ASSISTANCE

Adapted situation awareneSS tools and tailored training curricula for increaSing capabiliTie and enhANcing the proteCtion of first respondErs

European Commission

Project co-funded by the European Union within the Horizon 2020 Programme

assistance

Project Ref. N°	ASSISTANCE H2020 - 832576
Start Date / Duration	May 1, 2019 (39 months)
Dissemination Level[1]	PU (Public)
Author / Organisation	Francine Amon/RISE

Deliverable D7.6

Evaluation Report

31/07/2022

[1] PU: Public; PP: Restricted to other programme participants (including the EC services); RE: Restricted to a group specified by the Consortium (including the EC services); CO: Confidential, only for members of the Consortium (including the EC services).

ASSISTANCE

Nowadays different first responder (FR) organizations cooperate together to face large and complex disasters that in some cases can be amplified due to new threats such as climate change in case of natural disasters (e.g., larger and more frequent floods and wildfires, etc) or the increase of radicalization in case of man-made disasters (e.g., arsonists that burn European forests, terrorist attacks coordinated across multiple European cities).

The impact of large disasters like these could have disastrous consequences for the European Member States and affect social well-being on a global level. Each type of FR organization (e.g., medical emergency services, fire and rescue services, law enforcement teams, civil protection professionals, etc.) that mitigate these kinds of events are exposed to unexpected dangers and new threats that can severely affect their personal safety.

ASSISTANCE proposes a holistic solution that will adapt a well-tested situation awareness (SA) application as the core of a wider SA platform. The new ASSISTANCE platform is capable of offering different configuration modes for providing the tailored information needed by each FR organization while they work together to mitigate the disaster (e.g., real time video and resource location for firefighters, evacuation route status for emergency health services and so on).

With this solution ASSISTANCE will enhance the SA of the responding organisations during their mitigation activities through the integration of new paradigms, tools and technologies (e.g., drones/robots equipped with a range of sensors, robust communications capabilities, etc.) with the main objective of increasing both their protection and their efficiency.

ASSISTANCE will also improve the skills and capabilities of the FRs through the establishment of a European advanced training network that will provide tailored training based on new learning approaches (e.g., virtual, mixed and/or augmented reality) adapted to each type of FR organizational need and the possibility of sharing virtual training environments, exchanging experiences and actuation procedures.

ASSISTANCE is funded by the Horizon 2020 Programme of the European Commission, in the topic of Critical Infrastructure Protection, grant agreement 832576.

Disclaimer

Executive Summary

This report documents the evaluation of usability, usefulness, and the costs and benefits of using the ASSISTANCE SA platform. The evaluations of usability and usefulness were conducted via observations, questionnaires, and focus groups during the three demonstration pilots. The cost-benefit analysis also used questionnaires and the focus groups held during the pilot, as well as interviews.

Usability was measured using a Systematic Usability Scale (SUS) to assess the ability of first responders to use the situation awareness system (SA) tablets in the field and in tabletop exercises during the demonstration pilots. Usefulness, which is defined for this work as the overall SA platform's ability to enhance first responder capabilities, efficiency, and safety, was measured using an SA score based on the principles established by Endsley in 1995. The cost-benefit analysis is based on the intersection of the first responder organisation's willingness to pay for the ASSISTANCE SA platform (representing costs) and the benefits to European society from reduced lives lost in earthquakes, industrial accidents and terrorist attacks.

The usability results show that the SA platform, in its existing state, is not perceived as satisfactory by the majority of the first responders that participated in the pilot exercises. The TRL for the technology is 6 – 7 for this project, so feedback collected from the first responders can be used to guide further efforts to bring the technology to a state of market readiness.

The first responders found potential in the ASSISTANCE platform and could see the value of using the system to increase SA. The fundamental concept of the system is considered to have potential. It is also considered valuable to have a system that allows multiple first responder organisations to work closer together.

The cost-benefit results show that, priced at 30 k€ - 50 k€, if using the ASSISTANCE SA system can provide approximately 4 – 14 minutes of saved incremental time during the response, depending on the cost of the system and the type of response, it will be economically beneficial to society.

List of Authors

Organisation	Authors
RISE	Francine Amon, Lina Orrell, Ulrika Millgård, Lotta Vylund

Change control datasheet

Version	Changes	Chapters	Pages	Date
0.1	First draft	All	11	08/09/21
0.2	Internal version updated	All	61	08/09/22
1	Draft for review	All	81	18/07/22
2	Final report for submittal	All	81	27/07/22

Content

List of Figures

List of Tables

Acronyms

AB	Advisory Board
AHJ	Authority having jurisdiction
ASSISTANCE	Adapted situation awareneSS tools and taIlored training curricula for increaSing capabiliTie and enhANcing the proteCtion of first respondErs
CBA	Cost-benefit analysis
D#.#	Deliverable number #.# (D1.1 deliverable 1 of work package 1)
DoA	Description of Action of the project
EC	European Commission
EU	European Union
FR	First responder
FRS	Fire and rescue service
GA	Grant Agreement
H2020	Horizon 2020 Programme for Research and Innovation
IPR	Intellectual Property Rights
KPI	Key performance indicator
M#	#th month of the project (M1=May 2019)
PC	Project Coordinator
PIC	Project Implementation Committee
PSB	Project Security Board
PSC	Project Steering Committee
SA	Situation (or situational) awareness
SUS	Systematic Usability Scale
TL	Task Leader
TRL	Technical Readiness Level
WP	Work Package
WPL	Work Package Leader

1. Introduction

This report documents the evaluation of usability, usefulness, and the costs and benefits of using the ASSISTANCE SA platform. Usability is the ability of first responders to use the situation awareness (SA) system tablets in the field and in tabletop exercises during the demonstration pilots. Usefulness is the overall SA platform's ability to enhance first responder capabilities, efficiency, and safety. The usability and usefulness evaluations are presented in Chapter 2. The cost-benefit analysis finds the balance between the first responder organisation's willingness to pay for the ASSISTANCE SA platform and the benefits to European society from reduced lives lost in earthquakes, industrial accidents and terrorist attacks. The cost-benefit analysis is presented in Chapter 0. A summary of conclusions is provided in Chapter 4.

The usability and usefulness evaluations were conducted during the three demonstration pilots. Pilot 1 was in Izmir, Turkey, and the focus was on the emergency medical team's response to an earthquake. This pilot could be considered the simplest of the three pilots in the sense that there is nothing first responders can do to change the intensity of earthquakes; the damage inflicted on society comes from nature. The second pilot, held in Rotterdam, The Netherlands, focused on firefighter's response to an industrial explosion and fire. The complexity of the second pilot is thus a bit higher than the first pilot because the actions of the first responders determine, to some degree, the extent of the damage from the incident. The third pilot, held in Linares, Spain, focused on the police response to a terrorist attack. In this pilot the threat is not passive. The terrorists are actively trying to cause as much harm as possible, which further increases the complexity of the scenario and thus the importance of situation awareness.

In Figure 1 the overall validation activities are shown, with the activities addressed in this report highlighted in orange. The deliverable reports covering other aspects of the project are identified for each set of activities. Note that the gender, ethical, legal and societal aspects of the side effects of using the ASSISTANCE SA technology (improved efficiency and safety) on the civilians, first responder teams, and society are addressed in D8.7. Also, the results of the AR/MR/VR training are documented in D6.4 and are not included in this report.

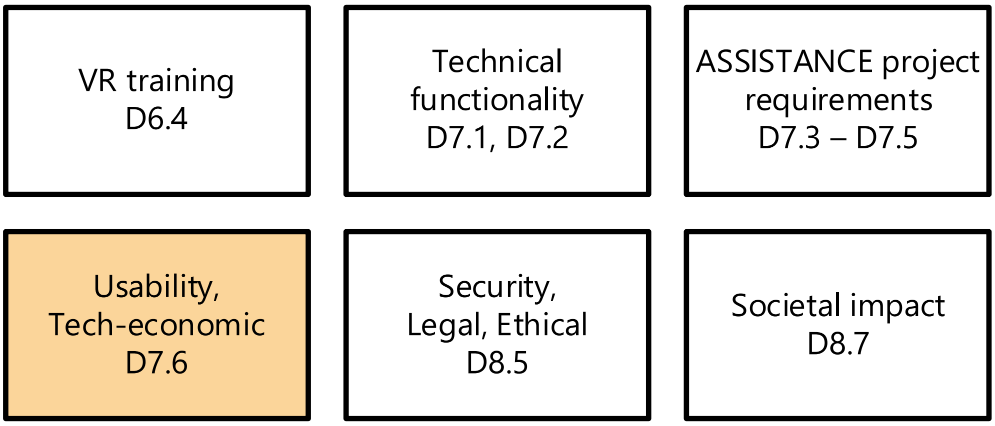

Figure 1: Validation and evaluation activities with their corresponding deliverables. The coloured cell indicates the block of activities documented in this report.

2. Usability evaluation

2.1. Scope of the usability evaluation

Task 7.4 is described as follows in the grant agreement:

> *The task will be devoted to providing and assessing the data collection. Furthermore, this task will assess the project's results from a tech-economic perspective, usability, etc. It will compare the cost of investing in the deployment of the ASSISTANCE system to the estimated saving from the mitigation of the consequences of the system. From the results, actions for continuous improvement of safety of the EU FRs will be proposed. (Grant agreement, p. 37)*

The interpretation of the description of work regarding the assessment of usability is that the evaluation is to be conducted on the whole system, on a general level, when all the technology is used together by the FRs. The result of the evaluation will be a measure of the FR's subjective perception of the usability of the ASSISTANCE system. The evaluation does not aim at assessing each user interface on a detailed level.

Besides looking at usability, the usefulness (or SA) will also be evaluated on a general level. The SA perspective is usually not included in a usability evaluation, but was included in this evaluation on a general level because usability and usefulness are connected, and because usefulness reflects one of the main objectives of the ASSISTANCE project:

> *"to increase FRs Situation Awareness (SA) for helping and protect different kinds of FRs' organizations that work together in a large scale disasters mitigation." (Grant agreement, p. 4)*

2.2. Theory about usability and usefulness

2.2.1. Usability

Using a product should support and facilitate the users to achieve their goals. An assessment of usability could be seen as answering the question "Can I make the product do what I want to do?" [1]. The definition of usability given in the international standard ISO 9241-11:2018 [2] is

> *… the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.*

Effectiveness is how well a user achieves specified goals regarding accuracy and completeness. The relation between resources used and the result achieved is captured in the term *efficiency*. *Satisfaction* is about the user's subjective experience when using the product, taking physical, cognitive, and emotional aspects into account. The experience is characterized by the user's needs and expectations [2].

The extent that usability is achieved depends upon the factors seen to the left in Figure 2. For instance, a product could have high usability in one environment, and at the same time have low usability in another environment. Some users may think that the product has a high level of usability, while another target group (with different characteristics) may think the opposite. There is no single intrinsic measure of the usability of a system, product, or service. Hence, all the contextual factors (users, goals and tasks, resources, and environment) need to be considered when developing or assessing usability [3].

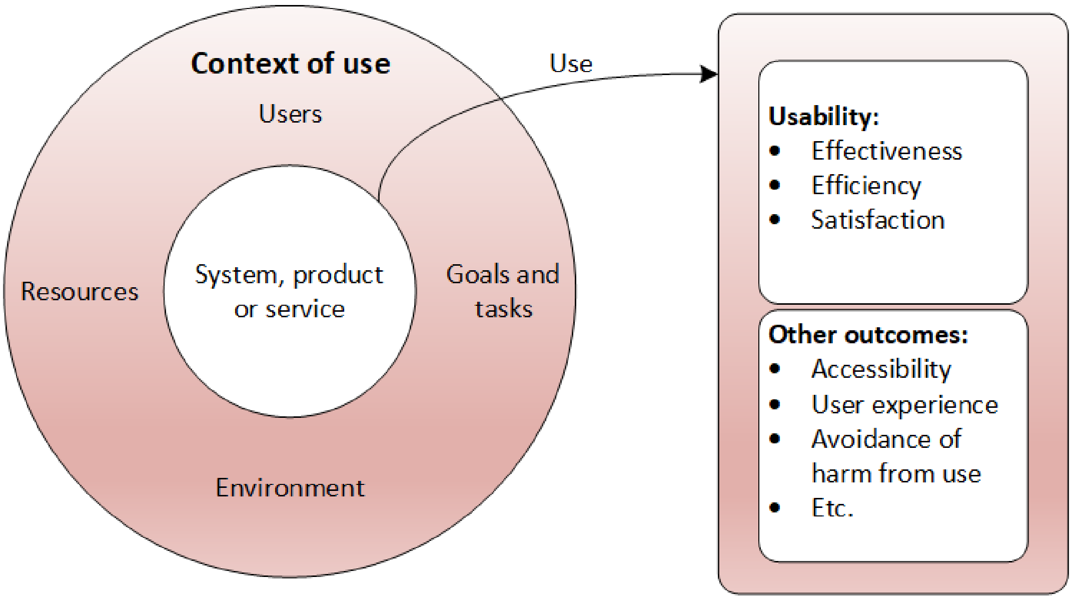

Figure 2: Usability that results from use of a system, product or service in a context of use. Recreated from [¡Error! Marcador no definido.].

2.3. Usability evaluation

McNamara & Kirakowski [1] argue that there are three primary factors which should be considered when evaluating technology, and usability (i.e., interaction between the user and the products) is one of them. The other two are functionality (i.e., technical issues about the product) and experience (i.e., the individual's personal experience of using the product). When it comes to usability the issues transparency, learnability, support offered to users, and clear and informative feedback are highlighted as particularly important. Moreover, it is recommended that the measurement of usability be based on the definition given in IS0 9241-11 in the right context of use.

2.3.1. Usefulness

In the context of the ASSISTANCE project, the usefulness of an SA system is tightly connected to the degree to which the system enhances the capabilities, efficiency, and safety of first responders. Therefore, to evaluate the usefulness of an SA system, it is necessary to evaluate the level of increased SA that it provides first responders. For decision-making in complex and dynamic environments, adequate SA is fundamental. Decision-making and performance can be significantly improved by system designs that enhance first responder SA [4]. Gutwin and Greenberg stated that awareness has these four basic characteristics [5]:

- Awareness is knowledge about the state of a particular environment.
- Environments change over time, so awareness must be kept up to date.
- People maintain their awareness by interacting with the environment.
- Awareness is usually a secondary goal—that is, the overall goal is not simply to maintain awareness but to complete tasks in the environment.

There are several definitions of SA. However, the most cited model is Endsley's three level model [6,7, 8]. Endsley defines SA as follows [4]:

> *"Situation awareness is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future"*

SA is about "knowing what is going on" [4], or as Van de Walle et al. stated: it is about the understanding of what has happened, what is happening now and what could happen [9]. According to Endsley this knowing is divided into three levels 1) Perception of elements in the given situation, 2) comprehension of the current situation and 3) projection of future status. The first level is about perceiving the available data in the situation. This perception is made by all senses, i.e., hearing, sight, taste, touch, and smell.

The collected data, derived from many systems, the environment, other actors, etc., must be merged into a unified whole [10]. The data that is noticed depends on the person’s mental model, which is based on the person’s understanding of the system, previous experience, and goals. If the person misinterprets the situation or has the wrong goals, important data may go unnoticed. The second level includes an understanding of the significance of the data perceived. The significance is understood in relation to the applicable goals. For instance, a firefighter team leader needs to comprehend if the current rate of fire spread is acceptable in the specific context of the objectives of the rescue operation. The final level is about predicting how the situation may evolve. The person operates at all three of these levels simultaneously and the SA constantly needs to be adjusted as the situation evolves. In addition, task and system factors also have an impact on SA. This is, for instance, workload and stress, the complexity of the situation and the system’s capabilities and user interface design [4].

In complex situations where team-based efforts are required, the team's SA is an important factor. For team SA, the coordinated awareness of the entire team is considered [6].

2.3.2. The importance of usability for SA support tools in an emergency response situation

An emergency is characterised by uncertainty, which is defined by emergence (cascading effects), time and resource constraints, surprise, and a high level of damage. This puts high demands on emergency response technical decision support [11]. It is a challenging work situation requiring several cognitive functions for decision-making, such as sense-making, problem detection, planning and re-planning, deciding, coordination, analysing, and judging [12]. Moreover, these cognitive functions need to be carried out by the operators while being under a high level of stress. Stressors are, for instance, the danger of the situation, fatigue, and the realization that a wrong decision can be a matter of life or death [13]. Another aspect of the challenge is that information in an emergency response situation often stems from several sources with varying quality.

Attention, according to Endsley [4], is a limited resource for each individual. Consequently, if a person operates on the verge of his or her ability and more attention is required somewhere, the attention must be reduced elsewhere. A complex and dynamic situation can give rise to demands for attention that exceed an individual's capacity, which can, for example, lead to important information being left unnoticed. This leaves little room for the users to deal with an unusable user interface [14]. In a study carried out by Marusich et al. [15], the results indicated that decision-making in a command-and-control situation was not always improved by making more information available.

On the contrary, an increased amount of information could result in information overload and hence, decrease the level of SA. Consequently, for situation awareness systems in crisis management scenarios it is crucial that SA systems are highly usable [16]. A prerequisite for obtaining an adequate situation awareness is that information is easy to understand, swift to process and easily assimilated and shared among distributed team members. Also, the information should provide the recipient with cues regarding which actions to undertake [9].

Besides the viability of SA enhancing displays for supporting improved SA, if the confidence level experienced is high and the SA is good, the outcome will most likely be good [17] as shown in Figure 3.

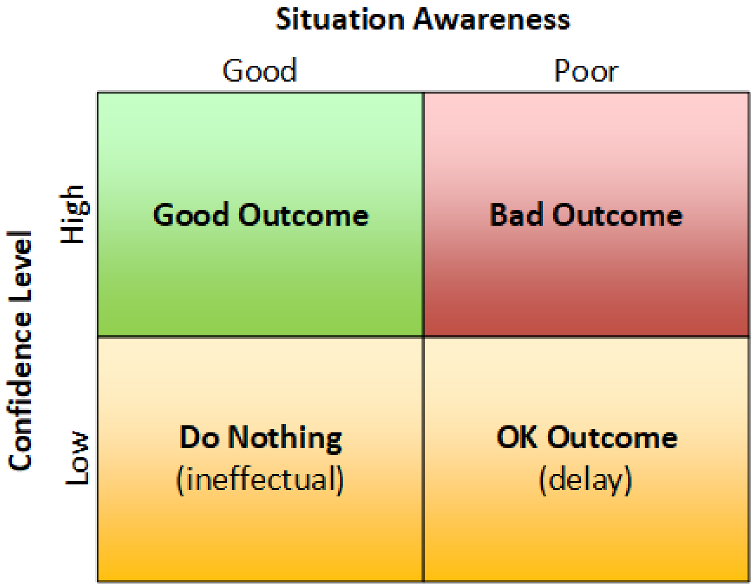

Figure 3: Relationship between situation awareness and confidence, taken from [17].

2.4. Preconditions for the usability evaluation during the pilots

The execution of the pilots was based on the use cases described in D2.3. The focus of these use cases was mainly on the possibility to assess technical functionality. About 20 practitioners, from emergency medical, firefighting and police organizations, attended each pilot. Each of these organizations was in focus for one of the pilots and had a less prominent role during the other two pilots.

The pilots were performed with the correct practitioners using the SA platform, in the correct context, with realistic scenarios, which is an essential basis for good usability measures. A combined questionnaire was used for collecting usability, usefulness, cost-benefit, and societal impact data, since there were enough practitioners participating in each pilot to support the chosen data analysis methods.

2.5. Methodology

2.5.1. Evaluation of Usability

The overall usability of the ASSISTANCE tools was evaluated by using the Systematic Usability Scale (SUS) method. It is a well-established method for global assessment of system usability in a fast and cost-efficient way [18, 19]. This method was originally created by John Brooke [20] and has proved to be a valuable and robust tool for assessing the overall level of usability of a broad range of user interfaces [19]. The objective of SUS is to provide a measure of people's subjective perceptions of a system's usability. The SUS score is easily understood, even for people who do not have specific competence in usability [19].

An evaluation using SUS consists of ten statements which the respondents score on a five-level scale; from "strongly disagree" to "strongly agree" [18]. These statements are listed below:

1. I think that I would like to use this system frequently in this kind of operation.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very difficult to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system

These statements cover the system's efficiency and effectiveness and the user's satisfaction, which are factors included in the definition of usability given in ISO 9241-11.

