an alert and the foreseen benefits have to be carefully weighed as short messages do not enable detailed instructions and can potentially have adverse effects. It should therefore seriously be considered which communities would benefit from such messages. Furthermore, there might be technical capacity issues such as how much traffic a single base station can handle as well as legal restrictions to consider. Sometimes, in order to get the message across, traditional methods can better ensure that most citizens are informed. The reliance on technology also makes assumptions on the availability of electricity. These types of services might not be useful in all crises or prolonged situations.

Police has a smaller role after a crisis. At that stage, police procedures are most related to aftercare for the personnel, i.e. those who have been involved in traumatic events or work assignments. Some sort of feedback channel for the citizens with analysis elements might be useful in order to increase trust in authorities and increase resilience at the national level. This type of tool might take citizens into account in a more direct way. Currently only the Finnish Safety Investigation Authority produces a report on larger hazardous events or disasters. Religious actors and social and health care sectors are usually in charge of the recovery phase.

Drone technology

Drone technology has much potential and can be quite cost effective. Essentially, drones can help in obtaining a more accurate situation awareness; they are also widely available. Such technology can be used to provide aid, give instructions and send tools or parts. Drone technology is versatile as other technology can be attached to it, such as sensors to detect chemicals or poisonous gasses, or heath sensors that can be used in different types of rescue scenarios, or drones can be used to deliver drugs in unreachable areas. Furthermore, drones can be used on the ground, in water as well as in the sky and their power sources vary from electricity to internal combustion engine.

The security issues related to drone technology should be discussed more comprehensively. Currently their use is mainly divided into military use and market driven, commercial use. There should be a third category related to safety. This would require European development and European components that would also lead to better standardization. A step towards this direction is enabling a common drone flight license in all EU member states since July 2020. Moreover, the devices are available to all and can also be used for criminal purposes, their use should therefore be well controlled. Technological innovation is needed to disable or override the controls of unsanctioned

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devices and to ensure their overall safety. For example, drones have to be controlled, but disabling or overriding the controls may be difficult to implement safely in practice. Overriding the control would require interoperable control equipment. Disabling the controls may also be difficult to implement. For example, wideband jamming of radio frequencies may require large amounts of power, may interfere legitimate users and would be ineffective against optical communications or drones controlled with a wire[36]. Denying an area for airborne drones may be easier to achieve with low-tech methods such as a shotgun[37] or a net or lines fixed in the air between objects on the ground (for example, some cafés and restaurants use this approach to protect their terraces against birds).

Location data for better preparedness

Finland has much expertise in the development of geo-spatial technology; its uses should be explored. Analysis of movement benefits the police in resource allocation (both personnel and patrol). However, the police cannot collect geo-location information on individual citizens and their routes.

New technology presents both opportunities and challenges. 5G would provide better opportunities to use geo-spatial data for strategic use (related to the better location opportunities), but it also presents a challenge, as it can be quite vulnerable to attacks.

Overall, the incorporation of the Galileo satellite navigation technology (GNSS) would be a great advantage in this field and Finland has been involved in its development. The technology is more accurate than GPS and it has different services for authorities and citizens.

Crowdsourcing and social media

Technology related to the analysis of video material and mass data is significant when citizens are provided tools to send data to the police. Indeed, Finland has developed a service for citizens (POUTA service) available in 2020. The project received funding from the EU and it allows citizens to send image, video and other data on voluntary basis, to the police, through a temporary website (created for specific information-gathering use). There is a similar kind of application or site available in Spain.

These types of technologies are beneficial for the police to collect relevant information on specific cases but more tools are needed for analysis of arising challenges or phenomena for better preparedness. However, the level of trust in the police can influence the willingness to send information; in Finland people generally trust the police to a high degree. However, one can never be entirely sure why some piece of information has been sent and by whom.

Automatic analysis of texts and images with machine learning and artificial intelligence

Machine vision has its benefits for the authorities. Cameras can spot violent movement in public events and help the police to allocate resources to the correct area. In a disaster gas leak or water

[36] e.g. https://www.cnbc.com/2018/03/20/aerones-cable-connected-drone-has-unlimited-airtime.html
[37] https://www.digitaltrends.com/cool-tech/new-york-man-arrested-after-allegedly-shooting-down-a-mavic-drone/

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contamination case, it could spot the leak or the location of damage. Facial recognition technology is also of interest.

As resources are scarce, automatic text analysis technology would save police time. This would benefit the police in general but it could be useful in a fast moving crisis as well.

New technological opportunities

Satellite technology has been used to detect mines and ancient dwelling grounds. This type of technology could be useful for analytic purposes. Police could use sensor data to its advantage to amplify occupational safety. In Finland, police resources are scarce, technology can help to allocate human resources where they are most needed. In general, tools are beneficial in order to diminish damages to citizens and police personnel.

An interview at the Emergency Response Centre was carried out on November 15, 2019, and the following points were made regarding current operations and future challenges:

- 7,500 – 12,000 emergency messages are received daily and roughly half of them leads to sending some help to the location.
- Advanced Mobile Location system for locating mobiles phones has made a big improvement to the operations, as the caller location is received automatically from all phones in Finland that have a Finnish phone subscription.
- The viral spread of message in social media enables an extremely quick spread of information on emergencies like a terror attack; authorities alerts can never be that quick.
- Radio and TV combined reach more people regarding emergency warnings than social media, but they do not support sharing to others like social media. Multiple channels need to be used concurrently to reach as many people as possible.
- Future direction: alerts from devices like smart phones and smart watches or cars; smart cities equipped with 5G may monitor and alert.

Official governmental - area civil protection (PAT - Italy)

One of the most obvious critical points is the possibility of analyzing the territory using the aid of satellite applications. This need is implemented both in the pre-crisis phase and during the first phases of the emergency. The Copernicus platform basically provides two services; one for planning (pre-crisis) and one for emergency management. The products that can be obtained are excellent and very useful. The criticality is that every request for access to services must always be carried by a national civil protection authority (national focal point) and this greatly reduces the effectiveness.

Length ofr the requests' procedures and costs are the critical points that reduce the possibility of using these precious instruments. It is very useful to use satellite systems, which in catastrophes could immediately provide a precise description of the situation, with regard to viability (feasibility to guarantee rapid assistance, access routes), general damage, situational picture. Also, online GIS implementation systems of available resources and their location, e.g. IT Alert[38].

[38] http://www.today.it/tech/allerta-protezione-civile.html

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Non-governmental, civil society organization (DRK – Germany and SAL - Belgium)

The most essential needs and requirements related to tools and technologies for the supply of vulnerable groups must focus (first) on the preparedness phase. Here is a very essential gap within the disaster management activities. A technical solution to map (updating) the needs of vulnerable people and the requirements for their needs-based support for an area could be the base of disaster management planning. It is crucial that this phase is well organized and all disaster management structures are connected with daily care services and further structures of daily life. If this is ensured and visualized e.g. on a map this could be part of the response phase in future.

The Salvation Army in Belgium is not working in the area disaster response but mainly in recovery phase. Because of this, SAL has no prior relationship with authorities in the disaster area, and has had to "cold call" due to lack of a working relationship. Certainly, this could lead to a lack of SAL type of NGO assistance in Belgian disaster management. Therefore, it can be concluded that the information exchange and communications between local authorities and not officially accepted NGOs is a challenge in the crisis phases.

4.3. Applicability of emerging opportunities in disaster management

The aim of this section is to speak about applicability of the emerging opportunities arising from recent technological advances to improve operation in different phases of disaster or crisis management. The applicability discussed in the following and the summarized in the Table 8.

Risk mitigation: In this phase, the technologies supporting automatic sharing of information between the disaster management stakeholders is essential. Especially, in the pre-crisis phase, it is necessary to have all the information on e.g. population, territory, resources and risks as well as results from security and safety inspections, risk analyses, emergencies, incidents, and system errors or failures of critical infrastructure etc. available. In addition, knowledge about the location of the risk areas and objects based on planning and risk objectives definition, and analysis of secondary risks that could occur is important. It is important to have tools for landscape analysis based on geographical information systems (GIS databases) such as geomorphology, hydrography, digital elevation terrain model, for a correct position of resources, as well as flexible and useful planning tools for creation of procedures, complete analysis of the territory and use of resources. For example, it is very useful to scan all official data bases to identify potential vulnerable groups for the area the organization(s) is in charge: How many elderly residences are in my area? How many outpatient care services are in my area? Which further special needs organizations? How many hospitals,? For the right management of emergencies it is necessary to know the official data of the persons profiles to identify potential vulnerable groups: people with disabilities, pathologies to be rescued in a specific way, and elderly population with special needs. In addition, it is important to know the reception centers for the population, hospitals and first aid centres - surgeries. Easy access to the databases of this information (maybe even centralized database) would be very useful. The use of real-time satellite pictures to analyse the new threats or changes that give information about the possible risks can be very useful in risk analysis related to specific territories.

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Preparedness: In this phase, the technologies and tools for analysing and using social media to gather information, analysis of its' quality and sharing it effeciently would be important. Ensuring the access for the information required in public warning systems, e.g. locations of mobile phones, can be a useful enabler for sending warning alerts to the mobile phones to the population present in the risk area. This could be possible e.g. through a GIS platform that identifies the network cells in the predefined risk area, into which the system can send alert messages in disasters. These systems can then be used to send early warnings for rapid alerting of resources and personnel when disaster occurs. It is also required to prepare by collecting information related to groups of care, support organizations and staff, and the resources necessary for the medical assistance to people. In addition, it is essential to map and collect information from all relevant network partners for need-based support, technical assistance to structures and infrastructures (fire prevention measures, etc.), professional and volunteer resources, devices, materials and vehicles of the support and rescue of people in some accessible databases.

For example, the COVID-19 pandemic has shown how unprepared the nations are, despite the fact that the epidemic risk is known and contemplated in several national emergency planning. Tools for analyzing the need, location of resources and related data flow processes to be better prepared for crisis are needed. In addition, it would be necessary to be able to control and verify the data flow in management processes, recording and checking the request flows, rescue responses and related information. Also, establishing proper means for rapid situation aware information capturing e.g. for realization of immediate reports on the damages to the population and to the structures. It is also estimated that the use of AI for analysing the information of threats before and during the emergency to evaluate the possible consequences and impacts (on-line risk analysis) is needed.

Response: When the disaster happens, e disaster management stakeholders have to act rapidly, and therefore the role of tools (of preparedness to disaster) is also essential in this phase. The responders should be able to access real-time information about the situation in the disaster area, e.g. information about vulnerable people, security cameras, automatic fire alarms, indicators of electricity cut off, different kinds of IoT enabled sensors, satellite images, information gathered by drones, and their positioning (geolocations) would be very useful. Sometimes the radio or telephone communications are not possible, because of the collapse or lack of mobile phone infrastructure. Therefore applications of satellite and ad hoc wireless infrastructure, e.g. georeferencing and atellitarian applications can be useful. In addition, the situation with real-time use of resources, materials, personnel and requests for help and intervention are needed. The precise knowledge of the location of the resources in real-time ensures better efficiency in the management of emergencies. The last but not the least need is that the responders should have efficient communications system to interact with the colleagues, leaders and involved groups in real time, with correct chain of command and control. Such systems should also support traceability and verification of the flow of information: sequences, analysis, arrival, resources, decisions etc.

Recovery: In this phase, tools enabling to find out the problematic areas, location and information of vulnerable people, and sharing information with them are important. The tools for analysis of the costs of intervention and administrative procedures are useful. In addition, tools that can be used in collecting lessons learned, implementation of procedures and best practises are important in the improving the disaster management processes. Also, the tools for training and education with the elements that emerged in the lessons learned can be very useful.

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Table 8. Applicability of emerging opportunities in disaster management cycle

Crisis/Disaster management cycle	Crowdsourcing/social media	Media/communication related opportunities	Creation and use of location based information	Use of drones	Automatic analysis of texts and images with machine learning and artificial intelligence	New technological opportunities (ex. 5G, IoT, sensor technologies, blockchains etc.)
Risk mitigation)		information sharing and communications between organizations	location of people and resources		analysis of satellite pictures	
Preparedness	People as sensors	information sharing and distributed data management	location of people and resources for PWS		data analysis for better situational awareness	
Response	finding vulnerable people	information sharing and management for real-time situation awareness	location of people and resources	more detailed information from disaster area	analysis of information coming from multiple sources	possibilities for more real-time and trustworthy information even from physical assets
Recovery	information on vulnerable people	information sharing and communications between organizations	location of people and resources	more detailed information from disaster area	analysis of information coming from multiple sources	possibilities for more real-time and trustworthy information even from physical assets

5. Conclusions

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The analysis of T&T for disaster management covered 118 tools developed within ~52 European research collaboration projects revealed large heterogeneity and wide variance in maturity of tools. The T&T are here classified and indexed to help analysis of the available tools considering especially the level of use and their maturity (TRL level) analysis. 31 of the analysed tools are intended to be used as guidelines, methods or training, 26 related to risk mitigation in nature disasters, 12 of the tools are related to standardization, cyber-physical or internet of things (IoT) in disaster management, and 53 are targeted for response to disasters. The maturity level of the tools varies for full scale from TRL-1 to TRL-9. 33 of the tools are estimated to be in TRL1-3 levels, 27 in TRL4-6 and 97 in TRL7-9 levels. There are essential gaps in transferring of the tools into real use because only 27 of the tools were in real use in disaster management. Therefore, it is recommended to investigate into transferring and further develop them towards real use. The tools helping application of satellite images has good potential to trigger real advances in natural disasters. In addition, most of the opportunities arising from e.g. use of location awareness information, use of drones, more real-time communications over 5G, interaction with IoT assets and sensors, are estimated to trigger real advance in opportunities immediate respond processes to disasters.

The Covid-19 pandemic related applications and tools has rapidly arisen during this work to be a hot topic for industries and research all over the world, which has increased the adoption of existing tools and efforts for new development actions. Technological tools are needed to find infected people using tests, follow the epidemic chains and ensure that all of the infected people are isolated as well as follow the global epidemic situation. Several tools relying on identification and positioning of people using smart phones for following the epidemic chains are being deployed and developed all over the world. For example, use of digital QR codes and positioning with smart phone application seems to be useful combination in following epidemic chains. However, there seems to be *serious trust and privacy related challenges* because the using location of individual persons with their contacts lead to risk for illegal use. There are also essential ethical arguments against surveillance because there are human rights to privacy that is very important for the functioning of democracies. Thus surveillance is an interference with fundamental rights, and it is manifested distrust. This is because when surveillance technology is used for one purpose, it does not mean that the technology will not be used for other purposes (without the knowledge of citizens).

The emerging opportunities arising from recent technological advances in positioning, use of social media, satellite imaging, internet of things, use of drones, 5G, AI and blockchain technologies are discussed in this work. From technological perspective, the emergence of smartphones, mobile and satellite access infrastructures and Internet of Things (IoT) has created an essential basis for new opportunities for disaster management. Smartphones can capture the geographic *location* of the user to help locate people affected by disasters. Furthermore, smartphones enable users to communicate in a richer way than basic mobile devices do, and *use* applications such as *social media* to rapidly exchange information during a crisis. Thus the role of smart phones for public safety warnings and emergency communications seem to very essential, however, the challenge is that these requires smart actions from people. The *IoT solutions* enable taking information out from different kinds of sensors, attached e.g. into people, vehicles, buildings, infrastructures, environment, on the ground etc. Such information streams can even be real-time, which could enable totally new level of situation awareness in disasters. In addition to monitoring, new ways for enabling control type of operation with cyber-physical systems (CPS) such as e.g. *unmanned robots* (e.g. drones etc.) can enable increasing level of information details, which can be obtained from the disaster areas. For example, it is estimated

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to be possible to enrich *satellite images* by using images exposed from drone cameras. In addition to these physical assets, advancement in the information sharing via heterogeneous communication channels and cloud computing with storing of *big data* exposed from different sources has led to possibilities for improving the situation awareness with authorities, but also enlarging it towards NGOs, communities and even ordinary people. Emergence of the social media applications has opened possibilities for new ways for information exposure and sharing between communities of people and organizations. The recent advancement in *machine learning/artificial intelligence* is estimated to make it possible for decision makers to get help in processing such large information basis for improving their operation in disasters. For example, increasing the smartness and combinations in processing of satellite images is estimated to provide new level in granularity of information exposed from the raw image data. The importance of positioning, use of social media, satellite imaging, internet of things, use of drones, 5G, AI and blockchain technologies have good potential to improve crisis management in future. However, it seems that the cost of using satellite pictures hampers the application of them for help in disaster management. In addition, it seems that the information sharing and communications between local authorities and not officially accepted NGOs is a challenge in the crisis phases.

The disaster management stakeholders of the BuildERS project estimated that the information sharing via communications and use of location based services related opportunities have the most essential meaning for them. The use of drones were estimated to enrich the information obtained from the disaster area especially when it is challenging to get such information otherwise. The importance of AI, crowdsourcing, social media and 5G, IoT, sensors, blockchain technologies were not yet seen to be so essential even if there are essential potential in future. It seems that the cost of using satellite pictures hampers the application of them for help in disaster management. In addition, it seems that the information sharing and communications between local authorities and not officially accepted NGOs is a challenge in the crisis phases. The information sharing and communications between different organizations, information on location of people and resources and analysis of satellite pictures are estimated to be essential in the mitigation phase. In preparedness, the applicability of crowdsourcing using people as sensors, information sharing and distributed data management, location of people and resource for public warning systems and data analysis for better situation awareness were estimated to be essential. It is important to find vulnerable people, share information for real-time situation awareness, locate people and resources, use of drones for more detailed information from disaster area and use all available trustworthy information in real-time even from physical assests in the response phase. In the recovery phase, the information sharing and communications between organizations, location awreness, and combining information from different kinds of sources were estimated to be most applicable.

When discussion more specifically about vulnerable and limited capability people, an essential challenge arise from the fact that most of the tools and new technological opportunities requires use of some physical asset device, such as e.g. smartphone or any IoT device. When such a person is located somewhere in the disaster area without such device or capabilities, then it is a real challenge to find him/her also from tools and new technologies perspective. Use of e.g crowdsourcing, drones/robots, imaging with artificial intelligence may provide some opportunities. However, application of these technologies for finding such vulnerable people highlight the need for essential information sharing based actions in preparedness phase. When the vulnerable people have the required physical assets, then the use of location aware services became easier, however, then the trust, security, privacy and ethical issues cause challenges. In addition, using e.g smartphones

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efficiently requires some preceding actions related application installation, configuration and skills to use the referred applications.

This digital divide between people related to unequal distribution of skills, access to technological means and tools stays to be an essential future challenge especially with vulnerable people in crisis. For example, old people, children, homeless people, people with limited economical resources can be such vulnerable people. Thus issues of fairness and inclusivity need great attention in the application of these technologies in crises or disaster in order not to oversee the vulnerable population groups. It is very essential that these issues are considered and included in the monitoring radar of the emergency planners and responders. Furthermore, the cease of vital infrastructures like electricity cutoff during storms (recent years in Estonia, Sweden) or the damage of communication infrastructure (telecommunication masts) due to wildfires (Portugal, Sweden) indicates the fragility of the technological tools in the hazard situation. The failure of the tools may retain dependent services and service users in risk or exacerbate the existing vulnerabilities. However, the potential of the discussed technical opportunities for improving operation in different disaster life-cycle phases is so essential that significant investment on research and development actions is recommended, however, consideration of trust, security, privacy and ethics related challenges is important.

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Annex A. List of research collaboration projects, and their results related to tools and technologies.

Project: [1.] Smart Mature Resilience for more resilient cities in Europe (**SMR**[39]). (H2020-EU.3.7 secure societies - protecting freedom and security of europe and its citizen, 653569, 1st jun 2015-30st jun 2018).
Description: Project issued resilience management guidelines in the Spring of 2018. **Prospective output for BuildERS** [Ref. Annex]: Evaluation of the usefulness and workability of the guidelines as part of the literature and desk research. **Analysis of the project relevant output:** Guideline framework that firstly enables cities evaluate their current resilience maturity and gives respective policy advise to improve it and secondly provides a network for participating cities to gain and share information about resilience challenges and policy implications. **Tool & Technology related results:** 1) Resilience Maturity Model [1.1], 2) Systematic Risk Assessment Questionnaire [1.2], 3) Resilince Building Policies [1.3], 4) System Dynamics Model [1.4], 5) Resilience Engagement and Communication Tool [1.5]
Project: [2] Expecting the unexpected and know how to respond (**DARWIN**[40]) (H2020-EU.3.7, 653289, 1st jun 2015-30 sep 2018).
Description: Focuses to develop European resilience management guidelines aimed at critical infrastructure managers, crisis and emergency response managers, service providers, first responders and policy makers. The project contributed to improve response to expected and unexpected events affecting critical infrastructures and social structures, including both man-made (e.g cyber-attack) and natural attacks (e.g flooding). **Prospective output for BuildERS** [Ref. Annex]: Evaluation of the usefulness and workability of the guidelines (as far as they are available) as part of the literature and desk research. **Analysis of the project relevant output:** DARWIN Resilience Management Guidelines (DRMG) - a collection of guidelines to help stakeholders monitor, anticipate and learn from crises. It comprises of several tools in a variety of formats. The main beneficiaries ought to be crises management managers and practioners for public safety. Collection of 13 capability cards and several tools (a computer game, simulation software, boardgame) supporting them by helping to understand their potential use. **Tool & Technology related results:** DARWIN Wiki [2.1], Serious Gaming [2.2], SimEnv [2.3], D-TORC [2.4]
Project: [3] Improved risk evaluation and implementation of resilience concepts to critical infrastructure (IMPROVER[41]) (H2020-EU.3.7, 653390, 1st jun 2015-30th sep 2018).
Description: Focuses to improve European critical infrastructure resilience to crises and disasters through the implementation of resilience concepts to real life examples of pan-European significance. The project concentrated on combinations of societal, organisational and technological resilience concepts and also researched cross-border examples. **Prospective output for BuildERS** [Ref. Annex]: The project delivers guidelines for resilience management. These guidelines are evaluated in terms of their usefulness and workability..

