D3.10

Analysis of Human Factor Involvement in the use of Autonomous Systems in DRR and Response and Specifications for User Requirements – Issue 3

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List of Acronyms

DRK	Deutsches Rotes Kreuz (German Red Cross)
EMS	Emergency Management Service
EKUT	Eberhard Karls Universität Tübingen
EUW	End-user Workshop
GUI	General User Interface
HCI	Human-Computer Interaction
HFE	Human Factors and Ergonomics
IT	Information Technology
THW	Bundesanstalt Technisches Hilfswerk (German Federal Agency for Technical Relief)
VOST	Virtual Operations Support Teams
WP	Work Package

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Executive Summary

This deliverable is the third and final issue on Human Factors involvement in disaster management systems.

In this issue a summary of the Human Factors theoretical framework and the full list of Human Factors requirements identified as important for HEIMDALL are provided. The Human Factors previously introduced in [7] and [8] are summarised and reflected within the context of new empirical data collected through interviews and questionnaires.

The deliverable, firstly, outlines the Human Factors field of study and the consequences of a Human Factors analysis for the design and development process of the HEIMDALL system.

Secondly, it provides an explanation of the methodology used to conduct fieldwork and gather empirical data, the qualitative interviews and questionnaires, and the subsequent analysis to identify requirements, arguments and concerns related to Human Factors and HEIMDALL.

This is followed by an overview of the Human Factors requirements identified as important for HEIMDALL through both, desk-based [7], and empirical research [8] throughout the project. Several new human factor requirements are introduced which were identified since [8].

Finally, the issue closes with the complete and updated list of Human Factors requirements for HEIMDALL in the Annex (Chapter 7).

1 Introduction

This is the final issue on three deliverables devoted to Human Factors involvement in disaster management systems, and part of T3.4. This task is dedicated to the analysis of the interaction between end-users and other stakeholders and the HEIMDALL system. In this regard, the results refer to features of human-machine interaction in technical and social terms in order to increase the acceptance of the HEIMDALL system. This task, in turn, comprises two different aspects, Human Factors, covered by deliverables [7], [8] and the edition at hand, and social and ethical aspects of human-machine interaction, which are part of [9], [10] and [11]. As explained in [7], [8], and reproduced here, Figure 1-1 shows the relationship between a more technical and a more social perspective of human-machine interactions as well as acceptance and acceptability.

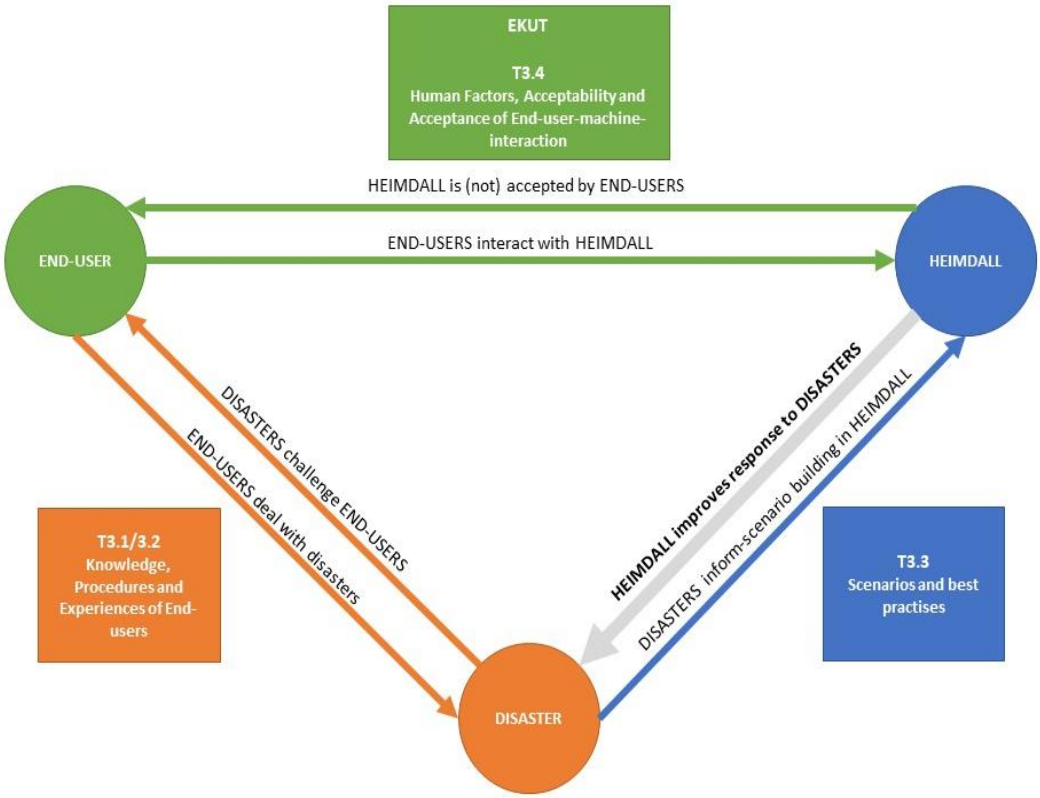

Figure 1-1 The role of WP3 in HEIMDALL (own compilation)

References [7] and [8] introduced Human Factors as the research field devoted to study different aspects of human-machine-environment interaction, including psychological, physical, cognitive, environmental, social, organisational and other contextual conditions [1]. Together with the corresponding emergent properties of any socio-technical system, they influence the overall working conditions, outputs and impacts of the human-machine-environment interaction. In other words, the objective of Human Factors is to optimise work environments and reduce mistakes, for example with regard to the physical design of a technology, the clarity of user interfaces, or preventing the overloading of individual capacities.

Applied to the HEIMDALL system, the objective of the Human Factors analysis outlined in [7] has been to identify conditions to support those professionals involved in managing an

emergency and their situation awareness. Those topics were translated into specific requirements for the design of the system, which were stated in [7] as preliminary specifications to be further developed during the empirical work, a first part of which has been presented in [8]. In this vein, this deliverable presents the combined results of the literature review, interviews, questionnaires and general observations throughout the project duration on the role of Human Factors for HEIMDALL.

The first part (chapter 2) of this deliverable provides a short summary of the literature on Human Factors and their importance for HEIMDALL's design. Chapter 3 outlines the methodology used for gathering data as well as the methods used for evaluating the empirical information.

Chapter 4 presents the main findings of evaluating all the data gathered throughout the project with respect to Human Factors, their operationalization as human factor requirements including a number of new ones that were added based on empirical observations, and their implications for the development and use of the system. Given the interconnectedness, overlaps and trade-offs involved with many of the human factors identified for HEIMDALL, this section is structured in six thematic clusters, focussing on (1) Access, usability and training; (2) language, communication and culture; (3) flexibility, productivity and integrity of data; (4) feedback, trust, security and responsibility; (5) responsibility, transparency, and autonomy; and, finally, (6) availability and affordability. The complete and updated list of Human Factors requirements for HEIMDALL can be found in the Annex (Chapter 7).

Due to some overlap between the results of the empirical work done on Human Factors and societal acceptance and ethical acceptability ([9], [10], [11]), some of the issues identified in the focus groups' analysis are also presented here.

The deliverable closes with some concluding remarks and some recommendations on Human Factors requirements which should be taken into account for the final design and future development of the HEIMDALL system.

2 Human Factors

Following [7] and [8], human factor issues arise in every domain where humans interact with the products of a technology-driven society. As sociotechnical systems and their interactions are becoming more and more complex, the need for understanding and improving these interactions becomes equally more significant [3]. The study of Human Factors, sometimes also referred to as the discipline of Human Factors and Ergonomics (HFE) [2], aims to provide a tool for unravelling these complexities of socio-technical systems by studying the knowledge, perceptions, attitudes, values and goals of people working with technology, and their interactions with elements of sociotechnical systems, as well as with the wider environment of the system ([3]: 528, cf. [5]: 15-16). Following an ecological approach to Human Factors, human operators and their work environment are reciprocally coupled ([20]: 55), and human and system effectiveness, safety and efficiency are viewed as interlinked ([19]: 84). This integrated understanding of socio-technical systems builds on the idea of interaction as a way of recognising the emergent properties of human-machine development processes ([21]: 2).

These emergent properties are significant for systems in real use, as users are not only able to compensate shortcomings and unexpected behaviour of the system, but also create new uses for it ([21]: 8-9). These effects were observed and reported in [8]. Therefore, as [8] highlighted, human factor analysis should include the emerging properties of the interaction with the ecological, economic, legal and socio-political context. As all mentioned aspects of human-machine interaction are intertwined and taking place in a specific environment, technological interventions should further take into account the co-production and co-evolution of humans, technology and environment (cf. e. g. [20]). Based on the premise that “system performance, safety, and satisfaction can be improved” ([15]: 527) by optimising technology design for human use, the study of human-machine interaction offers the opportunity to analyse the safety, productivity, human satisfaction, efficiency, effectiveness and estimation of human error that corresponds to each particular context [1].

In the context of HEIMDALL, the term Human Factors refers to understanding the connections between the individual and their working conditions, the type of activities performed, the division of functions, tasks and responsibilities and the interaction with colleagues, technologies and the broader environment. Following [7] and [8], this implies comprehending the organisational culture of specific working spaces and modes of decision-making, as well as the ways division of labour, workloads’ assignment, and communication between humans and technology are organised.

To identify Human Factors as important for HEIMDALL, it is vital to understand the context of disaster management processes, in which the system is being implemented. Disaster management is a decision-making scenario where operators “are faced with the assessment and prioritization of a large number of conflicting courses of action and the pressing need to take difficult trade-offs (e. g. ethical, technical, cost-benefit) for selecting and assigning often very scarce resources in response to overwhelming humanitarian crises.” ([16]: 122)

Therefore, disaster management operators require fast and precise information to communicate and act quickly under conditions of extreme stress [4]. In this context, HEIMDALL aims to support emergency services in their tasks by providing the right information at the right time in the right format to the right person [2]. To facilitate organisational coordination among end-users´ organisations, the system integrates a wide range of support tools including autonomous systems (satellite-, sea-, land- and air-based) from different agencies to be used by a large variety of stakeholders (firefighting units, medical emergency services, police departments, civil protection units, command and control centres) in a variety of emergencies (forest fires, landslides and floods).

In order to provide such support, a thorough Human Factors analysis has been undertaken both through desk-based research and empirical work. Core points to take into account for the

design of the HEIMDALL system based on a Human Factors perspective are presented in chapter 4.

3 Methodology

3.1 Introduction

In order to develop a systematic catalogue of Human Factors specific for the development of HEIMDALL, empirical research methods were applied to complement and further develop the insights from the literature review undertaken in [7][6] for the HEIMDALL context. These empirical results have provided insights into the specificities of humans interacting with the HEIMDALL system beyond the general Human Factors identified in the literature in [7]. The empirical work also aimed to examine the practical experience and specific knowledge of the end-users to incorporate their perspectives into both the Human Factors and the research on ethical issues and societal acceptance (see [9], [10]).

For this end, a total of 27 qualitative interviews (3 more than the 24 planned in the Grant Agreement) were conducted in order to gather opinions and attitudes towards different aspects of human-machine interaction, including but not limited to automation, transparency, usability, language and communication style. 14 interviews were conducted with HEIMDALL end-users, and 13 with other relevant actors. From all interviews, one has been provided via email, 6 have been conducted via skype, and the remaining majority face-to-face.

In addition to the interviews, three rounds of questionnaires were conducted in the context of the end-user workshops (EUW) at each release[1]. While these questionnaires were not initially planned in [7], they were introduced to capture the effects of the emergent nature of a system development process. Subsequently, they have proven beneficial for identifying user requirements and to support and further specify Human Factors as relevant for HEIMDALL. On the one hand, the new user requirements were added to the corresponding deliverables after each EUW. On the other hand, participants' insights provided new perspectives in order to collect and analyse data: reasons supporting why a requirement was or was not fulfilled, reasons for a new requirement, and in general, ideas and suggestions for new HFs or their further specification. The resulting mixed methods design hence allowed for a more comprehensive and complete understanding of Human Factors for HEIMDALL.

