D3.9

Analysis of Human Factor Involvement in the use of Autonomous Systems in DRR and Response and Specifications for User Requirements – Issue 2

Instrument	Collaborative Project
Call / Topic	H2020-SEC-2016-2017/H2020-SEC-2016-2017-1
Project Title	Multi-Hazard Cooperative Management Tool for Data Exchange, Response Planning and Scenario Building
Project Number	740689
Project Acronym	HEIMDALL
Project Start Date	01/05/2017
Project Duration	42 months
Contributing WP	WP3
Dissemination Level	PU
Contractual Delivery Date	M20
Actual Delivery Date	05/12/2018
Editor	Solange Martinez Demarco (EKUT)
Contributors	Prof. Dr. Regina Ammicht Quinn, Andreas Baur, Dr. Anne Burkhardt, Friedrich Gabel (EKUT)

Document History			
Version	Date	Modifications	Source
0.1	16/10/2018	First draft	EKUT
0.2	01/11/2018	Second draft	EKUT
0.3	19/11/2018	Third draft	EKUT
0.4	21/11/2018	Fourth draft	EKUT
0.5	26/11/2018	Internal review	EKUT
0.6	04/12/2018	Quality assurance review performed	DLR-KN
1.0.D	05/12/2018	Final version	EKUT
1.0.F	05/12/2018	Approval for submission	DLR-KN

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List of Acronyms

C&C	Command and Control Centre
DLR	Deutsches Zentrum für Luft-und Raumfahrt e.V. (German Aerospace Center)
DLR-KN	Deutsches Zentrum für Luft- und Raumfahrt e.V. (German Aerospace Center); Institute of Communications and Navigation
DRK	Deutsches Rotes Kreuz (German Red Cross)
EKUT	Eberhard Karls Universität Tübingen
ERCC	European Emergency Response Coordination Centre
HCI	Human-Computer-Interaction
IT	Information Technology
NGO	Non-Governmental Organisations
TETRA	Terrestrial Trunked Radio
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 second issue on human factors involvement in disaster management systems. In this issue a summary of the Human Factors theoretical framework is provided, and the preliminary list of Human Factors requirements presented in [4] is compared with the arguments and issues related to the development of the HEIMDALL system that interviewees manifested.

Firstly, it outlines the Human Factors field of study and the consequences that a Human Factors analysis has for the design of the HEIMDALL system. Then, it includes an explanation of the methodology used to do fieldwork and gather empirical data, the interviews, and the subsequent analysis to identify requirements, arguments and concerns related to human factors and HEIMDALL. This is followed by a comparison between the findings and the Human Factors desk-based requirements introduced in [4] as well as an overview of new issues identified. Among those requirements, 13 were thoroughly analysed during the interviews and three new points were identified as important for the development of the system. Although issues on their own, the points to consider are entangled and the discussion continuously referred to these other issues to clarify, support and/or emphasise their value.

To conclude, the issue closes with the list of updated Human Factors requirements, which will be further developed in the upcoming issue, i.e. D3.10.

1 Introduction

This is the second issue on three deliverables devoted to human factors involvement in disaster management systems, and part of T3.4. This task encompasses 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 D3.8 to D3.10, and social and ethical aspects of human-machine-interaction, which are part of D3.11 to D3.13. As explained in [4], 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.

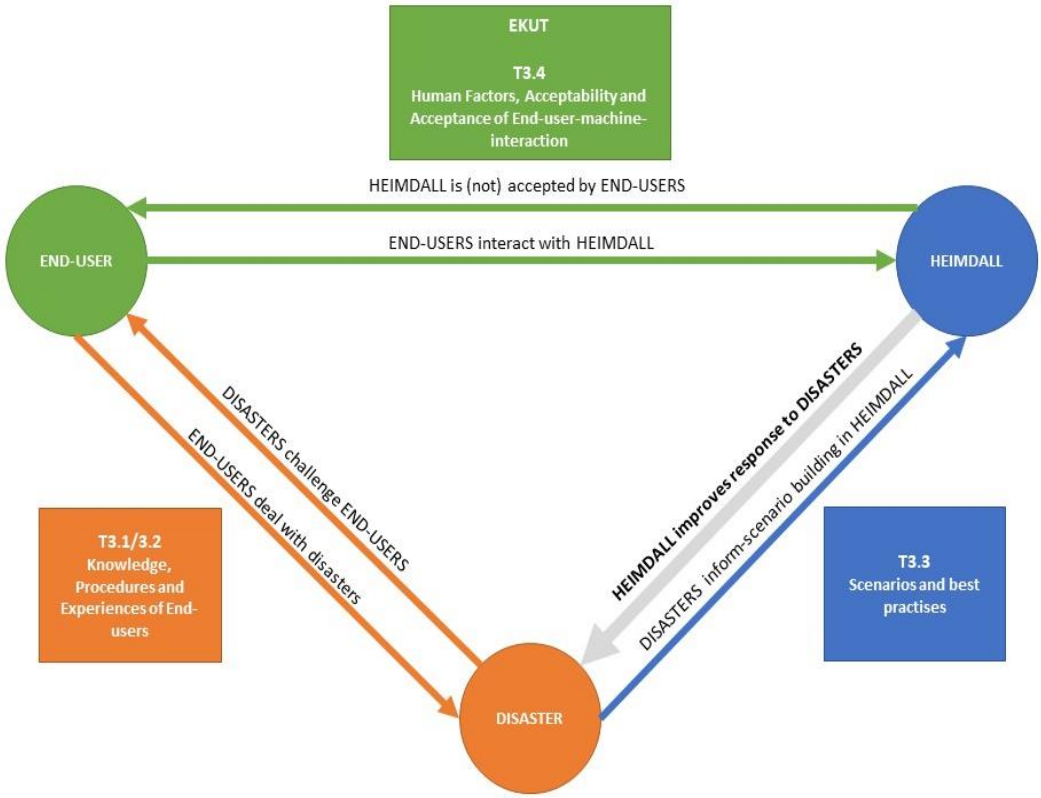

Figure 1-1 The role of WP3 in HEIMDALL (own compilation)