The SUS is designed based on the idea that usability does not exist in any absolute sense, instead usability is the result of many different interacting factors. Therefore, the answers to all statements must be considered in the analysis. No answer should be analysed in isolation [18]. To get reasonably reliable results for an evaluation made with SUS, a sample of at least 12-14 users is recommended [21]. The total number of participants during the pilots met this recommendation.

Bangor, Kortum and Miller [22] have proposed that is it possible for the SUS score to range from "worst imaginable" to "best imaginable". This was based on an examination of the correlation between SUS scores and people's adjective ratings of systems and products. T hey proposed a framework to tabulate the overall SUS score with the highest possible score of 100. The scores for questions having a positive tone are treated separately from the scores for questions having a negative tone. See [22] for the details of these calculations. From their analysis of nearly 1,000 SUS scores, it was shown that there is a strong correlation between the SUS score and an adjective rating. The proposed grading of the SUS score is shown in Figure 4.

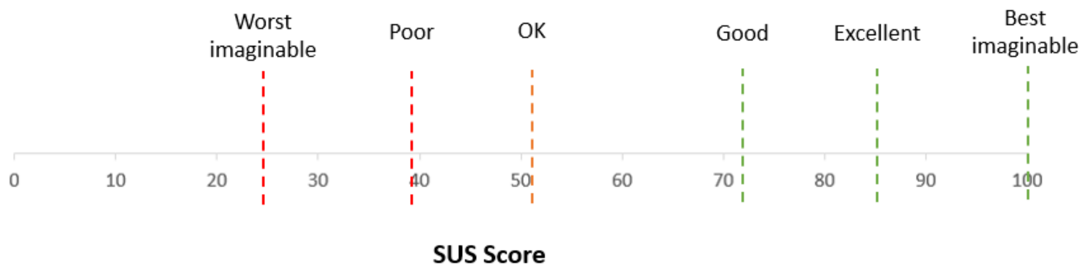

Figure 4: Grade rankings of SUS Score. Partly replicated from Bangor, Kortum & Miller [22].

The ranking of the SUS score used in this evaluation is shown in Table 1, which shows the guidelines for interpreting the results as “excellent”, “good”, “fair” or “poor” from a usability point of view, the average of the SUS scale is 68.

Table 1: The SUS score rankings used in this study.

85	Excellent
72	Good
68	Average
52	OK/Fair
51	Poor

The SUS evaluation method provides a measure of usability; however, it does not explain the meaning of the results. For this reason, the SUS analysis was complemented with focus group sessions, see Section 2.5.4 for more information.

2.5.2. Evaluation of usefulness together with usability

To supplement the usability evaluation with an SA perspective, the questionnaire respondents were asked to grade statements about SA. The statements were based on the design guidelines for interface design given by Endsley [4] to enhance SA, they are listed below:

- The ASSISTANCE platform made me aware of new situations.

- The ASSISTANCE platform made critical information stand out more than non-critical information.
- The ASSISTANCE platform gave me an overview of the situation and at the same time detailed information about the immediate tasks.
- The ASSISTANCE platform did not overload me with information.
- The ASSISTANCE platform generated support for predicting future events (how the situation can develop).
- The information received from the ASSISTANCE platform was presented in a useful way without any need of recalculations of the data.
- The information received from the ASSISTANCE platform was organized in a way, and in terms that correspond to my task.
- The information received from the ASSISTANCE platform was presented in a way that made it possible to share my attention between multiple tasks and sources of information.

The respondents were also asked to grade statements regarding how well they perceived that the ASSISTANCE platform supported them in completing task goals (within context of use in usability) and how trustworthy the user perceived the information from the ASSISTANCE platform. “Trust” is one quality that can be included with satisfaction, which is one of the measurables in usability according to ISO 9241-11. Since confidence (a possible synonym to trust) can affect SA [17], it was decided to add this aspect to the evaluation. The two additional statements related to task goals are listed below:

- The ASSISTANCE platform in general supported the task [task goal].
- I trusted the information that the ASSISTANCE platform provided to [task goal].

The three task goals identified for the three pilots were:

- Keep first responders safe - This includes for example, review whether areas are safe to conduct rescue operations, input regarding first responders in danger by environmental conditions or physical stress situations.
- Rescue victims - This includes for example, locate and identify victims, safe transport of victims, get secure evacuation routes.
- Establish safe zones - This includes for example, information/messages regarding safety assessment, establish a triage zone in a secure area, establish a command area, establish a drone landing area.

2.5.3. Questionnaire development and design

The questionnaire was developed by RISE in collaboration with the consortium partners UC and SBFF.

Since this questionnaire had the same target group as the questionnaire for cost/benefit-analysis (see Chapter 0) and the societal impact questionnaire for WP8, it was decided to combine these three questionnaires into one.

The questionnaire was sent for review to applicable project partners. In the first pilot the questionnaire was available in one English version and one Turkish version. In the second and third pilots an English version was offered to the end users after receiving assurance that an English version would work for all participants.

The first section of the questionnaire had questions about the respondent, such as the respondent's organisation, role, and experience. The aim of these questions was to gain an understanding of the practitioners and to be able to analyse the result of the questionnaire based on different types of users.

In the next section of the questionnaire the respondents were asked to rate statements regarding usability, followed by statements specifically about SA. The respondents also were given the opportunity to write comments in free text fields.

The final two sections of the questionnaire covered questions regarding cost-benefit analysis and societal impact. These sections are described in Chapter 0 and in D8.7, respectively.

Participants who actively participated in the pilots from an practitioner perspective were asked to answer the questionnaire.

2.5.4. Focus groups and observations

To gain a better understanding of the results of the questionnaire, the respondents were invited to join a focus group where an open discussion moderated by RISE representatives took place[2]. The focus groups were scheduled on the last day of the week-long pilot activities, after the users had answered the questionnaire. An additional focus group was held at the beginning of pilot 2 to help establish a baseline against which to measure improvement in SA later in the week.

To start the discussions these questions were prepared regarding usability and SA:

- Overall, what is your opinion of the ASSISTANCE platform?
- If you could change one thing about the ASSISTANCE platform, what would it be? Why?
- What one thing are you most excited about with the ASSISTANCE platform? Why?

[2] Representatives from UC and SBFF were available to moderate the focus group in the first pilot in person, while a RISE representative moderated virtually.

- Why would you continue to use the ASSISTANCE platform?
- What would stop you from using this platform?

To get a better understanding about how new technologies can enhance continuous improvement of safety of the FRs, the focus group during pilot 1 also included questions about improvement in information exchange, as this is one of the main objectives of ASSISTANCE.

- How do you send and receive information today to be able to take accurate decisions to perform these three tasks?
- What is good and what is lacking in the methods you use today to send and receive information?

Representatives from RISE, UC, CEL and TNO observed the FRs and made notes about SA and usability during the pilots.

2.6. Pilot 1: Earthquake in Izmir, Turkey

Firstly, in this section a short summary of the pilot is given with focus on the factors important for assessing usability. For more information about the pilot demonstration see deliverable report D7.3. In this pilot the emphasise was on the response from the medical emergency service.

The team leaders used the tablets that were the field components of the ASSISTANCE SA platform. The tablets had a touch screen and a touch pen that could be used to interact with the screen.

Technical partners were stationed in the command room (CR) and assisted the FRs in the field regarding decision-making. In most cases, the FR team leaders were given orders from the staff in CR (following a script of the scenario).

The users had the chance to get familiar with the SA system technology during a dry run prior the final pilot demonstration. Emphasis was on using the tablet during this process.

Due to the pandemic situation the usability evaluation was performed remotely. Two representatives from RISE (remotely via TEAMS) and two designated persons on site (from UC and SBFF) were available for questions and clarifications during the questionnaire response time. Since this was the first pilot demonstration, a debriefing session with the end users was conducted after the questionnaire had been answered. The end users were asked if they thought any important questions were missing in the questionnaire, or if any question was hard to understand. Moreover, they were asked to give general comments about their experience using the tools regarding usability. The weather during the pilot in Izmir was colder than usual in January, which may have affected the usability of the tablets.

2.6.1. Pilot 1 user profile

In total 20 persons answered the questionnaire. The profile of the respondents is presented in Table 2 below. Note, a respondent could choose more than one alternative for current position.

Table 2: Current type of service and position of the respondents. Note, a respondent was able to choose more than one alternative for current position.

Fire Service (12 respondents)	
Current position:	Number
First responders (FR)	5
Command centre	3
Team Leader for FR	3
Management	3
Training	2
Emergency medical service (7 respondents)	
Current position:	Number
First responders (FR)	2
Team leader for FR	1
Command centre	1
Management	4
Training	2
Other services (respondents: 1)	
Current position:	Number
Team member	1

The time of the total experience of the respondents in his/her service ranged from under two years up to more than twenty years. More than half of the respondents had more than 20 years of experience. The distribution of work experience was as follows:

- Under two years: 2 respondents
- 2-5 years: 3 respondents
- 6-10 years: 1 respondent
- 11-15years: 0 respondents
- 16-20 years: 3 respondents
- Over 20 years: 11 respondents

Six of the respondents, all from Turkey, had previous experience responding to earthquakes. One other respondent had answered that he/she had previous experience for similar events, such as floods, building collapse, chemical rescue.

Fifteen of the twenty respondents had been actively involved with the ASSISTANCE platform during the project before this pilot. The questionnaire was answered by four women.

2.6.2. Pilot 1 usability results

The results from the SUS are presented in Figure 5. The value on the Y-axis is the SUS Score (note, it is not percentage). About half of the total 21 respondents have a SUS score below 52, which can be considered as "poor" usability, and seven respondents have a SUS score below 72, which can be considered as "fair" usability. The two respondents scoring above 72, which can be considered as good usabilty, were both working in the emergency medical services. A thorough discussion of all the SUS and usefulness results is provided in Section 2.10.

Figure 5: The SUS result from the questionnaire in the pilot in Izmir, Turkey. Results above green line are considered "good", results below red line are considered "poor".

The emphasis in this pilot was on the response from the emergency medical service, and the SUS score for respondents from this service are presented in Figure 6. Note that there were seven respondents for this analysis, which is lower than the recommended minimum number of at least 12 – 14 respondents [21].

Figure 6: The SUS results from respondents from emergency medical service in the pilot in Izmir, Turkey. Results above green line are considered "good", results below red line are considered "poor".

The SUS score for the nine respondents who had replied that they "had come in contact with" the tablet during the pilot demonstration are presented in Figure 7. It was mainly the team leaders who interacted with the tablet during the pilot demonstration. Again, note that the number of respondents is lower than the recommended minimum number of at least 12 – 14 respondents [21].

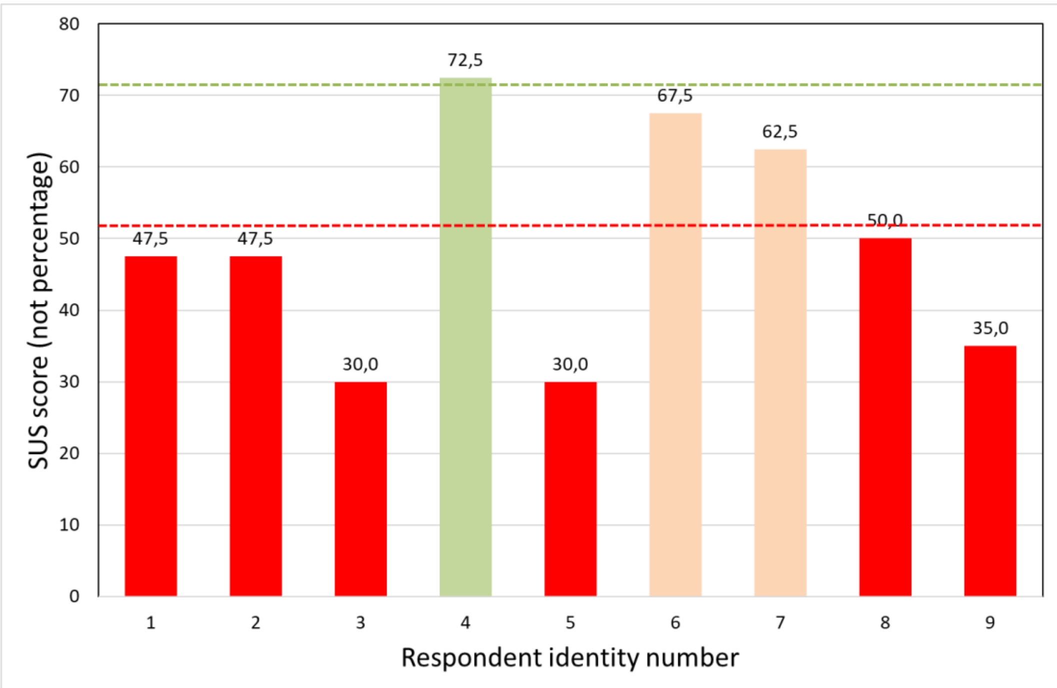

Figure 7: The SUS results from respondents who replied that they had come in contact with the tablet during the pilot demonstration. Results above green line are considered "good", results below red line are considered "poor".

2.6.3. Pilot 1 usefulness results

The mean and median results regarding the statements based on Endsley's design guidelines for SA are shown in Figure 8, Figure 9 and Figure 10. In total 20 repondents graded the statements (one respondent consequently answered "I don't know", and was excluded from the calculation of mean and median-value)

As can be seen in Figure 8, the respondents graded the statements very similarly and the mean and median were all from 3,6 – 4,1. Since three respondents answered "I don't know" for the statement "*generated support for predicting future events (how the situation can develop)*" the values for mean and median are calculated based on 17 answers. The statement "made me aware of new situations" differentiated from the others as the one with the highest score in total (average) and with the most (8) "strongly agree" answer options.

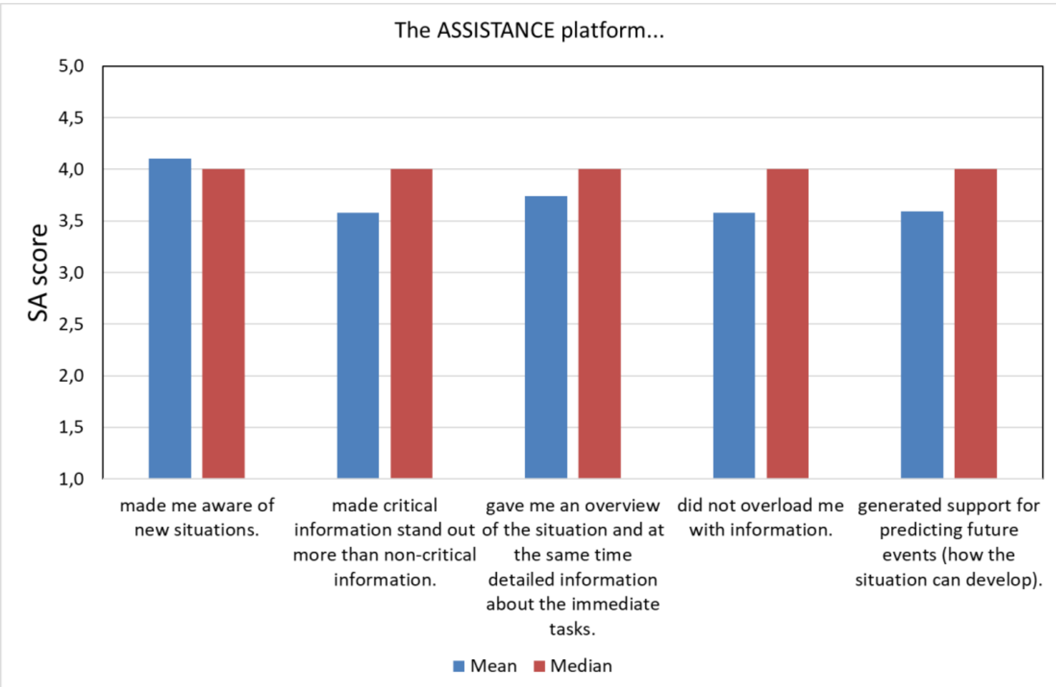

Figure 8: Results regarding statements based on Endsley's design guidelines with focus on how the respondent experienced the support of ASSISTANCE for SA. The SA score corresponds to 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

The results about how the respondents experienced the presentation of the information are shown in Figure 9. The mean and median were from 3 - 3,6. The statement "*presented in a useful way without any need of recalculations of the data*" distinguished as the question with lowest total score and with the most (6) "strongly disagree" answer options.

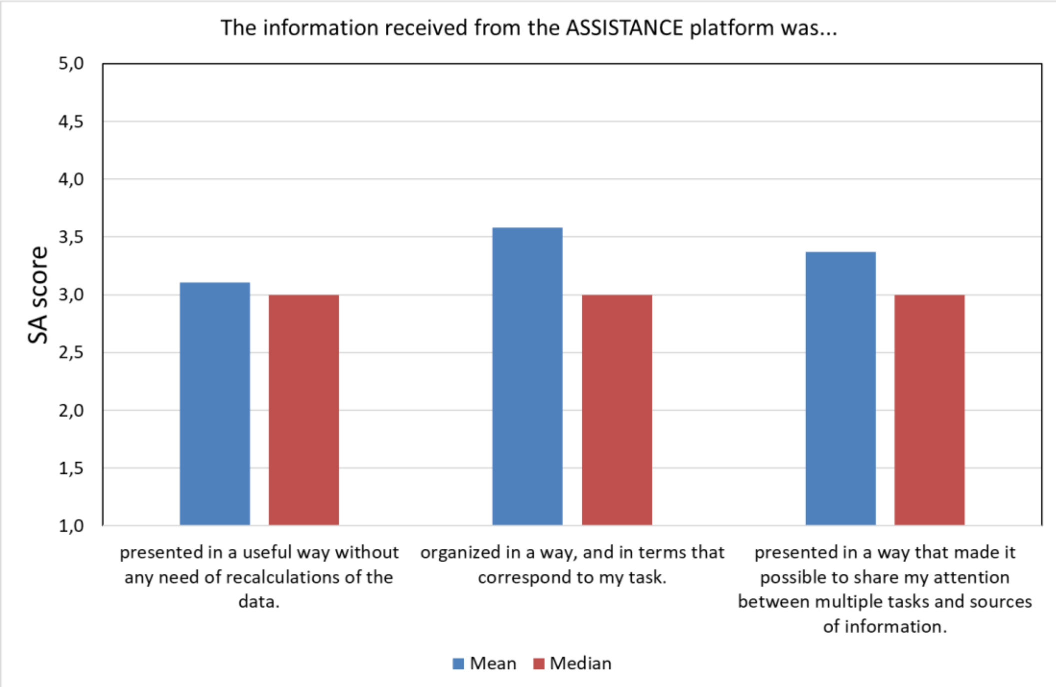

Figure 9: Results about how the respondent experienced the information presented in the ASSISTANCE platform, based on Endsley's design guidelines. The SA score corresponds to 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

The results about the respondents' experience regarding the support and trustworthiness of the ASSISTANCE platform for each task goal are shown in Figure 10. In total 20 respondents graded these statements (two respondents consequently answered "I don't know, and were therefore excluded from the calculation of mean and median-value). The mean and median values are all between 3,7 – 4,1. Thus, the task to "*rescue victims*", both concerning "*support the task*" and "*trust*", had the highest average score and the most answers of "strongly agree" and "agree" compared to the other task goals.