[39] https://cordis.europa.eu/project/rcn/194885/factsheet/en
[40] https://cordis.europa.eu/project/id/653289
[41] https://cordis.europa.eu/project/id/653390, http://improverproject.eu/

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Analysis of the project relevant output: Guidelines and training material published in several deliverables and on the webpage. Several models/methodologies were developed and the tools were validated by gathering feedback from potential users. Also a market analyses was prepared. **Tool & Technology related results:** CIRI [3.1], ITRA [3.2], IORA [3.3], ISRA [3.4], AESOP [3.5]
Project: [4] Realising European Resilience for Critical Infrastructure (RESILENS[42]) (H2020-EU.3.7, 653260, 1st may 2016-30th apr 2018).
Description: Focuses to develop a European Resilience Management Guideline to support the practical application of resilience to all critical infrastructure sectors. The project aimed at supporting the practical application and existing estimation of resilience in CI sectors, especially the project supported CI providers, guardians, first-responders in disasters and civil protection. **Prospective output for BuildERS** [Ref. Annex]: The project delivered guidelines and a tool kit for resilience management. These guidelines and tools are assessed. **Analysis of the project relevant output:** The main output is the European Resilience Management Guidelines (ERMG). There was also an interactive web-based platform, where a toolkit could have been used, but that cannot be opened anymore. According to project deliverables, the web-based platform is described to assess and audit resilience and use an online mapping software. **Tool & Technology related results:** Resilience Management Matrix Tool [4.1], GIS mapping tool [4.2], Audit Tool [4.3]
Project: [5] RESilience management guidelines and Operationalization appLied to Urban Transport Environment (RESOLUTE[43]) (H2020-EU.3.7, 653460, 1st may 2015-30th apr 2018).
Description: Focuses on providing resilience management guidelines for urban transport environment. The project aimed to create a synergic approach towards a resilience model of collaborative emergency services and decision making processes. **Prospective output for BuildERS** [Ref. Annex]: The European Resilience Management Guide-lines are evaluated and elements to be adopted are assessed. **Analysis of the project relevant output:** The project adopted ERMG to urban transportation systems (UTS) and created several mobile apps to support emergency services. The project created three applications related to emergency service operating and training. To create the application the project also delivered several smaller subtools as the functions of the applications. The outputs were validated in pilot studies and are represented in different deliverables and a webpage. **Tool & Technology related results:** CRAMSS Application [5.1], Game based Training App [5.2], Mobile Emergency Support App [5.3]
Project: [6] Increasing disaster Resilience by establishing a sustainable process to support Standardisation of technologies and services (ResiStand[44]) (H2020-EU.3.7, 700389, 1st may 2016-30th Apr 2018).
Description: Project focused to improve crisis management and increasing disaster resilience by establishing a sustainable process to support standardization of technologies and services. **Prospective output for BuildERS** [Ref. Annex]: The processes and tools developed in the project are reviewed and assessed. **Analysis of the project relevant output:** Standardization overview (ISO, CEN, national), identification of standardization gaps, and proposing a prioritized roadmap for improving disaster

[42] https://cordis.europa.eu/project/id/653260, webpage: http://resilens.eu/
[43] https://cordis.europa.eu/project/id/653460
[44] https://cordis.europa.eu/project/rcn/202694/factsheet/en

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resilience through standardization deliverables. The project contributed roadmap for standardization to improve disaster resilience. In addition, tool for assessing the impact of a possible standardisation project and feasibility of developing and implementing it in the domain of disaster resilience and crisis management. **Tool & Technology related results:** Standardization roadmap for improving disaster resilience [6.1]. ResiStand Assessment Framework (RAF) - execl tool for impact assessment of standardization [6.2].
Project: [7] European Disasters in Urban centres: a Culture Expert Network (3C – Cities, Cultures, Catastrophes) (EDUCEN[45]) (H2020-EU.3.7, 653874, 1st may 2015-30th apr 2017).
Description: Project focused on the role of culture (3C – Cities, Cultures, Catastrophes) in disaster management and risk reduction. Coordination and support project focusing on interplay between culture and disaster risk reduction. **Prospective output for BuildERS** [Ref. Annex]: Outputs provide insights how cities deal with risks, approaches for working with the most vulnerable, and the role of gatekeepers and volunteers. **Analysis of the project relevant output:** A handbook including visuals, maps, narrativs, videos etc. It is directed to both community members potentially suffering from disasters and policy-makers who should obstruct such situations. A diverse set of tools: games, analyses tools, models, guidelines. **Tool & Technology related results:** Training model for inclusive Disaster Risk Reduction [7.1], Social Network Mapping and Analyses tool [7.2], Collaborative Learning for DDR [7.3], Games to Foster Empathy [7.4].

Project: [8] Resilience-Increasing Strategies for Coasts - toolKIT (RISC-KIT[46]) (H2020-EU.3.7, 653874, 1st may 2015-30th apr 2017).	
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Name of the research project (ex. EU), short and long name	Resilience-Increasing Strategies for Coasts - toolKIT (RISC-KIT)
Identity and schedule of the project	RISC-KIT (FP7-ENVIRONMENT, 603458, 1st nov 2013-30th apr 2017)
Project description	Funded under FP7-ENVIRONMENT, RISC-KIT includes tools and management resources to increase resilience to hydro-meteorological risks. The project helps coastal authorities assess the risks in their coastal zones and implement measures to prevent or lessen coastal disasters. Start date: 1 Nov 2013; end date: 30 April 2017.
Output	A set of five tools that have been applied in ten case studies in Europe. These tools are supposed to help Europe's coastal managers, decision-makers and stakeholders to identify hot spot areas; produce timely forecasts and early warnings; evaluate the effect of climate-related, socio-economic and cultural changes on coastal risk; choose the prevention, mitigation and preparedness measures for their coast.
Link	https://cordis.europa.eu/project/id/603458

[45] https://cordis.europa.eu/project/id/653874
[46] https://cordis.europa.eu/project/id/603458

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Results related to tools & technologies	Five tools including database, management guide, different analyses tools; all of which are also open-access in web.
Name of the identified tool/technology	1) The Storm Impact Database [8.1] 2) The Coastal Risk Assessment Framework [8.2] 3) The Web-based Management Guide [8.3] 4) Hotspot Tool [8.4] 5) Multi-Criteria Analysis Tool [8.5]
Open estimation of the project outputs	The project outputs are useful for the targeted goal - improving resilience in coastal areas. The TRL of the tools was generally assessed 7. The deliverables were well-structured, but it is not very easy to test the outputs themselves, as using the online tools/maps etc one has to be a registered as a user to see them.
Project: [9] Analysis of Civil Security Systems in Europe (ANVIL)	
Name of the contributor	Ago Tominga
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Name of the research project (ex. EU), short and long name Identity and schedule of the project	ANVIL - Analysis of Civil Security Systems in Europe ANVIL (FP7-ENVIRONMENT, 283201, 1st oct 2011-30th sep 2015)
Project description	Programm funded under EU FP7 that examined relevant cultural phenomena and legal determinations of civil security around Europe. The project analysed efficiency in varying security systems in Europe and tried to get a clearer perspective upon which kind of security systems EU could benefit. Start date: 1 March 2012; end date: 28 Feb 2014.
Output	The project delivered several case studies, research papers and deliverables that gave an overview of security sectors in European countries.
Link	https://cordis.europa.eu/project/id/284678
Results related to tools & technologies	Couldn't identify any tools or technologies.
Name of the identified tool/technology	-
Open estimation of the project outputs	The project gave a comprehensive overview of European security systems and it challenges. The project concluded systematically a lot of information, but didn't produce any tools that could be found from their documentation.
Project: [10] emBRACE - Building Resilience Amongst Communities in Europe (emBrace)	
Name of the contributor	Ago Tominga
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Name of the research project	emBRACE - Building Resilience Amongst Communities in Europe

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(ex. EU), short and long name Identity and schedule of the project	emBRACE (FP7-ENVIRONMENT, 283201, 1st oct 2011-30th sep 2015)
Project description	Funded under FMP7, the project aimed tobuild resilience to communities in Europe by identifying key dimensions of resilience, develop indicators and indicator systems to measure resilience, model societal resilience and build networks. The project lasted from 2011-2015.
Output	Main outputs were a handbook with teaching and training material, framework for community disaster resilience and guidelines for indicators and indicator systems. The methodologies developed were tested in a number of case studies in Europe.
Link	https://cordis.europa.eu/project/id/283201
Results related to tools & technologies	The project analysed different tools and more than 100 indices for community resilience from which a heuristic tool was derived.
Name of the identified tool/technology	emBRACE conceptual framework of community resilience [10.1]
Open estimation of the project outputs	The project was to some a degree a metastudy of the community resilience field. Therefore it offers a conclusive view on resilience studies to both scientists and policy-makers. The handbook that the project delivered can assist policy-makers, but it is not very attractive. The only tool of the project was estimated TRL 7, but its impact without additional information is small.
Project: [11] Enhancing risk management partnerships for catastrophic natural disasters in Europe (ENHANCE)	
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Name of the research project (ex. EU), short and long name Identity and schedule of the project	ENHANCE - Enhancing risk management partnerships for catastrophic natural disasters in Europe ENHANCE (FP7-ENVIRONMENT, 308438, 1st dec 2012-30 nov 2016)
Project description	A Resilience programme funded under EU FP7 that aimed to provide new scenarios in selected hazard cases and develop and create innovation in multi-sector partnerships. Start date: 1 Dec 2012; end date: 30 Nov 2016.
Output	The project delivered more than 70 research papers, a handbook, project briefs and other deliverables. The output offered guidelines for policy management to increase resilience.
Link	https://cordis.europa.eu/project/id/308438
Results related to tools & technologies	Different guidelines and scenarios for potential crises caused by natural disasters. The focus was upon strategical guidelines to integrate different sectors and help them communicate with each other.

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Name of the identified tool/technology	MSP guidelines [11.1]
Open estimation of the project outputs	The project had wide-spread scientific outputs and the methodology was used in a vast number of studies. The webpage where most of the deliverables were uploaded has probably changed its owner, so the results are difficult to find. There may have been more tools developed, but some of the information is lost.
Project: [12] Preparedness and Resilience against CBRN Terrorism using Integrated Concepts and Equipment (PRACTICE)	
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Name of the research project (ex. EU), short and long name	PRACTICE - Preparedness and Resilience against CBRN Terrorism using Integrated Concepts and Equipment
Identity and schedule of the project	PRACTICE (FP7-SECURITY, 261728, 1st may 2011-31st oct 2014)
Project description	Programme funded under EU FP7 that set out to improve resilience of EU member states against terrorist attackswith chemical, biological, radiological or nuclear materials. Start date: 1 May 2011; end date: 31 Oct 2014.
Output	The project identified critical elements of attack scenarios, analysed the gaps in current response systems and allocated a system for decision-support, first-responders training and exercise. The results were validated with case studies and field exercises.
Link	https://cordis.europa.eu/project/id/261728
Results related to tools & technologies	A toolbox containing a web-based database, which combained existing and developed tools and equipment of different sectors. The toolbox offered different using opportunities to police/healthcare/politics etc sectors and had several security levels.
Name of the identified tool/technology	PRACTICE Toolbox [12.1]
Open estimation of the project outputs	The project had one main result - the toolbox. This has been kept as a reference in the web-page, but one needs a user to be accessed. The tools have potentially been developed further in following projects. The open-access outputs are quite information-sparse.
Project: [13] Bridging resources and agencies in large-scale emergency management (BRIDGE)	
Name of the contributor	Ago Tominga
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Name of the research project (ex. EU), short and long name	BRIDGE - Bridging resources and agencies in large-scale emergency management

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Identity and schedule of the project	BRIDGE (FP7-security, 261817, 1st apr 2011-30 jun 2015)
Project description	Funded under FMP7, BRIDGE developed technical and organisational solutions to improve disaster management. The project went through domain analyses to ensure usefullness of the developed tools; developed the systems; validated the concepts and prototypes. Start date: 1 Apr 2011; End date: 30 June 2015.
Output	Outputs were represented through a number of deliverables, articles and concept cases. They were directed mostly to give more information and make communication more efficient to disaster-responders.
Link	https://cordis.europa.eu/project/id/261817
Results related to tools & technologies	The project produced a number of technical (and physical) tools that are mostly directed towards giving more information to first-responders and creating computer models and software solutions for better communication between various responders.
Name of the identified tool/technology	ASA Software [13.1], Dynamic Tagging [13.2], SWARM [13.3]
Open estimation of the project outputs	The outputs combined software solutions with physical products and provided first-responders with a set of innovative tools. The tools were estimated fom TRL 7 to 9. The project probably had a wider influence by developing technologies that are now in wider use.
Project: [14] Collaborative research on flood resilience in urban areas (CORFU)	
Name of the contributor	Ago Tominga
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Name of the research project (ex. EU), short and long name	CORFU - Collaborative research on flood resilience in urban areas
Identity and schedule of the project	CORFU(FP7 environment, 244047, 1st apr 2010-30 jun 2014)
Project description	A collaborative flood resilience programme funded under EU FP7. The project concentrated on flood impacts in urban areas and assessed a number of scenarios taking into accordance relevant drivers: socio-economic trends, urban development, climate change. It included 17 partners from 11 countries (most from Europe, but China was also included). Start date: 1 April 2010; End date: 30 June 2014.
Output	Methodolocigal tools and a stratetical framework for enhanced flood resilience presented in a number of deliverables. Also pilot studies with the tools were conducted.
Link	cordis link: https://cordis.europa.eu/project/id/244047 webpage: http://www.corfu7.eu/
Results related to tools & technologies	Models and software applications to assess flood risk and assess real-time data that could help decision-making during disaster management.

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Name of the identified tool/technology	CORFU GIS-Based Flood Mapping Application [14.1]
Open estimation of the project outputs	The project developed several models and also assessed strategical frameworks that could ne used in flood resilience research. The tool the project developed was assessed TRL 7, but it is not working anymore.
Project: [15] Bottom-up Climate Adaption Strategies Towards a Sustainable Europe (BASE)	
Name of the contributor	Ago Tominga
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Name of the research project (ex. EU), short and long name	BASE - Bottom-up Climate Adaption Strategies Towards a Sustainable Europe
Identity and schedule of the project	BASE (FP7-ENVIRONMENT, 308337, 1st oct 2012-30 sep 2016)
Project description	Climate adaption programme funded by EU FP7. The project supported adaption planning and provided interdisciplinary evaluation of costs, challenges, opportunities etc. in different sectors such as urban, rural, healthcare. Start date: 1 Oct 2012; end date: 30 Sept 2016.
Output	The output includes reports, books, models etc. Originally there was also an online platform, but that is not supported anymore.
Link	cordis: https://cordis.europa.eu/project/id/308337/ homepage: https://base-adaptation.eu/
Results related to tools & technologies	Tools and models assessing future scenarios regarding the climate change.
Name of the identified tool/technology	BECCA tool [15.1], WITCH [15.2], ARIO [15.3]
Open estimation of the project outputs	The project tools are estimated TRL 7-9. The project is rather directed to international activites, but can be somewhat used in local level as well.
Project: [16] Smart Resilience Technology, Systems and Tools (SMARTEST)	
Name of the contributor	Ago Tominga
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Name of the research project (ex. EU), short and long name	SMARTEST - Smart Resilience Technology, Systems and Tools
Project description	Funded under FP7 the project assessed flood risk technoogies and developed tools. The project implied to advancing the understanding of how technologies should be tested with respect to their end uses. Start date: 1 Jan 2010; end date: 30 June 2013.

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Output	The main outputs were the assessments of existing flood risk technologies and development of flood risk tools. Originally the outputs could be reached via webpage, but at the moment that web page does not exist any more and it is quite difficult to find information regarding the project.
Link	https://cordis.europa.eu/project/id/244102
Results related to tools & technologies	A toolkit was developed. It was originally published online, but it is not accessible anymore. The tools wre used in case studies and can still be found separately from project reports or from the webpages of the partners that developed them.
Name of the identified tool/technology	Multi-Hydro [16.1], HOWAD- Prevent [16.2], FLORETO-KALYPSO [16.3], RAINS [16.4], FVAT [16.5]
Open estimation of the project outputs	The project produced several tools that had quite a high scientific impact, but they are slowly getting older/being outdated. Most of the information was originally in the project website, which does not exist anymore, but the project definetely had an impact in flood resilience research.
Project: [17] CAST- COMPARATIVE ASSESSMENT OF SECURITY-CENTERED TRAINING CURRICULA FOR FIRST RESPONDERS ON DISASTER MANAGEMENT IN THE EU (CAST)	
Name of the contributor	Geonardo Environmental Technologies
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Name of the research project (ex. EU), short and long name Identity and schedule of the project	CAST- COMPARATIVE ASSESSMENT OF SECURITY-CENTERED TRAINING CURRICULA FOR FIRST RESPONDERS ON DISASTER MANAGEMENT IN THE EU CAST (FP7-security, 218070, 1st mal 2009-30th Jun 2011)
Project description	Security-centered training course curricula on disaster management for first responders (FR)* in EU member states will be comparatively assessed with a specially developed matrix-based software: (1) for all EU member states (2) as derived from international best practices in the US, Russia, and Israel as countries with extensive experience in this field. The comparative assessment will cover: (a) Didactic areas (electronic and hardcopy teaching materials used, computer modelling, field exercises); (b) Subject areas (terror threats to FR; risk assessment and -management; catastrophic terrorism; weapons of mass destruction, -mass killing, -mass disturbance; synchronization of response staff; (c) comparative evaluation of training course curricula by virtual reality safety training with biofeedback. Representatives of FR organisations and SME's in security technology will be involved throughout the assessment.

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Output	A comprehensive survey of existing training programmes for disaster management was also conducted. Featuring 80 responses from across 25 EU Member States, covering themes such as the division of responsibility during a terrorist attack and procedures for the use of protective equipment. Utilizing the surveys and reports, CAST then formulated a series of “best practice” procedural guides to form the basis of common training curricula for FR staff. Low probability-high consequence threat scenarios that were explored included the wide area synchronised use of improvised explosive devices, large-scale chemical, biological or radiological releases in urban environments and chemical fires. These were then compared to existing equipment and training procedures to evaluate overall preparedness.
Link	https://cordis.europa.eu/project/rcn/91028/factsheet/en
Results related to tools & technologies	The results obtained in this project assist FR to decrease the probability of experiencing physical harm in their line of duty, increase their effectiveness in rescuing people and regaining control over an extremely hazardous situation, and strengthening their resilience against psychological trauma due to threats exceeding their daily routine operations. A main result is the development of a computer-based training tool (virtual reality) linked with a wireless biofeedback system. This development is a worldwide unique product, which will be used for CAST-training courses. It is the development of the hard- and software of a virtual reality biofeedback training tool with optical, acoustical and olfactorial stimulation of a threat scenario related to a disaster caused by terrorists. This system can be established as a very useful tool in trainings for various aspects: * Biofeedback training as a monitoring tool for the assessment of training programmes and for the preparedness of first responders * Biofeedback training as a mean for enhancement of situational awareness by supporting stress-management * Virtual reality as a mean for post traumatic treatment of first responders * Virtual reality Biofeedback training could furthermore help in the assessment of the right person for special force groups. It can be anticipated, that this should be a basic training of a first responder to prevent them from post traumatical stress disorders and to introduce the individual into its work within a task force group.
Name of the identified tool/technology	Database on Emergency Response Major Incidents (DERMI) [17.1] Driving situation simulator [17.2] Instructor supervision desk software [17.3]
Open estimation of the project outputs	The project developed several project outcomes that have potential to be used by first responders or other projects
Project: [18] Social Capacity Building for Natural Hazards: Toward More Resilient Societies (CapHaz-Net)	
Name of the contributor	Geonardo Environmental Technologies

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Name of the research project (ex. EU), short and long name	CapHaz-Net: Social Capacity Building for Natural Hazards: Toward More Resilient Societies
Identity and schedule of the project	CAPHaz-Net (FP7-environment, 227073, 1st jun 2009-31st May 2012)
Project description	CapHaz-Net contributs to the improvement of the social resilience of European societies to natural hazards by suggesting ways of how to do this. Improving the resilience is, above all, to be accomplished by strengthening social capacities. By social capacity they mean the societal assets, skills and resources necessary to anticipate, cope with and recover from stresses and disasters. The overall objectives of CapHaz-Net are: To identify and assess existing practices and policies for social capacity building in the field of natural hazards at all societal levels across Europe for elaborating strategies and recommendations for activities to improve social capacity building in order to enhance the resilience of European societies and communities to the impacts of natural hazards. The main research themes CapHaz-Net will deal with include: risk perception, social vulnerability, risk communication, risk education, societal resilience, social capacity building and risk governance.
Output	The overall goal of CapHaz-Net was to develop deeper insights and recommendations on how to enhance the capacities of European societies to prepare for, cope with and recover from the impact of a ›natural‹ hazard.
Link	https://www.slf.ch/en/projects/caphaz-net.html
Results related to tools & technologies	The goal is to provide an inventory of insightful practices with innovative and/or good qualities from which lessons and recommendations can be drawn. The review of communication practices considers all phases of the risk cycle (prevention/preparation, warning, emergency response, recovery/reorganization). However, the focus is clearly on communication to prevent/reduce severe impacts from natural hazards, to prepare people for natural hazards and to enable them to better cope with their consequences.