Furthermore, [4] introduced **Human Factors** as the research field devoted to study different aspects such as psychological, physical, cognitive, organisational and contextual conditions that together with the corresponding emergent properties of any socio-technical system 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. To that end, examples were mentioned such as considering the physical design of a technology, the clarity of user interfaces, or preventing the overloading of individual capacities.

In addition, a specific theoretical framework for the application of a Human Factors analysis to the HEIMDALL system was provided. In that sense, the objective of the analysis has been to identify conditions to support those professionals involved in managing an emergency and their situation awareness. Finally, those topics were translated into specific requirements for

the design of the system, which were stated as preliminary specifications to be further developed during the empirical work. In this vein, this deliverable presents the results of the interviews carried out until now and their connection to the desk-based requirements.

The first part (chapter 2) of this deliverable provides a short summary of the work done in [4] related to human factors and their importance for HEIMDALL's design.

Then, chapter 3 outlines the methodology used for the interviews as well as the methods used for evaluating the empirical information.

Chapter 4 presents the main findings of this process and discusses the implication this has on the requirements prepared for the design of the system. Due to some overlap between the results of the empirical work done on human factors and societal acceptance/ethical acceptability ([5]/[6]), some results from the focus groups 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 further design of the HEIMDALL system.

2 What are Human Factors for HEIMDALL?

Following [4], human factor issues arise in every domain in which humans interact with the products of a technology-driven society. Basically, the term Human Factors refers to understanding the connection 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 environment.

Among other aspects, a Human Factors analysis examines the knowledge, perceptions, attitudes, values, and goals of the people working with technology. In addition, for Human Factors it is also important to comprehend the organisational culture that is specific to each working space as well as how decisions are made. Finally, [4] stated that studying Human Factors implies understanding the division of labour between humans and technology, workloads' assignment, and the way humans and technology communicate with each other. Because all these different and intertwined aspects of the human-machine interaction take place in a specific environment, the combination provides the opportunity to study the safety, productivity, human satisfaction, efficiency, effectiveness and estimation of human error that corresponds to that particular context [1]. In this vein, current definitions of Human Factors propose that if an intervention is considered, it should affect the co-production and co-evolution of environment and individuals.

In addition, [4] emphasised that Human Factors, as any other discipline, introduces new understandings of socio-technical systems and complexities to be studied. In this sense, [12] and [2], proposed to consider Human Factors as the study of people and their interactions, the different types of interactions between people and elements of sociotechnical systems, and the options for improving those interactions in real settings. This definition of systems highlights the idea of interaction as a way of recognising the emergent properties of the process. According to him, the emergence aspect is important for three reasons. First, due to unexpected circumstances (time or space constraints, management pressures, personal motivations) the system might operate in unforeseen ways. Secondly, humans are able to make a system work even if poorly designed or if real-life situations were not anticipated. Thirdly, besides overcoming the system's shortcomings, users are prone to create new uses for it. Consequently, to the previous definition of Human Factors analysis, a study of emerging properties of the interaction with the ecological, economic, legal and socio-political context should be added. In particular, the emergent properties seem to be an important point for HEIMDALL as these effects were already observed during the interviews carried out and reported in this deliverable.

In this vein, [4] also outlined Human Factor aspects and issues that might arise during the design of HEIMDALL and that were a product of the desk-based research to be complemented with the empirical work introduced in this deliverable. However, in order to explain these aspects and issues, [4] suggested as the starting point the context in which HEMDALL is implemented: the exceptionality of a disaster or emergency situation in which individuals require information to act quickly under conditions of extreme stress. Since sharing information and communicating among first responders becomes difficult in such events, HEIMDALL aims to follow the idea of providing "the right information at the right time in the right format to the right person". To facilitate organisational coordination among end-users institutions 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 other words, the objective of HEIMDALL is to support the emergency services in their task rather than to drive them.

In order to provide such support [4] issued some Human Factors or aspects that should be considered for the design of the HEIMDALL system, which are presented in bold in the following paragraphs.

First responders have a well-developed sense of awareness of the situation or “the ability to maintain the ‘big picture’ in a dynamically changing environment” ([11]: 1). This aptitude allows them to rapidly absorb information, to judge its meaning, relevance, reliability and value, to decide about options for actions, to make a decision as well as to cope with plans not adjusted to the real circumstances [3]. To support this situation awareness, a Human-Computer-Interaction (HCI) intervention, as HEIMDALL is, should focus on the **usability** of such a system. According to [4], this concept involves a set of diverse and interconnected issues. End-users at the command and control centre and in the field depend upon the **best possible and timely data** in order to make the best possible decisions. This implies two challenges: on the one hand, HEIMDALL should always be connected to the remote sensors, and personnel and organisations must have access to the system to obtain the data coming from the sensors and to provide their own information and knowledge; on the other, visualisations and interfaces should offer the necessary information requiring little or no cognitive effort to decrease the end-users’ **mental fatigue** [10] and to provide a clear picture of the situation on a quick glance.