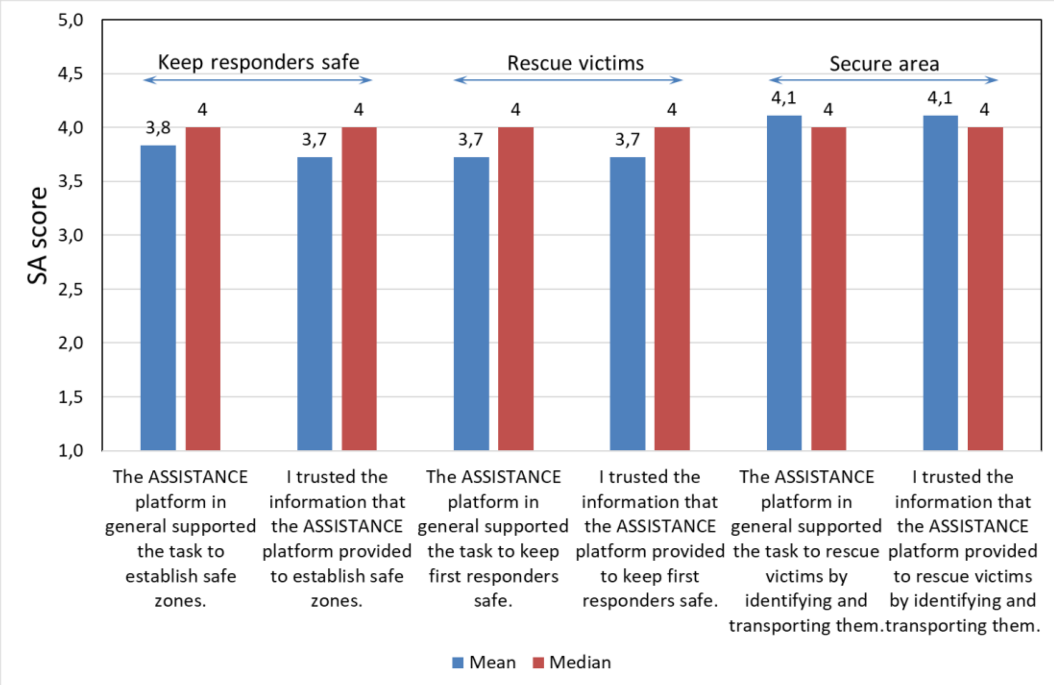

Figure 10: Results regarding support and trustworthiness of ASSISTANCE platform for each task goal. The SA score corresponds to 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

2.6.1. Pilot 1 respondent's comments

In general, the positive comments in the questionnaire could be summarized in the following sentences:

- Increased possibility to make the correct decisions with the right information.
- Increased safety and the possibility to handle the situation effectively.

Features mentioned in positive words were drone footage, wearable sensors, security of the area, choosing the transportation route. However, most of the comments in the questionnaire concerned a need for improved usability in general.

During the discussion in the focus group held after the pilot demonstration some comments regarding using the tablet were raised by the participants. The discussion was recorded and transcribed. Since the end users mainly interacted with the tablet, the comments were focused on this. Examples of perceived usability issues that the users encountered when interacting with the tablet are presented below, in no order of importance. These comments are on a general level, and the aim of collecting them was to gain a better understanding of the results of the evaluation. Hence, no further usability evaluation has been carried out regarding these issues.

Navigation

- Hard to navigate the tablet.
  - For instance, due to textboxes and small drop-down menus, which were hard to navigate with a (touchscreen-)pen.

- Writing messages by using a pen takes a lot of time, and time is crucial in an emergency response situation.
- It was hard to insert information about safe areas into the user interface. A comment was that due to bad adoptability of the pen as a substitute for a mouse in the application it was nearly impossible to correctly mark and close the safe area with the pen.

Attention

- Those who use the tablet in the field will not have time to constantly monitor the tablet, which requires that important warnings and messages get the user's attention while the user simultaneously performs other tasks. A comment was that important warnings and messages did not stick out enough, which increases the risk of failing to pay attention to important messages or things that require action.
- During the pilot demonstration information from all the teams was presented in each and every tablet, such as “Team 1 to area 1”, “Team 2 to area 2” etc. It required some effort by the team leader to discern which information was of concern to his/her team and not.

Information

- For some items in the interface there were no cues regarding if more information was available for the item. Examples of such items were UGV/UAV with cameras, FRs with wearable sensors. Without these cues it was for instance hard to tell which FRs were equipped with wearable sensors and the user had to click on all the FR-items to find those that had them.
- To find the newest sent/received messages, the user had to scroll down (which was difficult with the pen on a small scroll window) in a tablet with a complete list of messages to find confirmation regarding if a message had been sent or just to check what has been sent/received.
- Important information was hidden by pop up-windows.
- Pop-up windows could be mistaken as regular Windows messages due to their similar appearance. One comment was that there may be a risk of failing to notice an ASSISTIANCE tool notification that needs action.
- When it was sunny, the users had a hard time seeing the information on the screen due to glare.

2.7. Pilot 2: Explosion and fire in Rotterdam, The Netherlands

The arrangement for this pilot was slightly different than the pilot in Izmir. In this pilot the emphasis was put on the response from the fire service. Instead of having a fixed manuscript when performing the scenarios, the practitioners were given certain task goals to fulfil, with the requirement that ASSISTANCE tools must be used when performing the tasks. A few more restrictions were given based on the scenario limitations, such as this door cannot be opened during the scenario, etc. Otherwise, the users were free to solve the task as they preferred. Moreover, in this pilot the tablet was also used during a tabletop exercise. The FRs in the field used information from the drone and robot user interfaces and were given verbal information from the CR through radio communication. No users were stationed in the CR.

During this pilot two represents from RISE were on site to observe and ask questions during the baseline and practice exercises and the tabletop exercise and to facilitate the focus group.

The weather was extreme during the pilot in Rotterdam. There was a snowstorm on the demonstration pilot day (Friday) so the scheduled scenarios were cancelled.

2.7.1. Pilot 2 user profile

In total 19 persons answered the questionnaire. The profile of the respondents is presented in Table 3 below. Note, a respondent could choose more than one alternative for current position.

Table 3: Current type of service and position of the respondents. Note, a respondent was able to choose more than one alternative for current position.

Fire Service (15 respondents)	
Current position:	Number
First responders (FR)	8
Command centre	1
Team Leader for FR	6
Fire Brigade dispatcher	1
Researcher Fire Protection	1
Emergency medical service (2 respondents)	
Current position:	Number
First responders (FR)	1
Training and education	1
Command centre	1
Police (3 respondents)	
Current position:	Number
Team leader for FR	1
Command centre	1
Training and education	1

The time of the total experience of the respondents in his/her service ranged from less than two years, up to more than twenty years. More than half of the respondents had more than 16 years of experience. The distribution of work experience was as follow

- Less than 2 years: 2 respondents
- 2-5 years: 3 respondents
- 6-10 years: 1 respondent
- 11-15 years: 2 respondents

- 16-20 years: 6 respondents
- Over 20 years: 5 respondents

Thirteen of the nineteen respondents had been actively involved with the ASSISTANCE platform during the project before this pilot. The questionnaire was answered by six women.

2.7.2. Pilot 2 usability results

The results from the SUS are presented in Figure 11. The value on the Y-axis is the SUS Score (note, it is not percentage) and each vertical bar corresponds to a respondent. In total 19 responders answered the SUS questions. Not all participants in the pilot actively interacted with the tablet during the pilot demonstration.

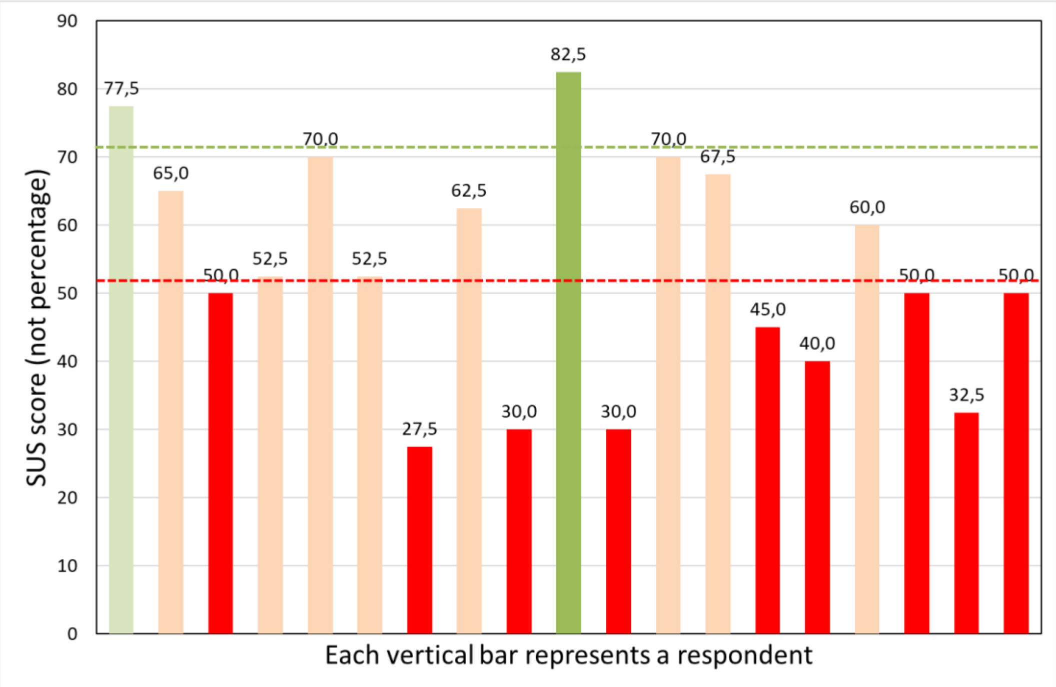

Figure 11: The SUS results for all the respondents of the questionnaire in the pilot in Rotterdam, Netherlands. Results above green line are considered "good", results below red line are considered "poor".

The SUS results for the five respondents who had replied that they "had come in contact with" the tablet during the pilot demonstration are presented in Figure 12. Two of the respondents had been team leaders for first responders during the pilot, one had been a first responder, one had been an observer and the last had replied that he/ she did not have a clear role in the pilot (however, this person was team leader for first responders and also first responder in his/her current position). The latter, together with a person who had the role of team leader, were those with a SUS score which correlated to a "fair" level of usability (52 < SUS score < 72).

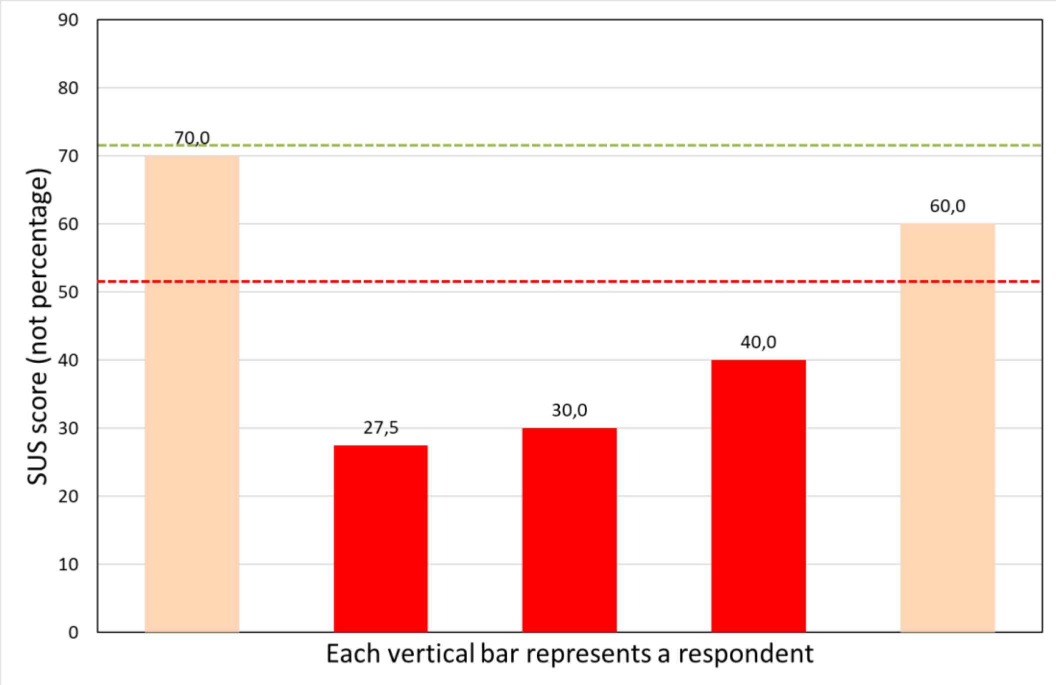

Figure 12: The SUS results from respondents who replied that they had come in contact with the tablet during the pilot demonstration. Results above green line are considered "good", results below red line are considered "poor".

Note that the number of respondents in Figure 12 is lower than the recommended minimum number of at least 12 – 14 respondents [21].

In this pilot the emphasis was on the response of the fire service. The SUS results from the respondents are presented in Figure 13. The two respondents who have SUS scores that correlate to "good" or "excellent" had roles as FRs in the scenario.

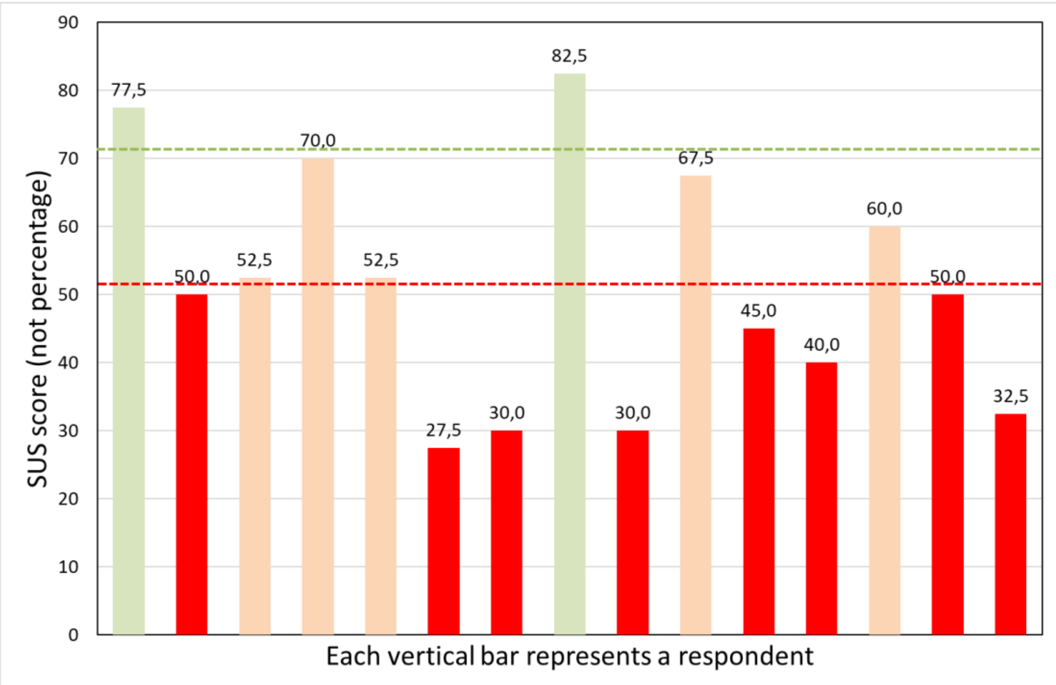

Figure 13: The SUS results from respondents within the fire service. Results above green line are considered "good", results below red line are considered "poor".

2.7.3. Pilot 2 usefulness results

The mean and median results regarding the statements based on Endsley's design guidelines are shown in Figure 14 and Figure 15. In total 17 repondents graded the statements.

As can be seen in Figure 14, the respondents graded the statements very similarly and the mean and median were all from 3 – 4. The statement "*made me aware of new situations*" differentiated from the others as the one with the highest score in total (mean) and with the most (5) "strongly agree" answer options. The statement "*made critical information stand out more than non-critical*" had the lowest score in total for the statements regarding "The ASSISTANCE platform…". However, only two answers were "strongly disagree" or "disagree".

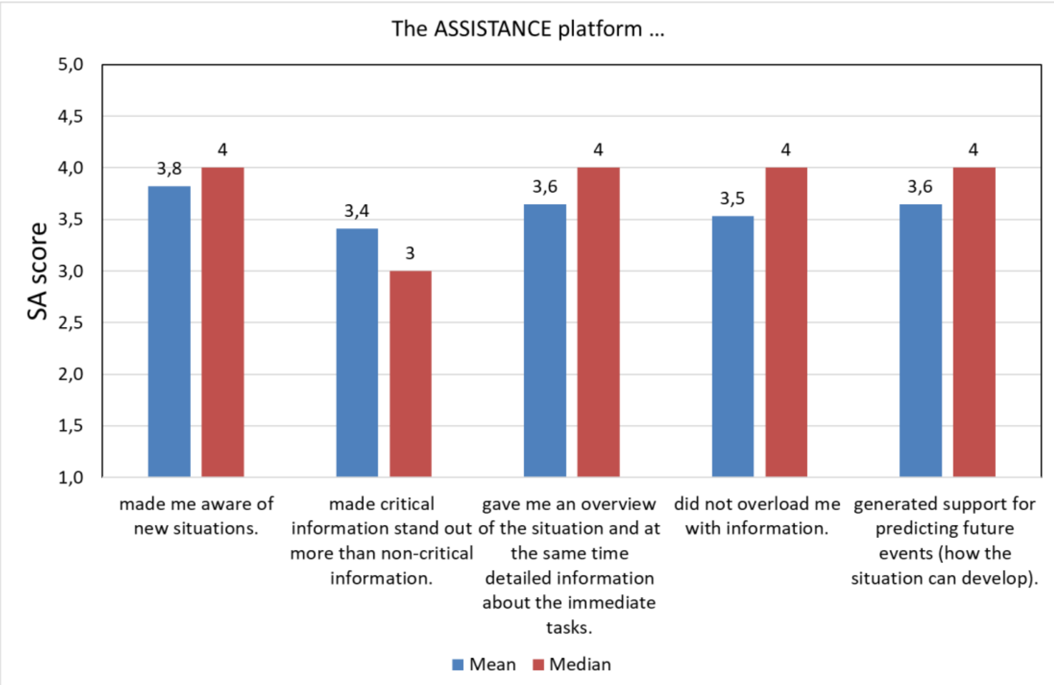

Figure 14: Results regarding statements based on Endsley's design guidelines with focus of how the respondent experienced the support of ASSISTANCE for SA. The SA score corresponds to 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

Regarding the results about how the respondents experienced the presentation of the information, shown in Figure 15, the mean and median were from 3 - 4. The statement "*presented in a useful way without any need of recalculations of the data*" distinguished as the question with lowest total score, with three respondents that graded the statement as "disagree" (no one choose "strongly disagree").

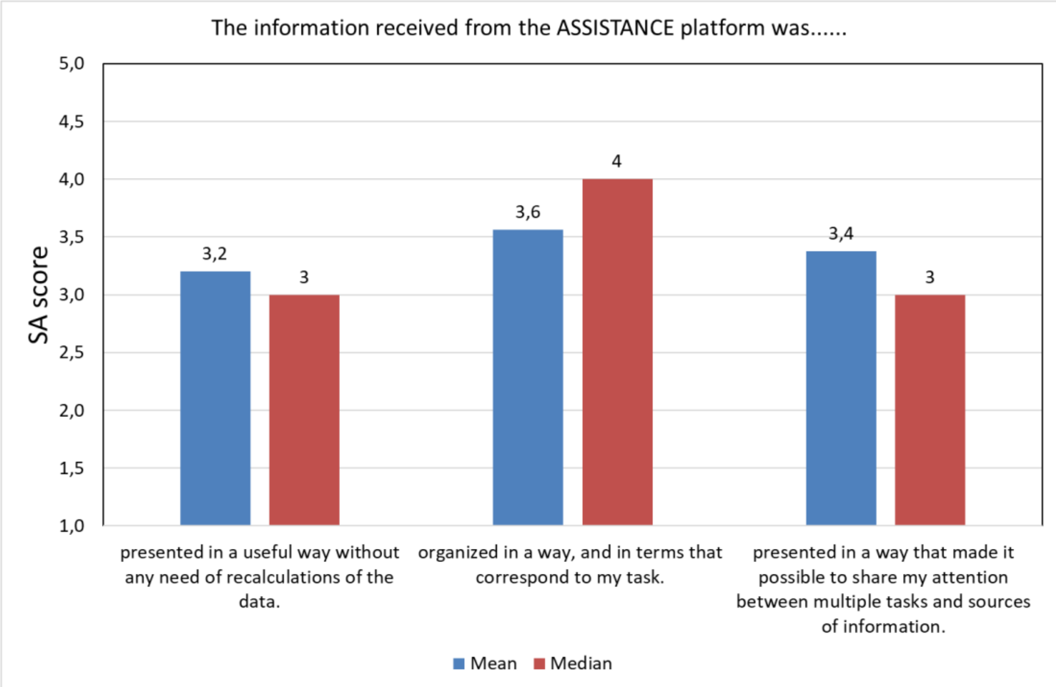

Figure 15: Results about how the respondent experienced the information presented in the ASSISTANCE platform, based on Endsley's design guidelines. The SA score corresponds to 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

The results about the respondents' experience regarding the support and trustworthiness of the ASSISTANCE platform for each task goal are shown in Figure 16. In total 17 respondents graded these statements (one respondent consequently answered "I don't know, and was therefore excluded from the calculation of mean and median-value). The mean and median values are all between 3,7 – 4,0. Thus, the task to "keep first responders safe", both concerning "*support the task*" and "*trust*", had the highest average score and most answers options of "strongly agree" and "agree" compared to the other task goals.

