Critical Action Planning over Extreme-Scale Data

D2.1 Data handling, Joint Scheme for Pilot and Demonstrator Research Design, Requirements Analysis and Initial Scenario Definition

Version 1.0

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V0.2	Jens Pottebaum (UPB)	16/04/2023	Adoption of deliverable template
V0.3	Jens Pottebaum (UPB)	20/04/2023	Alignment with D1.2
V0.4	Jens Pottebaum (UPB)	21/05/2023	Persona template added
V0.5	Jens Pottebaum (UPB)	24/05/2023	Emergency case update
V0.6	Jens Pottebaum (UPB)	29/05/2023	Contributions by all partners in shared doc
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V0.9	Jens Pottebaum (UPB)	16/06/2023	Switch to new template
V0.10	Jens Pottebaum (UPB)	26/06/2023	Alignment of inputs
V0.11	Jens Pottebaum (UPB)	26/06/2023	Alignment of inputs
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V0.13	Jens Pottebaum (UPB)	27/06/2023	Finalization of use case narratives
V1.0	Nikos Giatrakos, Antonios Deligiannakis (TUC)	29/06/2023	Final pass, minor corrections/formatting

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Executive Summary

CREXDATA focuses on a range of technologies envisaging impact in action-planning and decision-making. To evaluate outcomes with regard to the expected impact, WP2 documents and analyzes use cases to elaborate on requirements and KPIs. The CREXDATA system is adopted per use case in terms of demonstrator systems. This includes communication interfaces to use case domain-specific systems, implementation of custom data fusion operators to be mapped to generic ones, as well as configuration of CREXDATA components and visualization schemes in case specific User Interfaces. The use case validation refers to success criteria to operationalize the statements on expected impact. The final objective is to draw cross-pilot conclusions through mapping and reflection of case specific results. Demonstrators are developed following established standards of product development and Systems Engineering. Thus, as a side-effect, a foundation is set for strategic planning and exploitation.

This deliverable serves as a guideline for planning, execution, analysis and documentation of the CREXDATA use cases:

- weather-induced emergencies, with pilots in Dortmund, Austria and Finland, as well as an initial application scenario on pluvial flooding
- health, with two application scenarios on epidemiology and multiscale lung infection
- maritime, with two application scenarios on Collision Forecasting and Hazardous Weather Rerouting

The deliverable supports alignment of interfaces between the integrated system and use case-specific demonstrators, mapping of terminologies across use cases, and preparation of cross-impact evaluation. As simulators are use case specific, these are covered as an extension of CREXDATA system interfaces. The deliverable reflects research methodologies with regard to different approaches like data sets, experiments, studies and field trials. Besides the joint scheme for pilot and demonstrator research design across use cases including data handling process in accordance with D1.2, the deliverable presents per use case:

- initial demonstrator architectures,
- initial application scenario definitions and requirements analysis, and
- detailed application sub-scenarios resp. use case narratives.

Finally, the deliverable prepares for evaluation within use cases and across use cases. Success criteria and KPIs are adopted from the initial project description.

1 Introduction

WP2 documents and analyzes several diverse use cases to elaborate on the requirements and KPIs. Pilots are setup per use case based on a harmonized evaluation scheme. For each use case, WP2 develops or enhances the simulators to be integrated in demonstrators and to be used in pilots of CREXDATA. The system provided through WP3 (covering elements of WP4-5) is adopted per use case in terms of demonstrators. This includes communication interfaces to use case specific systems (like ARGOS in T2.1), implementation of custom data fusion operators (cf. WP3) to be mapped to generic ones, as well as configuration of CREXDATA components and visualization schemes in case specific UIs (especially in AR, see WP5). The use case validation refers to success criteria on three levels based on demonstrator implementation and pilot setup: functional test of the demonstrator, basic usability evaluation based on System Usability Scale (SUS), and case specific impact evaluation. The final objective is to draw cross-pilot conclusions through mapping and reflection of case specific results. [DoA, pp 7-8] This approach is depicted in Figure 1.

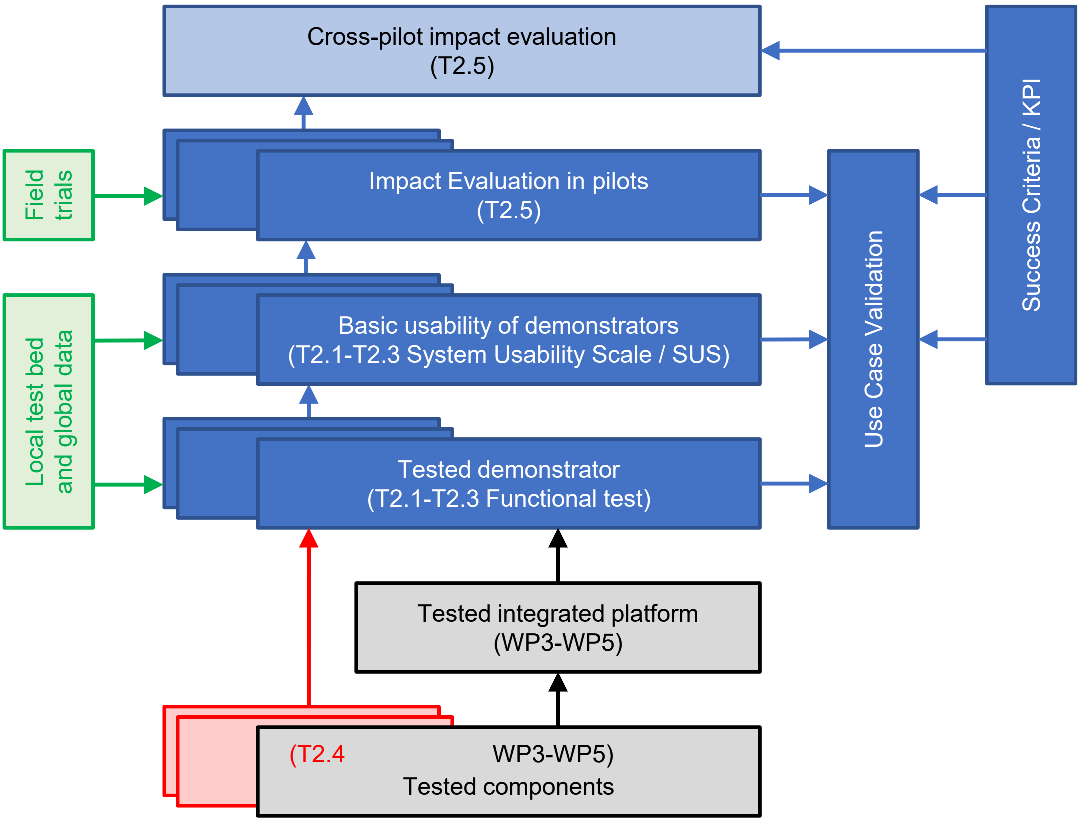


Figure 1: Research approach in Work Package WP2

1.1 Purpose of this document

This document serves as a guideline for planning, execution, analysis and documentation of the CREXDATA use cases. D2.1 sets up structure and procedures for research data acquisition, analysis and evaluation. The deliverable supports alignment of interfaces between the CREXDATA integrated system (grey boxes in Figure 1) and demonstrators, mapping of terminologies across use cases (dark blue boxes), and preparation of cross-impact evaluation (light blue box) especially in terms of consolidation of success criteria and KPIs. As simulators are use case specific, these are covered as an extension of CREXDATA system interfaces (red boxes). The deliverable reflects research methodologies with regard to different approaches like data sets, experiments, studies and field trials (green boxes). This joint structure will be reflected in the structure of deliverables D2.2/D2.3. (cf. [DoA, p.19])

1.2 Relation to other project documents

[GA] Grant Agreement (no. 101092749) with its

[DoA] Description of Actions (DoA, part of the [GA])

[CA] Consortium Agreement

[D1.1] Deliverable D1.1 Quality Assurance Plan

[D1.2] Deliverable D1.2 Data Management Plan

[D1.3] Deliverable D1.3 Ethics Manual

1.3 Contribution and structure of this document

Besides the joint scheme for pilot and demonstrator research design across use cases including data handling process in accordance with D1.2, the deliverable presents per use case

- initial demonstrator architectures,
- initial application scenario definitions and requirements analysis, and
- detailed application sub-scenarios resp. use case narratives.

In the initial stage of the CREXDATA project, the deliverable contributes content to bridge and to focus the inherent technology push (implemented in WP3 to WP5) and the ambitious requirements pull across all use cases.

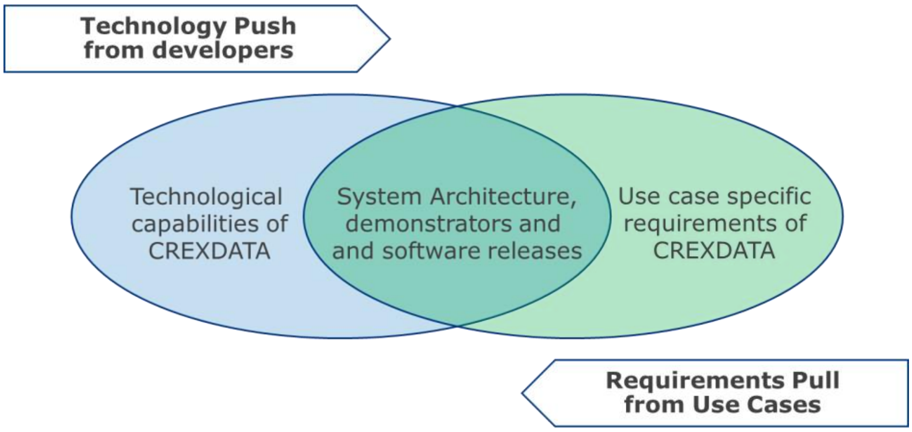


Figure 2: Contribution of D2.1: Cross-pilot mapping of technology push and requirements pull

The document is structured along these two perspectives. The joint scheme for pilot and demonstrator research design in Section 2 includes a fundamental terminology, alignment of methods and templates as well as details about data to be acquired and handled. More details on data handling procedures are included in [D1.2]. Section 3 shifts the perspective from methodological to technical. It provides the reference for requirements engineering and, later, evaluation activities by adopting CREXDATA fundamentals. Assumptions on the system architecture of the core CREXDATA system are integrated into a "reference architecture for CREXDATA demonstrators". Simulators are introduced based on the [DoA]. An overview on uptake of technologies is provided to prepare for cross-pilot evaluation. Section 4 provides insights into all three use cases, covering demonstrator specifications, application scenarios and data setups. Details are provided in the appendix. Section 5 prepares for evaluation within use cases and across use cases. Evaluation criteria are established with corresponding measures and indicators.

1.4 Target audience

- CREXDATA technology partners ("developers")
- CREXDATA use case partners
    - end users
    - technology partners providing demonstrator components
- Third party researchers in application-oriented research domains, especially
    - security
    - health
    - maritime

1.5 Glossary

Abbreviation	Expression	Explanation
UC	*Use Case*	Applications of CREXDATA technology resp. the CREXDATA system in real-world scenarios. Within the project three use cases

Abbreviation	Expression	Explanation
		are defined: weather induced emergencies, health and maritime.
	Pilot (site)	Conceptual term to describe a set of stakeholders within their context like spatial environment, equipment, data sources etc. For each Use Case, several Pilot (sites) can be specified (for instance, Dortmund and Austria in the emergency case).
	Application Scenario	Procedural and structural description of potential uptake of CREXDATA technologies in Use Cases (for instance, flooding and forest fires in the emergency case).
	CREXDATA system	Output of WP3, integrating technologies created in WP4 and WP5 without use case-specific customizations. It includes customization and configuration functionality, esp. through graphical workflow management.
	Demonstrator (system)	Technical system based on the CREXDATA system, which is customized and configured for specific Use Cases, Pilots and/or Application Scenarios. The Demonstrator might include additional components both as data sources and sinks (for instance, legacy systems of end users or the ARGOS system in the emergency case).

2 Joint scheme for pilot and demonstrator research design

Use Cases help to transform technological evolutions into impact in specific applications. The three Use Cases are very different in terms of stakeholders, data sources and user interface requirements. Thus, specific approaches are conducted. To prepare for later evaluation and to facilitate drawing of conclusions across Use Cases, these approaches are related to a joint scheme that is applied to all Use Cases and pilot sites (see Figure 3).

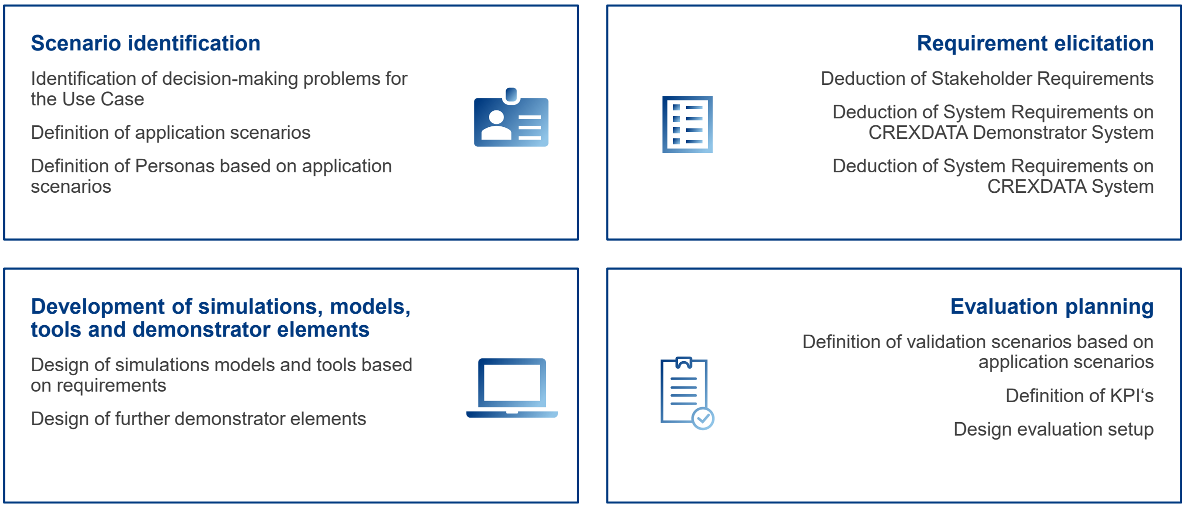


Figure 3: Elements of the joint scheme for pilot and demonstrator research design

2.1 Phases of the pilot design

Scenario identification (see Section 2.1.1) subsumes descriptive models of action-planning and decision-making problems, representative procedures or chronological descriptions of behaviours as well as stakeholders with their dependencies. A fundament is built for requirements elicitation (Section 2.1.2) along the cascade from stakeholder requirements, system requirements targeting the demonstrator system (including domain specific sub-systems like rescue robots in the emergency case) and, even more specific, system requirements of the core CREXDATA system. Simulations and domain-specific tools need to be adopted or even implemented in Use Cases (cf. Section 3.1). Evaluation targets conclusions across Use Cases (Section 2.1.3). This is prepared by a combined bottom-up and top-down approach: The DoA already provides evaluation criteria in terms of expected impact descriptions. They are broken down to specific criteria and indicators for Use Cases. Vice versa, stakeholder requirements are transferred to evaluation criteria. They are mapped bottom-up to overarching impact assertions.

2.1.1 Application Scenario Definition

The mapping of requirements pull and technology push is supported by a scenario-based requirements engineering approach. Application scenarios are either focused on the problem domain itself (i. e., emergencies, health and maritime) or an extension by anticipated use of new solutions (i. e., elements of the CREXDATA system). For such application scenarios, two main elements are essential: references to relevant stakeholders represented by personas (esp. potential end users of the CREXDATA system), and narratives of situations evolving in a domain of interest.

Table 1: Generic key stakeholder groups & roles to be detailed per Use Case

Key stakeholder group	Key stakeholder roles
Action planner	using information to analyse a situation, to identify and evaluate alternatives of potential actions, and to suggest ranked actions
Decision maker	using information to evaluate ranked actions, to assess consequences of their implementation, as well as to take and to communicate decisions
System administrator	responsible to administer IT systems with regard to data sources, information processing and/or user interfaces
Workflow designer	responsible to design workflows within an information system, including design of data/information processing pipelines

According to the overall project's objective, action planners and decision makers are key end users of the CREXDATA system. Dependent on specific use cases, these two roles might be overtaken by different people, or they are taken over by one single person. Similarly, system administrators might be responsible, in person, also for workflow design. For the purpose of application scenario-based requirements elicitation, each of these generic CREXDATA stakeholder roles is detailed by specific roles in use cases using a persona scheme according to [1]. From that fundamental publication, information like personal characteristics (age, …), work activities (job description and role at work), leisure activities, goals, fears, and aspirations, computer skills, specific technology attributes, quotes as well as references are adopted. "Goals and activation factors" is understood as optional. Other attributes like "A Day in the Life", demographic attributes and international considerations are not incorporated.

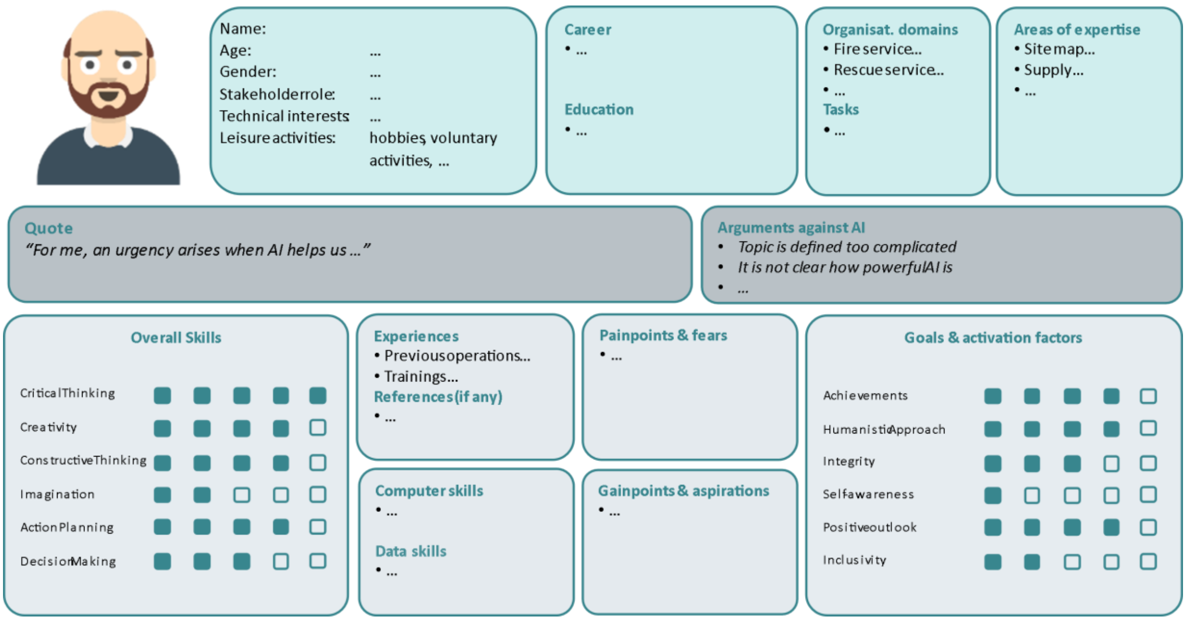


Figure 4: Persona template (to be detailed per specific end user group in Use Cases)

Such stakeholders act within a specific domain of interest, defined as "use case" domain in CREXDATA. Application scenarios can be defined on different levels of abstraction. Generic scenarios are used to introduce a domain and, for instance, categories of situations within that domain. On a more specific level, sub-scenarios can be described to detail specific situations which are kind of representative of certain problem situations. From such sub-scenarios, use cases (in terms of UML) can be derived. Thus, a template for such narratives is created that includes attributes conformant to informal scenarios, but that is also close to UML use case definitions. The template includes metadata like ID, name and author, but also detailed scenarios as well as pre- and post-conditions (cf. [2]).

Table 2: Application scenario (use case narrative)

Attribute[1]	Description
ID *	Unique identifier (<{Emergency, Health, Maritime}>_UC<ID>)
Name *	Title of the scenario (should be clear and meaningful)
Short description *	Short description, e.g., referring to the generic application scenario, related weather phenomena or hinting at used system
Author *	Person (partner acronym)
Last update *	Data of last update (yyyy/mm/dd)
Scope	Reference to CREXDATA technologies
Actors *	Stakeholders involved in the application scenario, referred to by using defined personas
Additional Actors	Stakeholders in the context outside of the system boundaries, affecting or being affected by the primary actors in the course of the scenario
Actors interested in the outcomes	Stakeholders not directly being part of the scenario, but interested in the outcomes in case the scenario is triggered
Pre-conditions	Events that should have happened before, or states that are reached so that this scenario can actually take place
Assumptions	In case of any assumptions, these should be stated.
Trigger	Event that causes the scenario to start
Detailed scenario *	Sequence of sub-scenarios or activities in chronological order, either focused on the as-is situation (practice scenario) or the to-be scenario (e.g., interaction scenario assuming that there is a system to interact with). Might be implemented by means like storyboards, user stories, activity diagrams, sequence diagrams or similar. Might include branching scenarios and extension scenarios. For such sub-scenarios, the same attributes are valid like for scenarios in general. In both cases, the position in the chronological order needs to be marked. In case of branching, the branching condition needs to be added as an attribute.
Post-condition	Description of the state that is reached by following this scenario, or if applicable the event that is triggered by finishing the scenario.

[1] Fields printed in bold letters and marked with an asterisk are mandatory.

Attribute[1]	Description
Benefits	Expected benefits of applying CREXDATA technologies in this scenario
Challenges	Foreseen challenges of applying CREXDATA technologies in this scenario, especially with regard to characteristics of extreme data
Related information	There could be additional information like duration of the scenario, frequency in which this scenario is expected to happen, concurrency to other scenarios etc.
Test settings	By default, it is assumed that the scenario will be included in field trials. If not, please indicate and explain. Additionally, test settings in lab infrastructures (DRZ, UPB, …) are described.

2.1.2 Requirements Elicitation

Requirements refer to characteristics that the CREXDATA system should provide. Along the product development process, requirements are specified from initial stakeholder requirements to specific, measurable, achievable, reasonable and time-bound (smart) system requirements (Figure 5, based on [3]). Even though CREXDATA is a research project, this process ensures a) a sufficient preparation of the evaluation and b) positive side-effects with regard to strategic exploitation planning. Application scenarios can be used as narratives to identify stakeholder requirements. At the same time, validation scenarios can be derived for later system validation in lab tests and field trials. System requirements need to be in scope of the technologies to be developed. Within the CREXDATA project, demonstrators are established to help facilitation of the requirements elicitation process. Stakeholders are interviewed or even observed with the aim to identify requirements of the demonstrator system. Engineers derive requirements for the technical CREXDATA system and its components resp. technologies from requirements.

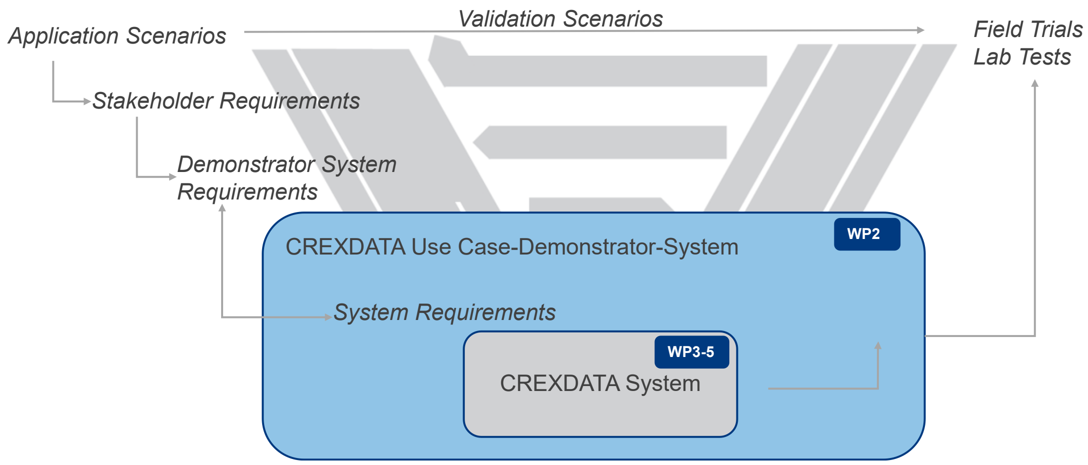


Figure 5: Allocation of WP2 terms along the V model of Systems Engineering

Especially on the level of specific, measurable, achievable, realistic and time-bound (demonstrator) system requirements, measures need to be established that help requirements analysis. Traceability needs to be ensured by metadata like unique IDs and provenance data. Comprehension by stakeholders in system development requires clear titles and descriptions. Categorisation in terms of liability and labelled references to other requirements help to analysis requirements within a requirement set concerning consistency, conflicts, supports etc. A template is provided in the following table.

Table 3: Standard list of attributes to specify requirements

Req Attribute	Description
ID	Unique ID of the single requirement (Req<ID>)
Version	Version number, starting with 0.01
Date_Created	Date of creation
Author_CreatedBy	Author identification (acc. to date of creation)
Date_LastChange	Date of last change
Author_LastChangeBy	Author identification (acc. to date of last change)
Name	Clear title of the single requirement
Description	Textual description acc. to template (see Figure 6 below)
State	{M - Must have, S - Should have, C - Could have, W - Won't have}
Category	{Functional, Quality, Restriction}
Ref_Pilot	{emergency, emergency_de, emergency_at, emergency_fi, health, maritime}
Ref_Stakeholder	Enumeration of string references to, for instance, organizations, organization types, personas, roles, specific people
Ref_Associated	Enumeration of links to refining documents (interview logs, storyboards, …) in whatever format is available (for instance, URL or SharePoint link)
Discussion	Optional text to document discussions with stakeholders (incl. developers)
ID_ParentReq	A requirement hierarchy is modelled by adding parent IDs (i. e., there is a subsumption relationship between the parent and this requirement).
ID_ConflictReq	Enumeration of requirement IDs that are in conflict with this requirement
ID_TraceToReq	Enumeration of requirement IDs that this requirement depends on
ID_DerivedFromReq	Enumeration of requirement IDs that this requirement is derived from

This is compliant to SpecObject in ReqIF [4, 5], SpecObjectRelations in SysML [6]. As an element within this scheme, the "description" field covers the content of the requirement itself. At a very specific (smart) level of requirements specification, this might lead to attribute-value pairs stating verifiable characteristics of the system under development. In many cases, requirements are stated in textual form. To ensure that all stakeholders understand such a requirement in exactly the same way, a scheme for phrasing a requirement is suggested (Figure 6, see [2])[2]. This scheme ensures, for instance, that the referenced system or sub-system is clearly addressed. The template is adapted to cover the entire MoSCoW scheme.

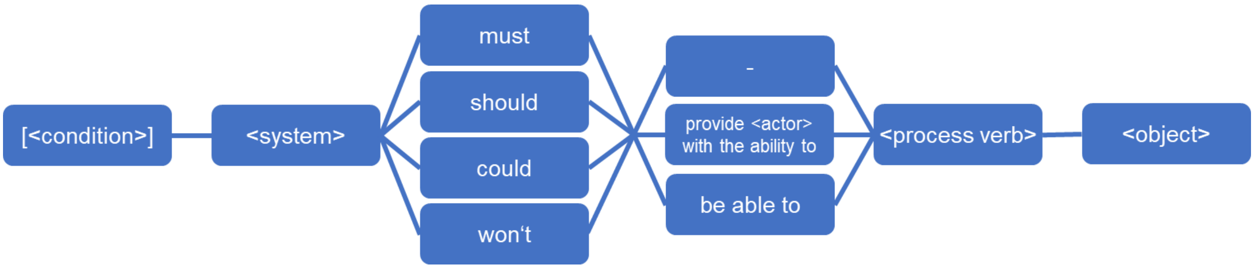


Figure 6: Standard scheme for the textual "description" of every single requirement (cf. Table 3)

2.1.3 Evaluation planning

The initial version of this deliverable in CREXDATA WP2 is focused on requirements engineering activities. Nonetheless, it is essential that requirements are measurable, so that their fulfillment can be verified and validated (cf. Figure 5). On top of that, evaluation subsumes research activities to investigate in how far the expected resp. envisaged impact is actually achieved(cf. [8]). These objectives depend on each other:

- Verification: Does the developed (demonstrator) system (component) fulfill specified stakeholder or system requirements? It refers to the "measurable" attribute of each requirement. Methods like inspection, code analysis or system tests can be used.
- Validation: Does the developed (demonstrator) system (component) satisfy actual user needs? There is always a gap in formulating explicit requirements based on actual implicit needs. Validation requires methods like interviews and observations in lab settings, walkthrough configurations and field trials.
- Evaluation: Is there an indication that the developed (demonstrator) system (component) help to achieve the expected impact stated in the [DoA]? V&V results from one or more use cases are analysed to draw conclusions regarding overarching objectives

In this deliverable, early considerations like available and prepared lab settings and possible environments for field trials are described per use case. The expected impact is extracted from the DoA as a first reference to be detailed throughout the project duration.

2.2 Research Data Handling process (logs, interviews, observations)

The "use cases" presented in CREXDATA can be understood as "case studies" from a design research perspective. Technology evolutions are brought into a real context of application. Pilot users test the research outcomes with respect to the impact expected for their work context. Conducting case study research, data is acquired from the system in use (esp. in terms of logs), from observers (observation minutes, video footage, behavior

[2] For more detailed considerations based on that source, see 7.

markups) and from interviews in single and group settings (audio and video footage, minutes).

The CREXDATA methodology for research data acquisition through case studies is based on the work by Yin [9], a linear yet iterative process consisting of six phases:

1. Planning
2. Design
3. Preparation
4. Use Case evaluation ("pilot study")
    a. Data collection
    b. Data analysis
5. Sharing of findings and conclusions

Based on the approach outlined by Yin, a single case study design is proposed for CREXDATA. It is regarded as a potentially continuous and repetitive process, with the possibility to adjust or redesign components of the case study based on outcomes of the case study (Figure 7).

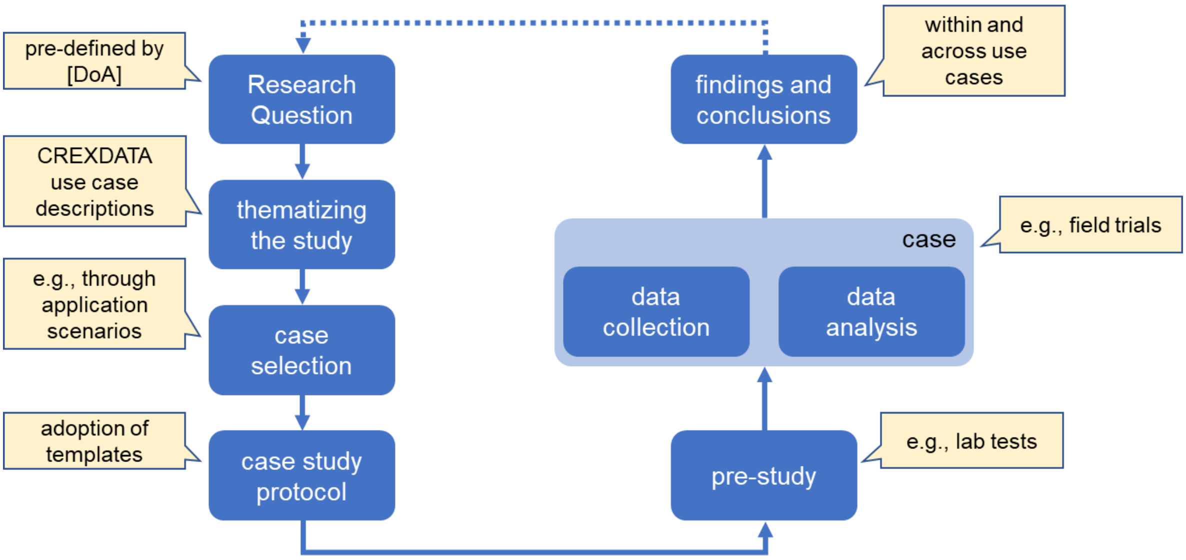


Figure 7: Use Case procedure adopted from (Yin 2013)

2.2.1 Data Collection

Interviews with stakeholders are conducted to gather an initial and foundational dataset to give an overview of the case and provide first data to important research questions. They also gather further information on contacts and data sources for use in subsequent research activities.

Observations gather information on how data and visualizations are used by stakeholders in a real-world situation. The 'Observation' method and tool should only be used in cases where a) there is an opportunity to carry out an on-site visit to observe how, for example, social media is used in real practice by an emergency service and b) observation will add significant value to the data collected.

2.2.2 Data Analysis

During the data analysis, data collected will be regarded using manual or software assisted qualitative content analysis. This qualitative approach aims to find answers to research questions by searching for indications and evidence. The final stage of a case study entails integration of the results of the data collection, analysis of the results and producing an individual summary of the case. First, Use Case and pilot study will have its own individual summary, set out in a Use Case report. Second, to enable cross-comparison of Use Cases, each study should be summarized in a common template.

2.2.3 Sharing of findings and conclusions

Using a generalized template, lessons learnt, experiences, indications and evidence that are collected during each study, are recorded. The submitted templates a) provide feedback to developers and b) demonstrate the positive impact of CREXDATA technologies in practice.

Details regarding the data management procedures are documented in [D1.2].

3 CREXDATA fundamentals

In the following Sections, CREXDATA technologies are briefly introduced with an application-oriented perspective. The focus in this deliverable is set on aspects that make benefits of technologies tangible in applications. Scenario definition and requirements analysis need to be focused on these aspects. Data collection should be done with these aspects in mind.