Mixed methods designs are generally applied when qualitative and quantitative methods are combined in a single study to address a phenomenon from different epistemological angles simultaneously ([13], [17]). In this case, the broadening of the methodology has proven useful to combine the more qualitative insights from the interviews, which provided a deep and contextual understanding of individual experiences and situations, and the more standardised insights gained from the questionnaires, which allowed for a more generalisable and theoretically grounded picture of Human Factors for HEIMDALL.

Furthermore, relating to the participatory approach to the design of the HEIMDALL platform, many reflective discussions over different understandings of certain terminology, needs and requirements took place at consortium meetings, telephone conferences and training sessions over the course of the project. From both this frequent exchange among the consortium and from observing end-users´ interactions with the platform, it was possible to gather further insights with regard to human factors and user requirements which are also reflected in the presentation of our empirical findings in chapter 4.

[1] One last questionnaire will be conducted at the occasion of the final demonstration for the purpose of gathering long-term user requirements which will be documented in [6].

3.2 Interviews

Two groups of interviewees have been selected based on their connection with the following distinction: (1) End-users, on the one hand, (2) experts and other relevant actors with respect to the field of disaster management in the EU, on the other.

The first group comprised members of the end-user organisations that are partners in the consortium, as well as further potential end-users not involved in the HEIMDALL project. With 14 interviews conducted with end-users, this category has made up the majority of the studied group. This has proven advantageous with regard to identifying Human Factors for HEIMDALL, as both potential end-users and those who were able to test the system throughout different stages of the development, could assess, evaluate and formulate with precision what they did and did not like about the system, how it meets the requirements of their organisational and regional context and where potential conflicts might arise.

The second group included scientific experts (e. g. in technology and engineering, geological and seismic risks), representatives of public institutions involved in disaster relief, experts in disaster/emergency medicine, and representatives of environmental agencies involved in disaster relief actions. Based on a reference in the Grant Agreement to crowdsourced data that could be understood as the platform being connected to a broader community of possible affected actors, this group was initially planned to include actors not directly related to disaster management. However, throughout the project it became apparent that this is not the case, as the platform´s use is in fact limited to end-user organisations. Therefore, we turned the focus of this second group towards interviewees who are experts in the field of disaster management, but who are not end-users, in order to complement the end-users´ perspectives with some more broad and contextual expertise. These interviews were particularly insightful with regard to more general societal questions, questions of implementation, and expertise regarding specific use cases.

The interviews were carried out in a variety of physical places including at the premises of the institutions organising HEIMDALL's project meetings, at the premises of the end-user organisations, and a few at the International Centre for Ethics in the Sciences and Humanities of the University of Tübingen, Germany. In addition, several interviews were conducted via Skype and one via email exchange.

In all the cases, the interviews were conducted as semi-structured expert interviews, following the general rule for guided interviews: "as open as possible, as structured as necessary" ([12]: 560). In order to address the specific research interests central to our research and to obtain comparable results, the interviews were structured along a number of guiding questions, covering the main topics of interest and providing space for additional upcoming questions as well as for spontaneous interventions by the interviewees. Even though the principle of openness was thereby limited to the aspects targeted by this questioning route, the questions were formulated in a rather open way. This gave the interviewers the option to adjust them to the current interview situation in terms of language, mode of expression of the interviewees and the amount of information already obtained by previous questions.

Interviewers were aware and reflective of the fact that it is impossible to fully avoid any influence on the interviewees' answers due to the dynamic and interactive nature of communication, the different roles within the interview situation and the resulting power relations between interviewer and interviewee (see [12]) and the way the interviewees were addressed in terms of their knowledge and experience. Furthermore, interviewers were also aware of the difficulties that some interviewees found when holding a discussion in English and offered the possibility to express themselves in their native language wherever possible.

The questioning route was structured in three parts [12]. At the beginning of the interview, the interviewees were invited to express their views as freely as possible. These questions aimed to establish a trustful atmosphere and a comfortable situation and covered mainly the personal experiences of the interviewees in their field of expertise. Subsequently, the interviews

focussed on the main topics of interest and provided space for the interviewees to direct their attention and answers on those topics. In the second part, the questions focused on aspects that were not covered by the desk-based literature review about Human Factors requiring specific fact-based information. In the final part, further questions were asked based on the inputs from the first and second part, including the interviewees' personal judgement on topics emerging from the conversations.

As explained in [8], prior to each interview the interviewees received the informed consent form, including a copy to keep, and, where necessary, the project information sheet.

The anonymity of the participants and the confidentiality of the analysis of the interviews was guaranteed throughout the research process. After the interviews were conducted, the audio files were stored in an encrypted container and transcribed by members of EKUT. Names and any other identifying information about the participants were removed and thus anonymised.

The transcriptions of the interviews were evaluated following the same method used for the focus group discussion, the descriptive-reductive content analysis method (see [14]: 183 et seq.). The objective was to identify and to summarise the main contents and arguments, increasing the density of the information by reducing the data volume. The final result was a list of arguments delving into the reasons for the Human Factors identified and presented in [7], [8] and in this deliverable, as well as new aspects to be taken into account for the development of HEIMDALL.

3.3 Questionnaires

In addition to the interviews, three rounds of questionnaires were conducted at the three end-user workshops (EUWs) organised along each release of the platform –and one more is planned for the final demonstration. Although neither stated in the Grant Agreement nor originally planned, the consortium considered these surveys extremely valuable for understanding end-users´ experiences while trying out the system and evaluating the implementation of user requirements at each release. EKUT as the partner with expertise in social science methods volunteered to develop the questionnaires and analyse the data gathered after each EUW. Moreover, this presented itself as an opportunity to collect additional inputs in terms of Human Factors, either as new ones or as further arguments supporting already identified ones.

The questionnaires for each EUW were prepared by members of EKUT based on previous research and input from the consortium. The questionnaires contained roughly between 40 and 70 questions distributed across several thematic sections, broadly following the storyline of each workshop. There was a mix of specific questions requiring the participants to choose among predefined answers or rate from 1 to 5 whether they liked and were able to use a functionality, and open-ended questions where they could enter their own thoughts and additional remarks.

Before handing out the questionnaires at each session, members of EKUT explained to the participants the aims and formalities of the questionnaire and why their participation was so valuable. The informed consent forms were handed out, signed and returned by the participants before the start of the session. The participants also received a copy to keep and, if desired, a project information sheet.

To analyse the questionnaires, a combination of qualitative and quantitative methods was used. To give a clear overview of which functions were already working well and which ones were liked better than others, these results were depicted in pie or similar charts. Thus, for example, it was recorded that from EUW 2 to EUW 3, end-users moved from 30% liking the GUI to 60%. Even though the analysis of the quantitative data is not part of this deliverable, each EUW's questionnaire raw data was shared with all the members of the consortium and the main results were presented at the HEIMDALL project meetings. On the other hand, the answers to the open-ended questions were evaluated by qualitatively assessing and

summarising the data. The results were provided to the consortium to contribute to overall improving the platform, identifying new and very specific user requirements, and utilised within the context of our work on Human Factors as presented within this deliverable.

Regarding the last survey planned for the final demonstration of the system, the nature and content for this questionnaire will be subject to further considerations in relation to the structure of the final demo under the conditions of the COVID-19 pandemic. To account for the possibility of a partly or entirely virtual event, the questionnaire will be designed in an online format. Considering that the development of the system within the scope of the HEIMDALL project will be concluded at the time of the rescheduled final demo, the questionnaire will likely focus on questions aimed at end-users´ opinions and preferences with regard to aspects such as the business model and the implementation and acceptance of the platform.

4 Empirical Findings

As outlined above, the aim of this final issue of the series of deliverables on Human Factors analysis within HEIMDALL is to summarise and contextualise all the requirements presented previously in [7] and [8], to present several new ones, and to complement previous descriptions by adding further insights obtained through our empirical work. The following chapter provides a refined and condensed account of the sum of empirical findings on Human Factors for HEIMDALL.

4.1 Human Factors requirements identified as important for HEIMDALL

Given the interconnectedness, overlaps and trade-offs involved with many of the Human Factors identified for HEIMDALL, and to avoid repetition, in this chapter each Human Factor is not listed separately. Instead, they are presented along six thematic clusters which were identified as core themes for HEIMDALL. They include (1) Access, usability and training; (2) language, communication, cultural differences and standardisation; (3) flexibility, productivity and integrity of data; (4) feedback, trust, security and responsibility; (5) responsibility, transparency and autonomy; and, finally, (6) availability and affordability. References to Human Factors requirements have been woven into the text wherever suitable and detailed descriptions of each requirement are provided in the Annex. Hence, following the outlined structure, this chapter aims to provide a broad and exhaustive overview of the role Human Factors play for the platform.

4.1.1 Access, usability and training

As explained in [7], the main point guiding a Human Factors analysis of any system supporting disaster management, as is HEIMDALL, is the context of application. Unlike other types of systems, HEIMDALL is to be used during an emergency, an exceptional situation in which individuals require information to act quickly under conditions of extreme stress. In this context, the HEIMDALL system aims at facilitating organisational coordination among many actors, integrating a wide range of support tools including autonomous systems (satellite-, land- and air-based) to be used by many different stakeholders (firefighting units, medical emergency services, police departments, civil protection units, command and control centres) in a diversity of incident scenarios or use cases (forest fires, landslides and floods).

As end-users both belonging to the HEIMDALL consortium and from other organisations have stressed throughout the development process, ease of use is one of the main requirements of such a platform. To summarize their opinions, it should be intuitive, easy to access, filtering information according to the needs of the user, and providing fast results: “It has to be intuitive, it has to be easy to access […] and provide some results quite fast” (Firefighter, Denmark). Or, as another interview put it, it should be

> “*user friendly and very easy to be used [so that] with five minutes of introduction you can start using [it]. Of course, then like a car, you can use it basically or you can use it for a driving competition but at least for the driving of the car, you need to start driving very very quickly (Firefighter, Director Coordinator, Italy).*

However, universal usability is quite a complex issue. As end-users differ in their expertise, knowledge, roles in the organisational structure, and technology they use, the system should be designed to take into account these differences in order to be efficient and productive to a variety of users and organisational contexts. In this vein, HF_1, HF_2, HF_3, and HF_4, operationalised different aspects of this usability requirement.

In terms of technology, HF_1 (The system shall be designed for different types of end-users and the different equipment they use) emphasises that different end-users rely on different kinds of equipment, which implies that the system should be developed in such a way that a variety of end-users’ operational equipment might be used to access vital information (cf. [1]:

55). Restricting the use of the platform to specific kinds of equipment or end-users, on the other hand, would pose discriminatory and potential legal issues as well as undermine the very objective of the platform. For example, based on experience in cross-border cooperation, an expert in communication technologies supporting disaster management organisations highlighted the fact that supporting local hardware solutions for storing data was key for enabling successful collaboration:

> *"It was very important that the servers for the solutions are on the side of the users, so we don't have anything in our area. Nothing in the cloud, nowhere. It is in the IT centres of Slovenia and of Friuli Venezia Giulia, because they want to have control over it, and need to have control over it. It makes it more complicated for us to maintain it and to support them. One is using a virtual machine, the other one is a real server. And now, how to back up the real server? How to get all the - how to get it maintained, they have different Linux versions. Not only versions, but also different Linux types. One is Ubuntu, the other one is a distribution of another one. It makes it more difficult, but this is life, you cannot tell them to choose another one, it does not work (laughs). (Research and Technology Projects Manager, Luxembourg)*

Moreover, it was observed that while desktops and laptops are common to all end-user organisations, they differ greatly in models, operative systems and installed software, and as consequence with respect to the support that they can provide. Additionally, it was mentioned that smartphones, tablets and whiteboards were being used more frequently, as they were perceived as flexible and handy to communicate in the field and to freely draw a picture of the situation in the control room. A more specific observation made at one of the training sessions highlighted that the visualisation of interfaces should be optimised for different screen sizes and resolutions, so that the frame and quality of the information displayed is the same for each user, regardless of different screen sizes, resolutions, brightness, contrast and size of font in the devices used.