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Name of the identified tool/technology	Tools used to deliver and raise awareness [18.1]: -One-way communication: Leaflets, brochures, information packs, video, newsletters - Reports, documents, protocols - Exhibitions/displays (non-staffed) - Advertising - Media (TV, radio, newspapers) - Internet (information provision) -two-way communication: Site visits - Exhibitions/displays (staffed) - Open house - Consultation document - Internet (information/feedback) - Free telephone line (automated and staffed) - Teleconferencing - Public meeting - Public inquiry/hearing - Deliberative opinion poll - Dialogue, two-way communication: Community Advisory Committees - 'Planning for real' - Meetings - Visioning - Deliberative Workshops - Internet Dialogue - Consensus building/conference and mediation - Deliberative mapping - Citizen panels - Citizen juries
Open estimation of the project outputs	As the project has a reviewing nature the project outputs provide usefull insight of the risk communication practices
Project: [19] Systemic Seismic Vulnerability and Risk Analysis for Buildings, Lifeline Networks and Infrastructures Safety Gain (SYNER-G)	
Name of the contributor	Geonardo Environmental Technologies
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Name of the research project (ex. EU), short and long name	SYNER-G: Systemic Seismic Vulnerability and Risk Analysis for Buildings, Lifeline Networks and Infrastructures Safety Gain
Identity and schedule of the project	Syner-G (FP7-environment, 244061, 1st nov 2009-31st Mar 2013)
Project description	SYNER-G is research project which has the following main goals: (1) To elaborate appropriate, in the European context, fragility relationships for the vulnerability analysis and loss estimation of all elements at risk, for buildings, building aggregates, utility networks (water, waste water, energy, gas), transportation systems (road, railways, harbors) as well as complex medical care facilities (hospitals) and fire-fighting systems. (2) To develop social and economic vulnerability relationships for quantifying the impact of earthquakes. (3) To develop a unified methodology, and tools, for systemic vulnerability assessment accounting for all components (structural and socio-economic) exposed to seismic hazard, considering interdependencies within a system unit and between systems, in order to capture the increased loss impact due to the interdependencies and the interactions among systems and systems of systems.
Output	SYNER-G developed an innovative methodological framework for the systemic assessment of physical as well as socio-economic seismic vulnerability at urban and regional level. The built environment is modeled according to a detailed taxonomy into its component systems, grouped in the following categories: buildings, transportation and utility networks, and critical facilities.

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Link	https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/systemic-seismic-vulnerability-and-risk-analysis-buildings-lifeline-networks-and
Results related to tools & technologies	SYNER-G developed an innovative methodological framework for the assessment of physical as well as socio-economic seismic vulnerability at the urban/regional level. The SYNER-G methodology and tools have been tested to selected case studies at urban level: the city of Thessaloniki in Greece and the city of Vienna in Austria, at system level: the gas system of L'Aquila in Italy, the road network of Calabria region in Southern Italy and the electric power network of Sicily, as well as in complex infrastructures: a hospital facility in Italy and the harbor of Thessaloniki, accounting for inter- and intra-dependencies among infrastructural components and systems.
Name of the identified tool/technology	A comprehensive tool box has been developed (EQvis) [19.1] containing several pre and postprocessing tools as well as other plug-ins such as the prototype software (OOFIMS), the Fragility Manager Tool, the MCDA software for modelling shelter needs and health impact. The product EQvis (European Earthquake Risk Assessment and Visualisation Software) [19.2] is an open source product that allows owners, practicing engineers and researchers the realistic risk assessment on systemic level. It has been based on the similar pre and post-processing modules of MAEviz (see Schäfer and Bosi 2013 for more information). The field of analyses that can be performed with EQvis is very large, e.g. Hazard Computation, Structural Damages, Functionalities, Repair Cost Estimations, Cost Benefit Analyses, Utility Network Damages, Multi Attribute Utility Analyses, Shelter Needs, Social Vulnerability, Temporary Housing, etc. The Fragility Manager Tool [19.3] offers the user to combine certain fragility functions and store them directly on the platform and use them. The platform can take the fragility curves for all buildings and bridges and assign them to all the objects correctly. In the next step different analyses can be computed. Socio-economic analysis tools delivered another plug-in: The socio-economic module. The connection between the OOFIMS module and the socio-economic module was computed and the output was again done through GIS data format.
Open estimation of the project outputs	
Project: [20] The Program for Risk and Vulnerability Analysis Development (PRIVAD)	
Name of the contributor	Geonardo Environmental Technologies
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Name of the research project (ex. EU), short and long name	The Program for Risk and Vulnerability Analysis Development (PRIVAD)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 833496

Identity and schedule of the project	Privad (funded by Swedish civil contingencies agency, 2011-2015)
Project description	The Program for Risk and Vulnerability Analysis Development (PRIVAD) continues the Framework Program for Risk and Vulnerability Analysis (FRIVA), which was finalized in 2011. Four scientific clusters covering the following research areas have been formed in PRIVAD: •Risk and vulnerability in a horizontal and vertical perspective •Risk and vulnerability analysis for interdependent critical infrastructure •Development of societal resilience through multi-organizational response preparedness •Information security in crisis management in authorities and society
Output	PRIVAD will serve to develop methods and tools for risk and vulnerability analyses at all levels of the society, in order to better be able to predict, prevent and handle all types of risks and threats to the society.
Link	http://www.risk.lth.se/research/previous-research-projects/privad-program-for-risk-and-vulnerability-analysis-development/
Results related to tools & technologies	Developed a survey of IT systems with one or more actors in the Swedish crisis management system in parallel with the fact that information on occurrences of IT-related problems will be collected. Selection of activities for mapping IT systems will be made so that the results are generally useful when support for risk and vulnerability analysis is formulated. The need for further surveys in other operations will be evaluated based on the results of the survey carried out. After this, a method for risk and vulnerability analysis will be formulated. The intention is for this to be used and evaluated in a case study together with a business. This provides the feedback needed to develop the support. PRIVAD represents a good model for offering user-friendly risk assessment methods. The project developed a model for risk assessment (albeit in IT sectors) that allows for an assessment of vulnerabilities and the specific targeting of solutions. Feeding several WPs.
Name of the identified tool/technology	<Names of the identified tool/technology>
Open estimation of the project outputs	
Project: [21] Strengthening CBRN-response in Europe (CBRN)	
Name of the contributor	Geonardo Environmental Technologies
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Name of the research project (ex. EU), short and long name	Strengthening CBRN-response in Europe, CBRN = chemical, biological, radiological and nuclear

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 833496

Identity and schedule of the project	This analysis is related to an Italian pilot project dealing with strengthening CBRN-response (http://cbrn.netseven.it/).
Project description	The project aims to implement the EU CBRN Action Plan (actions H.19, H.31, H.37, H. 57 and H.40) in Italy and more specifically the coordinated and integrated actions of first responders and law enforcement agencies in a CBRN security incident. It will: *Identify differences between national operational response frameworks of law enforcement and fire fighters to CBRN security incidents and critical issues existing in the coordination of first responders and law enforcement actions; *Define common approaches to deal with the critical issues by building on the experience of other EU countries such as Estonia and the Netherlands; *Develop common guidelines for response to national CBRN incidents and incoming assistance; *Translate the guidelines into the outline of a common training curriculum for both first responders and law enforcement training institutes. Expected results of the project are: (1) improved understanding of the different requirements of first responders and law enforcement officers in responding to CBRN security incidents; (2) applied good practices and lessons learned by other EU member States (mainly Estonia and the Netherlands), laying the fundation of a EU approach (3) developed and consolidated legal frameworks and set of operational rules to be applied in cases of CBRN security incidents by law enforcement agencies and first responders, mainstreamed in common interagency guidelines and curricula.
Output	
Link	http://cbrn.netseven.it/ 2020 projects dealing with CBRN: C-BORD, COSMIC, eNotice, ENTRAP, EuroBioTox, EU-SENSE, EXERTER, FIRE-IN, IN-PREP, NANOELECTROCHEM, NOSY, LLEANnet, I-LEAD, INCLUDING, PROACTIVE, ROCSAFE, SafeZone, STARI4Security, Target, Terriffic, TOXI-triangle. http://encircle-cbrn.eu/related-projects-2/cbrne-projects/h2020/
Results related to tools & technologies	
Name of the identified tool/technology	<Names of the identified tool/technology>
Open estimation of the project outputs	
Project: [22] MULTI-HAZARD COOPERATIVE MANAGEMENT TOOL FOR DATA EXCHANGE, RESPONSE PLANNING AND SCENARIO BUILDING (HEIMDALL)	
Name of the contributor	Geonardo Enviromental Technologies
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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 833496

Name of the research project (ex. EU), short and long name	HEIMDALL – H2020 MULTI-HAZARD COOPERATIVE MANAGEMENT TOOL FOR DATA EXCHANGE, RESPONSE PLANNING AND SCENARIO BUILDING. improving preparedness of societies to cope with complex crisis situations by means of providing integrated tools to support efficient response planning and the building of realistic multidisciplinary scenarios
Identity and schedule of the project	HEIMDALL (H2020-EU.3.7.5 increase europe's resilience to crises and disasters, 740689, 1st may 2017-31st Oct 2020)
Project description	HEIMDALL aims at improving preparedness of societies to cope with complex crisis situations by providing a flexible platform for multi-hazard emergency planning and management, which makes use of innovative technologies for the definition of multi-disciplinary scenarios and response plans, providing integrated assets to support emergency management, such as monitoring, modelling, situation and risk assessment, decision support and communication tools. HEIMDALL fosters data and information sharing among the relevant stakeholders, maximises the accuracy of valuable information and improves population awareness.
Output	Modular and highly flexible platform which will make use of a federated architecture to provide user-tailored interfaces and foster information sharing among the involved stakeholders. Additionally, the platform will provide citizens at risk and first responders on the field with valuable incident-related information, increasing population awareness.
Link	http://heimdall-h2020.eu/public-deliverables/
Results related to tools & technologies	Multi-hazard management platform which will offer services to be used either in a) the preparedness and mitigation phases; or in b) the response and recovery phases.
Name of the identified tool/technology	HEIMDALL Service Platform (SP) [22.1]
Open estimation of the project outputs	The platform seems to provide a full scale services to control centres, first responders and relevant stakeholders. We weren't able to find information on whether it is operational or not, however due to its complexity the question can be raised whether local populations will be able to use the platform.

Project: [23] Strengthening the context of people in need of care and/or help (KOPHIS)	
Name of the contributor	Geonardo Enviromental Technologies
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Name of the research project (ex. EU), short and long name	KOPHIS- Strengthening the context of people in need of care and/or help

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 833496

Project description	KOPHIS aims to strengthen people who live in private households and are in need of care services during all phases of a disaster.
Identity and schedule of the project	KOPHIS (Funded by BMBF/Ge, feb 2016-jan 2019)
Output	Recommendations of action and training for stakeholders
Link	https://www.kophis.de/
Results related to tools & technologies	Recommendations of action and training for stakeholders
Name of the identified tool/technology	Recommendations of action and training for stakeholders [23.1]
Open estimation of the project outputs	The project examines the netwokr and communication structures of privately cared persons and their protection and support in crisis situations. The project provides sound understanding into this group from the population and what disaster management stakeholders should take into consideration.

Project: [24] Next Generation Emergency Services (NEXES)	
Name of the contributor	Miia Myllylä
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Name of the research project (ex. EU), short and long name	NEXES - Next Generation Emergency Services
Identity and schedule of the project	NEXES (H2020-EU.3.7, 653337, 1st may 2015-30th Apr 2018)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 833496

Project description	NEXES received funding from the Horizon 2020 programme (2015-2018). According to the EU commission's cordis factsheet NEXES innovation and research action aimed to research, test and validate the integration of IP-based communication technologies and interoperability into the next generation emergency services, so that they obtain increased effectiveness and performance (EU Commission Cordis factsheet). The project innovations include: 1) more accurate location data by combining different types of location data (network operator data, device data and satellite-based data), 2) end to end connectivity between citizen, FR adn PSAP operator (incl. cross-agency interoperability and and cross-border communication, and, 3) total conversation: the combination of audio, real-time text and video to improve the accessibility of emergency services to all people NEXES leaflet: (https://cordis.europa.eu/docs/results/h2020/653/653337_PS/nexes-image4.jpg)
Output	1. NEXES IP-based eCall System prototype 2. Emergency Apps for First Responders 3. Emergency Apps for Citizens 4. Smart Devices Prototypes
Link	EU Commission Cordis factsheet: https://cordis.europa.eu/project/rcn/194850/factsheet/en EU Commission Cordis results of the project: https://cordis.europa.eu/project/rcn/194850/results/en NEXES leaflet: https://cordis.europa.eu/docs/results/h2020/653/653337_PS/nexes-image4.jpg
Results related to tools & technologies	Several applications: e.g. MyNEXES by Omnitor an Emergency App for Citizens. An app for First Responders by Rinicom and many others.
Name of the identified tool/technology	NEXES system and apps (several, see outputs). [24.1]

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 833496

Open estimation of the project outputs	The NEXES system was TRL level 7. Different parts of the system could have higher or lower TRL. Several apps were built within the project. MyNEXES (a mobile emergency application solution) reached TRL 7.
Project: [25] EnhANcing emergencY management and response to extreme WeatHER and climate Events (Anywhere)	
Name of the contributor	Juhani Latvakoski, Pekka Leviäkangas
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Name of the research project (ex. EU), short and long name	Anywhere (EnhANcing emergencY management and response to extreme WeatHER and climate Events)
Identity and schedule of the project	ANYWHERE (H2020-EU.3.7, 700099, 1st jun 2016-31st dec 2019)
Project description	Pan-European platform on extreme climate risks that will enable to identify, in a number of geographic regions, critical situations that could lead to loss of life and economic damages. Such early-warning system enable to improve protection measures and, in case of catastrophic situations.
Output	Platform for collecting wheather and climate related information (situation awareness tool integrating geolocalized information), early warnings (multi weather/climate related hazards early warning system), emergency management and response to extreme WeatHER and climate Events. The platform integrates many subtools e.g. for alerting, crowdsourcing and risk assessment. Maybe integrate also prediction tool (https://www.wiki-predict.com/login).
Link	http://anywhere-h2020.eu/
Results related to tools & technologies	A4EU platform
Name of the identified tool/technology	A4EU [25.1]
Open estimation of the project outputs	According to the public material, it is estimated that the A4EU platform enables application of multiple forecast type of tools, early warning systems, to raise the prepairness level for the weather type of disasters, transform the action from reactive to proactive. The platform enabled applications are being evaluated in 7 different pilot sites.
Project: [26] **Building Resilience through Education - BRTE**	
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Name of the research project (ex. EU), short and long name	Building Resilience through Education - BRTE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 833496

Identity and schedule of the project	BRTE (H2020-EU.1.3.3, 778196, 1st nov 2017-31st oct 2021)
Project description	The BRTE project focuses on finding innovative ways to strengthen the resilience of communities affected by recurring disasters. This is done by building capacity of an Etiophian Wolaita education institute to build critical infrastructure to enable resilience education and research, to establish educational platform for building human cappital and transform livelihoods, and to develop R&D and innovation capacity that will radically promote social and economic well-being.
Output	Research innovation hub, NOVAWSU, a gateway to the Innovation academy and NovaUCD where new high-tech and knowledge-intensive companies are nurtured and supported to enable them to grow, develop and create jobs.
Link	https://cordis.europa.eu/project/id/778196
Results related to tools & technologies	The results are mainly educational … but maybe research innovation hub, NOVAWSU, can be seen as a method type of tool
Name of the identified tool/technology	NOVAWSU [26.1]
Open estimation of the project outputs	Increasing the local intellectual capacities to build local resilience is very important in the areas affected by recurring disasters. However, how this is in efficient and concrete way…. It is very difficult to estimate.

Project: [27] IN-PREP - An INtegrated next generation PREParedness programme for improving effective inter-organisational response capacity in complex environments of disasters and causes of crises (IN-PREP)

Name of the contributor	Juhani Latvakoski
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Name of the research project (ex. EU), short and long name	IN-PREP - An INtegrated next generation PREParedness programme for improving effective inter-organisational response capacity in complex environments of disasters and causes of crises
Identity and schedule of the project	IN-PREP (H2020-EU.3.7.5, 740627, 1st sep 2017-31st aug 2020)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 833496

Project description	IN-PREP aims to improve collaborative response planning, addresses the lack of training capabilities and insufficient links in transboundary crises management. IN-PREP focuses on the challenges related to development of collaborative response planning, real-time information sharing and interoperability and co-ordination of the use of critical resources. will establish and demonstrate a next generation programme by enabling a reference implementation of coordination operations (Handbook of Transboundary Preparedness and Response Operations that synthesises the lessons learnt, recommendations, check-lists from past incidents) and a training platform (Mixed Reality Preparedness Platform a novel IT-based tool, which holistically integrates Information Systems (IS) and Situational Awareness (SA) modules over a decision support mechanism and the visualisation of assets and personnel) to the entirety of civil protection stakeholders (firefighting units, medical emergency services, police forces, civil protection units, control command centres, assessment experts) to meet these challenges. The proposed framework will not only improve preparedness and planning but can be also applied during joint interventions, thus improving the joint capacity to respond.
Output	IN-PREP contributes a collaborative training platform for crisis practitioners and first responders to train and plan collaboratively for future crisis events by Sharing response planning across borders and agencies securely, Communicating relevant information in real time and Coordinating critical resources
Link	https://cordis.europa.eu/project/id/740627
Results related to tools & technologies	The IN-PREP system is a collaborative training platform made up of three elements 1 A novel IT training platform called the Mixed Reality Preparedness Platform MRPP 2 Training modules that test coordination between agencies and their plans 3 A Crisis Management handbook which is cross organisational
Name of the identified tool/technology	IN-PREP Collaborative Training platform [27.1]: consisting of Mixed Reality Preparedness platform (MRPP), Training modules for testing co-ordination between agencies and their plans, Crisis management handbook for cross organizational operations
Open estimation of the project outputs	The IN-PREP table top exercises with the Collaborative training platform looks sensible approach towards increasing prepareness level across borders.
Project: [28] Nature insurance value: assessment and demonstration (NAIAD)	
Name of the contributor	Juhani Latvakoski
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Name of the research project (ex. EU), short and long name	NAIAD, Nature insurance value: assessment and demonstration

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 833496

Identity and schedule of the project	NAIAD (H2020-EU.3.5.2, 730497, 1st dec 2016-31st may 2020)
Project description	NAIAD aims to operationalise the insurance value of ecosystems to reduce the human and economic cost of risks associated with water (floods and drought) by developing and testing - with key insurers and municipalities - the concepts, tools, applications and instruments (business models) necessary for its mainstreaming. This is done in detail for 8 demonstration sites (DEMOs) throughout Europe and develop tools and methods applicable and transferable across all of Europe. NAIAD plans to contribute to providing a robust framework for assessing insurance value for ecosystem services by (i) enabling full operationalisation through improved understanding of ecosystem functionality and its insurance value at a broad range of scales in both urban and rural context; (ii) making explicit the links between ecosystem values and social risk perception; and (iii) the application of developed methods and tools in water management by relevant stakeholders, especially businesses, public authorities and utilities.
Output	Robust assessment framework to measure the insurance risk/value of Nature based solutions as the goal of the project.
Link	https://cordis.europa.eu/project/id/730497, http://naiad2020.eu/
Results related to tools & technologies	Open-web based insurance value platform, Eco. Engine platform designed for the insurance and financial actors to include physical system knowledge into single web application to analyse the system, an open web platform capable for combining many types of biophysical, social, economical and climate data and model into an effective policy support system, providing insurance value assessment to spesific stakeholders and policymakers.
Name of the identified tool/technology	Eco [28.1]
Open estimation of the project outputs	<write here your own estimation of the main project outputs related to technologies & tools for disaster mangement>
Project: [29] GIS-BASED INFRASTRUCTURE MANAGEMENT SYSTEM FOR OPTIMIZED RESPONSE TO EXTREME EVENTS OF TERRESTRIAL TRANSPORT NETWORKS (SAFEWAY)	
Name of the contributor	Juhani Latvakoski
Email address of the contributor	juhani.latvakoski@vtt.fi
Name of the research project (ex. EU), short and long name	SAFEWAY - GIS-BASED INFRASTRUCTURE MANAGEMENT SYSTEM FOR OPTIMIZED RESPONSE TO EXTREME EVENTS OF TERRESTRIAL TRANSPORT NETWORKS
Identity and schedule of the project	SAFEWAY (H2020-EU.3.4 - societal challenges - smart, green and integrated transport, 769255, 1st sep 2018 - 28th feb 2022)
Project description	SAFEWAY's aim is to design, validate and implement holistic methods, strategies, tools and technical interventions to significantly increase the resilience of inland transport infrastructure (ref. Trans-European Transport Network - TEN-T guidelines) by reducing risk vulnerability and strengthening network systems to extreme events. SAFEWAY targets to significantly improved resilience of transport infrastructures, developing a holistic toolset with transversal application to anticipate and mitigate the

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	effects extreme events at all modes of disaster cycle: 1) “Preparation”: substantial improvement of risk prediction, monitoring and decision tools contributing to anticipate, prevent and prepare critical assets for the damage impacts; 2)“Response and Recovery”: the incorporation of SAFEWAY IT solutions into emergency plans, and real-time optimal communication with operators and end users (via crowdsourcing and social media); 3)“Mitigation”: improving precision in the adoption of mitigation actions (by impact analysis of different scenarios) together with new construction systems and materials, contributing to the resistance & absorption of the damage impact.
Output	The project has not yet published any results, but there are essential objectives to develop results related to tools and technologies.
Link	https://cordis.europa.eu/project/id/769255, https://www.safeway-project.eu/en
Results related to tools & technologies	The tools and technologies related objectives of the project are related to 1) monitoring& identifying weather conditions and climate risks and hazards, 2) integration of infrastructure conditions to infrastructure information models (IIM), 3) development of crowsourcing concept using data from advanced driver assistance systems (ADAS) and floating car data (FCD) for real-time traffic monitoring and infrastructure monitoring, 4) development of predictive models for critical infrastructure assets, 5) development of modular GIS-based infrastructure management system (GIS-IMS) and 6) providing tools for improving management of critical european transport routes/corridors.
Name of the identified tool/technology	not yet available, estimated to be under development
Open estimation of the project outputs	<write here your own estimation of the main project outputs related to technologies & tools for disaster mangement>
Project: [30] RESIlience enhancement and risk control platform for communication infraSTructure Operators (RESISTO)	
Name of the contributor	Juhani Latvakoski
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Name of the research project (ex. EU), short and long name	RESISTO - RESIlience enhancement and risk control platform for communication infraSTructure Operators
Identity and schedule of the project	RESISTO (H2020-EU.3.7.4 - improve cyber security, H2020-EU.3.7.2 protect and improve the resilience of critical infrastructures, supply chains and transport modes, 786409, 1st may 2018 - 30th apr 2021)
Project description	The main goal of RESISTO is to improve risk control and resilience of modern Communication Critical Infrastructures (CIs), against a wide variety of cyber-physical threats, being those malicious attacks, natural disasters or even unexpected faults. The goal is divided to the following objectives: 1) Help managers of Communication CIs to guarantee improved business and asset continuity, delivering an innovative platform for optimized decision support in the face of physical, cyber and combined cyber-physical. 2) Develop an Integrated Risk and Resilience analysis and management tool, that takes account of cyber and/or physical threats and disruptions jointly at the level of telecommunication service functions and performance functions. 3) Provide, experiment and assess a suite of innovative cyber/physical security solutions for prevention, protection, detection and reaction that can deliver unprecedented cost-effective performances in a holistic technology framework.