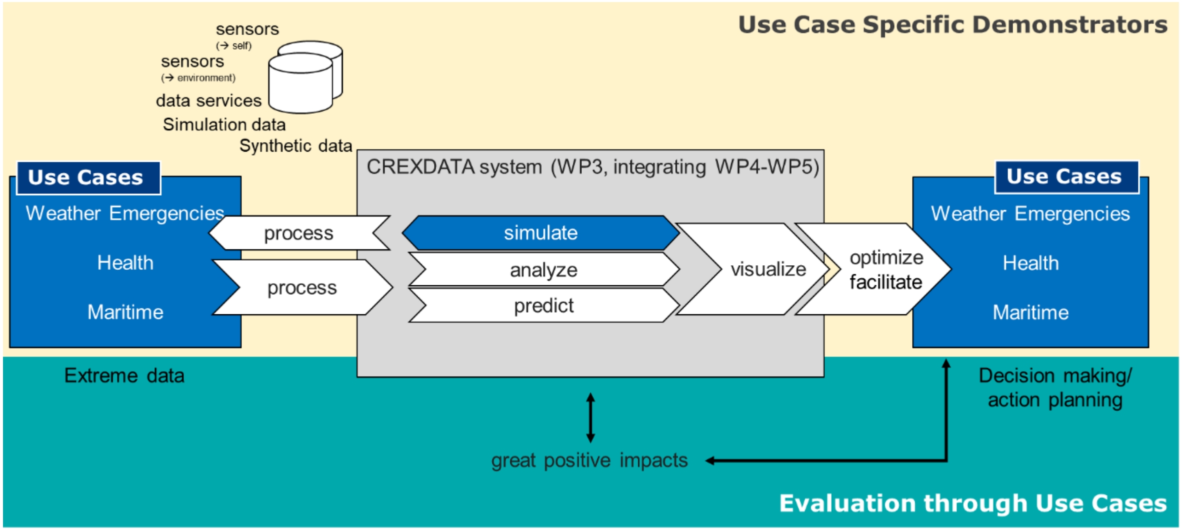


Figure 8: Impact oriented research within CREXDATA acc. to data-01-01

3.1 Reference System Architecture for Demonstrators

An initial system architecture is provided in [DoA, part B, p.16]. The core CREXDATA system is developed and configured through an IDE. It comprises application logics of all technologies that are subject of WP3 to WP5. Figure 9 provides an overview of the major elements of the CREXDATA system and a general view on interfaces (input and output).

The core CREXDATA system is integrated in WP3. The resulting system itself is made available for integration in demonstrators per use case. Thus, it can be understood as a sub-system of these demonstrator systems. Demonstrator system architectures are described per use case in Sections 4.1.2 (emergency case), 4.2.3 (health) and 4.3.4 (maritime).

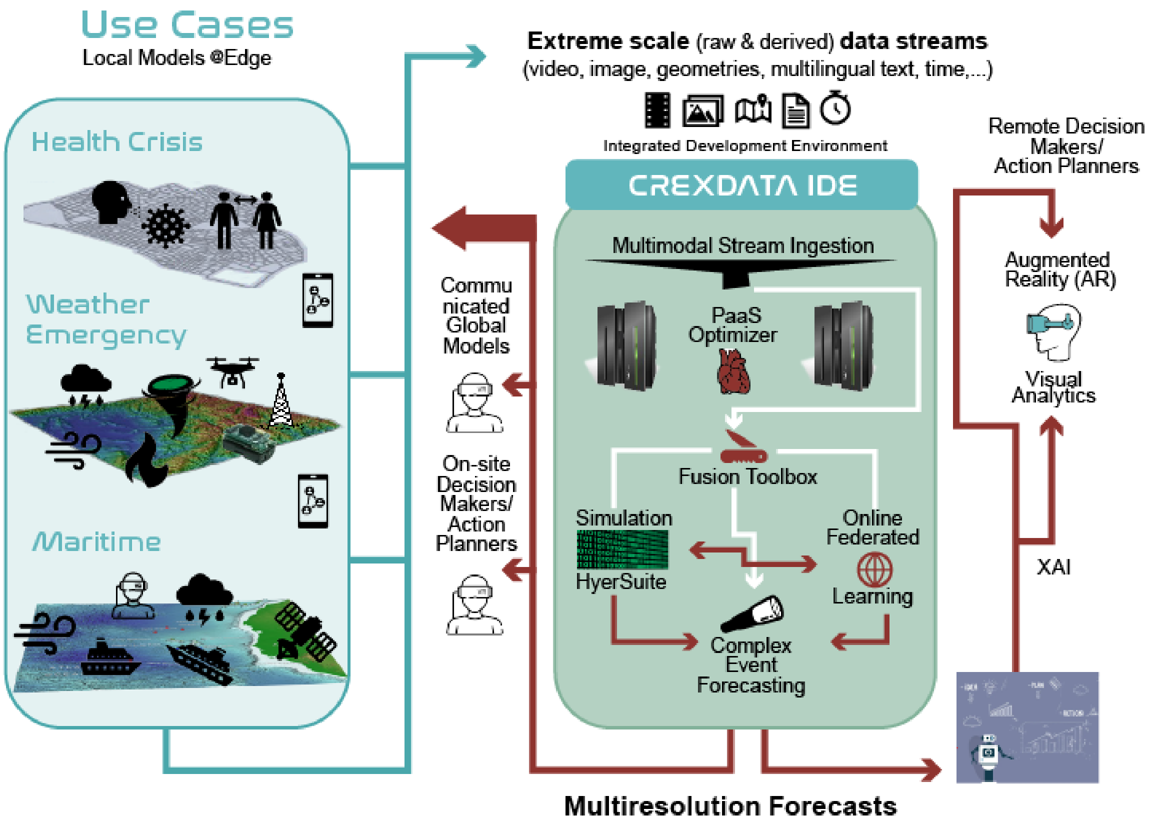


Figure 9: CREXDATA Concept Overview (crexdata.eu, based on [DoA, part B, p.16])

The following layers can be identified in the CREXDATA core system architecture:

Multimodal stream processing

The CREXDATA system consumes data from a variety of data sources. For training of models etc., access to data sets is required. For real-time data processing, streaming data from data sources needs to be handled. Therefore, technical solutions like Apache Kafka or RabbitMQ, general data formats like JSON and XML as well as domain specific data schemas need to be considered. Use case-specific data sources are identified in Section 4 and detailed in [D1.2]. In CREXDATA, these requirements will be mainly implemented by RapidMiner studio data access operators.

- Multimodal Stream Ingestion modeler (offline): For graphical workflow modelling, operators from data stream ingestion through analysis to visualization are needed. Therefore, extensions need to be implemented for data sources (per use case), for demonstrator system elements (like algorithms implemented in ARGOS in the emergency case) and especially for CREXDATA algorithms developed in WP4/WP5.
- Prediction-as-a-Service (PaaS) Optimizer: For testing and evaluating the PaaS algorithms, workflows need to be specified that include various computational elements distributed across technical systems (hardware resources, processors). There needs to be an opportunity to optimize computations across available resources (e. g., from drones to base stations to cloud services in the emergency case).

- Fusion Toolbox: The toolbox needs to be capable to execute entire models specified by the Multimodal Stream Ingestion modeler in real-time based on streaming data.

The definition of operators is both driven by use cases (data sources, demonstrator elements) and technology developments (WP4-WP5). Even though there is no algorithmic interdependency of PaaS optimizations with other CREXDATA technologies, workflows should be distributed across different computational devices/services to enable experiments.

Simulation HyperSuite

The hypersuite is created with the intention of a domain-specific integration of relevant simulators. Thus, it can be seen as a frame for use case-specific simulator sub-systems.

The Simulator HyperSuite is developed in WP2, providing data to algorithms of WP4-WP5. Details are provided in Section 3.2.

Machine Learning

Detailed use cases of Machine Learning (ML) typically require available data to learn from. Regarding stakeholder requirements elicitation, a guiding question is “Are there situations in which you think that data is available, but so far there is no way to make sense out of it?”. For training models, there needs to be an option to create or acquire labelled data sets (ground truth).

- Online Federated Learning: “online“ and “federated” are two attributes that focus the solution space with regard to ML in CREXDATA. Sequential steps can help requirements elicitation, from general relevancy of ML to online ML, and then even federated ML.
- Interactive Learning for simulation exploraticoon: Simulators are part of demonstrators in all three use cases. In contrast to ML models, simulation models are transparently known but need to be guided towards an optimum to identify best fitting parameter (sets). In CREXDATA, ML-based algorithms are integrated to reduce the efforts for such an exploration of the parameter space. Thus, relevant simulation types need to be identified and the principles of exploration need to be determined.

The algorithms are not dependent on other algorithms in WP4. Interactive learning with regard to simulations needs to be aligned with Simulation HyperSuite developments to cover relevant simulations.

Complex Event Processing

Complex Event Processing (CEP) includes both Event Recognition and Event Forecasting (CER/CEF). Based on an input data stream, events are recognized and forecasted based on, for instance, logical expressions. An event might mean a single point in time (e. g., threshold at river gauge reached) or it might have a duration (e. g., person endangered by rising river gauge). Event patterns are either learned from data (cf. ML) or defined based on semantics of a domain of interest (i. e., the three use cases).

- CEF: Event patterns are modelled by logical formulae and transition systems. Simple events represent events close to data sources, while complex events hold as soon as relevant simple events occur. Inputs to event forecasting need to be provided as multi-variable time-series data, for instance, through a single Kafka topic.
- Text Mining: In the context of CREXDATA, text mining is understood as a synonym for Natural Language Processing (NLP). For instance, RapidMiner includes a Text Processing operator. The intention is to learn from social media streams or to detect events in social media streams. As a rough differentiation, both identification of highly

relevant postings and analysis across a large number of postings are relevant. While in the first case, input for CEF might be generated, in the latter one this might be coupled with simulation exploration (verifying simulated futures).

CEF could be based on data streams created by other CREXDATA components (e. g., online federated learning and esp. text mining), but does not need such interdependent setups.

Explainability and Visualization

Explainable AI (XAI) and Visual Analytics require models and data as input to extend them with explainability and visualization layers. Thus, these algorithms are strongly dependent on ML and EP algorithms.

- Explainable AI: A focus should be set to ML models as input, independent from specific use cases (online, federated, interactive). The intention is not to implement own ML models, but to extend existing ones.
- Visual Analytics: Prerequisites are similar to XAI. For Visual Analytics, event streams (recognized and/or forecasted) are of similar interest like ML models. There is a direct interconnection with XAI models.
- Uncertainty Visualization: Situational awareness in decision-making situations includes an understanding of uncertainty in available data resp. information. For human actors, visualization of uncertainty semantics is required. Such semantics can be based, for instance, on established concepts of data/information quality dimensions, criteria and indicators (DQ/IQ).

Algorithms adding explainability and visual features require ML and/or CEP models as a basis. Therefore, requirements need to target the cascade from data sources through ML/CEP to XAI/Visual Analytics. Detailed use cases cannot be defined as long as ML/CEP use cases have not been defined.

Augmented Reality

Augmented Reality (AR) in CREXDATA shall be tested by Head-Mounted Displays (HMDs) like HoloLens 2. AR provides very special means to visualize data and information. It is based on the principle that reality is enriched by superimposed information (i. e., not only virtual objects like in Virtual Reality/VR). Therefore, specific use cases need to involve stakeholders close to an environment or to objects of interests. Information is visualized with reference to such real-world perceptions. AR is implemented in terms of AR applications (e. g., using the development environment Unity3D). Interfaces to other services (i. e., algorithms) need to be incorporated into such standalone applications.

AR is relevant in very specific situations where real objects are of interest. In CREXDATA, AR is meant to be one possible User Interface (UI) to access results from data processing pipelines. Thus, AR might be added as a sink in graphical workflows, visualizing results from ML, CEP, XAI and Visual Analytics.

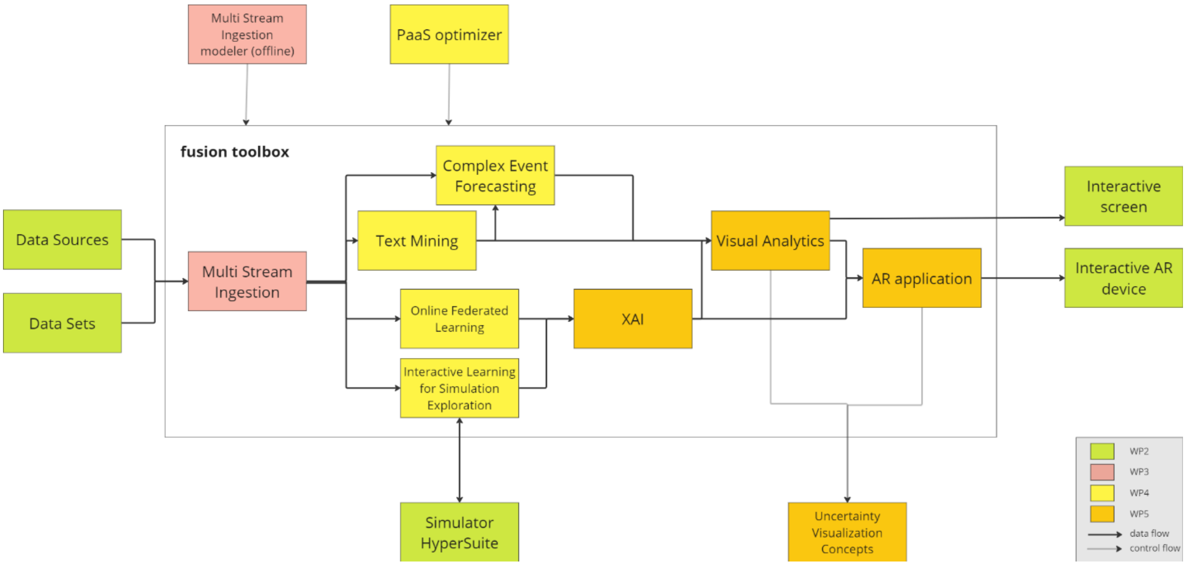


Figure 10: Elements of the CREXDATA system (to be integrated in demonstrator systems)

3.2 Simulators

Simulation models and tools are developed in task T2.4 specifically per Use Case, as they usually represent domain specific phenomena. From a technical perspective, simulators are components which are part of the Demonstrator systems developed per Use Case. They are integrated with the CREXDATA system based on the overall system architecture of WP3, incorporating the research outcomes of T2.1-T2.3. Simulation models and tools developed within CREXDATA will be made available open-source.

3.2.1 Simulator for the weather emergency Use Case

For the weather emergency case, no integrated solution for the different types of “simulation” is available. By nature, very different influence factors need to be considered in an emergency. In general, a separation is made between own and foreign situation. Resources are deployed (own situation) to cope with natural and man-made events evolving into an emergency to be mitigated (foreign situation). Different approaches of simulation can be recognised, but also very different understandings of the term “simulation”. In the CREXDATA simulation hypersuite for emergency management, the following elements will be integrated:

- weather related simulation: Typically, in meteorology there is no simulation as such, but nowcasting and forecasting. As a very specific phenomenon, fires depend on a trigger event that starts the fire (see, e. g., the Propagator forest fire simulation model [10]). Similarly, there could be flood simulators modelling the actual flow of water in urban surroundings or even the diffusion of water into buildings.
- weather data archives: Additionally, there are large archives accessible through data services to load satellite images and forecasts from a certain point in time and location in the past like (for instance, flooding events in Germany in 2021). So, instead of simulating a certain weather condition, it might be relevant to just select a weather situation in the past. This complies with typical behaviours of experience-based decision-making in the domain of emergency management.

- robotic simulation models: Physical robots can be extended by kind of digital twins in a virtual environment. By simulating environmental effects in such environments like Gazebo), “what-if” scenarios can be tested in such a safe space. By incorporating parameters representing the actual environment like wind speed relevant for UAVs measuring flood levels, action planning regarding deployment and routing of drones can be supported.
- domain specific simulation models: In requirements elicitation sessions, mainly two types of simulation models were indicated: a) people movements and b) spread of hazardous goods. People movement is relevant both for understanding a situation which is not controlled by Public Protection and Disaster Relief (PPDR) organisations, as well as situations in which evacuation is conducted under control of authorities. Spread of hazardous goods refers to information that is required to plan actions especially regarding spatial parameters. For instance, a contamination might be transferred through the air or, in case of a flooding, through water.
- event injection: There are several approaches in the field of emergency simulation used to train emergency management staff where scenario editors are used to “inject” incident data into simulated or real-time data streams. In case data from the field is missing, it could be injected through such kind of a tool. If this is done, corresponding uncertainty needs to be considered.

For such an integration, a core component is required that provides functionality for the orchestration and configuration of multi-domain services like those mentioned above.

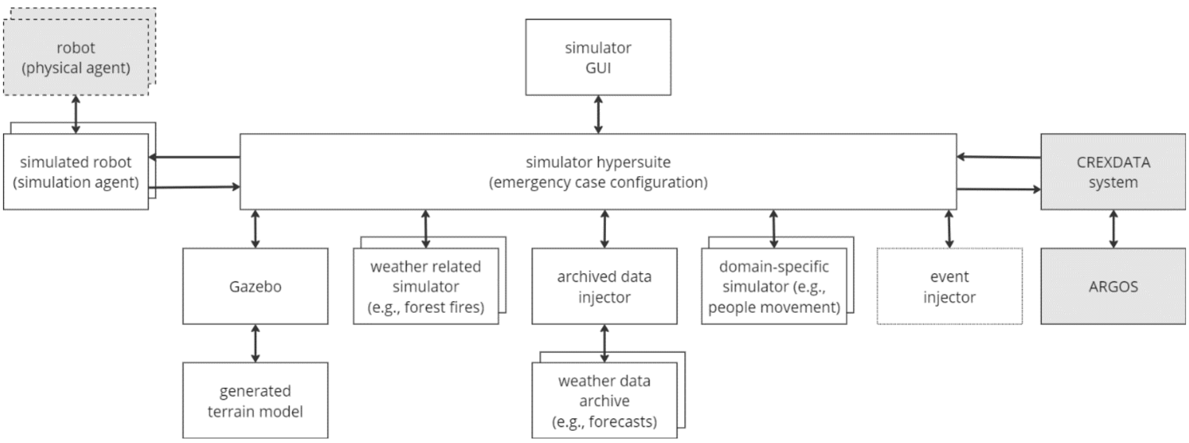


Figure 11: Architecture of the simulator system for the emergency case

3.2.2 Simulator for the health case

The health case is separated into two scenarios, each requiring specific types of simulation models. For the epidemiological scenario, the MMCACovid19 simulator is adopted [11]. For the multiscale lung infection scenario, the Alya [12] and PhysiBoSS simulators are coupled [13, 14].

3.2.2.1 Simulator for the epidemiology scenario

The *MMCACovid19* simulator is a flexible package written in Julia language that allows simulating the spread of a disease in a metapopulation with multiple agent types. The package implements a general Susceptible-Exposed-Infected-Recovered (SEIR) model and simulates an epidemic process using the Micro-Markov-Chain-Approach. Moreover, the simulator incorporates a wide range of data, including population demographics, epidemiological parameters, population mobility, healthcare system capacity, and intervention strategies, including confinements, mobility reduction and vaccination. Importantly, MMCACovid19 can be extended beyond COVID-19 to encompass general epidemiology by performing a calibration of the epidemiological parameters. Overall, the MMCACovid19 simulator serves as a powerful tool for decision-makers, public health officials, and researchers, enabling them to simulate, analyse, and optimize strategies in response to health crises like the COVID-19 pandemic. By providing valuable insights, it supports evidence-based decision-making and aids in mitigating the impact of the crisis on the population and healthcare systems.

emews-mmca-covid19 is HPC-based high-throughput model exploration workflow designed for running iterative calibration of epidemiological models and design of optimal interventions based on EMEWS, which provides a sophisticated platform for large-scale model exploration and optimization in HPC infrastructures. By combining it with the MMCACovid19 simulator, users can leverage the capabilities of both tools to enhance the understanding of the spreading patterns of an epidemiological outbreak and inform decision-making processes.

3.2.2.2 Simulator for the Multiscale lung infection scenario

The Lung infection scenario is based on the coupling of two simulators, an organ-level simulator Alya and the cell-level simulator PhysiBoSS. This coupling will allow for a mechanistic multiscale model that will encompass the pulmonary alveoli sacks' structure and cells, the vascular and lymphatic system around these, the airflow that comes in these sacks and the virus infection and cells' interactions.

Technically, PhysiBoSS simulates cell-agents with mechanistic models as well as their interactions and Alya will simulate the air pressure arriving to the lungs and the perfusion of the vascular and lymphatic vessels.

3.2.3 Simulator for the maritime case

The simulator will present and simulate a high-level overview of the Maritime Use Case test cases for the end user operators. The simulated events will be presented to the end users via GUI for evaluation and testing. In this use case, the simulator will not be open source.

- MT will create streams of simulated vessel positions, events, and weather conditions in order to simulate and optimise the navigation of a vessel under certain conditions (e.g., traffic, weather conditions).
- MT will develop a simulator system for the needs of the Maritime Use Case. The system that will be developed will be in position to use synthetic simulated data and simulate specific scenarios of emergency events.

3.3 Uptake of technologies from WP3-WP5

The use cases are defined in the [DoA] as an element of the prescriptive study to evaluate the impact of CREXDATA technologies. Thus, specific technologies from WP3 to WP5 (see short descriptions in Section 8) are integrated into technical systems and operational procedures in pilot sites. The uptake of technologies is specific for each use case. The weather emergency case is designed to include all types of CREXDATA technology, initially with limitations regarding the interactive learning for simulation exploration. Health and maritime use cases focus on single elements of the CREXDATA toolbox. Table 4 provides an initial indication of the uptake of specific technologies per use case.

Table 4: Uptake of technologies in Use Cases

	Emergency Case		Health Case	Maritime Case
	Dortmund	Austria		
T2.4 Simulation and Tools	X	X	X	X
T3.2 Graphical Workflow Specification	X	X	X	X
T4.1 Complex Event Forecasting	X	X	X	X
T4.5 Text Mining for Event Extraction	X	X		Not relevant
T4.2 Interactive Learning for Simulation Exploration	(X)	(X)	X	
T4.3 Federated Machine Learning	X	(X)	Possible, but not critical	
T4.4 Optimized Distributed “Analytics as a Service”	X	(X)	Possible, but not critical	X
T5.1 Explainable AI	X	(X)	X	
T5.2 Visual Analytics supporting XAI	X	(X)	Possible, but not critical	
T5.3 Visual Analytics for Decision Making under Uncertainty	X	(X)	X	(X)[1]
T5.4 Augmented reality at the field	X	X		(X)[1]
T5.5 Uncertainty Visualization in Augmented Reality	X	X		(X)[1]

[1] support of potential TUC, FR contribution

4 Initial specifications per Use Case

Emergency management and critical action planning call for timely and accurate decision making in several, diverse applications with the goal to optimize economic, societal, or environmental impacts. In the maritime domain, critical situations may occur due to imminent harsh weather conditions, vessel collisions, groundings, piracy events and a multitude of other hazardous situations at sea. Civil protection authorities face emergency situations of vegetation fire outbursts or sudden floods due to rapid weather-induced events as direct effects of climate change. Critical action planning is also of great importance in the life sciences domain. The recent world-wide health crisis of the COVID-19 pandemic demonstrated the need for governments and health agencies to make timely decisions to mitigate the impact (a) at a macroscopic level for the evolution of the COVID-19 pandemic at various levels of spatiotemporal resolutions, and (b) at a microscopic level, studying viral evolution for forecasting emerging mutations of clinical relevance. [DoA, part B, p.3]

In this Section, the initial specifications for application-oriented research in CREXDATA are documented with reference to the generic Pilot and Demonstrator Research Design presented in Section 4.

4.1 Weather Emergency Use Case

Weather induced emergencies are characterized by underlying weather phenomena, their evolution in time and space as well as their impact on the environment including people, nature and infrastructure. Large-scale data services are used for data logs, current satellite images and forecasts (like Copernicus services EFAS, EFFIS and EDO). Stationary sensor systems (like weather radars, automatic weather stations and river gauges) are used to verify satellite data, to trigger alerts in cases of critical values and to enable nowcasts. For similar purposes, multi-lingual text messages from social network sites are gathered and interpreted. Weather-related impact databases are only partially available as a source to train machine learning algorithms. Typically, weather information needs to be scaled from high-resolution to regional and local settings. Mobile robotic sensor platforms (Unmanned Ground and Aerial Vehicles/UGVs and UAVs) with their local viewpoint can complement these data sources with different types of cameras, laser scanners, radar and other sensors. The hydrological impact is specifically challenging with respect to specific terrain like in Austria and urban environment like in Dortmund; fire is based on environmental conditions but dependent on trigger/cause of fire. Operations responding to large-scale emergencies are coordinated in (mobile) control rooms with the need of situational awareness, even though they are not fighting the emergency face-to-face. They perform action planning and take decisions based on command posts closer to the site, and operational forces acting at a scene and being responsible for data collection (assisted by robots). Continuous monitoring is required, based on regular data updates or specifically dispatched reconnaissance robots. This can be complemented by human-generated content provided in terms of multi-lingual text messages, photos and videos via social media. Therefore, high data volumes of very different spatial and temporal resolutions and types need to be analyzed, while robotic platforms collect large amounts of data in high frequency . [DoA, part B, pp. 10-11]

The CREXDATA Use Case will actually deploy different types of mobile robotic sensor systems, utilize visualization concepts (including collaborative AR) from WP5 and implement them into the extended ARGOS system (provided to the control center staff) as well as the extended robotics situational awareness system (in the command car “RobLW”, see Section 4.1.6) and T5.4 on-site AR tools (both provided to commanders in the field) [DoA, p.8].

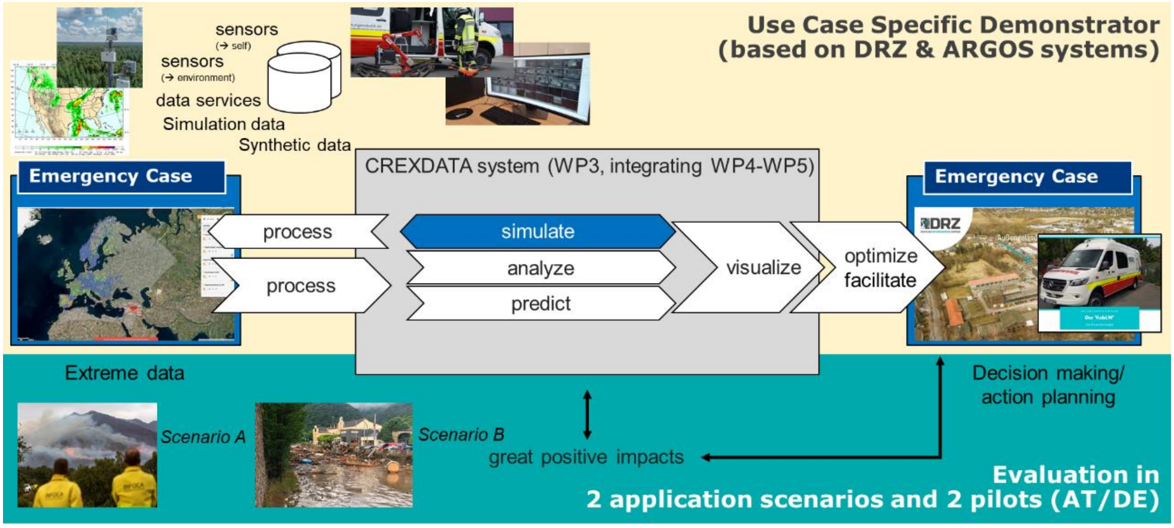


Figure 12: Impact oriented research within CREXDATA in the emergency use case

The evaluation will be performed in two kinds of settings (see Figure 13):

a) at the German Rescue Robotics Center, the existing indoor and outdoor test bed will be used. For this test bed, exact terrain information, building information models etc. are available for reproducible evaluation settings. Both UAVs and UGVs can be operated within the area.
b) two pilots will be setup to evaluate the system in relevant environments in an urban area (Dortmund, DE) and an alpine landscape (Innsbruck, AT).

So, in total four field trials are scheduled. Different levels of decision-making from local fire brigades (FDDO) through technical relief units (DCNA) to national stakeholders with links to the EU Civil Protection Mechanism (MoIFI) are considered. They take decisions with different functional, spatial and temporal responsibility. [DoA, p.8]

The purpose of this use case is to **improve situational awareness** significantly so that **informed decisions** are taken by civil protection **considering ranked future worlds** with **explicit uncertainties** avoiding disaster **impacts**. Use case validation is performed in reproducible test bed scenarios and in 4 field trials. [DoA, part B, p. 11]

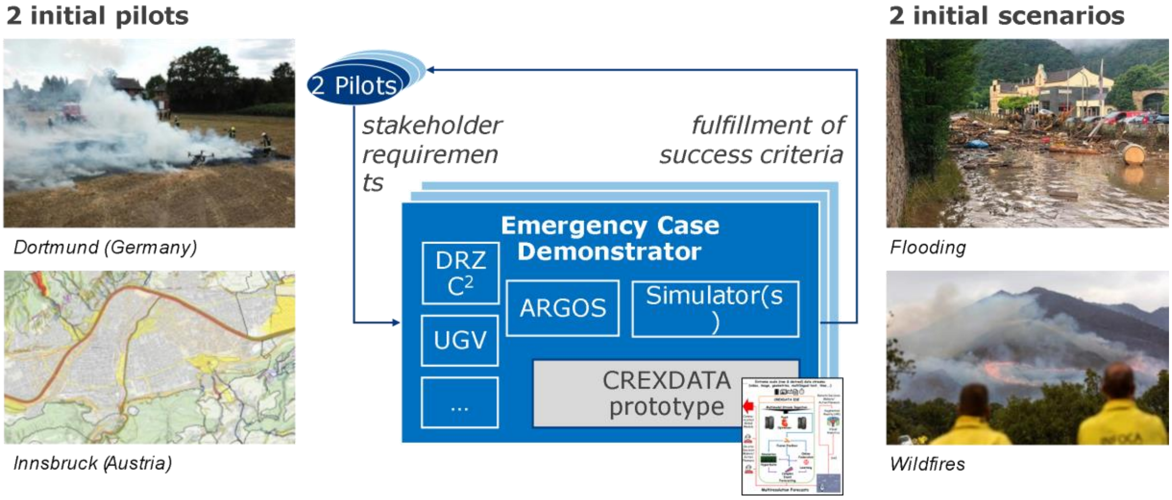


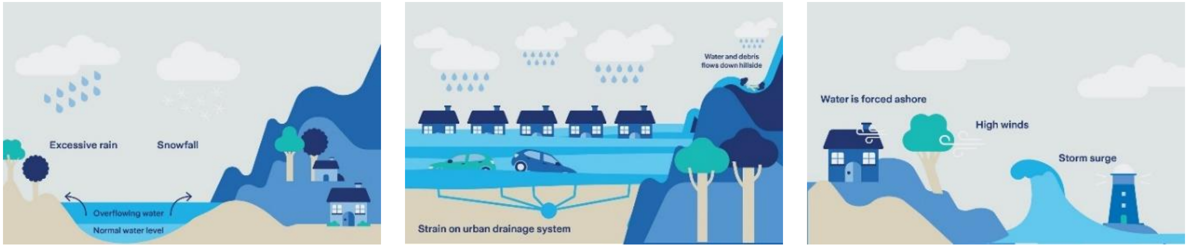
Figure 13: Demonstrator, pilot sites and application scenarios for the emergency case

4.1.1 General consideration on scenarios

In the first period of the project towards the first series of field trials, application scenarios are focused on hydrological weather phenomena, namely fluvial floodings. By aligning pilot sites to a common scenario setting, configurations of the system and the use of data sets can be managed much more consistently. Data sets from Dortmund, Austria and Finland can be used focusing on similar types of events to be forecasted, features to be learned and explained as well as simulations to be guided. At the same time, domain specific models will be setup in a way that the inclusion of further application scenarios like forest fires is well prepared. For instance, event types like "Vulnerable people endangered" remain relevant while data sources and the underlying simple event type model need to be extended. Additionally, stakeholders and their demonstrator contributions remain the same.

4.1.1.1 Flooding

Flooding is observed from indications of heavy rainfall to monitoring of affected points of interests. Due to heavy rainfall, the gauge of a river might rise or drainage systems might be overloaded. In general, this can be anticipated based on satellite images and forecasts. In case of fluvial flooding (Figure 14 a), the actual river gauge at a certain point in time at a very certain location needs verification. The impact of a rising gauge may depend on many influencing factors: terrain, bridges or walls channelling the water, congested tubes changing the prepared flow of water, materials in the river (mud, wooden material, debris, but even cars). Therefore, action planning depends on current data acquired by stationary sensors (e.g., river gauge sensors) or mobile equipment that is specifically dispatched (e.g., drones recording material at the water surface). Typically, sensor data itself is a) too voluminous and frequent to be analyzed by human operators and b) too specific/technical to be helpful to operational forces. [DoA, part B, p. 11]



a) fluvial flood b) pluvial flood c) coastal flood

Figure 14: Three common types of floods acc. to Zurich group [15]

4.1.1.2 Forest and wild fires

Forest fires are observed from critical drought situation (based on EDO) through fire spreading (with fixed observation systems) to monitoring of the fire zone (with mobile robots). To effectively fight large fires, it is necessary to detect them at an early stage to be able to immediately initiate suppression measures. The next step is to get qualified personnel and resources to the right place in the shortest possible time. For this purpose, continuous reconnaissance of the fire spread is the basis for an effective extinguishing operation. Prediction and quick response to situational events are crucial capabilities. This network can only function effectively if the emergency forces and command can rely on an optimal IT-supported information supply with prognostics. [DoA, part B, p. 11]

4.1.2 System Architecture for Demonstrator

The CREXDATA demonstrator system architecture can be read in terms of rows and columns (Figure 15). In rows, a layered IT system architecture is assumed from (Graphical) User Interface (UI, top layer) to data sources (bottom layer). The CREXDATA system is integrated as a middle layer, interfacing different types of IT sub-systems to be found in columns. These columns indicate fully functional systems. Such sub-systems of the demonstrator system are mainly domain specific systems with interfaces to the CREXDATA system (cf. Section 3.1). They build up a system that can be understood as a common information space [16]. Most importantly, components are ARGOS (provided by HYDS), robotics (provided by DRZ) and the AR system (developed in WP5).

