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Emerging technologies for the Early location of Entrapped victims under Collapsed Structures & Advanced Wearables for risk assessment and First Responders Safety in S&R operations

D1.6 Report on the functional specifications of S&R, V2

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Executive Summary

The structure of the D1.6 deliverable is the result of achieving the purpose and scope in which it applies (see subchapter 1.1).

This deliverable contains four chapters, a list of figures and one of tables, including an appendix with the references used in the text of the document.

Chapter 1 (Introduction) is structured in three subchapters, as follows.

Subchapter 1.1 (Purpose and Scope) identifies the purpose of deliverable D1.6 and its scope, as a result of the technological research developments that took place within the SnR project, during the time elapsed from deliverable D1.2.

Subchapter 1.2 (Structure of the Document) presents in essence the objective and results of the specific approach to each component of the D1.6 deliverable.

Subchapter 1.3 (User Requirements follow-up) presents the process of evolution and refinement of end-user requirements over the period elapsed, one year, from the start of the SnR project.

Chapter 2 (Chemical S&R TOOLS) is structured in three subchapters, as follows.

Subchapter 2.1 [Portable Membrane Inlet Mass Spectrometer (MIMS) follow-up] analyses future research directions to improve the performance of core characteristics (in terms of power supply, size, weight, user interface characteristics, etc.) of Portable Membrane Inlet Mass Spectrometer (MIMS) to identify the location of people trapped under rubble following a disaster. This analysis reviews possible technical solutions for the subsequent miniaturization of the portable membrane input mass spectrometer to optimize their capabilities to identify as accurately as possible the location of people trapped under the rubble.

Similarly, the conditions to be simulated in the exercise / training fields required for testing and validating the portable membrane input mass spectrometer (MIMS) proposed to be performed within the seven UCs of the SnR project are mentioned, according to user users requirements.

Subchapter 2.2 (Rescue MIMS on Robotics follow-up) contains the analysis of the main technical characteristics regarding the research, testing and validation of terrestrial robots of type COYOTE III or Seerkur Jr (with RESCUE MIMS mounted on their platform as an early warning system not as an S&R tool) for the main purpose of ensuring security for First Responders.

Last but not least, the ethical dilemmas that may result from human-robot interaction in S&R actions were also mentioned.

Subchapter 2.3 (Integration of the UAV system with RESCUE MIMS, first responders, K-9 dog teams and robotics in search and rescue operations) analyses the use of UAVs (Unmanned aerial vehicle) in S&R actions in terms of core characteristics required (power supply, size, payload, user interface characteristics and equipment maintenance) to achieve optimal operational cooperation with RESCUE MIMS, first responders, K-9 dog teams and robotics in search and rescue operations.

Also, the test conditions through field exercises offered within the SnR project, within the seven planned UCs, were analysed.

Chapter 3 (Gap Analysis for community resilience) is structured in five subchapters, as follows.

Subchapter 3.1 (Introduction, scoping and methodology) gives a brief overview of the results of phase A (M1-M4) of the study on the gap analysis for community resilience and a presentation of the purpose of phase B (M5-M12). In this sense, the methodology used in phase B of the study is presented, as an approach and chronology of implementation.

Subchapter 3.2 (Focus Group discussion and findings) contains the results resulting from the discussions and analysis carried out within the focus group, starting from the establishment of the resistance attributes of the community and the criteria of the end user.

Subchapter 3.3 (GAP analysis survey) shows the final structure of the GAP table, the overview of the GAP survey and the analysis of the results of the GAP survey and the summary of the key findings.

Subchapter 3.4 (Workshop validation / refinement of results and recommendations) contains the refinement of the previously obtained results and their validation during the session specifically dedicated to this topic - Gap Analysis for community resilience - carried out within the "End-user requirements and Beyond" workshop from April 14, 2021, within the SnR project.

Subchapter 3.5 (Conclusions and recommendations) reveals the conclusion of the GAP analysis that it is recommended that SnR project partners use the prioritization resulting from GAP analysis and feedback processing to identify the most relevant issues for their scope in the SnR project.

Gaps, needs, suggestions and recommendations on selected issues will provide an additional perspective on potential solutions and issues to be considered during the design / development and operationalization of equipment and technologies used in the search and rescue of people trapped under rubble.

Table of Contents

List of Figures

List of Tables

1 Introduction

1.1 Purpose and Scope

The purpose of deliverable D1.6, a continuation of deliverable D1.2, is to analyze, improve and update the requirements of end-users in the process of scientific research, prototyping, testing and validation of the R&D project (in particular the contributions made in WP5 [Design and implementation of specialised equipment for first responders] and WP8 [S&R Validation and Demonstration] but also WP9 Dissemination, Communication and Exploitation and in particular T9.4 Innovation Management for analyzing market developments), on chemical sensors for the identification of persons trapped under the rubble but also to ensure the protection of First Responders against dangerous toxic gas emissions, worn on their equipment, in the hand or on the platform of rescue robots, taking into account the results obtained by using "gap analysis" as a method of resource management and assessment of management efforts, comparing current performance with the desired performance in the future.

On this line, the minimum technical and operational requirements of the UAV (Unmanned aerial vehicle) were also mentioned, which, due to its ability to inform First Responder on the evolution of the operational situation in the field and its primary warning of dangers in the area, requires analysis and finding solutions for integrating this system with RESCUE MIMS, first responders, K-9 dog teams and robotics in search and rescue operations.

If the minimum basic characteristics (in terms of ergonomic, power supply, size, weight, user interface characteristics) for RESCUE MIMS, RESCUE ROBOT and Six Gas HAZMAT monitor with VOCs remain those required by end users in deliverable D1.2, in deliverable D1.6, we analyze the needs of RESCUE MIMS for its miniaturization to make it more portable (in the hand or worn as a backpack) and easier to mount on the platform of a RESCUE ROBOT and the minimum technical and operational characteristics for UAV (Unmanned aerial vehicle).

The purpose of end-users in carrying out the above-mentioned steps consists in the fact that the innovative equipment and technologies (mentioned in deliverables D1.2 and D1.6) that the SnR project wishes to achieve meet the requirements of end-users to increase the safety of First Responders and to optimize the R&D actions of people trapped under a disaster.

1.2 User Requirements follow-up

During the first year of the SnR project, it was discussed in a variety of forms (meetings, workshops, etc.) about the harmonization and optimization of the relationship "end-user demand - supply of equipment and technologies".

This exchange of information highlighted the need for end-users to be adaptable and flexible in their requirements, taking into account the technological and financial constraints affecting scientific research activity (in a complex field such as the whole process of research). search-rescue of people trapped under the rubble), testing (in the laboratory and through field exercises) and validation of the equipment and technologies proposed to be carried out within the SnR project.

It was agreed that the basic element in going through the above mentioned steps is to test and validate the equipment and technologies developed in the R&D project within complex UCs, as close as possible to the real operational situations that may occur. Obviously, it will also be possible to test the end-users' abilities to use these equipment's and technologies in the seven field exercises programmed within the SnR project.

According to the feedback obtained, within the SnR project, until the time of writing the D1.6 deliverable from end users, the development of support systems for S&R missions must focus on three main elements:

- Reliability in the field
- Usability in the field
- Durability in the field

With this basic requirement, a closer benchmark for them can be done. Reliability means to work as it should and when it should. Battery power, charging devices, power consumption, system run time etc are point focused on the reliability.

Usability is an issue when it comes to understanding what the new information is about and how the device can be used. For instance, it is mandatory to work with the device when wearing gloves, it is necessary that the device is easy interpretable even when there is high stress load.

Weight, bulkiness etc. need to be adjusted so that it is not an issue with the natural maneuverability of the operative staff. Durability is about weather resistance, environmental impacts, dirt, heat, rain, falls and crashes, sudden changes in pressure or temperature etc.

With these operative elements in the field, the scope of the use of technology needs to be defined as well. With the UC Pilots, the requirements of the end users, those people, who this project is about and developed for, will test technology for their use in the field and how the new technologies can be integrated in their routines as a support when saving lives.

The SnR project offers a wide variety of innovative equipment and technologies that cover the full spectrum of end-user requirements in the operational field of search and rescue of people trapped under rubble, as follows:

- **recognition of the tactical situation on the ground and assessment of existing risks** = an android application for the routing of end-users and communication with civil protection services, such as the police, the ambulance and/or other rescue vehicle, Unmanned Aerial Vehicles (UAVs) and rescue robots
- **ensuring the physical protection of First Responders** = Six Gas HAZMAT monitor with VOC Detection, smartwatch, Rescuer AR helmet, Radiation sensors (mainly X rays), ECG, EMG, respiration by means of fully textile electrodes, RESCUE MIMS and professional uniforms.
- **optimization of search-rescue actions of people trapped under rubble** = Rescue MIMS, AR Helmets and Smoke-diver AR helmet
- **ensuring an effective assessment of self-evacuated victims** = Smart-phone / Tough-phone, an android that provide information regarding the position of victims, their evacuation

trajectory or escape route, while also indicating candidate meeting points for assembly, treatment and rescue and first aid device for kids

- **coordinating the intervention of volunteers** = an application that will provide information about the emergency event such as meeting points for mission and resource planning, requirements for volunteer deployment (insurance, food, accommodation, responsibilities)
- **Training through AR/VR** = harmonized security training curriculum based upon agreed training material and practical exercises (modern, didactically refined lectures and seminars; documented in open-structured, user friendly; computer-based interactive models and virtual reality with biofeedback; realistic field exercises; evaluation of 3D computer-models during the practical field exercises.)
- **Using the CONCORDE Emergency Management System (EMS)** = a dashboard, from which all operational information can be accessed with one step click.

In deliverable D1.6, chapter 3 "GAP analysis for community resilience", a GAP survey was conducted to be distributed to all SnR project partners for the purpose, in order to make the best use of the approach undertaken report for the development of the technologies/wearables and the design/operationalization of the UCs. It is recommended that the concerned partners use the prioritization that resulted from the GAP analysis and feedback processing in order to identify the most pertinent issues for their scope.
To achieve the goal proposed in T1.2, PROECO, in cooperation with the partners of the SnR project, organised, on April 14, 2021, a workshop entitled "End-user requirements and beyond" with the participation of a significant number of rescuers, together with experts, people operational scientists and scientists, to extract the requirements and practical needs of users, as well as the validation of SnR pilots and operational procedures. These practical requirements and needs of end users, resulting from presentations and discussions on this workshop have been included in deliverable D1.6.

2 Chemical S&R Tools

2.1 Portable Membrane Inlet Mass Spectrometer (MIMS) follow-up

The purpose of this subchapter is to identify, from an end-user perspective, what the next steps may be to improve the performance of Portable Membrane Inlet Mass Spectrometer (MIMS) to identify the location of people trapped under rubble following a disaster.

The subchapter comprises 2 parts corresponding to the 2 objectives that help to achieve the proposed goal, as follows:

1. Listing in a general way, from the perspective of end users, the possible directions of miniaturization of the Portable Membrane Inlet Mass Spectrometer to optimize their capabilities to identify as accurately as possible the location of people trapped under the rubble in the multiple risk conditions specific to the area of intervention. This miniaturization is required to cut complexity and improving portability by creating an optimal balance that does not occasionally increase the final cost of the product or does not mainly affect the service life of the system components, e.g. vacuum pumps. The main concern in this approach is that this miniaturization of MIMS should avoid affecting sensitivity or other factors functional factors of Portable Membrane Inlet Mass Spectrometer [1].
2. Listing some recommendations, from the point of view of end users, of the most relevant UCs (field exercises) within the SnR project in which the performances of RESCUE MIMS can be tested and validated.

These exercise/training field exercises must provide the necessary conditions for testing and validating the key performance indicators (KPIs) specific to Portable Membrane Inlet Mass Spectrometer (MIMS) researched and carried out within the SnR project.

These key performance indicators (KPIs) refer to:

- Portability
- Sensitivity
- Reliability
- Easy operation
- Low LODs (limits of detection)
- Fast response times
- Ruins penetration
- Robustness
- Detection capability of a wide range of concentrations

It should be emphasized that the end-user requirements for the basic characteristics of portable RESCUE MIMS (power supply, size, weight, user interface, etc.) remain the same as those mentioned in deliverable D1.2, subchapter 2.1.

In line with these end-user requirements described above, deliverable 5.1 "Design & development of the RESCUE MIMS" develops a technological readiness level prototype (TRL) 6, as a state-of-the-art membrane inlet mass spectrometry (MIMS) technology, adapted to the particularities and needs of search and rescue (S&R). In this regard, specific components (hardware, electronics, housing, etc.) have been assembled under this prototype to meet most end-user requirements for ergonomic and usable design.

Deliverable 1.6 aims, from the point of view of end-users, to complete the optimization proposals for a possible later version (TRL>7) of RESCUE MIMS contained in the conclusions chapter of D5.1.

2.1.1 Mass Spectrometer Future Needs

MS (mass spectrometry) technology - the analysis of ions in vacuum by their mass-to-charge ratio m/z - is over a century old.

Its beginnings can be traced to Eugen Goldstein, who discovered positive ions in 1886, and Wilhelm Wien, who analyze them in 1898 using crossed electric and magnetic fields.

In 1918, Arthur Dempster developed the first sector magnet with direction focusing.

In 1919, Thomson's student, Francis Aston, constructed the first mass spectrometer with velocity focusing.

Because magnetic separators were large and heavy, different physical principles were investigated after the Second World War. In 1946, William Stephens proposed the use of time-of-flight. Angus Cameron demonstrated an early TOF-MS in 1948, and William Wiley and Ian McLaren of Bendix developed a TOF-MS with space and velocity focusing in 1955.

In the last 40 years, since its historical development, mass spectrometry (MS) has proven to be a powerful established analytical technique widely considered in the last period to be the gold standard for chemical analysis [2].

In essence, it works by creating ions from neutral atoms and molecules and separating them according to their mass-to-charge ratios.

Due to its versatility, mass spectrometers can be applied for both in-laboratory measurements and on-site operations, either as standalone devices or combined with other analytical instruments. MS offers, comparable to other chemical sensors a sum of qualities such as: high sensitivity, low detection limits (LODs), high selectivity, fast response times and broad applicability (analysis of almost all types of molecules; from small volatile compounds to big biomolecules and biological species).

Moreover, targeted compounds for analysis can belong to all states of matter (gaseous, liquid, solid). From a constructive point of view, the main components of a mass spectrometer include: sample inlet, ion source, mass analyser, detector, vacuum system.

More recently, the first 'hyphenated' technique, gas chromatography-mass spectrometry (GC-MS) was introduced by Roland Gohlke and Fred McLafferty at Dow Chemical in 1956.

Later techniques include liquid chromatography-mass spectrometry (LC-MS), capillary electrophoresis-mass spectrometry (CE-MS) and ion mobility spectrometry-mass spectrometry (IMS-MS).

Traditionally, MS is usually performed in analytical laboratories by lab-based mass spectrometers, which are typically large in scale, time consuming, and complicated in operation for the procedures of sample analysis. However, the increasing demands of in situ analysis in many fields, such as environmental monitoring [3], public security [4-5], space exploration [6-8], and personal health care [9-10], call for the miniaturization of mass spectrometers.

Mass spectrometers are used in a wide range of applications in the chemical, electronics, food processing, oil and pharmaceutical industries. They are commonly used to monitor nuclear installations (Colle et al., 2014), to detect environmental pollutants (Richardson, 2012), diagnose drug abuse (Ojanperä, Kolmonen, & Pelander, 2012), and monitor waste gas in systems vacuum (Sulzer et al., 2012). Mass spectrometers are deployed in environments as diverse as ocean depths to identify chemical traces (Bell et al., 2007) and also in space for extraterrestrial exploration (Petrie and Bohme, 2007; Hoffman, Chaney, & Hammack, 2008).

Proof of versatility of using MS is the AquaMMS, a portable mass spectrometer capable of monitoring the purity of water in to extremely high sensitivities [11].

The AquaMMS can monitor online a wide range of water quality indicators simultaneously. The system has the potential to allow the aquaculture industry to increase its productivity and efficiency in a variety of different ways.

NEREUS (new, efficient, rapid assessment of underwater spectra) is an autonomous underwater mass spectrometer system capable of continuing measurements of gases and vapors dissolved in the water column [12]. Rapid in situ measurement minimizes or eliminates artifacts that are often a problem when collecting and storing samples for analysis of volatile constituents and provides spatial and temporal resolution of chemical models than is possible with conventional techniques.

NEREUS is designed to operate either independently on a mooring or winch line, or aboard an autonomous underwater vehicle (AUV).

To the best of our knowledge, all current underwater mass spectrometers are based on membrane inlet mass spectrometry (MIMS) technology.

Another new use of portable MS is the Miniature Sector Mass Spectrometer with IonCCDDetection developed by a multidisciplinary team under the coordination of Leidos Inc. [13].

Dimensions and weight have been reduced from 80 cm x 80 cm x 80 cm, 90 kg to 16 cm x 15 cm x 23 cm, 5 kg.

The limitations of using such a device are due to the fact that it is intended exclusively for the field of national security (identification of explosives, drugs, etc.) and the limits of detection (LOD) and identification (LOI) of chemicals [Single digit ng detection (varies by compound), Low double-digit ng identification levels (varies by compound), Test samples were direct from GC, so no concentration values obtained for sensitivity (e.g. ppm or ppb levels)].

Another portable mass spectrometer allows on-site gas analysis is Mini-Ruedi, weighing 13 kilograms and mounted in a wheeled suitcase [14].

It should be noted that this MS cannot be used in the field of S&R as it is focused exclusively for water analyses to assess groundwater systems, investigate anthropogenic effects on waterbodies or to study gas exhalations from springs.

A number of scientific studies have shown in the past the capabilities of different analytical techniques (gas chromatography mass spectrometry (GC-MS), proton transfer reaction mass spectrometry (PTR-MS), chemical sensors, or ion mobility spectrometry (IMS)) for identifying potential markers of human presence in breath, skin emanations, urine, or blood [15-19].

Among the many areas that can be addressed through MS technology, their use as a carrier of "artificial sniffing" technology to detect various chemicals on the spot is a necessity, which began with the rapid growth of terrorist threats and organised crime activity on national security [20-21].

Regarding mass spectrometry (MS), the late developments in size and weight miniaturization (e.g. miniaturization of mass analyser, detectors, vacuum system, etc.), as well as in power consumption reduction converted them into portable devices ideal for in-field operations worldwide.

From an end-user's perspective, given their goal of using artificial sniffing technology to save people trapped under rubble, MS technology has advantages those other technologies lack and cover their disadvantages.

As an example, we will present the technical characteristics of a high-performance portable MS (Ion Trap MS), but used in fields other than S&R (see Table 2-1) [22].

Supplier	Model	Mass analyser	Mass range (m/z)	Power (W)	Weight (kg)
FLIR Systems Inc.	Griffin™ 824	Cylindrical ion trap	N/A	N/A	22.7
FLIR Systems Inc.	Griffin™ 844	Cylindrical ion trap	N/A	110-240 VAC	20
Purdue University	Mini 12	Rectilinear ion trap	N/A-900	50	15
Torion Technologies (recently acquired by PerkinElmer)	TRIDION™-9 GC-MS	Toroidal ion trap	45-500	80	14.5
University of Liverpool	SNIFFLES pre-prototype	Non-scanning linear ion trap	50-500	34	14
Torion Technologies (recently acquired by PerkinElmer)	GUARDION™-7 GC-MS	Toroidal ion trap	50-500	75	13
Purdue University	Mini S	Rectilinear ion trap	N/A-925	65	12
Purdue University	Mini 10	Rectilinear ion trap	N/A-550	70	10
BaySpec Inc.	Portability™	Linear ion trap	40-650	65	9.9

1st Detect	MMS-100TM	Cylindrical ion trap	15-625	N/A	8
Purdue University	Mini 11	Rectilinear ion trap	N/A-2000	30	5
908devices	M908 TM	Microscale ion traps	55-400	N/A	2
Samyang Chemical Corp	Palm portable (without pump)	Quadrupole ion trap	45-300	5	1.5

Table 2-1: Ion trap MS systems specially developed for threat detection [22]

These shortcomings of other technologies, which make it difficult to use them in identifying people trapped under rubble, such as ion mobility spectrometry (IMS), gas chromatography (GC), infrared spectroscopy (IR) or Raman spectroscopy, but not only these, are addressed in the content of subchapter 1.3. " State-of-the art in chemical detection technologies" of the deliverable D 5.1.

Regarding the current evolutions of MS typologies (see Figure 2-1), it is worth noting the trend of coupling and hybridization of the elements specific to different Mass Spectrometer System technologies, as fellow [23].

It must be remembered that MALDI-TOF Mass Spectrometry is a soft ionization technique to create ions with minimal fragmentation by using laser energy. In TOF, the protonated ions are accelerated by an electric field to make an ion have the same kinetic energy as any other ions that have the same charge.

In the same context, the triple quadrupole mass spectrometer (TQMS or QqQ), is a tandem mass spectrometer in which the first and third quadrupoles act as mass filters and the second acts as a collision cell to fragment the selected precursors/parent ions, and to generate fragment/daughter ions. The TQMS is probably the most famous and widely used tandem MS.

The Quadrupole Trap MS is a hybrid triple mass spectrometer. Different from classical triple quadrupole mass spectrometry, the Q3 can work as either a standard quadrupole mass filter or a linear ion trap (LIT) with higher sensitivity than traditional 3D ion trap.

The hybrid linear trap orbitrap MS that combines a linear ion trap and high-resolution Orbitrap is one of the tandem mass spectrometers. The LIT uses a set of quadrupole rods to confine ions radially and a static electrical potential on the end electrodes to confine the ions axially.

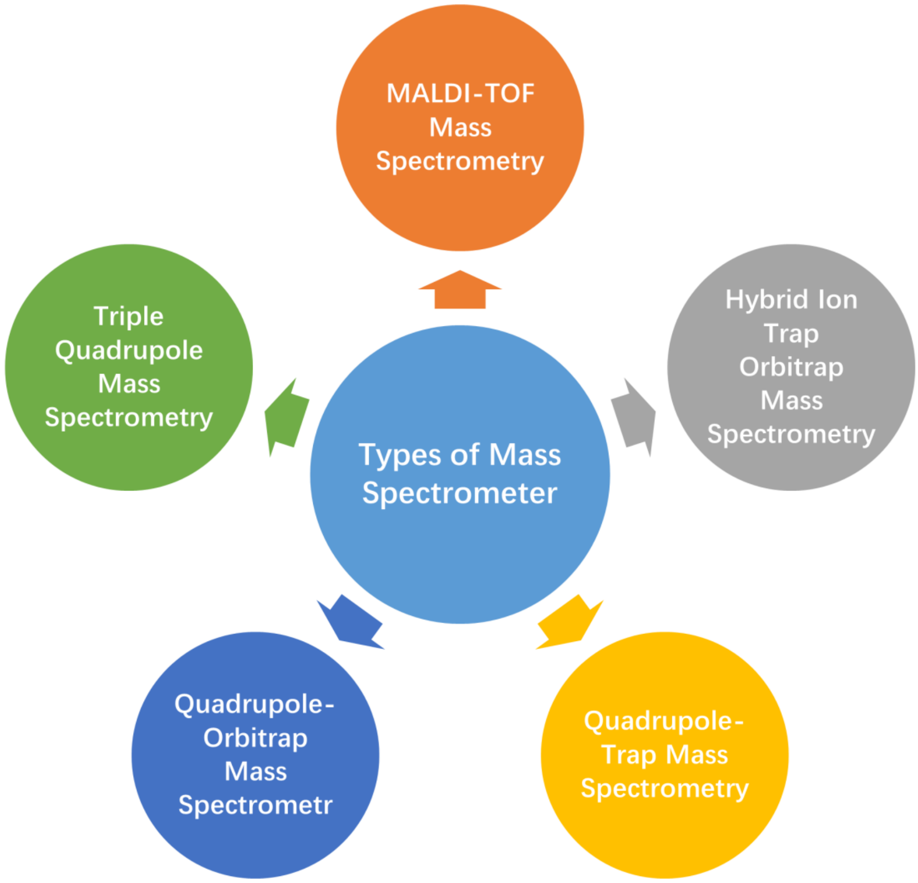


Figure 2-1: Types of Mass Spectrometer

In the quadrupole-Orbitrap mass spectrometer that combines the high-performance quadrupole precursor selection with high-resolution, accurate-mass (HR/AM) Orbitrap detection, the first mass analyser is a quadrupole, and the second one is high resolution Orbitrap.

Miniature mass spectrometers have made considerable advances in recent years (see Table 2-2), as highlighted by Dalton Snyder, Christopher J. Pulliam and Zheng Ouyang in the article "Miniature and Fieldable Mass Spectrometers: Recent Advances" (Analytical Chemistry, September 2015 DOI: 10.1021 / acs.analchem.5b03070).

Analysis of this presentation of existing field spectrometers reveals that none of them yet meet all the main requirements for the identification of trapped persons, as defined in subchapter 2.1.2 "Core characteristics required: power supply, size, weight, user interface characteristics" of the deliverable D1.2, in particular regarding the ability to identify VOCs emitted from manmade activities such as industrial processes and VOCs emitted by metabolic processes in the human body.

In this situation, RESCUE MIMS that will be provided in the SnR project will try to fill this gap (see chapters 4, 6 and 7 of deliverable D5.1" Design & development of the RESCUE MIMS") as much as possible, based on end-user requirements already mentioned.

Making a reasonable comparison, the development of miniature MS is similar to the advent of desktop computers through the miniaturization of large general purpose computers, e.g. ENIAC (Electronic Numerical Integrator and Computer), [24] which went through a process not only with reducing the size, but also improving the user interface.

Consequently, improvements in mass analysers, vacuum pumps, detection systems and control electronics have allowed a reduction in weight, energy requirements and the entire footprint of the entire mass spectrometer system (Yang et al., 2008).

Performance is now good enough to enable applications that require portability, and small size.

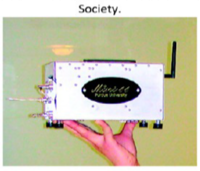
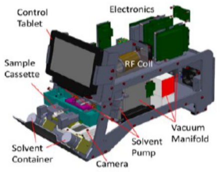
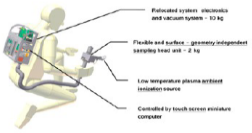
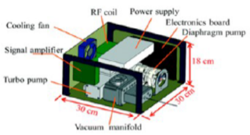
The increasing availability of such systems – which allow the instrument to be taken to the sample, rather than the other way round - implies many new opportunities for *in situ* analysis [25].

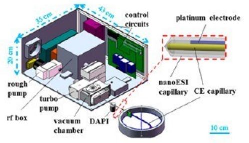
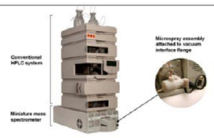
Miniature and field-portable mass spectrometers have played a prominent role in a variety of *in situ* analysis applications, including environmental analysis, process monitoring, forensics, space applications, and chemical and biological agent detection [26-29].

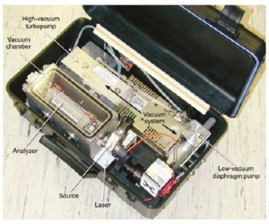
Mainframe instruments are evolving into desktop systems, backpack-mounted systems into hand-held units, and vehicle-mounted systems into airborne systems. The new paradigm will generate changes broadly analogous to those driven by the development of personal computers.

Up until now, different kinds of miniature mass spectrometers have been developed, mainly using an ion trap as the mass analyser, which is connected with different atmospheric pressure interfaces (APIs), including the membrane inlet (MI) [30-32], discontinuous atmospheric pressure interface (DAPI) [33-

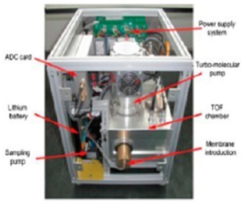
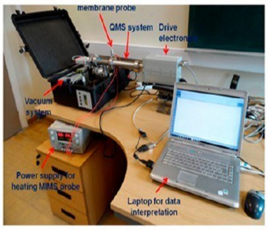
34], and continuous atmospheric pressure interface (CAPI) [35-36].