It was further stressed that particularly the simulation modules rely on high computing power and thus the effort required to run them might exceed the use of their results in an ongoing incident:

> *"That depend. (laughs). Because I've worked a bit with these simulations and it's very heavy data processing. That means that a simulation can last up to twelve to fourteen hours depending on your computer power, as you know. And if we have to get some operational use of this in the situation, then it has to be fast, accurate and reliable." (Firefighter, Denmark)*

Throughout the interviews and end-user workshops, end-users emphasised the added value HEIMDALL could offer in terms of gathering data from different sources. But in order to make accessible a variety of data to different end-user organisations that use different technologies, the system needs to take into account these differences. The empirical work has shown that the landscape of software-based assistance systems currently in use is very diverse and different organisations have different abilities and limitations as to which types of data they can use and to what purposes they use this kind of software (gathering data, decision support, documentation, training, etc.) [8].

In addition, end-user organisations are composed by members of different age groups, with different knowledge and expertise. To develop a system with such diversity of end-users is a challenge that can be addressed by a platform's ability to flexibly adjust to this variety. To this end, following [8], HF_2 (The system shall be designed to take into account different kinds of end-users in terms of different expertise, different knowledge and different positions in the organisational structure) focuses on access levels and interfaces that allow all end-users to access vital information without barriers. As previously mentioned, this means avoiding limitations such as a system developed for a specific technology, but also designing simple interfaces, and reducing the information load according to the role/user profile, see HF_10.

Moreover, HF_3 (The system shall be designed for different types of end-users having special needs (hearing-, speaking-, visual-, mobility impairments) to be able to insert, access and use the information) further specifies the universal usability of a platform such as HEIMDALL, in order to be an asset to a variety of end-users and organisations. End-users have different

capabilities and may have special needs with respect to hearing, speaking, seeing and/or reading, or moving. For example, a member of the HEIMDALL consortium repeatedly mentioned that due to their dyschromatopsia, which is a fairly frequent visual condition impairing the ability to distinguish between red and green colours, they have difficulties distinguishing symbology coloured accordingly.

Finally, HF_4 specifies that the system should also enable all end-users to access vital information regardless of different mental capabilities. This is, for one, a matter of communication style. For example, end-users stated that data and information ought to be comprehensible across different levels in the organisational structure, and, in case of external cooperation, among different organisations. Along the same lines, it is also a question of language and terminology (see chapter 4.1.2). Hence, the platform should provide information in ways that are simple and easy to understand. Following the insistence of end-users that the platform needs to be very simple and intuitive to use:

> *"[a] main requirement to the system would be that it should be easy to use. So, ease of use. Because, especially in context of the THW, because we don´t deal with these kinds of operations every day. And not everyone of us, either. And consequently, we may not have the experience of dealing with such systems." (Dispatch, THW, Germany, own translation)*

These comments also point towards the insight, that any of the challenges with regard to the usability of the platform – or in fact, any software – can be mitigated by offering to its users the necessary training and learning time, as stated in HF_9. The degree to which the platform can speed up and enhance operational procedures depends upon the ease of practitioners in using it. Understandably, training was a topic frequently mentioned by the end-users. According to them, in order to be successfully implemented, HEIMDALL will have to account for a period of learning and becoming accustomed with the system. While several end-users emphasised in general that simplicity was key to enable the ease of use of the platform, it was also stated more specifically that training was important because the kinds of incidents currently intended for the system to be applied seldom occur: "It's not something that you would use at every incident because, to be honest with you, a lot of our incidents are very generic." (Firefighter, Scotland). Hence, frequent training was considered key, "because we won't use it every day. Maybe, when we have these consequences, it is [a] one in a hundred years accident or at least ten years accident where you have these consequences. So, it is not that common that we would use it. Once a year […]" (Firefighter, Denmark). Especially the simulators were considered useful assets for training and preparedness for specific incidents:

> *"So, you can see, the simulation part being great for training. In addition to that, if there was a risk within a specific national park within Scotland, that was a priority to protect and we're concerned about wildfires, it would be ideal for continuous personal development for crews to maintain that scale of what they're going to do, where the access points are, where's this fire likely to develop at different times of the year. If you set a fire here, where it would go to. So, that type of tool would be excellent for them. So, for two parts, for training but also experienced individuals working within that area who want to pre-plan and equip themselves for an emergency happening within a specific area" (Firefighter, Station Officer, Scotland).*

Additionally, some interviewees also highlighted the value of the system in terms of enhancing end-users' general training, and as such enable a better crisis response: "I think the most useful part of those platforms is to help all the system to have better training and consequently, better plans. […] So […] the people that will make and take decisions will be able to take decisions, even with few data and uncertainty, which is a typical way that we take decisions" (Firefighter, Italy).

The training sessions hosted by end-user organisations from the consortium and involving other external end-users have provided good examples for the value and significance of such trainings. Documentation, online- and offline help can support in dealing with unforeseen circumstances or account for memory loss. Moreover, in order to account for the possibility that the system is used only for specific cases, an intuitive design that allows for fast learning

and easiness to recall after a period of non-use can contribute to reduce errors and foster trust in the system.

4.1.2 Language, communication style, cultural differences and standardisation

The previous considerations on the usability of HEIMDALL for different kinds of end-users, also point to differences in terms of language, communication style and cultural differences, as well as processes of standardisation.

One major concern of all the end-users was the availability of the system in different languages. End-users have stressed repeatedly that they would prefer to use the system in their native language for several reasons. For one, in order for the system to be used in specific and sometimes novel crisis situations, the availability of the tool in their native language can contribute to reducing the time it takes to get accustomed with the system, in order to use it productively and efficiently. Moreover, even though English is a common language on an international level, on a decision-making level and among high-ranking officials, most likely those working at a local/regional level will understand the system much better in their native language. Consequently, this was considered a must: “for the locals, this must be in German” (Expert, Austrian Geological Survey, Austria, own translation). This is particularly important because first responders in the field will likely communicate in their own language among themselves and with the control room:

> *“I think […] English is good for the management level, but if it's also used by first responders. So […] they need information in their language, of course. And I also think you have to […] think about the provision of information. So, if I am first responder and make pictures and- or explain something, mainly it will be in the language of the nation. So that means, yeah, English is good for the […] management level, but the provision from the information, […] it has to be translated into [German]” (Paramedic, Germany).*

This confirmed the impression that, while English may be useful on a high management level and for international cooperation, translations are required for the personnel on site:

> *“Some procedures, some information, which have [to be] shared among the firefighters or some things like that, need maybe a local language, it means the Danish language. But, on the other side, some things, by sharing information on different levels among, for example, department strategy, international department and management, top-level management and so, it could happen in English” (Firefighter, Denmark).*

Overall, under the stressful circumstances of an emergency situation a management tool that requires alternating to another language may provide an obstacle rather than a support, undermining the very objective of HEIMDALL. In this sense, interviewees emphasised that making the tool available in each language would contribute vastly to the acceptance of the tool:

> *“Of course, the acceptance is much bigger if you have it translated in all partner states’ languages. So, you really can reach the ground level, yeah, or the regional, local level. This would make your life easier, for sure. It is much more work, no question. So, it is the acceptance that’s for sure bigger” (Doctor, Germany).*

In other words, there is ample support for HF_5 (The system shall be designed considering translation, linguistic and cultural issues with regards to end-users), which aims to respond to the diversity of languages and cultures among different disaster management organisations across the EU.

On the other hand, language differences often provide a hurdle when it comes to cross-regional or cross border cooperation. For instance, a firefighter commander from Baden-Baden (Germany) explained that in spite of the goodwill of all involved they were having difficulties requesting a helicopter from Strasbourg (France), which was the closest location, due to bureaucratic and language obstacles. In contrast to incidents taking place at a local level or within the area of pre-established cooperation, for which procedures are already in

place, (new) cross-border cases are less common and might require the implementation of specific protocols, regulations, and/or agreed working procedures that might not be remembered as they occur less frequently. This impression was confirmed by the success story of sharing a helicopter in the case of the Northern Ireland-Ireland border, where such protocols are already in place and well known by the participating partners:

> *"Now, the Northern Ireland Fire and Rescue Service and the Irish Fire and Rescue Services, they've got a memorandum of understanding of what they do around the border. Sometimes, the closest- at a fire that could be, say, on the Southern, the Southern Irish side of the border, the nearest fire station could actually be in Northern Ireland and the Northern Ireland Fire and Rescue Service will respond to that incident. And it works the other way around. If there is an incident in Northern Ireland and the nearest fire station is actually in Southern Ireland. But through a local- an existing memorandum of understanding between the two organisations, they already [have] their data, whatever data is shared accordingly" (High Scientific Officer, North Ireland Environment Agency, North Ireland).*

Based on these experiences shared by interviewees and a subsequent consortium discussion, HF_20 (The user shall be able to see a pop-up notification with specific information about protocols, regulations and/or agreed working procedures of/with the respective country when creating a new scenario in case of a cross-border incident) was developed to further support users and facilitate cross-border cooperation with specific and helpful information provided by the system in order to speed up the process.

Incidentally, even if not due to a cross-border emergency, one core aim of HEIMDALL is the provision of fast data in order to free up time for other tasks and make emergency management processes more efficient. In contrast to other types of data, however, EO based data from Sentinel missions can only be accessed through authorised users of the Copernicus Emergency Management Service (EMS), requiring some time an effort to place such a request following the official process. Therefore, following HF_21 (The user shall be able to complete a form provided by the platform in order to request EO data to speed up the procedure for such request at the same time that fully complies with the official process and channels. The form should work as template for an e-mail that shall be transmitted through the official channels to the corresponding authority) the platform should provide a template for a form to request EO data, in order to speed up the procedure for such a request at the same time that it fully complies with the formal requirements. The form should also include explanatory notes, including steps to follow and persons to contact, and serve as a template for an email that shall be transmitted through the official channels to the corresponding authority. By providing this support, the time required to access EO data will be significantly reduced. Faster data means better up-to-date actions and therefore a better response to the ongoing disaster.