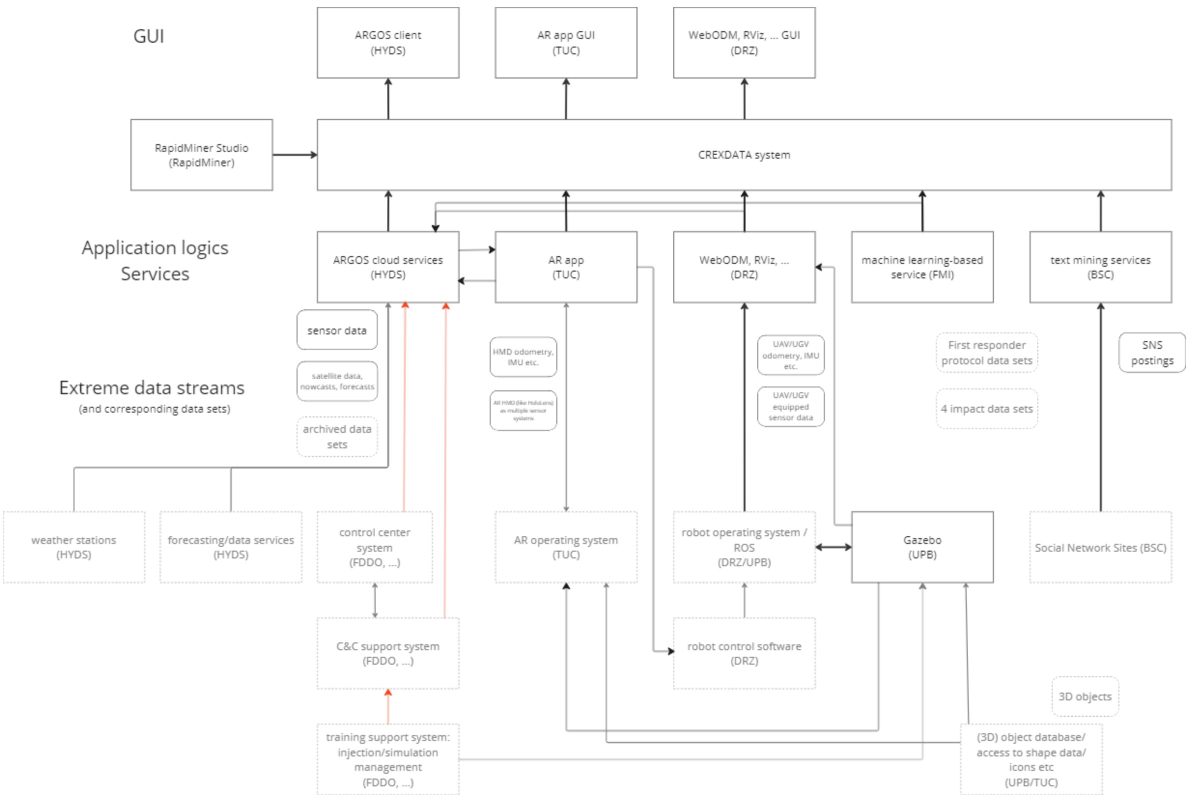


Figure 15: Demonstrator System Architecture for the emergency case: core CREXDATA system interlinked with application logics and data sources of ARGOS, AR, robotic platforms and FMI services feeding corresponding user interfaces.

At the UI layer, the system's core GUI is adopted from ARGOS. The initial view as an entry point is assumed to be a geo-based situational map with layers and links to special applications. Thus, geo-referenced data can be super-imposed or marked within layers on top of geographical maps. Additional views need to be available, like green-to-red scale listing of critical events, sortable by priorities, time stamps etc. Besides the ARGOS UI, special applications are required either as extensions to resp. configurations of existing software or as newly developed apps. With regard to visualizing sensor data from robotic systems, solutions like WebODM and RViz/RVizWeb should be adopted. With regard to AR, apps need to be developed for operational staff using development environments like Unity3D. It is essential to include Head-Mounted Displays (HMDs) to be used as See-Through devices on-site. Interaction is implemented, for instance, to perform queries to the system or visualize data processed by CREXDATA algorithms. Application logics are not limited to CREXDATA algorithms but benefit from existing solutions. This includes information processing for layer-based visualisation, to be prepared for an uptake of visual analytics and uncertainty visualizations from WP5. To enable modelling of entire data processing pipelines, not only WP4 functionality needs to be implemented in terms of RapidMiner operators. Similarly, operators need to be made available to connect, for instance, to weather related services. With regard to robotics, functionality should support analysing sensor data from multi-sensor systems, routing, etc.

Table 5: Demonstrator components extending the CREXDATA system (Weather Emergency UC / Dortmund)

Component	Description

ARGOS [DoA, part B, p.9]	• multi-hazard early warning system developed by HYDS • data fusion • with regard to mapping of geographical data sources (available as layers in the geo-service) • within mathematical models for specific topics (like height of snow on streets based on precipitation and ground temperature gradients) • ROS framework is applied using custom scripts to incorporate sensor data from robotic platforms
DRZ	• RobLW ("DRZ C2"/"Lagebildsystem"): mobile robot control and mission command post, equipped for robot operation as well as collecting data from robots and data processing to support situation awareness and decision making (see description in Section 4.1.6) • Ground Robots (UGV): various platforms with variable payload modules, selected depending on the mission (application and tasks); e.g., mid-size Telemax equipped for navigation and mapping • Aerial Robots (UAV): various commercial platforms, typically equipped with cameras; additional payload depends on the mission and taking into account weight considerations
FMI	• gradient boosting machine learning approach, used in various impact forecasting products and in previous research projects like SILVA
UPB	• Gazebo • RViz • event injection (cf. training support systems) • simulation configuration • data fusion

4.1.2.1 ARGOS system

ARGOS incorporates all processes required to manage weather-induced hazards, harmonising data, products, warnings, impact and protocols in one integrated solution. Core functionality is highlighted as hydrometeorological forecast, early-warning detection, exposure and vulnerability, impact forecasts, management protocols and dissemination. ARGOS has been designed from ground up to seamlessly integrate any source of information useful for operative management. It supports authorities in defining new rules of warning decision flows.

Integrated data services subsume

a) services that are activated in case of a large emergency
b) general services: EFAS, EFFIS, EDO, ...
c) sensor systems

Besides meteorological data, data from 112 calls, traffic cameras or social networks can be integrated (cf. Figure 16).

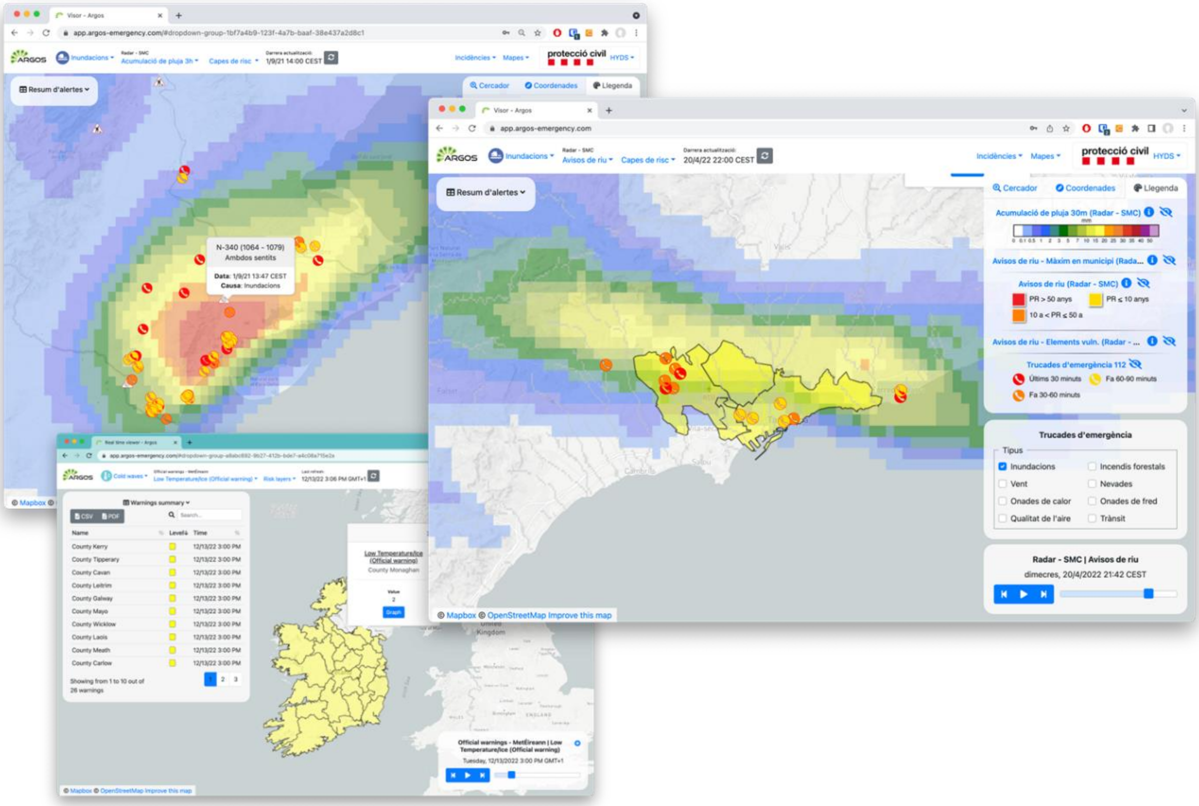


Figure 16: ARGOS service examples: radar data, forecasts, threshold visualization, geo-located emergency calls, warnings summaries, playback function etc.

Argos is built on top of an open architecture Figure 17 based on self-dependent modules, so that adding new weather data and sensors, building new products and warnings, growing sets of critical points, redefining protocols and expanding dissemination channels is supported. Due to its modular structure, communication with external services or platforms is inherently flexible in ARGOS. Real-time data is collected through available machine-to-machine interfaces, web map services (WMS) for geo-structured data or raw file transfer through sFTP servers. On the other side, Argos generated data (warnings, related products, registered values...) can also be pulled by other systems using its own API (Application Programming Interface, available in https://api.argos-city.com/). Communication interfaces will be adapted or even extended to integrate Argos in the whole CREXDATA system.

The cloud-based architecture enables collaboration between different operational authorities in width (e. g., between federal districts) and depth (i. e., on different levels of organisational responsibility). ARGOS is designed as a family of products to support different types of stakeholders (Argos City, Argos Site, Argos Flow, Argos Hydro). To do so, the following characteristics were enhanced from the very beginning on its construction (see all features in Figure 17):

- Easy adaptation: on new places, on new organisations with similar needs but different procedures.
- Impact oriented: not only weather monitoring but automatic activation in vulnerable elements based on previous knowledge

- Integrated solution: Based on the cloud, the system is available from any device with internet connection.

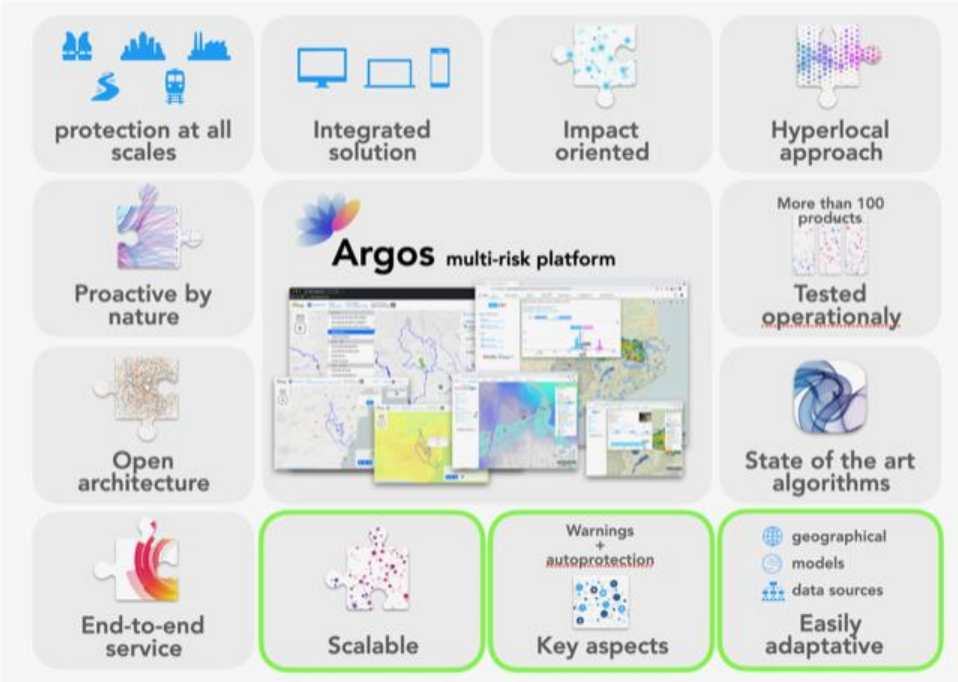


Figure 17: ARGOS features (https://www.hyds.es/argos/)

4.1.2.2 Robotics system

In CREXDATA, different types of robots are foreseen for experiments[3]. In general, Unmanned Ground Vehicles (UGVs) and Unmanned Aerial Vehicles (UAVs) are differentiated. In case of research setups, main building blocks of such robotic systems are basic platforms, communication hardware and payload like sensor systems or, for instance, robotic arms/manipulators (Figure 18). The Robot Operating System (ROS) is implemented on the platform, ensuring standard interfaces to, for instance, sensors. Commercial robots (esp. UAVs) are integrated systems not necessarily changeable. Robots are operated using a robot operator interface (base station). In the CREXDATA setup based on DRZ capacities, robots are deployed by operational staff, with a perspective to expert units entitled “Robotic Task Force” (RTF). Currently, the DRZ operates a special command vehicle called “RobLW” (robot command verhicle)[4] which is equipped with both command and research tools. It is a prototype for a vehicle with robot integration, combined with a joint utilisation concept between DRZ and Dortmund Fire Brigade. Therefore, it is operated by mixed crews from DRZ/project and fire brigade for certain scenarios. Within the RobLW, special information systems are used to process robotic sensor system data. They are subsumed under the term “DRZ Command & Control (C2) system” (German: “Lagebildsystem”). Two specific software products are WebODM and RViz. WebODM enables visualization of maps, point clouds, DEMs and 3D models from aerial images. RViz/RVizWeb provides functionality for 3D visualization of sensor data, robot model, and other 3D data in a combined view.

[3] https://rettungsrobotik.de/en/testing-facility/the-robotic-systems-on-an-overview

[4] https://rettungsrobotik.de/en/testing-facility/the-robotic-command-vehicle

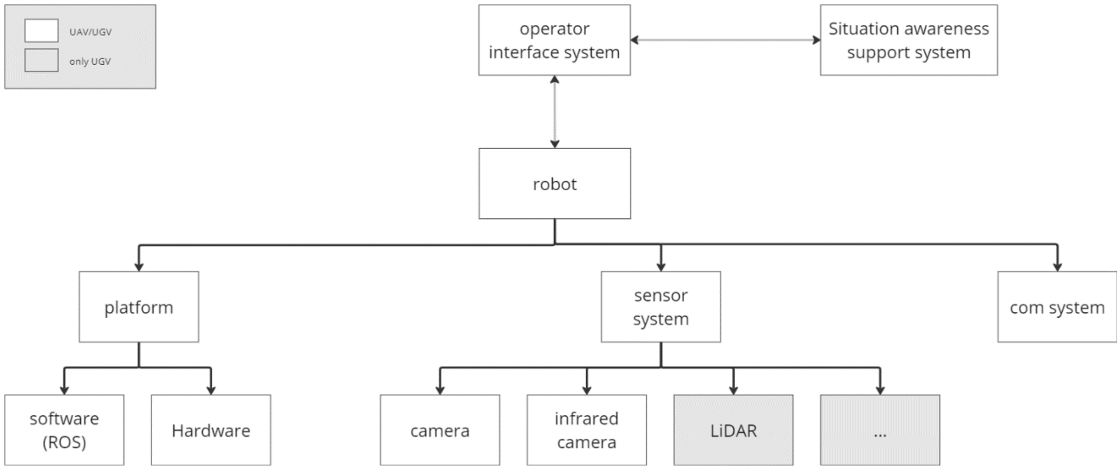


Figure 18: Architecture of the robotic demonstrator sub-system

The RobLW is equipped with a powerful server for the creation of 3D models, two operator PCs and two 43'' screens. For power supply and communication network setup, a 4 kW power generator, blue light/ Tetra radio, 2.4 and 5.8 GHZ receiver for drones, WLAN, 2 TETRA MRT and 4 TETRA HRT are available. A small workbench is built in with two fixed workstations plus an additional workstation for researcher/leader. Additionally, a flexible roof panel enables easy integration of various antennas.

As an option, even under-water robots could be used in CREXDATA (see, for instance, requirements in the Austrian pilot site). In parallel project, DRZ builds a test setting for such kind of robots. So this would enable use cases like:

- detection of physical or chemical contamination in the water that floods an urban area
- selection of sensors to see under water (from in water or above water)
- 3D mapping and/or object detection under water
- creation of realistic dataset for 3D mapping and object detection under water

4.1.2.3 FMI service

FMI develops impact-based forecasts which are derived from the available impact data. The tools are developed in close cooperation between FMI, MoIFI and the Rescue Department of Helsinki, and possibly other pilot site partners like FDDO outside of Finland. There will be a testing period during which the new products are piloted in real-time and the user experiences are collected to develop and enhance the machine learning-based model.

The model behind the tools developed by FMI for the Finnish showcase are utilizing machine learning (gradient boosting method). The Finnish showcase will be utilizing the ARGOS system in data and model output distribution as well as for utilizing the data provided by other pilots to extend the area of operation of the ML-based service of FMI. The same CREXDATA platform as the Germany and Austria pilots will be used in Finland as well. Eventually, the data produced and shared by FMI is available for the use of the technologies of WP3-5, for instance for input for explainable AI (XAI) of T5.1. Furthermore, uptake of the technologies and methodologies especially of WP5 is explored and communicated to the internal and external stakeholders throughout the project. Additionally, during the project FMI explores possibilities to expand the methodology to be used in different scenarios, applications, and geographical locations such as in the pilot of Dortmund and Austria. Within the limits of available data, the gradient boosting machine learning model is used as a base to forecast the number of ambulance units needed in both Helsinki and Dortmund areas in a weather emergency or to create early warning tools for flooding events.

The gradient boosting machine learning method is used to model the impact data, for example the number of emergency operations or road traffic accidents. The method graph is presented in the Figure 18.

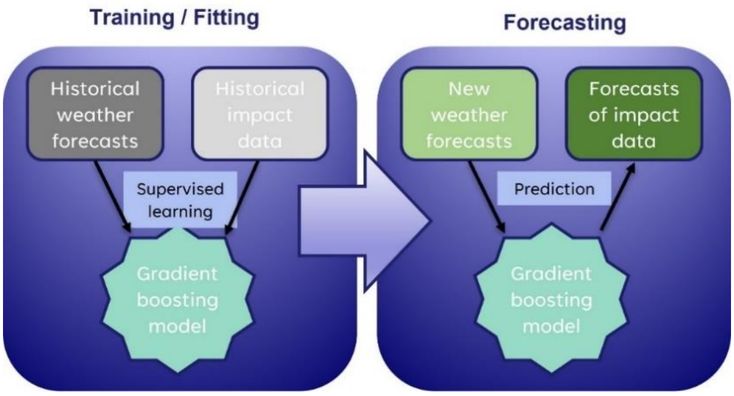


Figure 19: Use of gradient boosting machine learning in training and forecasting of weather impacts.

The ML method has been used in various impact forecasting products successfully, mainly in Finland, but also in the USA to model river streamflows. The method has been used also in previous research projects, for instance in a national level SILVA-project (2020-2023), where national level impact products were created (Figure 20). The model has been found reliable and accurate in several different applications; thus, it was chosen also for the main method in the Finnish showcase and as an input for T5.1.

For the modelling, the materials are collected spatially and temporally: local compilation and six-hour temporal compilation are used to unify the number of cases in Uusimaa and Helsinki areas. For the time series, a gradient boosting model is fitted using mainly surface weather parameters from the ECMWF HRES weather model from the Uusimaa and Helsinki area to explain the impact data. As additional information, information about the time of day and the season of each moment of time is included into the model. After matching, the provincial quantile limit values were derived for each data and month to illustrate the number of cases: the familiar green-yellow-orange-red colour coding is used in the visualization to distinguish the classifications determined by the quantile limit values from each other. The visualization is done by compiling the forecasts into five-day forecast maps by using rolling 24-hour sums.

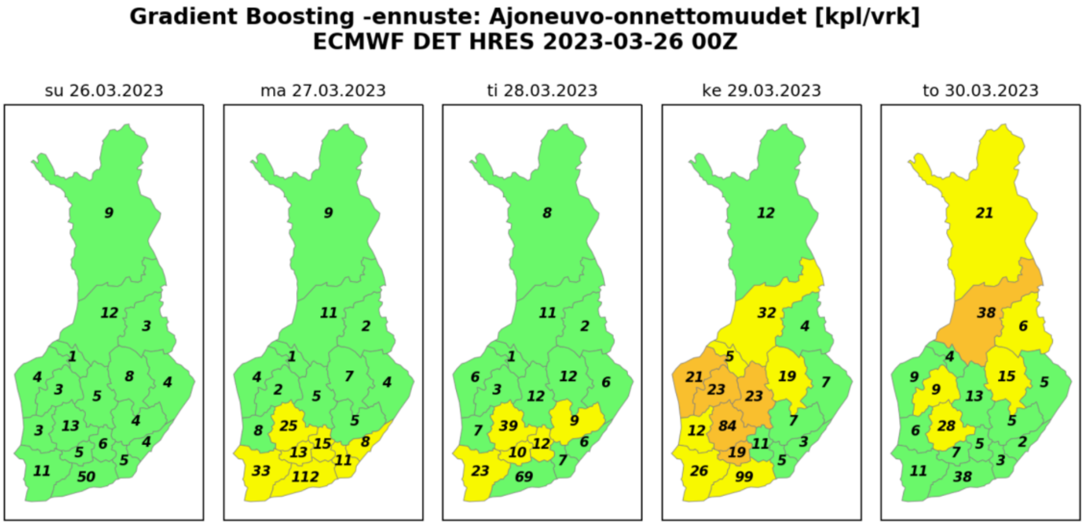


Figure 20: A 5-day outlook of gradient boosting forecast of car accidents per day per municipality. The colors (green, yellow, amber, red) represent the severity of the impact.

In the CREXDATA project, new forecasts of new datasets will be implemented, such as the numbers of ambulance operations mentioned before. In addition to that, we will refine the resolution of the old products from the county level to the municipality level. The possibility to include estimation on uncertainty of the impact forecast is exploded by utilizing instead of ECMWF HRES numerical weather prediction model, the limited and higher resolution ensemble model, MEPS. For the European context the possibilities to model the river streamflow data for early warning of the flooding events are explored.

4.1.3 Data sources

The Weather Emergencies use case is based on data sources that can be categorized into local and global environment (see Figure 12). Data about the local environment is gathered through stationary sensors systems which are extended by mobile robotic sensors platforms in case of an incident. Local data requires context metadata like position, orientation and accuracy of sensors. Temporal effects are induced by sample rate (of sensors), pre-processing at the edge (e.g., creating geo-referenced point clouds) and communication channels (with frequency and bandwidth). Decision-making is informed by processed data formats, but explainability for humans often requires raw data analysis (e.g., video) and visualization. Position, point/field of view and annotations from AR devices are new data sources. At the level of global environment data, Copernicus services provide both TBs of data archives and GBs of current and forecasted weather data covering various natural phenomena and their effects on forest fires, health etc. Both temporal and spatial resolution vary. Sensor systems are increasingly applied in terms of forest observation systems (even with drone extensions), river gauge installations and publicly accessible weather stations. Data is either pushed in certain time intervals so that it can be processed message-based, or data is retrieved on request through data services and APIs. In Austria, for example, there is the ehyd database providing pre-filtered data (https://ehyd.gv.at/). Raw data is accessed through national, European and global weather services. In case of Austria, the corresponding partner would be Geosphere. Multi-lingual and multi-modal social media extend that broad range of data sources. Social media networks are expanded to global scale; for an emergency, the identification of relevant assertions in terms of location and content are significant challenges. [DoA, part B, p. 11]

Table 6: Local environment data sources in the Weather Emergency Use Case [DoA, part B, pp.11-12]

Data sources	Data Source Volume (Vol), Velocity (Vel), Veracity (Ver), Characteristics/Description (Ch/D)
Data sources (local environment)	
Robot localization system	Ch/D: Position, orientation, velocity and acceleration of a robot, derived by fusing data from various sensors. E.g., odometry is often obtained by fusing data from wheel encoders, IMUs, and gyroscopes. Can be enhanced or substituted by visual odometry (extracting camera movement from consecutive images). Global pose (I.e., relative to a known reference frame) is typically obtained by combining data from GNSS receivers (e.g., GPS), magnetometers, odometry and matching range sensor data (e.g., from a lidar) to a known map. Pose data is transferred using designated ROS message types, e.g., geometry_msgs/Pose3D. Ver: Localization accuracy depends on chosen sensors and algorithms. Vel: Typically, between 10 and 100Hz. Vol: A single pose message is <1kB, overall data rate depends on required update frequency.
RGB video stream per camera (H-264, MPEG-4)	Vol: 1920 x 1080 (full HD) or 720 x 480 (standard definition). Vel: Common video stream data rates (e.g., 30fps) Ch/D: FPV Camera, Wide-angle camera Ver: If the connection is poor, a live stream may be blurred or stop for a short time
Thermal video stream (H-264, MPEG-4)	Ch/D: Images with temperature data, e.g., derived from near-infrared spectrum. Vol: Common thermal camera models offer resolutions up to 640x480 pixels. Vel: Common video stream data rates Ver: If the connection is poor, a live stream may be blurred or stop for a short time.
3D environment model	Ch/D: Map generated from robotic sensors. Commonly derived by combining localization data (see above) with range measurements (from cameras or lidars). Some solutions build the map "live" (Simultaneous Localization and Mapping – SLAM). Others build the model offline by processing collected data (most often images) in batch, which is much slower but often more accurate (e.g., using WebODM). Vol: Depending on the size, sparsity and type of the model (e.g., showing only the physical structure, or also including confidence, colors, temperatures, …). A model can easily reach several hundred MBs in size. Vel: Typically <10Hz. Ver: Depends on chosen sensors, algorithms and environmental conditions (e.g. ambient lightning, disturbance from smoke)

AR (HoloLens 2) (MPEG4)	Vol: 1920x1080px, Vel: 30fps (through miracast) Ch/D: Video stream, incl. annotations of AR users in the scene

Table 7: Global environment data sources in the Weather Emergency Use Case [DoA, part B, pp.11-12]

Data sources	Data Source Volume (Vol), Velocity (Vel), Veracity (Ver), Characteristics/Description (Ch/D)
Data sources (global environment)	
EFAS	Vol: ~1Gb/day, Vel: Twice per day. Regular internet velocities Ver: Probabilistic flow forecasts Ch/D: Temporal series, distributed fields, deterministic and probabilistic
EFFIS	Vol: ~1Gb/day, Vel: Twice per day. Regular internet velocities, Ch/D: Distributed fields
ECMWF forecasts	Vol: ~20Gb/day, Vel: 4 times /day. Regular internet velocities Ver: Deterministic and probabilistic forecasts, Ch/D: Distributed fields
Weather sensors	Vol: ~0.2Gb/day, Vel: ~Every 10 min. Regular internet velocities, Ch/D: Temporal series
Weather radar	Vol: ~5Gb/day, Vel: ~Every 10 min. Regular internet velocities, Ch/D: Probabilistic data

4.1.4 Use case analysis

The application scenario is setup based on various parameters to allow for a wide variety of sub-scenarios. Examples are fluvial vs. pluvial flooding, seasons, cascade effects (like debris/mudflow), prepared vs. escalating evolution of the situation as well as mainly affecting people vs. objects. Initially, the focus will be on pluvial flooding. So, the assumption is that the strain a heavy rain causes on urban drainage systems is too heavy. Figure 21 provides an overview of the generic scene elements that are scheduled for application scenarios: Each scenario shall include a river that passes a locality with potentially endangered inhabitants. This might be urban or smaller scale. It includes vulnerable buildings and people, as well as critical infrastructure (like energy or transport). In case of an emergency, the emergency management structure is either built up step by step (in case of unforeseeable events) or it is anticipated and well prepared (e. g., in case of precise weather forecasts). Assuming a large-scale weather induced emergency, the structure (see small box in Figure 21) includes the high-level strategic command in a crisis management room (led by the mayor in Germany, supported by a high-level fire officer like the director of a fire department). Search and Rescue, fire protection and technical relief are coordinated by a tactical command unit (mobile Command & Control / C^2 post, operating from a large command truck or bus). Technologies like AR and robots are operated close to the operation by lower-level commanders (C level, in small command cars like vans) and sub-ordinated operators.

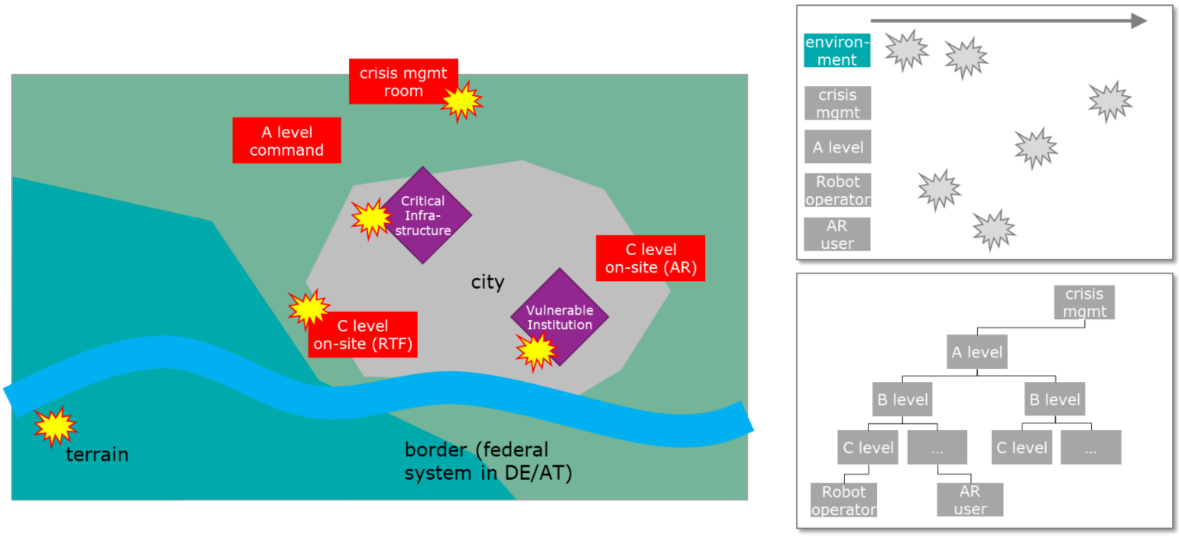


Figure 21: Elements of the spatial environment and basics of a command hierarchy

Figure 21 hints at different views within an emergency situation: the spatial view which is typically represented by geo-services and map-based user interfaces, an event stream view representing changes of the situation, and a structural view focusing on resources deployed by emergency response organizations. Figure 22 provides a more tangible insight into the operational environments that frame use cases of the CREXDATA demonstrator system. AR and robots are operated close to the actual incident by operational responders. They are led by low-level commanders (entitled "C level commanders" at FDDO). Mid-level commanders (B level) are not focused on initially. For the A level command post, a staff room is equipped where four to six or even more fire officers cooperate with regard to pre-defined tasks (like ICT, map, supply, press etc.). Different settings are feasible: a room setup within a command truck (entitled "ELW3"), or a stationary environment at fire station 1 in Dortmund. For the sake of clarity, the first is called "A level staff room" and the latter is called "crisis management room". For a large-scale disaster, the mayor of Dortmund activates and leads a crisis management team, being super-ordinated to the structures of FDDO. In all these staff environments, tools like the ARGOS system are relevant. The control center dispatches resources to the operation and tracks status changes (at station, departing to incident, active in an operation etc.) of resources[5].

[5] GPS is not available due to GDPR issues.

Figure 22: Environments for use cases of the CREXDATA application scenario

Figure 23 presents a swim-lane visualization of the evolution of such an event. Focusing on decisions (swim lane in the middle), a distinction is made to events that occur in the environment (e.g., change of weather forecasts, threshold reached at river gauge) and events that are triggered by own actions (e.g., a human is rescued or a drone reached the operational position).

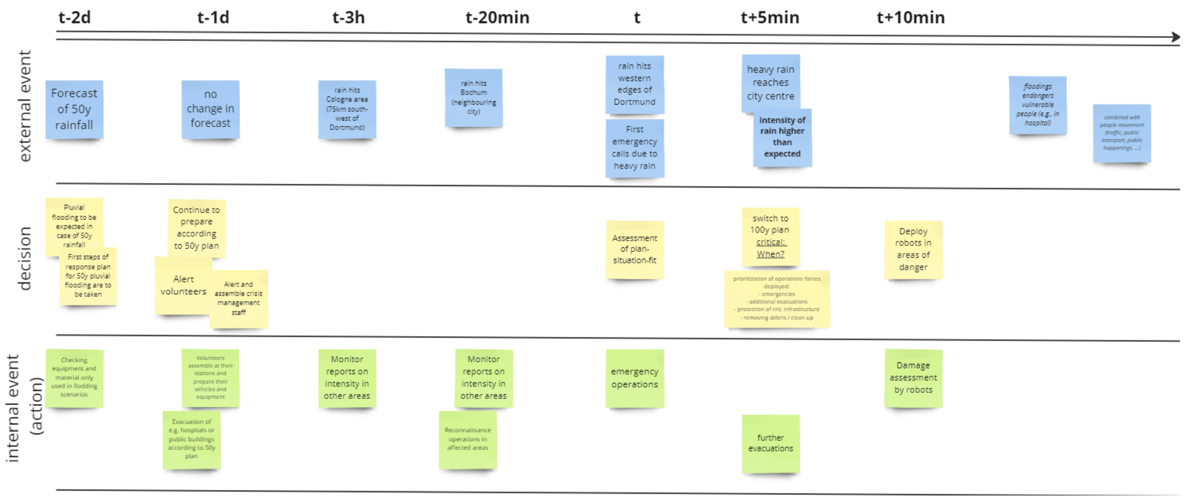


Figure 23: Elements of the temporal evolution of the scenario

Specific sub-scenarios within this overarching application scenario are provided in the appendix. These sub-scenarios are designed in a way that they can be either a) combined with each other for integrated test scenarios or b) used to derive specific test cases. While test scenarios would be relevant for field trials, test cases are required to setup lab-scale test environments (for instance, at DRZ and at UPB). Figure 24 presents an overview of the initial set of sub-scenarios.