The degree of **automation** or the adaptive allocation of tasks, which expresses a trade-off between delegating functions that can be automated and the unpredictability of each disaster with the additional workload that it can bring, has been one the issues that has gathered feedback from the end-users. In this sense, [4] stated that automation can generate more complexity and a lack of **transparency** in the ways it decides about the interactions. In this vein, the decision support and simulation modules were presented as either tools used for anticipating and predicting relevant information or as mechanisms for delegating decision and **responsibility**.

In addition, it was mentioned that **feedback** about the interaction that each user has with the system also relies on the level of **flexibility** in the distribution of tasks which, in turn, generates a specific type of human-computer interaction and depends on the context. As a thorny issue, **efficiency** and **productivity** are involved in this debate about adaptability and automation. In particular, during the interviews it was mentioned that due to the stressful circumstances under which the system would be used, careless mistakes are more likely to occur and the design of HEIMDALL should take this point into account.

In order to facilitate and foster the **open exchange of information,** increase efficiency and productivity and reduce errors, information should be communicated to the correct **hierarchies and structures.** Their visualisations, it was stated, should support **mental models** of end-users (common understanding of goals, tasks and procedures), their operational routines as well as to provide space for creativity and improvisation at the team and personal level. Moreover, the **versatility** of the system in terms of allowing exchanges or integration with other systems was emphasised.

In sum, in order to foster **trust** in the system, the correct combination of flexibility, versatility and openness should be achieved. Additionally, **communication style** (**rhetoric and terminology**), **language and the acknowledgement of cultural differences** were identified as issues that can also enhance trust via communicating in their native language. Accordingly, the interviews with end-users focused on the opinions, attitudes and emotions manifested in terms of the struggle for power, reliance, trust and complacency that a system such as HEIMDALL can generate.

Nevertheless, the correct use of the platform is also based on **training and learning time**. In this sense, because emergency teams seldom work together during non-emergency times, training opportunities are moments to test the system under realistic disaster scenarios. Hence, [4] highlighted the value of learning instances in which end-users can use and test the system as well as suggest changes and give feedback. This is particularly important for cross-border cooperation and/or cascade events that, as it has been previously mentioned, involve appreciation of inter-cultural and/or language issues.

On the other hand, [4] emphasised that the negative aspect of having a clear perception of the current emergency is the tension between the need for an ever-increasing amount of

data and respecting the right to **privacy** and **confidentiality** of all the stakeholders. Because HEIMDALL requires the localisation of first responders in the field, **surveillance** is part of the system. However, a balance should be reached so that the risks of leaks, breaches, hacks, misuses and dual uses of data are minimised while the necessary data for maintaining situation awareness is guaranteed.

Finally, a further tension was presented in [4]. Addressing aspects such as efficiency, productivity, flexibility, versatility, transparency, feedback, automation, reliability of data and responsibility might produce a system that is extremely expensive, in which case acceptance and adoption might be challenged. Based on the previous definition of Human Factors a thorough analysis in the case of HEIMDALL should include more contextual aspects such as legal, economic and socio-political circumstances. Since questions of **availability** and **affordability** are covered in [5] and [6], they will only be mentioned in this deliverable.

To conclude, [4] stated that all of these dimensions should be considered. If not, it is likely that further impacts and therefore requirements are neglected. Therefore, this deliverable reports on the series of intertwined questions that were asked and further aspects that were mentioned during the interviews with end-users (members and non-members of the HEIMDALL project) addressing these and further issues. The aim of these interviews has been to make sense of this tool for the first responders, to participate in its development while providing inputs and requirements and to produce a system that complies with a Human Factors perspective.

3 The Interviews

3.1 Methodology

3.1.1 Introduction

A Human Factors analysis of HEIMDALL requires the use of empirical research methods in order to develop a catalogue of human factors to be considered for developing the system. In this sense, 24 qualitative interviews were planned to be conducted, 12 of them with end-users and 12 with other relevant actors and experts in order to identify opinions and attitudes of the interviewees towards different issues related to human-machine interaction such as automation, transparency, usability, language and communication style, to name a few.

[4] indicated that the potential interviewees should be considered based on their connection with the following distinction: on the one hand, end-users, and on the other, experts and other relevant actors. In terms of the first group, the proposal was to interview members of all the end-users organisations that are partners in the consortium as well as further potential end-users not involved in the HEIMDALL project (e.g. the German Federal Agency for Technical Relief (THW) or the German Red Cross (DRK)). Additionally, members of relevant organisations operating in European countries not represented in the HEIMDALL consortium could help to identify Human Factors related to specific national contexts or connected to intercultural aspects.

For the second group, possible actors to be interviewed include scientists and researchers in the field of disaster risk reduction and disaster response; representatives of public institutions involved in disaster relief (e.g. the European Emergency Response Coordination Centre (ERCC)); representatives of social organisations concerned with vulnerable groups (e.g. the Christoffel Blindenmission or HelpAge); representatives of NGOs involved in disaster relief actions (e.g. Médecins sans Frontières); as well as politicians involved in the decision-making process; and/or citizens engaged with disaster-related topics (e.g. in social media and blogs).

Currently, 9 out of these 24 interviews have been carried out, with the remaining ones planned to be conducted between 2019 and early 2020. Out of these 9 interviews one was conducted with members of the German Institute for Disaster Medicine whereas the remaining ones were carried out with representatives of the end-user organisations that are part of HEIMDALL. While a few more interviews with end-users are expected, the focus for 2019 is on selecting other relevant interviewees based on criteria such as the level of involvement, experience and expertise as well as the snowball technique, and taking into account socio-demographic criteria like gender and age.