Furthermore, besides language, terminology and organisational differences were perceived as vital for successful cross-border cooperation:

> *"The communication between border, for example, or the comprehension of the terminology. That may be interesting because, if I have to cooperate with […] another country at my border, I need to know [how they] look organisational. Which is the same level of mine in my country? How is his name in the other country? Or maybe, they do not have that level. Maybe they have a lower level, or you need to interact with a higher level. So, this information is so important. Because if not, you try to prepare something that, ok, is good as a simulation game but is not tailored to the real actions" (Firefighter, Director Coordinator, Italy).*

Yet, they have also been mentioned when considering only one organisation, comparing countries and/or observing the diversity within a country. For example, a member of the Red Cross stated that even within their organisation, vast differences occurred across Europe: "Each national society [has] […] different skills and abilities" (Volunteer, Red Cross, Italy). A firefighter from Scotland emphasised the different administrative structures between European countries: "The structures in the UK are significantly different from those in Europe, mainland Europe. […] So, in Spain, for example, the police and fire[fighters] are run by the same ministry […] You have a number of different ambulance services across one country, whereas

in Scotland we have one. […] So, a lot of differences" (Firefighter, Local Senior Officer, Scotland). This view pertained also among experts in the field of disaster management which are not end-users themselves: "This is very difficult across the EU, because every country is structured quite heterogeneously. Especially considering their institutions" (Expert, Austrian Geological Survey, Austria, own translation). And finally, vast differences may occur even within one country:

> *"And unfortunately, in Germany, we have already 16 different laws, disaster laws – Katastrophenschutzgesetze. We have 16 different emergency – Rettungsdienstgesetze. We have 16 different police legislations. And this is already a big nightmare on our German, let's say, national level. How do we coordinate with different states? If there is a cross boarder - Because, you have to follow the rules and regulations in this country. And you just cannot say, because it's a disaster we skip all the laws and that's why it is a challenge itself" (Doctor, Germany).*

For this reason, it was emphasised that the system should be adapted to its regional or national context of application in order to be useful for and accepted by disaster managers:

> *"That is the reason why if you want to disseminate HEIMDALL platform or any other platform at the European level, another suggestion [is] to be prepared to be able to easily adapt the platform to the governmental structure of that country. Because that is very much influential. You cannot make one size fits all in all Europe. Because each country in Europe has its own typical organisation. But as soon as you know that, maybe with a few arrangements, you can- that is my suggestion, try to prepare the platform in a way that with a few small adaptations, you can tailor the system to the local authority" (Firefighter, Director Coordinator, Italy).*

In addition to language and organisational requirements, there might be cultural differences reflected, for instance, in the ways disaster managers of different organisations or from different countries communicate with each other in the field. For example, an interviewee recalled an anecdote highlighting such cultural differences:

> *"[…] The humour and the culture can be issues actually when you work on site. I spoke to one of our volunteer firefighters that was in Sweden last summer and he was quite- quite affected by the lack of Swedish humour when he came back because they got mad at him because he was just like he is. But that was- well, he met some resistance on his way of dealing with humour. So, that might be something that we should deal with because there is difference in culture" (Firefighter Chief, Denmark).*

In sum, end-users have put forward many reasons emphasizing the need for a platform in their native language and that takes cares of the (not so) subtle cultural differences, but that at the same time they also expect a system that considers uniformity of interface, commands and terminology to mitigate these differences, which supports HF_6 (The system shall be developed considering uniformity of interface, commands and terminology). In this context, interviewees acknowledged the value of a system that can trigger a process of standardisation. However, it became also clear during the interviews that there will be a trade-off between the degree of standardisation and cooperation between different European bodies of disaster management that can be facilitated by HEIMDALL, and the specialisation required to adopt the system to differing needs according to local and cultural backgrounds. As experienced even within the limited frame of the project consortium, cultural or organisational differences occur frequently with respect to the understanding of common concepts and terms. More than once, discussions on terminology were necessary in order to reach a common understanding of basic terms, such as, for example, the difference between scenario vs. situation, the meaning of vulnerability, or cascading effects. An end-user reflected upon that in an interview:

> *"And we were only using English and we – were the end-users, [and we] couldn't agree. And we are all in the same business. So, my concern would be that the people who are working on HEIMDALL understand what they mean now, because we've had a whole lot of time to get together and to argue it out and to come to a common agreement. But if I was to go and get the local fire service from Oberpfaffenhofen to come and say, "I'm going to give you a situation, and I want you to run scenarios about it, would they understand what I mean? Possibly. But probably not" (Firefighter, Scotland).*

A possible solution mentioned by another interviewee was to provide drop-down menus offering a range of different terms describing a phenomenon:

> *"And I think for the matching, it might be that you have a drop-down box of 30 options, so that it makes the matching easier. You know, so like if [Name of a person] was filling in a scenario about something, to make sure that if it was a flood and there's ten words you can use for "flood", well these five apply to that flood. And then it makes matching easier, you know? You just- because everybody will use different languages, [it is a] different culture, different dialect. So, if it was the same, a drop-down box, it would make the matching easier, I think" (Firefighter, Scotland).*

At the same time, it has to be kept in mind, that the more general and translatable terms and procedures are, the more likely (slight) cultural differences arise. So, there is a thin line between providing generic and commonly understood terms to make each other understood and losing some of the specificities entailed in certain concepts:

> *"So, how to define a semantic between different countries you have to define what is a water pump for example, when there is no translation you take the more general term. But in the end, nobody understands it anymore and it gets too generic." (Research and Technology Projects Manager, Luxembourg).*

On the other hand, if the semantics become too specific and complex, the effectivity of the tool may be significantly reduced, if too much time is lost deciding upon the right terminology:

> *"There are some semantics available from ugh, different organizations. The problem is, when the semantics gets too complex with several thousand terms, so nobody finds the right term anymore, it is the opposite. It is very detailed, and all the different things are there and very nicely structured, but it is not- it is very difficult to handle. How do you find the right term on your side for a thing when you have to go through the complete tree, and as you know, the people have no time when they have disaster? They do not want to go through it" (ibid.)*

Such agreements on terminology may prove difficult because of the current differences between end-users´ organisations, which can be summarised as different mental models. i.e. the common understanding of goals, tasks and procedures among members of an organisation. In the context of these issues, it is important to note that the style of communication and terminology of the system can also impact its overall usability and productivity. Once again, predefining shared procedures and providing frequent training was considered a possible solution for overcoming these differences:

> *"You have to do it beforehand, definitely. Effectively everything, the common information space and also the semantic topic and the protocol, it has to be done before the disaster happens, because this is something that you have to be prepared for. You cannot set this up anymore when the disaster happened, this does not work. And also, the people have to be trained, because they have to know how to share information, how they do this, or to make a mission, a shared mission" (Research and Technology Projects Manager, Luxembourg).*

Overall, participants expressed that they were in favour of a common system adopted throughout Europe to reduce these differences and contribute to a better cooperation among organisations. Following the objective of HEIMDALL to contribute to standardisation of procedures, tasks and response plans a broad implementation could homogenise emergency management and response work across Europe. As it is built strongly on the idea of cooperation and data sharing at inter-organisational or inter-regional level, this could facilitate better and faster information exchange and the sharing of common operational picture as well as higher degree of trust among personnel. In particular, this was held as valuable for those participants with experience in cross-border collaboration.

Nevertheless, limitations to this standardisation has been identified with regard to the implementation of such a system related to aspects such as the business model and the political framework for implementation as elaborated further in chapter 4.1.6.

And another interviewee added: "So, the implementation process for this project or for this study is extremely important. […] If you want to achieve or have an impact in the operational response you need to have this shared with the decision-making persons on a regional level

or a country level" (Doctor, Germany). Once more, the importance of ongoing training to ensure an adapted implementation of HEIMDALL in the long run was emphasised: "what I personally think is that before trying to propose any support platform as a usable tool for real emergencies, you should do a lot of trainings and tests before" (Firefighter, Director Coordinator, Italy).

4.1.3 **Flexibility, productivity and integrity of data**

Another limitation to standardisation lies in the uniqueness of each emergency which often creates ad-hoc and sometimes chaotic responses to each incident. This has led to the emergence of very flexible management procedures which allow for creative responses but on the other hand sometimes lack a degree of structured coordination. In this respect, interviewees regarded HEIMDALL well because the key benefit they expected from it was "to come from the chaos phase to a more structured process" (Doctor, Germany). At the same time, due to this structuration some doubts were raised as to how far the system would be able to allow for improvisation necessary to account for the particularities of each case – the "mission gap". Therefore, end-users emphasised that the system should both support and follow protocols and regulations, but at the same time provide space for creative and contingent responses. For example, one interviewee explained that

> *"it would be good to have a way or an agile tool to first, personalise it in a way that answers to your needs, that answers to the information that you collect so that you can easily enter it to the tool. On the other hand, [it would] also be good that in some way it is standardised or typified in which way [you can use it] so that later you can search, filter, look up, etc."* (*Analyst, Environment and Water Agency of Andalusia, Spain, own translation).*

In this sense, HF_11 (The system shall support operational routines but also be flexible and versatile) emphasises that upholding operational protocols and standard procedures contributes to prevent errors that might occur if they are not followed and to reduce the chances for careless mistakes. The platform was considered a useful support in that regard: "I think it can help to reduce the range of mistakes, sure" (Volunteer, Red Cross, Italy). "And again, any kind of support needs to be very much related with the existing situation, existing organisation on that particular territory" (Firefighter, Director Coordinator, Italy). At the same time, flexibility should be a guiding principle of the platform to allow for improvised responses in uncertain situations where standardised procedures are incapable of providing the necessary results. Otherwise, the results provided by the system might turn out too detached from the specifics of a given incident to be useful: "I think it can help to make a decision, but I think it can never take a, for example, a decision for us. Because really this is a laboratory situation, it´s mathematics, analytics" (Volunteer, Red Cross, Italy).

Therefore, aside from the wish to receive an indication of the reliability of the information provided (see HF_14) it was very important to the end-users to retain a degree of flexibility and autonomy regarding the decision-making.

This conflict between structuring the response process and thereby reducing stress and freeing up time for other tasks, and at the same time limiting the creativity within procedures has been of continuous discussion among the consortium throughout the project. It also remains a tension to be further negotiated beyond the development phase taking into account the feedback and different demands of the end-users. In this respect, several end-users have stressed that they would like to apply the system beyond its currently planned use cases (forest fires, floods, and landslides). In order to ensure a higher chance of adoption and to improve usability through frequent training, it was suggested to make use of the system in everyday operations, as well as for other big events, such as chemical and nuclear emergencies, or terrorist attacks. The modular structure of HEIMDALL and its ability to connect to other systems in general support such a broader application. However, this is a point that goes beyond the Human Factors analysis and into the acceptance of the platform as well as into the commercialisation perspective.

Related to standardisation, another aspect that has made its way to the list of Human Factors is associated with the time devoted to gather, sort, find and analyse data, including the subsequent increment in efficiency and productivity reflected in HF_15 (The system shall be designed to reduce execution time and tasks and provide with monitoring and backup options in case of damage). However, any software may experience technical problems, especially during unforeseen events. Hence, the system should provide back-up options to avoid loss of data in case of damage, and as end-users emphasised, 24/7 technical support.

In this vein, one end-user stated: “(o)ne of the problems that I see is the technical support, the technical support after acquiring [HEIMDAL] when something stops working (…) where should I find them, who is going to solve it?” (Incident Commander, Firefighter, Spain, own translation). In addition, another concern shared by all end-users was the possibility of a lack of reliable internet connection during a crisis, and particularly in remote areas. Similar concerns arose with regard to using the mobile app: “All the stuff about putting it [the data] to a smartphone at the fire, I mean- The landscape in Scotland and the infrastructure that's just not there to transmit information (laughs, chuckles). The reality of getting a smartphone 4G signal right in the middle of Scotland is just… (laughs)” (Firefighter, Scotland).

Furthermore, there was a great worry that HEIMDALL would not work due to the current lack of infrastructure and broadband service. These concerns were raised repeatedly throughout the project and emphasised again at one of the training sessions, where invited external end-users confirmed that there was a very high demand for a system that would be stable even if no internet connection were available. This point has also been mentioned frequently throughout the interviews. One concern, for example, was with respect to the benefits of scenario sharing being dependent upon a stable internet connection: “But the challenge here is […] that you have to have access to the internet to get use of this” (Firefighter, Denmark). The internet infrastructure, however, depends upon the national providers and is as such out of the hands of the users (Seismic Risks Engineer, French Geological Service, France).

These concerns related to the integrity of data and the access to the platform have been addressed by several Human Factors requirements. For one, HF_16 states that “the system shall offer an offline protocol when internet connection is lost, or infrastructure is damaged”. In this sense, HEIMDALL offers a satellite-based communication system option for cases of damages to the internet connection or infrastructure. Furthermore, and based on the inputs gathered during interviews and at the training session, HF_23 proposes to address the case of unstable internet connection by stating that “the user shall be constantly informed about the stability of the internet connection, including pop-ups alerting in case the connection is lost, in order to avoid loss of data inserted”.