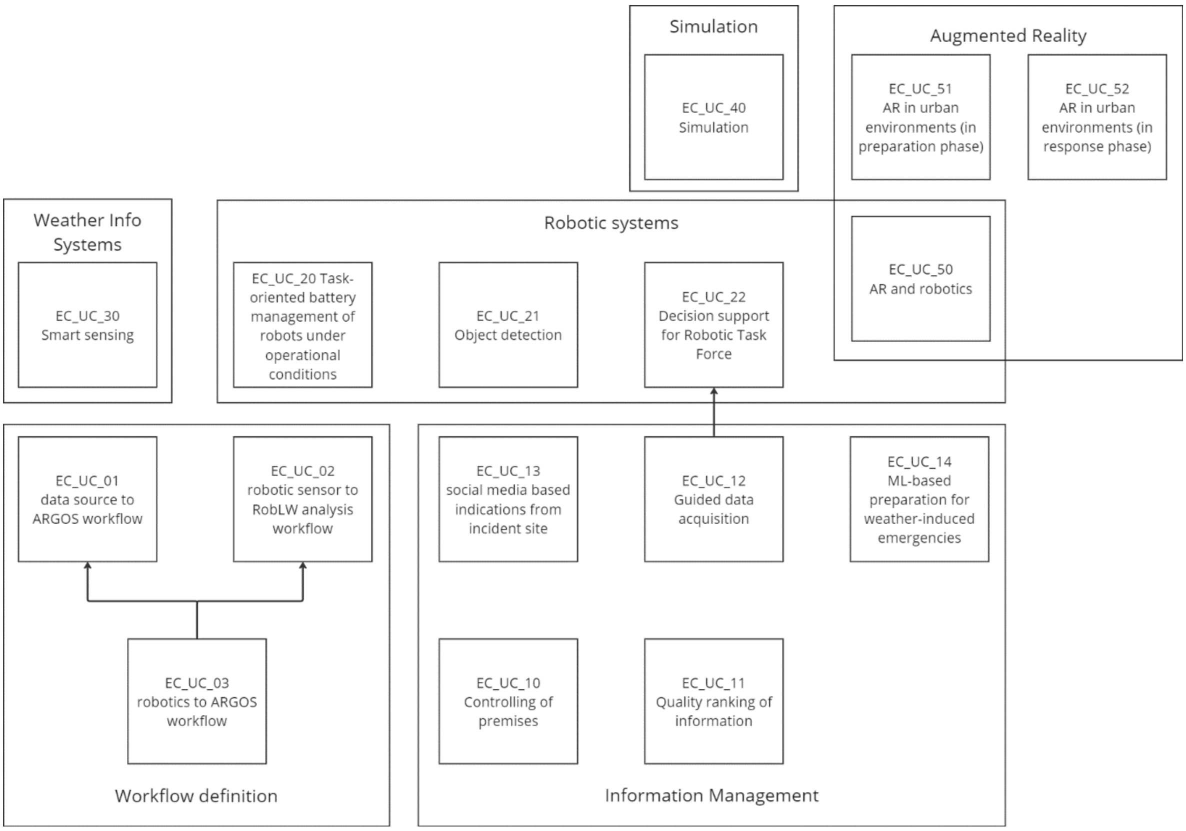


Figure 24: Overview of application sub-scenarios (use case narratives)

As an initial restriction, there will not be any sub-scenario where AR is used in staff room environments. That would have to be combined with physical object, so it is out of scope at least for the initial phase of CREXDATA.

4.1.5 Mapping of sub-scenarios to WP3-WP5 technologies

Table 8: Uptake of technologies in the Weather Emergency Use Case

Specific “use cases”	1	2	3	4	
T3.2 Graphical Workflow Specification	Em_UC_01	Em_UC_02	Em_UC_03	all others	
T4.1 Complex Event Forecasting	Em_UC_10	Em_UC_12			

Specific "use cases"	1	2	3	4	
T4.5 Text Mining for Event Extraction	Em_UC_13				
T4.2 Interactive Learning for Simulation Exploration	Em_UC_40 **	Em_UC_12 **			
T4.3 Federa-ted Machine Learning	Em_UC_20	Em_UC_21	Em_UC_30	Em_UC_12	Em_UC_14
T4.4 Optimi-zed Distributed "Analytics as a Service"	Em_UC_01 *	Em_UC_02 *	Em_UC_03 *		
T5.1 Explainable AI	Em_UC_11	Em_UC_14	Em_UC_20	Em_UC_22	Em_UC_30
T5.2 Visual Analytics supporting XAI	Em_UC_11	Em_UC_14	Em_UC_20	Em_UC_22	Em_UC_30
T5.3 Visual Analytics for Decision Making under Uncertainty	Em_UC_10	Em_UC_11	Em_UC_22	Em_UC_30	
T5.4 Augmented reality at the field	Em_UC_50	Em_UC_51	Em_UC_52		
T5.5 Uncertainty Visualization in Augmented Reality	Em_UC_50	Em_UC_51	Em_UC_52	Em_UC_11	
* to be detailed based on workflow descriptions ** to be detailed based on simulator selection					

4.1.6 Test and evaluation settings

The DRZ operates a LivingLab[6] with technical equipment for experiments and flexible testing and evaluation facilities, consisting of an 1300m2 large hall for an indoor testbed and an 1500m2 area for an outdoor testbed Figure 25 [17]. The hall accommodates various obstacle courses for testing robots, including a UAV parcour and the NIST standard test-lanes used, for instance, for the RoboCup competition. Additionally, there is a workshop area,

[6] URL www.rettungsrobotik.de

segregated workplaces and office space. The hall is fitted with a high-volume Motion Capture system with 40 cameras for accurate tracking of UGVs and UAVs during testing and evaluation in one of the largest coherent motion capture areas in Europe (35x10x10 m). The outdoor area features a reconfigurable building collapse scenario, a gas burning facility for forest fire simulation, a water pool with counter-current system and under-water motion capture as well as a wading water-pool with different underground materials.

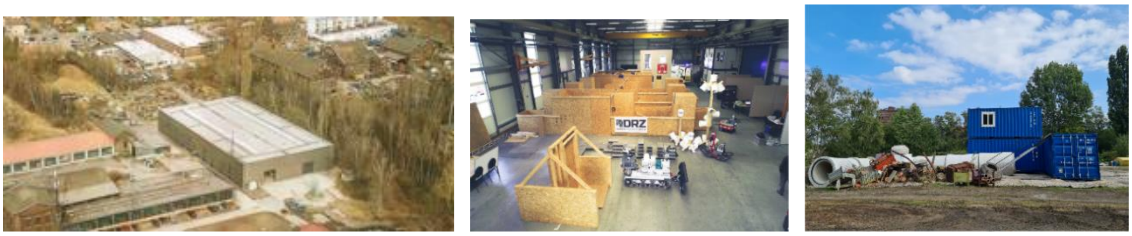


Figure 25: Indoor and outdoor test beds at DRZ

The operationalization of the solutions developed in CREXDATA is strengthened by the availability of the DRZ robotics command vehicle, RobLW Figure 26, serving as an emergency command vehicle for the First Responders to control the robots at an incident site. It is a van equipped for transport of UAVs and one mid-size UGV, and provides two workplaces inside the car equipped with data processing capacity and situation awareness interfaces.

Figure 26: Command car "RobLW" equipped with UAVs, UGVs and software solutions

UPB demonstrator and lab testbed

The demonstrator and laboratory test bed at UPB is a versatile and configurable facility for developing and evaluating technologies, algorithms and systems in a controlled environment. It serves as a platform for prototyping, testing and validating concepts. It enables researchers, developers and engineers to explore, test, and demonstrate experiments. The test bed includes observation capabilities by 9 fixed cameras and microphones, mobile extensions (cameras and mics) as well as research data synchronization and analysis software (Noldus Viso, The Observer and Face Reader). The observation system is able to observe the behavior of groups, analysis and evaluation of behavior patterns and self-reflection.

Figure 27: Behavioral research at the “Smart Innovation Lab” of UPB incl. Noldus observation system

Generally, the demonstrator laboratory test bed is modularly designed enabling sensor integration, actuator control, communication infrastructure, simulation environment integration, applications of virtual and augmented reality, and data analysis capabilities. It comprises interchangeable components, modules, and interfaces that can be adapted to specific research or development needs. This flexibility enables rapid reconfiguration to simulate different scenarios and environments. It enables researchers and developers to accelerate their innovation, gain insights, and make informed decisions in their respective fields. Moreover, the test bed can be integrated with simulation environments, such as Gazebo or ROS, enhancing its capabilities. This integration allows researchers to perform hybrid simulations, combining real-world hardware with simulated entities. It enables the evaluation of algorithms, system performance, and validation of control strategies in a virtual environment before deployment on physical assets.

Figure 28: Configurable lab environment at UPB

Thus, the lab is equipped with the required hardware, software and tools required to conduct the intended tests resp. run application scenarios. This includes computers, servers, networking devices, test automation tools, testing frameworks, simulators and specialized equipment relevant to the emergency management domain. The so called “Smart Innovation Lab”[7] can be configured in a way that it represents command posts of different command levels, up to A level staff environments. The lab provides a controlled and isolated test environment that mimics the real-world conditions in which the product or system will operate. This may involve setting up different operating systems, databases, network configurations and other relevant components to replicate the target environment accurately. It acts as a sandbox to experiment with Human Machine Interfaces, like Multi-Touch devices and AR. The Noldus system enables FAIR research data acquisition and management (cf.

[7] URL https://www.hni.uni-paderborn.de/en/pe/

[D1.2]). Documentation ensures consistency, repeatability, and traceability of the testing process. A skilled and trained team with expertise in testing methodologies, tools and technologies is available. Appropriate pivacy preserving measures are in place to handle personal information of probands.

Field trials

Field trials are conducted within real or at least realistic settings of stakeholders in Dortmund and Austria. Details are provided in the following Sections 4.1.7, 4.1.8 and 4.1.9.

4.1.7 Pilot site in Dortmund

The pilot site in Dortmund is based on a large bandwidth of experiences both in terms of practice and research background. For instance, CREXDATA benefits from previous EU-funded related research projects like PRONTO[8], NIFTi[9] and TRADR[10] (partially even conducted in collaboration with partners UPB, FhG/IAIS and NCSR). This subsumes both work results like scenarios, requirements and test results, as well as practitioners with experiences in such research settings.

4.1.7.1 Stakeholders

For the operational roles, specific personas are elaborated and documented in the appendix (Section 9.1.1). A level (Figure 45) and C level commanders (Figure 46) are qualified also for staff roles in the command & control staff room. Operational firefighting and rescue forces are introduced as “First responders” (Figure 47). Robots are operated by these responders, like other equipment. AR devices are mostly likely beneficial on the operational level.

An additional role that is not considered in the Dortmund pilot is the role of dispatchers working at Emergency Control Centers (ECC, in German “Einsatzleitstelle”/ELS) with its computing and storage infrastructure. Here, all operations are logged with geo-spatial data and communication channels. Status information of fire engines and command cars is tracked 24/7.

Table 9: Key stakeholder groups & roles of the Weather Emergency Use Case (pilot Dortmund)

Key stakeholder group	Key stakeholder roles
Action planner	• C2 staff member in high-level command room • Low-level commander on-site (C level)
Decision maker	• Crisis manager (e.g., mayor) • High-level commander in staff room (A level)
System administrator	• ICT task force expert • Robotic Task Force expert
Workflow designer	• ICT task force expert

[8] “Event Recognition for Intelligent Resource Management” URL https://cordis.europa.eu/docs/projects/cnect/8/231738/080/publishing/readmore/PRONTO-Visions-and-Goals.pdf, access 26.6.23

[9] “Natural human-robot cooperation in dynamic environments”

[10] “Long-Term Human-Robot Teaming for Disaster Response”, URL https://www.tradr-project.eu/, access 26.6.23

	• Robotic Task Force expert • to be tested: C² staff member in high-level command room

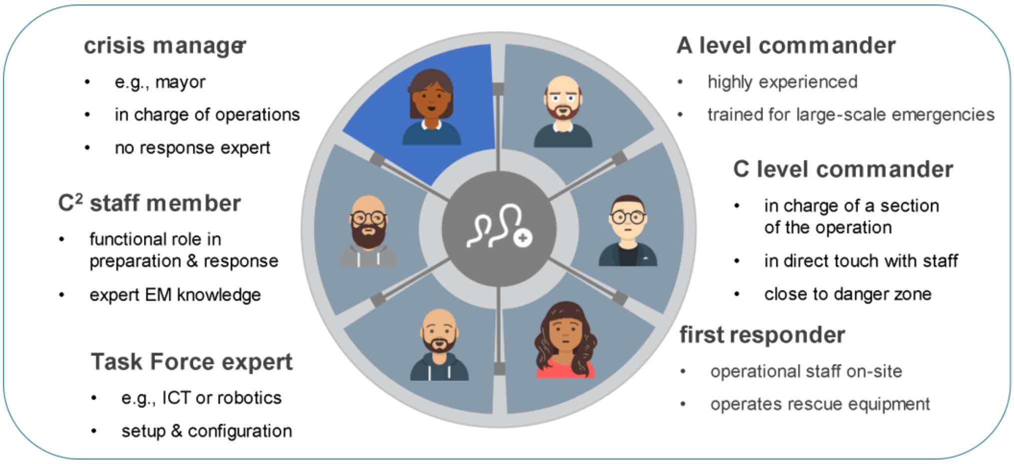


Figure 29: Personas derived from the list of key stakeholders

4.1.7.2 Application scenario

The application scenario is introduced in Section 4.1.4 as a preparation of use case analysis. In this Section, the fundamental scenario is adopted and transferred to the specific environment of the city of Dortmund. A pluvial flooding is assumed to happen in specific areas of Dortmund. All aforementioned use cases are assumed to be relevant in this application scenario. Thus, crisis management and high-level emergency management of FDDO are required. The emergency is extreme both in terms of spatial and temporal extensions. The scenario is drafted based on experiences made during the extreme weather event in western Germany, especially in the Ahr region and around Erftstadt 2021. A detailed report of 325 pages is available [18] (cf. [19, 20].

Some sub-scenarios with corresponding use cases are setup in small-scale reproduction in the test-bed at DRZ. For the overall situation, risk maps are available that were created in standard preparation activities[11]. Figure 30 presents some insights into these maps assuming a flooding with 100 years return period, which are available in the control center and in the A level command post. The RobLW is deployed in an operational Section that coordinates use of drones (UAVs and UGVs).

[11] https://geoweb1.digistadtdo.de/doris_gdi/mapapps4/resources/apps/starkregengefahrenkartetn100/index.html?lang=de&vm=2D&s=10000&r=0&c=393280.24263935274%2C5708048.11168041

Figure 30: Application scenario centered around Dortmund main station

4.1.7.3 Available data

The following data sources (cf. [D1.2, Section 3.1]) are available to provide data either continuously or in real-time during a test setup or in a field trial:

- Unmanned Vehicles[12] with robotic platform and payload in terms of sensor systems (off-the-shelf and experimental setups, see Section 4.1.2.2; available at DRZ and planned at UPB)
    a) UGVs
    b) UAVs
    c) Under-water robot (planned)
- RobLW[13]
    a) Applications for 3D model creation
    b) Communication networks
- AR devices (available at TUC and UPB)
    a) Microsoft HoloLens 2
    b) Tablets, smartphones
- Test bed
    a) Robot localization system (DRZ)
    b) Video observation system (UPB)

In desktop-like conditions, different devices are used to experiment with UIs. This subsumes laptops, tablets and smartphones, but also multi-touch displays and tables (cf. Section 4.1.6).

[12] URL https://rettungsrobotik.de/en/testing-facility/the-robotic-systems-on-an-overview

[13] URL https://rettungsrobotik.de/en/testing-facility/the-robotic-command-vehicle

In the course of the project, it might be relevant to incorporate further equipment of FDDO. For instance, there is a specialized Analytical Task Force (ATF) operating a wide ranging of measuring equipment [21].

The following datasets are available (see details in [D1.2, Section 2.1.2]):

- Emergency Cases FDDO 2020-2021
- Damage clearance tasks in Finland
- Warnings for flooding in Dortmund
- flight data from Erftstadt (flood event 2021), available at DRZ (owned by the pilot)[14]

4.1.8 Pilot site in Austria

For Innsbruck, the coordination in the event of an operation is compliant with the introduction of Section 4.1.4. The emergency dispatch center is led by "Leitstelle Tirol", they alert the emergency organization (fire department). Depending on the size of the event, there is also an official command (crisis management on municipality level) in addition to the fire department operational command. These two commands work closely together. In the case of pluvial flooding, as for example in the district of Amras, there was only one operational command at the fire department. This coordinates the disaster case. In addition, there is an operation site management and various operation teams on site in the disaster area. An exceptional situation in Innsbruck is that there is the Landeswarnzentrale Tirol, LWZ (in which the Leitstelle Tirol is integrated), which functions as an official coordinating body. That means that the Leitstelle Tirol and the fire departments provide data to the LWZ. Thus, they collect the data and sends the warning/alarm or all-clear to the population if requested by the authorities. Furthermore, the LWZ has a drone competence center, which can send drones to the disaster area on request and send aerial images, thermal images, etc. via live stream to the official geo-information-based situation management system KATGIS (provided by Geosphere Austria, the Federal Geological Service).

4.1.8.1 Stakeholders

For the Austrian pilot site, the following key stakeholders have emerged and are listed in Table 10.

Table 10: Key stakeholder groups & roles of the Weather Emergency Use Case (pilot Austria)

Key stakeholder group	Key stakeholder roles
Action planner	• Fire officer (Professional Fire Department Innsbruck) • Staff at ECC Tyrol (Leitstelle Tirol) • Staff at Tyrol National Warning Center (Landeswarnzentrale Tirol)
Decision maker	• Crisis manager (e.g. mayor of Innsbruck) • Fire chief (Professional Fire Department Innsbruck)
System administrator	• Task force expert at ECC Tyrol • Task force expert at Tyrol National Warning Center

[14] cf. https://www.youtube.com/watch?v=BIq9P9NHbT0

	• Task force expert at Professional Fire Department Innsbruck
Workflow designer	• Task force expert at ECC Tyrol • Task force expert at Tyrol National Warning Center • Fire officer & Task force expert at Professional Fire Department Innsbruck

Respective personas derived from the list of key stakeholders are:

- **Crisis manager** is in charge of the administrative-operational (official side) command. Depending on the size of the event and its impact, this is the mayor or the district administrator.
- **Fire chief** (dt. Branddirektor) is in charge of the overall tactic-operational command. This high-level commander is highly experienced and trained for large-scale events. Due to similarities see also A-level commander persona of FDDO.
- **Fire officer** is in charge of a Section of the tactic-operational command and plays a functional role in preparation and response. During an event, this persona is in direct touch with the first responders. Due to similarities see also C-Level commander persona of FDDO.
- **First responder** is an operational staff on-site. Due to similarities see also fire fighter persona of FDDO.
- **Dispatcher** coordinates emergency calls and dispatches resources to operations.
- **Task force expert** is experienced in his field and responsible for the setup and configuration, e.g. IT system, drones, thermal imaging camera, etc.

These roles can also be compared and possibly adapted to the specified personas in the Dortmund pilot site.

4.1.8.2 Application scenario

In the case of the Austrian pilot site, two application scenarios are under discussion, in which the fundamental scenario (introduced in Section 4.1.4) is adopted and transferred:

- pluvial flooding due to a heavy rainfall in the city of Innsbruck, i. e. Amras district
- fluvial flooding due to the Danube river in Lower Austria, i. e. Tulln an der Donau,

whereby the focus and implementation, as well as the exchange with stakeholders, are currently being placed on the use case in Innsbruck (Figure 31). If it is deemed necessary during the project, further discussions and activities will be made towards the fluvial scenario in Lower Austria.

In general, the application scenario in the city of Innsbruck aims to (i) increase the situational awareness of key stakeholders, i.e. emergency response teams and decision makers (see Figure 31) and (ii) expand the possibilities of technology use in an urban emergency in an alpine environment. Due to the topographical conditions, the city of Innsbruck must also expect cascading debris flows during heavy rain events. In addition, due to the narrowness of the valley, there is little space to drain the water. Thus, in the event of local heavy precipitation, the city's drainage system is most likely overloaded within a very short time. The time component depends on various factors, such as the amount and duration of precipitation, the mobilization of loose material from the slopes and other obstacles, but also on the time of year – e.g. leaves in autumn. In addition, such thunderstorm cells in alpine areas are often accompanied by hail which can cause blockage of drainage systems. In combination with a supra-regional, regional heavy precipitation event, the Inn River can also cause flooding in the city of Innsbruck and turn the disaster operation into a major event. Additional remedial measures are required here, e.g. with mobile flood protection and retention basins. But in this application scenario, we will mainly focus only on pluvial flooding, as these have been severely increasing in recent years and pose extreme challenges to emergency services. I.e. in a very short time, city districts can be completely under water, buildings have to be evacuated because their stability is no longer guaranteed, and people are in danger. In Innsbruck, debris flows can be triggered as secondary processes and endanger people and infrastructure. The action of the emergency forces is required in the shortest possible time. This application scenario is planned to be processed on the basis of the heavy precipitation event of July 2, 2016, which severely flooded the district of Amras (see pictures in Figure 31).

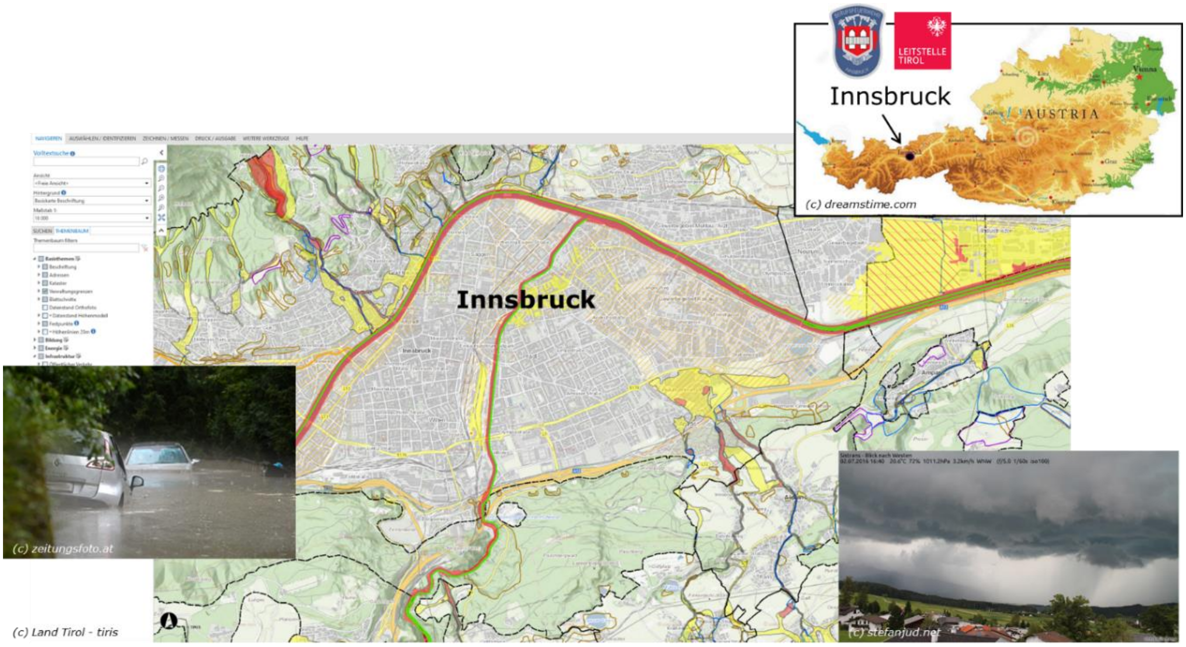


Figure 31: Spatial environment of the application scenario in Innsbruck (https://maps.tirol.gv.at/)

4.1.8.3 Available data

The following data sources (cf. [D1.2, Section 3.1]) are available to provide data either continuously or in real-time during a test setup or in a field trial. First indications after an initial workshop with third parties in Innsbruck are:

- Professional Fire Brigade Innsbruck:
  - a) Deployment protocols
  - b) Radio communication data (incl. location data)
- ECC Tyrol (Leitstelle Tirol):
  - a) Emergency call data (except from the police)
- National Warning Center Tyrol (Landeswarnzentrale Tirol) [optional, not yet sure - still in discussion]:
  - a) Deployment protocols

   b) Data collected and provided for the key stakeholders in the geoinformation-based systems (i) webGIS tiris OEI - Local operation information, and (ii) katGIS (Digital situation recording and situation information)
- IKB: Innsbrucker Kommunalbetriebe AG (municipal infrastructure service company) [optional, not yet sure - still in discussion]:
   a) Water level and (surface) runoff data of sensors in relation to the drainage system
   b) Supply bottlenecks (energy, electricity, etc.)
- Geosphere Austria [optional, not yet sure - still in discussion]:
   a) Meteorological raw data (precipitation, river and groundwater level, river flow rate of sensors)
   b) Rain radar data
   c) Weather forecasts incl. thunderstorm cells (national to local)
   d) Heavy rainfall forecasts for pre-defined, small areas
   e) INCA (Integrated Nowcasting through Comprehensive Analysis) data

The availability of continuous data (and especially in real-time) on the part of the stakeholders still needs to be clarified, as well as whether access to the local IT system is possible at all. This is also very critical from the point of view of data protection. In general, as discussions are still ongoing with the stakeholders, other or additional datasets may arise as the project progresses. Nevertheless, it should also be noted here that in the case of Innsbruck these data might not be available.

The following datasets (cf. [D1.2, Section 3.2]) might be made available:

- Professional Fire Brigade Innsbruck:
   a) Deployment protocols
   b) Radio communication data (incl. location data)
   c) Operational documentation during/after the event (pictures, etc.) if available
- ECC Tyrol (Leitstelle Tirol):
   a) Emergency call data (except from the police)
- National Warning Center Tyrol (Landeswarnzentrale Tirol) [optional, not yet sure - still in discussion]:
   a) Deployment protocols
   b) Operational documentation during/after the event
   c) Drone recordings during/after the event (aerial photos, thermal images, terrain maps, etc.)
   d) Data collected and provided for the key stakeholders in the geoinformation-based systems (i) webGIS tiris OEI - Local operation information, and (ii) katGIS (Digital situation recording and situation information)
- IKB: Innsbrucker Kommunalbetriebe AG (municipal infrastructure service company) [optional, not yet sure - still in discussion]:
   a) Water level, (surface) runoff data of sensors in relation to the drainage system
   b) Supply bottlenecks (energy, electricity, etc.)
- Geosphere Austria [optional, not yet sure - still in discussion]:
   a) Meteorological raw data (precipitation, river and groundwater level, river flow rate of sensors)

b) Rain radar data
c) Weather forecasts incl. thunderstorm cells (national to local)
d) Heavy rainfall forecasts for pre-defined, small areas
e) INCA (Integrated Nowcasting through Comprehensive Analysis) data

- Department of Bridge and Hydraulic Engineering (City of Innsbruck) [optional, still in discussion]:
  a) Hazard / susceptibility maps

However, as discussions are still ongoing with the stakeholders, other or additional datasets may arise as the project progresses.

4.1.8.4 Stakeholder requirements

A first workshop was held with the stakeholders of the Innsbruck application scenario on June 6, 2023, and discussions were initiated to which extent the technology from CREXDATA can be used and what the requirements are. These are as follows:

- Weather forecasting in different time scales (depending on the type of event): In the case of forecasted pluvial floods, and early prediction is deemed necessary (lead time >>1h).
- Forecasting of cascading events such as debris flows.
- Forecasting of critical events with enough lead time, of e.g. overloading of the canal/drainage system, instability of buildings, flooding of underground constructions (parking lots, underpasses)
- Facilitate and simplify communication among stakeholders in the event of an incident.
- Use of AR during pluvial floods: Visualization of predicted water level at different time intervals, trapped people in floating cars, etc.
- Use of underwater robots and/or drones during pluvial floods: Detection of trapped, buried people in floating cars, or of hazardous materials in water (chemical hazards), etc.

However, as discussions are still ongoing with the stakeholders, other or additional requirements may arise as the project progresses.

4.1.8.5 Evaluation planning

According to initial discussions with stakeholders, the CREXDATA demonstrator could be tested in the Emergency Dispatch Center Tyrol and/or in the Professional Fire Department Innsbruck. I.e. a control room, an command center and fire department personnel could be available. The possibility of extending the evaluation to other stakeholders, such as the Landeswarnzentrale Tirol or Geosphere Austria, could arise within the upcoming project period. Discussions with these stakeholders are ongoing.

Furthermore, in the above-mentioned workshop with stakeholders in Innsbruck (see 4.1.8.4), the following suggestions for possible scenarios for evaluation planning scenarios were discussed:

- Evaluation of existing hazard zone plans based on the design event.
- Simulation of a heavy precipitation event in a district of Innsbruck with a focus on which lead time is necessary for which scenario in terms of precipitation amount and duration. How does the alerting and deployment process work - can it be optimized in terms of time?

However, as discussions are still ongoing with the stakeholders, other or additional opportunities for evaluation may arise as the project progresses.

4.1.9 Involvement of Finnish experts

The involvement of Finnish experts, including Finnish Meteorological Institute (partner, FMI), The Ministry of Interior Finland (partner, MoIFI) and the Rescue Department of Helsinki (external stakeholder) is built around showcasing the use of machine learning in weather-related impact forecast and early warning tool development. The aim of the showcase is to negotiate with the data owners to find, utilize and make new datasets open within the project consortium as well as openly for everyone. The Finnish showcase focuses not only on one, but on several weather hazards which have a large impact on Finnish emergency management in different seasons. The aim is to use statistical modelling and machine learning to produce forecasting products that describe the forecasts in a useful and concrete way for the end users in Finland and possibly also in other pilot locations, such as in Dortmund.

4.1.9.1 Stakeholders

The Ministry of Interior Finland (MoIFI) is a partner in the CREXDATA project and their role in the emergency management is to make civil protection decisions on national level as well as international cooperation for instance with EU Civil Protection Mechanism. In the case of broad national and international emergencies, MoIFI takes decisions on civil protection and provides aid in equipment or resources to local rescue departments in Finland (Figure 32). There are 22 local rescue departments in Finland, of which each has their own responsibility areas as well as different capacities and protocols regarding emergencies.

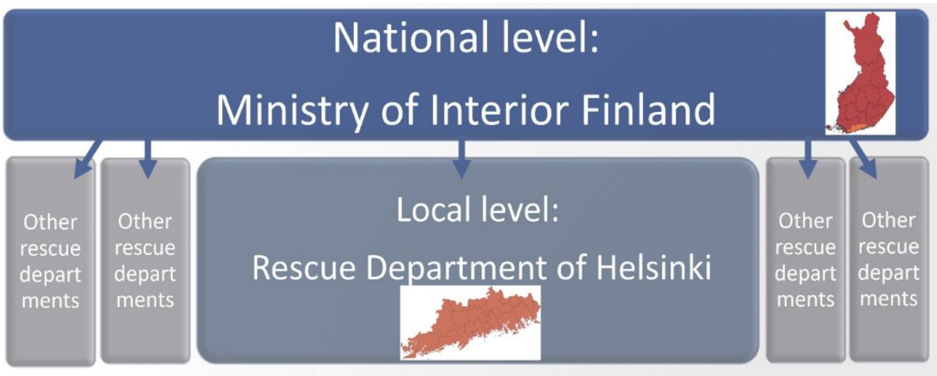


Figure 32: The structure of emergency management in Finland

The Rescue Department of Helsinki is an external stakeholder of CREXDATA and represents the local, 'grass root level' actor, operating in Helsinki urban area, and in Uusimaa county. The Rescue Department of Helsinki employs around 700 experts distributed on nine fire brigades around the city of Helsinki ensuring the safety of the capital. The tasks of the national level and local level emergency management very are different. On the national level decisions are made on strategic planning, policy development and major national and international catastrophes. The local level rescue departments are responsible for instance on risk assessment, prevention of accidents and preparing for weather hazards on their own area (Table 11). In weather-related hazards, both national and local level actors are dependent and base their decisions on accurate and modern weather forecasts, weather warnings and next-generation impact-based forecasts of FMI. The role of Rescue Department of Helsinki in CREXDATA is to provide expertise, test the machine learning-based tools developed by FMI, and bring end-user perspectives to the tool development. MoIFI integrates and distributes the experiences of the outcomes to the national strategic planning and informs the other national and international emergency management communities about the results.

Table 11: Main tasks of the ministry of interior Finland and local rescue departments

	Ministry of Interior Finland:	Local Rescue Departments:
Task	• Policy development and strategic planning on national level • Coordination and collaboration among different agencies and stakeholders • Resource allocation • Training and Capacity Building	• Emergency response at regional and local levels • Risk assessment, and prevention and identifying potential hazards • Public awareness and education for communities • Collaboration with other agencies

4.1.9.2 Application scenario

Currently FMI is providing for instance following services for end users where machine learning can be utilized and where it can give a significant support to the impact estimations of forecasters or emergency managers:

- Severe Weather Warnings: FMI issues alerts for hazardous weather events, enabling proactive measures and emergency planning.
- Early Warning Systems: Collaboration with civil protection to develop systems that detect and forecast (the impacts of) extreme weather events, including prompt evacuation and response coordination.
- Specialized Forecasts: Tailored forecasts for specific sectors like emergency management assist in decision-making, minimizing risks and optimizing operations.
- Data Dissemination: Collecting, analysing, and disseminating weather- or weather impact-related data, enabling risk assessments, emergency planning, and response coordination.