Instrument	Name & Developer	Mass Analyzer	System Power	System Weight	MS/MS	Sampling/ Ionization	Claimed Mass range and Resolution	Comments	Ref.
 Reproduced from Gao, L.; Song, Q.; Patterson, G. E.; Cooks, R. G.; Ouyang, Z. *Anal. Chem.* **2006**, *78*, 5994-6002. Copyright 2006 American Chemical Society.  Reproduced from Gao, L.; Sugiarto, A.; Harper, J. D.; Cooks, R. G.; Ouyang, Z. *Anal. Chem.* **2008**, *80*, 7198-7205. Copyright 2008 American Chemical Society.	Mini 10 Mini 11 Purdue University	Rectilinear ion trap	70 W 35 W; 2 hr on battery	10 kg 5 kg	Yes	Internal External Ambient Internal External Ambient	*m/z* 700, R = 700; *m/z* 1500, R = 750	both autonomous; sources include ESI, APCI, glow discharge electron ionization, DESI; mini diaphragm and turbo pumps; DAPI configuration; optional membrane inlet	71 13
 Reproduced from Li, L.; Chen, T. C.; Ren, Y.; Hendricks, P. I.; Cooks, R. G.; Ouyang, Z. *Anal. Chem.* **2014**, *86*, 2909-2916. Copyright 2014 American Chemical Society.	Mini 12 Purdue University	Rectilinear ion trap	50 W	15 kg	Yes	External Ambient	*m/z* 900, R = 500 (*m/z* 281)	autonomous; DAPI configuration; designed for point-of-care applications; mini diaphragm and turbo pumps	27
 Reproduced from Hendricks, P. I.; Dalgleish, J. K.; Shelley, J. T.; Kirleis, M. A.; McNicholas, M. T.; Li, L.; Chen, T. C.; Chen, C. H.; Duncan, J. S.; Boudreau, F.; Noll, R. J.; Denton, J. P.; Roach, T. A.; Ouyang, Z.; Cooks, R. G. *Anal. Chem.* **2014**, *86*, 2900-2908. Copyright 2014 American Chemical Society.	Mini S Purdue University	Rectilinear ion trap	65 W	12 kg	Yes	External Ambient	*m/z* 925, R = 1-2 amu	autonomous; DAPI configuration; mini diaphragm and turbo pumps; libraries for chemical identification; coaxial LTP source; separate handheld and backpack units	50
 Reproduced from Zhai, Y.; Feng, Y.; Wei, Y.; Wang, Y.; Xu, W. *Analyst* **2015**, *140*, 3406-3414, with permission of The Royal Society of Chemistry.	Continuous API Beijing Institute of Technology	Linear ion trap	N/A	6 kg	Yes	External Ambient	*m/z* 200-2500, R = unit	continuous API; differentially pumped with mini diaphragm and turbo pump;	69

Instrument	Name & Developer	Mass Analyzer	System Power	System Weight	MS/MS	Sampling/ Ionization	Claimed Mass range and Resolution	Comments	Ref.
 Reproduced from He, M.; Xue, Z.; Zhang, Y.; Huang, Z.; Fang, X.; Qu, F.; Ouyang, Z.; Xu, W. *Anal. Chem.* **2015**, *87*, 2236-2241. Copyright 2015 American Chemical Society.	CE-MS Beijing Institute of Technology, Purdue University	Rectilinear ion trap	N/A	N/A	Yes	External	N/A	DAPI configuration; nano-ESI source coupled to CE; mini diaphragm and turbo pumps	207
 Reprinted from Yang, M.; Kim, T. Y.; Hwang, H. C.; Yi, S. K.; Kim, D. H. *J. Am. Soc. Mass Spectrom.* **2008**, *19*, 1442-1448, with kind permission from Springer Science and Business Media.	Palm Portable Mass Spectrometer Sam Yang Chemical Company, Seoul, Korea	Ion trap	5 W	1.48 kg	N/A	Internal	*m/z* 45-300, R = 3 amu	ion getter pump; pulsed sampling	72
 Courtesy of BaySpec.	Portability Bayspec	Linear ion trap	N/A	17 lbs	Yes	External Ambient	N/A	battery-powered; "person portable"	277,278
 Courtesy of 908 Devices.	M908 908 Devices	Microscale ion trap array	4+ hr on battery	2 kg with battery	N/A	Internal	*m/z* 55-400	Rugged design; target compound lists for identification; novice user interface; continuous gas/vapor analysis, solids/liquids with swabs; operates at >1 torr	205
None	ChemCube™ Microsaic Systems	Quadrupole	50 W	14 kg	No	Internal	*m/z* 600, R = unit	N/A	161
 Reproduced from A miniature mass spectrometer for liquid chromatography applications, Malcolm, A.; Wright, S.; Syms, R. R.; Moseley, R. W.; O'Prey, S.; Dash, N.; Pegus, A.; Crichton, E.; Hong, G.; Holmes, A. S.; Finlay, A.; Edwards, P.; Hamilton, S. E.; Welch, C. J. *Rapid Commun. Mass Spectrom.* Vol. 25, Issue 21. Copyright © 2011 Wiley.	3500 MiD Microsaic Systems	Quadrupole	220-300 W	27 kg	N/A	External	*m/z* 800, R = 150 at *m/z* 219 (10% valley)	For benchtop chemists (*e.g.* LC); ESI source; requires nitrogen supply	101
 Courtesy of Microsaic Systems.	4000 MiD Microsaic Systems	Quadrupole	250-300 W	32 kg	No	External	*m/z* 50-800, R = 0.7 FWHM	For benchtop chemists (*e.g.* LC) ; ESI source; requires nitrogen supply	215

Instrument	Name & Developer	Mass Analyzer	System Power	System Weight	MS/MS	Sampling/ Ionization	Claimed Mass range and Resolution	Comments	Ref.
 Reproduced from Wright, S.; Malcolm, A.; Wright, C.; O'Prey, S.; Crichton, E.; Dash, N.; Moseley, R. W.; Zaczek, W.; Edwards, P.; Fussell, R. J.; Syms, R. R. *Anal. Chem.* **2015**, *87*, 3115-3122. Copyright 2015 American Chemical Society.	MEMS-enabled QqQ Microsaic Systems	Triple quadrupole	300-400 W	N/A	Yes	External	> *m/z* 600, R = 0.7 FWHM	Differentially pumped with two mini diaphragm and two mini turbo pumps; Not yet autonomous	103
 Courtesy of Kore Technology.	MS-200 Kore Technology, Ltd.	Converging annular time-of-flight	< 20 W; 6.6 hrs on battery	20 kg with battery	No	Internal	*m/z* 1000	For gas analysis; membrane inlet; ion and non-evaporable getter pumps	210
 Courtesy of Astrotech Corporation.	MMS-1000 1st Detect	3D ion trap	< 45 W on average; 65 W max	8 kg	Yes	Internal	*m/z* 500, R < 0.5 amu FWHM	Uses 110/220 VAC; benchtop configuration; membrane inlet; air is carrier gas; mini diaphragm and turbo pumps; power via line, battery or vehicle	219
 Courtesy of Astrotech Corporation.	OEM-1000 1st Detect	Cylindrical ion trap	< 45 W on average; 65 W max	< 8 kg	Yes	Internal	*m/z* 35-500, R < 0.5 amu FWHM	"can be integrated into customer specific packaging and equipment"; see MMS-1000	219
 ©The Johns Hopkins University Applied Physics Laboratory.	Suitcase TOF Johns Hopkins Applied Physics Laboratory	Reflectron time-of-flight	N/A	N/A	No	Internal	> *m/z* 50,000	mini diaphragm and turbo/drag pumps; matrix-assisted laser desorption/ ionization	88
 Courtesy of Inficon.	HAPSITE Inficon	Quadrupole	Rechargeable NiMH battery pack or AC converter	N/A	N/A	Internal	*m/z* 300	GC/MS system; accessories to expand sampling to solids and liquids; AMDIS libraries; non evaporable getter pump; optional SPME	73, 204

Instrument	Name & Developer	Mass Analyzer	System Power	System Weight	MS/MS	Sampling/ Ionization	Claimed Mass range and Resolution	Comments	Ref.
 Courtesy of Torion (PerkinElmer, Inc.).	Guardion-7™ Torion Technologies (PerkinElmer)	Toroidal ion trap	80 W (100-120 VAC or battery DC)	<13 kg	Yes	Internal	*m/z* 442, R = 270 (at *m/z* 222)	ruggedized; GC/MS system; gas, liquid, or solid samples; optional SPME	118
 Courtesy of Torion (PerkinElmer, Inc.).	Tridion-9 Torion Technologies (PerkinElmer)	Toroidal ion trap	60 W	14.5 kg	N/A	Internal	*m/z* 500, better than unit (*m/z* 45-300), nominal up to *m/z* 500	ruggedized; GC/MS system; gas, liquid, or solid samples; optional SPME	211,212
 Courtesy of Griffin Systems (FLIR).	Griffin 400 Griffin Analytical Technologies (FLIR)	Cylindrical ion trap	110-240 VAC or 24 V DC	34 kg	Yes	Internal	*m/z* 425, R = unit	ruggedized; GC/MS system; automated data analysis; chemical library; flexible sample introduction; external He cylinder; mini diaphragm and turbo pumps	220
 Courtesy of Griffin Systems (FLIR).	Griffin 450/460 Griffin Analytical Technologies (FLIR)	Cylindrical ion trap	110-240 VAC or 24 V DC	38.5	Yes	Internal	*m/z* 425, R = unit	ruggedized; GC/MS systems; automated data analysis; chemical library; flexible sample introduction; external He cylinder; mini diaphragm and turbo pumps	221
 Courtesy of Griffin Systems (FLIR).	Griffin 824 Griffin Analytical Technologies (FLIR)	Ion trap	110-240 VAC	22.7 kg	N/A	Internal	N/A	surface wipe sampling; narcotics and explosives detection modes	222
 Courtesy of OI Analytical.	IonCam OI Analytical	Mattauch-Herzog sector	150 W (with GC)	19 kg	No	Internal	*m/z* 250, 0.25 amu low mass to 1 amu high mass	non-scanning with IonCCD detector™; GC and direct air sampling modules; touch screen controls	209

Instrument	Name & Developer	Mass Analyzer	System Power	System Weight	MS/MS	Sampling/ Ionization	Claimed Mass range and Resolution	Comments	Ref.
 Courtesy of MassTech, Inc.	MT Explorer 100 MassTech,Inc.	3D ion trap	500 W	150 lbs without laptop	Yes	External	m/z 2500, R= better than unit	atmospheric pressure interface; "can be used in a field environment"; AP/MALDI, ESI, or APCI sources	279,280
 Courtesy of MassTech, Inc.	MT Explorer 50 MassTech, Inc.	3D ion trap	200 W	75 lbs	Yes	External/Ambient	m/z 30-2500, R= 6000 (at 2000 Da)	See MT Explorer 100; also compatible with DART	208
 Reprinted from *Int. J. Mass Spectrom.*, Vol. 334, Gao, W.; Tan, G.; Hong, Y.; Li, M.; Nian, H.; Guo, C.; Huang, Z.; Fu, Z.; Dong, J.; Xu, X.; Cheng, P.; Zhou, Z. Development of portable single photon ionization time-of-flight mass spectrometer combined with membrane inlet, pp. 8-12. Copyright 2013, with permission from Elsevier.	MI-SPI-TOFMS Shanghai University, Guangzhou Hexin Analytical Instrument Co, Ltd.	Reflectron time of flight	< 100 W; 2 hr on Li battery	15 kg (13 kg without battery)	No	External	> m/z 200, R = 450 (m/z 106)	single photon ionization; membrane inlet; mini diaphragm and turbo pumps	281
 Courtesy of Q Technologies.	AQUA MMS Q Technologies	Quadrupole	< 50 W	N/A	No	Internal	m/z 200, R = unit	optional membrane inlet; gas or liquid samples;	223,282
 Reproduced from Giannoukos, S.; Brkic, B.; Taylor, S.; France, N. *Anal. Chem.* **2014**, *86*, 1106-1114. Copyright 2014 American Chemical Society.	MIMS-Q University of Liverpool, Q Technologies	Quadrupole	N/A	N/A	No	Internal	m/z 1-200, R = unit	heated membrane inlet or fused silica capillary inlet with membrane probe; mini diaphragm and turbo pumps	224,225

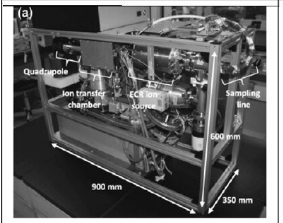
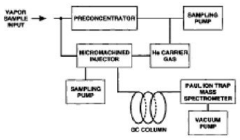
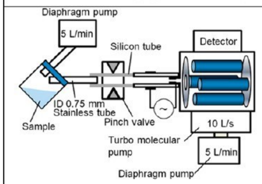
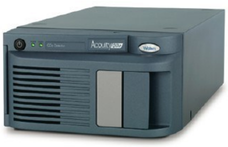
Instrument	Name & Developer	Mass Analyzer	System Power	System Weight	MS/MS	Sampling/ Ionization	Claimed Mass range and Resolution	Comments	Ref.
 Reprinted from *Spectrochim. Acta A Mol. Biomol. Spectrosc.*, Vol. 120, Urabe, T.; Takahashi, K.; Kitagawa, M.; Sato, T.; Kondo, T.; Enomoto, S.; Kidera, M.; Seto, Y., Development of portable mass spectrometer with electron cyclotron resonance ion source for detection of chemical warfare agents in air, pp. 437-444. Copyright 2014, with permission from Elsevier.	Mini ECRIS-MS Riken	Quadrupole	1 hr on battery	90 kg	No	Internal	*m/z* 50, R = unit	electron cyclotron resonance source; full-sized diaphragm and two full-sized turbo pumps	226
 Reproduced from Miniaturized system of a gas chromatograph coupled with a Paul ion trap mass spectrometer, Shortt, B. J.; Darrach, M. R.; Holland, P. M.; Chutjian, A. *J. Mass Spectrom.*, Vol. 40, Issue 1. Copyright © 2005 Wiley.	GC-QIT California Institute of Technology, Thorleaf Research	Paul quadrupole ion trap	42 W	5.4 kg	No	Internal	*m/z* 15-100, R = 220	GC/MS system	213
 Reproduced from Kumano, S.; Sugiyama, M.; Yamada, M.; Nishimura, K.; Hasegawa, H.; Morokuma, H.; Inoue, H.; Hashimoto, Y. *Anal. Chem.* **2013**, *85*, 5033-5039. Copyright 2013 American Chemical Society.	LP-DBDI LIT Hitachi, Ltd., Hitachi High-Technologies Corp., National Research Institute of Police Science	Linear ion trap	N/A	N/A	Yes	External	> *m/z* 300	low-pressure dielectric barrier discharge ionization; mini diaphragm pump for sampling; mini diaphragm and turbo pumps; pinch valve	51
 Courtesy of Advion.	Expression CMS Expression L Expression S Advion	Quadrupole	N/A	N/A	No	External	*m/z* 10-2,000 (L); R = 0.5 – 0.7 *m/z* (FWHM)	designed for fume hoods; ESI and APCI sources	216
 Courtesy of Waters Corporation, Milford, Massachusetts.	ACQUITY QDa Detector Waters	Quadrupole	110-240 VAC	29.4 kg (with diaphragm pump)	No	External	*m/z* 30-1250, R = 0.7 Da	built for chromatographic analysis;	217

Table 2-2: Miniature and Fieldable Mass Spectrometers

The attractiveness of the multiple possibilities for technical development of MS in various fields, makes the market forecast for their growth until 2024 to be 6.7% [37]. According to this forecast, the main application industries in the mass spectrometry market are:

- Pharmaceutical & Biotechnology
- Environmental Testing
- Food & Beverage Testing
- Petrochemicals
- Other Applications

It should be noted that the market forecast report does not address the use of MS, or MIMS, in the field of search and rescue, although the direct or indirect impact of disasters on industrial activity is well known.

This highlights the usefulness and need for the study, testing and validation of the RESCUE MIMS proposed in the SnR project.

From a constructive point of view, Membrane Inlet Mass Spectrometer (MIMS) is made up of the following fundamental components (see Figure 2-2): inlet, ion source, mass analyser, detector, vacuum system (diaphragm pump & turbo pump) and drive electronics.

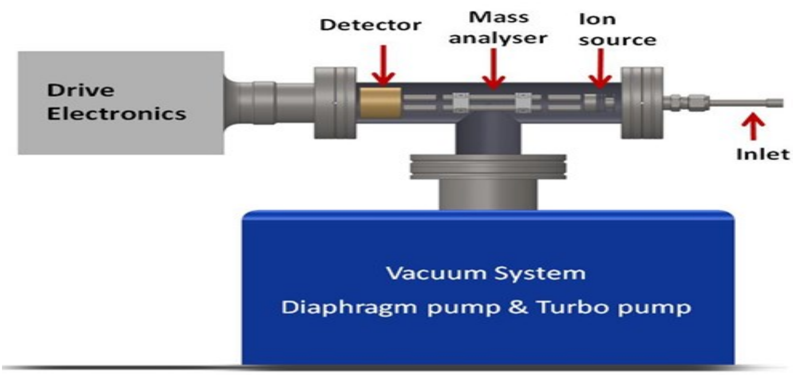


Figure 2-2: The classic components of a Membrane Inlet Mass Spectrometer

(Courtesy of NTUA D5.1)

From the point of view of historical evolution, MIMS dates back to the early 1960s, when it was introduced by Hoch and Kok for in situ analysis of the kinetics of photosynthesis through measurements of oxygen and carbon dioxide [38].

The first applications of MIMS to air analysis were reported in the early 1970s [29], but little attention to real-time monitoring of environmental samples was paid until the 1990s.

It was later used extensively for analysis of photochemical systems and for other physiological studies [39], including in vivo measurements of dissolved gases and organic compounds in blood [40-41].

Another early application of membranes in MS was the use of a polymer as an interface in GC/MS [42], which depends on the low permeability of helium relative to organic compounds.

The first application of MIMS in fermentation monitoring, published by Reuss et al. [43], was an important development, and fermentation monitoring with MIMS is commonly used today [44].

The use of hollow-fiber capillary membranes by Tou et al. in 1974 formed the basis for many subsequent advances [45].

The membrane introduction mass spectrometry (MIMS) method has been reviewed in the past, (Heinzle & Reuss, 1987; Kotiaho et al., 1991; Cooks & Kotiaho, 1992; Bauer, 1995; Hensen & Degn, 1996; Kotiaho, 1996; Lauritsen & Kotiaho, 1996; Srinivasan et al., 1997; Cowie & Hoyd, 1999), so this review is intended to update those treatments. Between 1995 and the present, several hundred papers have described the use of the rapid analysis capabilities of MIMS for monitoring dynamic chemical systems or rapidly prescreening samples for further analysis by slower off-line techniques.

As one of the results of the development of MS technology, MIMS is a simple analytical technique with great potential for metabolomics and volatolomics [46-48]. Its main advantage is the capability to be integrated onto mobile or portable field-deployable systems. It is based on the pervaporation process, which is a three-stage procedure.

Sample molecules originating from the gaseous, aqueous and solid phase absorb onto the surface of a membrane, they diffuse selectively through the membrane inlet and they finally desorb in the vacuum system and the MS for analysis.

These features of MIMS have facilitated the development of tools to effectively perform in-situ analysis and in-vivo monitoring.

From this perspective, analytical requirements for in-vivo applications are high sensitivity (i.e. large enrichment factors) and electivity in diverse biological matrices.

Thereby, it was accomplished a miniature MIMS system for the direct, real-time analysis of VOCs in human breath obtaining EI-MS2 spectra for selected VOCs at ppm levels [49].

In the same vein, total homocysteine concentration (tHcy) in human plasma or serum, a marker for a number of diseases or deficiencies, has been successfully measured at or below physiologically relevant levels using pre-derivatization to form volatile species followed by MIMS [50].

In another train of thoughts, was used the detection of dimethyldiselenide by MIMS during the incubation of hepatocytes with methylseleninic acid, a model compound for selenium anti-cancer drugs [51]. Although this study presents novel in-situ data, LODs were relatively high (1 lM) and still need improvement.

The biologically-mediated reduction of dicarbonyl compounds to the corresponding alcohols by immobilized yeast cells was monitored in-situ in a continuous plug flow reactor using MIMS, identifying reactants, intermediates and products.

Summarising the above information, MIMS is ideal for in-situ applications offering outstanding characteristics: high sensitivity (low limits of detection [LOD] – high pptv), selectivity, fast and accurate analysis (within seconds), with no or minimum sample preparation requirements, simplicity, adaptability to any type of instrument, and low impact on instrument cleanliness.

In the recent years, the European Union has funded several search and rescue projects (i.e. SGL for USAR, Darius, ICARUS, TOXI-triage, etc.) [52–56] to investigate state-of-the-art technologies and to develop novel approaches (including artificial sniffing and identification of VOCs emitted from the human body) for the early detection and localization of human victims (alive or dead) under the ruins of collapsed buildings after natural (e.g. earthquakes, tsunami, wildfires, etc.) or manmade (e.g. bombing attacks, terrorist events, industrial accidents, etc.) catastrophes.

As a practical implementation of this idea, a prototype RESCUE MIMS portable device for use in the rapid location of people trapped under rubble was described in the deliverable D1.2, subchapter 2.1.

Miniaturization of mass spectrometers and implicitly of MIMS, together with environmental ionization, is two directions of development in mass spectrometry that has advanced significantly in the last decade.

The integration of the techniques developed in these two fields leads to the development of complete miniature analytical systems that can be used, especially but not only for on-site analyzes [57].

There are a plethora of criteria systems for achieving a portable RESCUE MIMS. Thus, some researchers consider that the essential analytical criteria of RESCUE MIMS must be: response times, detection limits and linear dynamic range [58].

From the end user's perspective, to be portable, RESCUE MIMS must first and foremost be robust, inexpensive, designed to minimize power consumption while allowing battery operation, friendly to the user, easy to operate and dimensions and weight to allow use in the hand.

In applied research, trade-offs must be made between the geometry and the intake material and the performance (response speed, sensitivity) of the MS inlet membrane. Thin membranes are favored for quick response and sensitivity, but the membranes must also be thick enough to withstand the pressure differential along them.

Scientific attempts to study different materials to be used as a member of MIMS to diversify and improve their performance date back over 20 years [59].

One of the directions of modernization of MIMS, which implicitly to help its miniaturization is, was considered the realization of various interfacing configurations (see Figure 2-3) [60]**.**

A wide variety of ionization strategies and mass-spectrometer types (e.g., linear quadrupoles, quadrupole ion traps, and time-of-flight) have been coupled to membrane interfaces.

Membrane introduction mass spectrometry (MIMS) for chemical analysis involves the direct sampling of analytes in gas, liquid and solid samples through a semipermeable membrane coupled to a mass spectrometer, producing selective and sensitive quantification.

Because MIMS is an online technique in which samples can be run continuously on a membrane interface, it can produce real-time analytical results without the need for sample cleaning and chromatographic separation.

Membrane Input Mass Spectrometry (MIMS) uses a semipermeable membrane as the direct interface between the sample and the mass spectrometer. The membrane interface acts to separate the bulk sample matrix from the low pressure medium of a mass spectrometer (see subchapter 7.1 Components of the system pg. 56 from deliverable D5.1).

In general, MIMS performance is based on its ability to discriminate analyses (selectivity), to detect trace concentrations (sensitivity), and its rapid measurement response time (e.g., $t_{10\text{-}90}$ signal response times).

The dilemma of obtaining a portable RESCUE MIMS is to balance the relationship "miniaturization - increase functional performance".

in other words, the miniaturization must not affect the ergonomic, functional elements (including optional accessories of RESCUE MIMS.

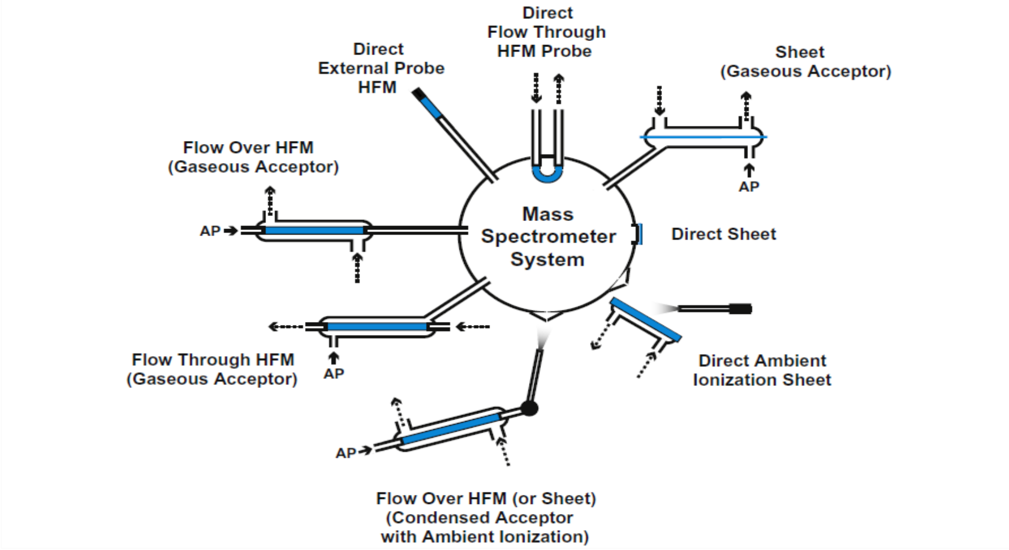


Figure 2-3: Membrane-introduction mass spectrometry (MIMS) interfacing configurations

Multiple variants of sheet and hollow-fiber membrane (HFM) interfacing strategies for MIMS are illustrated, adapted from a variety of sources. The uses of an acceptor phase (AP) as well as its flow direction are indicated, as are sample flow direction(s) (dashed arrows), where appropriate

For example, smaller vacuum pumps allow portability, but they are not without disadvantages, the most significant being the reduced pumping capacity and thus higher operating pressures. From this point of view, end users can consider that the Portable Inlet Mass Spectrometer (Peli case) from the SnR project (see Figure 2-4) requires as an improvement, in its future developments, the integration of CO electrochemical sensor in the system to overcome selectivity limitations.

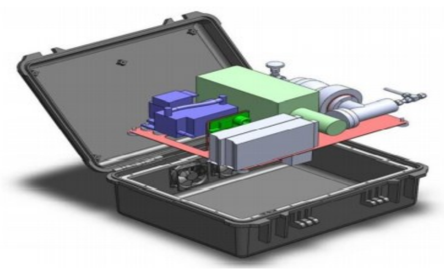


Figure 2-4: Portable RESCUE MIMS (Peli case)

(Courtesy of NTUA D5.1)

2.1.2 Testing Portable Membrane Inlet Mass Spectrometer (MIMS)

The use of a membrane input mass spectrometer (MIMS) to locate people trapped under debris by identifying human chemical signatures (HCS) is an innovative and future field of research.

To validate RESCUE MIMS, tests must be performed in two ways:

- Laboratory testing;
- testing in a field exercise.

Regardless of the method used to test the RESCUE MIMS portable prototype in the laboratory, from the perspective of end users it is necessary to test at least the following elements:

- Analytical performance (select and prepare the chemical mixtures, prepare method of analysis etc., calibration, running and data interpretation and cross checking of the results with other commercial instruments)
- Functional requirements based on the manual of Portable RESCUE MIMS (test ergonomic aspects, user interface and alarms). Analogously, the functionality of the connections with DSS system will be tested.

For this reason, the testing and validation of a portable RESCUE MIMS performance is mandatory to be done in some of the seven UCs (user cases) of the SnR project.

Since UCs in the SnR project are the responsibility of end users, it is in their interest, but not only, to make some useful recommendations on the most suitable UCs for RESCUE MIMS testing, from the perspective of the tactical moments of each scenario to assess how RESCUE MIMS meets planned key performance indicators (KPIs).

This is because an exercise is a controlled, goal-oriented activity used to test, practice or evaluate the processes or capabilities, in this case, of a portable RESCUE MIMS.

At the same time, field exercises allow the project team to test logistics, communications, stakeholder management plans and the effectiveness of a portable RESCUE MIMS.

This testing can be useful in a scenario for testing it as a S&R tool for detecting compounds related to human presence (we need scraps for this, for example, in an earthquake scenario);

From an end-user perspective, there are three basic UCs whose field-applied scenarios best match the testing of a portable RESCUE MIMS, as follows:

- Use Case 1: Victims trapped under rubble (Italy);
- Use Case 4: Forest fire expanded and threat to industrial zone (Attica Region, Greece);
- Use Case 5: Victims trapped under rubbles (France).

It should be noted that both of the above use cases present, from the end user's perspective, appropriate scenarios for testing the RESCUE MIMS laptop for the detection of "signs of human life" under debris.

Portable RESCUE MIMS testing in one or more UCs must be done taking into account the assessment of available travel logistics costs in accordance with the budgetary constraints of the SnR project.

From an end-user perspective, testing the functional capabilities of a portable RESCUE MIMS at different tactical moments of the above-mentioned user cases scenarios should, in a minimal way, measure the differences in information provided by the basic features of a portable RESCUE MIMS prototype to look for solutions to improve their performance.