The analysis of the gathered data reported in the next chapter provides (and will provide) insights into the specificities of humans interacting with the HEIMDALL system which might differ from or add to the ones identified by the literature review of human factors that was part of [4]. In addition, the interviews aim 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 [5], [6]).

3.1.2 Preparing, Conducting, Recording and Evaluating the Qualitative Interviews

In all of the cases except for one the interviews were personal face-to-face conversations between the interviewees and members of EKUT. The interviews with the HEIMDALL end-users were carried out before and after one of the HEIMDALL's project meetings in Oberpfaffenhofen, Germany. In the cases in which this was not possible, the interviews were conducted on the premises of one end-user institution in Barcelona (Spain) and one interview was done via Skype, which may be the case also for the interviews with other potential end-users and experts from different European countries. In addition, one further

interview was carried out at the International Centre for Ethics in the Sciences and Humanities of the University of Tübingen, Germany.

The interviews reported in this deliverable were conducted as semi-structured expert interviews, following the general rule for guided interviews: “as open as possible, as structured as necessary” ([8]: 560). However, the principle of openness was limited by the specific research interest guiding the interviews, which meant that other aspects were not touched upon. In addition, because it is impossible to fully avoid certain influence on the interviewees’ answers, the interviewers were aware of possible factors of influence, such as the different roles within the interview situation and the resulting power relations between interviewer and interviewee (see [8]) 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 gave them the possibility to express themselves in their native language.

In order to get comparable results, a general questioning route for all the interviews was developed, covering the main topics of interest and providing space for additional upcoming questions as well as for spontaneous interventions by the interviewees. The questions were formulated in a rather open way to give 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.

The questioning route was structured in three parts ([8]). The beginning of the interview provided the interviewees with the opportunity to express their views as freely as possible. These questions mainly addressed personal experiences of the interviewees in their field of expertise in order to establish a trustful atmosphere and a comfortable situation. Following this, the interviewers directed the focus of attention towards the main topics of interest and provided space for the interviewees to concentrate 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. Finally, based on the inputs from the first and second part, more questions were asked, including the interviewees’ personal judgement on topics emerging from the conversations.

Before the interviews started, the interviewers introduced themselves and the research project to the interviewees and handed out two copies of the informed consent forms, and when necessary, the Project Information Sheet ([7]). They explained the need for recording the interviews and guaranteed the anonymity of the participants and the confidentiality of the analysis of the interviews. They also emphasised the importance of the interviewees’ knowledge for the research and indicated the estimated duration of the interview as about one hour. Once the interviewees signed the consent forms demonstrating their voluntary participation, the interviews started.

Afterwards, the interviews were stored in an encrypted container and transcribed by members of EKUT. Names of the interviewees and other identifying information were anonymised. The transcripts of the interviews were evaluated following the same method used for the focus group discussion, the descriptive-reductive content analysis method (see [9]: 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 some of the Human Factors identified in [4] as well as new aspects to be taken into account for the development of HEIMDALL.

4 Main Findings

As previously explained, the aim of this issue of the Human Factor analysis within HEIMDALL is to identify requirements, compare with the ones reported in [4] and add new ones that evolved from the interviews. To this end, the interviews focused on the knowledge, opinions, experiences, attitudes, values and goals of the actors interviewed. In addition, some of the questions centred on comprehending the organisational culture specific to each working space, the decision-making processes, and the division of tasks between humans and technology. Furthermore, during the analysis and based on current definitions of the Human Factors study, the data was evaluated in order to identify potential emerging properties of the interaction between the human-HEIMDALL system and the ecological, economic, legal and socio-political context. In this sense, the chapter is divided into two parts, one devoted to compare the findings with the desk-based list of requirements elaborated for [4] and the second part dedicated to present the newly identified issues.

4.1 Comparison with the Preliminary List of Requirements

Following the structure of the interviews explained in 3.1.2, this section delves into the specifics of the questions asked and the answers provided during the main part of the interviews. In general, the issues presented and discussed here observe the order of the questions, and therefore, are compared with the requirements presented in [4] in a different order than the one given in that deliverable. Specifically, the topics touched upon with the questions asked were the same in every case, but as explained, the questioning route was open and therefore, the order and the phrasing were adapted to each participant. In addition, the reasoning behind the answers obtained have, in many opportunities, covered more than one of the requirements presented in [4], which creates unnecessary repetition if every point is treated individually.

4.1.1 Requirement HF_1: The system shall be designed for different types of end users and the different equipment they use

After the first part of the interviews, the transition to fact-based questions was focused on inquiring about the current use of software in the corresponding organisations and position in the hierarchy. While the answers produced mixed results, in all the cases the added value that HEIMDALL could offer in terms of gathering data from different sources was emphasised.

Regarding existing technological solutions to be used in case of an emergency, some of the interviewees stated that they only use one software, while others revealed the use of two or more different types of software, and a third group of interviewees mentioned that for some data they use web-based tools that offer, for example, meteorological data. In addition, while one of the software installations they referred to was developed in 1995, others are updated periodically, and yet others use a software only after an emergency situation to register the incident for lessons learnt and training. Whereas some organisations can access, use, process and edit several specific types of data (e.g. raster files are supported but vector files are not), others have more or even less options. Therefore, we can conclude that the landscape of software-based assistance systems is very diverse and also the current use and need for them shows big differences.

Connected to the use of software, another topic touched upon was the more general question of equipment and/or technology currently used. In this sense, the emphasis was on how data and information is shared and how communication works internally as well as with other end-user organisations. Once again, differences among the respondents highlighted cultural, organisational and functional variabilities as well as disaster type-based differences.