The scenarios of the Finnish showcase are built rather on the impacts of different weather hazards than one specific weather hazard. In Finland a variety of weather-related hazards are experienced throughout the year. The autumn and winter season are dominated by strong windstorms with strong winds, and occasionally also with heavy snowfall conditions. These windstorms and falling trees cause lot of clearance tasks for the rescue department and inconvenience for public in form of power outages, damage to infrastructure, hazardous road conditions, and threat to human lives. One of the tools developed in the project is specifically tailored for forecasting the number of clearance tasks of upcoming windstorms. During heavy snowfall cases, the tool forecasting the number of road traffic accidents helps the rescue department to plan their resource management in a case of difficult winter storm and extreme road weather conditions (Figure 33).

During the summer months, Finland experiences in increasing frequency extreme heatwaves and dry weather conditions, which increase the risk of forest fires as well. Forest fires cause threat to people and infrastructure. The preparedness of the rescue department for forest fires can be increased by providing a tool that is estimating directly the number of wildfire fighting events on the Helsinki and Uusimaa region instead of traditional weather forecast predicting weather conditions and leaving space for individual interpretation.

The impacts of weather-related hazards are often consequences of combination of meteorological, environmental and infrastructural factors. The Finnish ML-based service can be taken up for instance in the complex event forecasting of T4.1. The impacts of the complex events may be difficult to grasp and understood solely by human brain, and thus machine learning algorithms are excellent aid for instance in the data analysis, recognizing complex patterns in weather data, and detecting early signs of specific events. ML service can be developed to create more accurate impact forecasts and enhancement of weather warnings or early warning systems, which often are missing the estimation of weather hazard impacts. The information and analysis of FMI's ML service can be also utilized in T5.2 (Visual analytics supporting XAI) in simplifying and interpretation of complex and vast weather data. The outcomes of T5.3 (Visual analytics for decision making under uncertainty) can be possibly tested as an extension of the ML service tools to visualize the uncertainties of the forecasts in the understandable way, which is currently missing in the existing ML based tools of FMI.

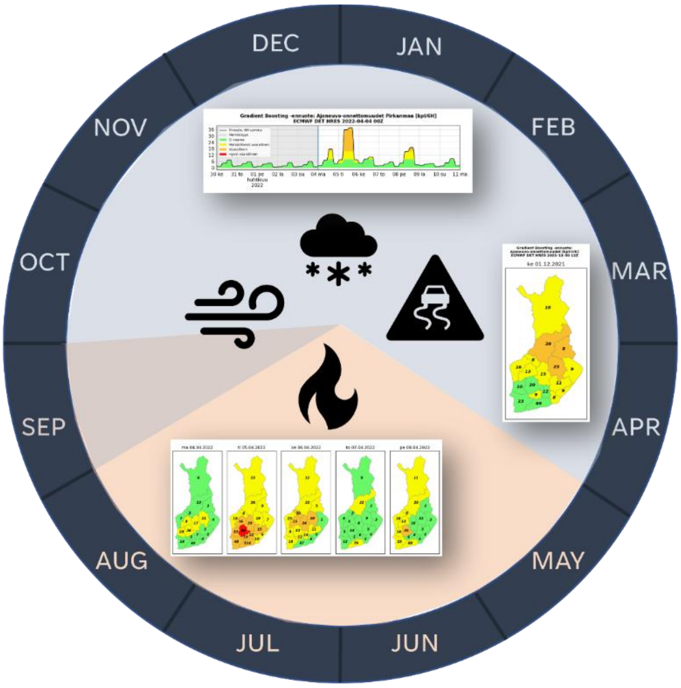


Figure 33: The seasonal occurrence of the main weather hazards in Finland (forest fires in summer, wind- and snowhazards in winter). The developed impact forecast tools aim to address various impact variables induced by these hazards.

4.1.9.3 Available data

In a Finnish national level SILVA-project (2020-2023), a comprehensive weather-related impact database was created. Of 13 collected impact datasets, four were made openly available. In CREXDATA we demonstrate the use of these four datasets presented in Table 19 with their volume, temporal and geographical coverage, and resolution. The advantage of these datasets especially from the machine learning perspective is that the time series lengths are long and the accuracy of both spatial and temporal resolution of the impacts is sufficient for training the model that requires large amounts of data to perform well. Additionally, currently the ECMWF HRES weather model is used, and later MEPS limited area ensemble weather prediction model is tested as the predictor data representing the weather-dependency of the impacts. In CREXDATA, the possibility of including new datasets and making them openly available is also being explored. The plan is also to utilize for instance the number of ambulance operations between 2007 and 2023. The open impact data can be made available to other partners also through ARGOS system, as well as selected meteorological data described more in details in D1.2.

Table 19: Impact datasets used for training and validating the gradient boosting machine learning method that are openly available. The ambulance operation dataset is a new dataset and the use is being explored in the project (not openly available).

DATASETS	VOLUME	TIME SERIES LENGTH	COVERAGE	RESOLUTION
Wind damage clearance	130k	22 yrs	National	• Municipal • 1 hour
Wildfire fighting events	63k	22 yrs	National	• Municipal • 1 hour
Traffic accident clearance	281k	22 yrs	National	• Municipal • 1 hour
Road traffic accidents	1.1M	24 yrs	National	• Municipal • 1 hour
Ambulance operations	~1M	16 yrs	Helsinki region	• Accurate coordinates • 1 second

4.2 Health Use Case

This use case will assess WP4 abilities to enable critical action planning and intervention by providing efficient parameter exploration forecasting and effective interventions in the modelling of epidemics and drug treatment optimization in COVID-19 infection. Additionally, this task will specify the requirements and scenarios that will be used by the novel tools developed in T2.5. The evaluation will be performed on two scenarios. In the epidemics scenario, we will use epidemiological compartmental models to build a digital twin for COVID-19 transmission that identifies efficient policies and enables accountability. In the drug treatment scenario, we will use multiscale mechanistic models to build a digital twin of a drug assay in COVID-19 patients that identifies the best treatment for each patient and condition. [DoA, p.8]

4.2.1 Stakeholders

Epidemiological simulations in a health crisis have the potential to benefit a wide range of stakeholders. Government and public health agencies can leverage these simulations to make informed decisions and effectively allocate resources, implement effective Non-Pharmaceutical Interventions and design optimal vaccination campaigns. By understanding the potential spread of diseases and evaluating the impact of different intervention strategies, policymakers can develop evidence-based policies and guidelines. Healthcare providers and hospitals can utilize the simulations to assess the strain on healthcare systems, such as the demand for hospital beds, ICUs, ventilators, and the healthcare workforce. This information aids in resource planning, capacity management, and optimizing healthcare delivery to meet the needs of the affected population.

Emergency management and disaster response agencies also find value in epidemiological simulations. These simulations assist in understanding potential scenarios, predicting resource requirements, and strategizing response plans. By incorporating simulation results into their preparedness efforts, these agencies can develop response protocols, coordinate multi-agency efforts, and ensure effective coordination and implementation of response measures. Additionally, researchers and academia benefit from epidemiological simulations as they provide a tool for testing hypotheses, exploring different scenarios, and analysing the potential impact of interventions. By contributing to scientific knowledge, simulations inform research directions and support the development of evidence-based guidelines for mitigating health crises.

Table 12: Key stakeholder groups & roles of the Health Use Case

Key stakeholder group	Key stakeholder roles
Action planner	• Epidemiologist or Biomedical researcher • Computer Science Researcher • Computational Systems Biology Researcher • Public Health Official • Emergency Response Manager • Healthcare Administrator • Clinician • Risk Manager
Decision maker	• Government Official • Public Health Director • Emergency Management Director • Policy Maker • Mayor/Local Authority • Public Health Committee • Drug development company CSO
System administrator	• IT / Data Science staff of Public Health Agencies • IT / Data Science staff of Hospitals • IT / Data Science staff of Research Centers
Workflow designer	• IT / Data Science staff of Public Health Agencies • IT / Data Science staff of Hospitals • IT / Data Science staff of Research Centers

Each of the identified stakeholders is interested in application scenarios for forecasting the evolution of new potential epidemics, detecting new outbreaks or wave and finding efficient intervention to reduce the impact from different perspectives. Likewise, they are also interested in novel, optimised drug treatments that provide alterative clinical care pathways for COVID-19 patients.

The list of functionalities proposed will address the specific end-user requirements regarding the healthcare system. All developed functionalities will potentially target one or more of the following key healthcare system managers, public health decision-makers and data scientist/IT service provider needs.

We have taken advantage of the EBI's Competency Hub developed by us in a recent project to characterise some of these personas in more detail. The PerMedCoE competency framework defines a series of competencies required of professionals in the field of computational personalised medicine. A competency is an observable ability of any professional, integrating multiple components such as knowledge, skills and behaviours. The competencies that an individual might need to fulfil a particular role are listed in the reference profiles, which can be used to guide career choices[15].

The PerMedCoE competency profile builds on the work done in several related initiatives, as we took inspiration from the competency profiles of BioExcel[16], CINECA[17] and ISCB[18] to create an initial draft that was updated with feedback from experts from the community. All the profiles are freely accessible through the EMBL-EBI Competency Hub[19] (Figure 34). Additionally, the Competency Hub allows users to create their own profile on the site and to compare it with the existing profiles (Figure 35), which can inform about career development options.

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15 This competency framework is available at: https://competency.ebi.ac.uk/framework/permedcoe/2.1 and https://permedcoe.eu/deliverables/ (Deliverable 4.2).

16 https://competency.ebi.ac.uk/framework/bioexcel/2.0

17 https://competency.ebi.ac.uk/framework/cineca/1.0

18 https://competency.ebi.ac.uk/framework/iscb/3.0

19 https://competency.ebi.ac.uk/framework/permedcoe/2.1

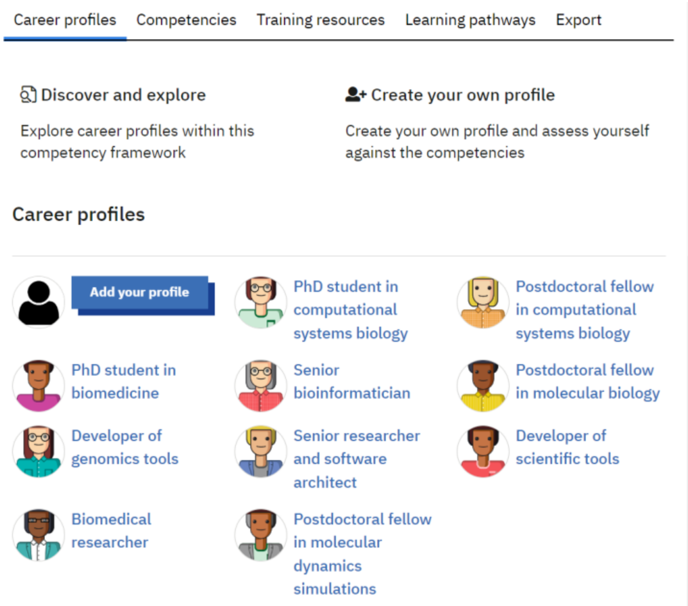

Figure 34: List of the developed personas in the PerMedCoE competency framework.

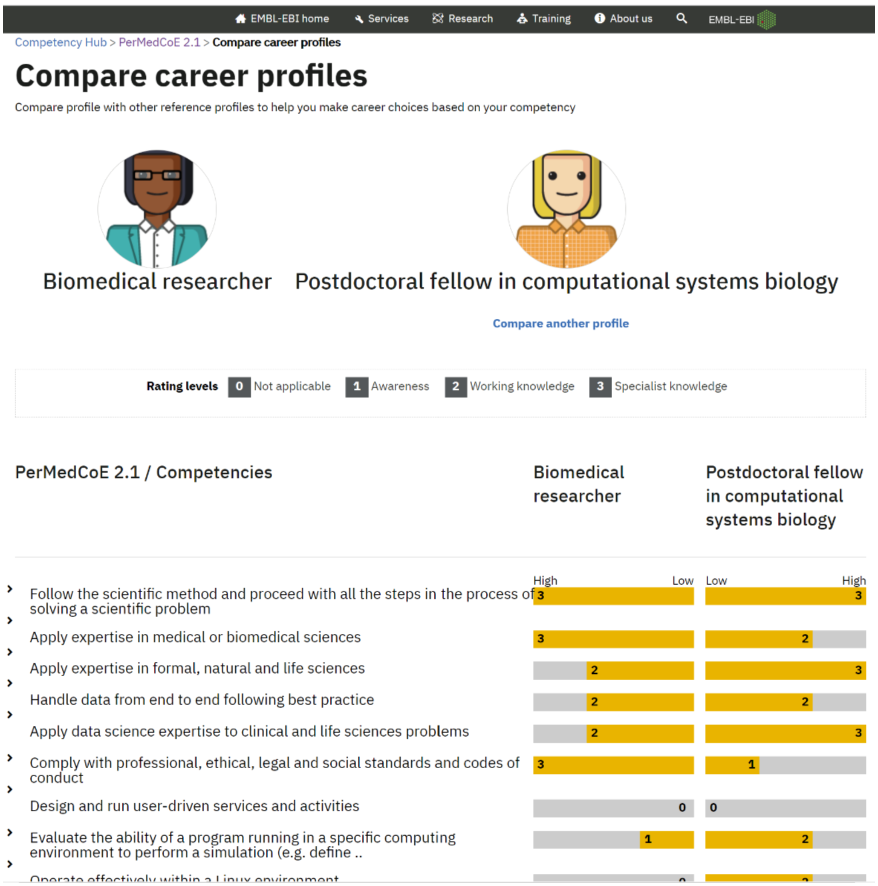

Figure 35: A comparison between two user profiles. Application scenarios (https://competency.ebi.ac.uk/framework/permedcoe/2.1)

Scenario 1: Designing Effective NPIs and Vaccination Campaigns for Controlling a Disease Outbreak using epidemiological modelling

In this scenario, a region is facing a sudden outbreak of a highly contagious infectious disease. The objective is to use epidemiological simulations to evaluate potential scenarios under different assumptions such as different reproduction numbers and fatality rates when those parameters are still unknown or hard to estimate due to the absence of data. In the second stage, optimization-via-simulation can be used for the design and implement effective Non-Pharmaceutical Interventions (NPIs) and vaccination campaigns to control the disease spread and minimize its impact on the population.

Scenario 2: Finding optimised drug treatments and alternative clinical care pathways for COVID-19 patients using multiscale modelling

In this scenario, a patient has been identified as being infected by SARS-CoV-2 and has been taking in charge by a hospital. The objective is to have a digital twin of the clinical care pathway using a multiscale model to propose clinical interventions of drugs and NPIs (such as mechanical ventilation) that allows the patient to have a healthy status. For this, first we will need to couple two simulators (Alya and PhysiBoSS) and fit different parameters to clinically-relevant variables. Second, we will use optimization-via-simulation to design and implement patient-specific, effective combinations of interventions that heal the patients.

4.2.2 Available data

As an initial assumption, no real-time data sources are available. Available data sets are described per health sub-scenario in the following Sections.

4.2.2.1 Scenario 1: Epidemiological modelling

The following datasets (cf. [D1.2, Section 4.2) are available on Zenodo. The open datasets consist of COVID-19 case reports and population mobility patterns in the form of origin destination matrices, both reported on a daily basis:

- COVID19 Flow-Maps GeoLayers dataset: Geographic layers on which the different data records are geo-referenced (e.g., mobility, COVID-19 cases). The different layers can be grouped into those that cover the whole territory of pain (e.g., municipalities) and those that are restricted to a specific region (Table1). Among those that cover the full territory of Spain, the record accounts for the first four levels of administrative division, that is, autonomous communities, provinces, municipalities and districts [22].
- COVID19 Flow-Maps Daily Cases Reports: This repository contains COVID-19 data for Spain, including daily cases at the level of autonomous communities as well as provinces, and higher spatial resolution for several autonomous communities (eight out of the nineteen autonomous communities publish reports with local daily COVID-19 cases at the level of municipalities or Basic Health Areas). Each record has an identifier, the associated date, the corresponding identifier of the layer and code of the region and a set of COVID-19 related fields, which include the number of new cases (daily incidence) and total cases. The dataset includes case reports for a time period of approximately two years [23].
- COVID19 Flow-Maps Daily-Mobility for Spain: This data-set contains daily aggregations of the hourly data provided by MITMA, aggregated at different levels of spatial resolution. The dataset includes Origin-Destination matrix for the mobility layer, with hourly resolution Each entry has a date and time period (the range between two consecutive hours), the origin and destination zones and the number of trips from a origin to a destination. Origin and destination zones correspond to

geometries from the MITMA mobility layer and internal trips (same layer of origin and destination) are also reported. Additionally, it also includes a data record containing the trips per person matrix on each mobility area on a daily basis. This indicator reports population-based daily mobility behaviour. For each date and zone from the MITMA mobility layer, the indicator reports how many persons have performed 0, 1, 2 or more than 2 trips. While the indicator does not provide the destination of the trips, it accounts for the fractions of people performing at least one trip or none, as well as the estimated total population in that zone for the given date, considering as population those persons who stay overnight in the zone on that date [24].

- COVID19 Flow-Maps Population data. Daily population and trips per person data from Spain 2020-2022. This data record contains daily population records based on a study conducted by the MITMA, that analysed the mobility and distribution of the population in Spain from February 14th 2020 to May 9th 2021. The study is based on a sample of more than 13 million anonymised mobile phone lines provided by a single mobile operator whose subscribers are evenly distributed. Data provided by MITMA is related to the layer mitma_mov. For the rest of the layers, the population was estimated using the population grid from GEOSTAT[20] [25].

4.2.2.2 Scenario 2: Multiscale lung infection modelling

- Anonymized patient omics molecular data. Publicly available pseudo-anonymized raw experimental data from patients. This dataset bundles different studies that will be the input used to analyze and personalize our multiscale models. It potentially consists of transcriptomics, genomics, copy number variations and proteomics data.
- Anonymized patient pulmonary 3D positional data. Publicly available pseudo-anonymized image data from patients. This dataset bundles different studies that will be the input used to have complex 3DaI setups for our multiscale models. Once analysed, this dataset will have positional data for each of the alveoli of the patients.

[20] https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/population-distribution-demography/geostat

4.2.3 System Architecture for Demonstrator

Table 13: Demonstrator components extending the CREXDATA system (Health Use Case)

Component	Description
Epidemiological Scenario	
T2.4 – Simulation and Tools	• Creation of a synthetic mobility dataset for evaluation of different scenarios • User interface development. The end-users of the user interface will be able to view the forecast the evolution of the epidemic process under different scenarios • Simulation Framework: Integration of population mobility data with the epidemiological models. The architecture will give the capability to simulate/replicate a test scenario using both, real and synthetic data of the COVID-19 pandemic in Spain, with potential extensions to other countries.
T3.2 Graphical Workflow Specification	• Graphical tools, for instance using different operators in RapidMiner, will be developed to allow a non-expert programmer to specify complex data processing workflows to enable the fusion of different spatiotemporal data sources georeferenced to different territorial units.
T4.1 Complex Event Forecasting	• NCSR/BSC will develop novel algorithms to forecast new outbreak hot-spots based times series of cases, population mobility
T4.2 Interactive Learning for Sim. Exploration	• Extreme-scale model exploration will be combined with interactive learning approaches to explore the large space of epidemiological parameters, as well as, optimal interventions.
T4.3 Federated Machine Learning	• Federated Machine Learning (FML) offers a privacy-preserving approach to calibrating epidemiological parameters in a pandemic scenario. It allows multiple data owners to collaborate and train a shared machine learning model without sharing their sensitive data. The calibrated epidemiological parameters obtained through FML will be validated using a time series of COVID-19 cases reported at different levels of spatial aggregations. Robust statistical methods can be applied to assess the accuracy and uncertainty of the calibrated parameters.
T5.3 Visual Analytics for Decision Making under Uncertainty	• Creates visual representations of the epidemic model outputs. This can include interactive maps, charts, graphs, and dashboards that depict the spread of the disease over time, hotspots of infection, and the effectiveness of interventions.
Multiscale lung infection Scenario	

Component	Description
T2.4 – Simulation and Tools	• Simulators: Coupling organ-level with cell-level simulation tool • Study the use of surrogate models for parts of the algorithms. • Use model exploration to fit some of the parameters using clinical data or desired simulated behaviours. • Prepare a set of design variables that control the treatment of patients (drug and mechanical interventions) that will be inspected using interactive learning.
T3.2 Graphical Workflow Specification	• Graphical tools, for instance using different operators in RapidMiner, will be developed to allow a non-expert user to use and browse complex workflows that simulate patient treatments using clinical data and bedside variables.
T4.1 Complex Event Forecasting	• NCSR and BSC will develop novel algorithms to forecast at early times the outcomes of a lung infection simulation.
T4.2 Interactive Learning for Sim. Exploration	• Extreme-scale model exploration will be combined with interactive learning approaches to explore the large space of potential clinical interventions and simulate the patient's clinical care pathway until recovery.
T5.3 Visual Analytics for Decision Making under Uncertainty	We will create visual representations of different simulations of the multiscale infection model. For instance, we will study the usefulness of GUIS and dashboards to ease the exploration of the parameter sensitivity analyses and their effect on model outputs.

Table 14: Uptake of technologies in the Health Use Case

Specific "use cases"	Parameters calibration and optimal intervention design	Forecasting of outbreak hotspots	Fusion of different spatiotemporal data sources	Forecasting of lung infection dynamics	Interactive learning of COVID19 patients clinical care pathway
T2.4 Simulation and Tools	X	X		X	X
T3.2 Graphical Workflow Specification			X		X
T4.1 Complex Event Forecasting	X	X		X	X
T4.2 Interactive Learning for Simulation Exploration	X				X

Specific "use cases"	Parameters calibration and optimal intervention design	Forecasting of outbreak hotspots	Fusion of different spatiotemporal data sources	Forecasting of lung infection dynamics	Interactive learning of COVID19 patients clinical care pathway
T4.3 Federated Machine Learning	X				
T4.4 Optimized Distributed "Analytics as a Service"					
T5.1 Explainable AI					
T5.2 Visual Analytics supporting XAI					
T5.3 Visual Analytics for Decision Making under Uncertainty	X	X		X	X
T5.4 Augmented reality at the field					
T5.5 Uncertainty Visualization in Augmented Reality					

4.3 Maritime Use Case

The scenarios will be validated using created streams of data, and in sea trial experiments with numerous vessels with several levels of autonomy as defined by the International Maritime Organization (IMO) in cooperation with the SMARTMOVE Lab of the University of the Aegean (UoA). Sea trials under realistic conditions guarantee an application-related real-world assessment. Data collection and sea trials will be conducted during dedicated experiments at the Aegean University sea testbed and during the Aegean Ro-boat Races planned to take place annually in the summer periods starting in July 2023. The sea testbed of the University of Aegean is located on the island of Syros in the Aegean Sea and offers close proximity to open sea testing grounds. It covers sea and land utilizing 100% WiFi coverage and is capable of hosting and deploy several types of UVs: air, land, sea and subsurface. A running prototype version of the IoT-Voyage Data Streamer – VDS will be deployed at the 1st Aegean Ro-boat Race taking place in July 2023.

During year 1 of the project the sea trial will be used mostly to collect real world datasets from onboard the competing vessels, while following this they will be used to test the components in real world maritime conditions.

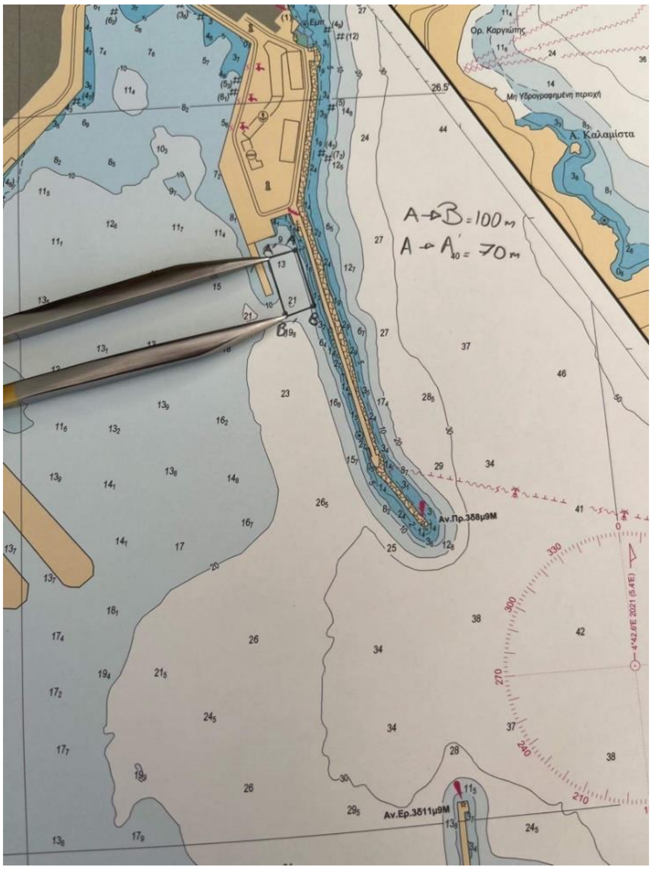

Figure 36: University of the Aegean sea test bed area on the island of Syros, Greece

Figure 37: Bird's eye view of the sea test bed of the University of Aegean on the island of Syros, Greece

4.3.1 Stakeholders

The following key stakeholder groups are identified in the context of the Maritime Use Case. Each stakeholder has specific interests directly linked to aspects regarding maritime safety, or is accountable for ensuring safe maritime operations, safe navigation as well as passenger, crew and cargo safety and is part of the decision making and accountability chain in the context of hazardous maritime events detection, forecasting and mitigation.

Table 15: Key stakeholder groups & roles of the Maritime Use Case

Key stakeholder group	Key stakeholder roles
Action planner	• Vessel pilot • Vessel crew • VTS operator • Port/coastal authorities • Remote operator
Decision maker	• Ship deck officers • VTS operator • Port/coastal authorities • Fleet managers • Vessel owners • Remote operator
System administrator	• IT / Data Science staff of the maritime service provider • IT / Data Science staff of the port authority • IT / Data Science staff of the vessel owners • Fleet managers • Insurance companies
Workflow designer	• IT / Data Science staff of the maritime service provider • IT / Data Science staff of the port authority • IT / Data Science staff of the vessel owners • Fleet managers • Insurance companies

Each of the aforementioned stakeholders are interested in application scenarios for global vessel safety, tracking and management from his/her own perspective. The envisaged functionalities address the specific end-user requirements regarding maritime safety. All developed functionalities will potentially target one or more of the following key maritime users and data scientist/IT service provider needs. Resulting functionalities that are listed below are in line with the importance evaluation results of the user requirements survey contacted by MT (see service importance evaluation Table 21):

- Vessel's route analysis and/or prediction.
- Early warnings of possible collisions and near-real time collision avoidance.
- Early warnings of possible intrusion of sea areas with hazardous weather conditions.
- Rerouting and mitigation actions for collision mitigation
- Rerouting and avoidance of sea areas with forecasted hazardous weather conditions.

The key personas involved directly in the detection and management of a maritime emergency are identified in Figure 38.

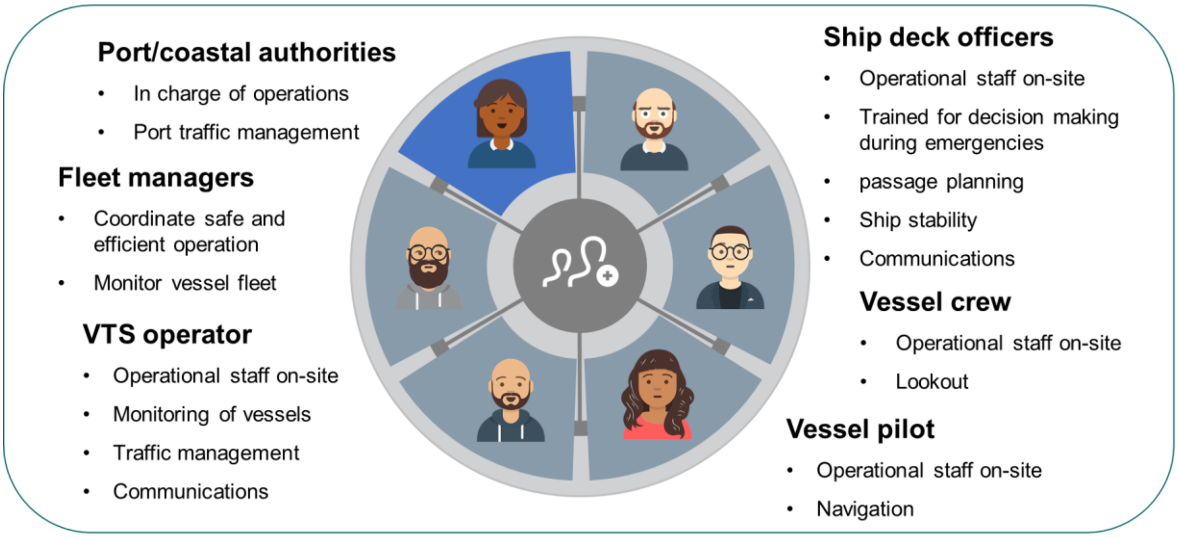

Figure 38: Overview of personas derived from the list of key stakeholders of the Maritime Use Case

Examples of the key personas involved in in the detection and management of a maritime emergency are presented in the appendix (Section 9.3.1, Figure 50 to Figure 55) based on the foundations presented in Section 2.1.1. The examples consist of typical personal traits and characteristics.

4.3.2 Application scenario

In the context of the Maritime Use Case two application scenarios will be examined:

- collision forecasting and rerouting
- hazardous weather rerouting

Both application scenarios that are part of the pilot will be evaluated in sea trial experiments using the vessel of high autonomy (test vessel) of the SMARTMOVE Lab of the University of Aegean. Regarding the collision forecasting application scenario, a collision event will be simulated at the sea test bed with the test vessel forecasting the imminent collision event in a short-term time horizon of under 15 minutes according to the KPIs. In a subsequent step a rerouting option will be provided in order to mitigate the collision event. Regarding the hazardous weather rerouting, using simulated and synthetic data streams, first a sea area will be designated as an area with hazardous weather conditions. The test vessel will be provided with information regarding its imminent approach to the area with hazardous weather conditions along with rerouting instructions. The demonstration of both events during sea trial experiments at the University of Aegean sea test bed will validate the pilot of the maritime use case under realistic conditions and guarantee an application-related real-world assessment.

Table 16 and Table 17 present the high-level usage scenarios for the CREXDATA Maritime Use Case incorporating the identified key stakeholders and considering the results of the user requirements survey (see: Section 4.3.5 Stakeholder requirements). For each of the scenarios, apart from the actor, the overview and the detailed description, the main benefits and challenges are provided.

Table 16: Collision forecasting and rerouting high level scenario description

Attribute	Description
ID	Maritime_UC01
Name	Collision Forecasting and Rerouting
Short description	Forecasting of probable collision events among vessel in a short time prediction horizon of under 15 minutes. In case of a collision event detection, the proposed service informs the relevant actors of the collision event detection and provides rerouting suggestions for the mitigation of the collision event. The actors decide either to follow the service's instructions or correct the proposed rerouting suggestion based on their own local view
Author	MT
Last update	09.06.2023
Actors	• Vessel pilot • Vessel crew • VTS operator • Ship deck officers
Additional Actors	• Vessels of different levels of autonomy
Actors interested in the outcomes	• Port/coastal authorities • Fleet managers • Vessel owners • Insurance companies
Detailed scenario	The pilot of vessel A is alerted of a possible collision event with vessel B, as their current routes will intersect. The pilot evaluates the emergency of the forecasted event and is provided with a set of alternative routes for vessel A to follow in order to avoid colliding with vessel B. Based on the experience of the vessel pilot, he/she may opt to accept the proposed route, correct the proposed suggestion or follow an entirely different route in order to avoid collision with vessel B
Benefits	• Route monitoring and collision event forecasting for vessel traffic increasing safe navigation and efficiency of maritime operations • Improved route predictions of the vessel traffic through fusion of local and global data streams • Automation of collision event detection forecast and mitigation steps through automated rerouting suggestions. • Increased situational awareness

Attribute	Description
	• Early identification of possible collision events providing comfortable response time windows and informed decision support • Exploration of collision mitigation alternatives • Vessel crew and VTS operator work effort alleviation during traffic monitoring, decision making and action planning for vessel collision events
Challenges	• Accuracy of vessel path prediction in short term time horizons • Accuracy of path planning and rerouting for collision event mitigation • Near real-time response of the system for collision event detection • Near real-time fusion of different stream inputs from local and global data sources • Quantification of prediction and solution uncertainty • Real time re-evaluation of vessel route after collision event detection and continuous monitoring of the involved vessels' routes • Small response time path planning methods for rerouting • Real-time extraction of extreme-scale situational data

Table 17: Hazardous weather rerouting high level scenario description

Attribute	Description
ID	Maritime_UC02
Name	Hazardous weather rerouting
Short description	Rerouting of vessels in order to avoid sea areas with forecasted hazardous weather conditions. Based on weather forecast updates vessels are monitored and alerted on changes of the weather conditions along their route and provided with rerouting instructions
Author	MT
Last update	09.06.2023
Actors	• Vessel pilot • Vessel crew • VTS operator • Ship deck officers
Additional Actors	• Vessels of different levels of autonomy

Attribute	Description
Actors interested in the outcomes	• Port/coastal authorities • Fleet managers • Vessel owners • Insurance companies
Detailed scenario	The crew of a vessel starts their journey and plan their route according to their initial weather forecast. As weather dynamically changes over the journey, the vessel crew receives hourly updates in case of weather conditions influencing the passage safety through specific sea areas. In case of changes affecting the safe passage, an alert with automatic rerouting suggestion is generated by the system alleviating the vessel crew from the task of continuously monitoring the weather conditions and updating the vessel route.
Benefits	• Route monitoring and rerouting according to updated weather forecasts for global vessel traffic, increasing safe navigation and efficiency of maritime operations. • Improved rerouting of the vessel traffic according to forecasted weather conditions through fusion of local and global data streams. • Automation of the weather monitoring during a vessel's journey • Safe navigation due to avoidance of hazardous weather areas. • Increased situational awareness and early identification of hazardous weather conditions that give operators time to plan an alternative route. • Informed decision making • Effective fleet intelligence and management based on future weather forecast at global scale • Vessel operators are alleviated from weather forecast monitoring tasks
Challenges	• Accuracy of rerouting as a function of weather forecast uncertainty • Reliability on longer vessel routes with duration exceeding the weather forecast time range • Fusion of different stream inputs from local and global data sources • Quantification of prediction and solution uncertainty

4.3.3 Available data

The following data sources will be collected during the annual Aegean Ro-Boat races organized by the University of the Aegean (UoA). Local environment data sources refer to sensors mounted on the UoA vessel. Additionally, the MT IoT-Voyage Data Streamer – VDS will be the only additional sensor mounted on both the UoA vessel and the RoBoat Race participating vessels during the races. Data from the RoBoat Race will be made available for batch processing to the CREXDATA partners after the end of the annual RoBoat Race (the partners could be in position to simulate the timeseries data in streaming mode, if applicable per dataset type). All the data sources listed here could be potentially used for the needs of the Maritime Use Case (see Section 9.3.2 in the appendix).