From an end-user perspective, testing the functional capabilities of a portable RESCUE MIMS at different tactical moments of the above-mentioned UC scenarios should measure the differences in information provided by the basic characteristics of the portable RESCUE MIMS prototype, to make an effective analysis of the results obtained, the problems encountered, the impact on the test environment and the recommended improvements.

From the end user's perspective, special attention should be paid to the testing and validation of portable RESCUE MIMS performance with those obtained by K9 dogs (experimental design, field testing including ethics in using canines at field trials).

Summarising the information in this subchapter, from the end user's perspective, we can conclude that the realization of a portable RESCUE MIMS that makes, within the SnR project, the qualitative leap from TRL 4 to TRL 6 is an indispensable tool in the future for identifying people caught under demolition through robustness, efficiency and ease of use in the intervention area.

2.2 Rescue MIMS on Robotics follow-up

The purpose of this subchapter is to identify, from an end-user perspective, what the next steps may be to improve, from the end user's perspective, the performance of a Coyote III micro rover robot or Seerkur Jr as a carrier, on its platform, of a payload represented by a Membrane Inlet Mass Spectrometer (MIMS).

The subchapter comprises 2 parts corresponding to the 2 objectives that help to achieve the proposed goal, as follows:

1. Identify the future needs of the end user in order to minimize the effect of the weaknesses of COYOTE III or Seerkur Jr and to optimize the strengths of this type of robot, including in the variant of using on its platform a chemical sensor type RESCUE MIMS. This improvement in the technical and operational performance of COYOTE III or Seerkur Jr can help, in the use of a RESCUE MIMS payload, as an early warning system/screening tool for the First Responders and K-9 dog’s teams against the negative effects of VOCs emissions from manmade activities such as industrial processes that exist in the area affected by a disaster. This provides increased protection for First Responders and K-9 dog’s teams by possibly allocating them to other areas of intervention, avoiding toxic environment.
2. Identify the conditions to be simulated in exercise/training fields required to test COYOTE III or Seerkur Jr, including the version with MIMS on the platform. These exercise/training fields exercises must provide the necessary conditions for testing and validating the key performance indicators (KPIs) specific to COYOTE III micro rover researched and carried out within the SnR project.

In the opinion of the end user, it is mandatory, at least, to test COYOTE III or Seerkur Jr in two field exercise scenario:

- The way of fulfilling the fundamental performance indicators of COYOTE III acting autonomously for video research of demolition.
- Coyote III or Seerkur Jr carrying a MIMS on the platform as an early warning system against the action of VOCs emissions from manmade activities such as industrial processes in order to ensure the protection of First Responders, as an early warning system.

In the opinion of the end user, the fundamental performance indicators (KPIs) of COYOTE III or Seerkur Jr (as a search-and-rescue robot), in any variant of use in the area affected by a disaster, are [61]:

- Survivability;
- Mobility;
- Sensing;
- Communicability;
- Operability.

It should be emphasized that the end-user requirements for the basic characteristics of COYOTE III micro rover or Seerkur Jr (power supply, size, weight, user interface, etc.) remain de same as those mentioned in deliverable D1.2, subchapter 2.2.

Summarising the above, the advantages of using unmanned ground vehicle (UGV) in disaster scenarios are multiple:

- Faster location of victims
- Shorter rescue times
- Less risk for the SAR operators
- Faster assessment of damage to buildings

2.2.1 Rescue MIMS on Robotics future needs

It has long become a paradigm that human, material, technological and financial resources are limited to the needs of individuals or local communities to develop sustainably and develop resilience to the destructive effects of disasters.

Which is why, going to the heart of the matter, a significant number of people die or remain temporary or permanently disabled because of unprofessional and time pressure rescue operations [62-63].

In the same sense, there was a significant increase in the costs of providing protective equipment for First Responders, in the case of search-and-rescue actions carried out in a harsh environment. (smoke, high temperatures, toxic gas emissions, high risk of explosions or collapse of buildings damaged by an earthquake etc.), which increases the risk of losing a human resource in the capital of which a significant amount of time and money has been invested in training and educating them in the field search-rescue.

In such a case, the dangerous and time sensitive nature of a disaster area makes it an ideal application for search and rescue terrestrial robotic exploration because they can improve the efficiency of the rescue operation and medical treatment to reduce the casualties among the population.

The purpose of research, testing and validation of robotic technology in this field is to enable humans, software agents, and autonomous robots to work together to save the lives of people trapped under rubble, including ensuring the protection of First Responders.

After the terrorist attacks in the USA - 9/11 -, there was an exponential development of research and development of a robotic search-and-rescue technique, as a necessary and mandatory emergency to ensure the resilience of local communities, but also at regional or national level, against the destructive effects of disasters.

The WTC disaster demonstrated concretely that small robots which can fit inside a backpack have a unique capability to collect useful data in USAR situations.

Robots can enter voids too small or deep for a person, and can begin surveying larger voids that people are not permitted to enter until a fire has been put out or the structure has been reinforced, a process that can take over eight hours [64].

They can carry cameras, thermal imagers, hazardous material detectors, and medical payloads into the interior of a rubble pile.

From the diversity of search and rescue robots that are used in areas where buildings have been damaged or collapsed, we will mention the most representative ones (see Table 2-3) [61].

It should be noted that the achievements in this area are different, comprehensive and diversified because of the difference in the level of skills, geographic and political factors, disaster types, types of debris, etc [61].

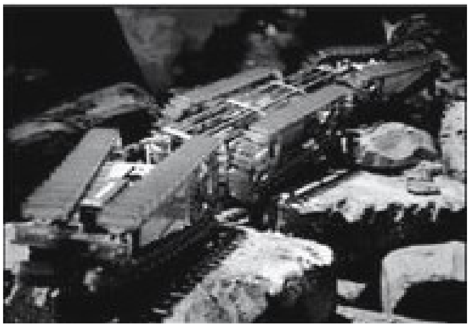
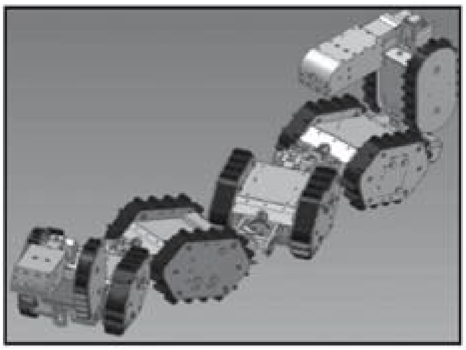
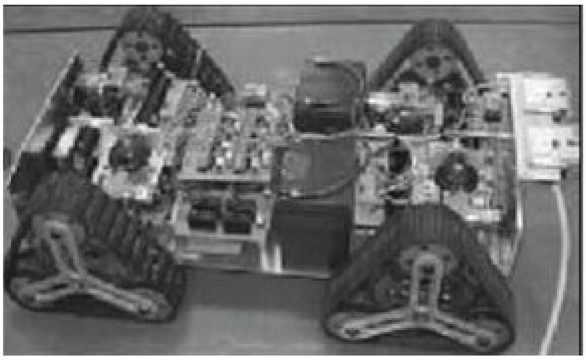
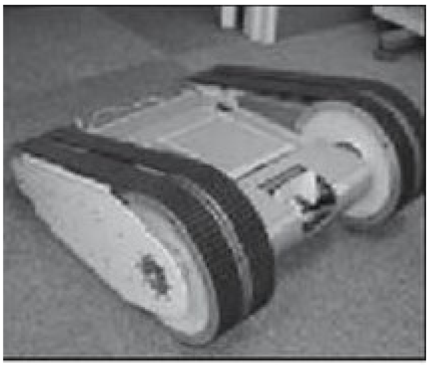
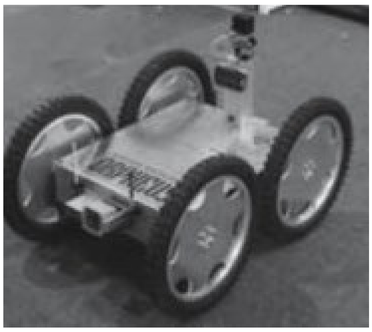
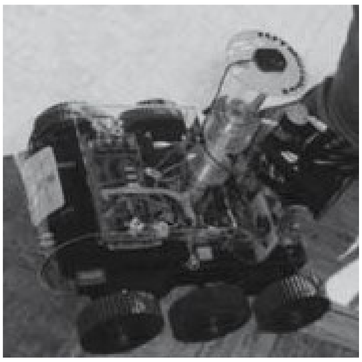
Number	Name terrestrial search-rescue robot	Remarks
1	 **Figure 2-5: SOURYU-I**	
2		

	 **Figure 2-6: SOURYU-II**	**Tokyo Institute of Technology**
3	 **Figure 2-7: Multi-unit rescue robot**	
4	 **Figure 2-8: Rescue mobile robot "RESDOG"**	**Okayama University**
5	 **Figure 2-9: UMRS (Utility Mobile Robot for Search)-V-S2**	**Kobe University**

<table>
<tr><td>6</td><td>
Figure 2-10: UMRS (Utility Mobile Robot for Search-V-M3</td><td></td></tr>
<tr><td>7</td><td>
Figure 2-11: Micro Traces</td><td rowspan="2">Inuktun (USA)</td></tr>
<tr><td>8</td><td>
Figure 2-12: Micro VGTV</td></tr>
<tr><td>9</td><td>
Figure 2-13: Bujold</td><td>Center for Robotic Assisted
Search and Rescue (CRASAR), Florida University</td></tr>
</table>

10	 **Figure 2-14: Urbie Hybrid5T**	**JPL's Machine Vision Group (DARPA Advanced Technology Office)**
11	 **Figure 2-15: AMOEBA-I**	**Shenyang Institute of Automation (SIA), Chinese Academy of Sciences (CAS)**
12	 **Figure 2-16: ROBRNO**	**Brno University of Technology, Czech Republic**
13	 **Figure 2-17: IUTMicrobot**	**Isfahan University of Technology, Iran**

<table>
<tr><td>14</td><td>
Figure 2-18: Coyote III micro rover</td><td rowspan="2">German Research Center for Artificial Intelligence (DFKI)</td></tr>
<tr><td>15</td><td>
Figure 2-19: Seerkur Jr</td></tr>
</table>

Table 2-3: Typology search-rescue robots

Within the European ICARUS project, two unmanned land vehicles have been developed that can help search and rescue people trapped under the rubble [65].

The large unmanned ground vehicle (LUGV) is intended to be a mobile base station.

It is equipped with a powerful manipulator arm and can be used for debris removal, shoring operations, and remote structural operations (cutting, welding, hammering, etc.) on very rough terrain.

The smaller unmanned ground vehicle (SUGV) is also equipped with an array of sensors, enabling it to search for victims inside semi-destroyed buildings.

From the point of view of the sensors mounted on the SUGV platform, it has, at the request of end users, a single chemical sensor to measure the concentration of CO2 in the air with direct contact.

SUGV does not have chemical sensors installed to identify VOs emitted by metabolic processes in the human body (to signal the presence of people trapped under the rubble) or from manmade activities such as industrial processes.

At the same time, the operational range of SUGV is limited to semi-destroyed buildings, which makes it inoperable in the case of completely collapsed structures, such as ” sandwiches”.

Another complex project on S&R in the European Union was DARIUS (Deployable SAR Integrated Chain with Unmanned Systems) [66].

The project aimed to develop and demonstrate interoperability of unmanned air, ground and maritime vehicles in Search and Rescue (S&R) operations.

The project started from the idea of using unmanned systems through military programs and numerous Research and Development (R&D) projects in civilian use.

Within the project, two types of ground robots were developed and validated, as follows:

- CAMELEON: unmanned ground robot system equipped with all last sensors, manipulators and accessories (manipulator arms, water disrupters, X-ray sensors, cameras for an optimal teleoperation fiber optic link in case of radio jamming and communications relay and also transport first aid kits);
- ROBOVOLC: unmanned ground robot system equipped with the following sensors:
    - Sensor for Environment Temperature
    - Infrared Temperature Sensor for ground
    - Humidity Sensor
    - Dual Axis Acceleration Measurement System for inclination measurement
    - GPS sensor
    - Two encoders mounted on two wheels as displacement sensors
    - Signal Conditioned ambient Pressure Sensor Transducers
    - A video camera (WEBcam) for image acquisition.

The analysis of the technical characteristic data of the two unmanned ground robots system listed above shows that these ground robots carried out in this EU project are not equipped with chemical sensors to identify people trapped under the rubble.

The EU project TRADR (Long-Term Human-Robot Teaming for Robot Assisted Disaster Response) use cases involve response to a medium to large scale industrial accident by teams consisting of human rescuers and several ground and airborne robots [67].

An Unmanned Ground Vehicle, the Cameleon E detect threats or identifying suspicious objects bay accessing hazardous or constrained areas instead of human operators.

The goal is that the UGV’s operator must have a good vision of the environment surrounding the robot.

The project does not envisage the use of the unmanned ground vehicle Cameleon E as a platform for the use of chemical sensors with VOCs to identify people trapped under rubble.

In the technological and operational context analyzed above, the realization of a COYOTE III micro rover whose platform allows the payload of a MIMS type chemical sensor is a novelty that ensures both a better protection of the First Responder to VOCs emitted from manmade activities such as industrial processes and increased chances the location of people trapped under the rubble by capturing VOCs emitted by metabolic processes in the victim’s body.

As highlighted in deliverable D1.2 chapter 2.2 of the SnR project, the required core characteristics (power supply, size, payload, user interface characteristics) are met by the COYOTE III micro rover or Seerkur Jr through technical features that offer a number of significant operational advantages, such as: robust but lightweight frame, mobility on difficult terrain, climb stairs and rocks, modular mount for sensors and manipulator, possible cooperation with other robots operating in the disaster-stricken area.

In the opinion of end-users, the COYOTE III or Seerkur Jr technical-tactical characteristics absolutely necessary for its efficient use in search-and-rescue operations, as set out in Annex 1, Part B of the SnR project:

- Proper sensors capabilities to help in maintaining a sense of orientation
- Image processing capabilities
- Automatic distribution of information to third parties and the Incident Management System
- Spatial awareness of their present state, the state of the surrounding environment
- Artificial intelligence supported behavior (task prioritization, risk assessment, aftermath simulation based on the data gathered on the field)

With regard to future improvements to the current core features of COYOTE III or Seerkur Jr, in the view of end-users, the course of action should be to reduce or eliminate the weaknesses of this type of technique (legged wheels may become fragile on high loads and limited power capacity [in the case of Coyote III], no long-term operation).

In the opinion of end-users, the power capacity of COYOTE III or Seerkur Jr must ensure an operational autonomy of at least two hours.

Another need to be solved is that the modular design approach allows adapting the rover structure according to specific payload requirements, a need that will be tested in lab and field exercises.

In its “Robotics solutions” segment (see Annex 1 part B, pp. 14-15 of Consortium Agreement), the SnR project avoids the specific dichotomy of dealing with this topic (either focusing exclusively on conducting robot mobility research on rough terrain or focuses exclusively on increasing the cognitive / intelligent behavior of robotic assets), by combining both aspects of research in the field.

As a partial conclusion, the use of COYOTE III or Seerkur Jr carrying on the platform a MIMS type sensor for First Responders protection by early warning of the presence of VOCs emitted from manmade activities such as industrial processes and/or the location of persons trapped under debris by capturing VOCs emitted by metabolic processes in the victim's body is a novelty in this field of research.

2.2.2 Testing Rescue MIMS on Robotics

Use of robots in search-and-rescue actions, both for video visualization research of a specific area in the disaster area to know the operational situation and to identify toxic environments - by wearing a RESCUE MIMS payload on its platform - to ensure First protection Responders and K-9 dogs is an area of applied research that provides high value-added operational value, including at the managerial level for on-scene incident commander.

This high added value brought to the search-rescue operations by the COYOTE III micro rover or Seerkur Jr, through the quality of the technologies it possesses (among which we mention: own power source, on-board sensor suite and computer and able to perform autonomous exploration tasks) must go through, like any prototype, testing and validation steps.

In this case, the paradigm for testing and validating the COYOTE III or Seerkur Jr prototype is that a robot that can, among other operational functions, carry a RESCUE MIMS payload and not a robot with chemical detection capabilities must be tested and validated.

An important aspect in the design and realization of the COYOTE III or Seerkur Jr system with a payload type RESCUE MIMS, is the realization of an architecture of this system, which also includes the corresponding DSS (Decision Support Services) elements, type ICD [an architectural scheme that addresses both the aspects of physical integration (mechanical / electronic) and logical (software / data / protocols)] with all sensor connected directly to the Concorde in order to report their outputs to the related operator.

This provides a better definition of the subsystems that will be part of the robotic testing platform, with protocols, data and related interfaces.

In the present case of a COYOTE III micro rover or Seerkur Jr with and without a RESCUE MIMS device mounted on its platform, an important aspect is the testing, in laboratory simulations and in different tactical moments of the field exercises, of the control interface.

According to end users, the data transmitted by COYOTE III or Seerkur Jr must be sent directly to the robot operator in the Control Room. Similarly, the data transmitted by RESCUE MIMS, if mounted on the COYOTE III or Seerkur Jr platform, must be transmitted separately in the Control Room. From End User Point of view it is a great vantage to have the mix of information from MIMS Box and Obstacle Detection System, in fact the operator can analyze the chemical inputs from MIMS Box together with the images with the Detections coming from Obstacle Detection System and he can understand at example if some people is in a dangerous situation and he can decide to make intervene the site operator directly in the Robot position.

In the latter case, it is mandatory to aggregate the output data of the MIMS sensor (CSV files) because the DSS has the role of making decisions, not to process the received data.

The tests will analyze the operation of the following elements of the architecture of the component systems:

- Telecom connections (Ethernet Connections (between LIDAR, MIMS box, camera and Obstacle Detection System via a HUB)
- Power connections (robot battery with LIDAR, Camera and Obstacle Detection System and MIMS battery with MIMS box)
- Data connections (between Control Room and Coyote III with its components and, separately, Control Room with MIMS box)

- Physical Connections [between Coyote III or Seerkur Jr (including batteries) and camera LIDAR, MIMS (including batteries), Obstacle Detection System]

In the opinion of end users, laboratory testing should be done in two phases:

- testing the main technical and operational characteristics (for example obstacles detection or stairs climbing) of the COYOTE III micro rover or Seerkur Jr
- testing the COYOTE micro rover or Seerkur Jr having a RESCUE MIMS mounted on the platform (its role being RESCUE MIMS being to be used as a screening tool - providing significant information's regarding safety of the responders and the canines before deployment in the destruction area)

Regarding testing and validation through field exercises, following the previously stated two-phase testing paradigm the SnR project offers a variety of UCs a COYOTE III or Seerkur Jr can be used. In its version having mounted on the platform RESCUE MIMS (as an early warning system not as an S&R tool), in the opinion of end users, one of the most suitable UCs is Use Case 4 (Forest fire expanded and threat to industrial zone Attica Region, Greece). The entire process of testing and validation of COYOTE III or Seerkur Jr with or without RESCUE MIMS mounted on its platform, offers another opportunity to achieve the objectives of the SnR project.

This refers to the analysis of problems and the synthesis of solutions to solve the dilemma regarding the ethical impact of human-robot interaction in search-rescue actions by stakeholders of S&R robots. While the analysis of ethical concerns about the use of robots in the military, medical or automotive industries has received increased attention over time, the same attention has not been paid to robots used in search-and-rescue actions. In the literature, there are few and modest references, such as the brief mention of S&R robots as a subcategory of „outdoor robots" [68].

A positive step in this direction was the EU FP7 TRADR project (grant no. 60963) [69], in which several workshops were organised to identify, analyze and make recommendations on ethical dilemmas specific to the use of S&R robots by rescuers. In a synthesis of the results obtained in the aforementioned European project [70], a series of aspects were concluded that can be a basis for the development of future research in the field. An overview of the stakeholders and values was used as a starting point for the analysis (see Table 2-4).

Stakeholder	Values
firefighter	personal safety, safety of others, access to information, well-being, effectiveness, ease of use, authority
victim	personal safety, health, well-being, access to information, contact
paramedic	personal safety, access to information, contact, health, well-being
policemen	personal safety, security, neutrality, effectiveness,

	courage, security, trust, access to information
press	impartiality, transparency, access to information
local authorities	access to information, sharing information, safety, healthy finances
observers	curiosity, safety
electricity company	access to information, safety

Table 2-4: Overview of the stakeholders and values that were identified in the workshops" End-user requirements and beyond", 14 April 2021

In the next step we discussed, in the aforementioned paper, value tensions involve conflicts between the values of different stakeholder groups, the values of a stakeholder or a value of a group of stakeholders, as they are defined in the specialty literature [70], as it follows:

- Hindering vs supporting safety
- Safety vs well-being
- Effectiveness of firefighter vs police
- Transparency vs privacy
- Safety and effectiveness vs healthy finances
- Transparency and access to information vs wellbeing

Finally, six ethical dilemmas were identified and discussed regarding the human-robot interaction in search-and-rescue actions (see Table 2-5).

#	Dilemma
1	Should S&R robots be employed when they might help saving lives, but their application might also lead to casualties?
2	Should one develop SAR technology that is intended for peaceful purposes even when it has clear military potential?
3	Should one replace infield workers by robots if that leads to suboptimal performance?
4	To what extent should information collected by robots be processed to make it more digestible, at the risk of losing or misrepresenting information?
5	Should one deploy robots, knowing that this may raise false expectations and runs the risk of degraded performance?
6	Should one deploy robots that may yield responsibility assignment problems?

Table 2-5: List of ethical dilemmas identified for robot-assisted S&R

As a partial conclusion of this subchapter, the use of a COYOTE III micro rover or Seerkur Jr, including the carrier version of a RESCUE MIMS on its platform, is not only an innovative leap for operational research of the disaster area, ensuring the protection of First Responders and K-9 dog teams but also a moment of analysis of ethical dilemmas caused by human-robot interaction in search-and-rescue actions (such as in the "End-user requirements and Beyond" workshop from April 14, 2021 within the SnR project).

2.3 Integration of the UAV system with RESCUE MIMS, first responders, K-9 dog teams and robotics in search and rescue operations

From a historical point of view, the appearance of UAV (Unmanned aerial vehicle) was determined by the military's desire to obtain real-time information from the battlefield.

The first test was made in the 1930s, in the form of a plane with a reusable radio control mechanism being considered as a basic model for all the new advances of today's world. Subsequently, military UAVs (most often called "drones") were developed with classic sensors and camera units and evaluated to carry missiles, becoming firearms.

In the last decade, the technological development of UAVs has determined a continuous increase of their use in various fields of activity.

This is mainly due to improved capacity and quality of images captured in real time, lower manufacturing and operating costs than other means of transport (e.g. helicopters), increased flight time and payload that a UAV can carry, compared to previously existing variants [71] [72]. It is estimated that in the next 5 years, more than 10,000 UAVs will be operationalized for use only [73].

If UAVs were initially used in areas of public order or military action, technological progress has made it possible to make an extremely varied offer for requests to improve the activity of various other areas of human activity (see Figure 2-6) [73]. We must mention that the multipurpose use of UAVs in different fields can be done by those who violate the law and can have a negative impact on the individual or a human community [74].

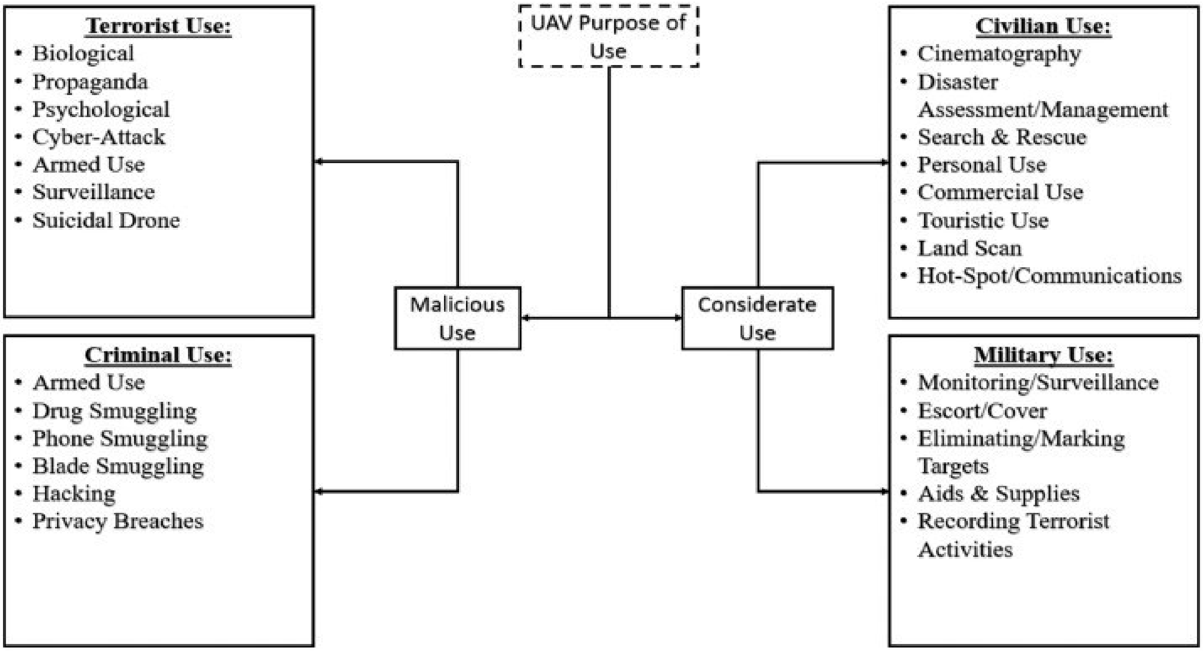


Figure 2-20: UAV multi-purpose usage

UAVs currently used in rescue search actions can perform a wide range of missions, of which we mention those that are absolutely necessary to be performed in such situations:

- Visualization of infrastructure elements (especially buildings and roads) or natural areas in the area affected by the disaster in a short time due to flight speed.
- Identification of the movement of persons who have self-evacuated from the affected area or of victims (including by equipping them with thermal sensors).
- The possibility to work at night.
- Informing and warning in real time First Responders, ground search-and-rescue robot operators, volunteer trainings or K-9 dog teams about the dangers that may arise in the intervention area due to the side effects generated by the disaster.
- The possibility of supplying the isolated population in inaccessible places with materials of first necessity or with food supplies.

Summarising the above, the use of UAVs in search and rescue actions reduces the exposure to the risk faced by emergency response agencies and volunteer teams during response tasks, reduces the cost of providing the response service and, in It provides UAVs with easy access to aerial data from a large area, giving the rescue team the opportunity to speed up the process of finding a missing person, where every second counts.

In this subchapter of the deliverable D1.6, we will analyze the contribution that UAVs can make to the search-and-rescue actions of people trapped under rubble following a natural disaster, as well as from the perspective of ensuring the protection of First Responders and K-9 dogs.

This contribution will be analyzed in the context of coordinating actions with terrestrial robots (with or without a RESCUE MIMS mounted on the platform) and with K-9 dog teams.

Last but not least, taking into account that minimizing the visual identification time of victims and sending real-time images to search the affected area depends on the fundamental parameters in the design of search algorithms (quality of sensory data collected by UAVs, energy limitations of UAVs, environmental hazards (e.g. winds, trees), level of information exchange / coordination between UAVs or other robots through operators, the ultimate goal of the D1.6 deliverable is to propose, in the opinion of end users, the minimum core characteristics required (power supply, size, payload, user interface, characteristics) and the minimum maintenance requirements for a UAV to achieve the above objectives.

2.3.1 Required efficiency and comfort in the working environment

To avoid confusion in reading and understanding this subchapter of the releasable D1.6, we will continue to use the term UAV (Unmanned aerial vehicle) and not the term "Drone".

Although in principle these two expressions represent the same thing, we preferred to use the expression UAV taking into account the use, according to the requirements of the SnR project, of these civilian devices in search-and-rescue actions of people trapped under rubble following a disaster (the term „Drone” was and is used mainly in the military or in actions that contribute to ensuring national security).

The general module, any UAV architecture (formerly called Unmanned Aircraft Systems – UAS -) consists of three main elements: Unmanned Aircraft (UmA), Ground Control Station (GCS), and Communication Data-Link (CDL) [75].

The classification of UAVs takes into account a number of technical or operational characteristics, the most relevant of which are: wing type, flight range, endurance, weight, flight altitude, and wing load (see Figure 2-7) [73].