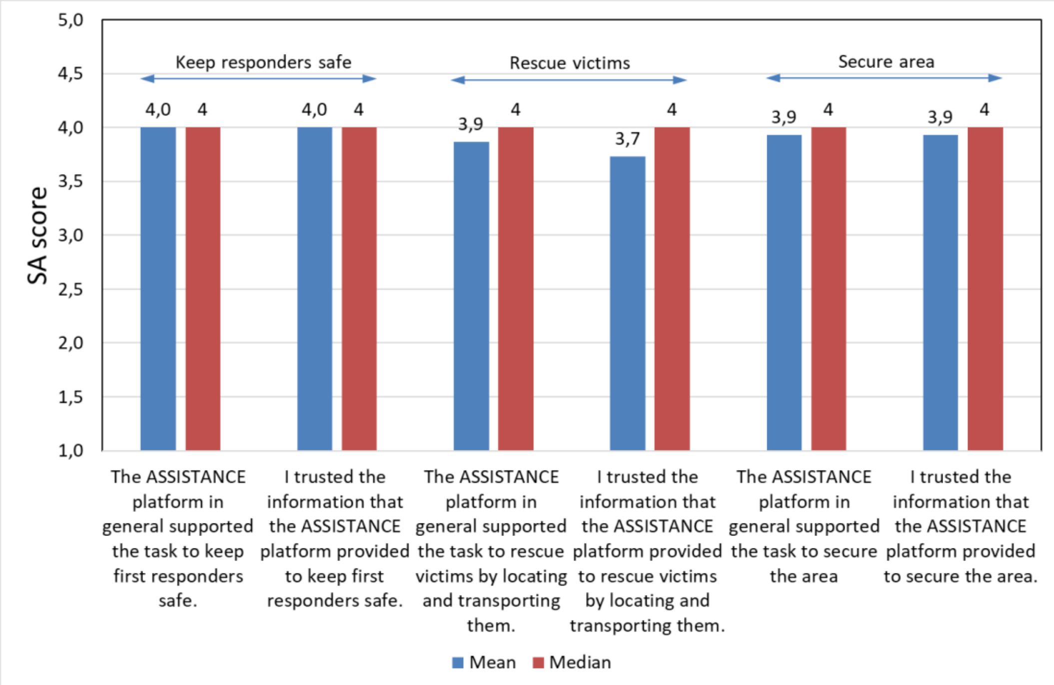

Figure 16: Results regarding support and trustworthiness of ASSISTANCE platform for each task goal. The SA score corresponds to 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

2.7.4. Pilot 2 respondent's comments

The positive comments collected in the free text portion of the questionnaire regarded using the drone- that it will be helpful for locating victims. Otherwise, the comments were about the overall lack of usability and interaction issues.

Some comments regarding using the tablet were raised by the participants during the focus group held after the pilot demonstration. The discussion was recorded and transcribed so comments from the end users regarding their user needs and their point of view about usability issues could be documented. Since the end users mainly interacted with the tablet, the comments were focused on this. Examples of perceived usability issues that the users encountered when interacting with the tablet are presented below, in no order of importance. These comments are on a general level, and the aim of collecting them was to gain a better understanding of the results from the questionnaire. Hence, no further usability evaluation has been carried out regarding these issues.

Tabletop exercise with end users - comments and spontaneous suggestions while accomplishing the scenarios at the tablet.

- Login/password
  - How to get password in the field? Ideally no login/password
- Send/receive messages
  - Keyboard should open automatically
  - Windows should be full screen, with larger fields and fonts/text

  - Minimize the numbers of clicks needed for all functions, e.g., click save and it closes automatically
  - Pop-up menus should be bigger
  - The content of the messages is not always clear
  - Sending messages to all teams would be a useful option, instead of sending identical messages to each team
  - Have a bar with buttons to select the receivers of messages (and all functions of the message menu)
  - It should be more obvious who is the sender and who is the receiver
  - Include a set of predefined messages (like status report, danger, etc)
  - Priority list should be buttons instead of bars/fields
  - Confirmed messages look like a Microsoft error message, need to look distinctly different
  - System is too slow, updating messages takes time
  - Saved messages from previous incidents should be in the background or shaded or at the bottom of the list, not visible in the current incident
  - Alert messages should be at the top of the list, not at the bottom
  - The columns describing the messages should be in this order:
    - Most recent timestamp
    - Sent from
    - Sent to
    - Content of the message
    - Type of message
    - ID column is not useful for FRs- hide it or save for resources column
  - Disable the rearrangement for each column
  - Not everyone knows what GIS is, write Global Information System instead (or call it something that people understand)
- HMI tailoring capabilities
  - Similar comments about keyboard, window/pop-up menu/text sizes, number of clicks, ease of operations
- Introduction of new areas
  - Have a predefined list of names for new areas (like sector 1, 2, etc)
  - Should be able to use fingers to close areas (not a mouse)
- Realtime measurement and visualisation
  - Useful function
  - FRs would need training to use it
- Other comments
  - The same general comments about keyboard, window/pop-up menu/text sizes, number of clicks, ease of operations apply to the rest of the actions on the checklist
  - Should be a visual indicator that the system is loading something
  - A useful function would be to allow FRs to move the cameras on the drones

2.8. Pilot 3: Terrorist attack in Linares, Spain

In this pilot the emphasis was on the response from the police. The arrangement for this pilot was a combination of the police having a fixed manuscript when performing the scenario, and the rest of the FRs (medical and firefighters) not following a manuscript. During this pilot the tablet was also used during a tabletop exercise.

Two representatives from RISE were on site to observe and ask questions during the dry runs, moderate the tabletop exercises and facilitate the focus group.

The weather in June during the pilot was very hot, over 40 degrees Celsius, which may have affected the usability results and the performance of the drones and robots.

2.8.1. Pilot 3 user profile

In total 19 persons answered the questionnaire. The profile of the respondents is presented in Table 4 below. Note, a respondent could choose more than one alternative for current position.

Table 4: Current type of service and position of the respondents. Note, a respondent was able to choose more than one alternative for current position.

Fire Service (12 respondents)	
Current position:	Number
First responders (FR)	5
Command centre	3
Team Leader for FR	4
Coordinator	1
Researcher Fire Protection	1
Emergency medical service (4 respondents)	
Current position:	Number
Team Leader for FR	1
Training and education	2
Command centre	1
Police (3 respondents)	
Current position:	Number
First responder (FR)	2
Team Leader for FR	1

The time of the total experience of the respondents in his/her service ranged from less than two years, up to more than twenty years. More than half of the respondents had more than 10 years of experience. The distribution of work experience was as follow

- Less than 2 years: 2 respondents

- 2-5 years: 2 respondents
- 6-10 years: 3 respondents
- 11-15 years: 3 respondents
- 16-20 years: 4 respondents
- Over 20 years: 5 respondents

Sixteen of the nineteen respondents had been actively involved with the ASSISTANCE platform during the project before this pilot. The questionnaire was answered by five women.

2.8.2. Pilot 3 usability results

The results from the SUS are presented in Figure 17 with a total 19 respondents. The value on the Y-axis is the SUS Score (note, it is not percentage) and each number on the X-axis corresponds to a respondent. The results in Spain show that none of the 19 respondents gave a SUS score above 72, "good".

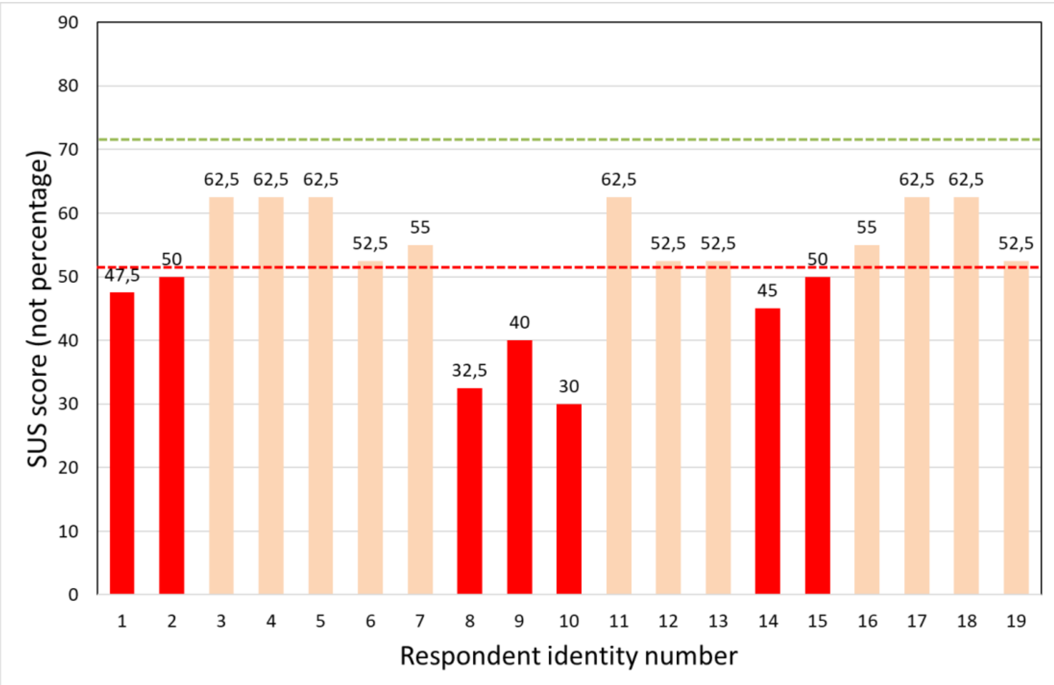

Figure 17: The SUS-result for all the respondents of the questionnaire in the pilot in Spain. Results above green line are considered "good", results below red line are considered "poor".

Figure 18 shows the results of the respondents who replied that they came in contact with a tablet during the pilot. Three of these were team leaders, two had a position in the command room, two were FR and one had another position.

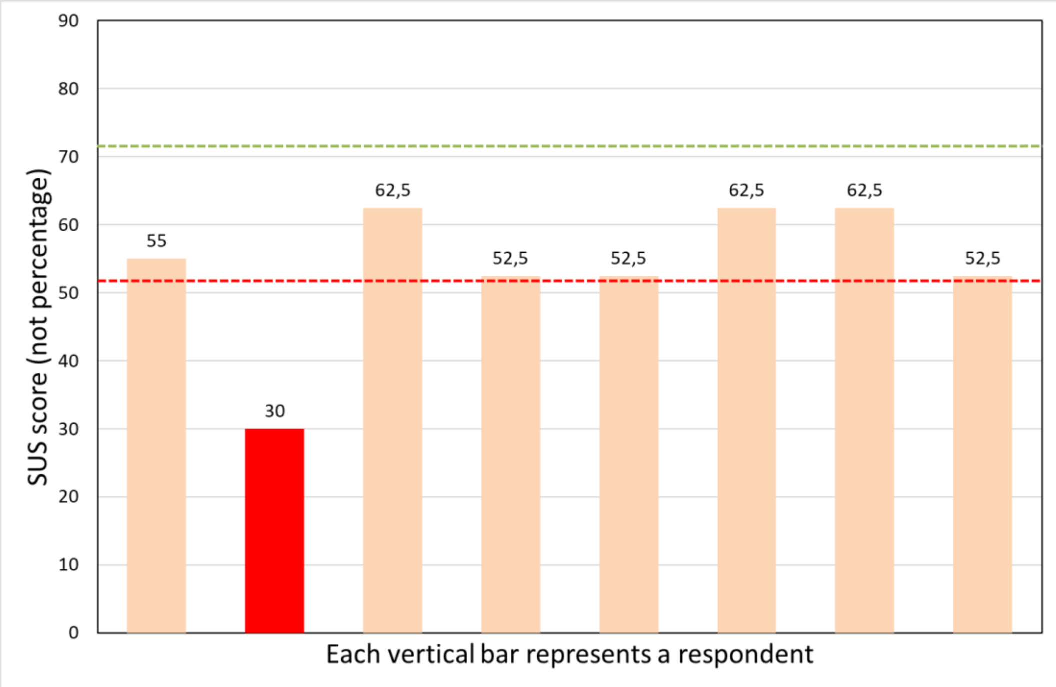

Figure 18: The SUS result from respondents who replied that they had come in contact with the tablet during the pilot demonstration. Results above green line are considered "good", results below red line are considered “poor”.

Note that the number of respondents in Figure 18 and Figure 19 is lower than the recommended minimum number of at least 12 – 14 respondents [21].

The emphasis in this pilot was on the response from the police, and the SUS results for respondents are presented in **¡Error! No se encuentra el origen de la referencia.**. There were only three police people responding the questionnaire and they all had come in contact with the tablet during the pilot.

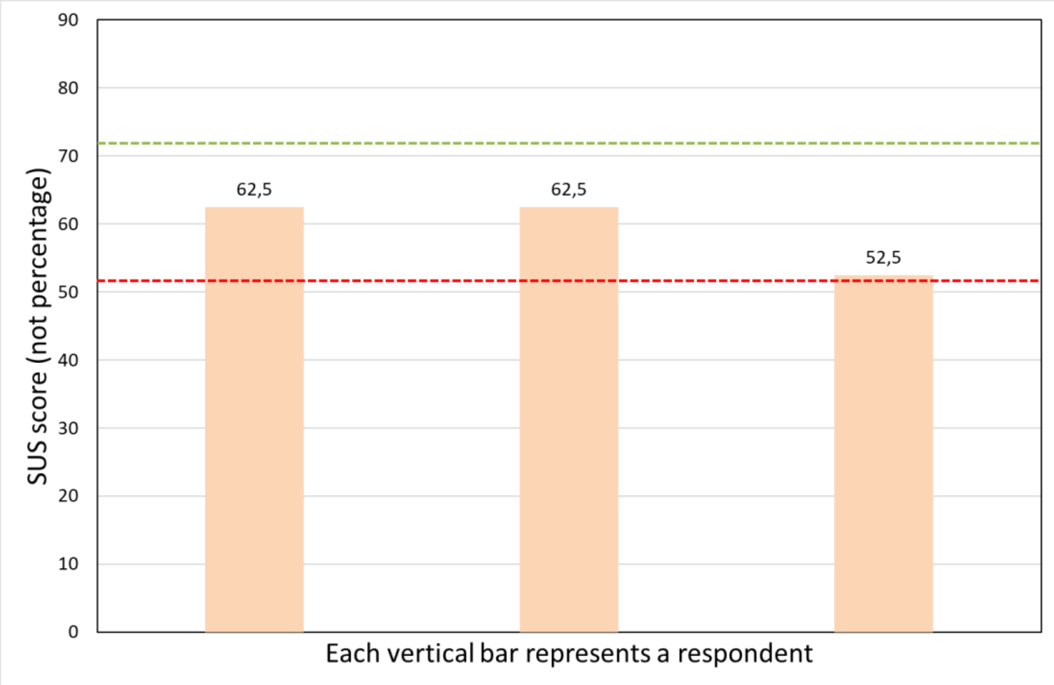

Figure 19: The SUS result from respondents within the police. Results above green line are considered "good", results below red line are considered "poor".

2.8.3. Pilot 3 usefulness results

The mean and median results regarding the statements based on Endsley's design guidelines are shown in Figure 20 and Figure 21. In total 18 repondents graded the statements (one respondent consequently answered "I don't know", and was therefore excluded from the calculation of mean and median-value)

As can be seen in Figure 20, the respondents graded the statements very similarly and the mean and median were all from 3 – 4,1. The statement "*made me aware of new situations*" differentiated from the others as the one with the highest score in total (mean) and with the most (5) "strongly agree" answer options. The statement "*did not overload me with information*" had the lowest score in total for the statements regarding "The ASSISTANCE platform…". However, there were four respondents that stated disagree. None of the answers were strongly disagree.

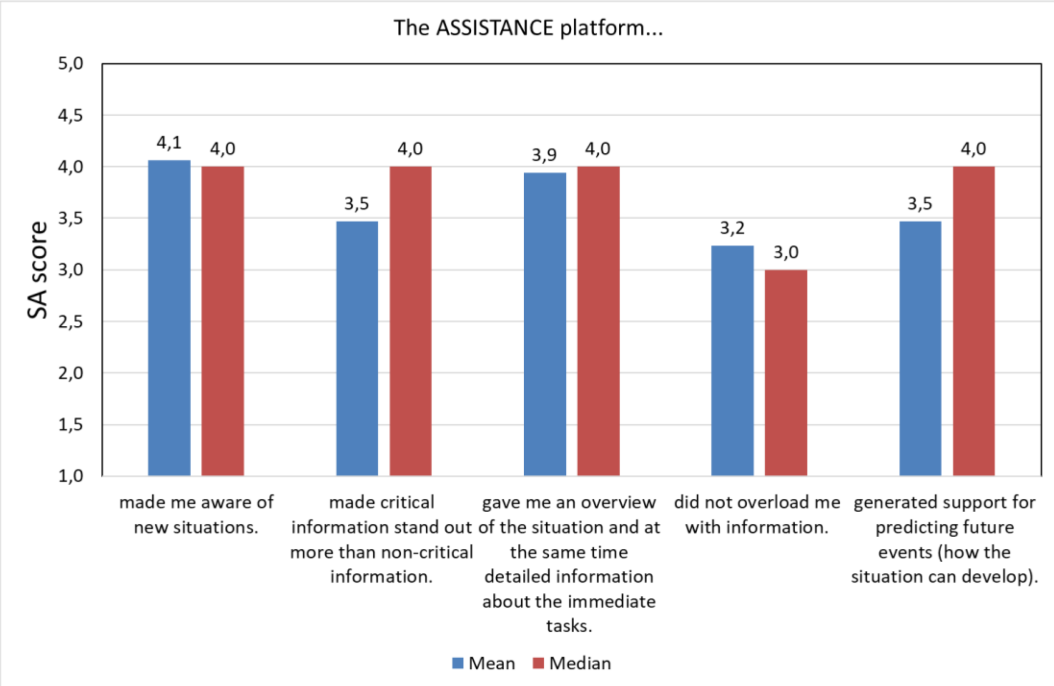

Figure 20: Results regarding statements based on Endsley's design guidelines with focus of how the respondent experienced the support of ASSISTANCE for SA. The SA score corresponds to 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

Regarding the results about how the respondents experienced the presentation of the information, shown in Figure 21, the mean and median were from 3 - 4. The statement "*presented in a way that made it possible to share my attention between multiple tasks and sources of information.*" was the question with lowest total score, with two respondents had graded the statement as "strongly disagree". The statement "*organized in a way, and in terms that correspond to my task*" differentiated from the others within presentation of information as the one with the highest score in total with nine respondents grading "agree" and one "strongly agree".