The following datasets (cf. [D1.2, Section 5.2]) are available on Zenodo. The open datasets consist of AIS related data and available for all partners to work on. Additional data will be generated and provided through the annual Aegean Ro-Boat Races organized by the University of Aegean that will be publicly released on Zenodo:

- Single Ground Based AIS Receiver Vessel Tracking Dataset: This dataset published by MT, contains all decoded messages collected within a 24h period (starting from 29/02/2020 10PM UTC) from a single receiver located near the port of Piraeus (Greece). All vessels' identifiers such as IMO and MMSI have been anonymized and no down-sampling procedure, filtering or cleaning has been applied.
- Heterogeneous Integrated Dataset for Maritime Intelligence, Surveillance, and Reconnaissance: This dataset contains ships' information collected through the Automatic Identification System, integrated with a set of complementary data having spatial and temporal dimensions aligned. The dataset contains four categories of data: Navigation data, vessel-oriented data, geographic data, and environmental data. It covers a time span of six months, from October 1st, 2015 to March 31st, 2016 and provides ships positions within the Celtic Sea, the Channel and Bay of Biscay (France). The dataset is proposed with predefined integration and querying principles for relational databases. These rely on the widespread and free relational database management system PostgreSQL, with the adjunction of the PostGIS extension, for the treatment of all spatial features proposed in the dataset.
- The Piraeus AIS Dataset for Large-scale Maritime Data Analytics: The AIS dataset (coming from MT's receiver) comes along with spatially and temporally correlated data about the vessels and the area of interest, including weather information. It covers a time span of over 2.5 years, from May 9th, 2017 to December 26th, 2019 and provides anonymized vessel positions within the wider area of the port of Piraeus (Greece), one of the busiest ports in Europe and worldwide. The dataset consists of over 244 million AIS records, an average of more than 10,000 records per hour, which makes it an ideal input for large-scale mobility data processing and analytics purposes.
- Hellenic Trench AIS Data: Data from Automatic Identification System (AIS) transmissions received from both satellite and terrestrial receivers of the Marine Traffic network (www.marinetraffic.com) for one year (31 July 2015 to 31 July 2016) along the Hellenic Trench, the core habitat of the eastern Mediterranean.

4.3.4 System Architecture for Demonstrator

Table 18: Demonstrator components extending the CREXDATA system (Maritime Use Case)

Component	Description
T2.4 – Simulation and Tools	• Creation of a synthetic dataset of simulated AIS data. • User interface development. The end-users of the user interface will be able to view the forecast motion of vessels in the future of each predicted route and potential mitigation actions • Simulation Framework: Integration of synthetic collision data with the VR interface. The architecture will give the capability to simulate/replicate a test scene using real historical and synthetic data. • Define paradigms for interactive exploration of the model behaviours using synthetic simulation data using VR
T3.2 Graphical Workflow Specification	• Integration of the maritime use case applications with the CREXDATA platform • Integration with the RapidMiner graphical workflow. Extension from INFORE with new operators: Fusion operator, forecasting operator and rerouting operator • Integration of existing RapidMiner operators from INFORE: Maritime Event Detector, Fusion • Development of new Kafka streams and related operators
T3.3 – System Integration and Released Software Stacks	• Development of software prototype
T4.1 Complex Event Forecasting	• MT/UoA will develop in-house models for route and collision forecasting • MT/UoA will develop an in-house solution for hazardous weather rerouting
T4.4 Optimized Distributed "Analytics as a Service"	• AKKA distributed tool to run fusion and route prediction models • Technical details and goals will be clarified at a later stage. Potential provision of AKKA performance analytics for resource optimization
T5.3 Visual Analytics for Decision Making under Uncertainty	• The pilot will support TUC for visual Analytics to facilitate decision making for the collision and weather rerouting under uncertainty • Technical details and goals will be clarified at a later stage.
T5.4 Augmented reality at the field	• The pilot will support TUC for an AR/VR prototype on the maritime use case • Technical details and goals will be clarified at a later stage.

Component	Description
T5.5 Uncertainty Visualization in Augmented Reality	• The pilot will support TUC for uncertainty visualization in augmented reality on the maritime use case • Technical details and goals will be clarified at a later stage.

Table 19: Uptake of technologies in the Maritime Use Case

Specific "use cases"	Collision Forecasting	Hazardous Weather Rerouting
T2.4 Simulation and Tools	X	X
T3.2 Graphical Workflow Specification	X	X
T4.1 Complex Event Forecasting	X[1]	X[1]
T4.2 Interactive Learning for Simulation Exploration		
T4.3 Federated Machine Learning		
T4.4 Optimized Distributed "Analytics as a Service"	X[2]	X[2]
T4.5 Text Mining for Event Extraction	Not relevant	Not relevant
T5.1 Explainable AI		
T5.2 Visual Analytics supporting XAI		
T5.3 Visual Analytics for Decision Making under Uncertainty	(X)[3]	
T5.4 Augmented reality at the field	(X)[3]	
T5.5 Uncertainty Visualization in Augmented Reality	(X)[3]	

[1] MT's models for route and collision prediction will be developed
[2] Akka distributed framework will be used to run fusion and route prediction models
[3] support of potential TUC contribution

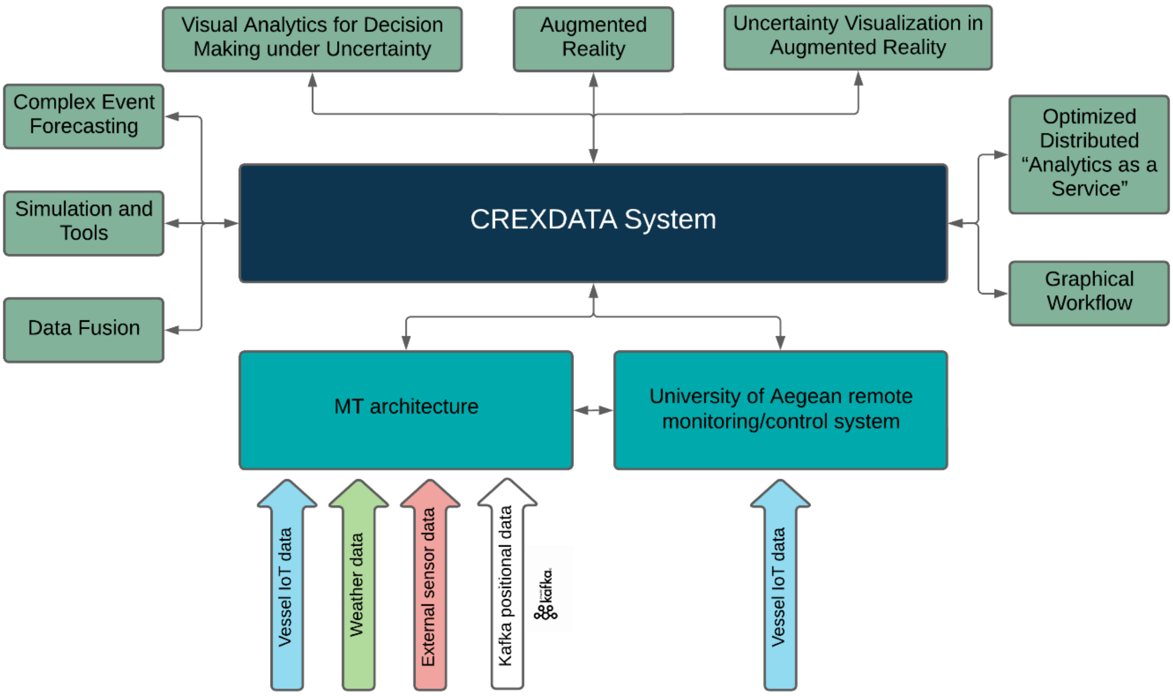

Figure 39: High level system architecture for the Maritime Use Case interlinked with the CREXDATA system and its components

Figure 40 presents the MarineTraffic system architecture supporting the deployment of the Maritime Use Case pilot.

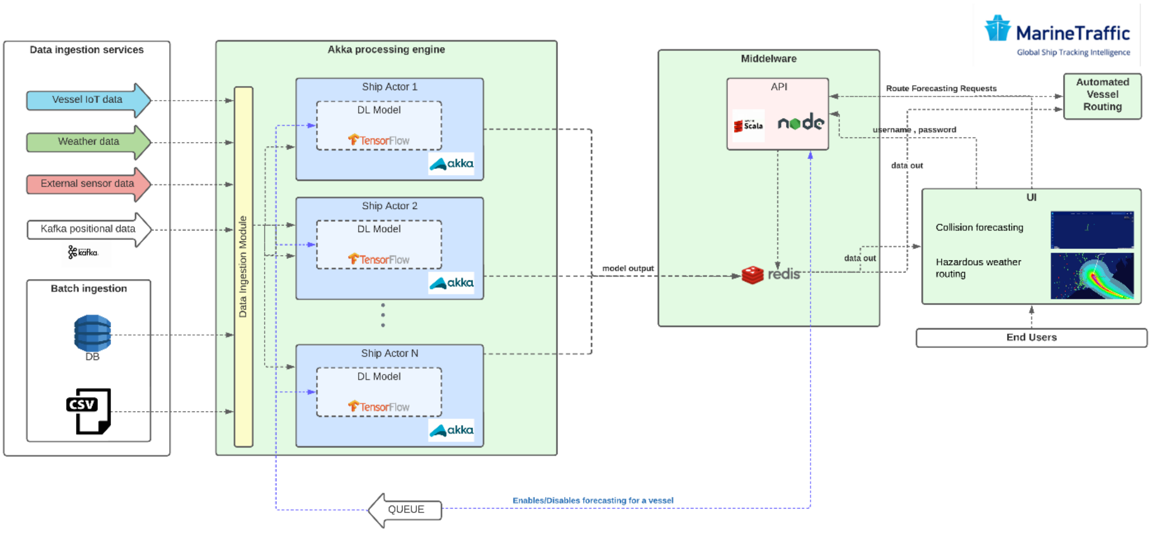

Figure 40: MarineTraffic system architecture for the Maritime Use Case

4.3.5 Stakeholder requirements

As part of D2.1, MarineTraffic conducted a user requirements survey alongside a workshop with selected representatives that have potential interests in the project's outcomes in order to quantify and assess the significance of the proposed services for hazardous maritime events for the maritime industry. The definition of the end-users' requirements relies on the design of two questionnaires, one for maritime users (port authorities, VTS operators, vessel pilots etc.) and one for data scientists. This approach aims to maximize the derived survey value, as questions were targeted and focused to both user categories. This in turn will lead to a greater response accuracy as questions remain domain relevant to the invited experts and aim to avoid the share of non-responses.

Additionally, it is possible to gain domain related insights and field related specifications as maritime users are able to set their requirements for the service operation and provide features more accurately than data scientists due to their field expertise, while they are ultimately the end-users of the proposed systems involved in the action planning and decision-making procedures. On the other hand, the Data Science survey provides significant insights for the technical design, methodology and system architecture of the CREXDATA data related services, which could be applied in the maritime domain. Appendix 4: Maritime Use Case: User Requirements Survey presents the questionnaires distributed to Data Scientists and Maritime Users in order to extract the user requirements for the Maritime Use Case.

The sample characteristics of the stakeholders (participants) responding to the user requirements questionnaires for Data Scientists and Maritime Users for the CREXDATA Maritime Use Case are presented in Table 20:

Table 20: Maritime Use Case User Requirements Survey. User characteristics

ID	User Questionnaire Type (Maritime-Data Science)	Type of organisation	Domain of expertise	Tasks
1	Data Science	Academia/Academic Research	Software engineering	Project management
2	Data Science	Academia/Academic Research	Machine learning, AI	Research, software development
3	Data Science	Academia/Academic Research	Machine learning, AI	Research, project management
4	Data Science	Industry	Vessel tracking/mobility	Big data analytics, knowledge extraction
5	Data Science	Industry	Machine learning, AI	Leading data science projects
6	Data Science	Industry	Machine learning, AI	Developing ML/AI techniques to tackle maritime intelligence problems
7	Data Science	Industry	Machine learning, AI	Predictive modelling, Data Analysis, Data Science
8	Data Science	Industry	Software engineering	Software development, Systems Engineering

ID	User Questionnaire Type (Maritime-Data Science)	Type of organisation	Domain of expertise	Tasks
101	Maritime	Academia/Academic Research	Software engineering	R&D
102	Maritime	Industry	Software engineering	Research and Innovation

The users' requirements survey defines the main requirements for the development of the collision forecasting and rerouting and the hazardous weather routing solutions that will be performed for all vessels of a fleet simultaneously (instead of on-demand requests per vessels) and that will rely on big data and AI technologies. With respect to the importance of forecasting the defined hazardous maritime events, maximum acceptable forecasting latency and the received information from the corresponding forecasting service, results for the respective requirement with the maximum number of consensus votes are presented in Table 21. Additionally, results related to the requirements of maritime users only for both services are also presented in case of multiple-choice selection with the same number of upvotes all respective features are considered.

Table 21: Maritime Use Case User Requirements

Requirement	Collision forecasting MAR_1	Hazardous weather routing MAR_2
service importance	very important	very important
maximum acceptable latency	minute latency	hour latency
provided information features to the end-users (Multiple choice selection)	• ETA to conflict point • prediction confidence • rerouting information with path suggestion	• ETA to destination port • prediction confidence • rerouting information with path suggestion
suggestions for possible courses of action	Yes	Yes
frequency of updating mitigation actions	Every minute	Every hour
data sources/ data sets for development	• real-time/Streaming AIS data • real-time/Streaming IoT vessel data • historical AIS data	• real-time/Streaming weather data • historical weather data
data sources/ data sets for evaluation	• Sea trial/experimental data	• Historical vessel data

In the context of facilitating informed decision making by the end-users during hazardous maritime event the Data Science User survey defines the respective requirements for the development of such services. In the context of the CREXDATA platform according to the respective questionnaire participants the development of such services should be based on specific data features that may be available through different data sources. Results are presented in Figure 41. Additional recommendations by the survey participants include the clear visualization of the range of plausible trajectories (short term) and the display of forecasts regarding the plausible area of adverse weather (long range).

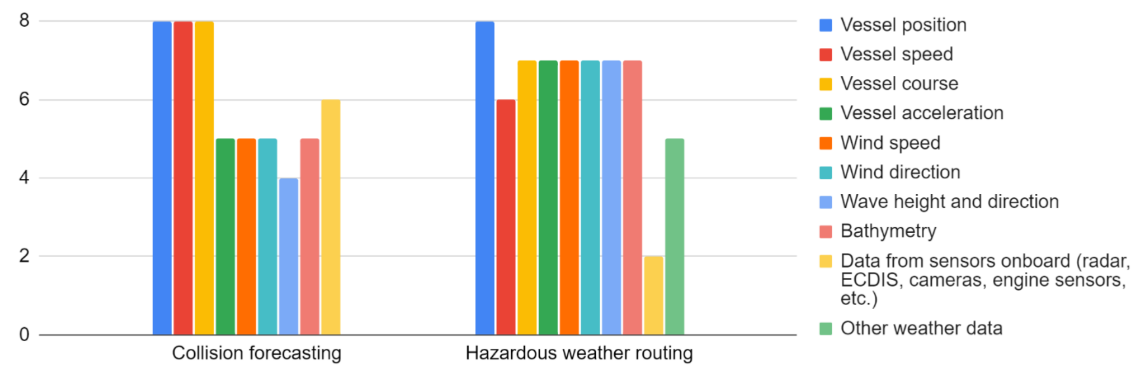

Figure 41: Information data features to be considered for the development of services for forecasting collision events among vessels and hazardous weather rerouting

According to Maritime users the following information features are relevant for informed decision making in the following maritime hazardous event scenarios (Figure 42).

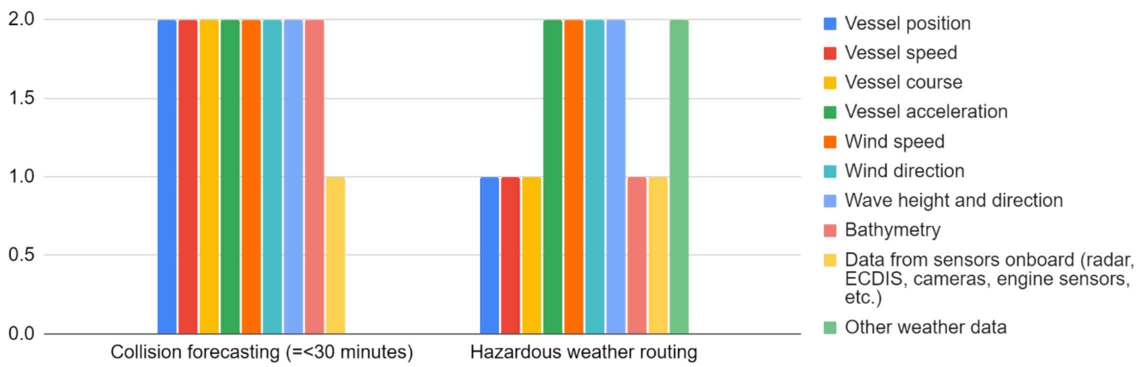

Figure 42: Information that will facilitate informed decision making for collision events among vessels and hazardous weather rerouting

Figure 43 and Figure 44 present the service quality and usability features rankings for the maritime collision forecasting service and the hazardous weather rerouting service respectively. Overall, users identify the prediction accuracy and the scalability as the most important aspects to consider during the development and deployment of both services.

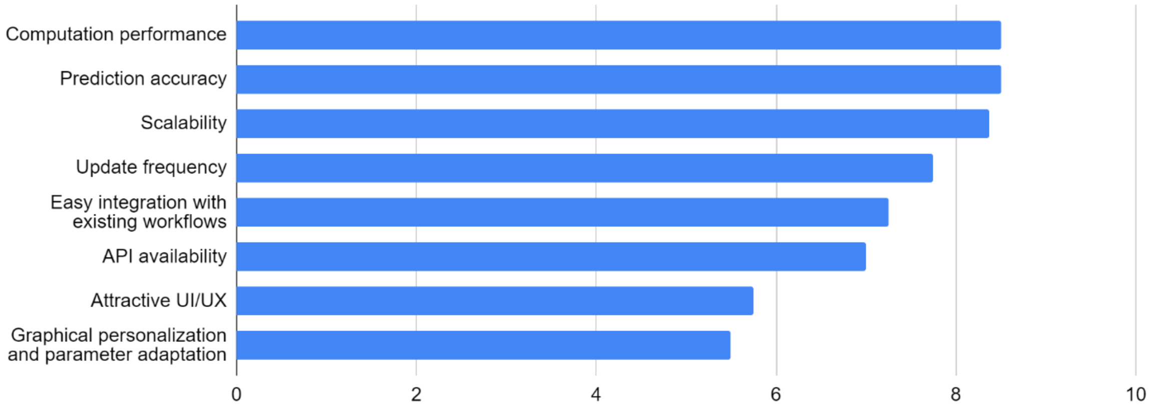

Figure 43: Service quality and usability features rankings for the maritime collision forecasting service

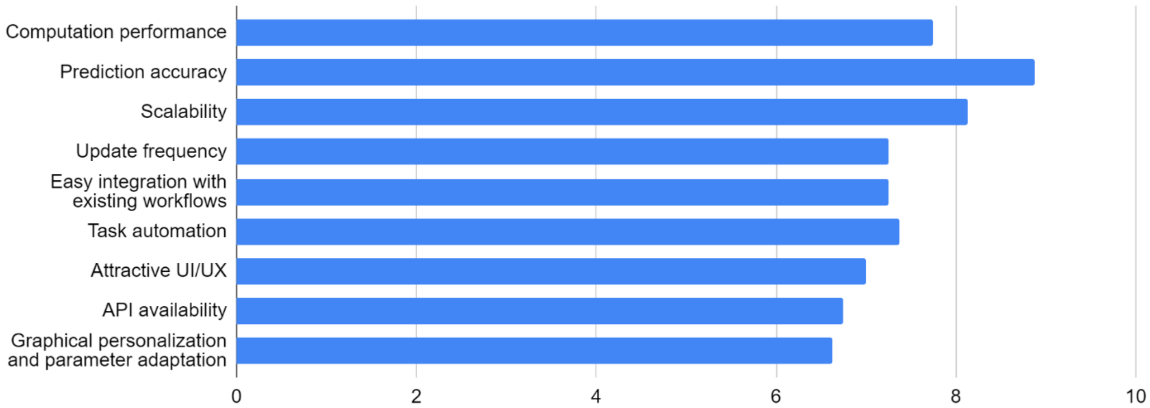

Figure 44: Service quality and usability features rankings for the maritime hazardous weather rerouting service

The derived requirements according to user requirements questionnaire following the standard list of attributes to specify requirements (compliant to SpecObject in ReqIF, SpecObjectRelations compliant to SysML), are found in Table 55 to Table 66 (Section 9.3.4 in the appendix):

4.3.6 Evaluation planning

The evaluation of the Marine Use Case Pilot will take place according to the respective CREXDATA milestones. MS2 on Month 16 indicates the completion of the initial version of CREXDATA' tools and integrated prototype. Milestone MS3 takes place two months later, i.e., on Month 18, marking the completion of the first evaluation of CREXDATA' tools and integrated prototype. Milestone MS4 takes place on Month 32, indicating the completion of the second version of CREXDATA' tools and integrated prototype, which will be made available to the use cases for the final use case evaluation and to the pilots and demonstrators of CREXDATA. The final milestone, i.e., MS5, takes place at Month 36, when the final evaluation will have been completed and its findings will have been addressed. Feedback from the pilots/demonstrators and the use case evaluation is incorporated into the tools from WPs3-5.

Table 22: Evaluation planning

Deliverables	Collision Forecasting	Hazardous Weather Rerouting	Evaluation
T2.4 Simulation and Tools	X	X	MS3[1] MS5 (final release)
T3.2 Graphical Workflow Specification	X	X	MS3[1] MS5[2]
T4.1 Complex Event Forecasting	X	X	MS3[1] MS5[2]
T4.5 Text Mining for Event Extraction	Not relevant	Not relevant	
T4.2 Interactive Learning for Simulation Exploration	X	X	MS5[2]
T4.3 Federated Machine Learning			
T4.4 Optimized Distributed "Analytics as a Service"	X	X	MS5[2]
T5.1 Explainable AI			
T5.2 Visual Analytics supporting XAI			
T5.3 Visual Analytics for Decision Making under Uncertainty	X		MS5[2]
T5.4 Augmented reality at the field	X[3]		MS5[2]
T5.5 Uncertainty Visualization in Augmented Reality	X[3]		MS5[2]

[1] first release
[2] final release
[3] support of TUC contribution

The evaluation framework for the CREXDATA Maritime Use Case considers both the technical specifications of the CREXDATA Maritime Use Case integrated services and the service offerings from the user's perspective. In addition, given the AI-oriented nature of the project and the fact that the pilot will rely on the deployment of data-driven models trained with machine learning techniques, the technical evaluation of the CREXDATA Maritime Use Case offering will cover aspects of trained model quality reported in a clear documentation (evaluation of the models will take place compared to state-of-the-art approaches).

The CREXDATA Maritime Use Case will be evaluated through test cases that comprise of sets of actions to be performed during pilot executions, with these actions being tailored so as to demonstrate how the CREXDATA maritime services satisfy the identified user requirements. Hence, the design of the CREXDATA maritime test cases is coupled with outcomes delivered from WP2 to WP4. The test cases will be aligned with the application scenarios (Section 4.3.2) and the user requirements that have been defined for the Maritime Use Case (Section 4.3.5). The initial test cases will provide a starting point for evaluation of the CREXDATA Maritime Use Case service offering that will be incrementally revised in the first release phase. Evaluation of the test cases will be tailored accordingly in each software release.

The development of the initial test cases will be based on the definition of simple examples of the respective relevant hazardous maritime events that are addressed as part of the CREXDATA project. These will provide insights to the value and usability of the envisaged features of automated rerouting for a) vessel collision mitigation and b) forecasted hazardous weather conditions that will be implemented as part of the CREXDATA Maritime Use Case services. The envisaged services will facilitate decision making through VR functionalities that will integrate relevant metrics (e.g. confidence intervals, probabilities, sensor inputs, statistics, etc.) for fusing decision making with visual analytics in a single user interface.

As part of the first software release the main models and solutions supporting the envisaged services will be developed. These include the models and solutions that will facilitate the fusion of different data stream inputs, the short-term vessel route prediction, the vessel collision forecasting, the vessel collision rerouting and the vessel weather rerouting. The work progress will be documented as part of the WPs 2-5. Subsequently after M18 the deployment of the envisaged services will commence. This includes also the development of the UI, supporting the AR solution of TUC and the finetuning of the service functionalities. The user requirements will be used as a reference for prioritizing evaluation criteria and elaborating on the test cases that will be employed in order to evaluate the relevant components in each release. Execution scenarios will delineate the details for realizing the test cases in the context of the Maritime Use Case and in the scope of the involved end-user parties. Relevant details will include the actors involved, the data sources required, the detailed piloting timeframe and evaluation indicators.

The evaluation of test cases will be based on the execution of scenarios that will be drawn in alignment with the user requirements that will be executed in the context of the pilot, and at each release version. For each test case the general steps outlined in Table 22 will be followed and reported in detail. The detailed definition of the specific test cases will take place before MS3 (first release phase) and results will be reported at MS5 (final release). Test cases will focus on both the evaluation and verification of the performance related KPIs for the developed systems of the developed cases as well as the evaluation of the developed services by end users.

Table 23: Test Case Steps

Test Case ID	
Release	*CREXDATA Maritime Use Case release version* *(Collision Forecasting/Hazardous Weather Rerouting)*
Test Case Description	*What feature is being tested / what function is being verified*
Test Case Actor	*Actor(s) taking part in the test case*
Test Environment	*The environment in which the test is being executed, including all relevant hardware and software components*
Test Case Preconditions	*Conditions to be met before test case execution, related to system, data, network etc.*
Test Data	*Variables and values relevant to the test case*
Test Case Steps	*Step 1*
	Step 2
	Step 3 …
Expected Result	*Result expected after the test case execution*
Actual Result	*Result obtained after the test case execution*
Status	*Pass, Fail, Blocked*
Defects Identified	*Defect ID:*
	Defect description:
	Severity:

5 Definition of success criteria and overarching KPIs

CREXDATA will yield a set of scientific, technological and societal outcomes. As the direct adopters of these outcomes, the project's use cases will demonstrate both with pilots and demonstrators how the previously identified tangible results contribute to exploiting extreme scale data and knowledge for extracting very precise prediction and multiresolution outcomes readily available, in an understandable form, to support critical decisions and action planning. The adoption in CREXDATA use cases demonstrates that tangible assets of the project are appropriate for integration and deployment in multidisciplinary and diverse scientific and industrial applications (health crisis management, weather emergencies, safe navigation in maritime domain). [DoA, part B, p.23]

The partners involved in each use case will expand the deployment and advance its TRL level towards production use. Moreover, they will try to attract additional customers in the specified markets, as well as to secure co-funding for the commercialization activity. [DoA, part B, p.30]

5.1 Project level success criteria and KPIs

There are several success criteria in the CREXDATA impact canvas that need to evaluated based on the application of technologies in specific use cases. Table 23 states a list of specific needs that are reflected in the application scenarios elicited in the three main use cases, operationalized in at least "4 pilots and 2 demos in operational environment". Target groups are stated as maritime professionals and authorities, public health authorities and civil protection authorities (also categorized as PPDR organisations) detailed by key stakeholder groups (see Section 16) and specific personas per use case.

Table 24: Impact Canvas [DoA, part B, p.31]

SPECIFIC NEEDS	EXPECTED RESULTS	D &E & C MEASURES
• Diminish time to create and deploy workflows. • Online learning & forecasting of business events. • Multiresolution forecasts on critical events. • Optimally configured infrastructure usage. • Truthful simulation models and data. • Safe vessel navigation at sea. • Proactive health crisis management/outbreak control & Non-pharmaceutical Intervention. • Limited impact & reduced recovery time/costs after weather induced events. • Rapid failure localization and classification. • Reduced equipment administration for target sectors. • Optimal usage of computing infrastructure.	• 10 concrete Exploitable, Tangible Assets: ([R1-R10] in Table 2). • CREXDATA Open-source Integrated Architecture & Repository ([R11] in Table 2). • Intangible assets (Table 2). • 2 lab-scale demos at dissemination events. • 4 pilots & 2 demos in operational environment in use cases. • Algorithmic models used in exploitable assets. >25 publications in top-tier journals and conferences. • 5 PhD/Master Theses.	**Exploitation:** Open-sourcing generic architecture and exploitable assets. Sell customization, consulting, KnowHow, patenting enhanced versions of software. Clear IPR and Commercial/Non-commercial use specifications. **Dissemination towards the scientific community and people working in R&D departments of authorities**: Top-tier Data Management, AI, Machine Learning, visual analytics, augmented reality, IoT conferences and conferences focused on use cases and other target exploitation groups (Smart Cities/ Factories/Grids – see Table 3). Organization of 1 scientific workshop. **Dissemination towards Service & Technology Providers, Adopters and Potential End Users**: Organization of 2 industrial workshops. Participation in 2 fairs; exhibition at 2 events, use of well-established dissemination channels of consortium members. Cooperation with 2-6 ongoing/future EU projects. **Communication towards citizens:** Web site, open EU repositories, Web 2.0 channels, social medial means. Clear KPIs per means (Section 2.2.2).
TARGET GROUPS	**OUTCOMES**	**IMPACTS**
Maritime Professionals and Authorities **Public Health Authorities** and Regulatory Bodies **Civil Protection Authorities** and Regulatory Bodies **Municipality Authorities, First Responders end users**: European and national. **European Smart Grid Providers.** **European Smart Factories.** **European Smart Cities.** **Scientific community** (AI, ML IoT, Data Management). **Extreme-scale Analytics-as-a-Service providers**, start-ups and users.	**Up-take by FDDO, DCNA, MoIFI, DRZ** in production **MT, FMI, BSC** to enhance by 15-30% the services & insights provided to authorities/professionals, **Up-take by HYDS** in >50% of weather scenarios **1 major Smart Grid provider** A/B tests ***CREXDATA*** or assets of it. **1-3 Smart Cities** (Dortmund, Chania, Barcelona) **exploit(s)/ use(s)** ***CREXDATA*** in their architecture. **1 Smart Factory** A/B tests ***CREXDATA*** or assets of it.	**Scientific:** • Generic data ingestion/fusion/simulation frameworks for relevant tasks. • Generic online federated learning, analytics optimization techniques. • Multiresolution forecasting suite of algorithms. • XAI methods under uncertainty. • XAI-aware advanced visual analytics at a glance. • Groundbreaking Augmented Reality capabilities. **Economic:** • Time-to-production reduction: 10x reduced workflow deployment time. • Reduced disaster & recovery costs: see Operational capacity below • Reduced administrative costs: 2-10x energy/communication reduction • Operational capacity: 10x train/inference speed, Forecast >5 critical business events 60 to 15min ahead of time • Across the above: >75 to 95% accuracy. • Support Open Innovation, Strengthen role of EU authorities/ SMEs. **Societal- Environmental:** • Supporting the Green Deal Strategy. • Limit societal impact of natural disasters & increase trust to authorities

WP2 is responsible for the outcome of up-take in production, i. e., in realistic use environments of target groups. Based on these target groups, an extension is envisaged towards other domains. As an example, UPB will take initiative to draw conclusions on robotic use cases with regard to applications in European Smart Factories.

Specific impacts that are expected are stated to be:

- Time-to-production reduction: 10x reduced workflow deployment time
- Reduced disaster & recovery costs
- Reduced administrative costs: 2-10x energy/communication reduction
- Extended operational capacity, based on forecasting capacities

Based on such impacts, conclusions shall be drawn with regard to support for the Green Deal strategy and limited societal impact of natural disasters and increase trust to authorities.

5.2 Mapping of Use Case level success criteria and KPIs

These high-level objectives are transferred to specific success criteria in each of the three use cases.

In the weather emergency case, the impact evaluation is enabled by a correlation of injected incident data and observed behavior of test personnel, captured by mobile observatory labs. KPIs are [DoA, p.8]:

a) 80% accuracy in critical event prediction in test bed scenarios,
b) System Usability Score (SUS) of interactive exploration tools for XAI above average,
c) SUS score of uncertainty visualization (in AR and control center) above average,
d) observable impact of system's output to action-planning in 90% of injections,
e) even under perceived risk, users follow system's advice in 80% of situations.

In the health case, the following KPIs will be achieved [DoA, p.8]:

a) Forecasting 7 parameter sets that reduce the COVID infection;
b) Use the runtime adaptation of simulation trajectories to improve the outcomes of 5 scenarios or patients;
c) Calibration of the epidemiological parameter to fit incidence time series;
d) Characterizing the space of parameters with 50% fewer simulations.

In the maritime case, the following KPIs need to be achieved [DoA, p.8]:

a) At least 80% accuracy in route forecasting/weather routing;
b) At least 80% accuracy in hazardous event detection/forecasting (e.g, grounding, collision);
c) Sub-second latency in route forecasting/weather routing and event detection/ forecasting over streaming data;
d) Forecast of maritime hazardous events 15 minutes before happening. The pilot will be validated in a sea trial experiment.