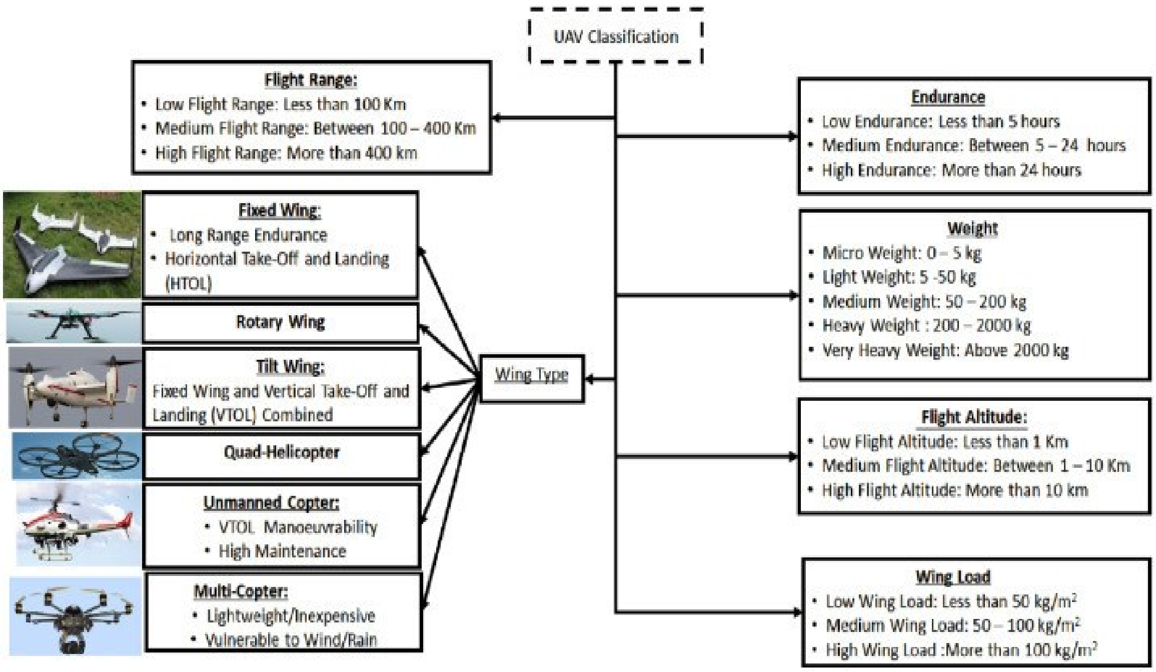


Figure 2-21: UAV classification

Taking into account the existing supply of UAVs on the market, from the point of view of end users, the most efficient type of Wing for search-rescue actions is the multi-rotor.

Based on the Vertical Take-Off and Landing (VTOL) principle, this type of UAV offers great maneuverability, an increased ability to carry a payload, which allows them to hover over a fixed location and provide a constant cellular coverage over certain areas with high accuracy and precision.

In comparison, fixed wing UAVs (Horizontal Take-Off and Landing -HTOL-) offer higher flight speed, more efficient energy consumption and a greater capacity to support a payload than Multi-Rotor UAV.

However, their use in search-and-rescue actions specific to the SnR project is strongly restricted by their inability to hover over fixed locations, in addition to their expensive software/ hardware nature.

In this context, the use of "Hybrid Wing" type UAVs in search-and-rescue actions remains a task for the future, due to its recent appearance on the market and, implicitly, to the lack of technical and operational data in the field addressed by the SnR project.

Regarding the remote control of a UAV, three basic situations can arise [74]:

- Remote control: known as static operator automation, where all decisions are made by a human remote operator, usually located in a control room.
- Remote monitoring: known as adaptive automation. It gives drones the ability to launch and perform a certain mission process independently, while allowing human intervention, if necessary.
- Fully autonomous control: known as static system automation, where drones can make all the necessary decisions to successfully complete the mission, without the need for human intervention.

From the point of view of the use of UAVs in search-and-rescue actions, in the opinion of end users, the most efficient and effective remote control variant is preferable, because the operative situations in the intervention area can show a high dynamics that require the immediate decision of a human controller. As for UAV communications, they can be classified into four main types (see Figure 2-8) [73]:

- **UAV-TO-UAV** = such communication is not yet standardized. In fact, Machine Learning can be leveraged in order to design and optimize a smart UAV-based wireless communication system [76].
- **Drone-To-Ground station** = this communication type is based on the already known and standardized industrial protocols, which are based on wireless communications such as Bluetooth and Wi-Fi 802.11 including 2.4 GHz and 5 GHz.
- **Drone-To-Network** = this communication type allows the choice of the network based on the required security level. It may also include cellular communications, which means relying on 3 GHz, 4 GHz, 4G+ (LTE) and 5 GHz.

- **Drone-To-Satellite** = this is the type of communication needed for sending real-time coordinates via the Global Positioning System (GPS). This allows any drone to be called back to its initial station in case it went beyond the line of control or outside the line of sight.

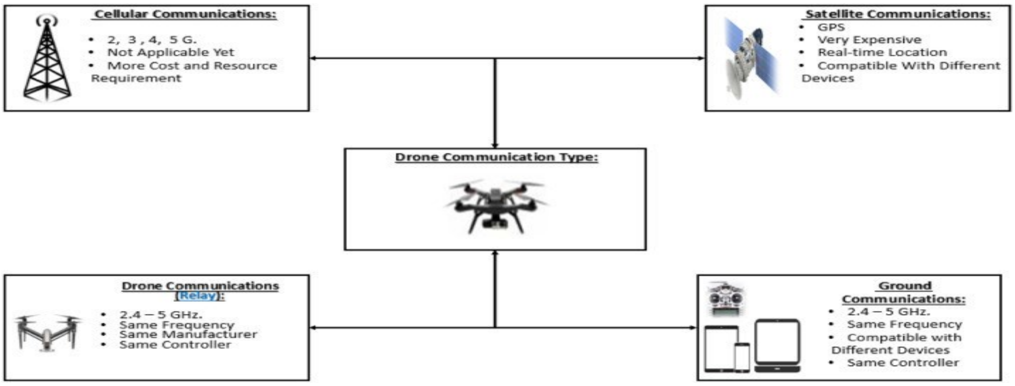


Figure 2-22: UAVs communications types

Another important aspect specific to the use of UAVs in search actions concerns security, safety and confidentiality issues that may arise not only during these actions but, as we will explain below, and during the testing of these UAVs in field exercises as a step in their validation.

Due to the importance of these issues in EU countries, but not only, legal provisions have been issued by each National Civil Aviation Authorities [77] to limit the use of UAVs to, for example, collect images and record videos with people and property without authorized permission or to fly over elements of national critical infrastructure.

In order to harmonize the legal regulations for the use of civilian UAVs, EASA (European Aviation Safety Agency) issued a brochure (Concept of Operations for Drones) for the guidance of the National Civil Aviation Authorities in the whole spectrum of the issue of the use of UAVs.

By issuing that document [78], the aim is to integrate UAVs into the existing aviation system in a secure and proportionate manner by proposing a regulatory framework that establishes a level of safety and environmental protection acceptable to society and provides sufficient flexibility to the new industry to evolve, innovate and mature.

One of the recommendations in the aforementioned document with a direct impact on research, manufacturing, testing and validation of UAVs used in search-and-rescue actions, is to establish three categories of operations and their associated regulatory regime:

- **Open** = the Open operation category of drones should not require an authorization by an Aviation Authority for the flight but stay within defined boundaries for the operation (e.g. distance from aerodromes, from people, etc).
- **Specific** = the "specific" operation category will require a risk assessment that will lead to an Operations Authorization with specific limitations adapted to the operation.
- **Certified** = the "certified" operations will be required for operations with a higher associated risk or might be requested on a voluntary basis by organisations providing services such as remote piloting or equipment such as "detect and avoid". Protection of other public interests

such as privacy and security entailed by drone operations will need to be addressed at the same time as the safety risk and will be dealt with at National Level.

The importance of creating a regulatory framework for the use of UAVs is revealed by the fact that this issue has also been analyzed in some EU research projects, as should be mentioned SESAR 2020 Exploratory Research project (2017 to 2019) [79].
Within this project, CORUS developed within the deliverable D.3 " U-space Concept of Operations" which enables a wide range of UAS (Unmanned Aircraft Systems) uses, accommodating the level of traffic today and that expected in the future [80].

The deliverable contains chapters that contain solutions to a number of areas in which the role, location and missions of UAVs are defined, as follows:

- Background Framework, Assumptions
- Airspace rules and procedures
- Safety & Social aspects
- Services and High Level Architecture

Summarising the above regarding the need for legal regulation of the use of UAVs, in the opinion of end users, UAVs testing should be carefully analysed in any project that includes this technique, in field exercises in accordance with the relevant legal provisions of the country where UAVs take place.
The importance and efficiency of the use of UAVs in search-and-rescue actions is also confirmed by the treatment of the problem in a number of completed or ongoing EU projects.
Thus, in the EU project entitled ResponDrone (2019-2022) which will develop and validate an integrated solution for first responders to easily operate a fleet of drones with multiple synchronized missions in order to enhance their situation assessment capacity and own protection [81].
This System of Systems will simplify and accelerate situation assessment and information sharing, decision making and operations management, while requiring a small crew to operate it.

The EU project entitled INACHUS (Technological and Methodological Solutions for Integrated Wide Area Situation Awareness and Survivor Localization to Support Search and Rescue Teams), which took place in 2015-2018, a laser-based 3D mapping system on UAV is its ability to accurately capture geometry in poorly lit areas, through narrow passages or through vegetation where the performance of image-based techniques is lower [82].

The embedded LIDAR can also collect high-resolution 3D data even in low visibility or bad weather conditions (haze, fog, rain or snow). A major advantage of a laser-based 3D mapping system on UAV is its ability to accurately capture geometry in poorly lit areas, through narrow passages or through vegetation where the performance of image-based techniques is lower.

One of the objectives of another EU project, ICARUS (2012-2016), was to develop unmanned aerial system (UAS) cooperation tools for unmanned SAR.

A highly integrated SAR payload, mounted on an Unmanned Aerial Vehicle as a multirotor system, has been carefully designed to support international SAR teams in their interventions [83].

The payload includes visible and thermal imagers, providing enhanced awareness in the field and real-time victim detection, tracking and geolocalisation.

It also offers fast mapping capabilities in several frequency bands (RGB, grayscale, thermal) and orientations, all in one single flight, avoiding multiple missions over the same area.

Automatic collision detection, real time target tracking and the possibility to carry and deliver a survival kit up to 1kg complements the advanced features of this state-of-the-art robotics tool.

In all the above mentioned projects, but not only in them, special attention was paid to the impact of dangerous meteorological phenomena on operations using UAVs.

The specialty literature mentions weather conditions that can cause loss of control, loss of communication, decreased aerodynamic performance and can adversely affect the operator, such as wind, turbulence, rain, solar storms, extreme temperatures, humidity, snow and ice [84].

It is noted that the classification of weather hazards of concern for UAVs operations range from moderate, to adverse, to severe (see Table 2-6) [84].

Severity	Hazards	Weather Types
Moderate	• Reduced Visibility	• Fog • Haze • Glare • Cloud cover
Adverse	• Loss of communication • Loss of control • Loss of command • Diminished aerodynamic performance • Reduced operator effectiveness	• Wind and turbulence • Rain • Solar storms • Temperature and Humidity • Snow and Ice
Severe	• Severe damage to or loss of aircraft • Unacceptable risk to operator and personnel	• Lightning • Hail • Tornadoes • Hurricanes

Table 2-6: Classification of weather hazards for UAVs in terms of severity

It follows the need that research and development of UAVs to provide operators with relevant guidance for mission planning and execution that will account for negative weather impacts and thus ensure mission success.

Another major aspect to consider when choosing a UAV for rescue search operations is the choice of AI artificial intelligence techniques (which are used to detect objects such as people, boats, vehicles, planes, etc.) from videos, and images) corresponding to the proposed purpose.

CNNs are a type of network created specifically for image and video processing. This is because deep learning for computer vision is usually associated with learning features using architecture of connected layers and neural networks.

The need for performing accurate and real-time human detection in aerial surveillance has sparked significant research in the past few years. Hence the need for a synthesis of the recent literature on AI services for UAVs [85]. The following is a summary of the networks that solve the problem of detecting various objects (see Table 2-7).

	Title	Year	Author	Objectives	Data	Description	Accuracy
1	Secure UAV-Based System to Detect Small Boats Using Neural Networks	2019	Lodeiro-Santiago et al	People and boats in sea	Image	In order to get the model used in this work performance improvements, modern object detector based on CNNs knowing as Faster R-CNN. This model depends in part on an external region used for selective search. The Faster R-CNN model has a design similar to that of Fast R-CNN, so that it jointly optimizes classification and bounding box regression task.	Correct classification of boats and pateras between 94 and 96 % (although these ratios can vary from 92 to 99% depending on the frame).
2	Small Target Detection for Search and Rescue Operations using Distributed Deep Learning and Synthetic Data Generation	2019	Yun et al	Targets (e.g., person overboard)	Image	Combination of image segmentation, enhancement, and convolution neural networks to reduce detection time to detect small targets.	The average precision was 82.16% and the average recall was 76.83%.
3	Vehicle Detection Based on Drone Images with the	2019	Wang et al	Vehicle monitoring	Image	the Faster R-CNN is improved by using ResNet and constructing Feature Pyramid Networks	96.83%

	Improved Faster R-CNN					(FPN) to extract the image features.	
4	Human Crowd Detection for Drone Flight Safety Using Convolutional Neural Networks	2017	Tzelepi and Tefas	Human crowd detection	Image	Adaptation of a pre-trained CNN, by totally discarding the fully-connected layers and attaching an additional convolutional one, transforming it to a fast fully-convolutional network that is able to produce crowd heat maps. Second, a two-loss-training model, which aims to enhance the separability of the crowd and non-crowd classes.	95.32%
5	Drone-surveillance for search and rescue in natural disaster	2020	Mishra et al	Human action detection for SAR	Image	Region-based methods include RCNN, SPP-Net, Fast R-CNN, Faster R-CNN, and Mask R-CNN, and RFCN. Another category is the one-step approach, which is also called regression and classification-based OD, which mainly includes YOLO and SSD.	98.00%
6	Comprehensive analysis of deep learning based vehicle detection in aerial images	2019	Sommer et al	vehicle detection	Image	SSD, Fast RCNN, and faster RCNN	88.70%
7	Using deep learning and low-cost RGB and thermal cameras to detect pedestrians in aerial images	2018	Candido de Oliveira & Wehrmeister	Human detection	Image	HOG+ SVM, CNN	90.00%

	captured by multirotor UAV						
8	Object recognition in aerial using convolution neural network	2017	Radovic et al	Aeroplane detection	Image	YOLO	84.00%
9	Okutama-Action: An aerial view video dataset for concurrent human action detection	2017	Barekatain et al	Human detection	Image (from Video)	SSD	0.18 mAP at 0.50IOU.
10	Region proposal approach for human detection on aerial imagery	2018	Marusic et al	Human detection	Aerial image	Evaluated method based on Faster RCNN detection model showed promising preliminary results, as well as fast processing of high resolution images.	Overall, detection model achieved 88.3% recall with precision of 67.3%.
11	Real-Time, Cloud-based Object Detection for Unmanned Aerial Vehicles	2017	Lee et al	Object detection	Image	Application of Faster Regions with CNNs (R-CNNs), a state-of-the-art algorithm, to detect not one or two but hundreds of object types in near real-time.	SSD300 for human 92,9 faster R-CNN 83,9 mAP overall for all objectives.
12	A Deep Learning Model Based on Multi Objective Particle Swarm Optimization for Scene Classification in Unmanned Aerial Vehicles	2017	Rajagopsl et al	Scene classification	Image	SSD300 for human 92,9 faster R-CNN 83,9 mAP overall for all objectives	97.88%

Table 2-7: Object detection method in UAV images & video

(UHASSELT contribution to D1.6)

The drone is equipped with different types of sensors (IR, Thermal, Lidar, Sonar etc) allowing it to be deployed towards different campaigns of data captures, for differing purposes.

The possibility to capture two images simultaneously, a normal full-color image combined with an infrared image, offers a solution for an up to now unfulfilled demand.

As a partial conclusion of this subchapter, in the opinion of end users, the use, in different forms, of UAVs in different phases of the rescue-search actions of victims trapped under rubble represents an opportunity and obligation for future projects in the above mentioned field.

2.3.2 Core characteristics required: power supply, size, payload, user interface, characteristics

In a rapid development of the drone supply market, it is difficult to highlight the offers of the largest players in the field. In order to facilitate the navigation for finding the optimal UAV solution for their use in the field of search-rescue of people trapped under debris, specialized sites have been provided.

Within such a site [86], the person or organisation concerned may find a list of manufacturing companies, in categories according to their drone services and basic offers (Hardware Companies Drone Industry News, Flight Operation Management, Data-Processing Tools, Marketplaces and Databases, Funders, Drone Delivery, Drone Racing, Drone Conferences, Training and Education).

To further facilitate this search, the offer of several manufacturers that are already well known in the market for the offer of UAVs that can or are already dedicated to search-rescue actions can be accessed [87] [88] [89].

In order to maximize the benefits of using UAVs in search-and-rescue operations of people trapped under the rubble (agility, speed, autonomy in behavior by participating in search-and-rescue operations in high-risk areas for First Responder or K-9 dog’s teams), it is useful and necessary to find technological solutions that take into account a number of key factors such as:

- Quality of sensory data
- Energy limitations
- Environmental hazards
- Information sharing (Data fusion and Network Connectivity)

From the end users point of view, a UAV used in search-and-rescue actions, as a first warning element (regarding the affected infrastructure in the intervention area, the situation of human victims, fire hazards, etc.) and subsequently directing the intervention for First Responders, COYOTE III micro rover and K-9 dog’s teams meet, in minimal mode, the following technical and operational characteristics:

- Diagonal 354 mm
- Weight (with battery and propellers) 1388g
- Maximum speed 50 km / h (P mode without wind)
- Max Flight Time 25 min
- Intelligent Flight Battery 3850mAh, 15.4V, LiPo, 297g
- Temperature Range 0 ° to 40 ° C (32 ° to 104 ° F)
- Satellite positioning GPS / GLONASS satellite
- Memory card MicroSD

M2ED OPTICAL CAMERA

- Sensor CMOS 1 / 2.3 "12M Pixels
- Aperture f / 2.8-f / 11
- Compression MPEG4 / H.264

THERMAL CAMERA M2ED

- Sensor Uncooled microbolometric
- Aperture f / 1.1
- Resolution 160 x 120
- Spectral band 8-14 um
- Compression MPEG4 / H.264

RANGE TEMPERATURES

- High gain temperature range -10 ° to + 140 ° C
- Low gain -10 ° C to + 400 ° C

AUXILIARY FLASHING

- Power 1.6W
- Intensity 157cd

AUXILIARY PROJECTOR

- Max power 26W
- Range 30m
- Illuminance 11 lux at 30m

AUXILIARY SPEAKER

- Power 10W max
- Decibel 100 db at 1 meter distance NB (only one auxiliary equipment possible on the drone)
- Mobile app DJI Pilot
- Payload 300g

An important aspect in the use of a UAV in search-and-rescue operations is its testing and validation in field exercises.

Within the SnR project, a variety of CPUs are planned where the technical and operational capabilities for UAVs can be tested, but, in the opinion of end users, the most eloquent testing can be done in Use Case 4 (Forest fire expanded and threat to industrial zone Attica Region, Greece).

The tactical moments specific to this UC allow the UAV operator, located in the Control Room, to provide First Responders, K-9 dog's teams and to the COYOTE III micro rover or Seekur Jr operator with information to ensure their protection and security, including for optimizing research and search in the area.

As a partial conclusion of this subchapter, in the opinion of end users, the use of UAVs in search-and-rescue actions will become one of the paradigms of the future in this field.

2.3.3 Equipment Maintenance

The maintenance rules for UAV equipment depend on the technical solution adopted and the result of the experimental tests.

However, the general and specific rules for the maintenance of the equipment of each type of UAV, in order to ensure its functionality, must be mentioned in a maintenance manual.

These rules must ensure that the UAV continuously provides optimum performance and flight safety.

One of the basic rules for the maintenance of a UAV is that of its mandatory technical verification after a number of flights performed and a number of flight hours (e.g. technical verification after every 200 flights or 50 flight hours).

Among the general rules for maintaining a UAV, in the specialty literature [90], are mentioned:

- Checking the Battery System
- Checking the Transformation System
- Checking the Airframe
- Checking the Motors
- Checking the Propellers
- Checking the Flight Control System
- Checking the Control and Video Transmission System
- Checking the Camera
- Checking the Vision System

An aspect that is directly related to the maintenance of UAVs concerns the training method of the operator of a UAV (in the opinion of end users this operator would be advisable to be a former First Responders, due to his theoretical and practical experience in managing rescue search actions).

Theoretically, almost anyone (with patience, perseverance and precision) can operate a UAV at the end of the training period, but the duration of the training period can vary from one type of UAV to another.

No matter how long this learning takes, the objectives are for the UAV operator to handle the UAV safely, to acquire the best possible operational skills and to gain sufficient self-confidence to be able to use the UAV in the area affected by a disaster.

GAP analysis for community resilience

3 GAP analysis for community resilience

3.1 Introduction, scoping and methodology

3.1.1 Brief overview of PHASE A (M1-M4) and scoping of PHASE B (M5 – M12)

This Section builds on the related work performed during M1 – M4 of the SnR project (PHASE A, documented in detail in D1.2) on the GAP analysis for community resilience. It reflects the related work performed on the aforementioned topic during M5 – M12 (PHASE B).

In PHASE A, the scope was to produce a preliminary structure of the GAP analysis survey that would then be further modified and refined in PHASE B. Obtaining and agreeing on a common understanding of what 'resilience', 'community' and 'community resilience' mean for the purposes of the SnR project was an important part of PHASE A. In summary, PHASE A comprised of the following:

- Structured literature review including major relevant EC-funded research projects & case study collection. This aimed at identifying and subsequently agreeing on the 'community', 'resilience' and 'community resilience', to be used for the purposes of the SnR project. It also aimed at identifying relevant tools and guidance, and investigating professional-volunteer interactions. A review of legislation/regulatory and standardization issues were also performed.
- Literature review & case study results processing and presentation; preliminary roundtable consultation among SnR consortium experts.
- Compilation of literature review & report drafting by also including a preliminary proposed survey structure for the GAP analysis that included major factors in the form of attributes and/or capacities that were found to positively contribute to the enhancement of 'community resilience'.

Below, the agreed definitions or concepts that were found suitable to the purposes of the SnR project are replicated for recollection and for avoiding misconceptions.

- *Community:* the **Community of practice and interest** was considered for the purposes of the SnR project. This composed of:
    a. **First responders** (e.g. Fire and rescue brigade, Emergency medical services, Civil protection, police-law enforcement personnel, Coast guard / Border security, by-stander individuals);
    b. **Early responders and sustained support** (e.g. Emergency Coordination Centres, Critical infrastructures and infrastructure operators; hospitals, registered national and international voluntary organisations active in disaster & spontaneous volunteers; utility companies, primary care organisations, public authorities, UAV/robots/vehicle manufacturers, infrastructure manufacturers, support aid manufacturers).

Interaction of this community with civil society volunteering organisations and social groups and/or vulnerable populations (e.g. impaired persons and persons with disabilities, persons mostly exposed or with limited resources) was also considered, however, PHASE A only set out the reference background of such possible interactions. A more in-depth analysis of these interactions will be performed in subsequent deliverables of WP2 dealing with the societal aspects of the SnR.

- *Resilience:* There exists several notions and approaches for defining resilience. In the context of crisis management, the need to **consider the social/community adaptive and transformative/learning nature of resilience** was considered essential among the resilience fundamental characteristics. Therefore, definitions that emphasized those aspects were found to be the most suitable for the project. Table 3-1 lists the most representative of these.

Source	Definition
DG-ECHO [91]	*"Resilience is the ability of an individual, a **community** or a country to cope with, adapt and recover quickly from the impact of a disaster, violence or conflict. Resilience covers all stages of disaster, from prevention (when possible) to **adaptation** (when necessary), and **includes positive transformation** that strengthens the ability of current and future generations to meet their needs and withstand crises."*
UNDRR [92]	*"The ability of a system, community or society exposed to hazards to **resist, absorb, accommodate, adapt to, transform and recover from** the effects of a hazard in **a timely and efficient** manner, including through the **preservation and restoration** of its essential basic structures and functions **through risk management."***
NAS [93]	*"The ability of a **system** to perform four functions with respect to adverse events: (i) planning and preparation, (ii) absorption, (iii) recovery, and (iv) **adaptation.**"*
Public Safety Canada [94]	*"Resilience is the capacity of a **system, community or society** to **adapt** to disturbances resulting from hazards by persevering, recuperating or changing to reach and maintain an acceptable level of functioning."*

Table 3-1: Resilience' as defined by major organisations

Community Resilience: PHASE A identified an absence of a widely accepted definition for community resilience as this was strongly influenced by the specific context and definitions of 'community' and 'resilience'. The Australian Institute for Disaster Resilience (AIDR) provided the definition that emphasized the aforementioned elements [95]: *"A **resilient community** has the opportunity, capacity and capability to identify and mitigate hazards and risks, absorb the effects of disruptive events, **adapt or transform** in anticipation or response to disruptive events and return to a functioning state."*

Therefore, the approach suggested by [96] was followed and focused instead on determining the commonly agreed factors/elements in the terms of attributes/capacities that were found to be of most relevance to the scope of the SnR project. These are presented in the preliminary GAP analysis table which was the result of PHASE A works (see Annex II) classified in four (4) domain areas: Human/Behavioral, Technological, Organizational and Legal.

In PHASE B, the aim was to refine the work that was performed in PHASE A so that the feedback obtained and the resulting recommendations would as much of **practical value and applicability** to the SnR technology/wearable developers and to the operationalization of the proposed Use Cases (UCs) as possible. The scope was thus limited and targeted on how to best combine the identified 'community resilience' attributes/capacities with the involved parties (i.e. technology/wearable developers and UCs participants and end-users) key requirements for the aforementioned aim, as next described in Section 3.1.2 - PHASE B - were performed through the T1.3 (GAP analysis for Community Resilience) works of WP1 (First responders Requirements and Governance model).

3.1.2 PHASE B methodology: approach and timeline

The PHASE B methodology relied on a participatory approach which combined several methods. These methods are presented below with a brief elaboration on how these were applied in the project:

- PHASE A structured literature review and case study findings (documented in detail in D1.2):

  As reported in D1.2, the structured literature review and case study collection set the ground for identifying and screening key 'community resilience' attributes/capacities that were most applicable to the SnR scope of works. It also identified potential shortcomings and issues faced by end-users during crisis management.

- Brainstorming SnR partner online meetings:

  Besides the plenary meetings and WP1 overview meetings two (2) T1.3-focused meetings were organised. The 1st Meeting on November 18th, 2020, was a brainstorming exercise that derived answers on who to include in the Focus Group discussion, who will the GAP survey be addressed to, who will benefit from the survey responses, and lastly, based on the previous information, how to further refine the GAP survey preliminary structure from PHASE A. The following major conclusions were derived:

  a. **What is the purpose of the refinement for the GAP survey?** To focus as much as possible in information that is of practical use for the development of the wearables/technologies and the operationalization of the UCs.
  b. **Who will the survey be addressed to?** The GAP survey will be primarily addressed to the end-users (i.e. from the SnR consortium community of practice and interest) of the wearables/technologies to be developed within SnR. It was decided the **GAP survey to be distributed to Consortium end-users** who are well aware of the specificities of the wearables/technologies to be developed and the UCs to be operationalized in order to obtain targeted feedback. In addition, it was decided not to exclude feedback from other Consortium partners, however in such case processing of the results by the different categories would be performed. Selected external experts will have the opportunity to review and comment/refine the findings at a relevant Workshop.
  c. **Who will benefit from the survey answers?** Primarily, the partners who are in charge for developing the SnR technologies/wearables and those implicated in the operationalization of the UCs. However, the applicability of the feedback applies to all relevant stakeholders.
  d. **How to proceed with the refinement?** It was decided that the best way to proceed with the refinement of the GAP survey structure is to identify the **pertinence** of the PHASE A reported 'community resilience' attributes/capacities **to key user needs**.

The 2nd Meeting on January 26th, 2021 reviewed the proposed updated structure for the GAP survey and finalized it.