On the other hand, data integrity, error and malfunction of the platform can also be human-induced. As a technological system which has to take into account many and sometimes conflicting needs and functions, the HEIMDALL system will certainly not be faultless. Moreover, it will be used by humans who are also not infallible and, what is more, will be using the system in situations of extreme stress. Therefore, referring to HF_7, the system shall be designed to take into account potential mistakes when using it and thus avoid confusion and potential failure of the system.

Nevertheless, in order to support for the creativity and dynamics of humans interacting with technology, the system has to provide constant exchange of feedback between the user and the system, which enhances trust in the system. To this end, beyond the current development status of HEIMDALL, to be commercialised the platform should be further developed following the specific requirements of each end-user organisation that intends to implement the system in terms of data requirements, steps to follow when responding to an emergency and potential mistakes that can be made when using HEIMDALL. In this sense, a process of continuous testing the implementation of the platform to adapt it to the needs and processes of each organisation can ensure that mistakes and errors are minimised and the system does not fail.

4.1.4 **Feedback, trust, security and responsibility**

As with any human-machine interaction, the success of the HEIMDALL system also depends upon its ability to interact with end-users, provide feedback and in turn take into account the feedback of the end-users. End-users have repeatedly uttered that they would like to receive pop-up notifications and alerts from the system frequently to explain its processes and provide updates about the status of certain actions. This matter is strongly related to the degree of automation of the modules provided by the system. As [7] and [8] have stated, the adaptive allocation of tasks through the automation of functions can at the same time as it delegates functions increase complexity and thus increase the mental load of the users required to understand the information provided. Thus, transparency of the actions performed by the system is important to enhance efficiency of the system as well as trust in it and thereby foster its overall use. Moreover, as emphasised in [8], a good design that prevents or mitigates errors or presents the users a confirmation option before an action taken affects the system can contribute to reducing the levels of stress, anxiety and tendency to clumsiness that are common in disaster management situations. These aspects are key for the acceptance of the system, as the following statement highlights: “And, so, if I really trust in this system. And I have worked before and see, okay, it's functioning. Then I am happy to receive this information and work with that. But if I don’t, if I'm not familiar with that, I am not necessarily keen to work with that” (Doctor, Germany).

As explained in chapter 2, the Human Factors research field studies how to improve working conditions and reduce errors. Requirements HF_7 and HF_8 (The system shall provide informative feedback about its status whenever the user is interacting with it), in line with the main objectives of such an analysis, were evaluated as serious issues that should be considered during the development of the system to improve working conditions and productivity and foster trust in HEIMDALL. Interactions observed during the EUWs as well as the training session confirmed the need for such requirements and their integration in HEIMDALL. End-users continuously manifested the need for feedback that acknowledges the actions made in the platform or the possibility to cancel, undo or return to a previous step, as well as the loading or acquisition of new data.

In particular, when referring to data, it is currently obtained from many different sources without an option to centralise its visualisation in a single screen. Much data is paper-based and has to be manually consulted and/or inserted in the corresponding platform during the emergency. Moreover, data coming from third-party systems, such as surveillance cameras are not accessible due to legal and technical reasons. The responses obtained from the interviewees highlighted the importance of a system that can concentrate, manage and if necessary, aggregate all this information as well as is flexible enough to allow for third-party data.

In this sense, the end-users stated many times and unanimously that one of the core strengths of HEIMDALL was the allocation and consolidation of large amounts of data. Having the best possible data in a timely manner was deemed capital for emergency operators to make the best possible decisions during both crisis preparation and response phases. However, more information is not necessarily better, and it is not always clear beforehand which information might be relevant. In order to be useful and reduce the time for emergency operators to process this data, therefore, it was viewed of utmost importance that the information presented should be significantly reduced in order to avoid overwhelming the user, which supports HF_10 (The interfaces of the system shall be designed considering the reduction of the information load on each user attending to the incident).

As laid out in [7], the cognitive capacity demanded of first responders to cope with the overload of information during an incident is enormous. If responders get overwhelmed by feelings of stress, anxiety and fear, this bears the danger of what is called “threat rigidity syndrome” ([4]: 34), reducing their capacities to effectively process the information necessary to manage the situation. This potential for mental fatigue can be decreased by providing information in a clear and structured way supported by neat visualisations and interfaces, reducing the cognitive

load for end-users, while at the same time providing a clear picture of the situation on a quick glance ([18]: 104). Therefore, filtering data and reducing the cognitive load of each end-user were considered key to limit their mental fatigue and improve the overall productivity: “I’m happy, if I get any support. And the key issue is really the relevance of the information. Because I am overwhelmed with information from all different sites and field and offices, headquarters, whatsoever” (Doctor, Germany).

In addition, based on observations of the end-users´ interactions with the system, HF_22 (The user shall be able to access at any time during an emergency a timeline/log/mission diary listing chronologically all the actions that have been performed) was added. This could resemble the idea of a contemporaneous log commonly used by disaster operators and would be very useful for documentation and transparency of decision-making, as well as for debriefing and legal proceedings:

> *“So, when we make a decision, we put what the decision was, why we made that decision and any rationale. So, I would simply enter that I made a decision based upon the information from HEIMDALL and the rationale was that, after running scenarios, my choice was to select scenario X. Because, in my opinion, it gives the best result. That would just be entered into my log” (Firefighter, Local Senior Officer, Scotland).*

And another interviewee added:

> *“And that's why we have decision logs. So, this is why I made this decision at this time. Timestamp, this is what we did. This is why I made this decision. This is the decision we made. The decision logs are used because they need to be used. They're legal documents that can be used in court” (Firefighter, Station Officer, Scotland).*

Hence, it was concluded that a list documenting chronologically all the actions that have been performed should be accessible to the user at any time during the emergency in order to track how it is evolving. As many times mentioned, the stress and pressure of an ongoing incident may lead to mental fatigue. In such situations of mental overload, it may be helpful for the end-user to consult the log in order to reconstruct what has been done up to that moment and to continue to work. Also, since actions will be performed in the system by different users at the same time, it may be necessary for the incident commander to relate to what actions have been triggered by other users in order to maintain a good overview over the whole situation. Consequently, this will also contribute to transparency and enhance trust in the system.

However, as too much information can also be distracting rather than useful, the information accessible during the incident should be tailored to the role/user profile: “Because when you get too much information also it can be too much, you are overloaded” (Research and Technology Projects Manager, Luxembourg). Different personnel will require different kinds of information to fulfil their tasks:

> *“Probably, each one of the authorities do not need all of this information. You understand? So, an important point is to be able to fit information but put- putting the system in the mind of the user of the information. Say, ok, I need to produce my own things, it is important to know that kind of public order can be prepared only by the prefect. Nobody else can prepare that kind of thing. Of course, I prepare as a fire chief specific information, I prepare specific orders. But that- in that case, they have another shape than other- maybe slightly or heavily different content” (Firefighter, Director Coordinator, Italy)*

More generally speaking, a first responder in the field might predominantly want to see an overview of the messages exchanged with the command room, while an incident commander may need to receive detailed information about simulation results and also, referring to HF_13 and HF_14, the parameters used in order to weigh the different results against each other. Hence, all-time access to a mission log, tailored to the role of the user could be an important asset to reduce stress, improve situational awareness and ultimately contribute to sound decisions.

To ensure the usefulness of the information presented, end-users were in favour of a well-defined structure and access levels, in order to take pressure off the emergency managers

working in the field under much stress. In this sense, although a complex issue, requirement HF_12 (The system shall support clear leadership structures in order to grant permissions and access to data, information, situation assessment, scenarios, and response plans) suggests a potential solution to the challenge of tailoring data. While clear structures guarantee decision-making responsibilities, adaptability to mental models and the context of the user provides space to modify actions that can be taken and access to data. In turn, the visibility of structures generates trust in the system and strengthens the level of authority and type of responsibility of each organisation and of the end-users.

Furthermore, considering the criticality of safety and security for a data management system such as HEIMDALL, the system must provide strong security measures:

> *"It has to be made quite clear that high access requirements are involved. For one, there may be data or information which could be misused by third parties. If one thinks of terrorism, amok, etc. And on the other hand, of course we also have the issue of data protection, quite clearly. Hence, it has to be quite clearly defined who is allowed to access what" (Civil Protection Officer, Germany)*

Security and data protection have thereby been presented with relation to trust and responsibility in real-life experiences of many end-users:

> *"It is a big issue, security issue and privacy issue when you have a common database somewhere or a storage facility. The main topic was that no information is stored, everything has to be transferred to the other. The owner is responsible […] to decide who should get the information and the recipient is responsible for securing it, when they get it. Both of them have to trust each other, and that is the problem when you have a big thing like this, with further partners. How are they supposed to trust partner E, whom they do not know, that he gets all the information? […] That is why the only one who can decide what information can be provided is the owner of the information" (Research and Technology Projects Manager, Luxembourg).*

Hence, considering HF_2, HF_10 and HF_12, HF_24 (recommends attention to security aspects with respect to the different profiles that constitute the structure of each end-user organisation. Each profile and user account should be developed considering security measures such as strong access control, for example, via login credentials with multi-factor authentication, rules and permissions. Such access control can reduce the likelihood of a potential security breach, help to make more informed and faster decisions and assign responsibilities based on the profiles and needs of the users.

4.1.5 **Responsibility, transparency and autonomy**

Another side to transparency is presented in HF_13 (The system shall be transparent on the decision support mechanisms and used criteria). This requirement stresses that as one of its core aims, HEIMDALL should provide advice on possible procedures for crisis preparedness, mitigation, response and recovery in the most transparent form, in order not to bias the end-user's decision. This involves support modules for the assessment of the situation, risks and vulnerabilities, the catalogue of scenarios, associated response plans, and the corresponding lessons learnt. Hence, with regard to the conflict between automation and responsibility, it has been the firm intention of the end-users that the decision support functionalities should clearly display the parameters used in the algorithms and the weights assigned to each of them.

Therefore, although these functionalities were well-regarded in terms of the added value they could offer to evaluate possibilities and reducing the time to come to a decision, it was strongly emphasised that the user should retain autonomy in decision-making. Human autonomy is indispensable because technological systems are prone to error, and a decision made by HEIMDALL could be faulty. In this sense, interviewees expressed the fear that decision makers might rely too much on the system: "I see that as a danger, that inexperienced decision makers might rely a little too much on this and that they may not see it as a recommendation, but as a precept of how a decision, or which decision should be made" (Dispatch, THW, Germany own translation). Hence, end-users stressed that they do not need a system that automates decisions but one that supports their work and facilitates human decision-making.

For instance, some interviewees emphasised that in their view, such a platform could only provide information to emergency operators as suggestions for decisions, but not take decisions for them, let alone be held accountable for them: “Decision support, yes. Automated decision-making, no. I consider this also legally problematic. […] I myself wouldn´t leave it to a system or an algorithm which decision should be taken” (Dispatch, THW, Germany, own translation). The problem of legal accountability was quite a common concern among the end-users:

> *“We need individuals making decisions. […] Whereas if you've got something, a machine, telling you this is what you need to do, you would need something to back that up, I would say. Because you can't go into court and say: Well the machine told me to do it. They're not going to buy that. It would have to be a logical reason, a logical process” (Firefighter, Scotland).*

On the other hand, end-users also stated that if the standardised process followed by the platform is too lengthy, at moments when time is a precious resource, the platform will not be used: “We need something to- that can be used very quickly, that can give us what we need, saving our time, which is probably- this is another must of any platform. You should not invest more time than using no platform” (Firefighter, Director Coordinator, Italy).