Application scenarios and use case narratives stated in Section 4 and related Sections in the appendix are preparative means to research on the actual fulfillment of these objectives. They are used as a basis for consistent stories in both requirements elicitation and evaluation.

6 Acronyms and Abbreviations

Each term should be bulleted with a definition.

Below is an initial list that should be adapted to the given deliverable.

- AI – Artificial intelligence
- AIS – Automatic Identification System
- API – Application Programming Interface
- AR – Augmented Reality
- ATF – Analytical Task Force
- C2 – Command & Control
- CA – Consortium Agreement
- CEF – Complex Event Forecasting
- CER – Complex Event Recognition
- CEP – Complex Event Processing
- D – deliverable
- DoA – Description of Action (Annex 1 of the Grant Agreement)
- DQ – Data Quality
- DWD – Deutscher Wetterdienst (German weather service)
- EB – Executive Board
- EC – European Commission
- ECC – Emergency Control Center
- ECMWF –European Centre for Medium-Range Weather Forecasts
- EFAS – European Flood Awareness System
- EFFIS – European Forest Fire Information System
- EDO – European Drought Observatory
- EMSA – European Maritime Safety Agency
- ERCC – Emergency Response Coordination Centre
- EMS – Emergency Management System (Copernicus)
- ETA – Estimated Time of Arrival
- EUCPM – European Union Civil Protection Mechanism
- GA – General Assembly / Grant Agreement
- GDPR – General Data Protection Regulation
- GPS – Global Positioning System
- GUI – Graphical User Interface
- HMD – Head-Mounted Display
- HMI – Human Machine Interface
- HPC – High Performance Computing
- HRES – High-Resolution Forecast
- ICU – Inertial Control Unit
- ID – (unique) identifier
- IDE – Integrated Development Environment
- IMO – International Maritime Organization
- IoT – Internet-of-Things
- IPR – Intellectual Property Right
- IQ – Information Quality
- IT – Information Technology
- KPI – Key Performance Indicator
- M – Month

- ML – Machine Learning
- MMSI – Maritime Mobile Service Identity
- MoSCoW – Must have, Should have, Could have, Won't have
- MS – Milestone
- NIST – National Institute of Standards and Technology (US)
- NLP – Natural Language Processing
- NPI – Non-Pharmaceutical Interventions
- PaaS – Prediction-as-a-Service
- PM – Person month / Project manager
- PPDR – Public Protection and Disaster Relief
- ReqIF – Requirements Interchange Format
- RobLW – Command car of a special robotic emergency response unit
- ROS – Robot Operating System
- RTF – Robotic Task Force
- Rviz – ROS Visualizer
- SEIR – Susceptible-Exposed-Infectious-Recovered
- SysML – Systems Modelling Language
- TRL – Technology Readiness Level
- UAV – Unmanned Aerial Vehicle
- UC – Use Case
- UGV – Unmanned Ground Vehicle
- UI – User Interface
- UML – Unified Modelling Language
- URL / URI – Uniform Resource Locator / Identifier
- UV – Unmanned Vehicle
- VDS – Voyage Data Streamer
- VTS – Vessel Traffic Service
- VR – Virtual Reality
- WebODM – Web Open Drone Map
- WMS – Web Map Service
- WP – Work Package
- WPL – Work Package Leader
- XAI – eXplainable Artificial Intelligence

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8 Appendix 1: References for research data handling

- Raw data
    - Video streams from stationary or mobile video cameras
    - Screen capturing from UIs
    - Audio streams
    - Logs of observers, interviewers, and loggers
    - Logs of IT systems and components
- Interview and workshop logs using coding schemes
    - Objective data (participants, surroundings, …)
    - Subjective data (assertions by interviewees and participants
        - Coding based on coding scheme (e. g., derived from success criteria and KPIs; cf. behaviours in the Noldus system)
        - Themes and sub-themes (derived by analysis of coding results)
    - Interpretation
- Noldus The Observer XT / Viso coding schemes (UPB)
    - Subjects (esp. observed persons)
    - Behaviours (observed behaviours with time duration and point events)
    - Modifiers (to further specify behaviours)
- Robot localization system (DRZ)
    - Traces of robots (resp. sensors) and other marked resources

9 Appendix 2: Application sub-scenarios

The term “use case narratives” is understood as a synonym in this context.

9.1 Emergency case: Application sub-scenarios

9.1.1 Personas

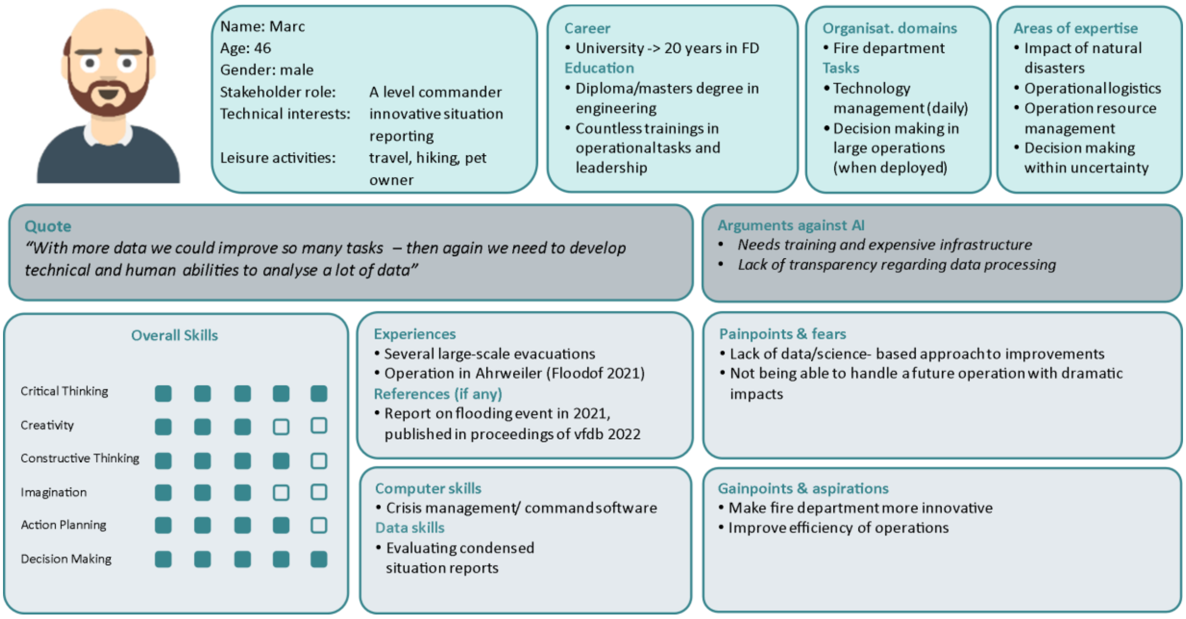


Figure 45: Persona “A level commander” (might be deployed as C2 staff member)

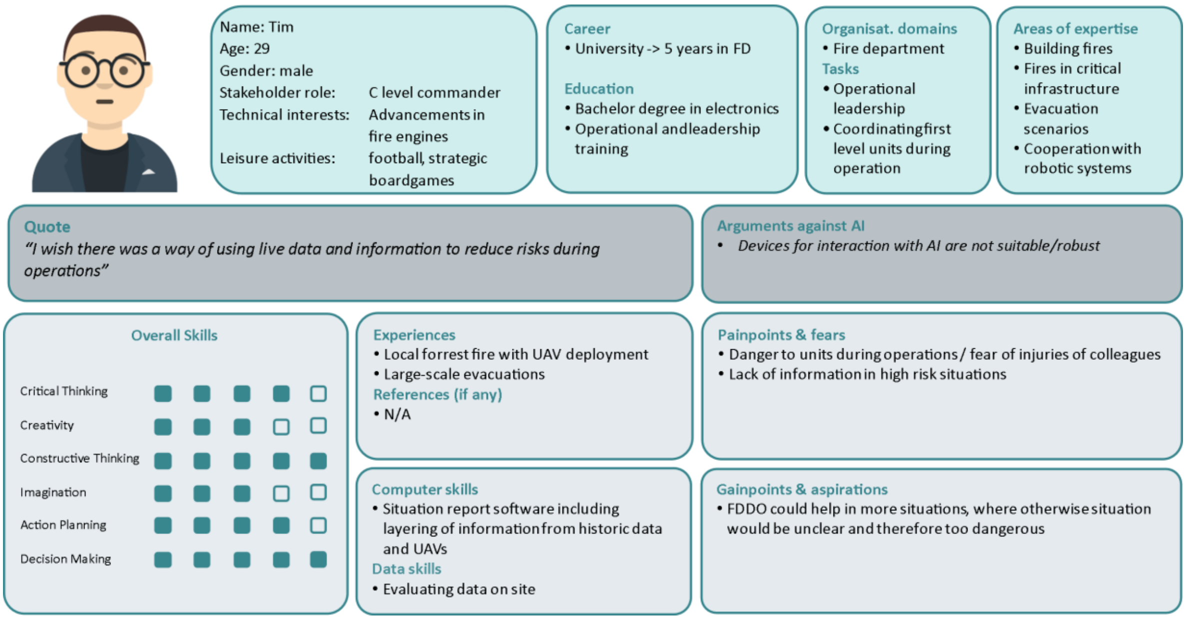


Figure 46: Persona "C level commander" (might be deployed as C2 staff member)

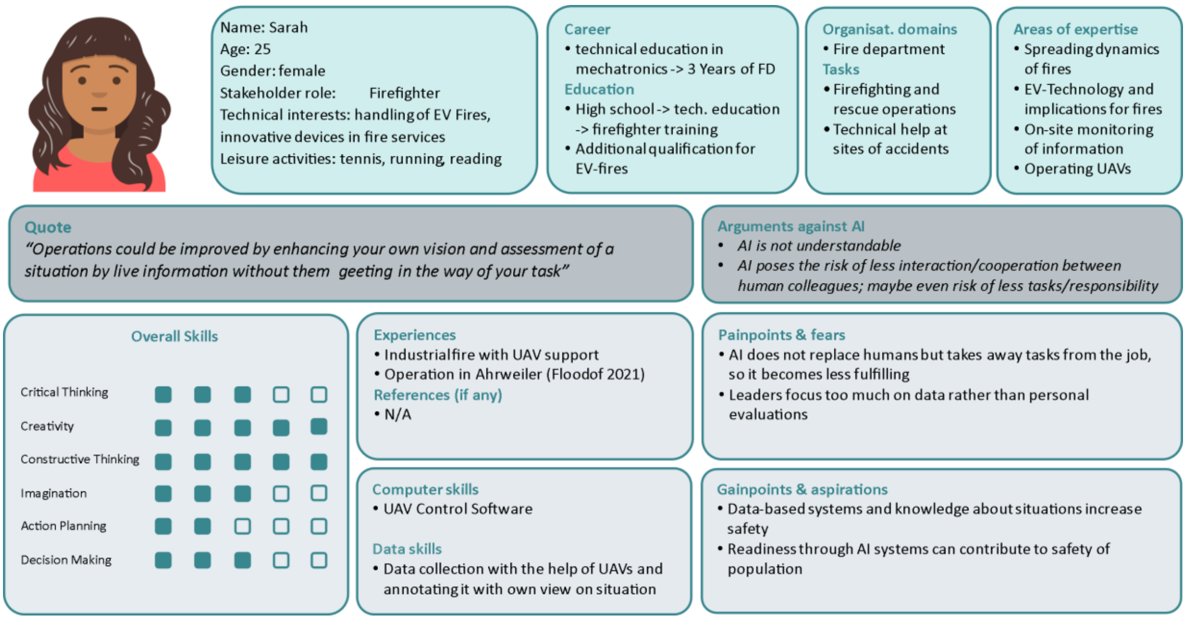


Figure 47: Persona "first responder"

9.1.2 Initial workflow descriptions (generic use case narratives / sub-scenarios)

Generic use case narratives resp. application sub-scenarios are motivated by generic workflows or situations that occur in several types emergencies more or less often. These scenarios are incorporated in more specific ones (see Section 9.1.3). Initially they are motivated by the WP3 perspective on workflows and data processing pipelines in demonstrator system elements like ARGOS and robotics sub-systems.

Table 25: Use case narrative: data source to ARGOS workflow

Attribute	Description
ID	Emergency_UC_01
Name	data source to ARGOS workflow
Short description	generic workflow from data source through data processing to visualization in the ARGOS client (web browser)
Author	Jens Pottebaum (UPB)
Last update	2023/06/27
Scope	• RapidMiner operators • Prediction-as-a-Service
Actors	• Task Force expert (ICT) • C^2 staff member
Pre-conditions	• data source connected in the ARGOS backend • license available and installed
Assumptions	
Trigger	• activation of corresponding layer in the ARGOS client • access to functionality (e. g., impact assessment algorithm) that requires data from data source

Detailed scenario	• ARGOS UI is opened in web browser
	• option 1: data from dedicated data service (e. g., rain forecast)
	  ○ activation of corresponding layer in UI
	  ○ request to ARGOS cloud server to provide data
	  ○ data pull from ARGOS cloud database
	  ○ data provision from cloud server to client
	  ○ visualize data
	• option 2: impact prediction
	  ○ activation of impact assessment functionality in UI
	  ○ setting input parameters (like area of interest, object/ point of interest, probability interval, …)
	  ○ push parameter values to algorithm (provided as a service in the ARGOS cloud)
	  ○ predict impact (run algorithm), if necessary request to ARGOS cloud server to provide data with data pull from ARGOS cloud database

Attribute	Description
	○ label and format assessment results (e. g., rasterized image to be displayed as a layer on top of maps) ○ data provision from cloud server to client ○ visualize data • continuously in the background: buffering data from data services like Copernicus, ECMWF etc.
Post-condition	Requested data is visualized in the ARGOS client UI.
Related information	see ARGOS documentation
Test settings	The scenario will be included in field trials as a backbone of fundamental work in terms of situational awareness. Task Force experts configure workflows using the graphical workflow designer in operations or mostly in preparedness phases, C2 staff member might modify and/or configure them in an operation. Test settings can be established in lab infrastructures (DRZ, UPB) and in the actual A level staff room of FDDO.

Table 26: Use case narrative: robotic sensor to RobLW analysis workflow

Attribute	Description
ID	Emergency_UC_02
Name	generic workflow from robotic sensor to RobLW analysis software
Short description	Short description, e.g., referring to the generic application scenario, related weather phenomena or hinting at used system
Author	Ivana Kruijff (DRZ)
Last update	2023/06/27
Scope	• RapidMiner operators • Prediction-as-a-Service
Actors	• A level commander • C level commander • First Responder (robot operator)
Pre-conditions	Flooding is predicted for a certain urbanized area, the robotic units are dispatched to the scene, sensors are equipped, robots are ready to be deployed; communication network is up
Assumptions	
Trigger	order is given from commander to robot operator
Detailed scenario	1. Drone flies through a designated area and collects imagery for 3D models, manually controlled by a robot operator

Attribute	Description
	2. images/video stream are sent through the communication network to the RobLW 3. Image analysis software segments buildings and detects building openings, i. e., doors and windows; additional software measures the distance of the lower edge of each opening from the ground 4. Prediction software (TBD) predicts the expected flood levels and the flooding risk for each building 5. results are sent to a client UI (within the RobLW, or another command post of higher level) 6. The results are visualized.
Post-condition	Prediction of flooding exists for each building visualized in client UI.
Related information	For the underlying workflow, see presentations like "Kombinierter Drohneneinsatz und digitale Lagemodelle" (EN: „Combined drone deployment and digital maps for situational awareness"), URL https://www.youtube.com/watch?v=x9Ifo3ZTCy8, access 27.06.2023
Test settings	The scenario will be included in field trials as a backbone of fundamental work in terms of situational awareness. Task Force experts configure workflows using the graphical workflow designer in operations or mostly in preparedness phases, C2 staff member might modify and/or configure them in an operation. Test settings can be established in lab infrastructures (DRZ, UPB) and in the actual A level staff room of FDDO.

Table 27: Use case narrative: robotics to ARGOS workflow

Attribute	Description
ID	Emergency_UC_03
Name	robotics to ARGOS workflow
Short description	generic workflow for data fusion from Satellite data/forecasts and robotic sensor systems
Author	Michael Hieb, Jens Pottebaum (UPB)
Last update	2023/06/27
Scope	• RapidMiner operators • Prediction-as-a-Service
Actors	• A level commander • C level commander • First Responder (robot operator)
Pre-conditions	see Em_UC_01 and Em_UC_02

<table>
<tr><th>Attribute</th><th>Description</th></tr>
<tr><td>Assumptions</td><td>see Em_UC_01 and Em_UC_02</td></tr>
<tr><td>Trigger</td><td>order is given from commander to robot operator</td></tr>
<tr><td>Detailed scenario</td><td>

Generic workflow to visualize the position of robots on the map in the ARGOS UI (see figure), from robot through operator interface system to ARGOS cloud and UI:

- Request to grant API key
- Provision of access token
- Send position
- Map data
- Send to client
- Visualize

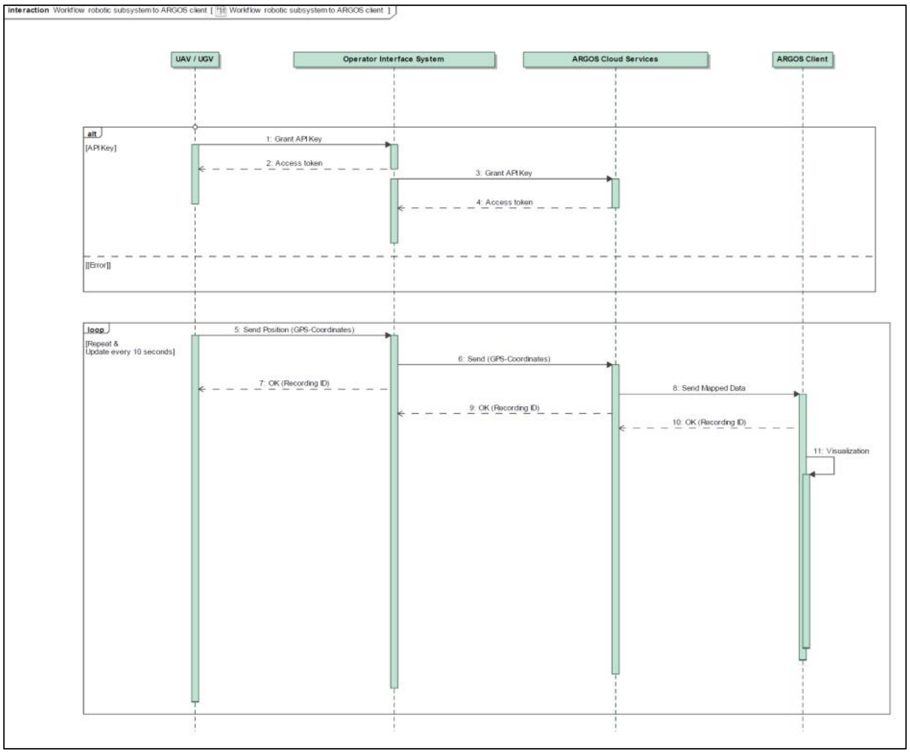


Figure 48: Sequence diagram for robotics to ARGOS workflow

Prediction based on robot sensor data and weather data

- activation of impact assessment functionality in UI
- setting input parameters (like area of interest, object/ point of interest, probability interval, …)
- push parameter values to algorithm (provided as a service in the ARGOS cloud)
- send order to robot operator to acquire specific imagery
- Drone flies through a designated area and collects imagery for 3D models, manually controlled by a robot operator

</td></tr>
</table>

Attribute	Description
	• images/video stream are sent through the communication network to the RobLW • Image analysis software segments buildings and detects building openings, i. e., doors and windows; additional software measures the distance of the lower edge of each opening from the ground • predict impact (run algorithm) based on RobLW data and data pull from ARGOS cloud database • label and format assessment results (e. g., rasterized image to be displayed as a layer on top of maps) • data provision from cloud server to client • visualize data
Post-condition	Requested data is visualized in the ARGOS client UI.
Related information	see Em_UC_01 and Em_UC_02
Test settings	The scenario will be included in field trials as a backbone of fundamental work in terms of situational awareness. Task Force experts configure workflows using the graphical workflow designer in operations or mostly in preparedness phases, C2 staff member might modify and/or configure them in an operation. Test settings can be established in lab infrastructures (DRZ, UPB) and in the actual A level staff room of FDDO.

9.1.3 Technology-focused use case narratives / sub-scenarios

More specific use case narratives are stated with a view on technologies developed in WP4-WP5, facilitated by established demonstrator system components resp. types of such components. These were elaborated with stakeholders of FDDO, supported by experts of DRZ, DCNA and UPB. Narratives are structured according to their primary focus. IDs show these categorisations:

- 1x: information management
- 2x: utilization of robotic systems
- 3x: utilization of weather information systems
- 4x: utilization of simulation models
- 5x: utilization of Augmented Reality (AR)

Table 28: Use case narrative: Controlling of premises

Attribute	Description
ID	Emergency_UC_10
Name	Controlling of premises
Short description	Controlling of premises is essential to a) prove that action plans are appropriate or b) recognize that plans have to be modified. The comparison of forecasted, nowcasted and actual situations enables decisions under situational awareness. The use case subsumes acquiring information, comparing actual and intended situation, revisiting action plans and taking decisions to a) keep or b) modify action plans. As an example, action planners might decide to prepare for a flooding with 50yr return period due to rain forecasts. This premise is decisive for resources that are deployed and actions that are activated. As soon as there is a probability that the actual flooding will exceed or exceeds this premise, actions need to be revised.
Author	Jens Pottebaum (UPB)
Last update	2023/06/06
Scope	• RapidMiner operators • CER and CEF • Visual Analytics
Actors	commanders (crisis, A level, C level), C2 staff members
Pre-conditions	action plan defined, actions initiated, situation evolved
Assumptions	In an emergency, there is never complete information. So rational decision-making is not possible. Action plans are selected resp. created based on premises from reconnaissance (situational awareness) and assumptions. Often, action planning is even based on past events and the experience of the emergency personnel. In Innsbruck, for example, there is no formal survey of “critical” infrastructure. Where critical infrastructure is and when and how it is evacuated is based on experience on the fire brigade personnel. The UC is relevant on all levels of command, with respective scopes. On higher command levels, activities might be performed by staff members.
Trigger	situational status meeting

Detailed scenario	• Presentation of forecast: heavy rain (100y return period) anticipated in 8 hours
	• Acquisition of
	  ○ “simulated" situation from preparation phase (cf. Figure 30), with mean precipitation across the entire city of DO
	  ○ action plan prepared for such a situation, including activation of command staff, positioning of units/engines,

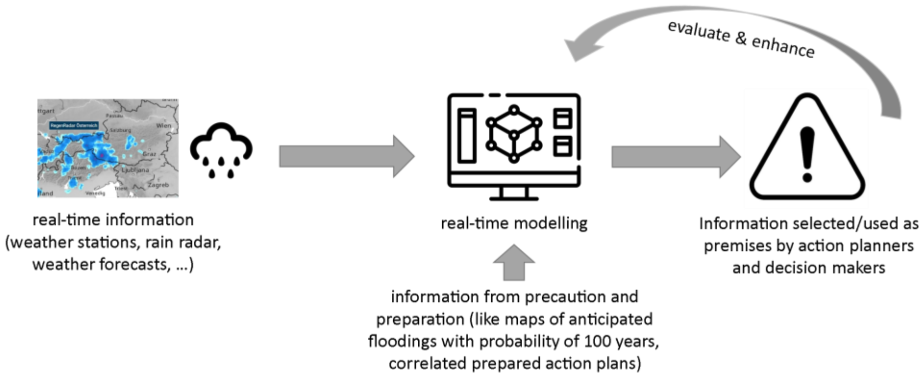
Attribute	Description
	dedicated dispatchers in control center, alarming of voluntary forces to staff stations • Communicate orders • Persons take over operational (command) roles • Units/engines move to operational positions • Early status meetings are conducted, observing updated satellite data, forecasts and impact assessments • Actual rain is detected in Bochum (west of DO) • Situation in Bochum confirms forecasts • Actual rain is detected in western parts of DO • Rain in Bochum exceeds forecasts • …  **Figure 49: Use case "Controlling of premises"**
Post-condition	Confirmed or modified action plans, ready to be deployed/communicated
Related information	UC is relevant in preparation and conduction of status meeting. These are typically conducted on a regular basis. Frequency might vary from lower frequency in preparative phases (e.g., when an extreme weather is anticipated through early forecasts) to higher frequency of about 30 min in response phase. As an example, in the flooding event 2021 in Western Germany there was a significant problem because commanders assumed 200yr return period, but reality exceeded this premise.
Test settings	The UC will be included in field trials. Test settings can be setup by configuring command posts (like RobLW, staff room of FDDO, similar room setup in UPB lab environment).

Table 29: Use case narrative: Quality ranking of information

Attribute	Description
ID	Emergency_UC_11
Name	Quality ranking of information
Short description	Decision Support by Quality ranking of information that could be made available resp. that could be acquired by technical or organisational measures (e.g., data for 100, 200 oder 500y return period?)
Author	Jens Pottebaum (UPB)
Last update	2023/06/11
Scope	• RapidMiner operators • XAI • Visual Analytics • AR
Actors	• Action planners (gathering, processing and analysing information) • Decision makers (interpreting and evaluating aggregated information) • C2 staff members (handling specific types of information)
Pre-conditions	Information is available to be visualized, based on data streams as inputs to data processing pipelines
Assumptions	Ranking of information according to its quality requires an established model of data quality (DQ) and/or information quality (IQ) [26, 27]. DQ and IQ are mixed up in many publications. Sometimes, terms like data or information maturity are used. As this use case refers to the interpretation of data in terms of information (including semantics), both DQ and IQ are relevant here.
Trigger	• Critical event that requires immediate action • Scheduled briefing of commanders (e.g., in staff environment), leading to decisions on actions to be communicated to sub-ordinated units
Detailed scenario	• forecasting on different time scales (maybe even acc. to relevancy on different command levels) • Metrics for DQ/IQ can be specified by users in command centres or command vehicles in the field to map the criteria to their specific temporal and local situation • Characteristics which typically increase the quality for decision makers of FDDO are timeliness as well as closeness • Top ranked information should be the one, which is closest to what the decision maker would see, if they had perfect vision of the event of interest

Attribute	Description
	• An automated process of ranking information should allow decision makers to open an “expand” or “information” UI-feature which enables them to retrace the systems’ evaluation or look at original data sources • Filter functions allow different levels of command to select specific information, which they want to be included in the ranking. Similar to the criteria of quality, the time of creation/reach of forecast, location of unit and type of source/sensor are useful categories.
Post-condition	Visualization of information, visually ranked by DQ/IQ dimensions, criteria and/or indicators
Related information	Briefings are often scheduled on a regular basis like, e. g., every 30 min. The frequency depends on command levels and course of an emergency situation.
Test settings	The use case can be incorporated in every setting that includes interpretation of information. Specific settings can be setup for, e.g., usability evaluation in lab environments.

Table 30: Use case narrative: directed data acquisition

Attribute	Description
ID	Emergency_UC_12
Name	Guided data acquisition
Short description	Reconnaissance is an essential and initial phase of the command and control procedures within the domain of PPDR. There are tactical procedures to gather information and, thus, acquire situational awareness. For instance, people are asked for observations, measurements are performed to estimate hazards in the air, or drones are deployed to get imagery from the air. When using CREXDATA services like interactive learning, it might be relevant to guide data acquisition not only with regard to PPDR tactics, but also with regard to the data gaps causing uncertainty in predictions. This use case encapsulates scenarios regarding guidance of data acquisition, especially through robotic sensor systems.
Author	Jens Pottebaum (UPB)
Last update	2023/06/27
Scope	• RapidMiner operators • CER/CEF • Interactive learning for simulation exploration (?) • ML (?) • Uncertainty visualization

Attribute	Description
Actors	• Crisis manager • A Level commander • C level commander • C^2 staff members (handling specific types of information)
Pre-conditions	As an input, predictions/decisions and situational data like, e. g., detect openings (cellars, …) are available.
Assumptions	Both real and virtual environments are considered.
Trigger	Data gap indicated (e. g., through low DQ/IQ in available data)

Detailed scenario	• selection of robot with corresponding sensor systems
	• deployment of robot in real environment, collection of data
	• streaming of data into CREXDATA system, available for technologies and the ARGOS system
	• recognition of data gaps
	• Branching scenario: Virtual data acquisition (Gazebo)
	  ▪ Activation of Gazebo, loading of environment through ARGOS configuration (data of active operation) and robot GPS data
	  ▪ Representation of real robot in virtual environment
	  ▪ Integration of data from operation and weather information (e. g., flooding or wind direction/strength)
	  ▪ Experimenting with routes and sensor configurations in virtual environment; if relevant, activation of virtual objects (like debris elements in water)
	  ▪ Data stream from sensors (stimulated by Gazebo) to CREXDATA system
	• Branching scenario: Real-world data acquisition
	  ▪ Routing for deployed robot; if relevant, configuration of swarm intelligence
	  ▪ Operating robots in the real environment
	  ▪ Data stream from sensors (real) to CREXDATA system
	• Visualization of data

Post-condition	potentially enhanced DQ/IQ in visualized data
Related information	
Test settings	The scenario will be included in field trials. Actors from high-level command to robot operators are involved. Test settings are established in lab infrastructures (DRZ, UPB) and in the actual A level staff room of FDDO. At DRZ, bot indoor and outdoor settings are created to test with environments of different scales in

Attribute	Description
	reproducible settings. Gazebo is setup at UPB, available at DRZ through cloud service. Indoor lanes are mirrored from DRZ to UPB.

Table 31: Use case narrative: social media based indications from incident site

Attribute	Description
ID	Emergency_UC_13
Name	social media based indications from incident site
Short description	Social media is used as a type of "sensor" (data source) for • providing additional/complementary information • verifying/validating other data (sources)
Author	Jens Pottebaum (UPB)
Last update	2023/05/04
Scope	• RapidMiner operators • CER/CEF • Text Mining • Visual Analytics • Uncertainty visualization
Actors	• Action planners (gathering, processing and analysing information) • Decision makers (interpreting and evaluating aggregated information) • C2 staff members (handling specific types of information)
Pre-conditions	A large-scale emergency is currently affecting a significant number of people. Within this group are several individuals who tweet about the incident and/or take pictures or videos and upload them. Also, the situation has to be relevant but to a certain extend unclear in the control centre, thus staff there are looking for additional information like social media.
Assumptions	
Trigger	• Hashtags concerning the incident of interest are trending locally and indicate the availability of relevant information • Social media accounts of emergency services are tagged in content generated by the population • There is demand within the control centre for additional information either from closer to the incident or from more sources than emergency services can deploy at once

Attribute	Description
Detailed scenario	Provide links to get a visual insight to what the actual situation looks like in the field (used in higher command levels). As a prerequisite, relevant postings need to be identified based on DQ/IQ indications. Entities need to be extracted by text analysis (event types, objects/object types, place names, …) • rankings, … → indicate postings to present relevant media (photos, video) • annotations → more intelligent search, input to event processing, …
Post-condition	Insightful media is presented at a command post (e. g., in a regular briefing in the A level staff room)
Related information	For later application scenarios on forest fires [28], detection of trigger events causing fire is envisaged. A fire department would send units (or drones) to that position to verify information. Additionally, data input for fire simulation could be derived. Intended social network is twitter (most relevant for real-time event recognition, available functionality in RapidMiner products). Candidates are facebook, Youtube and TikTok. Data might include geo-locations (needs to be switched on by users, either attached to profile or post), and does include time stamps. Related tools are EmerGent (FDDO) [29] and functionality developed in ANYWHERE [30, 31] (cf. https://www.kajoservices.com/).
Test settings	The scenario will be included in field trials, mainly in high-level command posts (like A level staff room). Test settings similar to staff rooms can be established at UPB and FDDO.

Table 32: Use case narrative: FMI ML-based service and tools

Attribute	Description
ID	Emergency_UC_14
Name	ML-based preparation for weather-induced emergencies
Short description	The ML-based service and tools enhance the preparedness of emergency management for weather-related emergencies on different national levels and temporal timescales. In the beginning, three main hazards are addressed in Finland: wind storms, wild fires, and extreme winter conditions. Later the service is expanded to be suitable to forecast impacts of different hazards, such as floods, and to be usable utilized on different geographical areas, (I.e. Dortmund).
Author	Ilona Láng-Ritter (FMI)
Last update	16/06/2023

Attribute	Description
Scope	• RapidMiner operators • XAI • Visual Analytics • Complex Event Forecasting
Actors	• Emergency operators of local rescue service (Rescue Department of Helsinki, RDH) • Emergency management of national level (Ministry of Interior Finland, MoIFI)
Pre-conditions	• Sufficient quality of impact datasets for training the ML-model • Forecast updated minimum twice a day or when the new weather prediction model updates. • Sufficient user training of the tools and their function (also uncertainties) • Active monitoring of the weather and ML tools regularly and timely by the emergency operators.
Assumptions	
Trigger	Critical weather-related event (windstorm) or conditions (heatwave and drought leading to increased risk of wild fires) emerging with up to one week timescale.
Detailed scenario	Case 1. Intense windstorm • Detected in the forecast within 1-5 days, wind speed forecast 20-30 m/s • Result: fallen trees on property, roads and in the worst case threatening human lives. • Cause for emergency management on local level (RDH): Increased amount of clearance tasks. • Cause for emergency management on national level (MoIFI): In very extreme windstorms MoIFI may need to arrange to some local areas more human resources or equipment. • Preparation aid of the tool: Monitoring the storm impacts (clearance task forecast) with up to 5-day outlook before the storm hits and just before the storm with 6-hour outlook to increase the short-term preparedness on county/municipal level Case 2. Wildfire • Long-lasting heatwave and drought leading to high wildfire risk • Cause for emergency management on local level (RDH): Increased amount of wild fire fighting tasks • Cause for emergency management on national level (MoIFI): In very extreme wild fire situations MoIFI may need to arrange

Attribute	Description
	additional human resourceshumaquipment, or in a very severe situation ask for help internationally. • Preparation aid of the tool: Monitoring the wild fire fighting task forecast on with up to 5-day outlook, monitoring daily the 6h-outlook product to increase the to increase the short-term preparedness on county/municipal level Case 3. Extreme winter conditions (snow fall, freezing rain) • Heavy snowfall (often induced by sea-snow-effect in Helsinki Region), rapid freezing or melting in winter in combination of snow or rainfall or freezing rain. • Result: Increased risk of traffic accidents, possibility of very severe chain-traffic accidents • Preparation aid of the tool: Monitoring the wild fire traffic accidend forecast with up to 5-day outlook, monitoring daily also the 6h-outlook product to increase the short-term preparedness on county/municipal level. Response to the forecasts and other relevant information: Recourse management and allocation up to one week advance or with short notice (6h-view). Resource management and planning on local and national level (national level only during extreme conditions). Possible extensions: Case 4. Any weather event that threatens the health of people • Extreme heatwaves threaten especially people in risk groups' (old people, children, people with heart disease) • Result: Ambulance tasks is increasing during these events • Cause for emergency management on local level (RDH): Increased amount of ambulance operations and high need for personnel in the first aid • Preparation aid of the tool: Monitoring the weather events causing suitable conditions for increased ambulance tasks. Case 5. Weather hazard- related tool for other area than Finland: Depending on the data availability similar tools for similar scenarios can be developed for instance in Dortmund or Austria.
Post-condition	Enhanced preparedness for weather-related emergencies and increased ability for impact estimation of emergency managers to benefit the resource planning and allocation.
Related information	Only data which is recorded by FDDO in sufficient amount is the number, type and location of operations. Cross-referencing with external data could help to understand the influence of weather, events in the city, traffic etc. on the number and

Attribute	Description
	duration of operations → increase preparedness of FDDO while being more specific at the same time → not just use more units Data streams which could feed into a system for early warnings would have to rely on established sensors or systems (FDDO is not using sensors on a level going beyond the scope of a single operation)
Test settings	Tested as a part of the use of existing weather-preparedness tools (i. e. weather warnings) in the Rescue Department of Helsinki and Interior ministry of Finland. As a later stage, also possibly tested by FDDO.