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	4)Support a progressive adoption path for the RESISTO platform and services through extensive validation in relevant use cases. 5) Contribute to the European Programme for Critical Infrastructure Protection and to the objectives of the Cybersecurity Strategy of the European Union
Output	The target of the project is to realize RESISTO platform, resilience enhancement and risk control platform for communication critical infrastucture operators. the platform is which is an innovative solution for CI holistic (physical/logical) situation awareness and enhanced resilience. Based on an Integrated Risk and Resilience analysis management, RESISTO implements an innovative Decision Support System to protect from combined cyber/physical threats, exploiting cyber/physical data improved correlation, integrated threat propagation modelling, and the Software Defined Security model. It provides state of the art security components and services for detection and reaction: Blockchain for data integrity, Machine Learning for threat Intelligence, IoT Security and smart spectrum surveillance for physical security, enhanced and holistic video-audio analytics for improved situational awareness, Airborne threat detection for malicious UAV prevention, vulnerability assessment and 0-day attack analysis services for attack prevention and mitigation. Through RESISTO, Operators will be able to select and adopt a set of mitigation actions and countermeasures that significantly reduce the impact of negative events in terms of performance losses, social consequences, and cascading effects, by efficiently restoring full operational status.
Link	https://cordis.europa.eu/project/id/786409
Results related to tools & technologies	The project has not yet realized the RESISTO platform, but the work is ongoing with state of the art, requirement analysis and detailed planning of the use cases that will be used for testing the RESISTO platform.
Name of the identified tool/technology	RESISTO platform (TRL 7 level as the target of the project) [30.1]
Open estimation of the project outputs	<write here your own estimation of the main project outputs related to technologies & tools for disaster mangement>
Project: [31] Smart M2M Grids – M2M Internet for dynamic M2M Information Business ecosystem (M2MGRids)	
Name of the contributor	Juhani Latvakoski
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Name of the research project (ex. EU), short and long name	M2MGRids - Smart M2M Grids – M2M Internet for dynamic M2M Information Business ecosystem
Identity and schedule of the project	M2MGRids (ITEA 2 Call 8, 13011, nov 2014 - may 2018)
Project description	The Smart M2M grids project is focused on creating enablers for a dynamic cyber-physical information business ecosystem connecting the physical world with the business processes of companies in real-time. The first goal is to connect physical world sensors, actuators and various embedded devices and machines (physical M2M objects) with IT systems automatically/ semi-automatically by applying and

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	extending horizontal open standards based M2M infrastructures for communication and services. The second goal is to enable information management for embedded and distributed application for smart interaction with physical M2M objects and IT back-office systems. The third goal is enabling smart information exchange between selected business cases related to energy, buildings, transportation and consumer M2M products and services to make the future world smart, smooth and secure for consumers/prosumers. The resulting system is aimed at boosting transfer towards a more sustainable society and a novel real-time service economy within selected industrial business cases. The project developed a horizontal M2MGrids architecture framework, with a set of novel horizontal capabilities related to information models, algorithmic operation, stream processing, communication overlays, security, and specific capabilities of horizontal platforms enabling embedded products to be part of the cyber-world. These novel capabilities were evaluated in use cases of the specific markets, such as the energy sector (residential energy consumption monitoring and optimisation, and energy-sensitive household appliances) and mobility sector (wearables, sports and wellness).
Output	
Link	https://itea3.org/project/m2mgrids.html
Results related to tools & technologies	Horizontal M2MGrids platform consisting of M2M service plaform, CPS communication hub and security policy service, which were evaluated in energy flexibility and traffic accident cases. [34.1]
Name of the identified tool/technology	M2MGrids platform
Open estimation of the project outputs	<write here your own estimation of the main project outputs related to technologies & tools for disaster mangement>
Project: [32] Storm surges as regional Geohazards (STarG)	
http://www.geo.uni-hamburg.de/de/geographie/-forschung/forschungsschwerpunkt-klima/starg.html). This project evaluated public discourses of regional geohazards in media, politics, the public at large and cognitive awareness through the reminder anchor StarG proved that the social fabric and the cultural frames of a society are decisive not only for collective memory but also for the perception risk and preparedness to deal with current threats.	
Other: [33] The other refers to actions and projects executed by multiple companies or other organizations separately, which has produced technologies and tools relevant for the resilience in disasters.	
Name of the identified tool/technology	eCall [33.1], Traffic situation service [33.2], RDS-TMS [33.3], RDS-TA [33.4], DPA [33.5], Cobra [33.6], DMA [33.7], TRASIM [33.8], SITMAN [33.9], Temporary Population [33.10], Insta Blue Aware [33.11], FMI Warnings [33.12], Tilannehuone [33.13], Radioation today [33.14], Watershed forecast [33.15], ArgGIS paikkatieto [33.16], 72-tuntia [33.17], Traffic signal priority [33.18]

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 833496

Project: [35] Enhancing decision support and management services in extreme weather climate events (beAWARE).

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Name of the research project (ex. EU), short and long name	beAWARE - Enhancing decision support and management services in extreme weather climate events
Identity and schedule of the project	Funding program: Horizon 2020, grant ID: 700475, start date: 01.01.2017, end date: 31.12.2019.
Project description	The goal of the project was to propose an integrated solution to support forecasting, early warnings, transmission and routing of the emergency data, aggregated analysis of multimodal data and management the coordination between the first responders and the authorities
Output	Output consisted of deliverables, a number of conference papers and one research paper. The project contributed to all cycles of DM, but especially to the immediate response phase, where novel data integration and machine learning methods were implemented.
Link	https://cordis.europa.eu/project/id/700475
Results related to tools & technologies	A toolkit consisting of several subtools that gather and analyse data from drone pictures, social media analyses, voice recognizion, sensors and sends the information to the responders and crisis centre staff.
Name of the identified tool/technology	beAWARE Final System
Open estimation of the project outputs	The project is a good all-around contribution to disaster management, that has produced one really universal system. The produced Final System is very ambitious, but would have needed to be proven to work in operational environment.
What are the key functionalities that the systems or tools are doing ?	Gather and analyse information from a variety of sources, detect disaster-affected areas.

Name of the identified tool/technology	beAWARE Final system (FS) [35.1]
Open estimation of the project outputs	The project is a good all-around contribution to disaster management, that has produced one really universal system. The produced Final System is very ambitious, but would have needed to be proven to work in operational environment.
What are the key functionalities that the systems or tools are doing ?	Gather and analyse information from a variety of sources, detect disaster-affected areas.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 833496

Project: [36] MOBNET - MOBile NETwork for people's location in natural and man-made disasters.	
Name of the contributor	Ago Tominga
Email address of the contributor	ago.tominga@gmail.com
Name of the research project (ex. EU), short and long name	MOBNET - MOBile NETwork for people's location in natural and man-made disasters
Identity and schedule of the project	Horizon 2020, 687338, 1 January 2016 - 28 February 2018
Project description	Project aimed at designing a Search and Rescue (SAR) system for the location of isolated victims in the case of natural or man-made disasters such as earthquakes, hurricanes or large snow storms.
Output	UAV technology and according algorithms to detect mobile phones of people under rubble.
Link	https://cordis.europa.eu/project/id/687338
Results related to tools & technologies	A 5 kg electronic payload currently mounted on a drone/helicopter, that detects and pinpoints mobile phone signals.
Name of the identified tool/technology	MOBNET BTS [36.1]
Open estimation of the project outputs	The project had one main aim - to develop a system that detects mobile phone signals under rubble. It seemed to be quite succesful, but there are very few materials available to see, whether it actually worked.
What are the key functionalities that the systems or tools are doing ?	Detect locations of peoples mobile phones

Project: [37] CUBE- New approach to decentralized production of electricity, water supply and Internet connection, in full autonomy and off-grid	
Name of the contributor	Frosina Ilievska
Email address of the contributor	frosina.ilievska@geonardo.com
Name of the research project (ex. EU), short and long name	CUBE- New approach to decentralized production of electricity, water supply and Internet connection, in full autonomy and off-grid
Identity and schedule of the project	H2020, project id: 827152, 01/09/2018-28/02/2019
Project description	CUBE refers to an autonomous and plug-and-play solar-powered system, able to create supply points in electricity, clean water and internet in IoT cubes of 585 x 585 x 585 mm.
Output	The cubes have the potential to make any building, housing or operation site (e.g., construction sites) autonomous .

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 833496

Link	https://cordis.europa.eu/project/id/827152
Results related to tools & technologies	The cubes combine inverting technologies to produce and store electricity (230V), filtering systems (reverse osmosis and UV lamp) to supply clean water and several connection types (4G/ 3G, edge and satellite connection) to link the cubes to an IoT platform, where big data are processed. Real-time analysis will deliver smart guidance and tailored training for low energy consumption by the users.
Name of the identified tool/technology	CUBE
Open estimation of the project outputs	The project outputs have beed tested in different scenarios and provide a very good tool that can be utilised in disaster affected areas to quickly provide electricity, water and internet connection.
What are the key functionalities that the systems or tools are doing ?	

Project: [38] Quakebots-Artificial Intelligence and IoT for seismic monitoring	
Name of the contributor	Frosina Ilievska
Email address of the contributor	frosina.ilievska@geonardo.com
Name of the research project (ex. EU), short and long name	Quakebots-Artificial Intelligence and IoT for seismic monitoring
Identity and schedule of the project	H2020, project id: 806911, 01/04/2018-30/09/2018
Project description	The objective of the Quakebots project is to introduce and validate a novel technology and tools for disaster management during earthquakes, with the ambition of minimizing both direct and indirect damage during and after a seismic event, increasing people safety and helping in the assessment of post-seismic damage to critical infrastructures.
Output	Quakebots is a distributed sensor network that is capable of automatically detect the occurrence of primary waves during a seismic event via IoT devices

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Link	https://cordis.europa.eu/project/id/806911
Results related to tools & technologies	Quake Engineering proposes a distributed sensor network that is capable of automatically detect the occurrence of primary waves during a seismic event, and acting as a distributed IoT P2P neural network, propagate an alert to all the other nodes in the network in cascade. This "signaling" wave propagates much faster than the harmful secondary waves, providing the users with a local acoustic and visual alert, giving them a small time frame in the magnitude of tens of seconds for taking safety critical actions.
Name of the identified tool/technology	Quakebots
Open estimation of the project outputs	The project outputs have been tested and are made available to the market.
What are the key functionalities that the systems or tools are doing ?	

Project: [39] AdvIOT- Advanced Methods for Analyzing and Improving the Reliability and Security of Novel Environmental-friendly Wireless Devices for Internet of Things	
Name of the contributor	Frosina Ilievska
Email address of the contributor	frosina.ilievska@geonardo.com
Name of the research project (ex. EU), short and long name	AdvIOT- Advanced Methods for Analyzing and Improving the Reliability and Security of Novel Environmental-friendly Wireless Devices for Internet of Things
Identity and schedule of the project	H2020, ID: 611606, 01.11.2013-31.10.2017
Project description	This project aims at strengthening research partnerships through staff exchanges and networking activities between 4 European research organizations, from Finland, United Kingdom, and France, and 4 organisations from China and Japan. The programme of exchange is focused on novel RFID- and WSN-based green IOT devices with renewable materials that will be developed for different applications by using additive manufacturing methods.
Output	The programme of exchange is focused on novel RFID- and WSN-based green IOT devices with renewable materials that will be developed for different applications by

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 833496

	using additive manufacturing methods. As a result of the AdvIOT, novel tools for testing, analyzing, and improving the reliability and security of these new devices in various demanding applications and environments, such as in healthcare, disaster prevention, and intelligent transportation, will be achieved.
Link	https://cordis.europa.eu/project/id/611606
Results related to tools & technologies	The main achievement of AdvIOT was a multidisciplinary approach for the creation of wireless systems by utilizing new materials in novel fabrication methods to enable innovative structures and reliability improvement. Pioneering work was done in design, development of fabrication methods and materials, reliability improvement, as well as practical implementation of wireless systems into identification, monitoring, and sensing applications.
Name of the identified tool/technology	AdvIOT
Open estimation of the project outputs	The projects results has proven to be effective as it provided a unique opportunity to integrate collaboration ideas into a coherent programme addressing an issue of high priority on the agenda of EU, China, and Japan.
What are the key functionalities that the systems or tools are doing ?	

Project: [40] Big data meeting Cloud and IoT for empowering the citizen clout in smart cities - BigClouT

Name of the contributor	Frosina Ilievska
Email address of the contributor	frosina.ilievska@geonardo.com
Name of the research project (ex. EU), short and long name	Big data meeting Cloud and IoT for empowering the citizen clout in smart cities - BigClouT
Identity and schedule of the project	H2020, ID: 723139, 1.07.2016-30.06.2019
Project description	The overall concept of the BigClouT project is to give an analytic mind to the city by creating distributed intelligence that can be implanted in the whole city network. The BigClouT project is bringing together resources and knowledge necessary from prestigious European and Japanese institutions for tackling those challenges. BigClouT will leverage the results of the ClouT project and bring them several steps further and add, in particular, distributed intelligence with edge computing principles, big data analytics capability and self-awareness property.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 833496

Output	BigClouT will offer an analytic mind to the city by creating distributed intelligence that can be implanted throughout the whole city network either for large or smaller urban areas.
Link	https://cordis.europa.eu/project/id/723139
Results related to tools & technologies	BigClouT provides a modular framework to build customised solutions for today's smart city challenges including concerns in interoperability and big data. BigClouT platform facilitates rapid and flexible collection of a variety of city data (citizens, sensors, web pages, legacy platforms, ...). BigClouT also provides high level programming tools for rapid prototyping of smart city applications and an easy-to-use tools to extract value from the raw city data
Name of the identified tool/technology	KNOWAGE; BigClouT data lake; sensiNact; SoXFire; ECA Verifier
Open estimation of the project outputs	The integrated platform has been used and tested in close to real life environments, which allowed to increase the maturity level of each component, as well as the integrated results.

What are the key functionalities that the systems or tools are doing ?

Project: [41] EPOS IP (European Plate Observing System Implementation Phase)

Name of the contributor	Eija Parmes
Email address of the contributor	eija.parmes@vtt.fi
Name of the research project (ex. EU), short and long name	EPOS IP (European Plate Observing System Implementation Phase)
Identity and schedule of the project	H2020-EU.1.4.1.1. 1 October 2015 - 30 September 2019
Project description	The European Plate Observing System (EPOS) aims at creating a pan-European research infrastructure for solid Earth science to provide virtual access to data, products and services and physical access to facilities. EPOS allows for a better understanding of the Earth dynamics and this scientific progress will be used for assessing geo-hazards and the secure and sustainable use and exploitation of geo-resources. The EPOS mission is to create a single sustainable, permanent and distributed infrastructure that integrates the diverse and advanced European Research Infrastructures for solid Earth science.
Output	Implementation, validation and readiness report of EPOS Seismology services, Tools for submission, validation and access to data, metadata and products, WEB portal

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 833496

Link	https://cordis.europa.eu/project/id/676564/results
Results related to tools & technologies	Tools for submission, validation and access to data, metadata and products, WEB portal
Name of the identified tool/technology	EPOS Web portal
Open estimation of the project outputs	EPOS Web portal In pilot operational phase in 2020 -2022

What are the key functionalities that the systems or tools are doing ?

Project: [42] EPOS IP (European Plate Observing System Implementation Phase)

Name of the contributor	Eija Parmes
Email address of the contributor	eija.parmes@vtt.fi
Name of the research project (ex. EU), short and long name	ASSIST - Alpine Safety, Security And Information Services and Technologies
Identity and schedule of the project	FP6-AEROSPACE 1 June 2005 - 30 November 2007
Project description	ASSIST aims at improving the capabilities of risk warning and risk management in the Alpine region by implementing an integrated pre-operational service based on existing precursor services and related infrastructure. The overall objective is to specify, design, implement and validate a generic solution for the production and exchange of data products used for risk prevention and risk event management. The project will focus on risks typical to mountainous areas e.g. avalanches, landslides, debris flows, floods, etc. The backbone of the overall concept are so-called Service Nodes. These nodes are autonomously operated by organisations responsible for risk management. The Service Nodes are capable to request and ingest raw input data (e.g. EO data), process the input data into products suitable for risk prevention/crisis management, distribute the products within the User Network (fixed/mobile regional risk management centres and - if required - to the mobile staff), exchange products with other Service Nodes operated by different organisations (e.g. police, hospitals, air rescue, fire fighters). These Service Nodes will be laid out to support a) day-to-day monitoring and predictions of risk mitigation scenarios b) operation during concrete crisis situations.
Output	To simplify and improve available information on natural hazard risks. The Assist project proposed a flexible information service which combines data from satellites with ground observations with airborne and meteorological data to help improve services delivered by risk management centres. In, particular, newly developed algorithms have shown the benefits obtained from the combined use of all-weather synthetic aperture radar (SAR) images and high resolution optical data.
Link	https://cordis.europa.eu/project/id/12317/results
Results related to tools & technologies	Harmonisation (OGC) of ingestion and access to Earth observation (EO) data products, Integration of Mobile Communication,Handling and Acceptance of Mobile Devices for In-Field Staff, Use of SAR EO Data, Use of Optical EO for landslide susceptibility analysis

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 833496

Name of the identified tool/technology	OGC compliant catalogue service for web (CSW) could successfully be shown
Open estimation of the project outputs	<write here your own estimation of the main project outputs related to technologies & tools for disaster mangement>
What are the key functionalities that the systems or tools are doing ?	
Project: [43] Copernicus emergency management system, EU and ESA	
Name of the contributor	Eija Parmes
Email address of the contributor	eija.parmes@vtt.fi
Name of the research project (ex. EU), short and long name	Copernicus emergency management system, EU and ESA
Identity and schedule of the project	
Project description	Copernicus Emergency Management Service (Copernicus EMS) provides information for emergency response in relation to different types of disasters, including meteorological hazards, geophysical hazards, deliberate and accidental man-made disasters and other humanitarian disasters as well as prevention, preparedness, response and recovery activities.
Output	The Copernicus EMS is composed of an on-demand mapping component providing rapid maps for emergency response and risk & recovery maps for prevention and planning and of the early warning and monitoring component which includes systems for floods, droughts and forest fires
Link	https://emergency.copernicus.eu/
Results related to tools & technologies	Satellite images , maps, impacts and statistics on disasters globally
Name of the identified tool/technology	Rapid mapping , Risk and recovery mapping
Open estimation of the project outputs	Active up to date monitoring of natural disasters
What are the key functionalities that the systems or tools are doing ?	Rapid mapping and risk estimation of natural disasters
Project: [44] US Earthquake Hazards Program - USGS	
Name of the contributor	Eija Parmes
Email address of the contributor	eija.parmes@vtt.fi
Name of the research project (ex. EU), short and long name	Earthquake Hazards Program
Identity and schedule of the project	USGS United States Geological Survey program
Project description	List and map recent and historic earthquakes, information on selected significant earthquakes, earthquake resources by state, webservices.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 833496

Output	Map and list of earthquakes globally
Link	https://earthquake.usgs.gov/
Results related to tools & technologies	A number of tools related to earthquake modelling, impact areas, forecasting, etc.
Name of the identified tool/technology	Earthquake mapping
Open estimation of the project outputs	Global useful view to earthquake locations and parameters

What are the key functionalities that the systems or tools are doing ?

Project: [45] E2mC Evolution of Emergency Copernicus services

Name of the contributor	Asta Bäck
Email address of the contributor	asta.back@vtt.fi
Name of the research project (ex. EU), short and long name	E2mC Evolution of Emergency Copernicus services
Identity and schedule of the project	H2020-EU.2.1.6.3. - Enabling exploitation of space data , 730082, 1 November 2016, 30 April 2019
Project description	E2mC aims at demonstrating the technical and operational feasibility of the integration of social media analysis and crowdsourced information within both the Mapping and Early Warning Components of Copernicus Emergency Management Service (EMS).
Output	The component will improve the timeliness and accuracy of geo-spatial information provided to Civil Protection authorities, on a 24/7 basis, during the overall crisis management cycle and, particularly, in the first hours immediately after the event. Heterogeneous social media data streams (Twitter, Facebook, Instagram,… and different data: text, image, video, …) will be analysed and sparse crowdsourcing communities will be federated (crisis specific as Tomnod, HOT, SBTF and generic as Crowdcrafting, EpiCollect,…).
Link	https://cordis.europa.eu/project/id/730082
Results related to tools & technologies	Component to combine the input from citizens in social media and crowdsourcing communities to Copernicus.
Name of the identified tool/technology	Copernicus Witness Service Component
Open estimation of the project outputs	Two demonstration loops validated the usefulness of Copernicus Witness and the S&C Platform

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 833496

What are the key functionalities that the systems or tools are doing ?	
Project: [47] COMRADES Collective Platform for Community Resilience and Social Innovation during Crises	
Name of the contributor	Asta Bäck
Email address of the contributor	asta.back@vtt.fi
Name of the research project (ex. EU), short and long name	COMRADES Collective Platform for Community Resilience and Social Innovation during Crises
Identity and schedule of the project	H2020-EU.2.1.1. - INDUSTRIAL LEADERSHIP - Leadership in enabling and industrial technologies - Information and Communication Technologies (ICT) , 687847, 1 January 2016, 31 December 2018
Project description	The COMRADES project will build an intelligent collective resilience platform to help communities to reconnect, respond, and recover from crisis situations. It will achieve this through an interdisciplinary, socio-technical approach, which will draw on the latest advances in computational social science, social computing, real-time analytics, text and social media analysis, and Linked Open Data.
Output	The open source COMRADES platform will go beyond the now standard data collection, mapping, and manual analysis functions provided by the underpinning, widely used Ushahidi crisis mapping tool, to include new intelligent algorithms aimed at helping communities, citizens, and humanitarian services with analysing, verifying, monitoring, and responding to emergency events.
Link	https://cordis.europa.eu/project/id/687847 ; https://www.comrades-project.eu/
Results related to tools & technologies	Services that analyse social media content for event recognition and rumour detection
Name of the identified tool/technology	Crisis Event Extraction Service (CREES), and Rumour veracity classifier
Open estimation of the project outputs	The project has produced add-on services that help in utilising user-generated content. The services classifiy content (e.g. tweets) to identify which relate to disasters and characterises them based on how true they
What are the key functionalities that the systems or tools are doing ?	