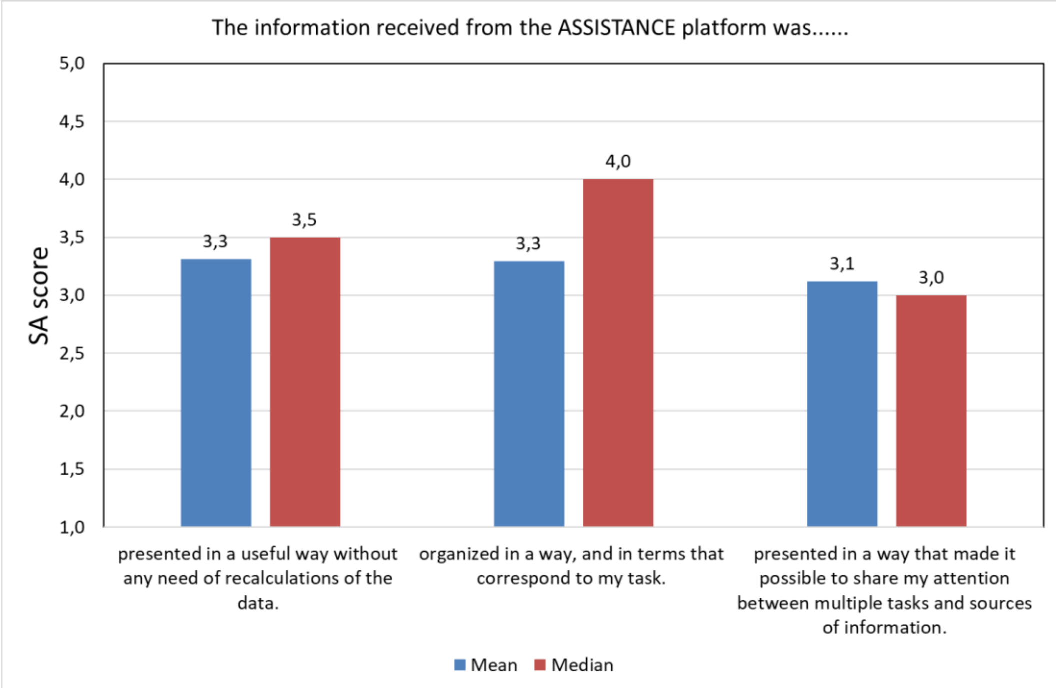

Figure 21: Results about how the respondent experienced the information presented in the ASSISTANCE platform, based on Endsley's design guidelines. The SA score corresponds to 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

The results about the respondents' experience regarding the support and trustworthiness of the ASSISTANCE platform for each task goal are shown in Figure 22. In total 18 respondents graded these statements (one respondents consequently answered "I don't know, and was therefore excluded from the calculation of mean and median-value). The mean and median values are all between 3,6 – 4,0. The task to "*secure the area*", both concerning "*support the task*" and "*trus*t", had the highest average score. Thus, the task to "*rescue victims*", concerning "*trus*t", had the most answers options of "strongly agree" (6) compared to the other task goals.

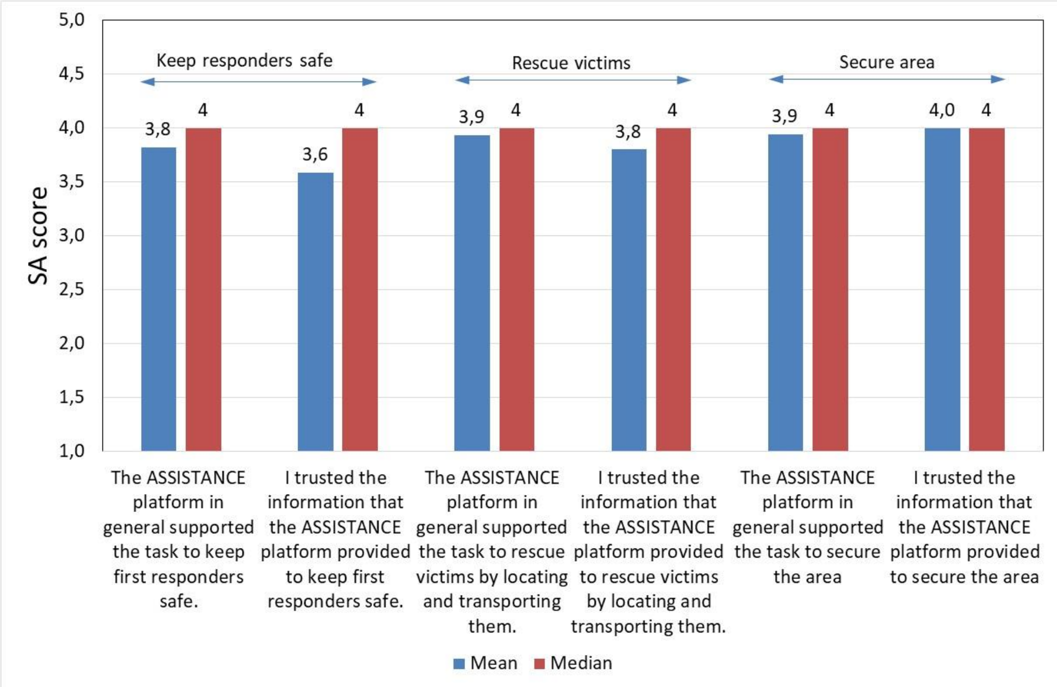

Figure 22: Results regarding support and trustworthiness of ASSISTANCE platform for each task goal. The grading corresponds to 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

2.8.4. Pilot 3 respondent's comments

The few comments in the questionnaire were about the concept of the ASSISTANCE SA platform as a whole, that it was perceived as positive, needed by FRs, and could be a true improvement in their work. In the other hand, as in the other pilots, there were also comments about the further development of the system so that it will work as intended.

A focus group was held after the pilot demonstration and the comments from the discussion were recorded and transcribed. Since the end users mainly interacted with the tablet, the comments were focused on this. Examples of perceived usability issues that the users encountered when interacting with the tablet and their user experience are presented below. Also, there are thoughts and comments regarding user interaction improvements to the platform that were implemented since the last pilot. These comments are presented in no order of importance. These comments are on a general level and the aim of collecting them was to gain a better understanding of the results of the SUS. Hence, no further usability evaluation has been carried out regarding these issues.

Positive comments about using the platform:

- Good to be able to check different devices and see images from a command perspective.
- Shared situation awareness across FR disciplines (common operational picture)

- It works for sharing information, a reason for continuing using ASSISTANCE platform.

Obstacles in using the platform:

- All the time you have to be looking at the screen. If the CR doesn't get an instant response, it's because I'm not standing right in front of the computer all the time.
- For crucial things (alerts, giving tasks) it isn't feasible
- It is hard to get past the difficulties with the network problems, tablets not working, etc. We can't confirm that it is working as well as we want.

Other comments regarding e.g. context and user needs:

- The tablet is aimed at the wrong level. If you give it to the fire crew they don't have time to use it. Maybe it could be used in a command vehicle where there is a designated dispatch person (or other "tablet specialist") that could monitor things so that someone in an appropriate role could ask questions and get images. For the ones that are actually out there, there is no time for this. It is too slow and complicated. The tablet can't interfere with normal practices.
- Team leaders need a tablet with 6 buttons: "evacuation", "go ahead", etc… this is enough because the rest interferes with the team and their communication on the radio right now. Maybe the future will be different, but for now this is enough. Too much technology can slow us in practice. Too much information is not always better.
- There is also an issue of trust in the data. If I know not everyone is entering the data (or not entering the data correctly) then I know that it is faulty. It needs to be that everyone is entering the data as a team, but then it slows them down because they are focusing on entering the data instead of actually doing the job.
- The commanders need a lot of information, but only commanders. They can get it in different ways, like from cameras, sensors, automatic trigger, with tracking. The tablets make work in the field go too slowly. It is not suitable for the field.

Thoughts and comments regarding user interaction improvements in the platform, as were implemented since last pilot:

- Yes, when we tried the tablet it was clearly improved.
- The buttons are bigger so you can push them with your finger instead of the little pen (this you can throw away).
- The text is also clearly bigger than before.
- The pre-written short messages that you can select instead of writing are much better.
- Marking an area is for sure easier now. Closing the loop was impossible, now it is just a double click.
- The number of clicks are reduced.
- Kudos to the team because they really did some changes that we asked for. I think that's good.

2.9. Combined results for all pilots

In this section the results of the mean values from all three pilots are gathered in the same graphs, see Figure 23, Figure 24, Figure 25 and Figure 26.

The mean results from the SUS are presented in Figure 23. The value on the Y-axis is the SUS Score (note, it is not percentage) and each number on the X-axis corresponds to the mean value from each pilot. These results show virtually no difference between any of the pilots in the usability of the SA platform, and the mean SUS scores are consistently just within the “OK/Fair” region. This is somewhat at odds with the focus group discussion for pilot 3, where the FRs said that they thought the usability of the tablets was much better than their previous experiences with it.

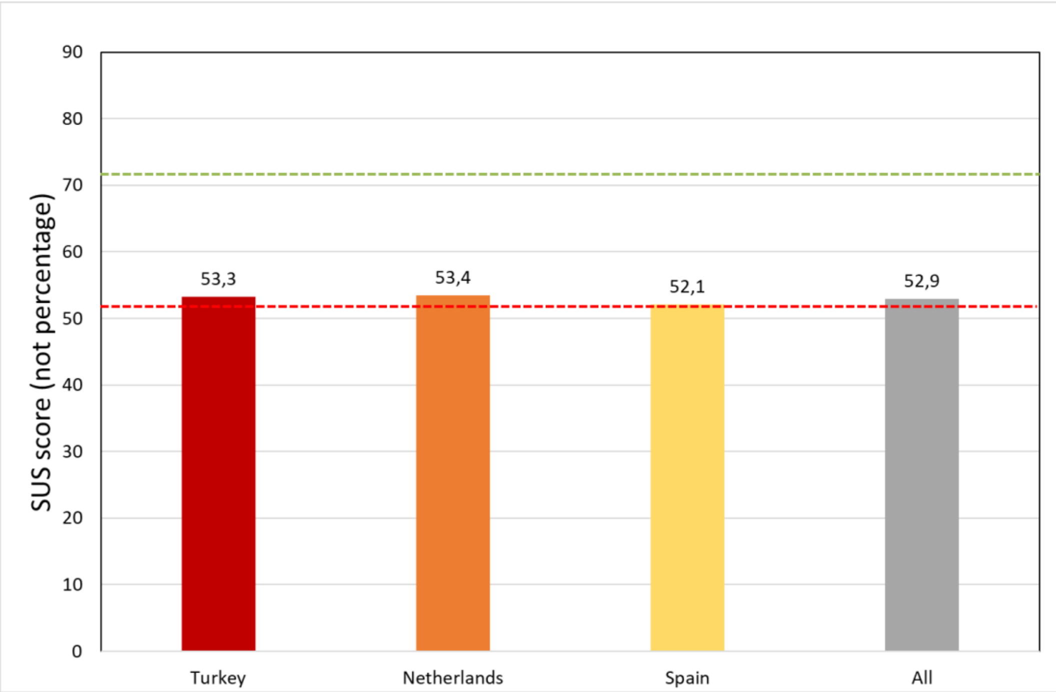

Figure 23: The mean SUS result for all the respondents of the questionnaires in the three pilots and the mean value for all three pilots together, represented in “all”. Results above green line are considered "good", results below red line are considered “poor”.

The overall results for the usefulness of the SA platform show in Figure 24 that there is some variation between pilots. The mean values were between 3,2 – 4.1. The statement “made me aware of new situations” was graded slightly higher than the other statements, which is important since this is the main purpose of a SA system.

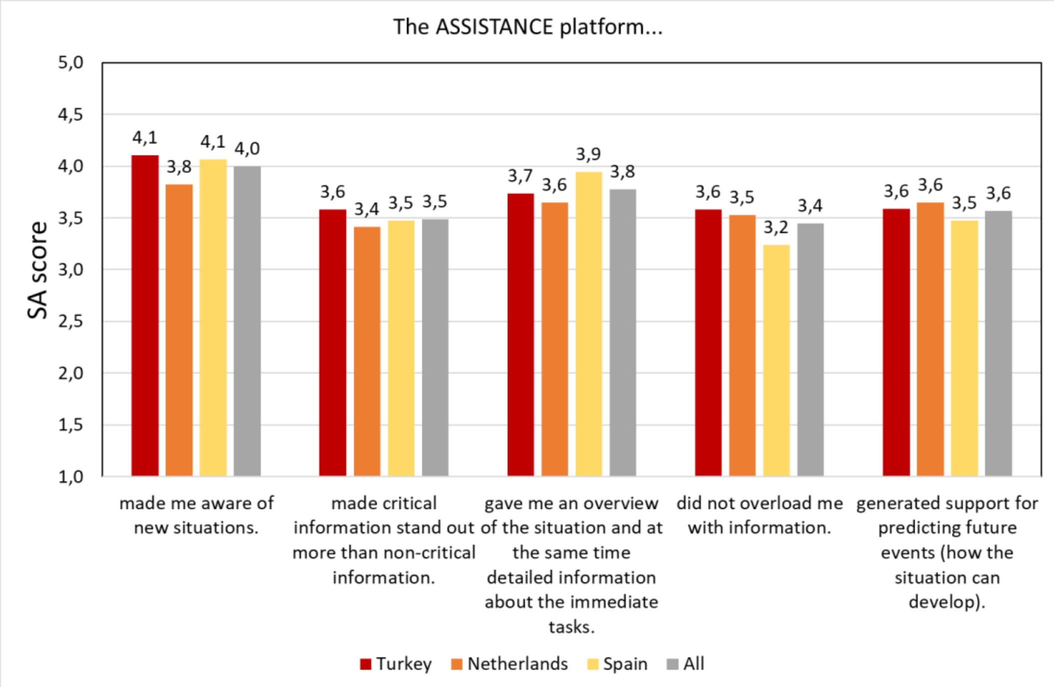

Figure 24: Results regarding statements based on Endsley's design guidelines with focus of how the respondent experienced the support of ASSISTANCE for SA. The SA score corresponds to 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree. The mean value for all three pilots together is represented in "all".

Regarding the results shown in Figure 25 about how the respondents experienced the presentation of the information, the statement "presented in a useful way without any need of recalculations of the data" had the lowest score by a very small margin. There was no substantial difference between the pilot results.

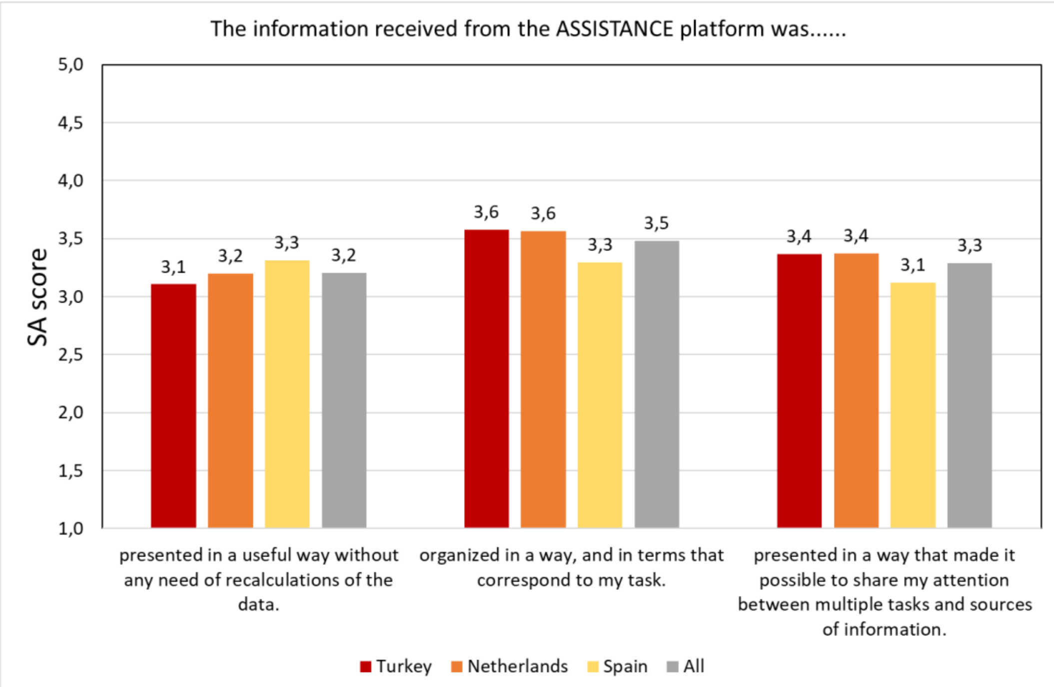

Figure 25: Results about how the respondent experienced the information presented in the ASSISTANCE platform. The SA score corresponds to 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree. The mean value for all three pilots together is represented in "all".

There was slightly more variation (but still not a significant amount) in the results about the respondents' experience regarding the support and trustworthiness of the ASSISTANCE platform for each task goal, which are shown in Figure 26. The mean values are all between 3,6 – 4,1.

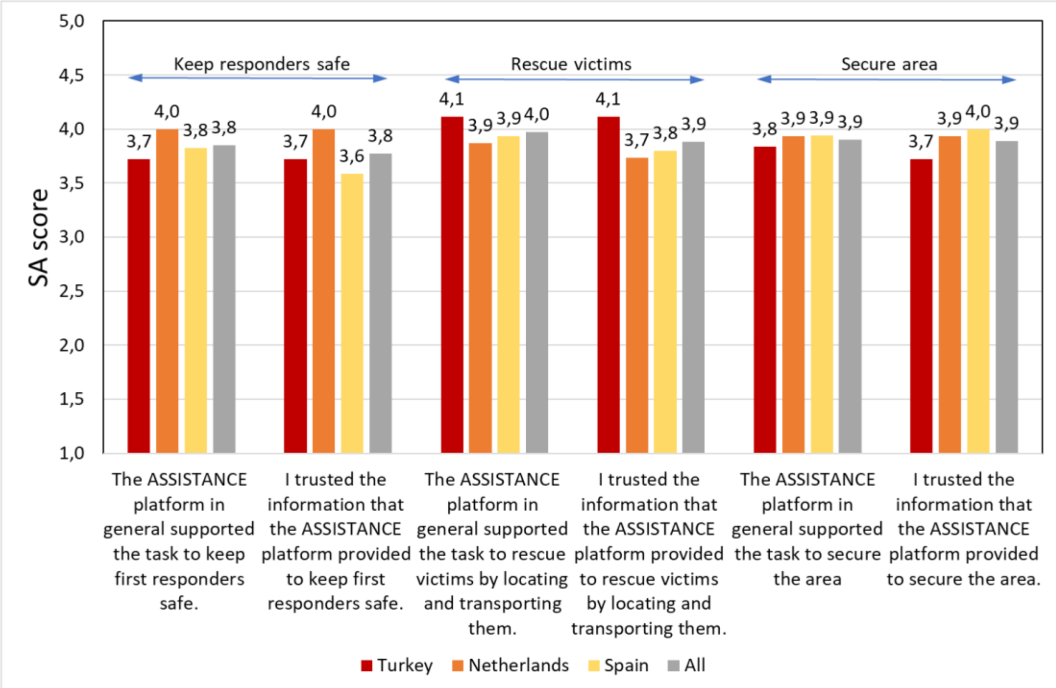

Figure 26: Results regarding support and trustworthiness of ASSISTANCE platform for each task goal. The SDA score corresponds to 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree. The mean value for all three pilots together is represented in "all".

Figure 27 shows the number of respondents that used the platform during each pilot and graded it as having poor usability. When the results are viewed this way, there is a big difference between the first two pilots and the last pilot, where only one respondent graded the usability as poor. This is an indication that the improvements made to the tablets between the second and third pilots were appreciated by the FRs.

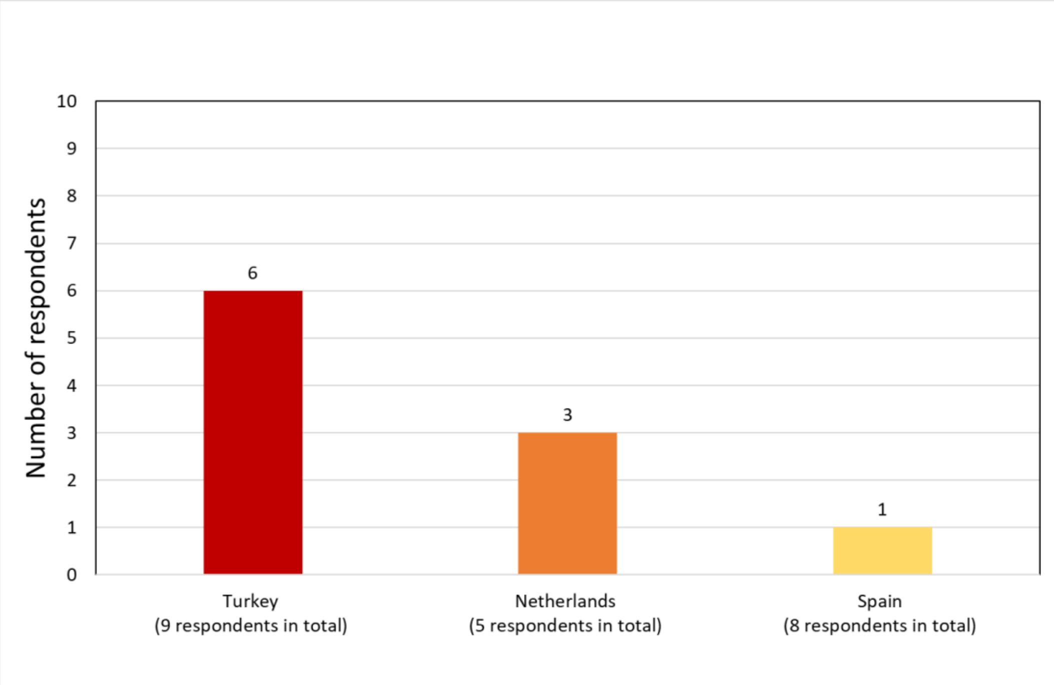

Figure 27: Respondents who replied that they had come in contact with the tablet during the pilot demonstration and scored the tablet under 52 (poor) for each pilot.