- Surveys involving end-users (i.e. from the community of practice and interest) from the SnR consortium partners (mostly performed and documented in D1.1):

  An important issue for advancing the refinement of the GAP survey was to decide on the key criteria / indicators that concerned the end-users meaning the **key user needs**. The identification of these key user needs stemmed from an end-user survey performed in T1.1 and documented in D1.1 and took into account the relevant literature review/case study findings. The following key user needs grouped in three (3) categories (Human/First responder-related; Technical information-related; Operational information-related) were selected:

  a. First responder education and training (Human/First responder-related)
  b. First responder safety (Human/First responder-related)
  c. Maneuverability (Operational information-related)
  d. Interoperability/Compatibility (Operational information-related)
  e. Ergonomy/Ergonomics (Technical information-related)
  f. Sensitivity to environmental conditions (Technical information-related)
  g. Size of impacted area/victims (Technical information-related)

- Expert opinions from SnR consortium partners (pre-Focus Group analysis):

  Prior to the Focus Group discussion, a pre-Focus Group analysis was performed in order to identify the pertinence of the 'community resilience' attributes/capacities to the key user needs. A **matrix** consisting of the 'community resilience' attributes/capacities identified from PHASE A versus the key user needs was formed and SnR expert consortium partners indicated the relevance they attributed to the different combination pairs of attributes/capacities vs. key user needs. This way, an in-depth insight was obtained on which 'community resilience' attributes/capacities may be of most pertinence to the key user needs. The analysis was made for clusters of respondents (first/early responders and others) and in aggregate. The matrix and the resulting expert feedback are reported in more detail in Section 3.2.1.

- Focus Group discussion:

  A Focus Group was formed composed from SnR consortium partners with expertise as first/early responders and/or technology developers. The information derived from the pre-Focus Group analysis was used to formulate relevant questions and steer the discussion on the issues that mattered the most. Chapter 3.2.2 elaborates on the aforementioned.

- GAP survey final structure and analysis of the responses:

  Following the input obtained from the Focus Group discussion, the GAP survey structure was updated and finalized. As aforementioned, the survey was administered within the SnR Consortium partners and their feedback processed. All SnR partners provided feedback to obtain a total of 28 responses (1 per organisation). The survey segregated feedback from three (3) major categories of respondents:

  a. First or early responder
  b. Technology Developer
  c. Other (to specify)

- Workshop for refinement of the GAP survey results with the participation of SnR consortium partners and selected external to the consortium experts:

  An online SnR Workshop titled “End-User requirements and beyond” was organised on April 14th, 2021. The Workshop consisted of three (3) sessions. Session III was dedicated to the presentation of the GAP analysis for community resilience approach and the obtained survey responses. A roundtable discussion with the participation of both internal and externa to the consortium experts identified the final refinements, key advantages and proposed improvements for future research on the methodological approach. Subchapter 3.4 elaborates on these. **Error! Reference source not found.** depicts the timeline for the implementation of the presented methodology.

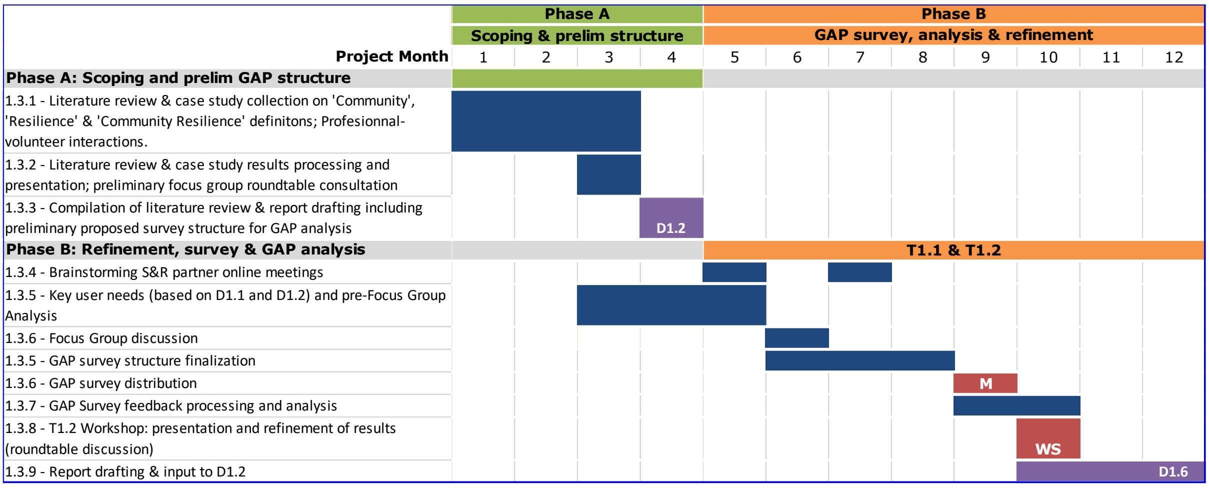


Figure 3-1: Major Phases and sub-phases for the GAP analysis

3.2 Focus Group discussion and findings

3.2.1 Pre-focus Group phase: community resilience attributes and end-user criteria

As aforementioned in Subchapter 3.1.2, a matrix was formed with the ‘community resilience’ attributes/capacities versus the end-user needs/criteria. SnR consortium partners were asked to identify the most relevant pairs in this matrix. In total, 20 SnR consortium partners participated in the exercise (19 for the Operational and Technical-information related user needs). Among these, six (6) were first/early responder organisations.

We processed the results in two ways:

a. By aggregating all answers provided and considering equal importance to the opinion of each organisation. Annex III Table 3-11 presents the aggregated results. Green-colored cells highlight the *[attributes/capacities; end-user needs/criteria]* pairs that were considered to be of most relevance and importance to the development of the technologies and/or the operationalization of the UCs **by the majority of the organisations**.
b. By looking at the answers provided by first/early responders as these are the partners that possess most experience in the field operations. Annex IV Table 3-12 presents the aggregated results. Yellow-colored cells highlight the *[attributes/capacities; end-user needs/criteria]* pairs

that were considered to be of most relevance and importance to the development of the technologies and/or the operationalization of the UCs **by the majority of first/early responder organisations**.

As it may be inferred by comparing the aforementioned tables in Annexes III and IV**,** several similarities may be found in the identified pairs between the aggregated responses and the ones provided by the first/early responders. Nevertheless, some differences also exist. This is expected by considering the different background and relevant experience that first/early responders may possess in relation to the rest of the SnR consortium partners. Moreover, in addition to the identified agreement on the relevant and important pairs, the aforementioned differences provided deeper insight on how to formulate relevant questions and steer the discussion in the Focus Group by considering the different perspectives of the participating experts. This was a valuable inference that derived from the processing that considered different clusters (i.e. aggregate and first/early responder).

3.2.2 Focus Group discussion and analysis

The focus group was held on 14 December 2020. It was facilitated by SAN with the participation of WP1 partners including CERTH, ESDP, HRT, JOAFG, JUH, PROECO, PSCE, PUI, SUMMA/SERMAS, UGL, UNICA, UNIFI, and VUB. The session lasted for two hours and was recorded with the consent of participating partners. The purpose of recording the focus group was to enable the analysis of the data at a later stage.

The focus group was a connecting step between the preliminary survey structure for GAP analysis (detailed in 3.1.1) and the final gap analysis survey (detailed in 3.3). The preliminary survey structure for GAP analysis was based on the initial Phase A of reviewing the literature and a collection of case studies (detailed in 3.1.1). The purpose of the focus group was to refine the questions for the final gap survey that was later conducted (detailed in 3.3).

To conduct a comprehensive focus group, a set of focus group questions were formulated based on the attributes and criteria identified in the preliminary survey structure for GAP analysis. A total of 13 questions were formulated based on how the 20 respondents from WP1 rated the attributes in relation to the seven criteria (Annex III Table 3-11 and Annex IV Table 3-12). Attributes that were considered most important were grouped and reworded into the following focus group questions:

1. In what ways can relations be strengthened between end-users on one hand and civil society organisations and local communities on the other?
2. In what ways can relations be strengthened between end-users and vulnerable populations?
3. In which part of a response is training needed the most?
4. How can the understanding of rescue processes be improved?
5. How can the physical and mental health of first responders or victims be protected?
6. What is the best way to locate and allocate resources?
7. What are the challenges in interoperability with other S&R organisations, civil society organisations and local groups?
8. What are the challenges of compatibility of communication systems and structures in relation to information sharing?

9. What are the challenges you face with victim localization, situation awareness, and risk assessment?
10. What are the limitations of detection, monitoring, and reporting devices under various environmental conditions?
11. In what ways can information and communication technologies (ICT), social media, and community networks reduce the aftermath of the disaster in terms of a size of the affected area and number of victims?
12. How do smart devices, real-time information sharing systems, and other equipment impact the maneuverability of you team?
13. How do your organisation's internal processes impact maneuverability?

The focus group results can be clustered around eight (8) key points of discussion:

1. Strengthening relations between end-users on the one hand and civil society organisations, local communities, and vulnerable populations on the other.

The focus group participants discussed the importance of involving NGOs and local communities in the entire disaster management cycle, including the early stages of mitigation and preparedness as well as response and recovery. This could be done through e.g., creating local risk maps and recovery plans or by conducting local risk analyses.

The active engagement of civil society organisations and other local actors could be strengthened through the creation of **an endowment plan (budget reserve)** for local resources, local volunteers, and NGOs which should be coordinated by a local authority, rather than in a top-down fashion. Delegating and giving authority to local authorities and representatives of local communities would have an **empowering** effect.

The participants of the focus group pointed out that the relationships between end-users and civil society organisations, local communities and vulnerable populations could also be strengthened through various events, meetings, gaming, media communication, and different forms of local outreach with vulnerable populations.

2. Training to Improve S&R

The focus group participants highlighted the importance of training in technologies, including **being familiar** with what technologies are available and how to use them in time-constrained situations. An emphasis was also placed on training first responders (FR) in **disabilities-specific technologies**. The participants pointed out the criticalness of practical training preceded by theoretical training, as well as training related to operational procedures. In all types of training, information, knowledge, and lessons learnt from other projects and disasters ought to be utilised.

3. Protection of physical and mental health of first responders.

One of the important issues discussed by the FG participants was the physical and mental health of first responders. When addressing physical health, the participants pointed out to **wearables providing protection**. Another important factor in ensuring first responders' safety was **decision-making and danger assessment procedures**. Danger assessment procedures seem crucial, yet many organisations do not have them in place. Firefighters were indicated as a service which usually has them implemented and could communicate the assessment outcome to other FRs. The coordination around this issue was reported to work well in many cases, however, if firefighters are not a part of a response action, then this becomes a problem. Clear decision-making procedures assist the FR in the coordination effort and help to reduce the pressure of having to make decisions on the spot, in the time constrained conditions.

Mental health was also addressed and especially the **cumulative stress issue**. FG participants pointed to a **gap** that exists in this area. They expressed an opinion that there should be a **procedure for monitoring and recognizing who is at risk, and providing training for FR on how to deal with stress** before it reaches dangerous levels.

4. Locating and allocating resources.

The FG participants expressed an opinion that the best way to allocate resources would **be through 112** who should hold all the necessary information sourced from mobile unit points via GPS navigation or the call centres. NGOs who participated in the FG pointed to **volunteers sometimes not being part of the information system and not having access to technologies** despite being involved in rescue missions which is a **gap**.

5. Challenges in interoperability with other S&R organisations, civil society organisations and local groups.

Several issues were discussed by the FG participants in relation to interoperability. **Different communication systems** used by various organisations involved and especially when working with volunteers were listed as one of the main challenges. The issues of **sharing terminology and technology**, including radio frequencies, were also addressed.

6. Challenges of victim localization, situation awareness and risk assessment

One participant explained that the challenges faced in relation to victim localization, situation awareness, and risk assessment were covered in the EU funded project CONCORDE, however, from the victims ′perspective or position. Other participants said that there are **challenges with GPS signaling** during disasters that can be overcome by using military satellite devices but this is expensive and not always accessible.

7. Limitations of detection, monitoring, and reporting devices under various environmental conditions.

Environmental conditions such as high relative humidity, high temperature, wind, and dust may cause problems with chemical devices and chemical compounds. Environmental conditions may also cause loosing connection with location devices when dogs are in collapsed structures as the available devices are not designed for dogs.

Participants stressed that the **control center (CC) should be locally staffed with members of different services such as transport services or civil defense**. The CC should include an **adaptable template** on how to manage crises in specific environmental conditions.

8. Impact of internal processes maneuverability.

The focus group participants pointed out that training exercises should be **adapted** to different equipment. It is also important to know what equipment is the most appropriate and also equipment usability.

3.3 GAP analysis survey

3.3.1 Final structure of the GAP table

The valuable inputs of the FG allowed identifying important attributes and criteria which helped to refine the GAP survey structure. Table 3-2 presents the feedbacks of the participants of the FG, and the corresponding changes that have been made to the survey.

FG Feedback	Changes
The participants highlighted additional possible options (Cooperative risk mapping, cooperative risk analysis and gamification) to efficiently involve NGOs and communities in the entire disaster management cycle and more precisely in the risk analysis.	The options of question concerning the cooperative risk assessment (question 3) have been refined.
The participants outlined the important type of trainings that may improve the crisis management.	Additional options have been added to the question investigating the implemented and needed type of training (question 6) like: • Training of end-user about interaction with people with specific disability. • Training of first responder on the usage of new technologies and its constraints. • Training of first responder about emergency medical skills (crisis research management).
The participants suggested a separation of possible procedures to improve physical and mental health. The participants agreed about the importance of implementing procedures for improving the physical health of first responders and victims. They also highlighted the importance of new technologies to identify and avoid dangers.	Questions concerning physical and mental health have been separated and different options have been included for each question. These options include: • Usage of new technologies to identify the risk and avoid dangers. • Usage of wearables and technologies to protect first responders.
The participants stated the difficulties for volunteer and NGOs to locate and allocate resources.	A question regarding the procedures facilitating the localization of resources has been included.
The participants stated the faced difficulties to interoperate with other S&R organisations, civil	Additional questions have been added to target the different aspect of interoperability and the options of the question concerning

society organisations and local groups including the technical interoperability.	technical interoperability have been developed to include the standardization of communication technologies.
The participants stated the difficulties faced in data collection including the cost and the access of full coverage communication solutions such as satellite.	The survey already targets the technical challenges faced in data collection for situation awareness and risk assessment. More options are developed to cover "Access to full coverage communication resources". This option also has been added to the question related to victim localization.

Table 3-2: GAP survey refinements based on FG discussion

The final structure of the GAP survey may be found in the following link: https://ec.europa.eu/eusurvey/runner/2fbdde33-dde4-fa21-ae32-04d68565494c. Next, relevant participation and the tool used to administer the survey are presented next.

3.3.2 GAP survey overview

The main purpose of the "*gap survey for community resilience in crisis management"* is to identify the gaps in key user needs that relate to important attributes/features which contribute to the improvement of community resilience in crisis management for guiding the development of technologies/wearables and the operationalization of the UCs. In addition, the survey aims at identifying their level of importance and collect relevant proposed corrective actions and/or mitigation measures.

As aforementioned, the survey has been circulated to the consortium partners of the SnR project. In total, 28 organisations participated in the survey. The survey responders have been segregated into three groups/categories, which are:

- First responder (e.g., Coast guard / Border security, Fire and rescue brigade, Emergency medical services, police-law enforcement personnel, Civil protection, by-stander individuals) and early responder (e.g., Hospitals, registered national and international voluntary organisations active in disaster management, Emergency Coordination Centres, Critical infrastructures and infrastructure operators, utility companies, primary care organisations). In total, eight (8) organisations constituted this group.
- Technology Developer: 11 organisations constituted this group.
- Other: nine (9) organisations constituted this group, including legal & Ethical experts, research Universities and dissemination & exploitation experts.

Error! Reference source not found. shows the percentage of each category of the survey responders.

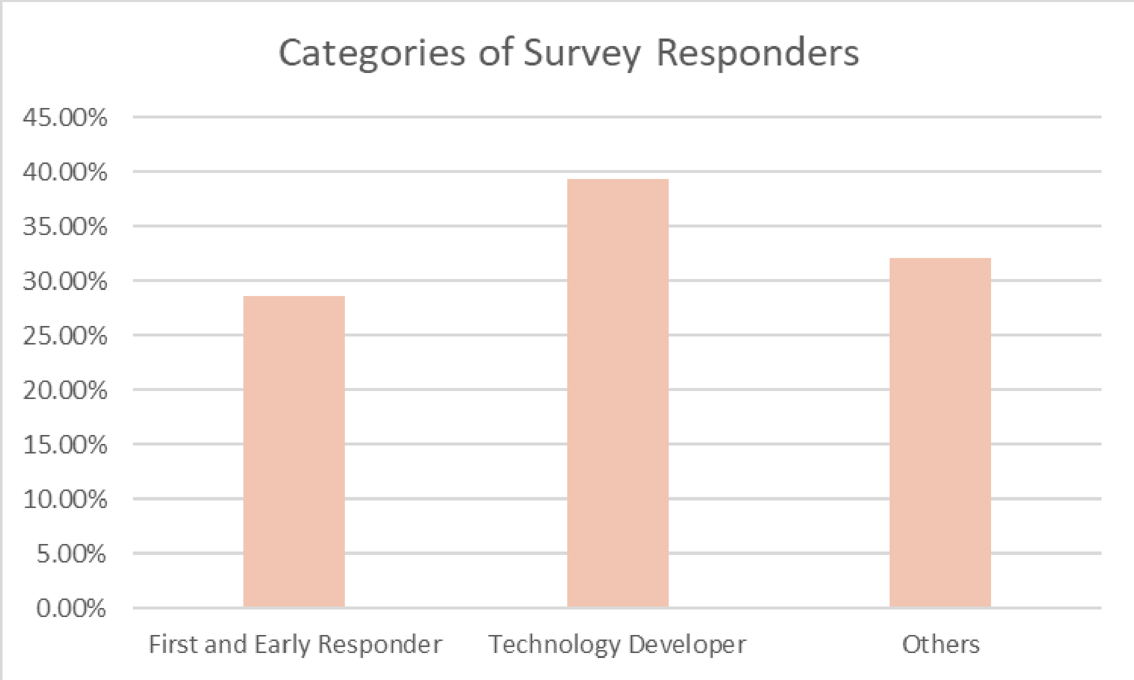


Figure 3-2: Percentages of categories of the survey responders

The survey was created and administered by using the European Commission's online survey management tool (EUSurveys - https://ec.europa.eu/eusurvey/home/welcome). The survey included 21 questions; the majority of the questions focused on the community resilience and crisis management procedures implemented and needed within the responders' organisation. Additionally, the survey included questions investigating the technical challenges faced during operations and the importance of relevant features and procedures. The survey provided to the responders the ability to include additional options and suggestions for each feature/procedure inquired. The administered GAP survey may be accessed through the following link: https://ec.europa.eu/eusurvey/runner/2fbdde33-dde4-fa21-ae32-04d68565494c.

3.3.3 GAP survey results analysis and summary of key findings

The results of the survey were analysed by category of responders. This strategy allowed to identify the different opinions among different group of responders as well as to define inputs based on the different expertise specifically the first and early responders and the technology developers.

We first started by identifying the most relevant procedures/ features and the challenges from the point of view of different category of responders. In the survey we asked the responders to attribute an importance score to each feature as per Table 3-3.

Importance	Score
Essential	3
Secondary	2
Auxiliary	1

Table 3-3: Importance score attributed to each feature in the survey

Error! Reference source not found. shows the reported normalized scores of importance attributed by each category of responder to each feature. As depicted, the "Procedure of improving the physical health of the first responder and victims" and "Training" are the two features with the highest score value for the category of first/early responders.

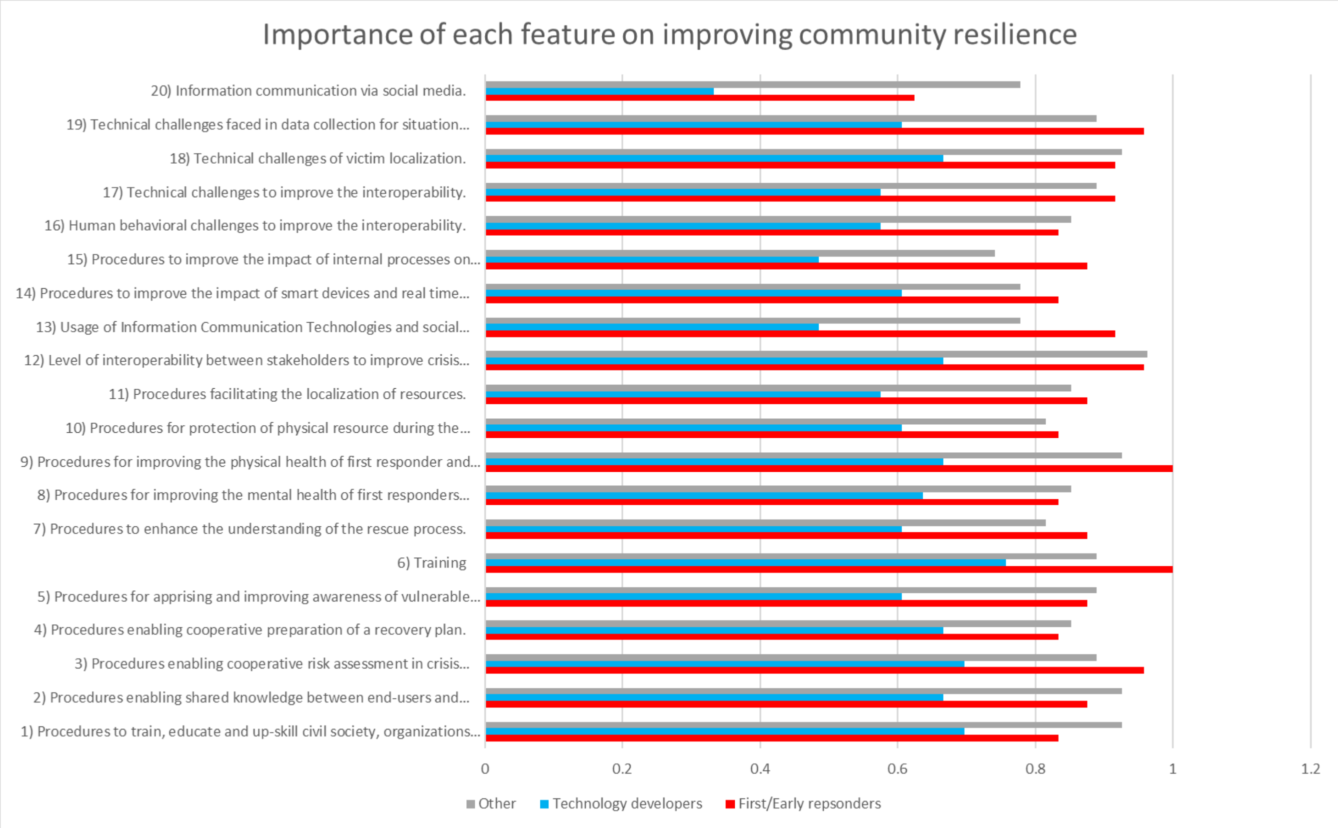


Figure 3-3: The normalized importance score of each studied feature on improving community resilience

Table 3-4, Table 3-5 and Table 3-6 show the top-5 most important features for each category of survey responders respectively:

Order	Feature
1	Procedures for improving the physical health of first responder and victims.
2	Training
3	Procedures enabling cooperative risk assessment in crisis management.
4	Level of interoperability between stakeholders to improve crisis management operation.
5	Technical challenges faced in data collection for situation awareness and risk assessment.

Table 3-4: Top 5 important features for the category - First and early (F/E) responders

Order	Feature
1	Training
2	Procedures to train, educate and up-skill civil society, organisations and local communities about the rescue process.
3	Procedures enabling cooperative risk assessment in crisis management
4	Procedures for improving the physical health of first responder and victims.
5	Procedures enabling shared knowledge between end-users and civil society, organisations and local communities.

Table 3-5: Top 5 important features for the category - Technology developer

Order	Feature
1	Level of interoperability between stakeholders to improve crisis management operation.
2	Technical challenges of victim localization.
3	Procedures to train, educate and up-skill civil society, organisations and local communities about the rescue process.
4	Procedures enabling shared knowledge between end-users and civil society, organisations and local communities.
5	Procedures for improving the physical health of first responder and victims.

Table 3-6: Top 5 important features for the category - Other

As outlined in the above three tables, the list of the five most important features for the three categories of responders has common features. Table 3-7 shows the similarities and differences on the raking of different category of responders by color-matching.

Order	1	2	3	4	5
First and early responder	Procedures for improving the physical health of first responder and victims.	Training	Procedures enabling cooperative risk assessment in crisis management.	Level of interoperability between stakeholders to improve crisis management operation.	Technical challenges faced in data collection for situation awareness

					and risk assessment.
Technology developer	Training	Procedures to train, educate and up-skill civil society, organisations and local communities about the rescue process.	Procedures enabling cooperative risk assessment in crisis management.	Procedures for improving the physical health of first responder and victims.	Procedures enabling shared knowledge between end-users and civil society, organisations and local communities.
Others	Level of interoperability between stakeholders to improve crisis management operation.	Technical challenges of victim localization.	Procedures to train, educate and up-skill civil society, organisations and local communities about the rescue process.	Procedures enabling shared knowledge between end-users and civil society, organisations and local communities.	Procedures for improving the physical health of first responder and victims.

Table 3-7: Top 5 important features for the different categories of survey responders

The identification of the similarities and dissimilarities of the features appearing from the list of the different responders allowed to focus on the shared important features and on the differences. As most of the questions on the survey concern the first and early (F/E) responders and technology developers, we focused mainly on these two categories, but also considered interesting feedback provided by others. *The intent is to highlight primarily from the F/E responders aspect (as they are the 'community' of our interest) and secondarily form the technology developer and others issues that are deemed as top priority by the different categories of responders.*

First, we present the feedback obtained on the top-5 features appearing on the list of the F/E responders. For each feature/procedure, a variety of options have been provided as activities to improve the target feature. We asked the survey responders to identify the level of implementation of each activity within their organisations. The "*Procedures for improving the physical health of first responder and victims*" has been ranked as the most important feature for the F/E responder organisations.

As shown in Figure 3-4, 50% of this category of responders stated that "*the usage of new technologies to identify the risk and avoid dangers (including real time awareness)*" as an activity / process not commenced / undertaken but needed. Also, around 40% stated that "the risk identification and dangers avoidance using telematic or direct communication", "the usage of new technologies to identify the risk and avoid dangers (including real time awareness)" and the "monitoring, recognition and management of physical heath of first responders" are needed and undertaken activities.

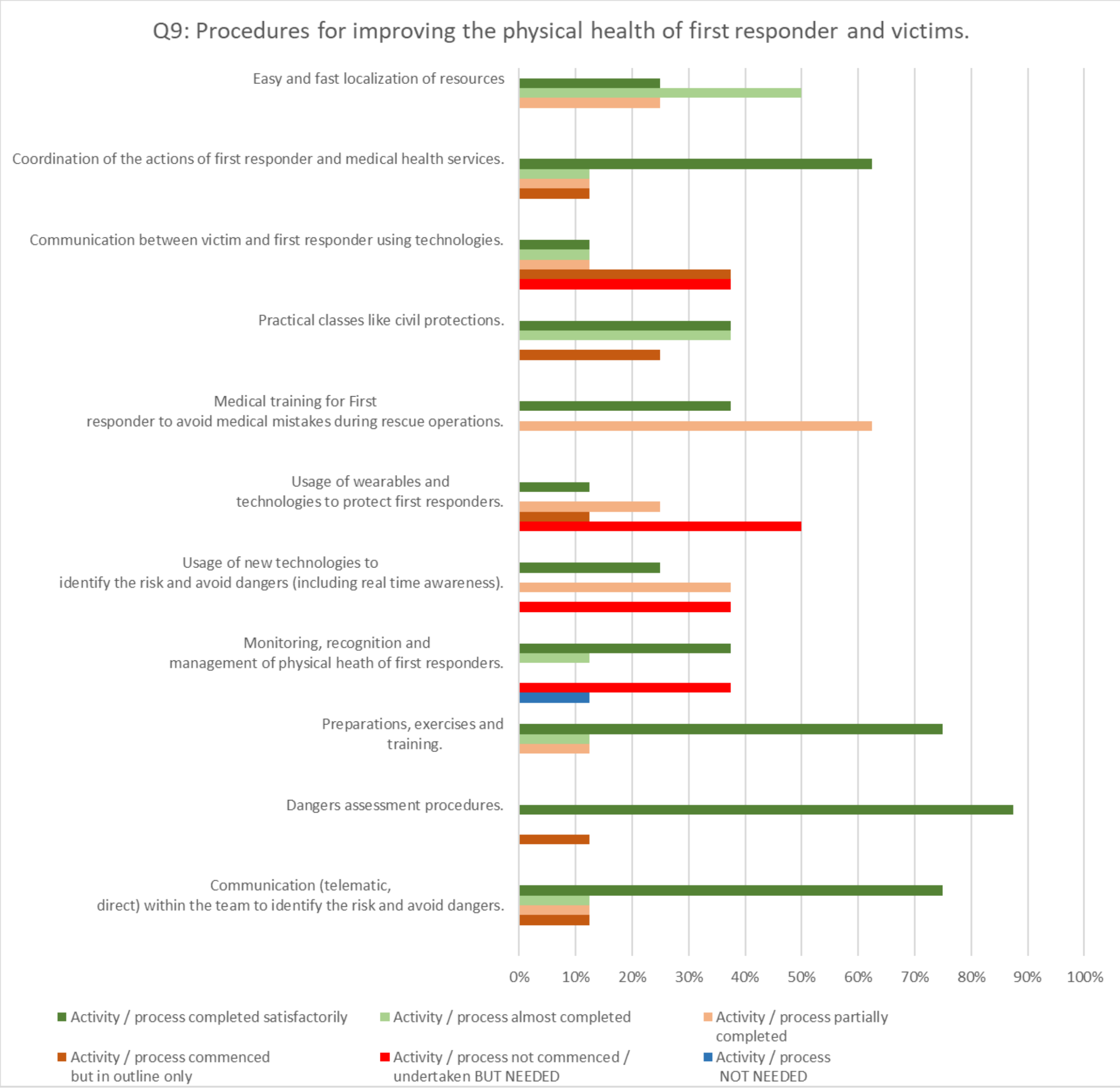


Figure 3-4: Level of implementation of activities related to the "Procedures for improving the physical health of first responder and victims" within F/E responders' organisations

As open suggestions to improve this feature, F/E responders' organisations suggest endowing professionals with latest wearable and portable technologies to improve their security. Also, they highlighted the need to improve the coordination and communication between different stakeholders.