Although a general agreement regarding the use of TETRA (Terrestrial Trunked Radio) radio system for communication among first responders in the field and command and control

centres (C&C) was identified in the interviews, HEIMDALL has to reflect the different ways first responders use communication technologies to talk to each other in the field and to fit to the existing communication infrastructures. These, however diverge in different European countries.

In addition, among other technologies, smartphones, tablets as well as flipcharts are worth mentioning. With regard to the first, some end-users mentioned that they are often provided with a company smartphone to be taken with them to the field in order to take photos, record video or audio, and share them with other end-users and/or C&C. Tablets were also considered a valuable technology because they can be used in the field and due to the size of the screens more data, such as maps, can be accessed. Nevertheless, interviewees stated that the material and the software are key aspects to implement them more widely. On the one hand, due the circumstances under which this technology is used roughness is extremely important. Internet connection and its different availability, especially in rural areas and during an emergency, also is of major importance. On the other, usability features such as brightness, contrast and size of the font should be main aspects to take into account when designing HEIMDALL's interface.

Regarding flipcharts or whiteboards, several participants belonging to the same end-user organisation mentioned that the possibility to freely write and draw (for instance on a map) is of utmost importance for disaster management. It was mentioned that a prototype of a software used for working on an interactive whiteboard was being tested. After working for years with flipcharts they saw in this new technology a helpful, easier and more productive tool to share the same operational picture with all those in front of the whiteboard.

Although desktops and laptops are also considered technologies common to all end-user organisations, models, operative systems and installed software indicate the great variety in terms of support that they can provide.

In sum, supporting requirement HF_1, HEIMDALL should be designed considering the difference among the users targeted, which differ in terms of culture, language (see also 4.1.2), organisational structure, and functions, and their difference access and use of technology (see also 4.1.3).

4.1.2 Requirement HF_5: The system shall be designed considering translation, linguistic and cultural issues in regard to end users

Particularly, in terms of language and culture, there is an agreement among all the interviewees regarding the added value of accessing HEIMDALL in their native language. Many reasons were put forward to support this argument. First, as a system used for specific crises and, most likely, by personnel not used to work with HEIMDALL, the language of their own country/region reduces the time spent on understanding the interface and identifying the tools and data needed, which is of utmost importance during such cases.

Secondly, although English is a language used on an international level, on a decision-making level and by many high-ranking officials, most likely those working at a local/regional level understand better the system in their native language. Thirdly, even if the software is implemented in English, first responders in the field will communicate under stressful circumstances among themselves and with the control room in their own language. Furthermore, legal frameworks might also state that any support offered to the emergency services should be provided in the language of the country.

Another reason, one that was compellingly explained by one of the interviewees, shows how important this point is when differences among concepts depend on subtleties. "I don't know if you remember. [Some time] back we had a couple of meetings that didn't seem to move on very quickly because we couldn't understand scenario versus situation. And we were only using English and we were the end users [who] couldn't agree" (strategic manager, firefighter). Therefore, the style of communication and terminology are further key elements to take into account during the development of the system.

In sum, referring to HF_5, the geographical target of HEIMDALL is the European Union, which as such is composed of many different countries with their own languages and cultures. In order to support its adoption and use, these aspects should be addressed.

4.1.3 Requirement 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 levels in the hierarchy

A further point to consider is how the interviewees evaluated the impact of HEIMDALL in their current procedures, roles and responsibilities. Because of the broad spectrum of issues covered under this label, a series of more specific questions were asked. One of the points discussed was the consequences of adopting the system in each organisation. Some of the answers focused on the possibilities of new roles or profiles needed for working with HEIMDALL, while other participants considered that new positions were not expected. Moreover, a third opinion concentrated on the modifications that both sides, the HEIMDALL system and the end-user organisation implementing the system should adopt: "(...) and there is an effort, I suppose, a joint effort, from both sides [HEIMDALL and the organisations] to see how it fits, ok? Because, (…) it is difficult that the software collects all the particularities of a territory, ok? Territories are obviously not homogeneous. And neither are the people" (coordination chief of the control room, firefighter) (own translation).

Regarding the question of whether or not new profiles are necessary, perspectives differed between the specificity of the added value that the system offers and the development of the business plan. In the first case, the interviewees explained that new positions depend on HEIMDALL offering modules or functionalities that require new tasks and/or knowledge. If this was not the case, even though there were comments suggesting a functional analysis to evaluate the impact of the system in each role, many interviewees held that the system could be implemented without requiring more personnel. Nevertheless, it was also pointed out that a tailored business plan was also a reason for requiring more positions. To this point, a reference to [6] can be made. The business plan should take into account the particularities of each potential user approached, be it at country, regional or local level, as well as its functional responsibility and financial possibilities. Therefore, a system providing options not currently covered in the organisational structure will likely require an individual to oversee its functioning as long as the institution has the financial means to recruit more personnel. More about availability and affordability is said in the section 4.2.

Additionally, comments were made related to offering IT support 24/7. In this sense, a system that provides support during emergencies should not be down or suffer from any glitches. However, software is not bulletproof, needs maintenance and these statements enlarge the scope covered by requirement HF_15 indicating that besides back-up options an administrative IT expert is expected to be recruited if HEIMDALL is adopted in any organisation (see 4.1.11).