2.9.1. Summary of focus groups and observations about improved safety and efficiency for FRs

SA is very important for decision-making in complex and dynamic environments. Today most FRs use radio communication or cell phones to exchange information if it is not possible to have face-to-face meetings. This is a good way to enhance SA because the FRs listen and get feedback directly about whether the message is received. Messages exchanged via text can be interpreted differently by different FRs.

The FRs felt that they are lacking needed capabilities because they cannot send images. Sending images can improve efficiency by allowing the receiver to read and interpret the image to suit their needs, rather than depending on the interpretation of someone else. Assessing a situation via radio or phone communication can be completely different if images are available as well.

It is important that the information exchange is fast and trustfully. The FRs think that a computer or tablet can steal attention from other things happening around them. The FRs can still pay attention to the surrounding environment when communicating through a radio or phone.

Some of the problems the first responders encountered during the pilots was coordination between the tasks and which team was doing which task. Other problems were about locating the victims and communicating risks to other FRs.

For example, in pilot 2 the FRs pointed out four main problems during the pilot:

- Insufficient information from the technology experts
- Coordination was chaotic/unstructured
- The number of victims at the location
- Clarity about which unit takes on which section

It could be observed that the FRs needed to discuss the coordination and location of victims several times and that some of the information that was exchange verbally between the FR teams led to some important facts being lost. Other observations were that the FR team seemed to prefer to let the technology partner explain what they could see on the drone image. One of the team leaders, after looking at the drone picture, used paper and pen to draw an overall picture of the site. This picture was used when discussing the situation.

2.10. Usability and SA discussion and conclusions

In all three pilots there were enough respondents to get valid overall results from the questionnaires. The end users had adequate experience and assigned roles during the pilots and the scenario and environment reflected a realistic context. The main objective of the pilots was not to evaluate usability and usefulness, so the set up emphasized testing the technical parts of the system. Therefore, the evaluation of usability and usefulness were done on an overall level and no detailed input has been evaluated.

The results from SUS clearly show in Figure 5, Figure 11, and Figure 17 that the usability of the ASSISTANCE platform, in its existing state, is not perceived as good[3] by the majority of the respondents. The comments about usability from the free-text fields in the questionnaire and from the focus groups confirm the results from the SUS analysis. One major usability issue is about the design of the user interface of the tablet, which in general terms is described as hard to navigate and enter information. It was described as cumbersome to send and receive messages with the tablet, and there is a risk that important messages could go unnoticed. Consequently, there is a need for further development work regarding usability. Note that the practitioners did not have sufficient opportunity to provide feedback to the developers of the tablets throughout the duration the project, except at the pilots, due to covid-related travel restrictions and increased workloads.

Recall that the technical readiness level (TRL) for the ASSISTANCE project is 6-7, which means that the ASSISTANCE tools are not yet fully commercialized. It can be difficult for

[3] Recall that a ”good” SUS score is above 72. Very few respondents scored the usability of the SA system above 72.

an end user to know exactly what can be expected of a product at TRL 6-7 regarding usability. This might explain the contrast in the result from the SUS and the results of the SA statements, where the SA statements indicate that the first responders found potential in using the system. The former can be seen as an evaluation of the product as it is, and the latter can be seen as an evaluation of the potential of the commercialized product (having satisfactory usability).

In addition, the pilots may have had an impact on the outcome. Disruption of the network caused delays in information exchange between the CR and tablets in the field. It can be difficult for an end user to ascertain which usability problems are due to the technology and are due to the circumstances of the pilot execution. It is not possible to extract this information from the answers of the questionnaire.

Moreover, the end users had limited possibilities to interact with the technology during the pilots. It was the mostly the technical partners who interacted with the ASSISTANCE tools in the CR. In the field it was the team leader who mainly used the tablet. However, in the "dry runs", which were carried out as a preparation for the pilot demonstration, most of the end users got the chance to get acquainted with the technology, although the focus was mainly on the tablet (in which information from the different ASSISTANCE modules was presented). Considering this, many of the respondents have had limited interaction with the technology prior answering the questionnaire, which could have affected their ability to provide high quality statements.

Even with these uncertainties, the usefulness for accomplishing the task goals trend to a more positive result than the SUS scores. Also, in a real situation, a new tool would not be used without having a very thorough training program and until the FRs trust the system fully. Trust is essential for SA and a new tool will not be accepted if it is not trusted (as commented by an end user). Time is also critical in most rescue scenarios.

In the first pilot in Izmir, Turkey, the results indicated that respondents from Turkey generally gave slightly higher scores than respondents from other countries in SUS, Endsley´s guidelines and task goals. All respondents from Turkey had experience of earthquakes. Different types of first responders specialise in different situations and may or may not see the same benefit from using the SA platform.

In all three pilots the statement “The ASSISTANCE platform made me aware of new situations”, had the highest mean and median value, compared to the other statements based on Endsley´s design guidelines.

When looking at the mean values from all pilots, the results are very similar and no clear conclusions can be taken from these results that a certain pilot had, for example, better results. Generally, first responder procedures are often very similar regardless of the incident scenario; this could be a reason why the results of all the pilots are so similar.

Some user interface updates had been done between the second and third pilots, in response to user comments during the tabletop exercise in Rotterdam. The tabletop exercise is a good example of how user input was implemented in the ASSISTANCE platform. These updates were appreciated by the users, although the questionnaire results from Spain did not show any major changes. Even if details are changed in the user interface, the general and overall experience of usability issues could remain the same since certain user needs have not been met. ISO 9241-11 states that usability is characterized by the user's needs and expectations and therefore it is of great importance that the user needs and expectations are gathered correctly in the earliest development phase. Valid user needs will also decrease the risks of guessing when developing the technology.

No other indicators have been found in the pilots that could imply any connection when it comes to respondent’s background (e.g. gender, service, country, experience) or pilot specific data (e.g. involvement in project, role, contact with different devices).

Caution should be used when implementing users’ comments and feedback without observing the user behaviours in planned usability tests because the behaviours and genuine user needs could differ from comments on a prototype. The user can rarely distinguish genuine needs and thoughts/comments about a product presented to them. If the ASSISTANCE platform is developed further, the questionnaires can be a way to measure changes and improvements along the way.

2.10.1. Continuous improvement of safety and efficiency

The results from the SA statements and comments indicate that the respondents found potential in the ASSISTANCE platform and could see the value of using the system to increase SA. The focus group discussion and observations during the pilots also indicate that technology such as the ASSISTANCE platform can improve the safety and efficiency of FRs.

A SA system could improve the problems discussed in Section 2.9.1. that the FRs encounter, such as insufficient information, coordination between tasks, locating victims and getting a clearer picture of the overall situation. Good usability is crucial for good SA and improved usability will most likely improve the SA as well.

There has not been an investigation of how the ASSISTANCE platform has or has not changed the FR´s usual way of working in the pilot scenarios. Observations and discussions with the FRs indicate that it is important to include this aspect. When introducing a new tool, it is important to investigate how the tool could or should change the way of working, for example it may be necessary to add new competence to the teams in the field and/or in the chain of command.

The fundamental concept of the system is considered to have potential. It is also considered valuable to have a system where you can work closely together with other types of FR organisations.

3. Tech/economic analysis

This chapter is devoted to an analysis of the economic aspects of purchasing and using the ASSISTANCE SA platform. There are two parts to this analysis: an estimate of the practitioner's potential willingness to pay for the SA platform and an assessment of the economic costs and benefits to society based on the use of the new technology compared with not using it. The background, approach, results and conclusions of these two aspects are presented and discussed separately in Section 3.2 and Section 3.1, respectively. A summary of the conclusions is presented in Section **¡Error! No se encuentra el origen de la referencia.**.

3.1. Willingness to pay assessment

3.1.1. Background for willingness to pay assessment

Each country, or even each FR organisation, could have a different set of rules about how they make large purchasing decisions. In some countries the emergency services may choose to form a group to conduct research about the best purchasing options for a specific type of equipment, or they may choose to make their decisions independently. Jurisdictions having authority (AHJ), for example the Swedish Civil Contingencies Agency, may require FR organisations to purchase or use specific equipment, such as a national dispatch system, to facilitate interoperability. The required equipment may be furnished by the AHJ, or the FR organisation may be required to purchase it. The process could be centralised for some items, e.g., expensive items, and decentralised for others.

There are usually different processes used for purchasing equipment, depending on the situation and the size and complexity of the equipment. For example, an expensive piece of complex equipment may need to be replaced because it is becoming too old. In this case, the planning process could take as long as a few years. Or the FR organisation may need to purchase new equipment to respond to new risks or responsibilities. Or the FR organisation may need to make a quick purchase to replace essential broken equipment. Although the purchase of an SA platform could be made under any of the above three scenarios, the usual scenario would probably be the first one, in which careful long-term planning is conducted.

New equipment can be purchased wholly upfront, such that the buyer pays for the entire piece of equipment (or SA system) before taking possession of it, and then is responsible for its maintenance and upgrades. Or the maintenance and upgrades could be included in a periodic fee paid to the manufacturer or a third party. Another option may be for the FR organisation to pay a one-time upfront fee and then lease or rent the equipment rather than own it outright.

The cost is sometimes connected to the number of people in the FR organisation's protection district so that smaller organisations can afford to buy the equipment. There may also be a cap on the cost so that larger organisations don't pay too much. The FR organisation might also be interested in participating in research to further develop the equipment in return for a reduced cost for using it and to ensure that the equipment is developed to suit their needs as much as possible.

For an SA platform that supports modules, such as the ASSISTANCE platform, there are some additional purchasing considerations. All or some of the modules may or may not be included in the upfront purchase price or the periodic maintenance and upgrade fees. The FRs may value the ability to choose the modules of interest and then switch modules at any time as their needs evolve, or at regular intervals.

Many FR organisations are required by law to go through a formal purchasing process for purchases totalling over an established monetary threshold. The steps in this process vary from country to country but generally follow this framework:

- The decision is made to purchase an expensive piece of equipment. Note that bigger items normally have service lives of around 10 – 15 years.
- Several specialists that have experience with the equipment form a team that will decide which features/functions they need and don't need, and they do research to find out what is available to purchase.
- The team of specialists (together with specialists from other FR organisations if they have joined forces) help determine the specifications. They consider the amount of money they can spend and whether the new item will enhance their capabilities enough to make it worth buying. It might be a whole new standalone item, or it might be something that can combine at least some of their existing separate systems into an improved system with better capabilities.
- For large purchases, the next step is to publish an open call for quotes. Normally the lowest offer that fully satisfies the requirement list for the item is chosen. This puts a lot of pressure on the quality of the specifications of the item.

3.1.2. Approach for willingness to pay assessment

It became clear during the first pilot focus group that it would not be productive to include questions about willingness to pay in the combined usability/usefulness/societal impact questionnaire that was given to the pilot participants because the people that participated in the pilots were usually not familiar enough with their organisation's purchasing processes.

A separate questionnaire was created for collecting information about practitioner willingness to pay for a SA system such as the ASSISTANCE SA platform.

This questionnaire was sent to the project partners with instructions to forward it to the most appropriate person within their organisation that understands the decision-making aspects of the purchasing process. In addition to the questions, which are listed in Section 3.1.3.1, a description of the ASSISTANCE platform and the modules was included for reference since the purchasing people were not always actively involved in the ASSISTANCE project. The consortium members were encouraged to interview their purchasing people so that they could answer or clarify any potential questions about the platform description.

Most of the practitioner partners responded to the questionnaire, the exception being MIR-PN, the national police in Spain. The cost evaluation activities were discussed at least briefly during each of the pilot focus groups and several interviews were conducted with individual practitioner partners to better understand their situation regarding willingness to pay for an SA system.

3.1.3. Results and discussion for willingness to pay assessment

The results of the willingness to pay assessment are presented as a whole (not per pilot) in Section 3.1.3.1, since the practitioner's willingness to pay is not tied to a specific pilot or type of FR organisation. Relevant comments collected during the focus groups and interviews are presented in Section 3.1.3.2.

Statistically, there are not enough responses in this assessment to make conclusions with acceptable certainty. The questions were not circulated beyond the ASSISTANCE consortium (with one exception) because the respondents needed to be quite familiar with the ASSISTANCE SA platform to be able to answer the willingness to pay questions, and most of the detailed information about the platform is not publicly available.

3.1.3.1. Questionnaire answers

The information collected is analysed below on a "per question" basis. The answers are bulleted. An analysis and/or discussion of each set of answers is provided in the "discussion" paragraph.

Question 1) What is the name and location of your organisation?

- Ambulance and Emergency Physicians' Association (AAHD, Ismir, Turkey)
- Agencia Valenciana de Seguridad y Respuesta a las Emergencias (AVSRE, Valencia, Spain)
- The Municipal Headquarter of the State Fire Service in Warsaw - Firefighting and Rescue Unit No. 6 (CNBOP[4], Jozefow, Poland)

[4] CNBOP interviewed a firefighting organisation to collect the questionnaire information.

- Gezamenlijke Brandweer, (GB, Rotterdam, The Netherlands)
- Södertörns brandförsvarsförbund (SBFF, Södertörn, Sweden)
- Räddningstjänsten Storgöteborg[5] (Gothenburg, Sweden)

Discussion:

Most of the ASSISTANCE practitioner partners answered the questionnaire, although some of them did not answer all the questions. There is an additional set of answers from Räddningstjänsten Storgöteborg, a large local fire and rescue service organisation with connections to RISE.

Question 2) What is your primary mission (firefighting, medical, police, etc.)?

- Medical
- Civil Protection / Forest Firefighting
- Firefighting, chemical rescue
- Firefighting (2x)
- Emergency services and preventive fire protection

Discussion:

Although MIR-PN did not answer the questions, some degree of police representation may be included in the answers from the partner who wrote "Civil Protection" in their primary mission. The respondents are heavily weighted toward firefighting.

Question 3) How many calls do you respond to each year, and roughly, what kind of calls?

- There is a single emergency number command centre. All the emergency calls received by this command centre. Daily 5000-6000 health calls and 800-1000 ambulance missions.
- 3 million calls per year. All kinds of urgency/emergency calls (112 service).
- On average there are 1 200 interventions yearly.
- 30 000 firefighting responses
- 12 000, Fire (forest, houses, cars etc…), Traffic (cars, train, ships), CBRNE, SAR, Medical (but not EMT), suicide and much more.

Discussion:

The range of number of calls is quite wide, from around 3 million for two of the respondents to around 1 200 for one respondent. At the high end of this range, the calls come into a central dispatch centre that covers a densely populated area. The types of calls are specific in two cases (emergency medical/ambulance and firefighting), but are much broader in the other responses, e.g., "all kinds of urgency/emergency calls" and

[5] This FR organisation is not part of the ASSISTANCE consortium. They were interviewed because they have close ties to RISE and wanted to help.

"Fire (forest, houses, cars etc…), Traffic (cars, train, ships), CBRNE, SAR, Medical (but not EMT), suicide and much more".

This highlights the need for flexibility in the way modules are included in the SA system. If an FR organisation has a narrow focus, they may not want to buy a system that includes a lot of functions that they won't use, and they also may place more value on the ability to use the system in conjunction with other FR organisations. Conversely, if an FR organisation has the need for a wide range of functionality, the SA system should be capable of providing it.

Question 4) How many citizens are in your protection district?

- Approximately 5 000 000 people (2x)
- There are approximately 110 000 people in the operational area.
- 1 200 000 people
- 800 000 people
- 860 000 people

Discussion:

These answers indicate that the number of people protected by the FR organisations in the ASSISTANCE projects varies by a factor of 50. This is important because the cost of the SA system may be difficult for smaller organisations to buy unless the cost structure is at least partially based on the number of people in the protection district.

Question 5) What kind of purchasing mechanism/requirements would apply for buying something like the above-described ASSISTANCE SA system?

- Public procurement by Ministry of Health if it is for ambulance use. Public procurement by Ministry of Interior if it is for command centre.
- Procurement Rules applicable to the Public Administration
- According to the Public Procurement Act from 11 September 2021 as a public entity, our organisation is obliged to obey above mentioned law when the purchase of equipment or services concerns the safety matters, it means that will be used during real operations that equals or exceeds 139.000 EUR. The other type of purchase of services or equipment that is not connected with safety issues as such, the valid threshold is 130.000 NET PLN. In that case we can mention buying equipment, on the one hand, for administration or, on the other hand, for redecorating purposes.
- Depending on the total costs in 4 years, a purchasing process must be started.
- This purchase would fall under the law of Public Procurement. That is because of the cost being more than approx. 40 000€ (over a three-year period).
- Either a yearly fee or buy it upfront.

Discussion:

Most of the responses indicate that a public procurement mechanism would be necessary to purchase the ASSISTANCE SA platform. Ordinarily, this process could be used either to buy the system upfront or lease it on a yearly fee basis.

Question 6) Can you make autonomous purchasing decisions, or do you make them as a team, or are you required to buy or use specific SA systems?

- We cannot make autonomous purchasing decisions. Public tender committee will make the purchasing decisions.
- We make them as a team.
- Every time when there are plans to provide different type of equipment or services, we are obliged to go through the whole decision-making process. Therefore, in that case there will be an analysis made by operational department in different provinces or at the national level, when there is a need to buy greater items of SA platform. When the positive decision is taken and depending on the predicted value, proper procedures are put into practice and the market is questioned about the best offer.
- We create a purchasing team to decide on the requirements.
- We can, as a fire service, make independent purchasing decisions. As of right now we do not have a government issued system.
- We form a team that makes a pre-purchase study for buying expensive equipment.

Discussion:

The answers range from no autonomy to full autonomy for purchasing an SA system, although most of the respondents would form a team to do the necessary research, write the specifications and make a recommendation.

Question 7) What kind of SA systems do you already have and how did you purchase them (buy upfront, rent, lease, freeware, other)?

- There is no properly working SA system. There were a few experimental systems but not working.
- Not exactly a SA system, but an integrated Communications and Emergencies Management System, which includes some equivalent functions or modules used by ASSISTANCE (Data & sensor management, GIS functions, messaging, resource location, security management, video visualization, advanced video fusion, routing module). It was bought upfront.
- We use the decision support system, that enable you to have a quick access to the information in question, how many capacities are on site, vehicles, rescuers, special equipment, any injured persons or calamities. Until now there is no system in use of that wide possibilities.
- We build the system internally.

- We use different systems for different capabilities. Some of the capabilities described in Assistance we do not have any system that can handle. Either because we did not know it existed or we do not see the need for it. It´s a mix of purchasing methods. Some are freeware, some are developed with us and a partner, some are leasing or web platforms with a monthly fee. We do not have a SA that I would call sufficient for our needs. Instead, we piece it together piece by piece in different systems.
- We have a system called Daedalus for administrative management that also provides maps and information that can be used while (and after) traveling to an incident. It can be expanded by adding modules. Most Swedish FRs have this system, which is bought on a yearly fee. We also have a system that tracks our vehicles (shows them on a map) so that it is easier to decide which resources to send to other incidents and optimize our response times, which is also bought on a yearly fee. We also have at least 1 drone that we bought upfront. We thought about buying a robot as a group with MSB and other fire brigades but didn't do it because the arrangement was too messy. Gas sensors (handheld). Radios.

Discussion:

With one exception, the respondents have existing SA systems that at least partially fulfil their needs. Purchasing a new SA system that can integrate existing systems or equipment is likely to be important to them. Their SA systems were bought or leased using virtually all possible purchasing mechanisms.