Project: [48] SUPER Social sensors for secUrity Assessments and Proactive EmeRgencies management	
Name of the contributor	Asta Bäck
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Name of the research project (ex. EU), short and long name	SUPER Social sensors for secUrity Assessments and Proactive EmeRgencies management
Identity and schedule of the project	FP7-SECURITY - Specific Programme "Cooperation": Security , 606853, 1 April 2014, 31 March 2017

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 833496

Project description	SUPER developes a holistic, integrated and privacy-friendly approach to the use of social media in emergencies and security incidents. It will operate at multiple time-scales (before/during/after events), while serving both strategic and tactical level operations.
Output	The project has produced a number of modules relating to extracting information from social media.
Link	http://super-fp7.eu/
Results related to tools & technologies	Technology for event detection; sentiment tracking; discussion thread extraction; real-time summarisation; rumour, doubt and credibility classification; integrated search, behavioral analysis; community identification; intelligent fusion and reasoning; +Spaces platform; messaging service.
Name of the identified tool/technology	Natural language processing tools
Open estimation of the project outputs	The project has developed a number of tools that are useful when wanting to monitor and analyse social media content and user behaviour. No information of the availability of the tools could be found.

What are the key functionalities that the systems or tools are doing ?

Project: [49] I-REACT: Improving Resilience to Emergencies through Advanced Cyber Technologies

Name of the contributor	Asta Bäck
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Name of the research project (ex. EU), short and long name	I-REACT: Improving Resilience to Emergencies through Advanced Cyber Technologies
Identity and schedule of the project	H2020-EU.3.7. - Secure societies - Protecting freedom and security of Europe and its citizens , 700256, 1 June 2016, 31 May 2019
Project description	I-REACT integrates existing services, both local and European, into a platform that supports the entire emergency management cycle. I-REACT will integrate multiple systems and European assets, including the Copernicus Emergency Management Service, the European Flood Awareness System (EFAS), the European Forest Fire Information System (EFFIS), and European Global Navigation Satellite Systems (E-GNSS), e.g. Galileo and EGNOS.
Output	Platform for collecting data from multiple sources + mobile app for reporting and alerting. The core components available as Open Source and Freeware + commercial value added services. http://www.project.i-react.eu/wp-content/uploads/2019/10/I-REACT-White-Paper.pdf
Link	https://cordis.europa.eu/project/id/700256
Results related to tools & technologies	Core consists of a reporting tool, social media analysis tools and a decision support system to integrate various data sources; value added services include various risk prediction maps, a wearable for person tracking and a smart glasses application.

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Name of the identified tool/technology	I-REACT core components = mobile reporting app, social media, Emergency Management
Open estimation of the project outputs	The project output consists of a wide interlinked set of tools.
What are the key functionalities that the systems or tools are doing ?	Providing predictive and real-time information of various types of hazards.
Project: [50] EmerGent - Emergency management in social media generation	
Name of the contributor	Asta Bäck
Email address of the contributor	asta.back@vtt.fi
Name of the research project (ex. EU), short and long name	EmerGent
Identity and schedule of the project	FP7-SECURITY - Specific Programme "Cooperation": Security ; 608352; 1 April 2014 - 31.7.2017
Project description	EmerGent investigates the current use of social media during emergencies, and the future potential for citizens and EMS involvement within the EMC when using social media, and assesses impact of social media in emergencies for citizens and EMS. To handle the vast amount of valuable and distributed information, methods for Information Mining (IM) and Information Quality (IQ) are developed to classify and rate the available and provided data from users. Information Gathering (IG) and Information Routing (IR), including the development of new social apps, is done as part of the "Novel Emergency Management". The development of new social apps is undertaken to obtain and provide visualisations of the most relevant information (as assessed by EmerGent) integrated with several social network providers. All analysis and impact assessment results lead to the creation of guidelines. These guidelines enable EMS and all other involved stakeholders to understand the benefits of social media and its integration into their process on different levels (conceptual & technical). The insights and results from the studies are incorporated into these guidelines. Through the collection and presentation of Information, the analysis of social media in emergencies and the development of IM and IQ methods, an IT-system for the "Novel Emergency Management in Social Media Generation" will be developed.
Output	
Link	http://www.fp7-emergent.eu/ ; https://cordis.europa.eu/project/id/608352
Results related to tools & technologies	The project dealt with using social media in emergencies both the emergency personel and ordinary people
Name of the identified tool/technology	Guidelines

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Open estimation of the project outputs	The project produced clear guidelines. It has not been easy to find information of the technical tools developed in the project.

What are the key functionalities that the systems or tools are doing ?

Project: [51] ESRI ArcGIS

Name of the contributor	Eija Parmes
Email address of the contributor	eija.parmes@vtt.fi
Name of the research project (ex. EU), short and long name	ESRI ArcGIS
Identity and schedule of the project	GIS applications
Project description	IS applications
Output	Maps and statistics from geoinformation
Link	https://www.esri.com/
Results related to tools & technologies	Geoinformation management and applications
Name of the identified tool/technology	ESRI COVID-19 hub
Open estimation of the project outputs	Very informative on COVID-19 and near up todate

What are the key functionalities that the systems or tools are doing ?

Project: [52] Humanitarian OpenStreetMap - HOTOSM

Name of the contributor	Eija Parmes
Email address of the contributor	eija.parmes@vtt.fi
Name of the research project (ex. EU), short and long name	HOTOSM
Identity and schedule of the project	Humanitarian OpenStreetMap team
Project description	HOT is an international team dedicated to humanitarian action and community development through open mapping
Output	Maps for preparation and management of disasters
Link	https://www.hotosm.org/
Results related to tools & technologies	Portable OSM, Satellite image mapping methodologies, coworking, OpenMapKit, OpenDataKit
Name of the identified tool/technology	POSM

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Open estimation of the project outputs	Positive to rely on largely used OSM
What are the key functionalities that the systems or tools are doing ?	
Project: [53] Steinbeis Advanced Risk Technologies - R-Tech Group	
Name of the contributor	Alessandro Galvani
Email address of the contributor	alessandro.galvagni@provincia.tn.it
Name of the research project (ex. EU), short and long name	Steinbeis Advanced Risk Technologies R-Tech Group Steinbeis Advanced Risk Technologies R-Tech Group
Project description	Our emerging risks radar tool examines relevant web-sources (experts, press, public), visualizes/prioritizes main topics of interest and lists the most relevant links to the sources - in the case we bring to your attention here, the tool looks at the case COVID-19. If you find the tool useful or would like to know more about it, pls do not hesitate to contact us
Output	<short description of the main output of the project related to technologies & tools for disaster mangement>
Link	https://www.risk-technologies.com/home.aspx?lan=230&tab=1&itm=1&pag=12#bl58
Results related to tools & technologies	<Crystallized description of the results related to tools & technologies>
Name of the identified tool/technology	<Names of the identified tool/technology>
Open estimation of the project outputs	<write here your own estimation of the main project outputs related to technologies & tools for disaster mangement>

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Annex B. Indexed tools and technologies in the catalogue

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[1.1] Resilience Maturity Model	A set of guidelines to provide cities with common understanding of resilience, that help them to consider their current status and identify correct policis to implement. It can be used as part of strategic planning.
[1.2] Systematic Risk Assessment Questionnaire	Excel based tool where users are asked about likelyhood of numerous scenarios. Based upon responses the users get some feedback regarding potential risks.
[1.3] Resilience Building Policies	Supporting tool of the resilience Maturity model. It provides real case studies of policy implications in the model and enables stakeholders supplement it.
[1.4] System Dynamics Model	Training tool that helps decision-makers of the cities explore and simulate the resilience implementations in strategic planning.
[1.5] Resilience Engagement and Communication Tool / resilience information portal	Collaborative environment enabling cities to improve their IT systems, platforms and software
[2.1] DARWIN Wiki	DAWIN Wiki is a set of guiding principles that can be used to help stakeholders in creating/assesment of crisis management activities. It is presented in 13 capability cards that help policy/decision makers in implementing resilience measures and its use is rather strategic (rather than intended to the first responders of the crisis).
[2.2] Serious Gaming	A computer game with the purpose to teach and to train people involvd in real crises. It is a multiplayer puzzle-game.
[2.3] SimEnv	A simuation environment with which bottlenecks in crisis management can be revealed. The user simulates different crisis scenarios where the emphazise is in organizing great numbers of people to nearby hospitals.
[2.4] D-TORC	A board game that introduces Capability Cards and simulates some crisis scenarios.
[3.1] CIRI	A methodology or a mapping tool that breaks resilience into structures, processes and components and helps decision-makers assess anayse their resilience at a given time.
[3.2] ITRA	A model that helps stakeholders assess temporal perfomance loss of technologies taken in use to increase resilience.
[3.3] IORA	A methodolgy for organisations to assess their organisational resilience.
[3.4] ISRA	?missing description?
[3.5] AESOP	A methodolgy for communication teams of critical infrastructure managers to assess and improve their communication flow during disasters.
[4.1] Resilience Management Matrix Tool	Methodology that enables stakeholders estimate the inherent (non-crises periods) and adaptive (response flexibility capacity during disasters) capacities of

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	resilience. It consists of 55 resilience evaluation items, an indicative measurement and a criteria assesment scale.
[4.2] GIS mapping tool	GIS-based interface for other tools (matrix and audit tool) developed in the project.
[4.3] Audit Tool	Software that offers guidelines based on user input from other tools and explains the results.
[5.1] CRAMSS Application	A software application that enabled collaborative workspace in which DSS operators could share information. It is combined with supporting modules that aid decision-making
[5.2] Game based Training App	A training app directed to all potential user categories of other RESOLUTE services. The games are based on narratives of different emergencies.
[5.3] Mobile Emergency Support App	Mobile app for emergency responders and civilians to share information.
[6.1] Standardization roadmap for improving disaster resilience.	Standardization roadmap for improving disaster resilience.
[6.2] ResiStand Assessment Framework (RAF)	Execl tool for impact assessment of standardization
[7.1] Training model for inclusive Disaster Risk Reduction	Disaster preparedeness model that is aimed at taking into account the needs of disabled people - improve their disaster resilience and autonomy in face of catastrophe. It covers sign language, audio descriptions and tactile tools.
[7.2] Social Network Mapping and Analyses tool	The tool proposes a social network analyses framework, which aims to increase coordination and emergency management in different phases of disaster preparations.
[7.3] Collaborative Learning for DDR	Framework and a set of techniques to help stakeholders communicate and clarify the scope of the problems. The tool offers supportive materials to a session between different stakeholders.
[7.4] Games to Foster Empathy	A collection of computer games that are free to download and play by everybody. The games are aimed to teach people about disaster resilience, sustainable development and teamwork.
[8.1] The Storm Impact Database	A repository of historical storm events in the projects case study areas.
[8.2] The Coastal Risk Assessment Framework	Modelling software identificating potential hotspots of coastal hazards and analyzing the risks in most critical hotspots.
[8.3] The Web-based Management Guide	Management guide developed to facilitate EU-wide learinging and information exchange in DRR management. It provides guidance to coastal managers, recommendations for DRR and methods for stakeholder involvement.
[8.4] Hotspot Tool	Storm hotspot modelling tool to evaluate effectiveness of DRR measures in planning and also give realtime early warnings.
[8.5] Multi-Criteria Analysis Tool	Summary-type of overview that assesses proposed measures in the case studies of the project, facilitates communication and presentation of project results, captures knowledge regarding how socio-economic and political factors are perceived and raises awareness in stakeholders.

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[10.1] emBRACE conceptual framework of community resilience	A framework that depicts the dynamic interactions of community resilience across three component domains: resources and capacities, actions and learning. The framework is directed to policy and decision makers to use when considering resilience-related programmes and initiatives.
[11.1] MSP guidelines	Multi-sector partnership guidelines: A framework to assess the healthiness of multi-sectoral partnerships.
[12.1] PRACTICE Toolbox	A web-based database with a catalogue of exisiting and innovative components provided and developed during the project.
[13.1] ASA Software	Adwanced Situation Awareness (ASA). UAV system, that provides a live video from bird's-eye perspective, infrared video and a real-time environmetal sampling data.
[13.2] Dynamic Tagging	Software that assists first responders in marking and observing disaster site. The marking can take place either by actual sensors or a map software.
[13.3] SWARM	Situation aWAre Resource Management (SWARM). Smartphone application that provides disaster responders with a continuous overview of the surroundings and the state and context of human resources.
[14.1] CORFU GIS-Based Flood Mapping Application	GIS-based flood risk mapping tool for stakeholders. A software solution based on ArcGIS Online that supported urban flood assesment activities. It enabled users create flood and flood risk maps online based on existing data.
[15.1] BECCA tool	Framework and criteria sets for evaluating climate adaption. It can be used as a checklist according to what stakeholders could ensure that all potentially relevant aspects of climate adaption interventions are evaluated.
[15.2] WITCH	A model that assesses economic impact of climate change (rising temperature) upon economies if different regions.
[15.3] ARIO	Adaptive Regional Input-Output model. Model that is supposed to be used in urban environment and assesses cost-benefits for different adaptive scenarios.
[16.1] Multi-Hydro	Model that delivers flood parameters for which the damage assessment and flood risk planning can be performed. It evaluates small-scale changes in the urban environment.
[16.2] HOWAD- Prevent	Tool that models damage effects of buildings. Includes flood risk systems and short overviews of flood precaution measures.
[16.3] FLORETO-KALYPSO	Open source tool that can perform damage assessment and cost-benefit analysis for individual buildings.
[16.4] RAINS	Tool that models damage effects of buildings. Includes flood risk systems and short overviews of flood precaution measures. It links rainfall characteristics to pluvial flood damage characteristics.
[16.5] FVAT	Flood Vulnerability Assesment Tool (FVAT). Web-based system with free access and is dedicated to the reduction of vulnerabilty in urban environment. System operates as a check-list for different dimensions of vulnerability.
[17.1] Database on Emergency Response Major Incidents (DERMI)	The database is designed as a training tool in terms of Lessons Learned from terrorist threats, large scale industrial accidents, and natural catastrophes. DERMI provides the first comprehensive

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	in-depth analysis of the strengths and weaknesses of initial response by first responders answering to a Call for service in extreme situations.
[17.2] Driving situation simulator	The driving situation simulator is a tool enabling multiple users to drive towards a scene of a larger accident by using advanced 3D graphics in virtual environments. The training is supervised by an administrator who can monitor the exercise from a top view.
[17.3] Instructor supervision desk software	The instructor supervision desk software is a web based application designed and implemented for use in crisis management training. The software allows for a training organisation to plan and setup en exercise for a target organisation in need of training
[18.1] CapHAzNet-tool Tools used to deliver and raise awareness	The overall goal of CapHaz-Net was to develop deeper insights and recommendations on how to enhance the capacities of European societies to prepare for, cope with and recover from the impact of a natural hazard. Tools used to deliver and raise awarness of the reports: -One-way communication: Leaflets, brochures, information packs, video, newsletters - Reports, documents, protocols - Exhibitions/displays (non-staffed) - Advertising - Media (TV, radio, newspapers) - Internet (information provision) -two-way communication: Site visits - Exhibitions/displays (staffed) - Open house - Consultation document - Internet (information/feedback) - Free telephone line (automated and staffed) - Teleconferencing - Public meeting - Public inquiry/hearing - Deliberative opinion poll - Dialogue, two-way communication: Community Advisory Committees - 'Planning for real' - Meetings - Visioning - Deliberative Workshops - Internet Dialogue - Consensus building/conference and mediation - Deliberative mapping - Citizen panels - Citizen juries
[19.1] prototype software (OOFIMS), the Fragility Manager Tool, the MCDA software.	A comprehensive tool box has been developed (EQvis) containing several pre and postprocessing tools as well as other plug-ins such as the prototype software (OOFIMS), the Fragility Manager Tool, the MCDA software for modelling shelter needs and health impact (Fig. 6.1). The product EQvis (European Earthquake Risk Assessment and Visualisation Software) is an open source product that allows owners, practicing engineers and researchers the realistic risk assessment on systemic level (Fig. 6.2). It has been based on the similar pre and post-processing modules of MAEviz (see Schäfer and Bosi 2013 for more information). The field of analyses that can be performed with EQvis is very large, e.g. Hazard Computation, Structural Damages, Functionalities, Repair Cost Estimations, Cost Benefit Analyses, Utility Network Damages, Multi Attribute Utility Analyses, Shelter Needs, Social Vulnerability, Temporary Housing, etc.
[19.2] the Fragility Manager Tool	The Fragility Manager Tool offers the user to combine certain fragility functions and store them directly on the platform and use them. The platform can take the fragility curves for all buildings and bridges and assign them to all

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	the objects correctly. In the next step different analyses can be computed. Socio-economic analysis tools delivered another plug-in: The socio-economic module. The connection between the OOFIMS module and the socio-economic module was computed and the output was again done through GIS data format.
[19.3] MCDA software	the MCDA software for modelling shelter needs and health impact. The connection between the OOFIMS module and the socio-economic module was computed and the output was again done through GIS data format.
[22.1] HEIMDALL Service Platform (SP)	The system is designed as an integrated service platform using various data sources as inputs and proposing a set of services that can be useful to control centres, first responders and local populations during the preparedness and response phases.
[23.1] Recommendations of action and training for stakeholders	Through the usage of qualitative interviews, quantitative and surveys, as well as dialogue forums, the project provides recommendations for prevention, self-care and rescue of affected people.
[24.1] NEXES system and apps (several, see outputs).	Nexes system on which several apps are based. e.g. A Mobile Emergency Appication Solution for the citizens that supports total conversation for better accessibility.
[25.1] A4EU	Platform for collecting wheather and climate related information (situation awareness tool integrating geolocalized information), early warnings (multi weather/climate related hazards early warning system), emergency management and response to extreme WeatHER and climate Events. The platform integrates many subtools e.g. for alerting, crowdsourcing and risk assessment. Maybe integrate also prediction tool (https://www.wiki-predict.com/login).
[26.1] NOVAWSU	Research innovation hub, NOVAWSU, a gateway to the Innovation academy and NovaUCD where new high-tech and knowledge-intensive companies are nurtured and supported to enable them to grow, develop and create jobs.
[27.1] IN-PREP Collaborative Training platform	IN-PREP Collaborative Training platform: consisting of Mixed Reality Preparedness platform (MRPP), Training modules for testing co-ordination between agencies and their plans, Crisis management handbook for cross organizational operations.
[28.1] Eco	Open-web based insurance value platform, Eco. Robust assessment framework to measure the insurance risk/value of Nature based solutions as the goal of the project. Engine platform designed.
[30.1] RESISTO platform (TRL 7 level as the target of the project)	RESISTO platform, resilience enhancement and risk control platform for communication critical infrastucture operators. an innovative solution for CI holistic (physical/logical) situation awareness and enhanced resilience. Based on an Integrated Risk and Resilience analysis management, RESISTO implements an innovative Decision Support System to protect from combined cyber/physical threats, exploiting cyber/physical data improved correlation, integrated threat propagation modelling, and the Software Defined Security model. It provides state of the art

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	security components and services for detection and reaction: Blockchain for data integrity, Machine Learning for threat Intelligence, IoT Security and smart spectrum surveillance for physical security, enhanced and holistic video-audio analytics for improved situational awareness, Airborne threat detection for malicious UAV prevention, vulnerability assessment and 0-day attack analysis services for attack prevention and mitigation. Through RESISTO, Operators will be able to select and adopt a set of mitigation actions and countermeasures that significantly reduce the impact of negative events in terms of performance losses, social consequences, and cascading effects, by efficiently restoring full operational status..
[31.1] M2MGrids platform with horizontal solutions for services, communications and security	Horizontal M2MGrids platform, consisting of M2M service plaform, CPS communication hub and security policy service, which were evaluated in energy flexibility and traffic accident cases.
[32.2] Multi-source information engine (MIFE)	Data fusion model engine that gathers data from sensors on a robot or some other way, analyses the data and as a result provides locations of possible survivors and the presence of dangerous gases.
[32.3] Portal and mobile application for search&rescue operation (SaR-ESS)	Digital transformer of collected information sharing it to responsible teams and persons for proper.
[32.4] Common Operational Picture (COP)	System that links end users with the entire INACHUS system by providing a comprehensive map-centric view of the incident site.
[33.1] eCall	European in-vehicle emergency call system, eCall. In case of a traffic accident, eCall in-vehicle system (IVS) opens a voice connection between vehicle occupants and public safety answering point (PSAP) and sends the minimum set of data from vehicle to the PSAP The in-vehicle system can be activated automatically by sensors in the vehicle or manually by vehicle occupants (e.g. by pressing a button).
[33.2] Traffic situation service	The service provides information on traffic situation in Finland. The service provides information on incidents and roadworks on the road network, road conditions (e.g. weather), traffic congestion, information on railway traffic and information and warnings related to sea traffic.
[33.3] RDS-TMC	RDS-TMC (Radio Data System - Traffic Message Channel). RDS-TMC can be used for transmission of real-time traffic information to navigators and other mobile devices or in-vehicle devices. The information is transmitted in a subcarrier of a regular FM broadcast signal.
[33.4] RDS-TA	Traffic announcements in FM broadcasting with RDS-TA support. If RDS-TA technology is used, all FM car radio receivers with RDS-TA capability tuned to different programs of the same FM broadcaster (e.g. a national broadcaster) will switch to the program which provides a spoken traffic announcement. When the traffic announcement is over, car radio receivers return to the program selected by the user.