Moreover, referring to the comment of mutual adaptation, interviewees explained that HEIMDALL should be developed taking into account the diversity of potential users, their experience, knowledge and position in the hierarchy that are acknowledged in HF_2. According to participants' opinions, HEIMDALL is a system to be used by personnel that might or not be used to work with software, in organisations composed by members of different age groups and having particular structures and hierarchies. To develop a system with such diversity of end-users is a challenge. But its success depends on responding with a platform that flexibly adjusts to this variety. Access levels and interfaces that allow all end-users to access vital information contribute towards improving disaster preparedness, crisis management and response, the objective of HEIMDALL.

4.1.4 Requirement HF_11: The system shall support operational routines but also be flexible and versatile

Stressing the importance of tailoring HEIMDALL to the geographical, environmental, cultural and organisational conditions, participants mentioned that this project is not the first of its type. Many other software solutions were or are currently being tested and previous and current experiences have not always been satisfactory. HEIMDALL should learn from these experiences in order to improve its outcome regarding flexibility and versatility.

Specifically, current emergency management procedures were presented as very flexible, creating ad-hoc and chaotic responses for every incident. As such, interviewees emphasised that protocols, regulations, and rules are followed, but that the particularities of each case −the mission gap− imply that improvisation is always necessary. Therefore, HEIMDALL was well regarded because "(t)o come from the chaos phase, the ad-hoc phase to a more structured process, this, I would say, might be the key benefit from this kind of tool" (paramedic). At the same time interviewees also mentioned some concern related to the degree of flexibility of the system that might be lacking for this reason. This conflict between structuring but at the same time limiting (the creativity within) procedures is not a new one but might have to be continuously discussed in the context of the project.

To exemplify the limitations of current solutions and support the development of a flexible and versatile system, participants made several references. One case was that of a software that was not taking into account parameters that were necessary when fighting some forest fires, which demanded more time and generated an additional task to be covered in order to add to the simulations obtained. Other comment was connected to the added value of integrating HEIMDALL with interviewees' own human resources system to identify personnel in their shift or tracking resources in the field. Also, linking the system with other sources of data not originally offered was stressed. In other words, participants confirmed the value of HF_11 regarding the value of a system design that is flexible and versatile.

Connected to this point, another argument that was held in many interviews is the need for a system that supports everyday work and that can be integrated into end-users' routines. According to the interviewees, HEIMDALL should cover events beyond forest fires, floods, and landslides to ensure a higher chance of adoption. In this sense, "What is the use for the day to day? (…) We have to see how we apply it in the day to day that is much more important in the number of events than big emergencies that are big emergencies, yes, but which in number or percentage of events in comparison to the day to day are the less" (coordination chief of the control room, firefighter) (own translation). Furthermore, participants also found chemical and nuclear emergencies as use cases for the system. Nevertheless, because the currently proposed HEIMDALL system would only be activated in those specific incidents, other comments indicated that training might be a way to remind of its existence and to motivate to use it when the time for those types of events has come. In addition, a modular and versatile development that can add new functionalities and, in the future, even potentially provide support for management of daily incidents could be the answer to this issue.

4.1.5 Requirement HF_6: The system shall be developed considering uniformity of interface, commands and terminology.

In line with the argument in favour of a more structured process, interviewees acknowledged the value of a system that can trigger a process of standardisation. As mentioned in 4.1.12, even an agreement on terminology is difficult because of current differences among end-users organisations. However, as participants explained, a common system adopted throughout Europe can reduce these differences and contribute to a better cooperation among organisations. In other words, it means common expectations in terms of exchanging information, reducing the time needed to respond to a crisis with the consequent increment in efficiency, sharing the same operational picture, and therefore, better understanding.

Interviewees, however, identified a main barrier to achieve this standardisation: how to implement such system on a European level? In this sense, some interviewees uttered the suggestion that the European Union should work on making the implementation of HEIMDALL obligatory, while others stated that at least it should be a country level decision to require its implementation at regional and local level. Once again, the business plan is the tool to provide an answer to this issue.

4.1.6 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

Gathering and visualisation of data were main aspects of the system that every interviewee acknowledged. However, subsequent questions related to user profiles and levels of access to data generated mixed reactions.

Referring to 4.1.4, flexibility seems to be the preferred option for approximately half of the interviewees, whereas a well-defined structure and access level was the opinion of the other half. Those supporting flexibility or with no clear answer to the question indicated that a decision about this matter depends on the case. Then again, those supporting the structures in terms of granting permissions explained that end-users in the field are working under such stress and with no time to devote to studying the data that access to all the data the system might provide is unnecessary and not feasible. Moreover, while a commander or a manager requires data in order to make a decision, the type of data used by, for example, fire analysts or control room personnel is different.

In addition, a comment from one of the interviewees highlighted the difficulties of providing an answer to this issue. In their view, there might be a conflict in terms of adopting HEIMDALL before a national policy clearly states levels of access to and sharing of data.

Although a complex topic, requirement HF_12 suggests a potential solution. 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.

4.1.7 Requirement HF_10: The interfaces of the system shall be designed considering the reduction of the information load to one person/member of the crisis management task force

HEIMDALL aims to integrate large amounts of data in an efficient and clear presentation in order to support decision-making and response processes as well as to reduce response time. This was another point unanimously valued by all the interviewees. Having the best possible data in a timely manner was acknowledged as the key issue in order to make the best possible decisions during either the crisis preparation or the response phase.

Currently, data is obtained from many different sources without an option that centralises 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.

However, participants insisted on two aspects: on the one hand, HEIMDALL should be a system that reduces the amount of data displayed. Filtering data and reducing the cognitive load are key elements to limit the mental fatigue and improve the productivity of each end-user. Due to the identification of the valuable data increments in efficiency (less personnel involved) and time response are also expected. Therefore, referring to HF_10, options

should be implemented that allow adjustment of the information required based on the user profile and the circumstances of the particular case.