Question 8) ***How much money would you pay for the whole ASSISTANCE system as described above, including the modules? Please answer using each of the purchasing mechanisms below if possible. You can answer in ranges if you want (ex: 15 000 € - 25 000 €).***

a. Upfront purchase wholly owned by you, additional modules at extra cost
b. Upfront purchase, includes flat yearly maintenance fee and module upgrade cost
c. Start-up cost, then lease according to population in district, includes module upgrades, ceiling on the total cost for very large populations
d. Suggested other cost structure (explain it please)

- None of the options above, as we do not require the ASSISTANCE system
- The total cost of the system shouldn't exceed 47 000 EUR. We would prefer the **b** mechanism for the purchase.
- **a** (15k-20k), **b** (5k initial costs), **c** (5k initial costs)
- I don´t see **a** as an option. That is because you have a system that will be outdated shortly after implementation. But IF we were forced to buy at this mechanism, we would pay around 30 000-50 000€. For **b**, I would say the same amount as specified on **a**. The maintenance fee around 10 000€

(including support). For **c**: Depending on how seamless it integrates with other systems and our existing equipment 3 000-5 000€. If no new hardware is needed the cost could go up further. Another option could be a Basic or Premium subscription. One where you get the SA and one with SA and all modules. Buying the individual module here and there will create a problem for your support operations. (Oh, yes you need that module to do that thing in that other module and so on). Better to make them as bundles.
- We do not want to buy an SA system at this time.

Discussion:

For the whole system (including the modules) they are willing to pay 15 k€ - 20 k€, 30 k€ - 50 k€, or 47 k€ for it upfront (the **a** option), although there is a comment that this is not an optimal purchasing mechanism due to future obsolescence of the system. The most popular purchasing mechanism is the **b** option, and the respondents are willing to pay 47 k€ (total), 5 k€ as an initial cost, and 30 k€ - 50 k€ with a yearly maintenance/support fee of 10 k€. For the **c** option, 5 k€ as an initial cost, and 3 k€ - 5 k€. No one specified the per capita cost for this option, although there was suggestion to offer a Basic and Premium package and to bundle the modules.

Question 9) Which of the above cost structures would work the best for you?

- B (3x)
- Not applicable
- Based on experience we would rather buy according to option C. Option A and B tend to be costly when new upgrades come out or support is needed. “You” are no longer viewed as a customer once you have bought the system. We would rather have the subscription to still have an ongoing customer relationship.
- Either buying it upfront or on a yearly fee.

Discussion:

Option **b** was the most popular answer. One respondent would consider the **a** option, however, there was a concern expressed in the Question 8 answers about obsolescence when purchasing a system with the **a** option and that both the **a** and **b** options are vulnerable to the problems of losing status as a customer after the system is purchased.

Question 10) Would you be interested in providing input on the continuing development of the SA system (new modules) by working with the developers in exchange for a cost reduction? If so, how much of a cost reduction?

- Yes, our committee would be interested in providing input. No idea for cost reduction.
- No

- If there is a such possibility, this idea is attractive because enable us to tailor the system to our internal requirements and reduce the costs of the system in total.
- Of course. Because we test the system in practice and thereby improve the system, the recurring costs (at cost price) are acceptable.
- In the "old days" that is how we financed most of our systems. In exchange for input to the developer we got a "free-copy" of the system. That was kind of unproductive since it made us emotionally attached to "our" system. Furthermore, we did not budget for a cost for the system since it was "free" so when we wanted to break free it would raise the cost significantly. With that being said if the developer organizes a workshop or so once a year for end-users, we would be interesting in participating and deliver our input as well as getting a lesson in the latest developments of the system.
- We do not want to buy an SA system at this time.

Discussion:

Most of the respondents were interested in having a role in the further development of the SA technology for two reasons: to be able to influence the development to better suit their specific needs, and to get a discount or free use of the system. Being able to use the system at the cost price was acceptable to two respondents. One respondent warned that it is possible to become financially dependent on keeping the system when involved in this type of arrangement.

Question 11) Assuming that you already have the main SA platform, how much would you pay for the individual modules? (as either a monthly fee or an upfront cost)

a. Chemical hazards tool
b. Damaged asset location and routing
c. Hostile drone neutraliser

- CHT (upfront cost), Damaged asset location and routing (upfront cost), Hostile drone neutraliser (not interested)
- None of the options above, as we do not require the ASSISTANCE system
- CHT – approx. 5 000 €, DAL&R – 1 000 €
- CHT – 10 k€, DAL&R – 1 k€, Hostile drone – 4 k€
- We do not want to buy an SA system at this time.

Discussion:

The respondents are willing to pay between 5 k€ and 10 k€ for the Chemical hazards tool (CHT), 1 k€ for the Damaged asset location and routing module (DAL&R), and 4 k€ for the Hostile drone neutraliser. They were most interested in the CHT and DAL&R.

Question 12) Would you prefer any of the core capabilities to be offered as modules instead of having them already included in the SA platform? If so, which ones?

- Yes, we prefer to buy modules.
- It would be interesting that all the core capabilities were offered as modules with possibility of integration with systems in use.
- The frontend needs to have a better way of working. AI is needed for developing a good system.
- The Drone swarm for improved network coverage module seems more like add-on module to me and not one of the core ones. That could also apply to the robot management module**.** I think the group of customers (right now) for those to modules is small. At least in my country where those kinds of resources would be on government level and not owned by the local Fire service.
- We do not want to buy an SA system at this time.

Discussion:

The respondents indicate that they would like most or all the major functions of the SA system to be modularised so that they have more control over which functions and capabilities they can select.

Question 13) If you could add any of the core capabilities or modules to your current system, which (if any) would you choose?

- Chemical hazard tool, Data & sensor management, GIS functions, Messaging, Resource location, Security management, Video visualisation, Advanced video fusion.
- Using a drone to measure pollution would have been interesting a year ago, but now we already have such equipment. The same goes with the module to predict the spread of chemical/toxic clouds. Other solutions, such as an interceptor drone, do not seem necessary today, especially in the Fire Department.
- Maybe the Chemical Hazmat Tool but we already have something like this.
- I would say that the first 7 modules (Data & sensor management, GIS functions, Messaging, Resource location, Security management, Video visualization, Advanced video fusion) would be a great addition to the dispatch system that we have today. The routing module would also be a great addition.
- We like the resource location function, the advanced video fusion, and the chemical hazard tool. For a system like this, it would be best to have all the functionalities be optional, so that practitioners can choose the ones they want.

- Our conversation showed that they could be interested in training with the use of VR, but VR platforms would have to be directly adapted to their assumptions and needs[6].

Discussion:

The CHT is the most popular module, but many of the other modules and functions are also interesting to the respondents, e.g., Data & sensor management, GIS functions, Messaging, Resource location, Security management, Video visualisation, and Advanced video fusion.

3.1.3.2. Input from focus groups and interviews

Regarding interoperability, it is desirable to have an SA platform that can easily interface with the existing systems used by the FR organisations so that they do not need to change everything at the same time and because some of the existing systems might be required by the AHJ. Ideally, a new SA system would be able to combine the data from the required systems and make it better.

In Sweden there are around 290 fire and rescue organisations that each do their own purchasing separately. In recent years there has been a trend for them to join forces and make large purchasing decisions together; this way they have critical mass to influence the development of the products. SBFF has had some experience working with software developers to create systems from the ground up, but the results were not great.

Currently, the FRs in the Stockholm area work the same way but they have different SA systems. When they upgrade their SA system, they want everyone to use the same system. They want a system that can follow the action of the front lines and share information all the way up to central management. They currently have 3 – 4 systems that work on different levels of the incident command chain. This is seen as an inefficiency.

Existing commercial SA systems often target a specific level or function in the incident command chain. There are not many systems that combine the whole chain from the front lines and back. SBFF wants this; they want a system that is scalable (can zoom out for the bigger picture or zoom in to see the details of ongoing or historic incidents). This would help them be more effective in their decision-making process and provide better service to the citizens. They don't want the system to make the decisions, at least not yet, but suggestions would be welcome. Information about the consequences of their options (at the different levels of the command chain) would be very useful.

---

[6] This comment is not relevant to the ASSISTANCE SA platform, however, it is included here because it is useful information for the AR/MR/VR training platform developers.

3.1.4. Conclusions of willingness to pay assessment

The cost or fee structure of the SA system should be set up to easily accommodate a public procurement process, since most FR organisations would probably buy it in this manner. Most of the respondents prefer to buy the system upfront with a yearly maintenance and support fee, although adjusting the price to meet size of the FR organisation (per capita cost) is seen as a good option.

The SA needs of the respondents varied widely, most of them already have SA systems that at least partially fulfil their needs. They prefer that the platform is capable of interfacing with their existing systems and equipment, especially in cases where they are required to use specific systems by their AHJ. Purchasing flexibility with respect to the platform and its core capabilities and modules is important because of the wide range of SA needs. However, bundling the interdependent modules may be necessary so that the system functions properly.

The respondents indicated that they are willing to pay 15 k€ - 50 k€ to buy the SA system upfront as a one-time cost. They prefer to buy the system upfront but include an annual maintenance and support fee of up to 10 k€/year. Leasing the system for a cost tied to the number of citizens in their protection district was an option, but only the initial cost of 3 k€ - 5 k€ was provided in the answers. Most of the respondents were interested in becoming involved in the development of the SA system to influence its suitability for their needs and to get a discount on the price.

When asked which core capabilities should be offered as modules, the respondents preferred to have all the core capabilities/functions/modules as separate items that could be chosen when they purchase or upgrade their system. They are willing to pay 5 k€ - 10 k€ for the CHT, 1 k€ for the DAL&R, and 4 k€ for the Hostile drone neutraliser. When asked which of the core capabilities or modules they would buy to use with their existing systems, the CHT was the most popular choice. Others include the Data & sensor management, GIS functions, Messaging, Resource location, Security management, Video visualisation, and Advanced video fusion.

3.2. Economic costs and benefits to society

The assessment of the techno-economic costs and benefits to society will be referred to as the cost-benefit assessment (CBA) part of the analysis in the following text. The cost part of the analysis is represented by the willingness to pay for a complete SA system (30 k€ - 50 k€) derived in Section 3.1.3.

3.2.1. Background for CBA

No research was found in the literature that specifically addresses the societal costs and benefits of FRs using advanced SA systems. Weinholt provides a brief review of some studies about the importance of response time in terms of societal damage expressed as life savings, serious injury reduction and damage to property and the environment [23]. Most of these studies found a positive relationship between shorter fire and rescue service (FRS) and/or ambulance response times and reduced societal damage [24, 25, 26, 27, 28, 29]. Some of the studies found a positive relationship for some types of societal damage, but not others [30, 31] and some studies did not find any relationship between response time and societal damage [32]. It is therefore reasonable to conclude that the societal costs associated with FR response time are complex and dependent on many factors, e.g., type and size of incident, amount and type of response resources, vulnerability of affected civilians and surroundings, population density, ease of access to the incident site, etc.

Response time is often used as the measure of societal impact when planning the location of first responder and medical care facilities, but there may be measures other than time savings that could be used to analyse the societal costs and benefits of using advanced SA systems. The practitioner partners had no suggestions when asked if they were aware of other measures that should be considered.

CBA is a systematic approach for making decisions, e.g., about whether a project or product is worth its cost [33]. There are other methods of assessing the value of a product or service, such as lifecycle costing (LCC), however, CBA is very scalable and flexible, and the concept is generally well understood, so CBA is the method chosen for this analysis.

3.2.2. Approach for CBA

There are numerous procedures for conducting a CBA, depending on the available information and the nature of the decision(s) to be taken. An approach based on a simplified use of the Guide to Cost-Benefit Analysis of Investment Projects [34] is used for this analysis, consisting of these basic steps:

1. Define context and objectives
2. Define assumptions
3. Identify costs of solution
4. Identify benefits of solution
5. Quantify costs and benefits

3.2.2.1. Define context and objectives

This CBA is intended to determine whether the cost of the ASSISTANCE SA platform outweighs the benefits of using it. The response to an incident can be broken into various time intervals. For the purposes of this study, the time intervals of interest are shown in Figure 28. The reasons these time intervals were chosen for this analysis are: because the ASSISTANCE SA platform is capable of reducing the response time by alerting FR about the best route to take to the incident; the SA system can also contribute to the reduction of operational time by several means, for example, aiding FRs in finding the source of the problem or victims faster; finally, the SA system can provide routing guidance for evacuating victims to the closest hospitals or other care facilities.

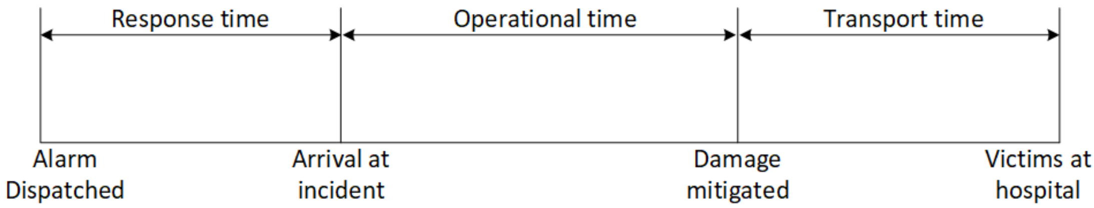

Figure 28: Time intervals used in this analysis.

3.2.2.2. Define assumptions

Several large assumptions were necessary to conduct this assessment; therefore, the results have a high degree of uncertainty and should not be used conclusively. The assumptions are as follows:

- The local modelling methods used to determine the unknown variables (b and s in equation 1) for the calculations in equations 1 and 2 can be generalised to adequately represent the entire European Union (EU) and the timeline shown in Figure 28.
- Using only the VSL, rather than including injuries and damage to property and the environmental in the benefits calculations is an acceptably conservative approach.
- The ASSISTANCE SA platform is capable of being expanded enough to cover an entire earthquake, industrial accident or terrorist attack incident.
- The risk of death at a fire incident is similar to the risk of death at an earthquake or terrorist attack incident.

3.2.2.3. Identify costs of solution

The costs of the solution are summarised in Section 3.1.4.

3.2.2.4. Identify benefits of solution

The possible benefits could be expressed in monetized terms of reduced death and injuries and reduced damage to property and the environment. Given the difficulty of finding data about damage to property and the environmental as a function of time, and the relatively large value of a statistical life (VSL), the benefits are expressed only in terms of the value of lives saved.

3.2.2.5. Quantify costs and benefits

The range of 30 k€ to 50 k€ is used as the cost of the full ASSISTANCE SA platform, including all the modules, is used in the analysis.

Ideally, a time baseline would have been established during the early part of each pilot week in which the FRs became familiar with the location, the non-ASSISTANCE tools and equipment at their disposal, and the best procedures for working together in newly formed teams. The baseline would provide an estimate for the time it takes to perform the pilot tasks without using the ASSISTANCE technology. This approach was attempted during the second pilot; however, it was not possible to clearly measure the time needed to perform the tasks because of interruptions in the activities and adjustments made to the tasks to accommodate all the participants.

Determining the time to perform the pilot tasks using the ASSISTANCE SA platform was likewise not possible because of difficulties with the network connection between the tablets used in the field and the SA platform used in the control room.

In lieu of a direct time comparison to determine the incremental time savings of using the ASSISTANCE SA system, the results are presented in terms of the necessary increment of time saved to compensate for the cost of the system.

The approach by Jaldell [29] and Sund [35] to estimate the value of incremental time savings in first responder performance is used in this analysis. The total damage (risk of death) is given by:

$$D(i,j) = \sum_{t=1}^{N} \left(\frac{b_{i,j,t}}{POP_i}\right) \times I_i \times s_{i,t} \qquad \text{Equation (1)}$$

Where D is the damage associated with the incident, N is the number of time intervals, $b_{i,j,t}$ is the population in region i reached by the FRs in time t, POP_i is the total population of the protection district, I_i is the annual number of incidents (in this case earthquakes, industrial accidents or terrorist attacks), and $s_{i,t}$ is the average damage per incident at time t.

First, it is necessary to predict the total time needed for first responders to arrive at the location of all the citizens within their protection district, perform their tasks, and transport the victims to a hospital (variable b). Jaldell and Sund did this using a global information system (GIS) modelling package applied to a city in Sweden. They were only looking at the response time in their studies so a factor of three was used for this analysis to include the operational and transport times. The function for this b is shown in Figure 29, scaled to the population of the EU in 2021.

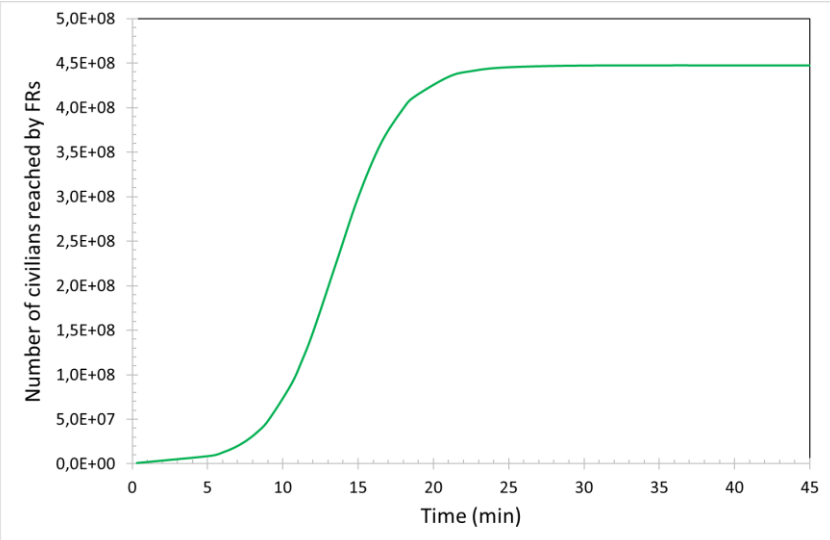

Figure 29: Time function for FRs to reach, rescue and transport victims to a hospital. Scaled from Sund [35].

Next, an estimate of the risk of death due to the incident (variable s) is needed. Sund compared three equations for s that produce relatively higher, middle, or lower values for s. The equation chosen for this analysis is the one that consistently produces the middle values for s compared with the other equations:

$$s_{i,t} = \frac{e^{\alpha+\beta\times\ln t}}{(1+e^{\alpha+\beta\times\ln t})^2} \quad \text{Equation (2)}$$

Where α and β are empirical constants for fire events: α = -6,013 and β = 0,2408. It is assumed that α and β are also representative values for earthquakes, industrial accidents and terrorist attacks. The function for s is shown in Figure 30.

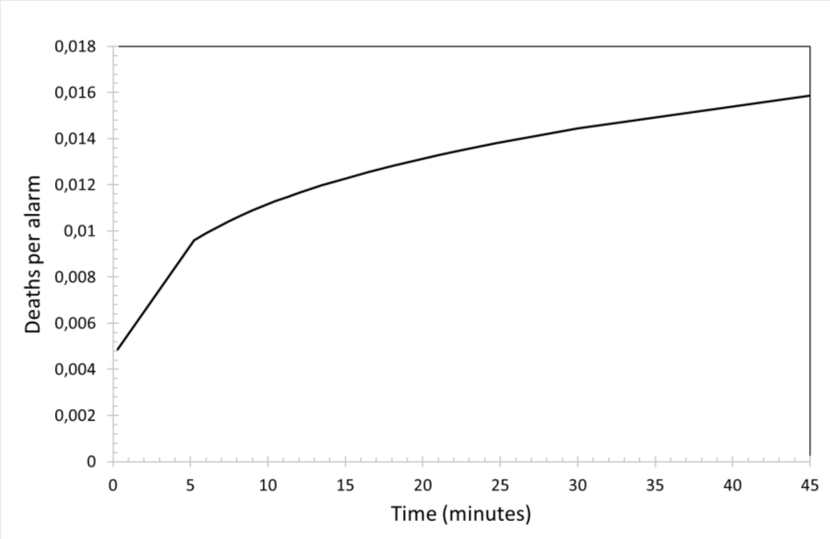

Figure 30: Time function for the risk of death at an incident.

Finally, the results of equation 1 are multiplied by the VSL to determine the benefit of using the ASSISTANCE SA platform in terms of incremental time saved during the response. The values for the constants in equation 1 and the VSL are listed in Table 5.

Table 5: Constant descriptions and values for Equation 1.