In one of our interviews, an end-user stated: “There is no system that can replace common sense and the gut feeling” (Firefighter, Denmark). Again, referring to the end-users’ preference to retain human autonomy in decision-making, this statement highlights that emergency managers, based on their experience and training, are usually equipped with quite a good judgement in the situations they find themselves in to make decisions, and that they would like technology to support but not replace this authority. Points repeatedly stressed by end-users were the transparency of simulation results in terms of how they were obtained and explanations that are easily accessible and understandable. While it was considered useful to be alerted by the system if certain mistakes have been made in the past, it was made clear by the end-users that this should be accompanied by a comprehensive explanation:

> *“I take a decision. Or I want to take a decision. Then, the system warns me off that decision because in the past something went wrong due to that. But then I also want to be able to read what exactly happened in the past and why it happened, so I can judge whether I can take the decision anyway, because other basic conditions and circumstances apply. That would be that. So, not the raw warning without explanation, but there always also has to be a little bit of gut feeling involved” (Dispatch, THW, Germany, own translation).*

The importance of this aspect is, however, not only obvious to end-users. In a conversation with a member of the French Geological Service, they stressed that the uncertainty of simulation results ought to be evident to the user: “The point is […] to represent the uncertainty in a way that is understandable by the users that are not necessary experts of the phenomenon we are dealing with”.

It is vital for emergency managers who carry the responsibility for decisions made based on simulation results, to be able to appropriately weigh the reliability of such results. Hence, HF_17 emphasises that the user shall be able to see a measure of uncertainty to the results of the simulators. This measure provides end-users a margin of error or degree of reliability in the results which is key to improve usefulness, trust and use of the platform. Based on observations from the HEIMDALL training session, it should also be easy to see for the user when several simulations have been performed, how they differ, i. e. it should be indicated in the visualisation of results which parameters each simulation took into account and how they were weighed.

In addition, HF_18 states that the user shall be able to manually modify parameters of the simulators. While the simulators were generally perceived as valuable tools, end-users emphasised at consortium meetings and in the interviews that they would like to be able to manually modify the parameters used in the simulation and to set their own thresholds. That is owed to the fact that different criteria may be of different importance depending on regional or organisational characteristics, and that the algorithms may not always be able to take these

specifics into account. For example, a firefighter chief from an area in Southwest Germany that is prone to flooding, explained this with regard to weather data. For one, the weather data provided by different meteorological services sometimes differ and only by comparing them, the incident commander can estimate based on their experience how these measures may affect this specific area. In this sense the interviewee stressed that they would prefer to insert the data manually after assessing it themselves. And secondly, the effect that, for example a forecasted 50 litres of rainfall per square kilometre can have on an area depends very much on the previous conditions, regional circumstances and also on the severity and duration of the successive rainfall. For example, the outcome may vary significantly if the conditions have previously been dry and stable or if there has been a lot of antecedent rainfall, on geographical conditions. The state-wide warnings issued by the meteorological service, may therefore not always apply to the same extent to a specific area. The local knowledge required to evaluate the situation in contextual terms, however, may not be represented by the data in the system. Therefore, the interviewee would prefer to set their own thresholds and interpret the data themselves. Again, this point related to the understanding of end-users that human autonomy and responsibility should be retained when using technological decision support, especially accounting for the uncertainties and contingencies of a dynamic and evolving incident. Overall, being able to set their own criteria for simulations may enhance transparency of the results and thereby trust in the system and render the tool more valuable in the eyes of its users.

Additionally, crisis situations demand making decisions under conditions of high uncertainty, stress, anxiety, sometimes leading to careless mistakes. Therefore, emergency managers require up-to-date, but also reliable, information. Considering that the currently common practice of paper-based communication among organisations yields only sporadic cooperation among organisation, end-users stressed that an integrated platform could be a valuable tool for enhancing such cooperation. However, there was a concern that it would have to be ensured that it is up-to-date and there is no lack of information.

According to many of the end-users, a key challenge involved with this would be taking into account that some data may only be available on a local level, or in the field, and how this data would be fed into the system. After all, the results generated by HEIMDALL's functionalities will only be as good as the data used, or, as one end-user stated in an interview: "Garbage in, garbage out" (Firefighter, Denmark).

In this sense, a member of the Italian Red Cross mentioned that up-to-date information especially on critical aspects like roads, buildings, people and hospitals is considered vital. And another end-user highlighted, that in order to be perceived as added value, the system would have to provide information not already available to their organisation, such as, for example, critical infrastructure:

> *"So, there is an awful lot of local knowledge already. So, it's very difficult. We would want quite generic stuff. So, that high-level sort- we wouldn't really need to know there's a row of ten cottages because we already know that. Or the crews attending would already know that. But if there was critical infrastructure in the area or like, you know, so like, there's a water plant up there so your run-off from your fire cannot enter that waterway. So that critical infrastructure was aware- if I was made aware of it that would be good" (Firefighter, Scotland)*

It was also advised that data reported from citizens about the situation in the field is often incorrect and should not be entered into the system unchecked. For example, a firefighter from a flood-prone area in Germany explained that a citizen reporting a flooded street may well imply just a blocked drainage, rather than the river having flooded.

Carrying forward the previous considerations, end-users insisted that the system should only "present factual information. It shouldn't have any bias and the system shouldn't interpret the data" (Strategic Manager, Firefighter, Scotland). This insistence is grounded in the end-users understanding that in the end, humans are responsible for the decisions made while managing an incident. This involves a trade-off between swiftness and trustworthiness of the information given. In this sense, HF_14 stresses that the system shall be able to assign levels of certainty

to the information items provided by the different systems and actors (autonomous systems, sensors, and end-users). The way the data is presented may (negatively) influence the decision taken by the user by being suggestive or biased. In case the validity or veracity of data is not ensured, or in case data is erroneous and leads to a bad outcome, end-users will be responsible for the decisions made based on it.

Furthermore, enhancing transparency also implies that HEIMDALL can clearly distinguish between actions proposed in pre-prepared response plans and those executed in previous emergencies. For this purpose, HF_19 (The user shall be able to clearly distinguish between actions proposed that are stated as such in pre-prepared response plans and actions that were performed in similar previous scenarios) was added to the list of human factors seeking to address another aspect of the tension between creating efficiency through automation and retaining responsibility with the human decision makers.

Answering the requests of the end-users for transparent and unbiased information, HEIMDALL has adopted several measures during its development. It has not numbered the different options presented by decision support tools, so that end-users are less likely to be influenced by the presented order. Moreover, the system grants end-users the possibility to manually alter the parameters of the decision support tools to further improve their autonomy and trust in the system. Other options that might further improve the answer to this issue include stating the source of data, especially in the case of autonomous systems and sensors, and/or indicating the margin of error, and therefore, the accuracy of the results of the simulators.

As stated in [8], there is also a matter of responsibility and accountability towards the broader society to consider with respect to transparency: “There is a need for transparency of information, also from the emergency services to the population and more and more we have the need to explain why we did what we did. Because in the end, society ask and they have the right to know” (Incident Commander, Firefighter, own translation). In other words, providing transparency will not only help to improve the end-users work, but it will also help to be accountable and provide better explanations to the population.

Finally, if information from social media is utilised, relying on the services of groups such as VOST[2] improves the veracity of the information and also adds value to the system while incorporating another source of data. However, while the value of utilising social media data was acknowledged by the end-users, it was agreed that implementation of such an external source of data will remain entirely optional. After a lengthy conversation the agreement arrived at was that the benefit of this implementation depends very much upon the level of trust between the VOST group and the respective emergency organisation, which calls for a case-by-case application.

4.1.6 Availability and affordability

As previously stated, it is in the very nature of the study of Human Factors, that these are not viewed in isolation from other, more technical or, on the other hand, broader societal aspects. As such, we observed many connections between aspects related to Human Factors and aspects which are more directly related to questions of acceptance and acceptability covered more extensively in the corresponding deliverables [9], [10] and [11]. However, we would like to briefly touch upon those aspects that are closely linked to Human Factors and therefore

[2] The Virtual Operations Support Teams, a network of volunteers able to support emergency services online in case of a crisis using communication technologies and social media tools to validate the data generated during an emergency. For a more detailed discussion about the advantages and challenges of employing digital volunteers for utilising social media data during emergencies, see [11].

should not be excluded from a deliverable focussing on the Human Factors impact on HEIMDALL.

One issue which was repeatedly mentioned in the context of a number of Human Factors, and which seems to be of the utmost importance, is how HEIMDALL is offered to end-user organisations, referring to the business model as much as how it is implemented. Hence, interviewees highlighted the various forms in which the business plan affects the support that HEIMDALL can provide to the work of end-user organisations before, during and after disasters. The affordability of the system was thereby a key concern among the end-users:

> *"So, I think that is a significant risk to how easily HEIMDALL will be able to be sold to people who haven't been involved in the designing of it. […] So, if it's, let's just say it's 10,000€, that's a significant investment, I would say, for some smaller local authority fire services. And if it comes right down to, I don't know what a scenario is, then that's at the heart of HEIMDALL. Why would you buy it? […] And I don't think it will be 10,000€ and I can be quite conservative there [group laughter], because there will be an ongoing reconstruction cost- […] and the European procurement laws have – you look at the lifetime of a thing, so if you have it for ten years at a cost of, say, 5,000€ a year, suddenly it's 50,000 and you've not even got it yet. So, I think the pricing will be very interesting to see, how successful it is or not" (Firefighter, Scotland).*

And another interviewee summarised: "I think, yes, we would like it. It boils down to: Is it affordable and how - what's the quality of data that we have to put into it?" (High Scientific Officer, North Ireland Environment Agency, North Ireland). Hence, beyond acceptance of the system, the successful implementation of HEIMDALL also depends to a large degree on legal, political and economic contextual conditions that should be considered in the business model. For example, a firefighter from Italy stressed that macro-economic factors, although currently not considered by emergency operators, could be a useful asset for the recovery phase: "Maybe, at civil protection level, we are not used to taking into account all the largest macro-economic impact. Yes, we cannot take care of that, but it could be nice" (Firefighter, Director Coordinator, Italy).

In this sense, there were arguments for and against a private company offering HEIMDALL. While this could bring benefits with respect to technical support and modifications, there was a serious concern with respect to the confidentiality of information. Moreover, if the system was commercialised, many users stated that there should be different options to acquire it, such as for free at local level and paid for when adopted at regional/national level; or a set of minimum functionalities are for free and as modules are added, the price increases. For example, "and from the financial or commercial view, maybe it's a good idea to offer it for free for a smaller scale or for a basic service." (Doctor, Germany). Also, the need for such differentiation was elaborated in the Scottish context:

> *"I think there's two parts of the system that would help us in Scotland. One would be specifically for the Scottish Fire and Rescue Service. And the other one would be for the Resilience Partnerships. The Resilience Partnerships would use it as a multi-agency tool and probably more of a generic view of how to manage an incident, a major incident, whereas the Fire Ser-vice would need it more specific and be able to put in the simulation models and training, etc. […] So, […] I don't think it would be necessary for us to have the information the Resilience Partnerships would have […] and vice versa. They wouldn't need it so specified. So, we'd probably need a package that's quite condensed and another package that can be very- more generic" (Firefighter, Station Officer, Scotland).*

Moreover, they added that training should be included with the purchase of the platform: "I think if the Scottish Fire and Rescue Service was to buy the HEIMDALL product, it would have to come with a training package." (Firefighter, Scotland). This was also considered an ethical aspect in the sense that: "it would be unfair to just give somebody something and expect them to be able to use it straight away without showing them how to use it […] and keeping them up to date with it" (ibid.)

As has been shown throughout this set of deliverables, studying human factors is more than evaluating the working conditions and the options for reducing mistakes it is also about taking

into account that human-machine-environment interaction generates many unforeseen new uses of technology. It has therefore been stressed in [8], that following evidence from focus group discussions, interviews, observations done during the project meetings and informal conversations with members of the consortium, there is much interest in developing other use cases from those originally given to the system.