Training has been ranked by first and early responders' organisations as second most important procedure for improving community resilience. The survey investigated the needed and implemented types of trainings. **Error! Reference source not found.** illustrates the collected results from F/E responders. It is clear that the majority of needed trainings are implemented in most of F/E responders' organisations. However, the "***Training of end-user about interaction with people with specific disability***" is implemented in only 50% of this category of organisations but needed in more than 60%. Which means that this type of training is still needed for some F/E responders' organisations.

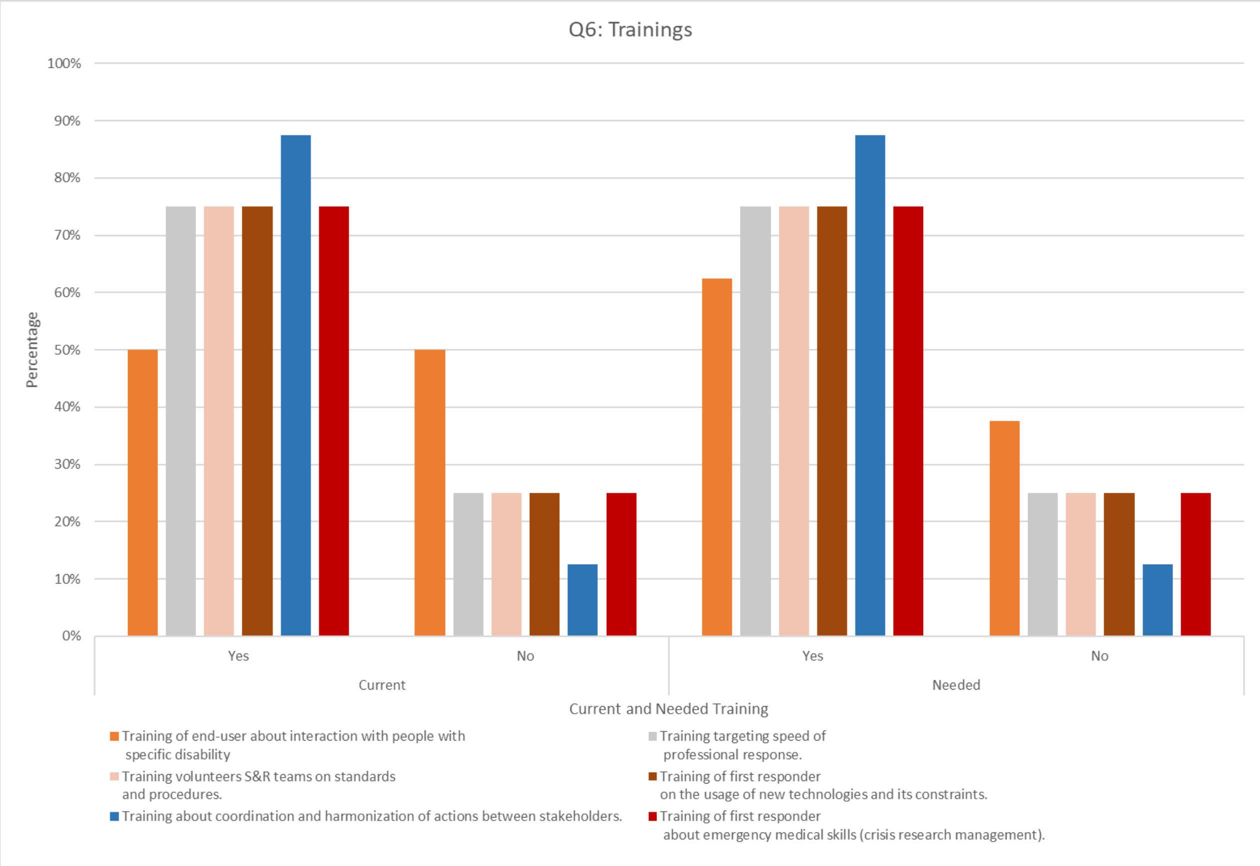


Figure 3-5: Needed and implemented trainings in the F/E responders' organisations

To improve training, F/E responders suggested including the learning of emergency procedures for **Chemical, Biological, Radiological and Nuclear (CBRN)** risks. They also underlined the difficulties they are facing to perform practical training due to the COVID-19 situation.

Concerning the procedures enabling cooperative risk assessment, the majority of F/E responders' organisations are satisfied with the implemented activities for cooperative risk identification and cooperative risk assessment via a series of meetings as it may be inferred from the results presented in **Error! Reference source not found.**.

However, more than 20% of this category of organisations described the activities of cooperative risk identification and assessment (via **meetings or gamification**) as a needed and undertaken activity. Accordingly, these activities need to be implemented in some organisations in order to improve community resilience.

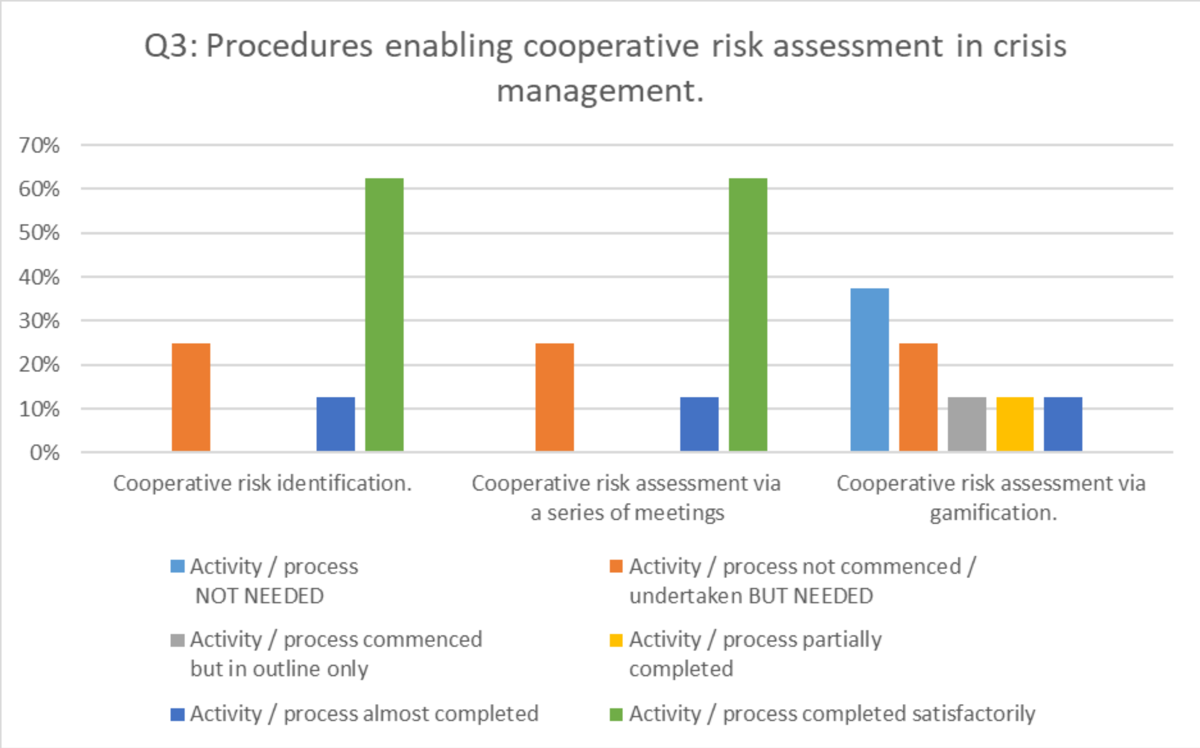


Figure 3-6: Level of implementation of procedures enabling cooperative risk assessment in crisis management (F/E responders' organisations)

To improve the cooperative risk assessment the first and early responders' organisations suggested increasing **the level of involvement of certified local volunteer teams** that can support SAR operations. Moreover, they pointed out that **public administrations need to improve their awareness** and take into account the **cooperation with civil authorities and local communities**.

The F/E responders' organisations have attributed high importance score to the "*Level of interoperability between stakeholders to improve crisis management".*

The collected results presented in **Error! Reference source not found.** illustrate that most of these organisations are satisfied with the implanted strategic and tactical levels of interoperability between crisis management stakeholders.

50% are satisfied with the relevant administrative level. In addition, more than 10% considered tactical and strategic level as a needed but not undertaken activity and more than 20% considered activities performed in administrative level as a partially completed.

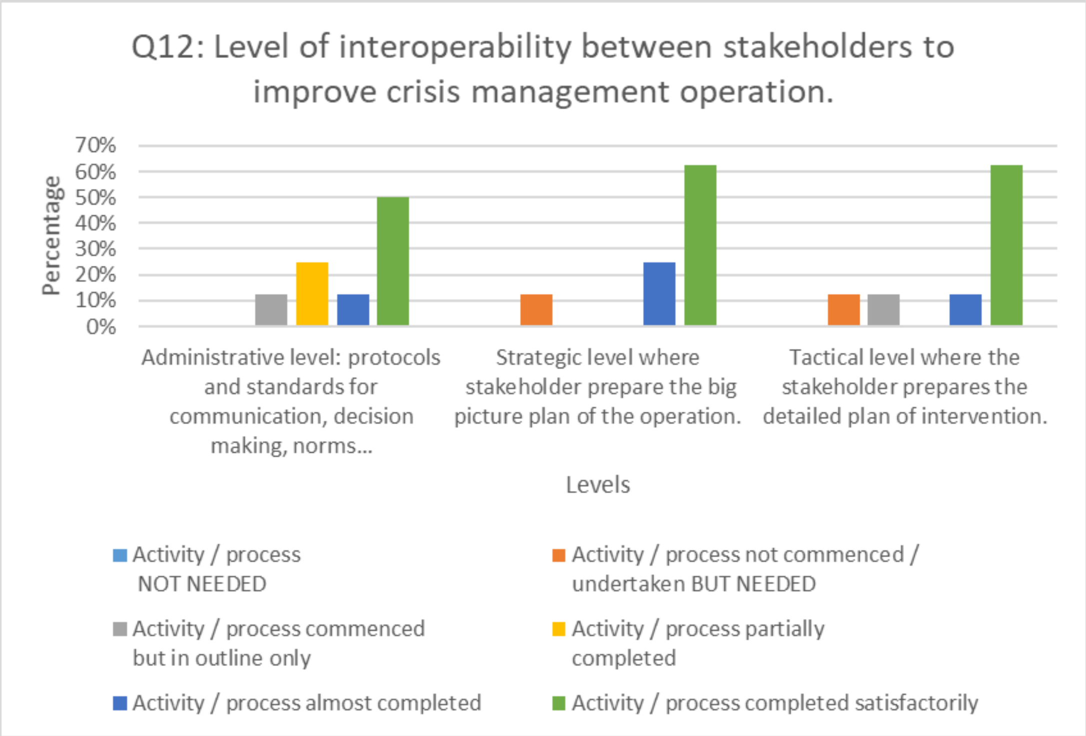


Figure 3-7: Implementation of level of interoperability between stakeholders (F/E responders' organisations)

To enhance the level of interoperability, first and early responders' organisations proposed to **organise joint trainings** between stakeholders to secure the plans and procedures. Furthermore, they suggested to **use the same channels of communications** between different stakeholders and to **use common protocols** defining the relevant competencies.

Regarding the **technical challenges** faced in data collection for situation awareness and risk assessment, the survey inspects the main possible challenges faced by different organisations. For F/E responders' organisations the challenges are presented in **Error! Reference source not found.**. The results show that 87.5% of these organisations face a variety of challenges related to data collection which are:

- Limitation of sensory and equipment efficiency/resilience (false positive, loss of connectivity...) due to environment conditions (temperature, wind, dust, obstacles...)
- Analysis of collected data for risk assessment.
- Integration of collected data.
- Access to full coverage communication resources.
- Financial cost of supporting software.
- Delay of real time information.

Also, 75% of these organisations face challenges in "*Financial cost of used equipment*" and "*Expensive cost of alternative communication technologies.*"

For data collection, F/E responders' organisations stated that they face an additional challenge which concerns the medical record and the way to make it useful for the professionals in their environment. Moreover, they proposed to upload all clinical data collected from the victim to the medical records.

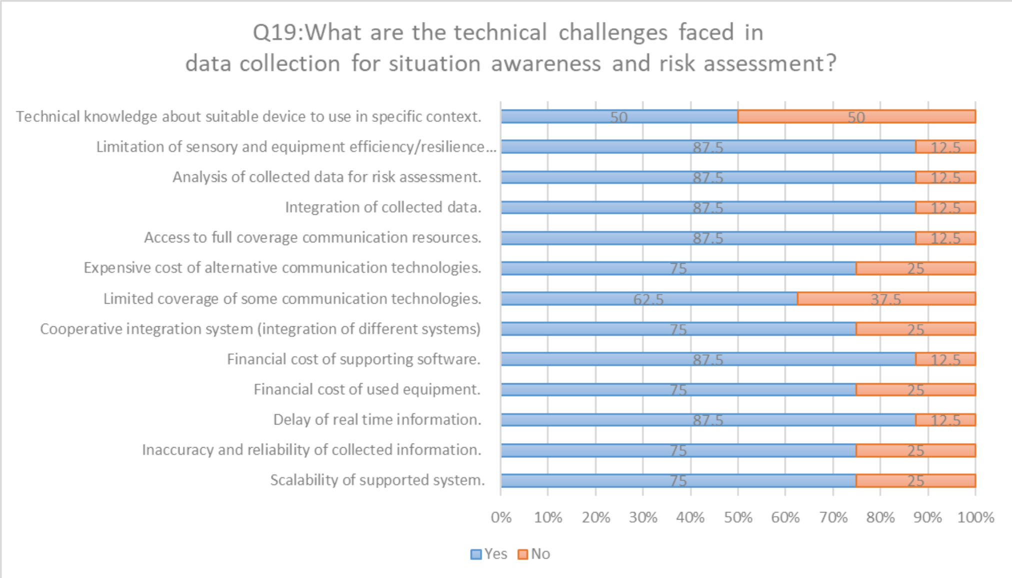


Figure 3-8: Technical challenges faced in data collection for situation awareness and risk assessment (first and early responders' organisations)

In relation to the challenges faced in data collection from the point of view of the technology developers, **Error! Reference source not found.** shows the respective results.

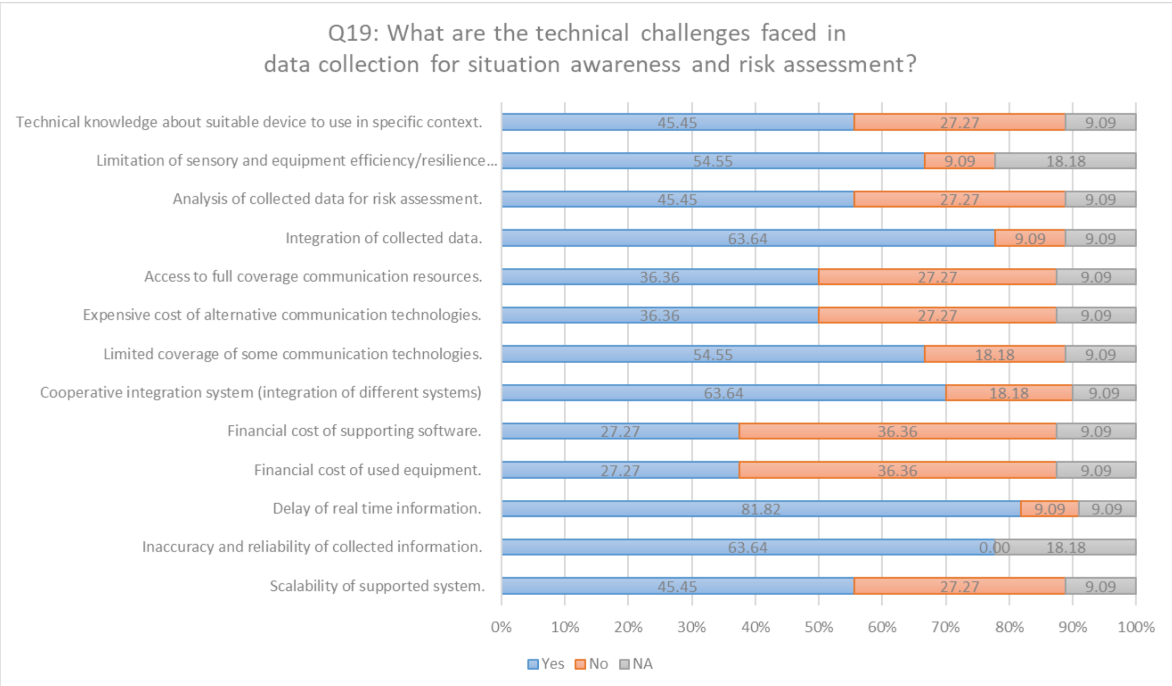


Figure 3-9: Technical challenges faced in data collection for situation awareness and risk assessment (Technology developers)

The challenge most faced is the **delay of real time information**. Also, an additional challenge that has been highlighted by this category for responders concerns **the accuracy and reliability of collected information**.

To improve data collection, technology developers suggested to do **trials of developed technology in various environmental conditions** and/or to **develop algorithms that can detect malfunctioning in data collection**.

Besides the similarity in the most important features to improve community resilience, the differences in features in the importance list between the categories of responders have also been studied. Next, we present and interpret the answers of F/E responders regarding the features appearing in the five most important features in technology developer and/or others and which does not appear on the top-5 list of the F/E responders.

First, the "*procedures to train, educate and up-skill civil society, organisations and local communities about the rescue process*" appeared on both the list of technology developer and others. The results presented in

Figure 3-10 shows that more than 60% of F/E responders' organisations are satisfied with theoretical and practical training used for the education of rescue process. 50% of these organisations say that "*a **cooperative platform for the analysis of lessons learned** from the past experience of different entities involved in crisis management*" is a non-commenced process that is undertaken but it is needed within their organisations. Furthermore, around 40% of these organisations stated that the use of an online platform for theoretical training and the use of a cooperative platform to organise regular practical drills are both needed and undertaken activities. In this respect, the portfolio of solutions dashboard developed in EU H2020 project DRIVER+ (https://pos.driver-project.eu/en) may constitute a useful resource.

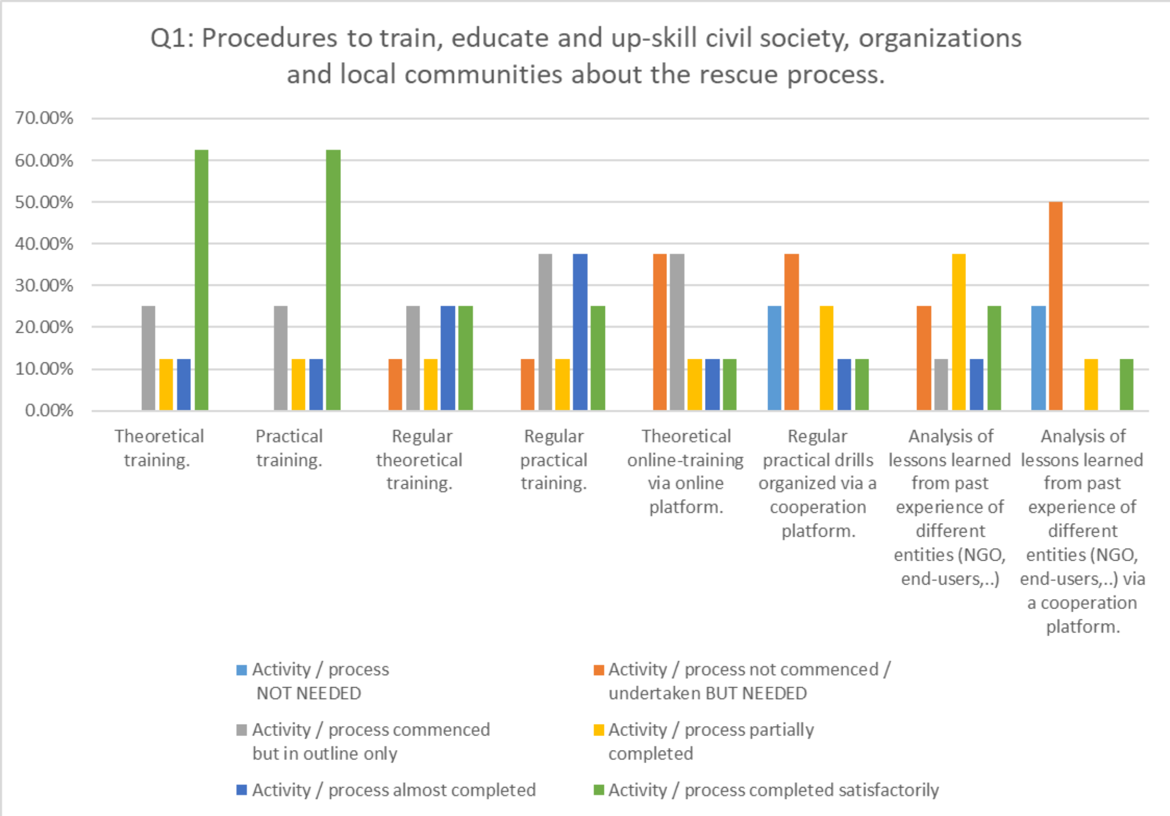


Figure 3-10: Level of implementation of procedures to train, educate and up-skill civil society, organisations and local communities about the rescue process (F/E responders' organisations)

Second, from the feedback reported in

Figure 3-11: **,** for the feature concerning the "*Procedures enabling shared knowledge between end-users and civil society, organisations and local communities*" which also appeared on both the list of technology developer and others (not a top-5 priority reported from F/E responders), we may notice that in 10% of F/E responder's organisations, the regularity of meetings dedicated for sharing knowledge is a not undertaken but a needed activity. Also, 25% of these organisations claimed that the cooperative programs and internationalization are partially completed activities.

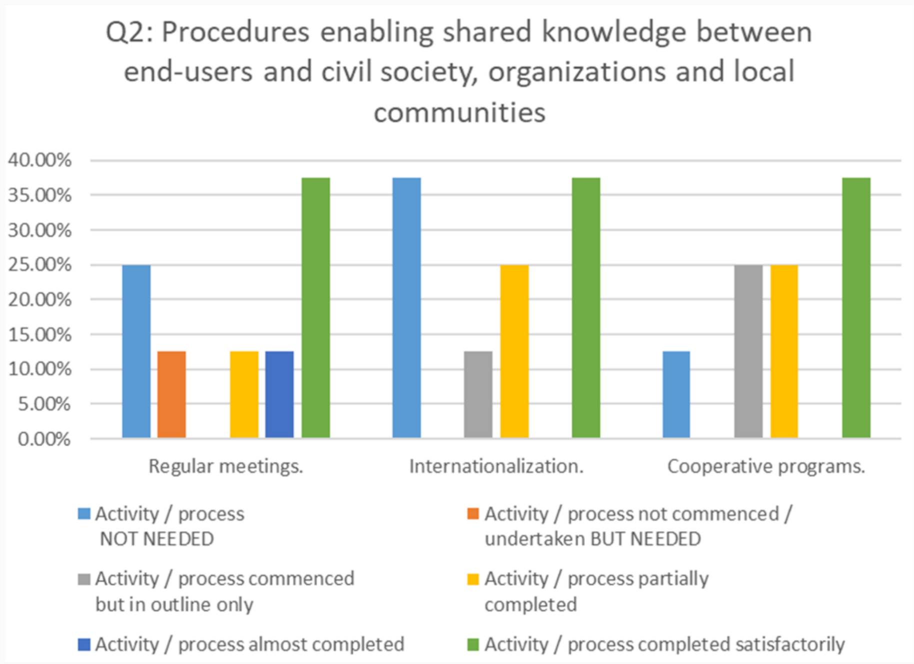


Figure 3-11: Level of implementation of procedures enabling shared knowledge between end-users and civil society, organisations and local communities (F/E responders' organisations)

Finally, the feature concerning "technical challenges faced in victim's localization" appears only in the list of the last category of responders (i.e. Others). The results collected from first and early responders and from technology developers are presented in **Error! Reference source not found.** and **Error! Reference source not found.** respectively.

As shown in **Error! Reference source not found.**, 75% of F/E responders' organisations face challenges related to victim localization which are:

- Access to full coverage communication resources.
- Cooperative localization of victims (integration of different systems).
- Financial cost supported software.
- Real time information (Speed of localization).
- Inaccuracy and reliability of collected information.

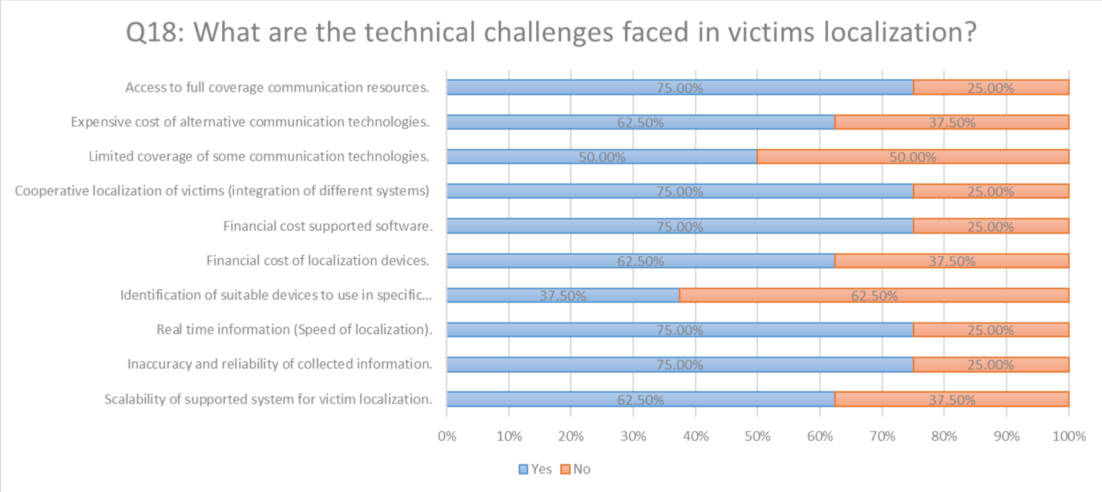


Figure 3-12: Technical challenges faced in victim's localization (F/E responders' organisations)

An additional challenge highlighted by technology developers that can be inferred from **Error! Reference source not found.** is the **ability to identify suitable devices to use in specific context**. Moreover, in order to provide a better victim localization system, the technology developers also suggested to do **trials of developed technology in various environmental conditions** and/or to develop **algorithms that can detect malfunctioning of victim localization**. Besides, they suggested reporting the last accurate known position.