Constant	Description	Value
N	Total number of time periods	21
i	Incident type	Earthquake, industrial accident, or terrorist attack
j	Combined emergency resource	Medical, firefighter, police
I	Annual number of incidents	2[7], 25[8], 57[9]
POP	Total population in protection district	447700000 people in EU in 2021[10]
VSL	Average value of a statistical life in EU	3835524[11]

3.2.3. Results and discussion for CBA

The results of the quantification of the benefits of using the ASSISTANCE SA platform are presented in Figure 31. Note that since the same functions were used for all three

---

7 Average number of earthquakes measuring 6 or higher on the Richter scale during the past 90 years. See https://www.volcanodiscovery.com/earthquakes/europe/largest.html)

8 See https://environment.ec.europa.eu/news/industrial-accidents-commission-report-shows-improvement-preventing-major-accidents-involving-2021-09-29_en

9 See https://www.consilium.europa.eu/en/eu-response-to-terrorism/#group-section-Facts-and-figures-ZTQd0BwPwu

10 See https://european-union.europa.eu/principles-countries-history/key-facts-and-figures/life-eu_en

11 Original value was 3371000 dated 2011, adjusted for inflation to 2021 value. For VSL see http://old.heatwalkingcycling.org/index.php?pg=requirements&act=vsl&b=1#:~:text=If%20not%20known%2C%20use%20the,%2D27%20countries%20plus%20Croatia). For inflation adjustment see https://www.in2013dollars.com/europe/inflation/2011?endYear=2021&amount=100.

incident types, the curves have the same shape, but are scaled according to the annual number of incidents. The most critical time savings with respect to saving lives occurs in the 3 to 6 minutes range and the curves tend to flatten out over longer times. Long incremental time savings imply longer overall time for response, operational and transport times. The flattening of the curves may be an indication that for longer times more victims would have died regardless of how quickly they arrive at a hospital. Very short incremental time savings, less than about 1 minute, are important but not as likely to make a big difference in victim survivability as the 3 – 6 minutes range. This is probably because most of the activities during the response take several minutes to perform, so 1 minute or less is not as significant as longer time increments.

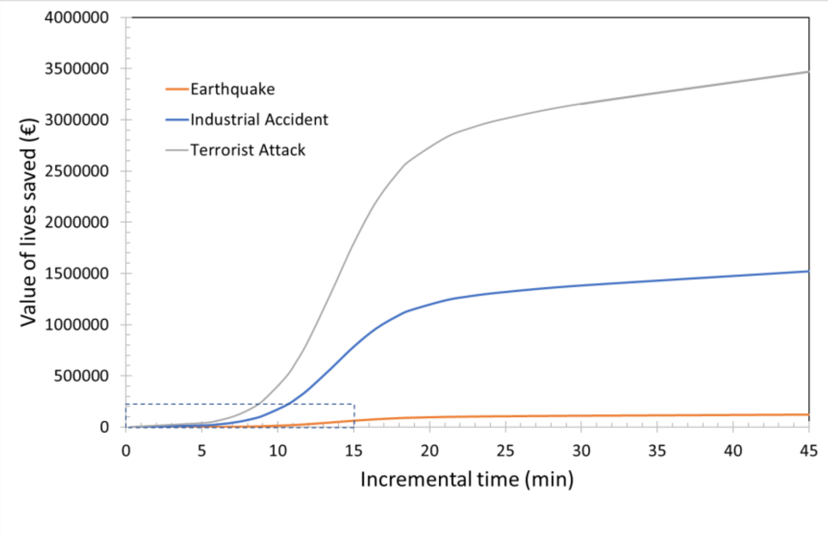

Figure 31: Value of lives saved as a function of incremental time.

The CBA results are shown in Figure 32, which is a blow up of the area of Figure 31 enclosed by the dashed box.

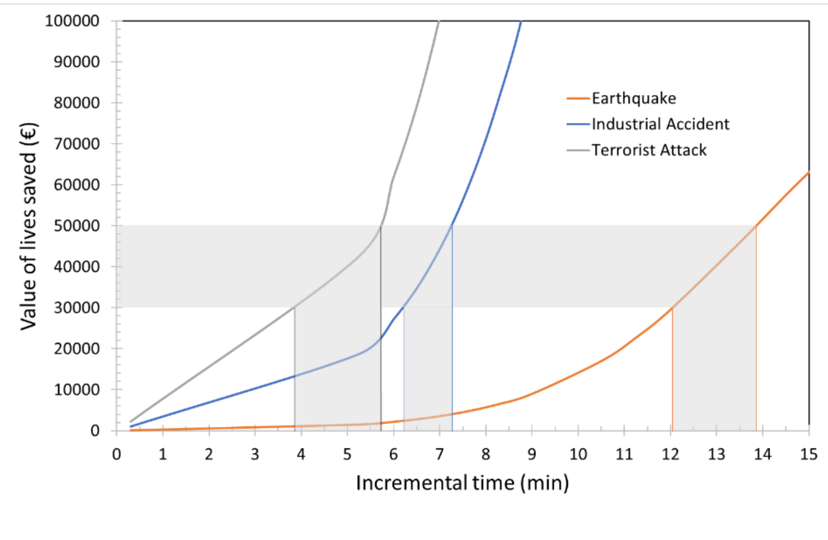

Figure 32: CBA results for earthquake, industrial accident, and terrorist attack.

The results in Figure 32 show that, for the cost range of 30 k€ - 50 k€ (indicated by the horizontal grey band) the incremental time savings for earthquakes is about 12 – 14 minutes. In other words, if the ASSISTANCE SA platform can provide an incremental time savings of at least 12 minutes (shown as the left edge of the vertical grey bars under each curve) then the cost of 30 k€ is compensated by the benefit to society. Likewise, if the SA system can save at least 6 minutes during industrial accident responses the benefits will outweigh the cost of 30 k€. For terrorist attacks, the threshold for an SA system costing 30 k€ is an incremental time savings of at least 4 minutes. The values for an SA system costing 50 k€ are indicated by the right edge of the vertical grey bars under each curve.

3.2.4. Conclusions of CBA

The practitioner partners of the ASSISTANCE consortium provided the range of acceptable costs for the CBA, which was 30 k€ - 50 k€ per system. Making some rather large assumptions, it is possible to estimate the benefits of using the ASSISTANCE SA platform by modelling the time of the response and the risk of death at an earthquake, industrial accident or terrorist attack.

The results show that, if using the SA system can provide approximately 4 – 14 minutes of saved incremental time during the response, depending on the cost of the system and the type of response, it will be economically beneficial to society.

4. Summary of conclusions

The results from SUS clearly show that the usability of the ASSISTANCE platform, in its existing state, is not perceived as satisfactory by most of the respondents. The comments about usability from the free-text fields in the questionnaire and from the focus groups confirm the results from the SUS analysis. Note that the practitioners did not have sufficient opportunity to provide feedback to the developers of the tablets throughout the duration the project, except at the pilots, due to covid-related travel restrictions and increased workloads.

The results from the SA statements and comments, however, indicate that the respondents found potential in the ASSISTANCE platform and could see the value of using the system to increase their SA.

When analysing the results from the questionnaire, recall that the TRL for the ASSISTANCE project is 6-7, which means that the ASSISTANCE tools are not yet fully commercialized. It can be difficult for an end user to know exactly what can be expected of a product on TRL 6-7 regarding usability. This might explain the contrast in the results from the SUS and the results of the SA statements.

The problems the FRs encountered during the pilots were, for example, insufficient information, coordination between tasks, locating victims and getting a clearer picture of the overall situation. A system that could help FRs solve these kinds of problems could improve the efficiency and safety of FRs. The fundamental concept of the system is considered by the FRs to have this potential. It is also considered valuable to have a system where different FR organisations can work closer together.

The cost-benefit results show that, priced at 30 k€ - 50 k€, if using the SA system can provide approximately 4 – 14 minutes of saved incremental time during the response, depending on the cost of the system and the type of response, it will be economically beneficial to society.

Annex 1: Tech/economic questions for demonstration pilot participants

Cost evaluation (used at the Rotterdam pilot[12])

Your answers to the following questions will help us estimate the costs of damage to humans (life and injuries), property and the environment when comparing your *normal* response (as you did on Monday) with your response *using the Assistance tools* (as you did on Friday).

Do you feel that you learned the technology well enough this week to provide a reasonable estimate of the time saved/not saved?

○	Yes
○	No (if No, skip to end of questionnaire)

Compared with your response on Monday, did the *overall ASSISTANCE situational awareness system* allow you to perform your duties more quickly today?

○	Yes, it took a faster time today (Friday)
○	No, it took a slower time today (Friday)
○	It took about the same amount of time on both Monday and Friday
○	I didn't use the situational awareness system on Monday or Friday
○	I don't know

If it took a faster or slower time, approximately how much less/more time? Give your answer in minutes, please.

[Free text answer ______________]

Which part of the *ASSISTANCE situational awareness system* do you feel was most valuable to your overall response?

☐	The mission management module
☐	The damaged assets location and routing module
☐ ☐ ☐ ☐ ☐	The chemical hazards tool Drone deployment Robot deployment Realtime measurements Creation of new zones

[12] The tech/economic questions for all pilots were essentially the same, although the schedule of each of the pilots was slightly different. The Rotterdam pilot had baseline exercises on Monday and the actual pilot was scheduled for Friday. This schedule changed due to weather, so the questionnaire was given to the participants on Thursday instead.

☐	Visualisation of data/images/video from various sources
☐	I didn't use the situational awareness system in the pilot
☐	I don't know

Compared with your response on Monday, was there a difference in the time required to *keep first responders safe* when using the *overall ASSISTANCE situational awareness system* today? This includes, for example, *evaluating whether areas are safe to conduct rescue operations and monitoring first responders in dangerous environmental conditions or physical stress situations.*	
○	Yes, it took a faster time today (Friday)
○	No, it took a slower time today (Friday)
○	It took about the same amount of time on both Monday and Friday
○	I didn't use the situational awareness system on Monday or Friday
○	I don't know

If it took faster or slower time, approximately how much less/more time? Give your answer in minutes, please.

[Free text answer ______________]

Compared with your response on Monday, was there a difference in the time required to *rescue victims* when using the *overall ASSISTANCE situational awareness system* today? This includes, for example, *locating victims, safely transporting victims, securing evacuation routes.*	
○	Yes, it took a faster time today (Friday)
○	No, it took a slower time today (Friday)
○	It took about the same amount of time on both Monday and Friday
○	I didn't use the situational awareness system on Monday or Friday

If it took faster or slower time, approximately how much less/more time? Give your answer in minutes, please.

[Free text answer ______________]

Compared with your response on Monday, was there a difference in the time required to *secure the area* when using the *overall ASSISTANCE situational awareness system* today?

This includes, for example, locating fires and gas leakages and evaluating their impact, checking and monitoring the plant, transformer and tank.	
○	Yes, it took a faster time today (Friday)
○	No, it took a slower time today (Friday)
○	It took about the same amount of time on both Monday and Friday
○	I didn't use the situational awareness system on Monday or Friday
○	I don't know

If it took faster or slower time, approximately how much less/more time? Give your answer in minutes, please.

[Free text answer _____________]

Annex 2: Questions for willingness to pay assessment

Your organisation:	
1)	What is the name and location of your organisation?
2)	What is your primary mission (firefighting, medical, police, etc.)?
3)	How many calls do you respond to each year, and roughly, what kind of calls?
4)	How many citizens are in your protection district?
Your purchasing method(s):	
5)	What kind of purchasing mechanism/requirements would apply for buying something like the above-described ASSISTANCE SA system?
6)	Can you make autonomous purchasing decisions, or do you make them as a team, or are you required to buy or use specific SA systems?
7)	What kind of SA systems do you already have and how did you purchase them (buy upfront, rent, lease, freeware, other)?
Your cost evaluation of the ASSISTANCE system:	
8)	How much money would you pay for the <u>whole</u> ASSISTANCE system as described above, including the modules? Please answer using each of the purchasing mechanisms below if possible. You can answer in ranges if you want (ex: 15 000 € - 25 000 €). a. Upfront purchase wholly owned by you, additional modules at extra cost b. Upfront purchase, includes flat yearly maintenance fee and module upgrade cost c. Start-up cost, then lease according to population in district, includes module upgrades, ceiling on the total cost for very large populations d. Suggested other cost structure (explain it please)
9)	Which of the above cost structures would work the best for you?
10)	Would you be interested in providing input on the continuing development of the SA system (new modules) by working with the developers in exchange for a cost reduction? If so, how much of a cost reduction?
11)	Assuming that you already have the main SA platform, how much would you pay for the individual modules? (as either a monthly fee or an upfront cost) a. Chemical hazards tool b. Damaged asset location and routing c. Hostile drone neutraliser

12) Would you prefer any of the core capabilities to be offered as modules instead of having them already included in the SA platform? If so, which ones?
13) If you could add any of the core capabilities or modules to your current system, which (if any) would you choose?

References

1 McNamara, N., & Kirakowski, J. (2006). Functionality, usability, and user experience: three areas of concern. interactions, 13(6), 26-28.

2 ISO 9241-11:2018 Ergonomics of human-system interaction – Part 11: Usability: Definitions and concepts (2018) https://www.iso.org/standard/63500.html

3 Nielsen, J. Usability Inspection Methods, Conference Proceedings, CHI '94 – "Celebrating Interdependence", Boston MA, 1994.

4 Endsley, M. R., Bolstad, C. A., Jones, D. G., & Riley, J. M. (2003, October). Situation awareness oriented design: from user's cognitive requirements to creating effective supporting technologies. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 47, No. 3, pp. 268-272).

5 Gutwin, C., Greenberg, S.: The importance of awareness for team cognition in distributed collaboration (2001) http://grouplab.cpsc.ucalgary.ca/grouplab/uploads/Publications/Publications/2004-WATeamcognition.APABook.pdf

6 Salmon, P., Stanton, N., Walker, G., & Green, D. (2006). Situation awareness measurement: A review of applicability for C4i environments. Applied ergonomics, 37(2), 225-238.

7 She, M., & Li, Z. (2017, July). Team situation awareness: A review of definitions and conceptual models. In International Conference on Engineering Psychology and Cognitive Ergonomics (pp. 406-415). Springer, Cham.

8 Sapateiro, C., & Antunes, P. (2009, May). An emergency response model toward situational awareness improvement. In International conference on information systems for crisis response and management, Göteborg, Sweden. https://www.researchgate.net/profile/Pedro-Antunes-25/publication/228807131_An_emergency_response_model_toward_situational_awareness_improvement/links/0912f5088449f14e62000000/An-emergency-response-model-toward-situational-awareness-improvement.pdf

9 Van de Walle, B., Brugghemans, B., & Comes, T. (2016). Improving situation awareness in crisis response teams: An experimental analysis of enriched information and centralized coordination. International Journal of Human-Computer Studies, 95, 66-79.

10 Endsley, M. R., Bolstad, C. A., Jones, D. G., & Riley, J. M. (2003, October). Situation awareness oriented design: from user's cognitive requirements to creating effective supporting technologies. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 47, No. 3, pp. 268-272).

11 Potter, S. S., Woods, D. D., Roth, E. M., Fowlkes, J., & Hoffman, R. R. (2006). Evaluating the Effectiveness of a Joint Cognitive System: Metrics, Techniques, and Frameworks. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 50, 314–318.

12 Endsley, M. R., Hoffman, R., Kaber, D., & Roth, E. (2007). Cognitive Engineering and Decision Making: An Overview and Future Course. Journal of Cognitive Engineering and Decision Making, 1(1), 1–21.

13 Grier, R. A. (2015). Situation awareness in command and control. In R. R. Hoffman, P. A. Hancock, M. W. Scerbo, R. Parasuraman, & J. L. Szalma (Eds.), The Cambridge handbook of applied perception research, Vol. 2, pp. 891–911). Cambridge University Press. https://doi.org/10.1017/CBO9780511973017.053

14 Redish, J. G. (2007). Expanding usability testing to evaluate complex systems. Journal of usability studies, 2(3), 102-111.

15 Marusich, L. R., Bakdash, J. Z., Onal, E., Yu, M. S., Schaffer, J., O'Donovan, J., ... & Gonzalez, C. (2016). Effects of information availability on command-and-control decision making: performance, trust, and situation awareness. Human factors, 58(2), 301-321.

16 Nurse, J. R., Creese, S., Goldsmith, M., Craddock, R., & Jones, G. (2012). An initial usability evaluation of the secure situation awareness system. http://idl.iscram.org/files/nurse/2012/176_Nurse_etal2012.pdf

17 Endsley, M., and Selcon, S., Designing to Aid Decisions through Situation Awareness Enhancement, Conference proceedings, 2nd Symposium on Situation Awareness in Tactical Aircraft, Patuxent River, MD, 1997. https://www.researchgate.net/profile/Mica-Endsley/publication/210198488_Design_and_Evaluation_for_Situation_Awareness_Enhancement/links/56426c3c08aebaaea1f8e86f/Design-and-Evaluation-for-Situation-Awareness-Enhancement.pdf

18 Brooke, J. (2013). SUS: a retrospective. Journal of usability studies, 8(2), 29-40. https://uxpajournal.org/wp-content/uploads/sites/7/pdf/JUS_Brooke_February_2013.pdf

19 Bangor, A., Kortum, P. T., & Miller, J. T. (2008). An empirical evaluation of the system usability scale. Intl. Journal of Human–Computer Interaction, 24(6), 574-594. https://www.tandfonline.com/doi/pdf/10.1080/10447310802205776?needAccess=true&cookieSet=1

20 Brooke, J. (1996). SUS: A 'quick and dirty' usability scale. In P. Jordan, B. Thomas, & B. Weerdmeester (Eds.), Usability Evaluation in Industry (pp. 189–194). London, UK: Taylor & Francis

21 Tullis, T. S., & Stetson, J. N. (2004, June). A comparison of questionnaires for assessing website usability. In Usability professional association conference (Vol. 1, pp. 1-12). https://www.researchgate.net/publication/228609327_A_Comparison_of_Questionnaires_for_Assessing_Website_Usability

22 Bangor, A., Kortum, P., & Miller, J. (2009). Determining what individual SUS scores mean: Adding an adjective rating scale. Journal of usability studies, 4(3), 114-123. https://uxpajournal.org/wp-content/uploads/sites/7/pdf/JUS_Bangor_May2009.pdf

23 Weinholt, Å, and Granberg, T., New collaborations in daily emergency response, International Journal of Emergency Services, v4, n2, p177-193 (2015) http://dx.doi.org/10.1108/IJES-01-2015-0002

24 Jayaraman, S., Mabweijano, J., Lipnick, M., Caldwell, N, Miyamoto, J., Wangoda, R., Mijumbi, C., Hsia, R., Dicker, R., and Ozgedis, D., First things first: effectiveness and scalability of a basic prehospital trauma care program for lay first-responders in Kampala, Uganda, PLoS ONE, v4, n9, p1-7 (2009)

25 Geduld, H., and Wallis, L., Taxi-driver training in Madagascar: the first step in developing prehospital emergency care system, Emergency Medicine Journal, v28, n9, p794-796 (2011)

26 Scholten, A., van Manen, J., van der Worp, W., Ijzerman, M., and Doggen, C., Early cardiopulmonary resuscitation and use of automated external defibrillation by laypersons in out-of-hosptial cardiac arrest using an SMS alert service, Resuscitation, v82, n10, p1273-1278 (2011)

27 Mattsson, B., and Juås, B., The importance of the time factor in fire and rescue service operations in Sweden, Accident Analysis and Prevention, v29, n6, p849-857 (1997)

28 Jaldell, H., Lebnak, P., and Amornpetchsathaporn, A., Time is money, but how much? The monetary value of response time for Thai ambulance emergency services, Value Health, v17, p555-560 (2014)

29 Jaldell, H., How Important is the Time Factor? Saving Lives Using Fire and Rescue Services, Fire Technology, v53, p695-708 (2017) DOI: 10.1007/s10694-016-0592-4

30 Challands, N., The relationships between fire service response time and fire outcomes, Fire Technology, v46, p665-676 (2010)

31 Lu, L., Peng, C, Zhu, J., Satoh, K., Wang, D., and Wang, Y., Correlation between fire attendance time and burned area based on fire statistical data of Japan and China, Fire Technology, v50, p851-872 (2014)

32 Särdqvist, S., and Holmstedt, G., Correlation between firefighting operation and fire area: analysis and statistics, Fire Technology, v36, n2, p109-129 (2000)

33 Layard, R., and Glaister, S., Cost-Benefit Analysis, Cambridge University Press, Cambridge, MA (1994)

34 Guide to Cost-Benefit Analysis of Investment Projects, Economic appraisal tool for Cohesion Policy 2014-2020, European Commission Directorate-General for Regional and Urban policy, (2015) doi:10.2776/97516

35 Sund, B., and Jaldell, H., Security officers responding to residential fire alarms: Estimating the effect on survival and property damage, Fire Safety Journal, v97, p1-11, (2018) https://doi.org/10.1016/j.firesaf.2018.01.008