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[33.5] DPA	Dissemination of public announcements and emergency announcements in FM and TV broadcasting. Public authorities may send public annoucements and emergency alerts. Emergency alerts will be broadcast immediately by all FM radio and TV broadcasting stations, and public announcements will be broadcast as soon as possible.
[33.6] Cobra	Dynamis' COBRA software. In 2017 Belgium adopted COBRA software to connect all governmental agencies, hospitals, and high risk companies and contain all relevant information for emergency situations and events. The tool is available to these groups online and provides real-time situation reports, cartography with visualization of infrastructure, storage of all contact information, and secure chat rooms.
[33.7] DMA	Disaster Mangement Application (software). This application is intended to be used as an input for decision-making model that helps search and rescue teams determine the number of personnel to deploy and to help locating survivors and to determine in which stages are the survivors.
[33.8] TRASIM	TRASIM exercise platform can be used for implementing interactive exercises that test the effectiveness of an organization's situation management procedures and operating models and train key individuals to operate in disturbed and exeptional situations. The Trasim exercise platform and the exercise concepts that draw upon it make it easy to independently execute an exercise. Proven exercise scenarios are easy to reiterate, and the use of the platform increases the efficiency of exercise activities. The platform makes it easy to handle pre-assignments, instructions and written feedback. Furthermore, those who participate in the exercise or prepare it need not be in the same physical location. An online platform makes it possible to prepare and execute an exercise irrespective of time and place.
[33.9] SITMAN	Online environment for decision making and communication. With SITMAN, an up-to-date situational awareness can be shared with selected participants simultaniously via SMS/Email messaging. Management and other experts are able to convey information, maintain a real-time situational awareness, and lead crisis or incident management activities regardless of time and location.
[33.10] Temporary Population	A web dashboard for estimating different population types by municipality from past mobile positioning data. Permanent residents, workers, temporary residents, regular visitors, transit, domestic visitors, etc.
[33.11] Insta Blue Aware	Light, scalable, web based situational awareness solution. UIA04-158 SURE: Smart Urban Security and Event Resilience.
[33.12] FMI Warnings in Finland	Warnings of five-day period in land and sea areas related to weather forecast. The severity of the awareness level is shown on the map by means of a three-colour code system, also warning symbols are used.

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[33.13] Tilannehuone	The purpose of Tilannehuone.fi is to provide a clear and easy-to-understand snapshot of emergency alarms in Finland. Alarms can be viewed on map, where the alarm types are located as icons as well as in a list showing alarms in chronological order.
[33.14] Radiation today in Finland	The map displays about 260 external dose rate monitoring stations updated hourly. Local rates can be seen by clicking the map points.
[33.15] Watershed forecast and flood warnings in Finland	The map presents automatic flood warnings and water level forecasts for lakes and rivers.
[33.16] ArcGIS platform for location aware services	The platform can be used for binding data for the geographical information systems. For example, it has been applied to visualize the information related to the coronavirus geographical data, see https://coronavirus-resources.esri.com/?adumkts=industry_solutions&aduse=
[33.18] Traffic signal priority for emergency vehicles	The system gives priority to emergency vehicles at intersections with traffic lights. This allows emergency services arrive faster to the place where they are required.
[32.1] INACHUS robot	A snake-like robot with multiple sensors that detects victims in the rubble and maps their location
[35.1] beAWARE Final System (FS)	A platform that gathers and analyses data from sources such as social media, drones, weather databases. The data is assessed automatically in the platform and sent to the responders.
[36.1] BTS	UAV platform detecting people with mobile phones in rubbles
[37.1] CUBE	The cubes combine inverting technologies to produce and store electricity, filtering systems to supply clean water and several connection types.
[38.1] Quakebots	IoT sensors that measure seismic events on buildings with rapid notification system
[39.1] AdvIOT	AdvIOT focused on novel RFID- and WSN-based green IOT devices with renewable materials that will be developed for different applications by using additive manufacturing methods.
[40.1] Knowage	NOWAGE is an open source business intelligence suite providing different analytical tools to create reports, charts, graphs and interactive cockpits, in order to visualise data on maps, to perform multidimensional analysis, to extract knowledge, etc. KNOWAGE supports a wide range of data sources, structured databases, NoSQL databases, and also different tools and platforms.
[40.2] BigClouT data lake	The BigClouT Data Lake is a shared repository that is used to manage both static and real-time data from BigClouT partners. Based on the popular CKAN open data platform, the BigClouT project enabled its extension with a real-time capability allowing it to provide high performance queries over real time (streaming) data from city sources. Currently managing approximately 120GB of BigClouT city data, it has over 100 data resources stored in a variety of formats (JSON, csv, txt, pdf, etc.) which can be queried directly via a standardised API, via http queries or via an SQL based query language.
[40.3] sensiNact	sensiNact is an open IoT platform dedicated to the smart city domain. It provides support for various IoT protocols

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	and platforms to provide a homogenous access over heterogeneous city data sources. The BigClouT project enabled the development and validation support for additional data platforms and IoT protocols, thus increasing sensiNact's readiness level.
[40.4] ECA Verifier	ECA Verifier is an open source plugin for sensiNact studio and gateway, which implements the functionality of self-aware conflict resolution for service composition. It improves the degree of dependability of the platform by automatically detecting and resolving conflicts among applications developed and deployed in sensiNact. The BigClouT project allowed the demonstration of the feasibility of the verifying mechanism based on ECA and thus improved the verifier's readiness level.
[40.5] SOXFire	SOXFire is a multi-community city-wide sensor network for sharing big, social, sensor data in smart cities. The goal of SOXFire is to provide practical distributed and federated infrastructure for IoT sensor data sharing among various users/organisations in a way that is scalable, extensible, easy to use and secure with preserving privacy. SOXFire supports not only access to physical IoT sensors but also crowd sensing and SNS/Web sensing where city employees, citizens and WEB developers contribute in a different ways, while using unified APIs. The BigClouT project enabled the tool's deployment to other cities (going international) and enhancement of flexibilities as a common platform element.
[41.1]	EPOS, the European Plate Observing System, is a long-term plan to facilitate integrated use of data, data products, and facilities from distributed research infrastructures for solid Earth science in Europe.On October the 30th 2018, the European Commission granted the legal status of European Research Infrastructure Consortium (ERIC) to EPOS. The ERIC legal framework provides EPOS with legal personality and capacity recognised in all EU Member States and with the flexibility to adapt to the specific requirements of each infrastructure.
[42.1] OGC compliant catalogue service for web (CSW)	Harmonisation of ingestion and access to Earth observation (EO) data products. With the established concept of metadata handling along the Open GIS consortium (OGC) specifications, the integration of different kinds of products has successfully shown to be feasible. A variety of different products from optical and SAR sensors (both space-borne and air-borne), as well as derived products as e.g. line plots can be handled by the Assist demonstrator.
[43.1] Copernicus Emergency management system (EMS) Rapid mapping	The Copernicus EMS Mapping addresses, with a worldwide coverage, a wide range of emergency situations resulting from natural or man-made disasters. The satellite imagery is used as a main datasource about disasters
[43.2] Copernicus Emergency management system (EMS) Risk and Recovery mapping	This service consists of the on-demand provision of geospatial information. This information supports emergency management activities not related to the

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	immediate response phase. This service addresses prevention, preparedness, disaster risk reduction or recovery phases and is divided in 2 sub-categories.
[44.1] Earthquake mapping	Provides real time maps of earthquakes globally
[45.1] Copernicus Witness	A set of tools to gather and analyse social media data to link it to locations, and 114ummari crowdsourcing to check and add new data.
[47.1] Crisis Event Extraction Service (CREES)	CREES provides a Web API and accessible tools for classifying social media posts. Main purpose is to identify whether a post deals with a crisis situation, what kind of a crisis it is and what type of a message it is, e.g. affected individuals or a caution.
[47.2] Rumour veracity classifier	The service classifies whether a piece of news in a text is true, false or unverified
[48.1] Natural language processing tools	Technology for event detection; sentiment tracking; discussion thread extraction; real-time 114ummarization; rumour, doubt and credibility classification; integrated search, behavioral analysis; community identification; intelligent fusion and reasoning; +Spaces platform; messaging service.
[49.1] I-REACT Value added services	Value added services such as predictions, maps and wearable devices, best used in connection to the I-REACT Core Components.
[49.2] I-REACT Core components	Platform for collecting data from multiple sources and a mobile app for reporting and alerting.
[50.1] Emergent guidelines	Guidelines for using social media both for emergency services personnel and ordinary citizens
[51.1] ESRI COVID-19 hub	Get maps, datasets, applications, and more for coronavirus disease 2019 (COVID-19).
[52.1] POSM Portable OSM	POSM integrates best-of-breed tools from a variety of sources and developers on a single hardware device that can be deployed for mapping efforts, particularly when internet access is absent. POSM broadcasts a wireless signal that other devices can connect to in order to locally access tools that ordinarily require an internet connection. POSM let's you bring the standard toolset along for the ride when you don't have access to cheap and fast internet connectivity.
[53.1] COVID19 Risk radar	Our emerging risks radar tool examines relevant web-sources (experts, press, public), visualizes/prioritizes main topics of interest and lists the most relevant links to the sources - in the case we bring to your attention here, the tool looks at the case COVID-19
[54.1] Societal Impact Assessment (SIA) Framework for Crisis Management (CM)	DRIVER+ we developed a Societal Impact Assessment (SIA) Framework for Crisis Management (CM) aiming to evaluate the societal impact an innovative CM solution can have on society. the method, the assessment criteria as well as the taxonomy of functions to be standardized as an ISO standard. Therefore we are looking for your support.

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Annex C. Catalogueof tools and technologies with categories

Main category: tool or technology type	
Sub-category	Technologies or tools
Technology - physical system related	MyNexes [24.1], DMA [33.7]
Technology - communication related	MyNexes [24.1], eCall [33.1], RDS-TMC [33.3], RDS-TA [33.4], COBRA [33.6], DMA [33.7], TRASIM [33.8], SITMAN [33.9], RESISTO [30.1], beAWARE FS [35.1] , SOXFire [40.5], Comrades crees [47.1], SUPER tools [48.1], I-REACT Core comp [49.2] , ESRI COVID-19 hub [51.1]
Technology - information or knowledge related	MyNexes [24.1], Anywhere [25.1], COBRA [33.6], DMA [33.7], TRASIM [33.8], SITMAN [33.9], HEIMDALL [22.1], RESISTO [30.1], [33.10] Temporary Population, FMI warnings [33.12], Watershed forecast [33.15], Tilannehuone [33.13] , Radioation today [33.14], ArcGIS paikkatieto [33.16], 72-tuntia [33.17], Mife [32.2], SaR-ESS [32.3], COP [32.4] , beAWARE FS [35.1], Knowage [40.1], BigClout data lake [40.2], sensiNact [40.3], SOXFire [40.5], Copernicus Witness [45.1] , Comrades crees [47.1], Comrades Rumour [47.2] , SUPER tools [48.1] , I-REACT Core comp [49.2] , ESRI COVID-19 hub [51.1]
Tool - guideline or method	DPA [33.5], IN-PREP [27.1] , FMI warnings [33.12] , 72-tuntia [33.17] , BigClout data lake [40.2], Emergent guidelines [50.1] , ESRI COVID-19 hub [51.1]
Tool - application, software solution or ICT service	CRAMSS [5.1], Resolute Game [5.2], ESSMA [5.3], MyNexes [24.1], Anywhere [25.1], eCall [33.1], traffic [33.2], RDS-TMC [33.3], RDS-TA [33.4], DPA [33.5], COBRA [33.6], DMA [33.7], TRASIM [33.8], SITMAN [33.9], PRACTISE [12.1], SWARM [13.3], HEIMDALL [22.1] , RESISTO [30.1] , IN-PREP [27.1], [33.10] Temporary Population, FMI warnings [33.12] , Watershed forecast [33.15] , Tilannehuone [33.13], Radioation today [33.14] , ArcGIS paikkatieto [33.16], Traffic signal priority for emergency vehicles [33.18] , 72-tuntia [33.17] , beAWARE FS [35.1] , sensiNact [40.3], ECA Verifier [40.4] , SOXFire [40.5] , Copernicus Witness [45.1] , Comrades crees [47.1] , Comrades Rumour [47.2] , ESRI COVID-19 hub [51.1]
Tool - physical product	ASA [13.1], Dynamic [13.2]
Process Tool - can be applied in Research & Development process	DMA [33.7], TRASIM [33.8], SITMAN [33.9], [33.10] Temporary Population, ArcGIS paikkatieto [33.16] , ESRI COVID-19 hub [51.1]

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Process Tool - can be applied in continuous improvement of operation process of disaster mgt	MyNexes [24.1], DMA [33.7], TRASIM [33.8], SITMAN [33.9], HEIMDALL [22.1] , IN-PREP [27.1], [33.10] Temporary Population, sensiNact [40.3] , SOXFire [40.5] , Copernicus Witness [45.1] , ESRI COVID-19 hub [51.1]
Process Tool - can be applied in the actual real-time operation process of disaster mgt	CRAMSS [5.1], ESSMA [5.3], MyNexes [24.1], A4EU [25.1], COBRA [33.6], DMA [33.7], SITMAN [33.9], ASA [13.1], Dynamic [13.2], HEIMDALL [22.1] , beAWARE FS [35.1] , Copernicus Witness [45.1] , Comrades crees [47.1] , I-REACT Core comp [49.2] , ESRI COVID-19 hub [51.1]
Main category: Purpose	
Sub-category	Technologies or tools
Communication oriented	ESSMA [5.3], CRAMSS [5.1], MyNexes [24.1], eCall [33.1], COBRA [33.6], DMA [33.7], TRASIM [33.8], SITMAN [33.9], PRACTISE [12.1], RESISTO [30.1] , IN-PREP [27.1] , beAWARE FS [35.1] , Comrades crees [47.1] , SUPER tools [48.1] , I-REACT Core comp [49.2] , Emergent guidelines [50.1] , ESRI COVID-19 hub [51.1]
Information/data oriented	ESSMA [5.3], MyNexes [24.1], A4EU [25.1], traffic [33.2], DMA [33.7], TRASIM [33.8], SITMAN [33.9], PRACTISE [12.1], ASA [13.1], Dynamic [13.2], SWARM [13.3], HEIMDALL [22.1] , RESISTO [30.1] , IN-PREP [27.1], [33.10] Temporary Population, Watershed forecast [33.15] , Tilannehuone [33.13] , Radioation today [33.14] , ArcGIS paikkatieto [33.16] , Mife [32.2] , SaR-ESS [32.3] , COP [32.4] , beAWARE FS [35.1] , Knowage [40.1] , BigClout data lake [40.2] , sensiNact [40.3] , Copernicus Witness [45.1] , Comrades crees [47.1] , Comrades Rumour [47.2] , SUPER tools [48.1] , I-REACT Core comp [49.2] , ESRI COVID-19 hub [51.1]
Decision making / operational actions oriented	CRAMSS [5.1], MyNexes [24.1], A4EU [25.1], DMA [33.7], TRASIM [33.8], SITMAN [33.9], PRACTISE [12.1], HEIMDALL [22.1] , RESISTO [30.1] , IN-PREP [27.1], [33.10] Temporary Population, Traffic signal priority [33.18] , beAWARE FS [35.1] , Copernicus Witness [45.1] , Comrades crees [47.1] , Comrades Rumour [47.2] , SUPER tools [48.1] , I-REACT Core comp [49.2] , ESRI COVID-19 hub [51.1]
Location detection based services related e.g predictions	A4EU [25.1], eCall [33.1], DMA [33.7], [33.10] Temporary Population, ArcGIS paikkatieto [33.16] , beAWARE FS [35.1] , ECA Verifier [40.4] , SOXFire [40.5] , Copernicus Witness [45.1] , Comrades crees [47.1] , I-REACT Core comp [49.2]
Warnings and Alerting	MyNexes [24.1], A4EU [25.1], traffic [33.2], RDS-TMC [33.3], RDS-TA [33.4], DPA [33.5], DMA [33.7], SITMAN [33.9] , FMI warnings [33.12] , Watershed forecast [33.15] , Tilannehuone [33.13] , Radioation today [33.14] , beAWARE FS [35.1] , I-REACT Core comp [49.2]
Main category: Owner	
Sub-category	Technologies or tools

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Unofficial civil society organization	DMA [33.7] , 72-tuntia [33.17]
Authorities, usage limited to authorities only	DPA [33.5] , IN-PREP [27.1], [33.10] Temporary Population, Traffic signal priority for emergency vehicles [33.18]
Authorities, usage allowed also for other stakeholders	A4EU [25.1], eCall [33.1], traffic [33.2], DMA [33.7], SWARM [13.3] , FMI warnings [33.12] , Watershed forecast [33.15] , Radioation today [33.14] , 72-tuntia [33.17]
Service integrator/provider	CRAMSS [5.1], Resolute Game [5.2], ESSMA [5.3], MyNexes [24.1], eCall [33.1], RDS-TMC [33.3], RDS-TA [33.4], COBRA [33.6], DMA [33.7], TRASIM [33.8], SITMAN [33.9], PRACTISE [12.1], ASA [13.1], Dynamic [13.2], SWARM [13.3] , RESISTO [30.1] , ArcGIS paikkatieto [33.16] , beAWARE FS [35.1] , Knowage [40.1] , ESRI COVID-19 hub [51.1]
Tool developer	CRAMSS [5.1], Resolute Game [5.2], ESSMA [5.3], DMA [33.7], TRASIM [33.8], SITMAN [33.9], PRACTISE [12.1], HEIMDALL [22.1] , RESISTO [30.1], [33.10] Temporary Population, Tilannehuone [33.13] , ArcGIS paikkatieto [33.16] , Mife [32.2] , SaR-ESS [32.3] , COP [32.4] , beAWARE FS [35.1] , Knowage [40.1] , BigClout data lake [40.2] , sensiNact [40.3] , ECA Verifier [40.4] , SOXFire [40.5] , Copernicus Witness [45.1] , Comrades crees [47.1] , Comrades Rumour [47.2] , I-REACT Core comp [49.2]
Individual persons or communities	eCall [33.1], DMA [33.7], TRASIM [33.8] , I-REACT Core comp [49.2] , Emergent guidelines [50.1]
Main category: Potential users/customers	
Sub-category	Technologies or tools
Unofficial response system with civil society organizations	Resolute Game [5.2], CRAMSS [5.1], A4EU [25.1], COBRA [33.6], DMA [33.7], TRASIM [33.8], SITMAN [33.9], PRACTISE [12.1], ASA [13.1], Dynamic [13.2], SWARM [13.3], HEIMDALL [22.1] , IN-PREP [27.1], [33.10] Temporary Population, FMI warnings [33.12] , Watershed forecast [33.15] , Tilannehuone [33.13] , Radioation today [33.14] , ArcGIS paikkatieto [33.16] , 72-tuntia [33.17] , beAWARE FS [35.1] , Comrades crees [47.1] , Comrades Rumour [47.2] , I-REACT Core comp [49.2] , Emergent guidelines [50.1] , ESRI COVID-19 hub [51.1]
Official response systems with authorities	ESSMA [5.3], Resolute Game [5.2], CRAMSS [5.1], A4EU [25.1], eCall [33.1], COBRA [33.6], DMA [33.7], TRASIM [33.8], SITMAN [33.9], PRACTISE [12.1], ASA [13.1], Dynamic [13.2], SWARM [13.3], HEIMDALL [22.1] , IN-PREP [27.1], [33.10] Temporary Population, FMI warnings [33.12] , Watershed forecast [33.15] , Tilannehuone [33.13] , Radioation today [33.14] , ArcGIS paikkatieto [33.16] , Traffic signal priority for emergency vehicles [33.18] , Mife [32.2] , SaR-ESS [32.3] , COP [32.4] , beAWARE FS [35.1] , Knowage [40.1] , Copernicus Witness [45.1] , Comrades crees [47.1] , Comrades Rumour [47.2] , SUPER tools [48.1] , I-REACT Core comp