In addition, a concern frequently mentioned among the end-users was how to secure successful adoption of HEIMDALL and in how far this should be stipulated from national governments or the EU. For some end-users, the successful adoption is based on its acquisition at a national level, whereas others proposed that the European Union should push forward its implementation. The opinions thereby diverged between interviewees who were in favour of a top-down implementation of HEIMDALL initiated by the European Union, and those who preferred a more contextual decision, at least on the country level, as to whether the system should be implemented at regional and local level: “But, it might have a lot of sense to propose HEIMDALL at national level starting from the European mechanism of civil protection. So, to share and to train people to work on the system for international emergencies” (Seismic Risks Engineer, French Geological Survey, France). Thus, in fact, a combination of a top-down and bottom-up implementation might be the solution, also with respect to the acceptance of the tool elaborated in [11]:

> *“You have to go from both sides. If you go only from the head, the acceptance on the bottom may be missing and then you have a solution that they put on and nobody will use it, because they do not like it. On the other side, if you go only from the bottom, then nobody will pay for it (laughs).” (Research and Technology Projects Manager, Luxembourg)*

In summary, beyond societal acceptance and ethical acceptability of the system, affordability and availability are key elements to consider, in order to understand how HEIMDALL can positively affect the work of end-user organisations before, during and after disasters and enhance the overall resilience of the affected societies, as this final quote shows:

> *“So, if there's a computer system that does it [decision support] and is available to do it and we're trained on it, then it just gives us that resilience and that continuity. Whereas right now, a lot of our success depends who goes where and does what. Because it's just knowledge and experience. So that would help in that manner” (Firefighter, Scotland).*

5 Conclusions and Recommendations

This final issue on the three deliverables devoted to Human Factors involvement in disaster management systems provided an overall summary of the work undertaken with regard to Human Factors as part of Task 3.4, presenting insights from empirical data as well as observations within consortium discussions and training exercises.

It firstly provided an overview of the field of Human Factors analysis and elaborated Human Factors and the implications of their analysis in the context of HEIMDALL (chapter 2). Secondly, it explained the methods used to gather data in interviews and questionnaires and their evaluation (chapter 3). And finally, it presented an overall summary of the findings concerning Human Factors and Human Factors requirements considered for HEIMDALL, covering insights from the literature, interviews, questionnaires, consortium discussions, and observations from the training sessions. In general, the preliminary list of requirements which was presented in [7] was supported by the empirical data, while the arguments over tensions and feasibilities deepened over the course of the research process, leading to a much clearer picture with regard to the context, benefits and constraints of each point. In terms of recommendations for the further development of HEIMDALL beyond its prototype phase in the following main points are summarised in thematic clusters to highlight their linkages and interconnections:

- *Access, Usability and Training:*

Any Human-Computer Interaction (HCI) intervention, like the one applied in HEIMDALL´s design, should focus on the usability of such a system for a variety of different end-users with different needs and abilities. This implies simplicity in the design of the user interface, as well as considering a variety of different end-users and their respective organisational, legal and cultural contexts, and ensuring the necessary training and learning time for HEIMDALL´s users.

- *Language, Communication Style, Cultural Differences and Standardisation:*

Considering the stressful circumstances of an emergency situation, a disaster management tool needs to provide support tailored to the needs, roles and characteristics of its users. Hence, the system should be available in the language of each country where it is implemented and account for cultural and communicational differences by offering uniformity of commands and terminology, and providing particular assistance for bridging cultural and linguistic differences in cases of cross-border and cross-agency cooperation. The system is thereby expected to find an adequate middle ground between standardisation and adaption to specific contexts.

- *Flexibility, Productivity and Integrity of Data:*

The challenge lies in supporting operational routines of end-user organisations, while remaining flexible and versatile enough to allow for creative responses in contingent emergency situations, and for exchanges and integration with other systems. The system could thereby improve productivity by structuring the response process, but at the same time it should provide the necessary flexibility for the users to feel confident to rely on its services. This also touches upon the question of integrity of the data in the system and points to the need to provide options for backups, alternative access to the platform when infrastructure is damaged and minimisation of human errors with the consequent failure of HEIMDALL.

- *Feedback, Trust, Security and Responsibility:*

One such option to reduce malfunction of the platform is to provide on-going interactive feedback including pop-up notifications about performed processes. Other possibilities are the design of interfaces that reduce the mental load of end-users and providing all time access to a log documenting the actions undertaken in the system. In addition, strict user profiles can help to ensure security and attribute responsibility through strong access control and reduce cognitive load by tailoring information to each role. All these measures contribute to enhance trust in the system and therefore its adoption by end-user organisations.

- *Responsibility, Transparency and Autonomy:*

Related to trust and responsibility, the system should offer measures to ensure transparency and maintain human autonomy. This entails that decision support tools should be understood as an additional information base to enhance the user´s operational picture, but not as an autonomous mechanism of decision making. According to end-users, humans should be held responsible and accountable for decisions made. Trust in the system in this regard can be enhanced by transparently displaying to the user the rationales and mechanisms behind the decision support modules and the used criteria and weights.

- *Availability and Affordability:*

Finally, as the previous thematic clusters highlighted, Human Factors cannot be viewed in isolation from other, more technical, or broader societal issues. As such, the overall success of HEIMDALL will also depend upon the business model and how it is implemented. It was considered of the utmost importance that the system is both affordable for a variety of different end-user organisations and adjustable to their needs, implying a modular business model including basic, advanced and full packages, as well as trial periods. As one of the core aims and benefits expected from HEIMDALL is to contribute to standardising disaster management operations throughout Europe, its aim must be to be broadly implemented across the EU.

It also became quite clear throughout the process, that all of these points are entangled, also with matters of ethical acceptability and societal acceptance [11], and that the constitution of each point affects others, ultimately impacting the overall success of a system like HEIMDALL to improve and support emergency preparedness and response operations across Europe.

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7 Annex: Complete List of Human Factors Requirements

Table 1

Requirement ID	HF_1
Requirement: The system shall be designed for different types of end-users and the different equipment they use.	
Source	EKUT
Summary	As not all end-users have the same equipment, the system should be developed in such a way that a variety of end-users' operational equipment might be used to access vital information without barriers.
Benefits	If HEIMDALL is developed in such a way that access to vital information is achieved through a variety of operational equipment, this system will improve disaster preparedness, crisis management and response because it places less barriers for end-users to access helpful information.
Negative impacts	The restriction to specific kinds of equipment and/or the design of interfaces for only specific types of end-users are not only a matter of discrimination and a potential legal issue but can also undermine the main objective of the platform by not considering the characteristics of this situation.
Constraints	

Table 2

Requirement ID	HF_2
Requirement: The system shall be designed to take into account different kinds of end-users in terms of different expertise, different knowledge and different positions in the organisational structure.	
Source	EKUT
Summary	The platform should be developed in such a way that permissions are granted, and interfaces designed to allow end-users to access vital information without barriers.
Benefits	The aim of the HEIMDALL system is to improve disaster preparedness, crisis management and response. The accessibility of the information by all end-users could only contribute towards achieving this goal.
Negative impacts	Limiting the access to the platform by design (of interfaces), responsibilities (position in the organisation) or capabilities (expertise, knowledge, technical skills) is a matter of discrimination, a potential legal issue and can undermine the main objective of the platform by not considering all the potential scenarios.
Constraints	

Table 3

Requirement ID	HF_3
Requirement: The system shall be designed for different types of end-users having special needs (hearing-, speaking-, visual-, mobility impairments) to be able to insert, access and use the information.	
Source	EKUT
Summary	As end-users have different capabilities, the platform shall be developed in such a way that permissions are granted, and interfaces designed to allow end-users to access vital information without barriers.
Benefits	If HEIMDALL is developed in such a way that access to vital information is achieved through a variety of operational equipment, this system will improve disaster preparedness, crisis management and response because it places less barriers to end-users and citizens to access helpful information.
Negative impacts	The restriction of permissions and/or the design of interfaces for only end-users with certain abilities are not only a matter of discrimination and a potential legal issue but can also undermine the main objective of the platform by not considering the characteristics of this situation.
Constraints	

Table 4

Requirement ID	HF_4
Requirement: The system shall be designed for end-users and with different mental capacities.	
Source	EKUT
Summary	The platform should be developed in such a way that interfaces are designed to allow end-users with different mental capacities to access vital information without inappropriate barriers.
Benefits	If HEIMDALL is developed in such a way that end-users with different mental capacities can access vital information, this system will improve disaster preparedness, crisis management and response because it places less barriers for end-users to access helpful information.
Negative impacts	The design of interfaces for only end-users with certain mental capacities is not only a matter of discrimination and a potential legal issue but also can undermine the main objective of the platform by not considering the characteristics of this situation.
Constraints	

Table 5

Requirement ID	HF_5
Requirement: The system shall be designed considering translation, linguistic and cultural issues with regards to end-users.	
Source	EKUT
Summary	The platform should be developed taking into consideration that different languages and different cultural customs and practices are major obstacles that might affect its adoption and use.
Benefits	The aim of this project is to develop a working prototype that can be applied on managing crisis situations, preparing for them, and responding in improved manners. HEIMDALL's geographical focus is the European Union, which as such is composed of many different countries with their own languages and cultures. Therefore, in order for this platform to be implemented successfully in this region these aspects must be addressed.
Negative impacts	One of the aims of HEIMDALL is to provide a system to help European Union's end-users, who by definition do not share language and culture. By failing to prevent these issues of misunderstanding HEIMDALL negatively affects its chances to succeed.
Constraints	The consortium has to bear in mind that regardless of training time and documentation available, the more general and translatable terms and procedures are, the more likely that slight (cultural) differences might arise. In some cases, this may create big difficulties. In addition, similar terms do not always have the same meaning in different organisational and/or cultural contexts.

Table 6

Requirement ID	HF_6
Requirement: The system shall be developed considering uniformity of interfaces, commands, and terminology.	
Source	EKUT
Summary	The platform should be developed based on common terminology, commands, and interfaces to ensure fast and clear communication among end-users.
Benefits	The consistency in terminology, commands, and interfaces supports clear communication between organisations by ensuring simplicity and effortless exchange of information and knowledge, and reducing the stress and anxiety created by the disaster itself.
Negative impacts	The trade-off between standardisation of terminology and critical view of the categories in place is the possibility that vulnerable groups, defined priorities and/or strategies proposed and adopted might negatively affect some individuals, regions and/or infrastructure.
Constraints	It has to be kept in mind that regardless of training time and documentation available, the more general and translatable terms and procedures are, the more likely that slight (cultural) differences might arise. In some cases, this may create big difficulties. In addition, similar terms do not always have the same meaning in different organisational/cultural contexts.

Table 7

Requirement ID	HF_7
Requirement: The system shall be developed taking into account potential mistakes in using it and leading to confusion and/or failure of the system.	
Source	EKUT
Summary	The platform should anticipate that users can make serious and/or careless mistakes while using the tool, either by rapidly detecting mistakes and offering a comprehensible and fast mechanism to undo them or by preventing them. Nevertheless, errors might occur, and technical support should be provided in terms of administrators' rights or physically present administrators.
Benefits	Crisis situations generate higher levels of stress, anxiety, and clumsiness (by pressing the wrong buttons, for example) and make people more prone to errors. Good design should prevent or mitigate these errors or present the users with a confirmation option before the action affects the system.
Negative impacts	
Constraints	As disasters do not hold on to plans it might be necessary to find creative ways to solve problems. This is not always possible, as the platform should prevent (careless) mistakes. Both claims are contrary and should therefore be discussed in advance.

Table 8

Requirement ID	HF_8
Requirement: The system shall provide informative feedback about its status whenever the user is interacting with it.	
Source	EKUT
Summary	The user should receive confirmation of every action they perform in the platform.
Benefits	The HEIMDALL platform aims at being used by many different end-users, in various situations and under stressful circumstances. By receiving feedback to the actions performed the users are assured of their impact.
Negative impacts	
Constraints	Feedbacks, such as confirmations and acceptance clicks need time and may easily lead to bureaucratic frustration and stress. On the other hand, these security mechanisms are important in terms of accountability and responsibility.