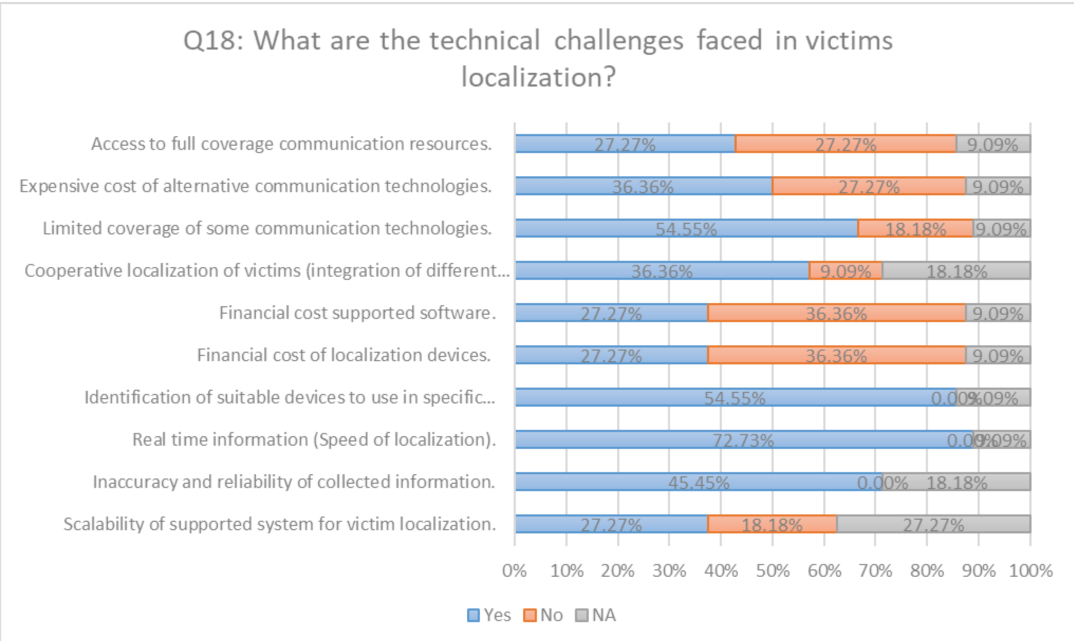


Figure 3-13: Technical challenges faced in victim's localization (Technology developers)

To summarize the previous as well as the other findings from the survey results, we presented in Table 3-8 the main GAP survey results and the respective key findings.

<table>
<tr><th>Result</th><th>Finding</th></tr>
<tr><td>50% of the first and early responder organisations stated “the usage of new technologies to identify the risk and avoid dangers (including real time awareness)” as an Activity / process not commenced / undertaken but needed</td><td>The usage of new technologies to identify the risk and avoid dangers is very important activities that need to be exploited to improve the physical health of first responders and victims. These procedures could be improved in term of:
• Usage of wearables and technologies to protect first responders.
• Monitoring, recognition, and management of physical heath of first responders.
• Usage of new technologies to identify the risk and avoid dangers (including real time awareness).</td></tr>
<tr><td>10% of the first and early responder organisations stated “the Training about interaction with people with specific disabilities” as an Activity / process not commenced / undertaken but needed.</td><td>In some first and early responder organisations, training needs to be improved in term of:
• Training about interaction with people with specific disabilities.
• Learning emergency procedures for chemical, biological, radiological, and nuclear risks.</td></tr>
<tr><td>More than 20% of first and early responders’ organisations described the activities of cooperative risk identification and assessment (via meetings or gamification) as a needed and undertaken activities.</td><td>The cooperative risk identification and assessment via meetings or gamification are activities that need to be implemented in some first and early responders’ organisations.
In addition, the increase of the level of involvement of certified local volunteer teams that can support SAR operations can helps the cooperative risk identification and assessment.</td></tr>
<tr><td>10% of first and early responders’ organisations considered tactical and strategic level as needed and undertaken activities and more the 20% considered administrative level as a partially completed activity.</td><td>Level of interoperability need to be improved in term of:
• Administrative level: protocols and standards for communication, decision making, norms…
• Joint training between stakeholders to secure the plans and procedures.</td></tr>
</table>

87.5% of first and early responders' organisations face a variety of challenges related to data collection including the analysis of collected data. Whereas around 50% of technology developers do not face this challenge.	Trial of developed technology in various environmental conditions and/or development of algorithms that can detect malfunctioning could improve the data collection for risk assessment. Also, based on technology developer's opinion, the analysis of collected data for risk assessment is a challenge that could be overcome.
Software simulations of the procedures in the expected environments and situations is an undertaken and needed activity in 87.5% of the first and early responder's organisations	Software simulations of the procedures could be an efficient procedure to enhance the understanding of the rescue process.
Mental health training is a needed and undertaken activity in 50% of first and early responder's organisations.	Some first and early responder's organisations need to include mental health trainings to improve mental health of first responders.
Use of sensory technologies during the discovery phase (for risk assessment) and before intervention is undertaken and needed in 50% of the first and early responders' organisations	More sensory technologies could be exploited to enhance discovery phase.
For more than 60% of first and early responders' organisations the most faced interoperability human behavioural challenge is the coordination of action plan of involved stakeholders.	To overcome this challenge, the first and early responders' organisations suggest organising joint unified training. Also, they propose to implement interoperability among several devices and software since each organisation has different technology. Moreover, they propound the multi-operability of device (same devices for several purposes).
All the first and early responders' organisations agree that interoperability and compatibility of different systems used within involved entities is a challenge that needs to be addressed to improve technical interoperability.	A solution that allows the interoperability and compatibility of different systems will improve needed technical interoperability. As suggestions, first and early responders' organisations propose to use the same communication codes.

Table 3-8: Main GAP survey results and the respective key findings

To avoid overloading this report with details, we presented the rest of the results of the survey from the point of view of F/E responders in the Annex V (Table 3-13). The annex also provides the results related to technical challenges from the point of view of technologies developers (Table 3-14).

3.4 Workshop validation/refinement of results and recommendations

During the workshop, some experts highlighted the importance of the learning from past experiences of different entities involved in crisis management, specifically lessons learned from the COVID-19 crisis. These feedbacks also underscore that COVID-19 crisis effects on interoperability could also be discussed further with first responders' organisations.

The workshop (WS) "End-user requirements and beyond" was organised on April 14th, 2021 with the participation of both internal and external to the SnR Consortium partners. The WS reached a peak participation of 305 experts, including several non-EU (e.g. from the Philippines, Japan) provided the opportunity to refine the GAP analysis results and receive recommendations on it, under the Session III – Gap Analysis for community resilience. It also served as means of verification and validation of the approach undertaken in a dedicated Session III that included presentations of the approach (PHASE A and PHASE B), findings and recommendations from the FG discussion and a presentation of the major findings form the GAP survey obtained feedback. A roundtable interactive discussion with the participation of key external experts leading the European Conference of Transport Institutions (ECTRI) Thematic Group on Security & Resilience that also allowed for interventions and questions from all participating experts, including first and early responders further discussed and commented on the presentations and the findings. The workshop presentations and relevant discussion have been uploaded on the SnR website.

The discussion that arose, took place primarily within the context of 4 major questions that were asked. The questions and a summary of the relevant comments and suggestions are provided in Table 3-9.

Major issues addressed in the roundtable discussion and relevant comments /suggestions
Question 1: What are the major advantages/potential improvements of the proposed approach?
Main comments/suggestions: - The method received positive comment in relation to its potential to address gaps in building common concepts. - A question was asked to understand how the GAP survey answers reflected the recent COVID-19 experience. The answer was that although no question addressed explicitly the COVID-19 experience, nevertheless, the survey was run almost after being more than a year within the COVID-19 crisis, and therefore, one may assume that the feedback obtained from the survey responses, especially in relation to the interoperability on the field, should also reflect first / early responder relevant experience, even though only implicitly. GAP survey feedback nevertheless included issues affected by COVID-19 such as the inability or increased difficulty to participate in physical events such as trainings. It was recognized that this is an important thing to keep in mind for future adaptations. - The top-down-bottom-up approach received praise in its ability to bring a holistic view to the collective knowledge by shedding light into spots that otherwise would remain in 'silos' while covering for contextual and local perspectives and parties involved.

<table>
<tr><td colspan="2">Advantages that this method offers and drawbacks or areas for potential improvement were also summarized. These are presented below.</td></tr>
<tr><td>Advantages
✓ Stakeholder-oriented participatory approach that breaks ‘silo’- thinking.
✓ Actively engages stakeholders/end-users in the formulation of a common understanding of essential principles and concepts.
✓ Easily adaptable under different context and audience. This potential also extends to the use of different participatory methods for consensus-building (e.g. Delphi, NGT, Stakeholder analysis).
✓ Allows integration of quantitative methods (e.g. multi-criteria analysis, vulnerability, risk analysis). Creative thinking is also encouraged.
✓ Top-down & bottom-up approach.
✓ Facilitates and enhances positive communication between concerned stakeholders and parties.
✓ Established based on widely accepted research and participatory methods → positively valued when considering the ‘community’/social component.</td><td>Drawbacks / areas for improvement
✓ Time-expensive approach requiring expert commitment.
✓ Requires experience in moderating stakeholder / focus group meetings and good prior preparation for these.</td></tr>
<tr><td colspan="2">Question 2: How to best integrate the survey feedback and relevant recommendations (including those provided in the WS) into the SnR technical and operational development?</td></tr>
<tr><td colspan="2">Main comments/suggestions:
The proposed approach for best integrating the GAP analysis based on the processing of the feedback was:
a. Present the prioritization of the issues so that the different categories of respondents may refer to for considering their importance in the development of the technologies / wearables and the operationalization of the UCs.
b. Based on the relevant prioritization, interested parties should consider the maturity reported by first / early responders to the issue and the suggestions and recommendation for bridging the reported gaps as high-level directions for guiding their research.
c. Error! Reference source not found. in the Conclusions and Recommendations section provides a schematic representation of the aforementioned as these are suggested for the project and reflected in this report.</td></tr>
<tr><td colspan="2">Question 3: How could the proposed approach be linked with evaluations/measurements of resilience?</td></tr>
<tr><td colspan="2">Main comments/suggestions:
a. It is important to understand how ‘resilience’ is defined and measured. Recent approaches, similarly to the approach undertaken herein, link resilience with relevant attributes/capacities. Such is the approach also undertaken in the EU-funded H2020 project EU-CIRCLE [97] where indicators where defined for these attributes/capacities.
b. Several experts agreed that defining such indicators to the defined ‘resilience’ attributes/capacities was a commendable approach as it offers the advantage to both consider different dimensions of resilience (e.g. psychological) according to the scope of</td></tr>
</table>

the project and be also possibly combined into a composite 'overall' resilience index or reflect separately the different attributes. c. Building and sharing a common understanding of the context and the scope of the project is very important. d. It was clarified as answer to a relevant question that was asked that developing or producing specific measurements of resilience was out of the scope of the SnR project.
Question 4: Which resilience assessment/management framework/model do you know/recommend to be most suitable for integrating the proposed approach?
Main comments/suggestions: Based on the comments that arose from the previous question, the suggested direction was to consider 'resilience' models that relied on participatory approaches and that can be customized to contextual 'resilience' indicators. Frameworks as the ones proposed from projects EU-CIRLCE [97], IMPROVER [98] and the CoBRA framework by the United Nations Disaster Protection Office (UNDP) [99] were mentioned to be along this line of thought.

Table 3-9: Main points of the roundtable discussion

3.5 Conclusions and recommendations

A methodological approach has been presented for identifying gaps, challenges and needs in building 'community resilience' for the 'community' of our interest, i.e. F/E responders. It has been presented in two major Phases, A and B, in a top-down and bottom-up approach that allowed:

- Building a common understanding of the key terminology, highly debated in the scientific literature, among consortium partners;
- Prioritizing important issues and features to be addressed for the development of S&R technology/wearables and the operationalization of UCs.
- Providing high-level guidance for the aforementioned.

The results, feedback obtained and relevant suggestions / recommendations have been extensively discussed and summarized in the previous sections and we need not reinstate these here. Nevertheless, we aim at concluding by providing additional suggestion in how to proceed with the documented findings for the continuation of the SnR project.

Therefore, in order to make best use of the approach undertaken in this report for the development of the technologies / wearables and the design / operationalization of the UCs, it is recommended that the concerned partners use the prioritization that resulted from the GAP analysis and feedback processing in order to identify the most pertinent issues for their scope. The gaps, needs and suggestions and the recommendations on the selected ranked issues will provide further insight on potential solutions and issues to consider during the course of the design / development and operationalization. **Error! Reference source not found.** provides schematically the aforementioned.

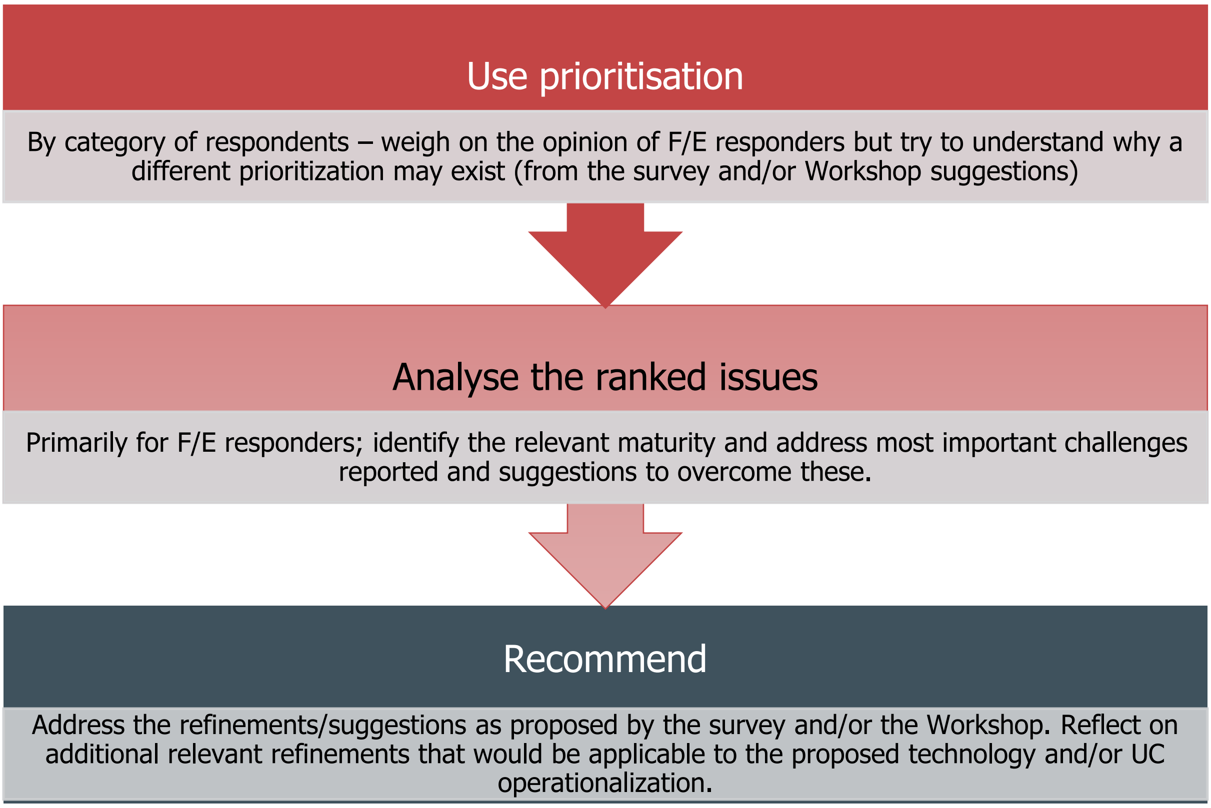


Figure 3-14: Schematic recommendation on how to proceed and best use the findings

4 Conclusions and final proposals

The conclusions and proposals presented in this section of deliverable D1.6 refer to the current state of the process of defining end-user requirements for chemical sensors (Six Gas HAZMAT monitor with VOC Detection and RESCUE MIMS (wear First Responders uniform, in hand, as backpack or on the platform of a RESCUE ROBOT) as foreseen by the SnR project in WP1 (First responders Requirements and Governance model) at T1.2 (End User Requirements for SAR equipment and tools) and the results obtained so far in the scientific research activity of the prototypes referred to.

This activity, completed in M12, included the study of equipment and technologies already on the market, a multitude of technical meetings and coordination between the partners of the R&D project, the organisation of a workshop ("End-user requirements and Beyond "of April 14 ,21), and a permanent online exchange of ideas and possible technical and operational solutions necessary to achieve the purpose and objectives mentioned in deliverable D1.6, as a continuation of the achievements mentioned in deliverable D1.2 (M4).

The fundamental conclusion of this deliverable, complemented by a series of partial conclusions specific to each subchapter, is that the minimum technical and operational characteristics proposed by end users in D1.6, but also the continuation of those proposed in D1.2, constitute a solid working basis. and complete for scientific research and, in the future, testing and validation within 7 UCs (User Cases) of the SnR project of the prototypes of equipment proposed to be realized.

A concrete example in favor of this fundamental conclusion is already the future optimization proposals, within the SnR project, mentioned in subchapter 8.2 " Proposals for optimization of a future version of RESCUE-MIMS (TRL 7-9)" of the deliverable 5.1 "Design & development of the RESCUE MIMS".

In this context, the end-users' proposal is that, together with the partners in the SnR project, they should continue their efforts to achieve the equipment and technologies referred to in T1.2 in deliverables D1.2 and D1.6, in particular due to the fact that there are chances reasonable to obtain a higher added value than initially forecast.

Another conclusion concerns the issue of gap analysis for resilience of the community, the results of which help end users to ensure a managerial act in crisis situations that takes into account the development gaps between local communities of their critical infrastructure, so as to ensure optimal use of equipment and technologies used in rescuing people trapped under the rubble.

This conclusion, discussed and summarized in detail in Chapter 3 "GAP analysis for community resilience" of deliverable D1.6, concludes with the recommendation that SnR project partners use the prioritization resulting from the analysis (see subchapter 3.5 "Conclusions and recommendations", figure 3-14) and GAP processing feedback to identify the most relevant issues for their scope.

It is recommended that the concerned partners use the prioritization that resulted from the GAP analysis and feedback processing in order to identify the most pertinent issues for their scope.

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Annex II: PHASE A: preliminary GAP survey structure

Focus Domain / Area	Attribute / Capacity	Current State	Desired State (=Goal)	Needs (= objectives for desired goals)	Compliance/ Condition Status (1=poor; 4=v.good)	Identified Gaps	Importance / Priority (1=essential; 2=secondary; 3=auxiliary)	Comments / Notes	Proposed actions / solutions
A	Human / Behavioral								
A1. Knowledge, training and learning	1. S&R Training and human skills needed								
	2. Understanding/ knowledge of rescue processes								
	3. Awereness of / lessons from past disasters								
A2. Community empowerement and inclusiveness	1. Organization empowerement in S&R								
	2. Inclusiveness of vulnerable populations								
A3. Societal capacity	1. Connectivity and engagement with civil organisations and local communities								
	2. Networking through media channels								
A4. Health Services	1. Physical and/or mental health during S&R operations (either of first responders or of victims - please specify)								
B	Technological								

B1. Technology for effective disaster response	1. Detection, monitoring and reporting equipment								
	2. Compatibility & interoperability with other S&R actors								
	3. Use of open or other data-collection and sharing platforms								
B2. Use of drone technologies (if applicable)	1. Victim's localization, situation awareness and risk assessments								
B3. Communication & information sharing technologies	1. Appropriate communication infrastructure								
	2. Real time crisis information collection, sharing & reporting								
	3. Inter- and extra-organisational communication structure								
	4. Use of/ connection with early warning systems								
B4. First responder equipment	1. Use of smart devices to improve technical skills, cognitive capabilities and information sharing								
	2. Availability and access to appropriate equipment								
C	Organizational								
C1. Processes and procedures	1. Early action systems for expediting response/recovery								

	2. Processes standardization								
C2. Governance / Leadership / Institutional capacity	1. Effectiveness, efficiency, and capability to respond quickly								
	2. Capacity to deal with disaster and share/manage information								
C3. Resources / logistics	1. Resource availability and appropriate allocation								
	2. Sharing of risk management tools and standards								
C4. Contingency planning	1. Business continuity plans / disaster risk management plans								
C5. Coordination and collaboration	1. Interoganizational / cross-organisational (non-volunteer related)								
	2. Interaction with local community and / or volunteer emergency response & coordination teams / use of local knowledge								
D	Legal								
D1. Legislative / regulatory issues	1. Legal / regulatory relevant limitations								
	2. Legal / regulatory harmonization with other S&R actors or in foreign context.								

Table II-1: PHASE A preliminary structure for the GAP analysis survey

Annex III: PHASE B: Pre-Focus Group analysis: aggregated results

		End-user most relevant criteria for the purposes of the S&R project (selected based on the analyses reported in D1.1 and D1.2)						
		Technical information - related			Operational information - related		First Responder - related	
Focus Domain / Area	Attribute / Capacity (for Community resilience)	Ergonomy / Ergonomics	Sensitivity to environmental conditions	Size of impacted area/victims	Maneuverability	Interoperability / Compatibility	First Responder education and training	First Responder Safety
A	Human / Behavioral							
A1. Knowledge, training and learning	1. S&R Training and human skills needed	2	7	9	3	7	15	16
	2. Understanding/knowledge of rescue processes	1	4	8	5	9	18	13
	3. Awereness of / lessons from past disasters	4	11	11	3	3	19	14
A2. Community empowerement and inclusiveness	1. Organization empowerement in S&R	0	2	2	3	5	11	3
	2. Inclusiveness of vulnerable populations	4	4	9	3	5	9	4
A3. Societal capacity	1. Connectivity and engagement with civil organizations and local communities	4	6	6	2	11	10	4
	2. Networking through media channels	1	4	12	1	5	2	1
A4. Health Services	1. Physical and/or mental health during S&R operations (either of first responders or of victims - please specify)	6	2	2	2	0	8	16
B	Technological							
B1. Technology for effective disaster response	1. Detection, monitoring and reporting equipment	16	13	12	9	13	8	11
	2. Compatibility & interoperability with other S&R actors	6	2	5	5	19	6	10
	3. Use of open or other data-collection and sharing platforms	2	1	4	3	19	5	3
B2. Use of drone technologies (if applicable)	1. Victim's localization, situation awareness and risk assessments	7	9	15	9	8	11	9
B3. Communication & information sharing technologies	1. Appropriate communication infrastructure	3	4	6	8	16	5	6
	2. Real time crisis information collection, sharing & reporting	4	11	11	9	16	5	13
	3. Inter- and extra-organizational communication structure	0	3	4	4	16	1	6
	4. Use of/ connection with early warning systems	8	11	5	7	12	1	9
B4. First responder equipment	1. Use of smart devices to improve technical skills, cognitive capabilities and information sharing	16	5	4	10	11	16	11
	2. Availability and access to appropriate equipment	11	6	2	15	5	7	15
C	Organizational							
C1. Processes and procedures	1. Early action systems for expediting response/recovery	7	7	12	16	6	5	7
	2. Processes standardization	5	3	3	6	17	8	8
C2. Governance / Leadership / Institutional capacity	1. Effectiveness, efficiency, and capability to respond quickly	2	3	4	15	3	9	2
	2. Capacity to deal with disaster and share/manage information	0	6	11	8	12	14	4
C3. Resources / logistics	1. Resource availability and appropriate allocation	2	4	13	6	2	9	12
	2. Sharing of risk management tools and standards	1	1	1	4	12	8	7
C4. Contingency planning	1. Business continuity plans / disaster risk management plans	2	4	6	4	3	8	3
C5. Coordination and collaboration	1. Interoganizational / cross-organizational (non-volunteer related)	3	4	3	4	14	7	2
	2. Interaction with local community and / or volunteer emergency response & coordination teams / use of local knowledge	3	4	6	4	13	11	6
D	Legal							
D1. Legislative / regulatory issues	1. Legal / regulatory relevant limitations	0	1	4	2	8	3	2
	2. Legal / regulatory harmonization with other S&R actors or in foreign context.	0	3	2	6	15	4	3

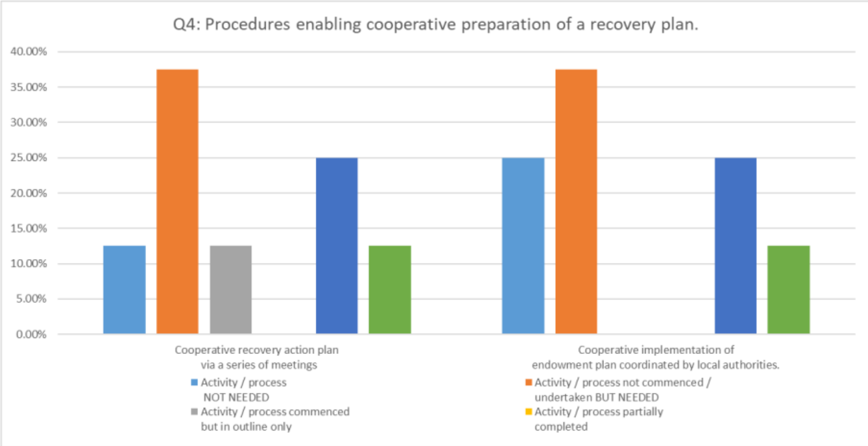
Table III- 1: PHASE B: Pre-Focus Group analysis: aggregated results

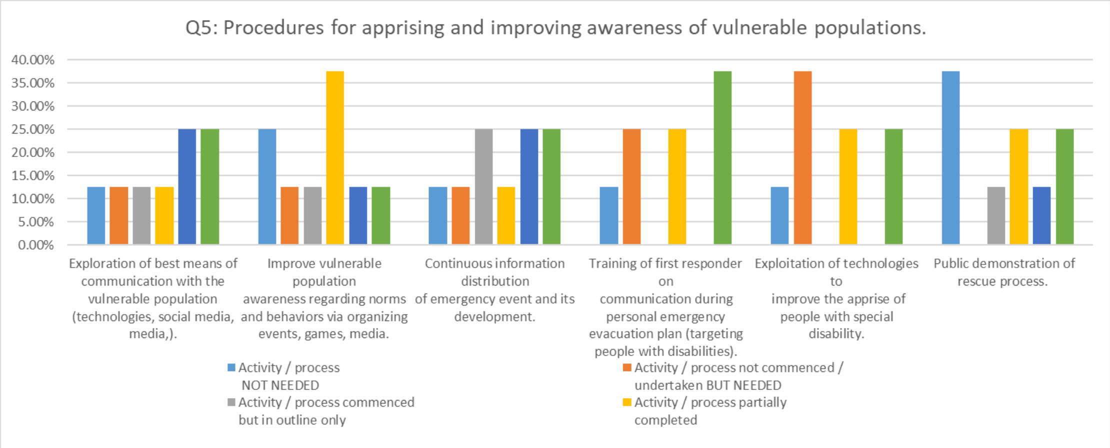
Annex IV: PHASE B: Pre-Focus Group analysis: first/early responder results

		End-user most relevant criteria for the purposes of the S&R project (selected based on the analyses reported in D1.1 and D1.2)						
		Technical information - related			Operational information - related		First Responder - related	
Focus Domain / Area	Attribute / Capacity (for Community resilience)	Ergonomy / Ergonomics	Sensitivity to environmental conditions	Size of impacted area/victims	Maneuverability	Interoperability / Compatibility	First Responder education and training	First Responder Safety
A	Human / Behavioral							
A1. Knowledge, training and learning	1. S&R Training and human skills needed	0	5	4	1	4	3	5
	2. Understanding/knowledge of rescue processes	0	1	1	2	5	6	2
	3. Awereness of / lessons from past disasters	0	5	4	1	1	6	3
A2. Community empowerement and inclusiveness	1. Organization empowerement in S&R	0	1	0	0	1	5	1
	2. Inclusiveness of vulnerable populations	1	1	5	1	4	5	4
A3. Societal capacity	1. Connectivity and engagement with civil organizations and local communities	3	4	2	1	5	1	1
	2. Networking through media channels	1	3	4	0	2	1	0
A4. Health Services	1. Physical and/or mental health during S&R operations (either of first responders or of victims - please specify)	2	1	1	0	0	4	5
B	Technological							
B1. Technology for effective disaster response	1. Detection, monitoring and reporting equipment	6	1	4	1	5	2	5
	2. Compatibility & interoperability with other S&R actors	4	1	1	2	6	1	4
	3. Use of open or other data-collection and sharing platforms	1	0	1	1	6	1	1
B2. Use of drone technologies (if applicable)	1. Victim's localization, situation awareness and risk assessments	1	2	6	1	1	5	2
B3. Communication & information sharing technologies	1. Appropriate communication infrastructure	2	1	1	2	5	4	1
	2. Real time crisis information collection, sharing & reporting	0	4	0	1	6	2	4
	3. Inter- and extra-organizational communication structure	0	1	0	1	6	0	1
	4. Use of/ connection with early warning systems	5	5	0	2	3	0	1
B4. First responder equipment	1. Use of smart devices to improve technical skills, cognitive capabilities and information sharing	6	2	1	5	1	4	1
	2. Availability and access to appropriate equipment	4	1	1	5	2	4	5
C	Organizational							
C1. Processes and procedures	1. Early action systems for expediting response/recovery	2	4	1	6	1	2	1
	2. Processes standardization	3	1	0	2	6	2	1
C2. Governance / Leadership / Institutional capacity	1. Effectiveness, efficiency, and capability to respond quickly	1	2	1	5	1	3	1
	2. Capacity to deal with disaster and share/manage information	0	2	2	2	6	6	1
C3. Resources / logistics	1. Resource availability and appropriate allocation	1	2	2	1	1	5	5
	2. Sharing of risk management tools and standards	1	1	0	2	5	1	2
C4. Contingency planning	1. Business continuity plans / disaster risk management plans	0	1	2	1	2	3	1
C5. Coordination and collaboration	1. Interoganizational / cross-organizational (non-volunteer related)	1	3	1	2	6	3	1
	2. Interaction with local community and / or volunteer emergency response & coordination teams / use of local knowledge	2	2	1	2	6	2	1
D	Legal							
D1. Legislative / regulatory issues	1. Legal / regulatory relevant limitations	0	1	3	0	1	1	1
	2. Legal / regulatory harmonization with other S&R actors or in foreign context.	0	2	0	1	5	1	1

Table IV-1: PHASE B: Pre-Focus Group analysis: first/early responder results

Annex V: Gap survey for community resilience in crisis management's results

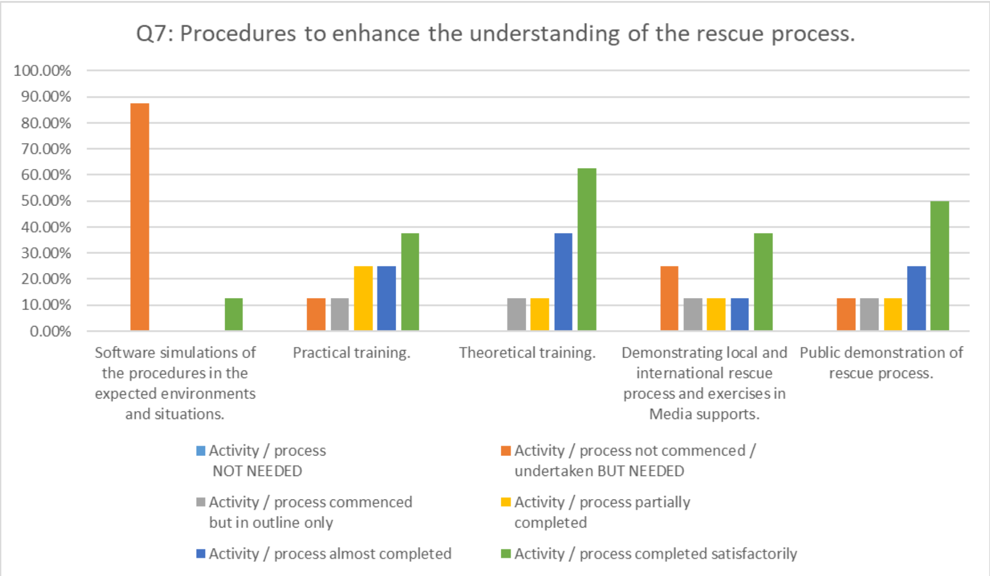
Question 4: Procedures enabling cooperative preparation of a recovery plan.	
 **Implemented and needed procedures enabling cooperative preparation of a recovery plan (F/E responders)**	
Suggestions	Increase the level of involvement of local volunteer teams and other local stakeholders.
	To improve the capacitation between stakeholders and institutions is needed. It is desirable or recommended taking into account this type of issues to improve the preparedness to establish meetings and endowment between all stakeholders.
Question 5: Procedures for apprising and improving awareness of vulnerable populations.	