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	[49.2] , Emergent guidelines [50.1] , ESRI COVID-19 hub [51.1]
Communities of people	CRAMSS [5.1], DMA [33.7], TRASIM [33.8], SITMAN [33.9], PRACTISE [12.1], HEIMDALL [22.1] , FMI warnings [33.12] , Watershed forecast [33.15] , Tilannehuone [33.13] , Radioation today [33.14] , ArcGIS paikkatieto [33.16] , 72-tuntia [33.17] , beAWARE FS [35.1] , Comrades crees [47.1] , Emergent guidelines [50.1] , ESRI COVID-19 hub [51.1]
Individual ordinary people	ESSMA [5.3], MyNexes [24.1], eCall [33.1], traffic [33.2], RDS-TMC [33.3], RDS-TA [33.4], DPA [33.5], DMA [33.7], SITMAN [33.9], PRACTISE [12.1], HEIMDALL [22.1] , FMI warnings [33.12] , Watershed forecast [33.15] , Tilannehuone [33.13] , Radioation today [33.14] , ArcGIS paikkatieto [33.16] , 72-tuntia [33.17] , I-REACT Core comp [49.2] , Emergent guidelines [50.1] , ESRI COVID-19 hub [51.1]
Individual people with limited capabilities/low social capital	MyNexes [24.1], DMA [33.7], SITMAN [33.9], HEIMDALL [22.1] , FMI warnings [33.12] , Watershed forecast [33.15] , Tilannehuone [33.13] , Radioation today [33.14] , ArcGIS paikkatieto [33.16] , 72-tuntia [33.17] , I-REACT Core comp [49.2] , Emergent guidelines [50.1]
Tool product developer or service integrator/provider	DMA [33.7], SITMAN [33.9], HEIMDALL [22.1], RESISTO [30.1], [33.10] Temporary Population, FMI warnings [33.12] , Watershed forecast [33.15] , Tilannehuone [33.13] , Radioation today [33.14] , ArcGIS paikkatieto [33.16] , Knowage [40.1] , BigClout data lake [40.2] , sensiNact [40.3] , ECA Verifier [40.4] , SOXFire [40.5] , Comrades crees [47.1] , Comrades Rumour [47.2] , SUPER tools [48.1] , I-REACT Core comp [49.2] , Emergent guidelines [50.1] , ESRI COVID-19 hub [51.1]
Main category: Level of Use	
Sub-category	Technologies or tools
Idea, concept or method	DMA [33.7] , RESISTO [30.1] , IN-PREP [27.1]
Research Prototype	DMA [33.7] , RESISTO [30.1] , IN-PREP [27.1], beAWARE FS [35.1], Super tools [48.1]
End user evaluated research prototype	ESSMA [5.3], Resolute Game [5.2], CRAMSS [5.1], Dynamic [13.2], SWARM [13.3], MIFE [32.2], Sar-ESS [32.3], COP [32.3], ECA verifier [40.4], Super tools [48.1]
Preliminary product or service	A4EU [25.1], Copernicus Witness [45.1], Comrades crees [47.1]
Product or service in pilot use of end users	MyNexes [24.1], A4EU [25.1], SITMAN [33.9], PRACTISE [12.1], SOXFire [40.5], KNOWAGE [40.1], sensiNact [40.3], Emergent [50.1]
Product or service in real use of end users	A4EU [25.1], eCall [33.1], traffic [33.2], RDS-TMC [33.3], RDS-TA [33.4], DPA [33.5], COBRA [33.6], TRASIM [33.8], SITMAN [33.9], ASA [13.1], [33.10] Temporary Population, FMI Warnings [33.12], Tilannehuone [33.13], Radiation today [33.14], Watershed forecast [33.15], ArcGIS paikkatieto [33.16], 72-tuntia [33.17], Traffic signal priority for emergency

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	vehicles [33.18], BigClout data lake [40.2], Comrades Rumor [47.2], I-REACT Core comp [49.2], Emergent [50.1], ESRI COVID-19 hub [51.1]
Main category: TRL level	
Sub-category	Technologies or tools
TRL-1	DMA [33.7] , RESISTO [30.1]
TRL-2	DMA [33.7], SWARM [13.3] , RESISTO [30.1]
TRL-3	DMA [33.7]
TRL-4	CRAMSS [5.1], TRASIM [33.8], ECA verifier [40.4]
TRL-5	A4EU [25.1], TRASIM [33.8], HEIMDALL [22.1] , IN-PREP [27.1], Super tools [48.1]
TRL-6	A4EU [25.1], TRASIM [33.8] , IN-PREP [27.1], , beAWARE FS [35.1], Comrades crees [47.1]
TRL-7	ESSMA [5.3], Resolute Game [5.2], MyNexes [24.1], A4EU [25.1], Dynamic [13.2], SWARM [13.3] , IN-PREP [27.1] , MIFE [32.2] , Sar-ESS [32.3] , COP [32.3] , SOXFire [40.5], KNOWAGE [40.1], sensiNact [40.3], Copernicus Witness [45.1], Emergent [50.1]
TRL-8	TRASIM [33.8], PRACTISE [12.1], ASA [13.1], Comrades Rumor [47.2], ESRI COVID-19 hub [51.1]
TRL-9	eCall [33.1], traffic [33.2], RDS-TMC [33.3], RDS-TA [33.4], DPA [33.5], COBRA [33.6], TRASIM [33.8], SITMAN [33.9], [33.10] Temporary Population, FMI Warnings [33.12], Tilannehuone [33.13] , Radiation today [33.14], Watershed forecast [33.15] , ArcGIS paikkatieto [33.16], 72-tuntia [33.17] , Traffic signal priority for emergency vehicles [33.18], BigClout data lake [40.2], I-REACT Core comp [49.2]
Main category: Crisis/Disaster lifecycle	
Sub-category	Technologies or tools
Understanding disaster risk (risk mitigation)	A4EU [25.1], DMA [33.7], TRASIM [33.8], SITMAN [33.9] , RESISTO [30.1] , IN-PREP [27.1], [33.10] Temporary Population, FMI warnings [33.12] , ArcGIS paikkatieto [33.16] , 72-tuntia [33.17] , beAWARE FS [35.1] , Knowage [40.1] , BigClout data lake [40.2] , sensiNact [40.3] , ECA Verifier [40.4] , SOXFire [40.5] , I-REACT Core comp [49.2] , ESRI COVID-19 hub [51.1]
Preparedness to disaster	A4EU [25.1], DPA [33.5], DMA [33.7], TRASIM [33.8], SITMAN [33.9], PRACTISE [12.1] , HEIMDALL [22.1] , RESISTO [30.1] , IN-PREP [27.1] , Watershed forecast [33.15], FMI warnings [33.12] , Tilannehuone [33.13] , Radioation today [33.14] , ArcGIS paikkatieto [33.16] , Copernicus Witness [45.1] , I-REACT Core comp [49.2] , Emergent guidelines [50.1] , ESRI COVID-19 hub [51.1]
Immediate Response to disaster	ESSMA [5.3], CRAMSS [5.1], MyNexes [24.1], A4EU [25.1], eCall [33.1], traffic [33.2], RDS-TMC [33.3], RDS-TA [33.4], COBRA [33.6], DMA [33.7], SITMAN [33.9], PRACTISE [12.1], ASA [13.1], Dynamic [13.2], SWARM [13.3] , HEIMDALL [22.1] , IN-PREP [27.1], [33.10] Temporary Population, Watershed forecast [33.15], FMI warnings [33.12] , Tilannehuone [33.13] , Radioation today [33.14] , ArcGIS paikkatieto [33.16] ,

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	Traffic signal priority for emergency vehicles [33.18] , Mife [32.2] , SaR-ESS [32.3] , COP [32.4] , beAWARE FS [35.1] , Copernicus Witness [45.1] , Comrades crees [47.1] , Comrades Rumour [47.2] , SUPER tools [48.1] , I-REACT Core comp [49.2] , Emergent guidelines [50.1] , ESRI COVID-19 hub [51.1]
Recovery	traffic [33.2], RDS-TMC [33.3], RDS-TA [33.4], COBRA [33.6], SITMAN [33.9], PRACTISE [12.1], SWARM [13.3] , HEIMDALL [22.1] , IN-PREP [27.1], [33.10] Temporary Population, Watershed forecast [33.15], FMI warnings [33.12] , Tilannehuone [33.13] , Radioation today [33.14] , ArcGIS paikkatieto [33.16] , Copernicus Witness [45.1] , Comrades crees [47.1] , Comrades Rumour [47.2] , SUPER tools [48.1] , Emergent guidelines [50.1] , ESRI COVID-19 hub [51.1]

Table 9. Analysis of categories of rechnologies & tools Technologies & tools related to risks related to natural disasters.

Main category: tool or technology type	
Sub-category	Technologies or tools
Technology - physical system related	Prototype software (OOFIMS) (SYNER-G [19.1]), Fragility Manager Tool (SYNER-G [19.2]), MCDA software (SYNER-G [19.3]).
Technology - communication related	The Web-based Management Guide (RISC-KIT [8.3]), EPOS System [41.1], I-REACT Value added services [49.1] , I-REACT Core comp[49.2]
Technology - information or knowledge related	The Web-based Management Guide (RISC-KIT [8.3]), A4EU platform (ANYWHERE [25.1]), Eco platform (NAIAD [28.1]) , EPOS System [41.1], EMS Rapid mapping [43.1], EMS risk recovery [43.2], Earthquake mapping [44.1] , I-REACT Value added services [49.1] , I-REACT Core comp[49.2]
Tool - guideline or method	MSP guidelines (ENHANCE [11.1]), Eco platform (NAIAD [28.1]), CSW [42.1]
Tool - application, software solution or ICT service	The Storm Impact Database (RISC-KIT [8.1]), The Coastal Risk Assessment Framework (RISC-KIT [8.2]), The Web-based Management Guide (RISC-KIT [8.3]), Hotspot Tool (RISC-KIT [8.4]), GIS-Based Flood Mapping Application (CORFU [14.1]), Multi-Hydro (SMARTeST [16.1]), HOWAD- Prevent (SMARTeST [16.2]), FLORETO-KALYPSO (SMARTeST [16.3]), RAINS (SMARTeST [16.4]), FVAT (SMARTeST [16.5]), Prototype software (OOFIMS) (SYNER-G [19.1]), Fragility Manager Tool (SYNER-G [19.2]), MCDA software (SYNER-G [19.3]), A4EU platform (ANYWHERE [25.1]),]), Eco platform (NAIAD [28.1]) , EPOS System [41.1] , EMS Rapid mapping [43.1] , EMS risk recovery [43.2] , Earthquake mapping [44.1] , I-

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	REACT Value added services [49.1] , I-REACT Core comp[49.2]
Tool - physical product	I-REACT Value added services [49.1]
Process Tool - can be applied in Research & Development process	Hotspot Tool RISC-KIT ([8.4]), Prototype software (OOFIMS) (SYNER-G [19.1]), Fragility Manager Tool (SYNER-G [19.2]), MCDA software (SYNER-G [19.3]) , EPOS System [41.1] , EMS Rapid mapping [43.1] , EMS risk recovery [43.2] , Earthquake mapping [44.1]
Process Tool - can be applied in continuous improvement of operation process of disaster mgt	Prototype software (OOFIMS) (SYNER-G [19.1]), Fragility Manager Tool (SYNER-G [19.2]), MCDA software (SYNER-G [19.3]), A4EU platform (ANYWHERE [25.1]), Eco platform (NAIAD [28.1]) , EPOS System [41.1] , EMS Rapid mapping [43.1] , EMS risk recovery [43.2] , Earthquake mapping [44.1]
Process Tool - can be applied in the actual real-time operation process of disaster mgt	Hotspot Tool RISC-KIT ([8.4]), Prototype software (OOFIMS) (SYNER-G [19.1]), Fragility Manager Tool (SYNER-G [19.2]), MCDA software (SYNER-G [19.3]) , EMS Rapid mapping [43.1] , EMS risk recovery [43.2] , Earthquake mapping [44.1] , I-REACT Value added services [49.1] , I-REACT Core comp[49.2]
Main category: Purpose	
Sub-category	Technologies or tools
Communication oriented	Multi-Criteria Analysis Tool (RISC-KIT [8.5]) , EPOS System [41.1] , EMS Rapid mapping [43.1] , I-REACT Value added services [49.1] , I-REACT Core comp[49.2]
Information/data oriented	]), A4EU platform (ANYWHERE [25.1]), Eco platform (NAIAD [28.1]) , EPOS System [41.1] , CSW [42.1] , EMS Rapid mapping [43.1] , EMS risk recovery [43.2] , Earthquake mapping [44.1] , I-REACT Value added services [49.1] , I-REACT Core comp[49.2]
Decision making / operational actions oriented	The Web-based Management Guide (RISC-KIT [8.3]), Hotspot Tool RISC-KIT ([8.4]), MSP guidelines (ENHANCE [11.1]), GIS-Based Flood Mapping Application (CORFU [14.1]), A4EU (ANYWHERE [25.1]) , EPOS System [41.1] , EMS Rapid mapping [43.1] , EMS risk recovery [43.2] , Earthquake mapping [44.1] , I-REACT Value added services [49.1] , I-REACT Core comp[49.2]
Location detection based services related e.g predictions	The Coastal Risk Assessment Framework (RISC-KIT [8.2]), Multi-Hydro (SMARTeST [16.1]), HOWAD- Prevent (SMARTeST [16.2]), FLORETO-KALYPSO (SMARTeST [16.3]), RAINS (SMARTeST [16.4]), FVAT (SMARTeST [16.5]), A4EU (ANYWHERE [25.1]) , EPOS System [41.1] , EMS Rapid mapping [43.1] , EMS risk recovery [43.2] , Earthquake mapping [44.1] , I-REACT Value added services [49.1] , I-REACT Core comp[49.2]

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Warnings and Alerting	Hotspot Tool RISC-KIT ([8.4]), Prototype software (OOFIMS) (SYNER-G [19.1]), Fragility Manager Tool (SYNER-G [19.2]), MCDA software (SYNER-G [19.3]), A4EU (ANYWHERE [25.1]) , EMS Rapid mapping [43.1] , EMS risk recovery [43.2] , Earthquake mapping [44.1] , I-REACT Value added services [49.1] , I-REACT Core comp[49.2]
Main category: Owner	
Sub-category	Technologies or tools
Unofficial civil society organization	
Authorities, usage limited to authorities only	
Authorities, usage allowed also for other stakeholders	A4EU (ANYWHERE [25.1]) , EMS Rapid mapping [43.1] , EMS risk recovery [43.2] , Earthquake mapping [44.1]
Service integrator/provider	GIS-Based Flood Mapping Application (CORFU [14.1]), Multi-Hydro (SMARTeST [16.1]), HOWAD-Prevent (SMARTeST [16.2]), FLORETO-KALYPSO (SMARTeST [16.3]), RAINS (SMARTeST [16.4]), FVAT (SMARTeST [16.5]), Prototype software (OOFIMS) (SYNER-G [19.1]), Fragility Manager Tool (SYNER-G [19.2]), MCDA software (SYNER-G [19.3]), Eco platform (NAIAD [28.1]) , EPOS System [41.1] , EMS Rapid mapping [43.1] , EMS risk recovery [43.2] , Earthquake mapping [44.1]
Tool developer	The Storm Impact Database (RISC-KIT [8.1]), The Coastal Risk Assessment Framework (RISC-KIT [8.2]), The Web-based Management Guide (RISC-KIT [8.3]), Hotspot Tool (RISC-KIT [8.4]), Multi-Criteria Analysis Tool (RISC-KIT [8.5]), MSP guidelines (ENHANCE [11.1]), FLORETO-KALYPSO (SMARTeST [16.3]), RAINS (SMARTeST [16.4]), FVAT (SMARTeST [16.5]), Prototype software (OOFIMS) (SYNER-G [19.1]), Fragility Manager Tool (SYNER-G [19.2]), MCDA software (SYNER-G [19.3]), Eco platform (NAIAD [28.1]) , EMS risk recovery [43.2] , I-REACT Value added services [49.1] , I-REACT Core comp[49.2]
Individual persons or communities	I-REACT Core comp[49.2]
Main category: Potential users/customers	
Sub-category	Technologies or tools
Unofficial response system with civil society organizations	The Storm Impact Database (RISC-KIT [8.1]), The Coastal Risk Assessment Framework (RISC-KIT [8.2]), The Web-based Management Guide (RISC-KIT [8.3]), Hotspot Tool (RISC-KIT [8.4]), Multi-Criteria Analysis Tool (RISC-KIT [8.5]), MSP guidelines (ENHANCE [11.1]), RAINS (SMARTeST [16.4]), FVAT (SMARTeST [16.5]), Prototype software (OOFIMS) (SYNER-G [19.1]), Fragility Manager Tool (SYNER-G [19.2]), MCDA software (SYNER-G [19.3]), A4EU (ANYWHERE [25.1]) , EPOS System [41.1] , EMS Rapid mapping [43.1] , EMS risk recovery [43.2] ,

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	Earthquake mapping [44.1] , I-REACT Core comp[49.2]
Official response systems with authorities	The Storm Impact Database (RISC-KIT [8.1]), The Coastal Risk Assessment Framework (RISC-KIT [8.2]), The Web-based Management Guide (RISC-KIT [8.3]), Hotspot Tool (RISC-KIT [8.4]), Multi-Criteria Analysis Tool (RISC-KIT [8.5]), MSP guidelines (ENHANCE [11.1]), GIS-Based Flood Mapping Application (CORFU [14.1]), Multi-Hydro (SMARTeST [16.1]), HOWAD- Prevent (SMARTeST [16.2]), RAINS (SMARTeST [16.4]), FVAT (SMARTeST [16.5]), Prototype software (OOFIMS) (SYNER-G [19.1]), Fragility Manager Tool (SYNER-G [19.2]), MCDA software (SYNER-G [19.3]), A4EU (ANYWHERE [25.1]) , EPOS System [41.1] , EMS Rapid mapping [43.1] , EMS risk recovery [43.2] , Earthquake mapping [44.1] , I-REACT Value added services [49.1] , I-REACT Core comp[49.2]
Communities of people	The Coastal Risk Assessment Framework (RISC-KIT [8.2]), Hotspot Tool (RISC-KIT [8.4]), FLORETO-KALYPSO (SMARTeST [16.3]), EMS Rapid mapping [43.1] , EMS risk recovery [43.2] , Earthquake mapping [44.1]
Individual ordinary people	Hotspot Tool (RISC-KIT [8.4]), , EMS Rapid mapping [43.1] , EMS risk recovery [43.2] , Earthquake mapping [44.1] , I-REACT Core comp[49.2]
Individual people with limited capabilities/low social capital	I-REACT Core comp[49.2]
Tool product developer or service integrator/provider	Multi-Criteria Analysis Tool (RISC-KIT [8.5]), MSP guidelines (ENHANCE [11.1]), GIS-Based Flood Mapping Application (CORFU [14.1]), Multi-Hydro (SMARTeST [16.1]), SMARTeST [16.2], FLORETO-KALYPSO (SMARTeST [16.3]), RAINS (SMARTeST [16.4]), FVAT (SMARTeST [16.5]), Prototype software (OOFIMS) (SYNER-G [19.1]), Fragility Manager Tool (SYNER-G [19.2]), MCDA software (SYNER-G [19.3]), Eco platform (NAIAD [28.1]) , CSW [42.1] , EMS Rapid mapping [43.1] , EMS risk recovery [43.2] , Earthquake mapping [44.1] , I-REACT Value added services [49.1] , I-REACT Core comp[49.2]
Main category: Level of Use	
Sub-category	Technologies or tools
Idea, concept or method	Eco platform (NAIAD [28.1])
Research Prototype	Multi-Criteria Analysis Tool (RISC-KIT [8.5]), Eco platform (NAIAD [28.1])
End user evaluated research prototype	Eco platform (NAIAD [28.1]) , CSW [42.1]
Preliminary product or service	The Coastal Risk Assessment Framework (RISC-KIT [8.2]), A4EU (ANYWHERE [25.1])
Product or service in pilot use of end users	The Storm Impact Database (RISC-KIT [8.1]), The Web-based Management Guide (RISC-KIT [8.3]), MSP guidelines (ENHANCE [11.1]), GIS-Based

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	Flood Mapping Application (CORFU [14.1]), HOWAD- Prevent (SMARTeST [16.2]), RAINS (SMARTeST [16.4]), FVAT (SMARTeST [16.5]), Prototype software (OOFIMS) (SYNER-G [19.1]), Fragility Manager Tool (SYNER-G [19.2]), MCDA software (SYNER-G [19.3]), A4EU (ANYWHERE [25.1]) , EPOS System [41.1] , I-REACT Value added services [49.1]
Product or service in real use of end users	Hotspot Tool (RISC-KIT [8.4]), SMARTeST [16.1], SMARTeST [16.3], A4EU (ANYWHERE [25.1]) , EMS Rapid mapping [43.1] , EMS risk recovery [43.2] , Earthquake mapping [44.1] , I-REACT Core comp[49.2]
Main category: TRL level	
Sub-category	Technologies or tools
TRL-1	Eco platform (NAIAD [28.1])
TRL-2	RISC-KIT [8.5], NAIAD [28.1]
TRL-3	Eco platform (NAIAD [28.1]) , CSW [42.1]
TRL-4	Eco platform (NAIAD [28.1])
TRL-5	A4EU (ANYWHERE [25.1])
TRL-6	A4EU (ANYWHERE [25.1])
TRL-7	The Storm Impact Database (RISC-KIT [8.1]), The Coastal Risk Assessment Framework (RISC-KIT [8.2]),The Web-based Management Guide (RISC-KIT [8.3]), Hotspot Tool (RISC-KIT [8.4]), MSP guidelines (ENHANCE [11.1]), HOWAD- Prevent (SMARTeST [16.2]), RAINS (SMARTeST [16.4]), FVAT (SMARTeST [16.5]), Prototype software (OOFIMS) (SYNER-G [19.1]), Fragility Manager Tool (SYNER-G [19.2]), MCDA software (SYNER-G [19.3]), A4EU (ANYWHERE [25.1]) , EPOS System [41.1]
TRL-8	GIS-Based Flood Mapping Application (CORFU [14.1]), HOWAD- Prevent (SMARTeST [16.2]), FLORETO-KALYPSO (SMARTeST [16.3])
TRL-9	SMARTeST [16.1] , EMS Rapid mapping [43.1] , EMS risk recovery [43.2] , Earthquake mapping [44.1] , I-REACT Value added services [49.1] , I-REACT Core comp[49.2]
Main category: Crisis/Disaster lifecycle	
Sub-category	Technologies or tools
Understanding disaster risk (risk mitigation)	The Coastal Risk Assessment Framework (RISC-KIT [8.2]), Hotspot Tool (RISC-KIT [8.4]), Multi-Criteria Analysis Tool (RISC-KIT [8.5]), MSP guidelines (ENHANCE [11.1]), Eco platform (NAIAD [28.1]) , EPOS System [41.1] , EMS Rapid mapping [43.1] , EMS risk recovery [43.2] , Earthquake mapping [44.1] , I-REACT Value added services [49.1] , I-REACT Core comp[49.2]
Preparedness to disaster	The Storm Impact Database (RISC-KIT [8.1]), The Web-based Management Guide (RISC-KIT [8.3]), Hotspot Tool (RISC-KIT [8.4]), GIS-Based Flood Mapping Application (CORFU [14.1]), SMARTeST

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	[16.1], HOWAD- Prevent (SMARTeST [16.2]), FLORETO-KALYPSO (SMARTeST [16.3]), RAINS (SMARTeST [16.4]), FVAT (SMARTeST [16.5]), Prototype software (OOFIMS) (SYNER-G [19.1]), Fragility Manager Tool (SYNER-G [19.2]), MCDA software (SYNER-G [19.3]) , EPOS System [41.1] , CSW [42.1] , EMS Rapid mapping [43.1] , EMS risk recovery [43.2] , Earthquake mapping [44.1] , I-REACT Value added services [49.1] , I-REACT Core comp[49.2]
Immediate Response to disaster	CSW [42.1] , EMS Rapid mapping [43.1] , Earthquake mapping [44.1] , I-REACT Value added services [49.1] , I-REACT Core comp[49.2]
Recovery	EMS Rapid mapping [43.1] , Earthquake mapping [44.1]

Table 10. Analysis of categories of Technologies & tools related to guidelines, methods, organizational development, training and education.