On the other hand, interviewees emphasised the need for factual information, presenting data with no bias or interpretation, which supports requirement HF_14 that is presented in 4.1.8.

4.1.8 Requirement HF_14: The system shall be able to assign levels of certainty to the information items provided by the different systems and actors (autonomous systems, end users, and citizens)

Referring to the type of data that end-users should have access to, the interviewees insisted on “present[ing] factual information. It shouldn't have any bias and the system shouldn't interpret the data” (strategic manager, firefighter). Their argument was based on the concepts of responsibility and influences on decision-making. In their view, end-users are responsible for decisions made while managing a crisis. Therefore, reliable data is their main input to make these decisions. In case the validity or veracity of data is not ensured, or in case data is erroneous, end-users will be responsible for the decisions made based on it. In the same vein, if HEIMDALL presents biased data that can negatively impact the decisions to be made, responsibility will be in the end-users hand. For these reasons, the interviewees considered requirement HF_14 of utmost importance.

Following the argument of [6], mentioning the source of data is one of the options, especially in the case of autonomous systems and sensors. In addition, indicating the margin of error, and therefore, the accuracy of the results of the simulators is another possible alternative. Finally, in the case of social media, relaying on the services of groups such as VOST[1], guarantees the veracity of the information and also adds value to the system while incorporating another source of data.

4.1.9 Requirement HF_13: The system shall be transparent on the decision support mechanisms and used criteria

In addition to the data presented, participants explained that also decision support functionalities should indicate the parameters used and the weight assigned to each of the parameters in the algorithms. According to the interviewees, although these functionalities are a good added-value in terms of evaluating possibilities and reducing the time necessary for these evaluations, it was stressed that transparency is essential to trust the system.

In this sense, agreeing with requirement HF_13, the interviewees explained that they do not need a system that automates decisions but one that supports their work and facilitates human decision-making. Autonomy is indispensable because HEIMDALL could make a mistake or have not enough data to identify details or subtleties that end-users do know due their experience or knowledge of the area. Based on the observations made during project meetings, if the system provides options they should not be numbered. In this way end-users are less likely to be (badly) influenced by those. Additionally, transparency and possibilities to manually alter those parameters are other ways to enhance trust in the system and the end-users’ autonomy.

One of the interviewees added that in terms of transparency there is one more aspect to consider. “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.

[1] 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.

Because in the end, society ask and they have the right to know" (incident commander, firefighter) (own translation).The use of HEIMDALL "forces the emergency services to clarify, order, collect [and] neatly register the information and that translate into better lessons learnt, in the analysis [of them], so the actions will improve and the service to the citizen will also improve" (incident commander, firefighter) (own translation). In other words, providing transparency will not only help to improve the end-users work, it will also help to be accountable and provide better explanations to the population.

4.1.10 Requirements HF_7 and HF_8: The system shall be developed taking into account potential mistakes when using it, and therefore, shall provide informative feedback about its status whenever the user is interacting with it

As mentioned above, the interviewees are aware that HEIMDALL will not be infallible. Nevertheless, end-users are humans, and therefore, also not faultless. When asked about a notification option to ensure a smooth interaction with the system, participants considered it a meaningful functionality. 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 reduce the levels of stress, anxiety, and tendency to clumsiness that are common in disaster management situations.

Furthermore, as mentioned in section 4.1.3, no software is bulletproof and HEIMDALL is not an exception. In terms of a business plan, a thought should be given to this matter in order to provide technical support at any time either through administrator's rights or physically present administrators.

In sum, 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, 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.

4.1.11 Requirement HF_9: The system shall consider the necessary learning time of their users

Training was also a topic mentioned throughout the interviews. The understanding that was shared among all the participants is that HEIMDALL is not different from other software in use or current procedures followed in the sense that it needs training. According to the interviewees, HEIMDALL, in order to be successfully implemented, will require a learning period as well as time to become comfortable with the system. Moreover, a second barrier is, as previously mentioned, the use of the system for specific cases. Therefore, following requirement HF_9, 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.

In addition, requirement HF_9 also stated another valuable tool for supporting training and learning periods, documentation, or online and offline help can provide information to overcome unforeseen circumstances or memory loss.

Nevertheless, as stated for some other requirements, training should not be considered only when developing the system, but also when preparing the business plan and tailoring it to the specific end-user as well as throughout the utilisation period. To complement this last point, some interviewees also highlighted the value of the system in terms of enhancing end-users' general training.

4.1.12 Requirement HF_15: The system shall be designed to reduce execution time and tasks and provide with monitoring and backup options in case of damage

As stated in previous sections, HEIMDALL should reduce the time devoted to gather, sort, find and analyse data with the subsequent increment in efficiency and productivity. Then again, section 4.1.3 stated that a system such as HEIMDALL should not suffer from glitches or crashes due to unforeseen events. However, as any other software, HEIMDALL is not faultless and support should be provided 24/7 for these cases. In other words, requirement HF_15 should be expanded to cover not only back-up options, but also technical support.

In this vein, one of the participants stated that "(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) (own translation). In line with other requirements that suggest elements to be considered in the business plan, back-up and technical support options should also be covered.

4.1.13 Requirement HF_16: The system shall offer an offline protocol when internet connection is lost, or infrastructure is damaged

Finally, one concern shared by all the interviewees was the lack of reliable internet connection during a crisis throughout the areas they serve, and most likely, all over Europe. In some cases, there was even a clear worry that HEIMDALL could not work due to the current lack of infrastructure and broadband service.