Implemented and needed procedures for apprising and improving awareness of vulnerable populations (F/E responders)

Suggestions	Encourage contact between volunteer associations related to vulnerable people or with disabilities: violence against women, migrant population, extreme poverty, elderly.
	Train the teaching groups in charge of students of all ages and train them in those specific risks of the geographical place in which they live.
	Carry out analysis and training with each specific disability.

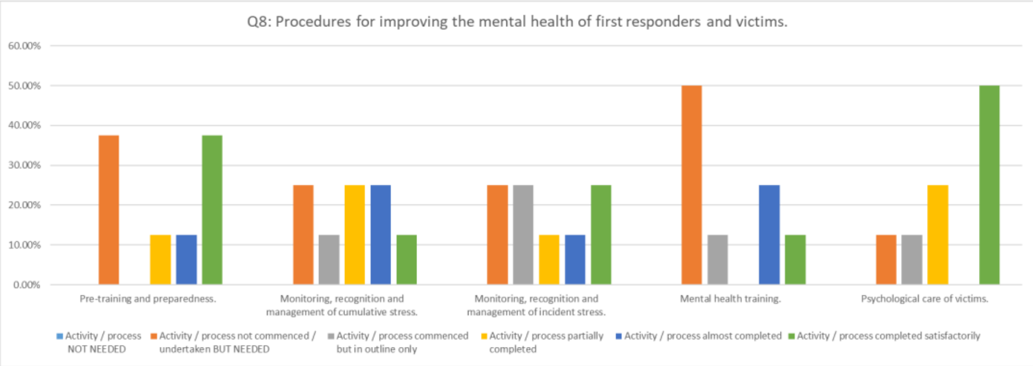
Question 7: Procedures to enhance the understanding of the rescue process.



Implemented and needed procedures to enhance the understanding of the rescue process (F/E responders)

Suggestions	Encourage the gamification, online simulation and improve the software and digital platforms.

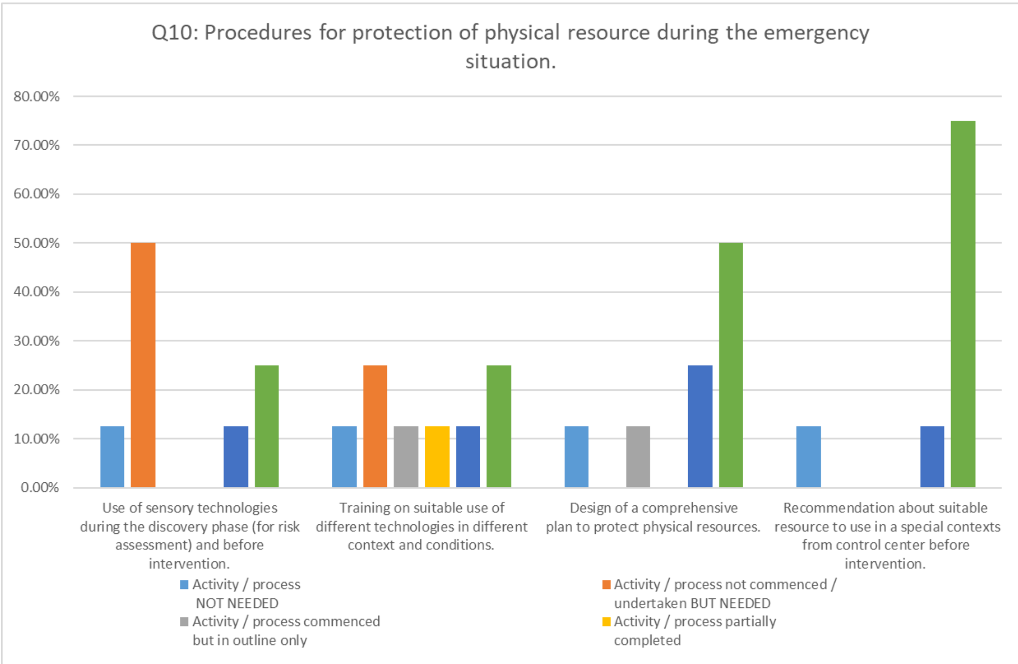
Question 8: Procedures for improving the mental health of first responders and victims.



Implemented and needed p Procedures for improving the mental health of first responders and victims (F/E responders)

Suggestions	Mental health monitoring campaigns by the work risk prevention service.
	Improving barriers against stress.

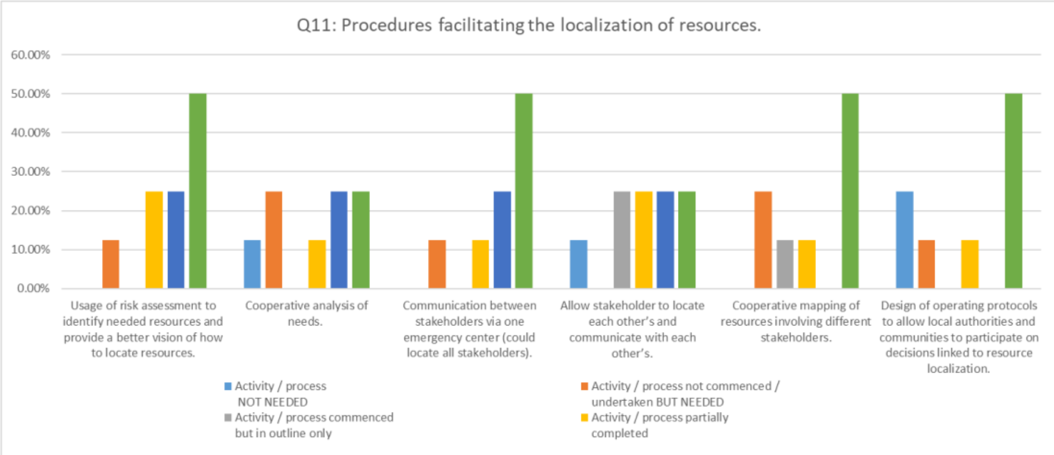
Question 10: Procedures for protection of physical resource during the emergency situation.



Implemented and needed procedures for protection of physical resource during the emergency situation (F/E responders)

Suggestions	Elaborate harmonized procedures with all the first responders and stakeholders.
	Risk assessment.

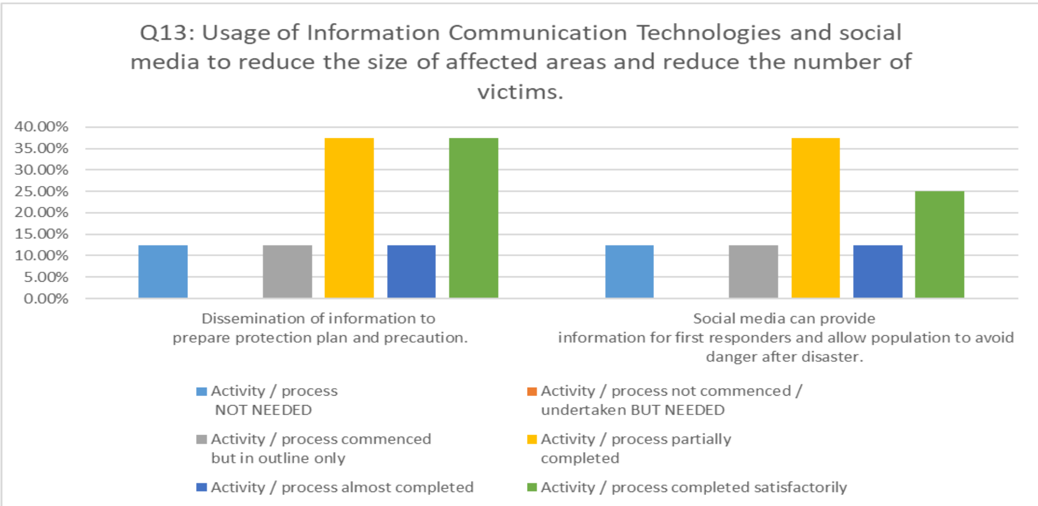
Question 11: Procedures facilitating the localization of resources.



Implemented and needed procedures facilitating the localization of resources (F/E responders)

Suggestions	Wearable technologies to locate the first responders during the rescue.

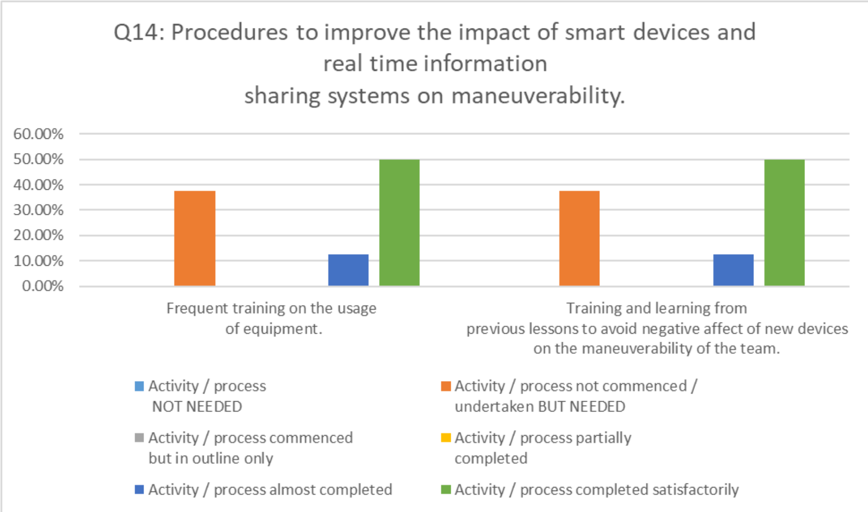
Question 13: Usage of Information Communication Technologies and social media to reduce the size of affected areas and reduce the number of victims.



Implemented and needed of ICT and social media to reduce the size of affected areas and reduce the number of victims (F/E responders)

Suggestions	Short messages deliver to mobile phones given instructions for precaution measures.
	Dedicated messages to be sent to mobile phone either via dedicated apps or reverse 112 for proactive measures.

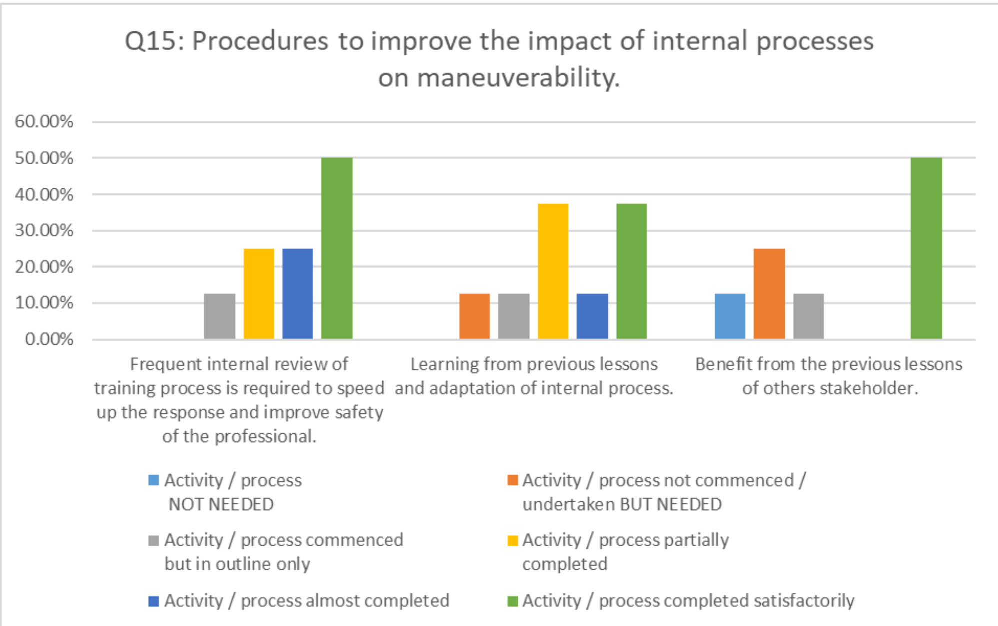
Question 14: Procedures to improve the impact of smart devices and real time information sharing systems on manoeuvrability.



Implemented and needed procedures to improve the impact of smart devices and real time information sharing systems on maneuverability (F/E responders)

Suggestions	It is important not only to introduce smart devices but also to give the appropriate information and training to manage it.
	Promote the use of smart devices through examples.

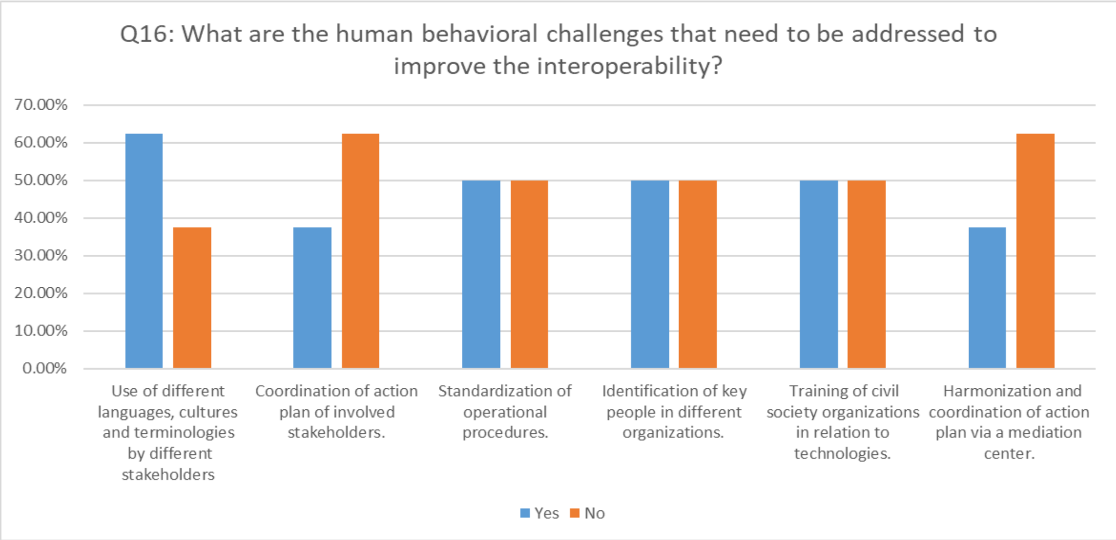
Question 15: Procedures to improve the impact of internal processes on manoeuvrability.



Implemented and needed procedures to improve the impact of internal processes on maneuverability (F/E responders)

Suggestions	To establish periodically debriefing in specific incidents.

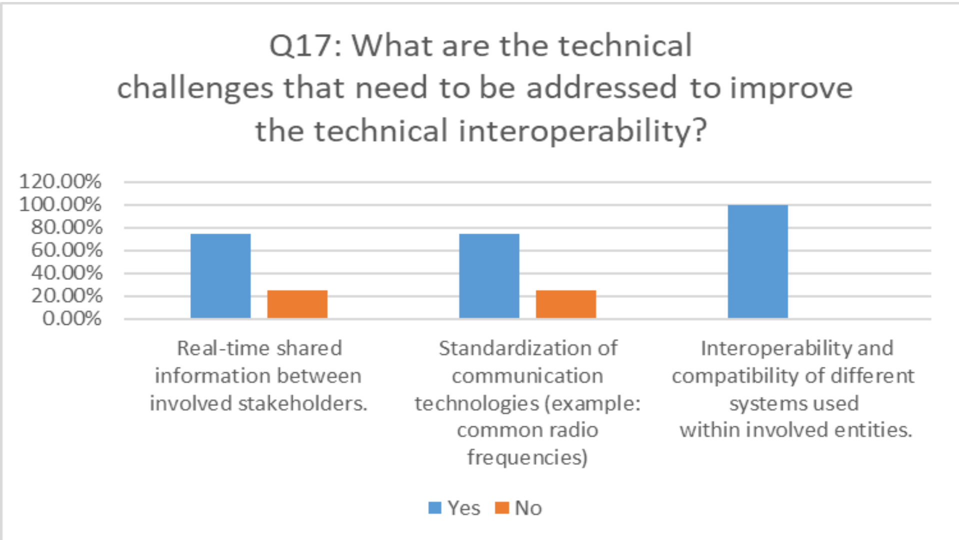
Question 16: What are the human behavioral challenges that need to be addressed to improve the interoperability



The human behavioral challenges that need to be addressed to improve the interoperability (F/E responders)

Suggestions	Interoperability among several devices and software since each organisation as different technology.
	Joint and unified training
	Multi-operability for the same device. Same devices for several purposes.

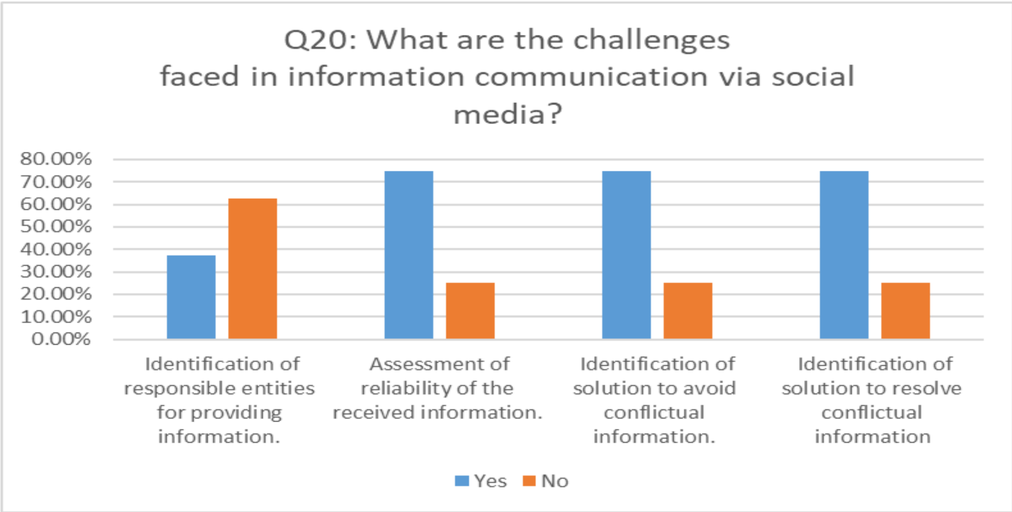
Question 17: What are the technical challenges that need to be addressed to improve the technical interoperability?



The technical challenges that need to be addressed to improve the technical interoperability (F/E responders)

Suggestions	Unifying common codes

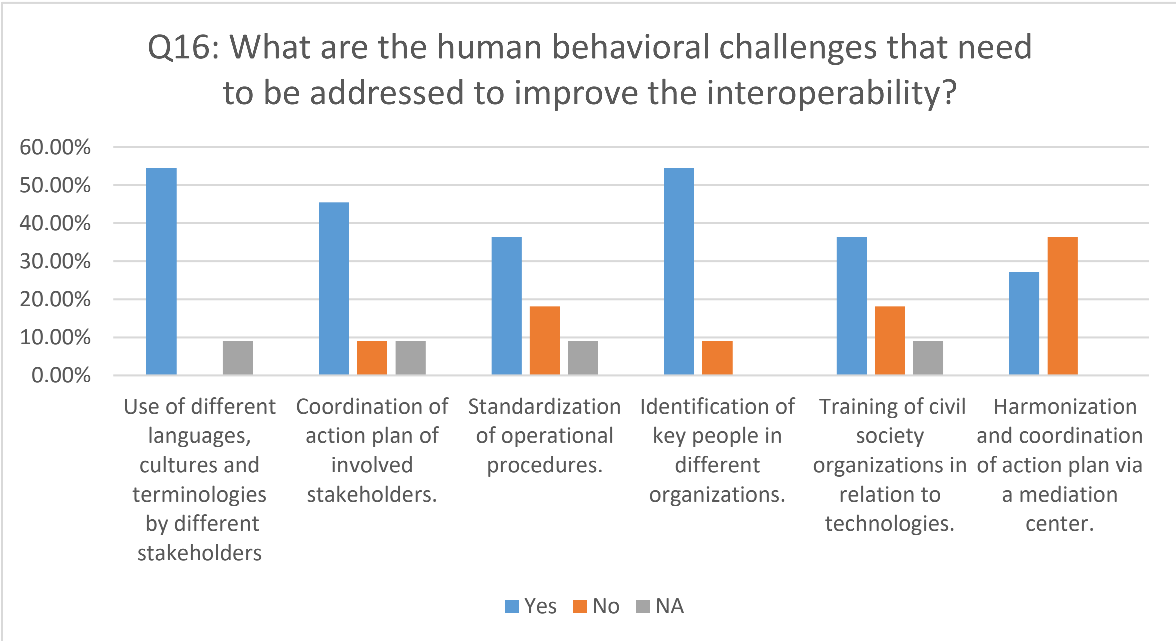
Question 20: What are the challenges faced in information communication via social media?



The challenges faced in information communication via social media (F/E responders)

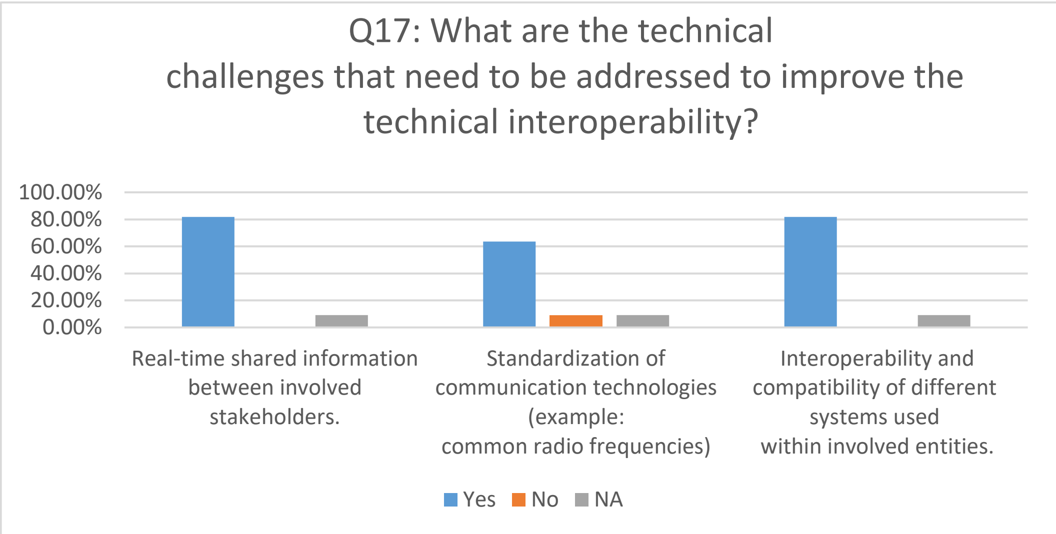
Table: Additional survey results (first and early responders)

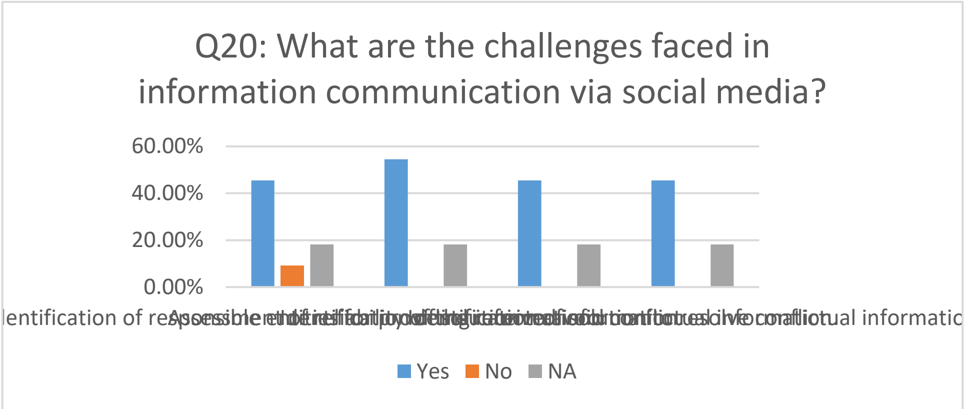
Question 16: What are the human behavioral challenges that need to be addressed to improve the interoperability?	



The human behavioral challenges that need to be addressed to improve the interoperability (Technologies developers)

Suggestions	Establish an interoperability framework (set of policies, guidelines, standards, rules and recommendations), use of open architecture techniques, adopt interoperability initiatives and solutions to enable voice interoperability such as multi-protocol IP gateway solution, data standardization

	Design of the integration platform must take into account the interoperability of all used technologies.
Question 17: What are the technical challenges that need to be addressed to improve the technical interoperability?	
 **The technical challenges that need to be addressed to improve the technical interoperability (Technologies developers)**	
Question 20: What are the challenges faced in information communication via social media?	



The challenges faced in information communication via social media (Technologies developers)

Suggestions	Social media info should direct (include specific links) to established and reliable sources to be able to cross-check information provided.

Additional survey results (technologies developers)