Main category: tool or technology type	
Sub-category	Technologies or tools
Technology - physical system related	DERMI [17.1], Driving Situation Simulator [17.2], Instructor Supervision desk software [17.3], INACHUS robot [32.1], Mobile Base Station [36.1]
Technology - communication related	CapHAzNet-tool [18.1], Final System [35.1]
Technology - information or knowledge related	SimEnv [2.3], DERMI [17.1], Driving Situation Simulator [17.2], Instructor Supervision desk software [17.3], Multi-source Information Engine [32.2], SaR-ESS [32.3], Common Operational Picture [32.4], Final System [35.1]
Tool - guideline or method	Resilience Maturity Model [1.1], Resilience Building Policies [1.3], DARWIN Wiki [2.1], CIRI [3,1], IORA [3.3], AESOP [3.3], Resilience Management Matrix Tool [4.1], Training model for inclusive Disaster Risk Reduction [7.1], Social Network Mapping and Analyses tool [7.2], Collaborative Learning for DDR [7.3], emBRACE conceptual framework of community resilience [10.1], DERMI [17.1], Driving Situation Simulator [17.2], Instructor Supervision desk software [17.3], Recommendations of action and training for stakeholders [23.1], NOVAWSU [26.1], SIA Framework [54.1]
Tool - application, software solution or ICT service	Resilience Maturity Model [1.1], System Dynamics Model [1.4], Serious Gaming [2.2], GIS Mapping Tool [4.2], Audit Tool [4.3], Game Based Training App [5.2], Final System [35.1], SIA Framework [54.1]
Tool - physical product	D-TORC [2.4], DERMI [17.1], Driving Situation Simulator [17.2], Instructor Supervision desk software [17.3], Mobile Base Station [36.1]
Process Tool - can be applied in Research & Development process	Resilience Maturity Model [1.1], City Resilience Dynamics [1.4], DARWIN Wiki [2.1], SimEnv [2.3],

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	Training model for inclusive Disaster Risk Reduction [7.1], DERMI [17.1], Driving Situation Simulator [17.2], Instructor Supervision desk software [17.3]
Process Tool - can be applied in continuous improvement of operation process of disaster mgt	ITRA [3.2], DERMI [17.1], Driving Situation Simulator [17.2], Instructor Supervision desk software [17.3] , SIA Framework [54.1]
Process Tool - can be applied in the actual real-time operation process of disaster mgt	ITRA [3.2], Final System [35.1]
Main category: Purpose	
Sub-category	Technologies or tools
Communication oriented	DARWIN Wiki [2.1], IMPRVER AESOP, Social Network Mapping and Analyses tool [7.2], CapHAzNet-tool [18.1], Final System [35.1]
Information/data oriented	SimEnv [2.3], CapHAzNet-tool [18.1], Recommendations of action and training for stakeholders [23.1], INACHUS robot [32.1], Multi-source Information Engine [32.2], SaR-ESS [32.3], Common Operational Picture [32.4], Final System [35.1], Mobile Base Station [36.1], SIA Framework [54.1]
Decision making / operational actions oriented	Resilience Maturity Model [1.1], Resilience Maturity Model [1.1], Resilience Building Policies [1.3], City Resilience Dynamics [1.4], System Dynamics Model [1.4], DARWIN Wiki [2.1], CIRI [3,1], ITRA [3.2], IORA [3.3], Resilience Management Matrix Tool [4.1], Collaborative Learning for DDR [7.3], emBRACE conceptual framework of community resilience [10.1], Final System [35.1]
Location detection based services related e.g predictions	GIS Mapping Tool [4.2], Audit Tool [4.3], Final System [35.1], Mobile Base Station [36.1]
Warnings and Alerting	System Dynamics Model [1.4], DERMI [17.1], Driving Situation Simulator [17.2], Instructor Supervision desk software [17.3], Final System [35.1]
Main category: Owner	
Sub-category	Technologies or tools
Unofficial civil society organization	Training model for inclusive Disaster Risk Reduction [7.1], Recommendations of action and training for stakeholders [23.1], Mobile Base Station [36.1]
Authorities, usage limited to authorities only	
Authorities, usage allowed also for other stakeholders	Recommendations of action and training for stakeholders [23.1], NOVAWSU [26.1], Mobile Base Station [36.1]
Service integrator/provider	Resilience Maturity Model [1.1],System Dynamics Model [1.4], Game Based Training App [5.2], Games to Foster Empathy [7.4], DERMI [17.1], Driving Situation Simulator [17.2], Instructor Supervision desk software [17.3], Final System [35.1] , SIA Framework [54.1]

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Tool developer	Resilience Maturity Model [1.1], Resilience Maturity Model [1.1], Resilience Building Policies [1.3], City Resilience Dynamics [1.4], System Dynamics Model [1.4], DARWIN Wiki [2.1], Serious Gaming [2.2], SimEnv [2.3], D-TORC [2.4], CIRI [3,1], ITRA [3.2], IORA [3.3], AESOP [3.3], Resilience Management Matrix Tool [4.1], GIS Mapping Tool [4.2], Audit Tool [4.3], Game Based Training App [5.2], Training model for inclusive Disaster Risk Reduction [7.1], Social Network Mapping and Analyses tool [7.2], Collaborative Learning for DDR [7.3], emBRACE conceptual framework of community resilience [10.1], CapHAzNet-tool [18.1], DERMI [17.1], Driving Situation Simulator [17.2], Instructor Supervision desk software [17.3], INACHUS robot [32.1], Multi-source Information Engine [32.2], SaR-ESS [32.3], Common Operational Picture [32.4], Final System [35.1] , SIA Framework [54.1]
Individual persons or communities	Training model for inclusive Disaster Risk Reduction [7.1], Social Network Mapping and Analyses tool [7.2] , EDUCEN Games to Foster Empathy, Recommendations of action and training for stakeholders [23.1]
Main category: Potential users/customers	
Sub-category	Technologies or tools
Unofficial response system with civil society organizations	Resilience Maturity Model [1.1], Resilience Maturity Model [1.1], Resilience Building Policies [1.3], City Resilience Dynamics [1.4], System Dynamics Model [1.4], DARWIN Wiki [2.1], Serious Gaming [2.2], SimEnv [2.3], D-TORC [2.4], CIRI [3,1], ITRA [3.2], IORA [3.3], AESOP [3.3], Resilience Management Matrix Tool [4.1], GIS Mapping Tool [4.2], Audit Tool [4.3], Game Based Training App [5.2], Training model for inclusive Disaster Risk Reduction [7.1], Social Network Mapping and Analyses tool [7.2], Collaborative Learning for DDR [7.3], Games to Foster Empathy [7.4], emBRACE conceptual framework of community resilience [10.1], NOVAWSU [26.1], Final System [35.1], Mobile Base Station [36.1] , SIA Framework [54.1]
Official response systems with authorities	Resilience Maturity Model [1.1], Resilience Maturity Model [1.1], Resilience Building Policies [1.3], City Resilience Dynamics [1.4], System Dynamics Model [1.4], DARWIN Wiki [2.1], Serious Gaming [2.2], SimEnv [2.3], D-TORC [2.4], CIRI [3,1], ITRA [3.2], IORA [3.3], AESOP [3.3], Resilience Management Matrix Tool [4.1], GIS Mapping Tool [4.2], Audit Tool [4.3],, Game Based Training App [5.2], Training model for inclusive Disaster Risk Reduction [7.1], Social Network Mapping and Analyses tool [7.2], Collaborative Learning for DDR [7.3], Games to Foster Empathy [7.4], emBRACE conceptual

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	framework of community resilience [10.1], CapHAzNet-tool [18.1], NOVAWSU [26.1], INACHUS robot [32.1], Multi-source Information Engine [32.2], SaR-ESS [32.3], Common Operational Picture [32.4], Final System [35.1], Mobile Base Station [36.1] , SIA Framework [54.1]
Communities of people	Resilience Maturity Model [1.1],System Dynamics Model [1.4], DARWIN Wiki [2.1], Serious Gaming [2.2], D-TORC [2.4], CIRI [3,1], ITRA [3.2], IORA [3.3], Training model for inclusive Disaster Risk Reduction [7.1], Social Network Mapping and Analyses tool [7.2], Collaborative Learning for DDR [7.3], Games to Foster Empathy [7.4], emBRACE conceptual framework of community resilience [10.1], DERMI [17.1], Driving Situation Simulator [17.2], Instructor Supervision desk software [17.3], Recommendations of action and training for stakeholders [23.1], NOVAWSU [26.1], Final System [35.1] , SIA Framework [54.1]
Individual ordinary people	Resilience Maturity Model [1.1], DARWIN Wiki [2.1], Collaborative Learning for DDR [7.3], EDUCEN Games to Foster Empathy, DERMI [17.1], Instructor supervision desk software [17.3], Recommendations of action and training for stakeholders [23.1], NOVAWSU [26.1]
Individual people with limited capabilities/low social capital	Resilience Maturity Model [1.1], DARWIN Wiki [2.1], Training model for inclusive Disaster Risk Reduction [7.1], Collaborative Learning for DDR [7.3], Games to Foster Empathy [7.4], DERMI [17.1], Driving Situation Simulator [17.2], Instructor Supervision desk software [17.3], Recommendations of action and training for stakeholders [23.1]
Tool product developer or service integrator/provider	Resilience Maturity Model [1.1],System Dynamics Model [1.4], CapHAzNet-tool [18.1], DERMI [17.1], Driving Situation Simulator [17.2], Instructor Supervision desk software [17.3] , SIA Framework [54.1]
Main category: Level of Use	
Sub-category	Technologies or tools
Idea, concept or method	CapHAzNet-tool [18.1], Recommendations of action and training for stakeholders [23.1], NOVAWSU [26.1] , SIA Framework [54.1]
Research Prototype	Resilience Maturity Model [1.1], Serious Gaming [2.2], SimEnv [2.3], D-TORC [2.4], Final System [35.1] , SIA Framework [54.1]
End user evaluated research prototype	CIRI [3,1], ITRA [3.2], IORA [3.3], AESOP [3.3], Game Based Training App [5.2], Collaborative Learning for DDR [7.3], DERMI [17.1], Driving Situation Simulator [17.2], Instructor Supervision desk software [17.3], INACHUS robot [32.1], Multi-source Information Engine [32.2], SaR-ESS [32.3], Common Operational Picture [32.4], Mobile Base Station [36.1]

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Preliminary product or service	System Dynamics Model [1.4], Training model for inclusive Disaster Risk Reduction [7.1], emBRACE conceptual framework of community resilience [10.1]
Product or service in pilot use of end users	Resilience Building Policies [1.3], City Resilience Dynamics [1.4], Resilience Management Matrix Tool [4.1], GIS Mapping Tool [4.2], Audit Tool [4.3], Social Network Mapping and Analyses tool [7.2]
Product or service in real use of end users	Resilience Maturity Model [1.1], DARWIN Wiki [2.1], Games to Foster Empathy [7.4]
Main category: TRL level	
Sub-category	Technologies or tools
TRL-1	CapHAzNet-tool [18.1], DERMI [17.1], Driving Situation Simulator [17.2], Instructor Supervision desk software [17.3], NOVAWSU [26.1]
TRL-2	DERMI [17.1], Driving Situation Simulator [17.2], Instructor Supervision desk software [17.3], NOVAWSU [26.1]
TRL-3	D-TORC [2.4], DERMI [17.1], Driving Situation Simulator [17.2], Instructor Supervision desk software [17.3] , SIA Framework [54.1]
TRL-4	SimEnv [2.3], DERMI [17.1], Instructor supervision desk software [17.3]
TRL-5	DERMI [17.1], Instructor supervision desk software [17.3]
TRL-6	DERMI [17.1], Instructor supervision desk software [17.3], Final System [35.1], Mobile Base Station [36.1]
TRL-7	Resilience Maturity Model [1.1], Resilience Maturity Model [1.1], Resilience Building Policies [1.3], City Resilience Dynamics [1.4], System Dynamics Model [1.4], Serious Gaming [2.2], CIRI [3,1], ITRA [3.2], IORA [3.3], AESOP [3.3], Resilience Management Matrix Tool [4.1], GIS Mapping Tool [4.2], Audit Tool [4.3], Game Based Training App [5.2], Training model for inclusive Disaster Risk Reduction [7.1], Social Network Mapping and Analyses tool [7.2], Collaborative Learning for DDR [7.3], emBRACE conceptual framework of community resilience [10.1], DERMI [17.1], Instructor supervision desk software [17.3], INACHUS robot [32.1], Multi-source Information Engine [32.2], SaR-ESS [32.3], Common Operational Picture [32.4]
TRL-8	DARWIN Wiki [2.1], DERMI [17.1], Instructor supervision desk software [17.3]
TRL-9	Games to Foster Empathy [7.4]
Main category: Crisis/Disaster lifecycle	
Sub-category	Technologies or tools
Understanding disaster risk (risk mitigation)	Resilience Maturity Model [1.1], Systematic Risk Assessment Questionnaire [1.2], Resilience Engagement and Communication Tool [1.5],

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	DARWIN Wiki [2.1], CIRI [3.1], Collaborative Learning for DDR [7.3], CapHAzNet-tool [18.1], Recommendations of action and training for stakeholders [23.1], NOVAWSU [26.1], Final System [35.1]
Preparedness to disaster	Resilience Maturity Model [1.1], Systematic Risk Assessment Questionnaire [1.2], Resilience Building Policies [1.3], Resilience Engagement and Communication Tool [1.5], DARWIN Wiki [2.1], ITRA [3.2], IORA [3.3], AESOP [3.3], Resilience Management Matrix Tool [4.1], GIS Mapping Tool [4.2], Audit Tool [4.3], Training model for inclusive Disaster Risk Reduction [7.1], Social Network Mapping and Analyses tool [7.2], Games to Foster Empathy [7.3], emBRACE conceptual framework of community resilience [10.1], DERMI [17.1], Driving Situation Simulator [17.2], Instructor Supervision desk software [17.3], Recommendations of action and training for stakeholders [23.1], NOVAWSU [26.1] , SIA Framework [54.1]
Immediate Response to disaster	Serious Gaming [2.2], SimEnv [2.3], D-TORC [2.4], AESOP [3.3] , Training model for inclusive Disaster Risk Reduction [7.1], Recommendations of action and training for stakeholders [23.1], NOVAWSU [26.1], INACHUS robot [32.1], Multi-source Information Engine [32.2], SaR-ESS [32.3], Common Operational Picture [32.4], Final System [35.1], Mobile Base Station [36.1]
Recovery	CIRI [3,1], Recommendations of action and training for stakeholders [23.1], NOVAWSU [26.1] , SIA Framework [54.1]

Table 11. Analysis of categories of Technologies & tools related to standardization, information exposed from multiple ecosystems or cyber-physical (IoT) systems in disaster management

Main category: tool or technology type	
Sub-category	Technologies or tools
Technology - physical system related	INACHUS Robot [32.1], BTS [36.1], CUBE [37.1], Quakebots [38.1]
Technology - communication related	M2MGrids platform [31.1] , CUBE [37.1], Quakebots [38.1], POSM [52.1], Resisto platform [30.1]
Technology - information or knowledge related	M2MGrids platform [31.1] , Quakebots [38.1], AdvIOT [39.1] , POSM [52.1] , Resisto platform [30.1]
Tool - guideline or method	Roadmap [6.1] , POSM [52.1]
Tool - application, software solution or ICT service	M2MGrids platform [31.1] , Quakebots [38.1] , POSM [52.1] , Resisto platform [30.1], SWARM [13.3]
Tool - physical product	BTS [36.1] , CUBE [37.1] , Quakebots [38.1], ASA [13.1], Dynamic tagging [13.2]

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Process Tool - can be applied in Research & Development process	Roadmap [6.1] , POSM [52.1]
Process Tool - can be applied in continuous improvement of operation process of disaster mgt	CUBE [37.1] , POSM [52.1] , Resisto platform [30.1]
Process Tool - can be applied in the actual real-time operation process of disaster mgt	M2MGrids platform [31.1] , CUBE [37.1] , POSM [52.1] , ASA [13.1] , Dynamic tagging [13.2]
Main category: Purpose	
Sub-category	Technologies or tools
Communication oriented	M2MGrids platform [31.1] , POSM [52.1] , Resisto platform [30.1]
Information/data oriented	M2MGrids platform [31.1], INACHUS Robot [32.1] , BTS [36.1] , Quakebots [38.1] , AdvIOT [39.1] , POSM [52.1] , Resisto platform [30.1] , ASA [13.1] , Dynamic tagging [13.2] , SWARM [13.3]
Decision making / operational actions oriented	CUBE [37.1] , POSM [52.1] , Resisto platform [30.1]
Location detection based services related e.g predictions	
Warnings and Alerting	Quakebots [38.1]
Main category: Owner	
Sub-category	Technologies or tools
Unofficial civil society organization	M2MGrids platform [31.1] , BTS [36.1] , AdvIOT [39.1] , POSM [52.1]
Authorities, usage limited to authorities only	M2MGrids platform [31.1]
Authorities, usage allowed also for other stakeholders	M2MGrids platform [31.1] , BTS [36.1] , Quakebots [38.1] , AdvIOT [39.1] , SWARM [13.3]
Service integrator/provider	M2MGrids platform [31.1] , POSM [52.1] , Resisto platform [30.1] , ASA [13.1] , Dynamic tagging [13.2] , SWARM [13.3]
Tool developer	M2MGrids platform [31.1], INACHUS Robot [32.1] , CUBE [37.1] , Quakebots [38.1] , Resisto platform [30.1]
Individual persons or communities	M2MGrids platform [31.1] , Quakebots [38.1]
Main category: Potential users/customers	
Sub-category	Technologies or tools
Unofficial response system with civil society organizations	Roadmap [6.1], M2MGrids platform [31.1] , BTS [36.1] , Quakebots [38.1] , AdvIOT [39.1] , POSM [52.1] , ASA [13.1] , Dynamic tagging [13.2] , SWARM [13.3]
Official response systems with authorities	Roadmap [6.1], M2MGrids platform [31.1], INACHUS Robot [32.1] , BTS [36.1] , CUBE [37.1] , Quakebots [38.1] , POSM [52.1] , ASA [13.1] , Dynamic tagging [13.2] , SWARM [13.3]
Communities of people	M2MGrids platform [31.1] , CUBE [37.1] , Quakebots [38.1] , AdvIOT [39.1] , POSM [52.1]
Individual ordinary people	M2MGrids platform [31.1] , CUBE [37.1] , Quakebots [38.1] , POSM [52.1]
Individual people with limited capabilities/low social capital	M2MGrids platform [31.1] , CUBE [37.1] , Quakebots [38.1]

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Tool product developer or service integrator/provider	Roadmap [6.1], M2MGrids platform [31.1] , CUBE [37.1] , Quakebots [38.1] , POSM [52.1] , Resisto platform [30.1]
Main category: Level of Use	
Sub-category	Technologies or tools
Idea, concept or method	Roadmap [6.1], M2MGrids platform [31.1] , Resisto platform [30.1]
Research Prototype	M2MGrids platform [31.1] , Resisto platform [30.1]
End user evaluated research prototype	M2MGrids platform [31.1], INACHUS Robot [32.1] , BTS [36.1] , Dynamic tagging [13.2] , SWARM [13.3]
Preliminary product or service	AdvIOT [39.1]
Product or service in pilot use of end users	
Product or service in real use of end users	CUBE [37.1] , Quakebots [38.1] , POSM [52.1] , ASA [13.1]
Main category: TRL level	
Sub-category	Technologies or tools
TRL-1	Roadmap [6.1], M2MGrids platform [31.1] , Resisto platform [30.1]
TRL-2	Roadmap [6.1], M2MGrids platform [31.1] , AdvIOT [39.1] , Resisto platform [30.1]
TRL-3	M2MGrids platform [31.1]
TRL-4	M2MGrids platform [31.1]
TRL-5	
TRL-6	BTS [36.1]
TRL-7	INACHUS Robot [32.1] , Dynamic tagging [13.2] , SWARM [13.3]
TRL-8	POSM [52.1] , ASA [13.1]
TRL-9	CUBE [37.1] , Quakebots [38.1]
Main category: Crisis/Disaster lifecycle	
Sub-category	Technologies or tools
Understanding disaster risk (risk mitigation)	Roadmap [6.1], M2MGrids platform [31.1] , AdvIOT [39.1] , POSM [52.1] , Resisto platform [30.1]
Preparedness to disaster	Roadmap [6.1], M2MGrids platform [31.1] , CUBE [37.1] , Quakebots [38.1] , POSM [52.1] , Resisto platform [30.1]
Immediate Response to disaster	Roadmap [6.1], M2MGrids platform [31.1], INACHUS Robot [32.1] , BTS [36.1] , CUBE [37.1] , POSM [52.1] , ASA [13.1] , Dynamic tagging [13.2]
Recovery	Roadmap [6.1], M2MGrids platform [31.1] , CUBE [37.1] , POSM [52.1]

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