Table 9

Requirement ID	HF_9
Requirement: The system shall consider the necessary learning time of their users.	
Source	EKUT
Summary	The platform should have an intuitive design that provides for rapid learning and easily connects with the users' knowledge and expertise. In addition, documentation should be available for any type of user.
Benefits	Intuitive design reduces learning time, provides for better understanding of the situation, collaborates in exchanging information and coordinating efforts and relieves from anxiety and stress. Moreover, it becomes a reliable tool. Furthermore, it diminishes the necessary time to recall when using it after some time.
Negative impacts	
Constraints	Intuitive design, unfortunately, does not resolve the necessary learning process and practice time, which should occur during non-emergency times. In addition, documentation (or online/offline help) should be provided to overcome any unforeseen circumstances, which shall be easy to search, navigate, and understand.

Table 10

Requirement ID	HF_10
Requirement: The interfaces of the system shall be designed considering the reduction of the information load on each end-user attending to the incident.	
Source	EKUT
Summary	The amount of information displayed should be balanced to reduce the concentration required, mental fatigue, and stress of the risk/crisis situation.
Benefits	HEIMDALL aims to integrate large amounts of information in an efficient and clear presentation in order to support decision-making and reduce response processes and times. Therefore, the volume of this information shall be balanced in order to achieve these concomitant goals while reducing the mental fatigue (learning/forgetting processes) and concentration associated with the emergency situation, dissatisfaction with the system and anxiety.
Negative impacts	The drawback of selecting the type, amount and interfaces' design is the possibility of incomplete, inaccurate, or biased information or its representation.
Constraints	The HEIMDALL consortium, especially the end-users, have to discuss the extent and form of the information processed and presented within the platform to facilitate work for their end-users. This is important as more information is not necessarily better and it is not always clear beforehand which information might be relevant. Therefore, options should be implemented to allow for adjustment of the information based on the needs of the users as well as preventing them to be overloaded.

Table 11

Requirement ID	HF_11
Requirement: The system shall support operational routines but also be flexible and versatile.	
Source	EKUT
Summary	The platform should uphold operational protocols and standard procedures, but it should also be flexible to deviate from routines when circumstances demand.
Benefits	The presentation of and support in executing operational procedures exempt end-users from errors that might happen if they are not followed and reduces the chances for (careless) mistakes. By developing a flexible system, the platform is prepared for not fully predictable or uncertain situations in which standardised procedures or mechanisms are incapable of providing the corresponding information, result, or plan. In addition, the versatility of the system contributes to accomplish the overall objective of HEIMDALL, which is to improve preparedness of societies to cope with complex crisis situations by permitting the generation of new functionalities.
Negative impacts	
Constraints	

Table 12

Requirement ID	HF_12
Requirement: The system shall support clear leadership structures in order to grant permissions and access to data, information, assessment of situations, scenarios, and response plans.	
Source	EKUT
Summary	The platform shall support and make visible clear responsibility structures in order to grant permissions and access to data, information, assessment of situations, scenarios, and response plans. In turn, this shall be reflected on the interfaces' design, the adaptability of it to the context of the user and the actions that the user can perform.
Benefits	The visibility of the structures generates trust in the platform and clearly identifies the level and kind of responsibility of each organisation and of the end-user. This is reflected on the permissions granted, and the available data, information, scenarios, and plans, as well as on the interfaces' design, the adaptability of it to the context of the user and the actions that the user can perform.
Negative impacts	
Constraints	

Table 13

Requirement ID	HF_13
Requirement: The system shall be transparent on the decision support mechanisms and used criteria.	
Source	EKUT
Summary	The system shall provide advice on possible procedures for preparedness, mitigation, response and recovery phases (assessment of the situation, risk and vulnerabilities; catalogue of scenarios, associated response plans, and corresponding lessons learnt) in the most transparent form in order to not bias the end-user's decision.
Benefits	Transparency on decision support mechanisms and used criteria is associated with trust in the HEIMDALL system, decision implementation, and corresponding levels of structural responsibilities.
Negative impacts	
Constraints	Unfortunately, not only is full transparency not possible, but also decision support is likely to be misunderstood as decision-making. Providing options is different from deciding what option to take. This subtle difference might be neglected when using HEIMDALL, which is a system that provides decision support. Nevertheless, decision support must be prevented from being misunderstood as decision-making, which is the task and responsibility of end-users.

Table 14

Requirement ID	HF_14
Requirement: The system shall be able to assign levels of certainty to the information items provided by the different systems and actors (autonomous systems, sensors, and end-users).	
Summary	The platform should provide real and trustworthy data. To this end it should generate a system to assign levels of certainty to the information provided. It may be honest and simple to assign a high level of certainty to the data provided by the first responders but there needs to be a validation process for the data provided by the autonomous systems and sensors.
Context	
Benefits	Crisis situations generate higher levels of stress, anxiety and clumsiness which is why reliable data is of utmost importance.
Negative impacts	The aim of up-to-date information is always a negotiation between time/speed and trustworthiness. The system shall facilitate work by giving important information right away which might lead to uncritical use of data without further investigation of sources.
Constraints	

Table 15

Requirement ID	HF_15
Requirement: The system shall be designed to reduce execution time and tasks and provide end-users with monitoring and backup options in case of damage.	
Source	EKUT
Summary	The system shall facilitate the work and data sharing within disaster management structures by shortening the time necessary to find, get and sort data.
Benefits	Faster data means better up-to-date actions and therefore a better response to the ongoing disaster.
Negative impacts	It is a likely situation of automated or semi-automated tasks (faster and less demanding tasks) to go hand in hand with new and/or more tasks and a loss of control on the previous tasks. This may lead to more confusion if these technological assisting devices fail or they are not monitored in an appropriate way. Previously assigned personnel that get other/more tasks might be confused and overburdened in case the device breaks.
Constraints	

Table 16

Requirement ID	HF_16
Requirement: The system shall offer an offline protocol when internet connection is off, or infrastructure is damaged.	
Source	EKUT
Summary	The platform shall offer an offline protocol and the corresponding satellite-based communication system option in case of damages to the internet connection or other infrastructure.
Benefits	The integration of an offline protocol and the corresponding satellite-based communication system option into the HEIMDALL platform reduces the anxiety and stress of end-users and population and increases the trust in the platform.
Negative impacts	
Constraints	

Table 17

Requirement ID	HF_17
Requirement: The user shall be able to see a measure of uncertainty to the results of the simulators.	
Source	EKUT
Summary	No simulation is perfect, there is always a degree of uncertainty to its results. In order to appropriately weigh the reliability of simulation results, the user should be able to see a measure of uncertainty to the results of the simulators.
Context	
Benefits	Reliability is a key issue to improve usefulness, trust and use of the platform. The measure of uncertainty of the simulators provides the end-users a margin of error or degree of trust in the results.
Negative impacts	
Constraints	

Table 18

Requirement ID	HF_18
Requirement: The user shall be able to manually modify parameters of the simulators.	
Source	EKUT
Summary	As different criteria may be of different importance depending on regional or organisational characteristics, the users shall be able to manually modify parameters of the simulators in order to run simulations based on their own criteria thresholds.
Benefits	Enabling end-users to run simulations with their own criteria and thresholds enhances transparency of results. Moreover, transparency of the parameters ensures trust in the system.
Negative impacts	
Constraints	

Table 19

Requirement ID	HF_19
Requirement: The user shall be able to clearly distinguish between actions proposed that are stated as such in pre-prepared response plans and actions that were performed in similar previous scenarios.	
Source	EKUT
Summary	Access to pre-defined plans and previous scenarios and associated actions should not follow the same path. In order to avoid confusion and distinguish between them, differences access points are necessary.
Benefits	Providing the context from which a proposed action is derived enables transparency and a more complete basis for decision-making.
Negative impacts	Although completely unbiased decisions are not possible, without clearly stating the difference between pre-defined plans and actions corresponding to previous emergencies, there is the risk of negatively influencing future decisions.
Constraints	

Table 20

Requirement ID	HF_20
Requirement: The user shall be able to see a pop-up notification with specific information about protocols, regulations and/or agreed working procedures of/with the respective country when creating a new scenario in case of a cross-border incident.	
Source	EKUT
Summary	The user shall be able to see a pop-up notification with specific information when creating a new scenario in case of a cross-border incident: • Information about legal/regulatory or organisational frameworks specific to the other country (which might be useful e.g. if no cooperation has previously been established), or; • Information about legal agreements, protocols and/or working procedures between the two countries that are already in place.
Context	In contrast to incidents taking place at the local level, which end-users are used to and for which they follow everyday procedures, cross-border cases are less common and might require the implementation of specific protocol(s), regulation(s) and/or agreed working procedures that might not be remembered, as they occur less frequently.
Benefits	A reminder of protocol(s), regulation(s) and/or agreed working procedures is an added value for a platform that among other use cases, target cross-border cooperation.
Negative impacts	
Constraints	

Table 21

Requirement ID	HF_21
Requirement: The user shall be able to complete a form provided by the platform in order to request EO data to speed up the procedure for such request at the same time that fully complies with the official process and channels. The form should work as template for an e-mail that shall be transmitted through the official channels to the corresponding authority.	
Source	EKUT
Summary	The user shall be able to request and swiftly receive EO data through a standardised process that fully complies with the official process and channels.
Benefits	In contrast to other types of data, EO based data from Sentinel missions can only be accessed through Authorised Users of Copernicus Emergency Management Service (EMS). By providing a template with explanatory notes including steps to follow and persons to contact, the time required to access the data will be significantly reduced. Faster data means better up-to-date actions and therefore a better response to the ongoing disaster.
Negative impacts	
Constraints	

Table 22

Requirement ID	HF_22
Requirement: The user shall be able to access at any time during an emergency a timeline/log/mission diary listing chronologically all the actions that have been performed.	
Source	EKUT
Summary	A mission diary/log provides all the necessary information regarding the actions performed up to any specific time during the emergency. Access to it is most useful to create a shared common picture of the incident.
Benefits	At any time during an incident stress and mental fatigue might generate a situation in which an end-user needs to consult the evolution of the emergency in order to remember what has been done up to that moment and to continue to work.
Negative impacts	
Constraints	The information shown should be adjustable to the needs of the role (e.g. the incident commander may need to see instantly which parameters were used in different simulations while a first responder in the field doesn't need that information).

Table 23

Requirement ID	HF_23
Requirement: The user shall be constantly informed about the stability of the internet connection, including pop-ups alerting in case the connection is lost, in order to avoid loss of data inserted.	
Source	EKUT
Summary	The user shall be constantly informed about the stability of the internet connection, including pop-ups alerting in case the connection is lost, in order to avoid loss of data inserted. Associated to HF_16, this HF should trigger an offline back-up plan designed to avoid any data loss.
Benefits	At any time during an incident the stability of the internet connection might be lost and more generally the infrastructure might be damaged, which requires proactive measures in terms of warnings and back-up offline protocols to continue the 'normal' operation of the incident management,
Negative impacts	
Constraints	

Table 24

Requirement ID	HF_24
Requirement: The system shall be designed considering the different profiles that constitute the structure of any end-user organisation. Each profile and associated user account shall be developed considering security measures such as strong access control (login credentials with multi-factor authentication, and rules and permissions).	
Source	EKUT
Summary	The user system shall be designed attending to the different profiles that constitute the structure of any end-user organisation. Considering HF_2, HF_10 and HF_12, each profile and associated user account shall be developed considering security measures such as strong access control (login credentials with multi-factor authentication, and rules and permissions).
Benefits	Access control does not only provide benefits in terms of any potential security breach but can also contribute to tailor the information presented to the users based on their profiles and needs.
Negative impacts	
Constraints	

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