Participants' worries can be eased, and a use case can be found in their arguments that support requirement HF_16 as well as HEIMDALL's proposition of satellite-based communication development that is part of WP 4.

4.2 New Identified Issues

4.2.1 Affordability and Availability

One issue that was important for many of the interviewees, and already introduced in 4.1.3, is how HEIMDALL is offered to end-user organisations (business model) and how it is implemented. Although affordability and availability are discussed in [6], a brief explanation of these topics and their value for a Human Factors analysis is necessary. Studying the use of the system is more than evaluating the working conditions and the options for reducing mistakes. Current definitions of Human Factors acknowledge that human-machine-environment interaction generates many unforeseen new uses of technology. There is, in this sense, evidence from focus group discussions, interviews, observations done during the project meetings and informal conversations with members of the consortium supporting the idea of developing other use cases from those originally given to the system.

On the other hand, Human Factors studies also evaluate the emergent properties of the interaction between humans, technology and contextual conditions such as legal, economic, political or environmental circumstances. For example, during the interviews a concern that many interviewees put forward was how to successfully adopt HEIMDALL. There were a variety of arguments in support of this worry. For some of the participants, implementing the system only makes sense if it is acquired at a national level or pushed forward by the European Union with the objective of homogenising the mitigation work on (inter)national, regional and local levels. The standardisation of procedures, tasks and response plans that HEIMDALL would bring could also involve improvement in cooperative work at inter-organisational or inter-regional level, better and faster exchanging of information and 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.

Other interviewees evaluated arguments for and against a private company offering HEIMDALL. In this case, the negative side was identified as how to guarantee the confidentiality of the information, while the fast response time to requests for modifications, new requirements or technical support is an aspect that favours private enterprises. Moreover, in case the system is commercialised many evaluated as necessary to provide 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.

In sum, 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.

4.2.2 The Greater Good of Society

To conclude the interviews participants had the opportunity to give their own opinion about the impact that HEIMDALL could have on society. They were given a number of topics, some which were already mentioned and others that were new to the discussion. The feedback to these questions has been separated along two different aspects: one related to effects on the work of the organisations and the second one connected to communicating with the population.

In the first case, the topics touched upon were dual use and misuse and tracking of personnel. Regarding misuse, the interviewees insisted on two points: to avoid wrong or misleading decisions, data received should be unbiased and trusted. Nevertheless, experience and knowledge of the first responders would also detect and rule out any information not matching with theirs. In this sense, security breaches or bypassing of access controls to alter or falsify data is not ruled out but offset. Additionally, as explained in [6], data such as critical infrastructure is unlikely to be part of HEIMDALL's datasets due to their status as classified information.

However, the discussion of tracking of personnel brought forward mixed results. The reactions in this case varied due to current procedures that, in some cases offer a tracking option, and others which are culturally and/or legally not in favour of such a measure. An answer to this issue was agreed among developers of the system to provide this option to those organisations that currently track personnel with their own equipment.

Finally, a general agreement has been also identified in regard to the value of including a functionality to send warnings and alerts to the population. In particular, the interviewees emphasised the possibility of sending messages suggesting measures to take and actions to be done either to prepare or response to a disaster. Yet, participants also manifested that these alerts should be a responsibility of specific personnel with experience and knowledge, such as communication teams. In addition, some suggested that adopting communication policies and providing some training to the population in terms of dealing with different type of crises are also valuable political measures to support and foster the output of HEIMDALL's warnings and alerts.

In sum, the participants' views related to society highlighted how HEIMDALL can improve the service end-user organisations already provide and the potential negative aspects that should be avoided during the development of the system.

5 Conclusions and Recommendations

This second issue on three deliverables devoted to human factors involvement in disaster management systems provided a summary of the Human Factors theoretical framework and delved into the arguments and issues that interviewees manifested in connection to potential human factors affecting the development of the HEIMDALL system.

Firstly, it provided an outline of the Human Factors field of study and the implications of a human factors analysis for the HEIMDALL system. Secondly, it briefly explained the methods used to empirically gather data, the interviews, and the subsequent analysis to identify requirements, arguments, concerns and opinions related to human factors and HEIMDALL. Finally, it presented a comparison between the findings and the Human Factors desk-based requirements introduced in [4] as well as an overview of new issues identified. It outlined a list of 13 requirements which were discussed during the interviews and three new points to take into account for the development of the system. In a similar fashion to [6], the points to consider are entangled and the analysis continuously referred to these other issues to clarify, support and/or emphasise their value.

In general, interviewees supported the preliminary list of requirements that was part of D3.8, although some concerns regarding their feasibility or controversies with other issues were manifested. In terms of recommendations for the development of HEIMDALL, participants emphasised that the design of the system should take into account the following points:

- Different types of equipment
- Diversity in terms of experience, knowledge and level of hierarchy of the end-users
- Translation, linguistic and cultural differences
- Flexibility and versatility but supporting current operational routines
- Standardisation of terminology and commands
- Clear leadership structures in order to establish access levels and grant permissions
- Reduction of cognitive load
- Provision of information indicating levels of certainty
- Transparency on decision support mechanisms and used criteria
- Interactive feedback
- Learning and training periods
- Monitoring, back-ups and technical support options
- Provision of satellite communication

In addition, 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. In this sense, beyond acceptance of the system, the successful implementation of HEIMDALL depends on legal, political and economic contextual conditions that should be considered in the business model. For example, 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.

Lastly, participants stated their opinion in terms of how HEIMDALL’s functionalities can improve the work of the organisations and better communicate with the population.

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