Table 33: Use case narrative: Task-oriented battery management of robots under operational conditions

Attribute	Description
ID	Emergency_UC_20
Name	Task-oriented battery management of robots under operational conditions
Short description	Robotic resources are limited, so their deployment needs to be planned with regard to specific mission targets. Planning subsumes selection, payload (e.g., sensors), routing and interaction with the environment (incl. communication with other robots). Standard information like type of drones is used, complemented by current status data. Changing and charging of batteries needs to be part of resource management in preparation and response phases. Standard functionality for battery management is available. But for operational decisions, there needs to be a mapping between foreseen tasks and energy consumption. Standard models of battery management do not include effects of the environments, like hot temperatures, strong winds and muddy ground. These influence factors depend on the environment, and they are interdependent.
Author	Jens Pottebaum (UPB)
Last update	2023/06/11
Scope	• RapidMiner operators • Federated ML • XAI • Visual Analytics
Actors	• C level commanders at RobLW • Robot operators • Robotic Task Force experts
Pre-conditions	• robotic equipment is dispatched to the operation

Attribute	Description
	• Tasks are delegated to the unit that deploys robots
Assumptions	The environment is not standard, but affected by, e.g., heavy rain, wind conditions or abnormal temperatures.
Trigger	Deployment of one or more robotic system is considered
Detailed scenario	(to be detailed)
Post-condition	Increased efficiency in utilization of limited robotic resources
Related information	Robotic systems like UGVs and UAVs or even under-water drones are deployed as single units or within swarm settings with different levels of autonomy. The longer an emergency duration, the more important is battery management.
Test settings	Field trial settings that involve robots and that fulfill pre-conditions and assumptions. DRZ indoor lanes and outdoor setups, where the influence of environmental conditions (like mud, wind etc.) on battery utilization can be teste.

Table 34: Use case narrative: Object detection

Attribute	Description
ID	Emergency_UC_21
Name	Object detection
Short description	Detect object in sensor data (from sensors like radar, video cameras, thermal cameras). Objects might be trapped or injured persons, debris in water, openings/doors under-water etc.
Author	Ivana Kruijff (DRZ)
Last update	2023/06/27
Scope	• Relevance of ML • RapidMiner operators
Actors	• First responder (robot operator) • C level commander
Pre-conditions	example: flooding affected objects, now moving/laying under-water
Assumptions	
Trigger	order given from C level commander to robot operator
Detailed scenario	(to be detailed)

Attribute	Description
Post-condition	object(s) detected and visualized on situational map (RobLW and/or ARGOS, potentially extended by Gazebo)
Related information	Several projects have been undertaken with similar subjects. Nonetheless, this scenario is requested by stakeholders of pilots both in Germany/Dortmund and Austria.
Test settings	The scenario will be included in field trials in Dortmund and, potentially, in Austria. Additionally, test settings are setup in lab infrastructures (DRZ, UPB, FDDO “Brandhaus”) to provide reproducible surroundings.

Table 35: Use case narrative: Decision support for Robotic Task Force

Attribute	Description
ID	Emergency_UC_22
Name	Decision support for Robotic Task Force
Short description	Decision support for Robotic Task Force (with a number of drones) resp. robot operators (for single drones). assist robot operators (using predictions of water, wind, fire etc. to assist robot operators and/or autonomous robot navigation/planning); option: Robotic AR interfaces (cf. Emergency_UC_50).
Author	Ivana Kruijff (DRZ)
Last update	2023/06/27
Scope	• Complex Event Forecasting? • XAI • Visual Analytics
Actors	• C level commander (RTF) • First responder (robot operator) • Task Force expert (RTF)
Pre-conditions	deployment of RTF
Assumptions	
Trigger	tbc
Detailed scenario	• Which sensor system? • Which sensors? • On which platform (UAV, UGV)? • Swarm deployment? (to be detailed)
Post-condition	tbc

Attribute	Description
Related information	Terminology is focused on a "Robotic Task Force" (RTF) which is intended to be founded at FDDO. As long this is not yet institutionalized, the term RTF is used for operational Sections dedicated to the deployment of robotic equipment.
Test settings	The scenario will be included in field trials in Dortmund. Additionally, test settings are setup in lab infrastructures (especially at DRZ, smaller scale at UPB, scenery at FDDO "Brandhaus") to provide reproducible surroundings.

Table 36: Use case narrative: Smart sensing

Attribute	Description
ID	Emergency_UC_30
Name	Smart sensing
Short description	In case of an actual extreme fluvial floodings event, it is very likely that river gauges stop sending data as soon as the water level gets extreme. Thus, in most critical situations there is no information available any more.
Author	Jens Pottebaum (UPB)
Last update	2023/06/11
Scope	• RapidMiner operators • CER/CEF • Federated ML • XAI • Visual Analytics
Actors	• crisis managers • A level commanders • C2 staff members (S2 – situational map)
Pre-conditions	• River gauge sensors are installed in upriver areas. • Data from river gauge sensors is retrieved through ARGOS, utilizing available communication networks.
Assumptions	

Trigger	• t-8h: A fluvial flooding event is anticipated, weather forecasts show heavy rain in upriver areas.
	  ○ Forecasts show how the water level will rise and fall along its track over time.
	  ○ Actual sensor data is fed into these simulation models to calibrate simulations.

Attribute	Description
Detailed scenario	• t-1h: Heavy rain in upriver areas, upstream river gauges confirm rise of water level. • t-30 min: upstream river gauges exceed tresholds, heavy rain in urban area • t0: upstream river gauge does not send data any more (either flooded or even destroyed) o An information is presented to users that a) the sensor is not available any more and b) the information provision is changed to ML/simulated information t+15 min: upstream river gauges are replaced by ML/simulated data feeds, also feeding simulation models to assess development of water levels over time.
Post-condition	continuous river gauge information available, labelled by source (sensor, or model) and uncertainty (sensor quality, network quality, model DQ/IQ)
Related information	cf. applications of sensors in collaboration of HYDS and RAB consultants in the H2020 ANYWHERE project
Test settings	The provision of information can be validated in simulated experiments in command posts, either in field trials or lab settings. The generic scenario needs to incorporate fluvial floodings. Real setups would require sensor installations at selected rivers (like Danube).

Table 37: Use case narrative: Simulation (cf. 3.1.1)

Attribute	Description
ID	Emergency_UC_40
Name	Simulation
Short description	Short description, e.g., referring to the generic application scenario, related weather phenomena or hinting at used system
Author	Jens Pottebaum (UPB)
Last update	2023/06/27
Scope	• Simulators (cf. 3.1.1) • Interactive Learning for Simulation Exploration • RapidMiner operators
Actors	• C^2 staff members • Task Force experts
Pre-conditions	tbc
Assumptions	

Attribute	Description
Trigger	tbc

Detailed scenario	potential use cases of simulation identified by FDDO
	• Currently action planning of FDDO is based on external simulations (DWD) → Influence on situation is simulated (weather) but not the situation itself (impact) → currently no simulations by FDDO itself
	• Current situations for fixed plans based on simulated impact: bomb-clearing, heavy rain with expected flooding
	• Level of water and its rate of change, flow dynamics, flow rate of retracting water etc. could be simulated for different levels of precipitation but factoring in local factors like sealed surfaces, drainage system etc.
	• Currently action planning of FDDO is based on external simulations (DWD) → Influence on situation is simulated (weather) but not the situation itself (impact) → currently no simulations by FDDO itself
	• Current situations for fixed plans based on simulated impact: bomb-clearing, heavy rain with expected flooding
	• Level of water and its rate of change, flow dynamics, flow rate of retracting water etc. could be simulated for different levels of precipitation but factoring in local factors like sealed surfaces, drainage system etc.
	• Traffic flow during stages of public alerts in combination with impact of weather (impassable streets) could be simulated to improve dispatchment of units (time and safety)
	• Action planning use cases with regard to units/equipment
	    o Routing in damaged areas
	    o decision for locations, assembly points for evacuation
	• Decision support regarding robots: Robots are used in such a way that the exploration of a simulation is optimized (optimal input data to eliminate uncertainties in a simulation); cf. Em_UC_50
	    o Where in the environment should I, as a commander/operator, measure what and how in order to optimize the forecast for a certain phenomenon?
	    o How should I adapt that iteratively in the dynamic environment?

Post-condition	Identified parameters informing action-planning and/or decision-making
Related information	

Attribute	Description
Test settings	The scenario will be included in field trials. Actors from high-level command (e.g., evacuation of people from predicted flood areas) to robot operators (e.g., routing for robots) are involved. Test settings are established in lab infrastructures (DRZ, UPB) and in the actual A level staff room of FDDO. At DRZ, both indoor and outdoor settings are created to test with environments of different scales in reproducible settings. Gazebo is setup at UPB, capable to integrate simulated data. Indoor lanes are mirrored from DRZ to UPB.

Table 38: Use case narrative: AR and robotics

Attribute	Description
ID	Emergency_UC_50
Name	AR and robotics
Short description	First responders wear a head-worn Augmented Reality (AR) device such as the Hololens 2 device while robots are deployed in the emergency site. While operating onsite during an emergency (flooding, fire) AR-systems can be used to augment the robot operator's view to support their decision on next steps and risk management. For example, a ground robot operator can see predicted flood levels in the area where their robot is operating in order to decide whether to proceed further and which way to take to avoid submersion or getting cut off. A drone operator can see where fire is expected to spread.
Author	Stavroulakis Alexios, Katerina Mania (TUC), Ivana Kruijff (DRZ)
Last update	2023/06/27
Scope	• AR • Uncertainty visualization
Actors	• First responder / robot operator • C level commander
Pre-conditions	Robot has been deployed in risk area.
Assumptions	Potential Points of View: a) seeing the robot augmented with information (like hazard levels for the robot) or b) viewing the scene from the viewpoint of the robot. This work should be linked with a relevant use case.
Trigger	Flooding (or fire) is predicted in the area where the robot is operating, i.e., area it is supposed to explore or area surrounding the pathway(s) towards its specified waypoint(s).

Attribute	Description
Detailed scenario	One potential sequence (variations are possible) 1) Robot operator is controlling the robot to explore a given Section of the risk area, return time is estimated at 10 minutes 2) AR displays a prediction of flood level that will block robot's return path in 30 min 3) Robot operator decides to continue exploration and monitor the prediction 4) Robot operator initiates return when remaining time before predicted flooding equals estimated return time plus 20% Potential Augmented Reality operations: • Operator's data visualization: The operator, utilizing an AR interface, can receive and visualize the data sent by the UAV/UGV. The AR display overlays the received data onto a live video feed or a map representation, providing real-time visualization of the collected data. This could include overlaying flood extent boundaries, water depth measurements, or other relevant data points, enabling the operator to assess the situation and make informed decisions based on the data received. • Robot safety alerts: The AR interface can receive and combine data from multiple sources, including sensors on the robot, environmental monitoring systems, and other relevant data feeds. By analyzing this combined data, the AR system can assess potential hazards or dangers that the robot may encounter during its mission. • Data transmission monitoring: The AR interface can display the status of data transmission between the UAV/UGV and the control station. It can show the signal strength, data transfer rate, and any potential errors or disruptions. This allows the operator to monitor the data transmission process and ensure that the collected data is being successfully sent back to the control station. • Emergency response collaboration: The AR interface can integrate with the command center's system to provide real-time data updates to emergency responders. As the UAV/UGV collects and transmits data, the AR display at the command center can overlay the received data onto a shared map, allowing responders to visualize and assess the situation collaboratively. This can assist in coordinating rescue efforts, identifying critical areas, and making informed decisions based on the data received. • Historical data comparison: The UAV/UGV can send collected data to the control station, where the AR system overlays data onto historical flood data. By visualizing the current data in conjunction with historical records, the AR display can help identify trends, patterns, and changes over time. This comparison aids in understanding the evolving nature of the

Attribute	Description
	flooding site and supports decision-making processes (Ragia et al. 2015; Suzuki et al. 2022). • Data validation and quality control: The AR interface can provide tools for data validation and quality control. As the UAV/UGV sends data, the AR display at the control station can enable operators to compare the received data with predefined standards or reference datasets. The AR system can highlight any inconsistencies or anomalies, allowing for immediate feedback and adjustments in data collection procedures. • Potential of robot-augmented human vision for exploring and controlling robots in constrained environments [32–34]. • Robot operator: Navigation based on the visualization of a hazardous situation (distance-dependent effect of water/demolition edges or fire on robots).
Post-condition	Robot safely exits the risk area.
Related information	
Test settings	The scenario can be carried out indoor or outdoor (e.g., the collapsed building construction) in the DRZ Living Lab (or in another location) with simulated predicted flooding projected in AR. By default, we will explore the potential of the scenario or parts of it to be tested in field trials. Additionally, test settings in labs (DRZ, UPB) may be organized.

Table 39: Use case narrative: AR in urban environments (in preparation phase)

Attribute	Description
ID	Emergency_UC_51
Name	AR in urban environments (in preparation phase)
Short description	During periods of regular weather buildings have to be assessed regarding their risk of flooding in case of different levels of rainfall. The simulated water level can be used to augment the real observations by an operations planner. The impact of every category of rainfall is depicted as a range of water levels to show uncertainty.
Author	Oliver Krueger (FDDO)
Last update	2023/06/06
Scope	• AR • Uncertainty visualization
Actors	• First responder • C level commander • Operation planner
Pre-conditions	Areas of interest meaning prone to flooding or with buildings of higher impact risk (vulnerable inhabitants) are selected to evaluate their risk

Attribute	Description
	of flooding. Database has to be set up, where operation planners can add the evaluation of each building. Interaction with the AR-device used to visualize the simulated impact has to have been trained.
Assumptions	The usage of AR in planning activities can be structured around the limitations of use regarding the AR device (compatibility with other equipment, ergonomics in emergency operations, environmental impacts on devices).
Trigger	The FDDO wants to prepare plans of action for specific areas or buildings / make them part of a large-scale evacuation strategy for future events of pluvial flooding (continous trigger). Specific triggers arise, when the use of buildings changes and makes a (re-)evaluation necessary or when a lack of information on a specific area is recognized.
Detailed scenario	• Operation planner arrives at building of interest or in area which is to be analysed regarding impact risks of different severities of flooding scenarios • Map of city / digital twin of city exists (assumption) with possibility to add information specific to each building • Fire officer does walkaround with AR device • Within the GUI of the AR device he can select between different impact simulations of heavy rainfall • Each simulation is depicted as a range of outcome (water levels) with understandable values for probability • The simulation of water levels augments the view of the planner on buildings • Existing information about the inhabitants of the buildings or sources of danger which have to be considered (e.g. high-voltage electrical systems) can be selected by the planner on site to be visualized as an additional layer of augmentation • For the building in general but also for each door/window/opening the fire officer can see and evaluate at which level of flooding they are affected • Values of water level and maybe a corresponding critical duration for rain in this area can be attached to the information model regarding the building/area • Within the platform buildings can be compared or analysed to get risk scores of areas • In future cases of flooding or in the preparation after such a forecast becomes relevant the risk score map can help decision making for evacuation processes or protection activities
Post-condition	After the use of AR during the on site assessment of the impact of flooding relevant information is added to a map / database. This database can be used while dealing with a flooding scenario or

Attribute	Description
	preparing one that is forecasted. The process of risk assessment might require constant check-ups on changes of condition and is therefore likely to never be entirely finished.
Related information	To evaluate as many buildings as possible at once it might be necessary for the AR device to be able to operate continuously for several hours. In case a larger system/unit for data processing or hosting a local network is needed, it could be installed in a suitable car/truck. The operation planner would then evaluate buildings/areas in a certain radius around this mobile base-station. Additionally, if one already develops a digital twin of e.g. critical zones, one could take this immediately for exercise purposes.
Test settings	To test this application / use case there are countless opportunities in the city centre of Dortmund. To test the use of AR a flooding simulation has to be developed for a specific area / representative critical building. Then an operation planner could test the evaluation process and with it the interaction with the layers and functions of the AR device as well as underlying software. Additionally, an expansion of the trials to Innsbruck is envisaged.

Table 40: Use case narrative: AR in urban environments (in response phase)

Attribute	Description
ID	Emergency_UC_52
Name	AR in urban environments (in response phase)
Short description	While dealing with the situation resulting from flooding the safety of first responders is in the hands of their C-level commander, who is also on site. To support their decision on next steps and risk management AR-systems can be used to augment the commander's view.
Author	Oliver Krueger (FDDO)
Last update	2023/06/06
Scope	• AR • Uncertainty visualization
Actors	• First responder • C level commander • Operation planner
Pre-conditions	A flooding scenario has developed into a situation in which fire fighters have to operate under risk, for example to rescue people out of building surrounded by water.

Attribute	Description
Assumptions	For the area in which the operation takes place there is existing data of sufficient quality on its state/condition/features before the flooding happened. Also, AR-devices are assumed to be robust enough for use during the on-site operation meet relevant requirements regarding ergonomics.
Trigger	Demand for decisions by C-level commanders on site regarding next steps of operation. Especially decisions regarding risk to reward ratios or the effectiveness of measures could be supported by augmenting the commanders' perception.
Detailed scenario	• A unit of firefighters is deployed by the operation control centre to safe people from a building surrounded by water • Conditions regarding the drive to the location and also the building are unclear to the dispatchers in the control room • A fire truck and a C-level command-vehicle leave the fire station with the C-level leading the way • The commander is sitting in the passenger seat wearing an AR-Device • The first measure of support by the AR-System is to augment the view ahead by images/video/information regarding road conditions. Possible construction sites with dug outs can be hidden under the surface of the water and pose danger to the vehicles. Therefore their location is shown through the device. • After reaching the building the units have been sent to, the commander has to decide on how to proceed with the operation. Thus, especially the risk to reward ratio of measures to fulfill the goal of the operation has to be evaluated. • While still in the car or exploring the outside of the building, depending on e.g. the waterproofness of the AR-device, the commander can look at the current state of the building • Through augmentation the commander has access to more information on the building. These could include: the number and location of entrance points (avoids getting trapped), locations of sources of danger (electrical systems, gas and oil tanks, chemicals stored in the building), the number of people supposed to live in the building as a whole or per apartment or even if there are still currently people in it (sensor systems), etc. • Due to the availability of information and it being visualized in an easy-to-understand manner, uncertainty is decreased resulting in the C-level commander being able to make more informed decisions. These could affect the outcome of the operation by increasing safety and/or effectiveness of measures (see post-condition)
Post-condition	Decisions of C-level commanders are optimised in two possible ways. 1. Due to AR-use, threats are visible to the commander, which otherwise would have been invisible to them. Therefore, units

Attribute	Description
	are stopped from proceeding with the operation and saved from possible danger/injury (see also related information). 2. Due to AR-use, the absence of threats is visible to the commander, which they might have assumed to exist otherwise. Therefore, units can proceed with their operation under safe conditions and can rescue people affected by the flooding.
Related information	See Emergency_UC_51 If commanders have any doubt about the safety of their units in situations of incomplete information, they would not go ahead with the operation. Self-protection always comes first (cf. [35]). Optimization-case 1 is therefore significantly less likely to happen than case 2 due to the improbability of its assumption.
Test settings	The outdoor testbed of DRZ simulating a road with a construction site and building (container) next to it can be filmed and turned into a 3D-model representing its original state at a given time. Also, sources of danger can be marked within the models. After that, the testbed can be modified to create discrepancies between the conditions. Experiments with AR-devices can determine if decision making under uncertainty can be improved.

9.2 Health case

9.2.1 Specific focus for the uptake of technologies (WP3-WP5)

Table 41: Required focus of requirements elicitation with regard to critical events

T4.1 Complex Event Forecasting			
Complex event type	**Relevancy**	**Derived needs**	**Examples/ references**
Detection of cases outbreak hotspots	Avoid local health system collapse Simulation of the evolution of cases in forecasted hotspot and the nearby areas for evaluating the potential severity of the outbreak Depending on the uncertainty of the forecasted potential outbreaks as well its estimated impact on the healthcare capacity, decision maker(s) may opt to disregard the forecasted	The use and visualization of metrics or variables which quantify and interpret the uncertainty of the outbreak prediction to the end users has the potential to facilitate informed decision making an accurate action planning by the decision makers and the action planners respectively.	[11] [36]

	outbreak event or perform mitigation actions. <u>Decisions include:</u> Which mitigation actions should be performed, what is the available time horizon to perform them and the possible cooperation with nearby areas (hospitals/districts /municipalities) <u>Actions include:</u> Calling Self-isolations Local confinements with reduced mobility Enforce the used of protective measurements (e.g., masks)		
Detection of the outcomes of lung infection interventions	To know as soon as possible if the delivered treatment had a beneficial effect on the patient. Simulation of the evolution of the patient with a given treatment and forecast their outcome by evaluating the effect on the patient's health. <u>Decisions include:</u> Which clinical interventions should be performed and what is the available time horizon to perform them. <u>Actions include:</u> Diverse drugs and their combinations. Mechanical respiration	The use and visualization of metrics or variables which quantify and interpret the uncertainty of the disease level prediction to the clinicians has the potential to facilitate informed decision making an accurate action planning by the decision makers and the action planners respectively.	[37] [38]

Table 42: Required focus of requirements elicitation with regard to interactive learning for simulation exploration

T4.2 Interactive Learning for Simulation Exploration		
Complex event type	**Relevancy**	**Derived needs**
Models' parameter calibration	Avoidance of the exhaustive search of the parameter space while learning the distribution of epidemiological parameters	Deployment of a fast-retraining mechanism for novel strains and drugs.

	using Approximate Bayesian Computation or other optimization algorithms. Fine tuning epidemiological parameters is critical to evaluate the current state of a pandemic as well as to estimate the speed at which new cases will grow. Likewise, the fine tuning of the multiscale parameters is critical to evaluate the current healthy status of an infected patient.	Provision of visual analytics tools and functions to the end users for exploring the parameters space and the uncertainty.
Optimal intervention design	Avoidance of the exhaustive search of the parameter space. Design intervention strategies combing NPIs, and vaccination campaigns to minimize the number of deaths, avoid healthcare system collapse, subject to allow the mobility required to avoid great economic impact. For the multiscale modelling, design novel, optimised drug treatments that increase the chances of survival of an infected patient.	Provision of visual analytics tools and functions to the end users for exploring the parameters space of optimal intervention strategies.

Table 43: Required focus of requirements elicitation with regard to uncertainty

T5.3 Visual Analytics for Decision Making under Uncertainty			
Typical uncertainties that might benefit from VA	**Relevancy**	**Derived needs**	**Examples/ references**
Uncertainty of the forecasted cases outbreak hotspots	Avoid local health system collapse Simulation of the evolution of cases in forecasted hotspot and the nearby areas for evaluating the potential severity of the outbreak Depending on the uncertainty of the forecasted potential outbreaks as well its estimated impact on the healthcare capacity, decision maker(s) may opt to disregard the forecasted outbreak event or perform mitigation actions. <u>Decisions include:</u> Which mitigation actions should be performed, what is the available time horizon to perform	The use and visualization of metrics or variables which quantify and interpret the uncertainty of the forecasted cases outbreak hotspots to the end users has the potential to facilitate informed decision making and accurate action planning by the decision makers and the action planners respectively.	

	them and the possible cooperation with nearby areas (hospitals/districts /municipalities) Actions include: Calling Self-isolations Local confinements with reduced mobility Enforce the used of protective measurements (e.g., masks)		
Uncertainty of the estimated parameters	Multiscale and epidemiological models have a long list of parameters that need to be fitted. For most of them, researchers can use experimental data, but for some of them there are no data to fit them against and they need to be constrained around some values. The use of common validation, verification and uncertainty quantification methodologies allow to better characterize the accuracy and efficacy of the models.	We will need to design and deploy different test suites for the systematic and automatic testing and validating methodologies.	[39]
Uncertainty of lung infection interventions	To know as soon as possible if the delivered treatment had a beneficial effect on the patient. Simulation of the evolution of the patient with a given treatment and forecast their outcome by evaluating the effect on the patient's health. Decisions include: Which clinical interventions should be performed and what is the available time horizon to perform them. Actions include: Diverse drugs and their combinations. Mechanical respiration	The use and visualization of metrics or variables which quantify and interpret the uncertainty of the disease level prediction to the clinicians has the potential to facilitate informed decision making an accurate action planning by the decision makers and the action planners respectively.	

9.3 Maritime case

9.3.1 Personas

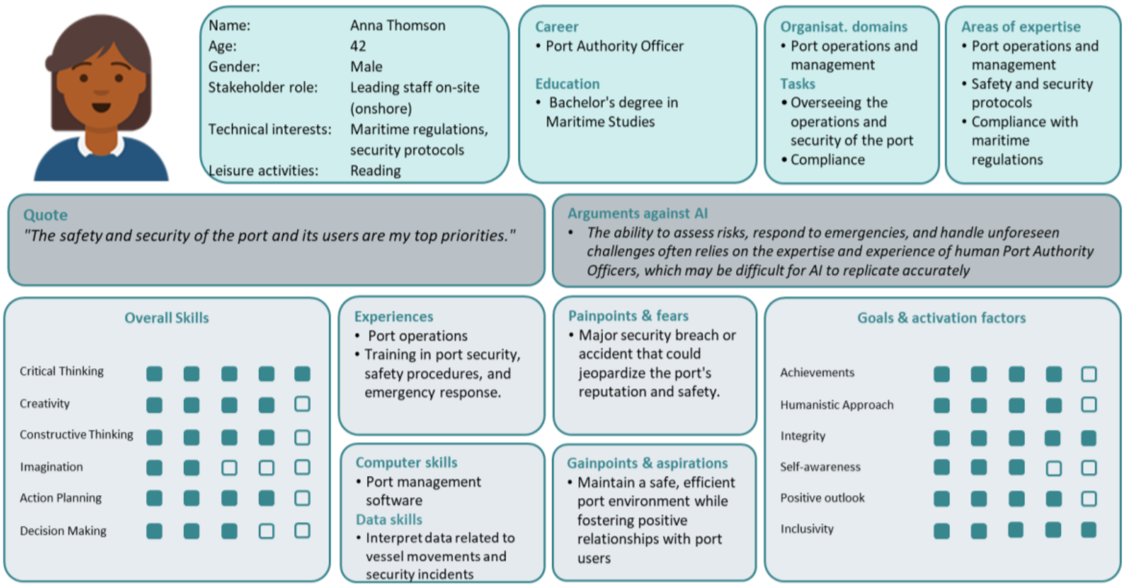


Figure 50: Persona of a port/coastal authority officer

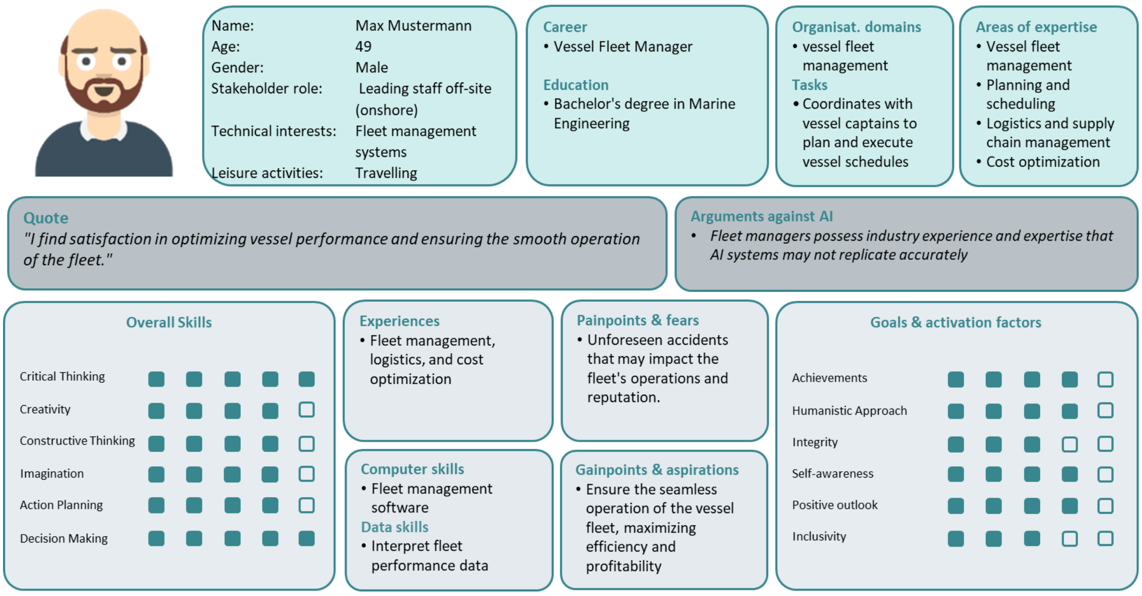


Figure 51: Persona of a fleet manager

Name:	Sofia Papadopoulou
Age:	29
Gender:	Female
Stakeholder role:	Leading staff on-site
Technical interests:	Navigation systems, maritime regulations, safety procedures
Leisure activities:	Swimming, hiking, photography

Career
- Ship deck officer

Education
- Master's degree in Nautical Science

Organisat. domains
- Maritime industry

Tasks
- Navigate the vessel, monitor equipment, and execute safety procedures

Areas of expertise
- Navigation
- Safety protocols and emergency response
- Bridge equipment operation
- Cargo handling and stowage

Quote
"As a deck officer, I embrace the responsibility of ensuring the safe and efficient operation of the ship."

Arguments against AI
- *Human deck officers possess a deep understanding of maritime regulations and navigational practices that may not be easily replicated by AI algorithms*

Overall Skills

Critical Thinking	■ ■ ■ ■ ■
Creativity	■ ■ ■ ■ □
Constructive Thinking	■ ■ ■ ■ □
Imagination	■ ■ ■ □ □
Action Planning	■ ■ ■ ■ □
Decision Making	■ ■ ■ ■ □

Experiences
- Working on various types of vessels
- Training programs on ship handling, navigation, firefighting.

Computer skills
- maritime navigation software

Data skills
- Interpret navigational data, weather reports

Painpoints & fears
- Encountering extreme weather conditions or emergencies that could pose risks to the vessel

Gainpoints & aspirations
- Ensure the safety of the crew and cargo during voyages.
- Become a captain

Goals & activation factors

Achievements	■ ■ ■ ■ □
Humanistic Approach	■ ■ ■ ■ □
Integrity	■ ■ ■ ■ □
Self-awareness	■ ■ ■ ■ □
Positive outlook	■ ■ ■ ■ □
Inclusivity	■ ■ ■ □ □

Figure 52: Persona of a ship deck officer

Name:	Pierre Allaire
Age:	36
Gender:	Male
Stakeholder role:	Staff on-site (onshore)
Technical interests:	Radar technology
Leisure activities:	Playing tennis, photography

Career
- VTS Operator (Vessel Traffic Service Operator)

Education
- Diploma in Marine Traffic Management

Organisat. domains
- Vessel Traffic Services

Tasks
- Managing and monitoring vessel traffic

Areas of expertise
- Maritime traffic regulations and protocols
- Surveillance systems
- Vessel monitoring
- Emergency response coordination

Quote
"I find it rewarding to play a critical role in facilitating the smooth flow of maritime traffic."

Arguments against AI
- *Effective communication and coordination with vessel captains, port authorities, and other stakeholders require human interaction and understanding, which AI may struggle to replicate*

Overall Skills

Critical Thinking	■ ■ ■ ■ ■
Creativity	■ ■ ■ ■ □
Constructive Thinking	■ ■ ■ ■ □
Imagination	■ ■ □ □ □
Action Planning	■ ■ ■ ■ □
Decision Making	■ ■ ■ □ □

Experiences
- Training in VTS operations, radar operation, communication and emergency response

Computer skills
- VTS software and radar systems

Data skills
- Interpret real-time vessel traffic data

Painpoints & fears
- Potential accidents or emergencies that may occur due to human error or equipment failure

Gainpoints & aspirations
- Ensure the safety and efficiency of vessel movements within the designated area

Goals & activation factors

Achievements	■ ■ ■ □ □
Humanistic Approach	■ ■ ■ □ □
Integrity	■ ■ ■ □ □
Self-awareness	■ ■ ■ ■ □
Positive outlook	■ ■ ■ ■ □
Inclusivity	■ ■ ■ ■ □

Figure 53: Persona of a VTS operator

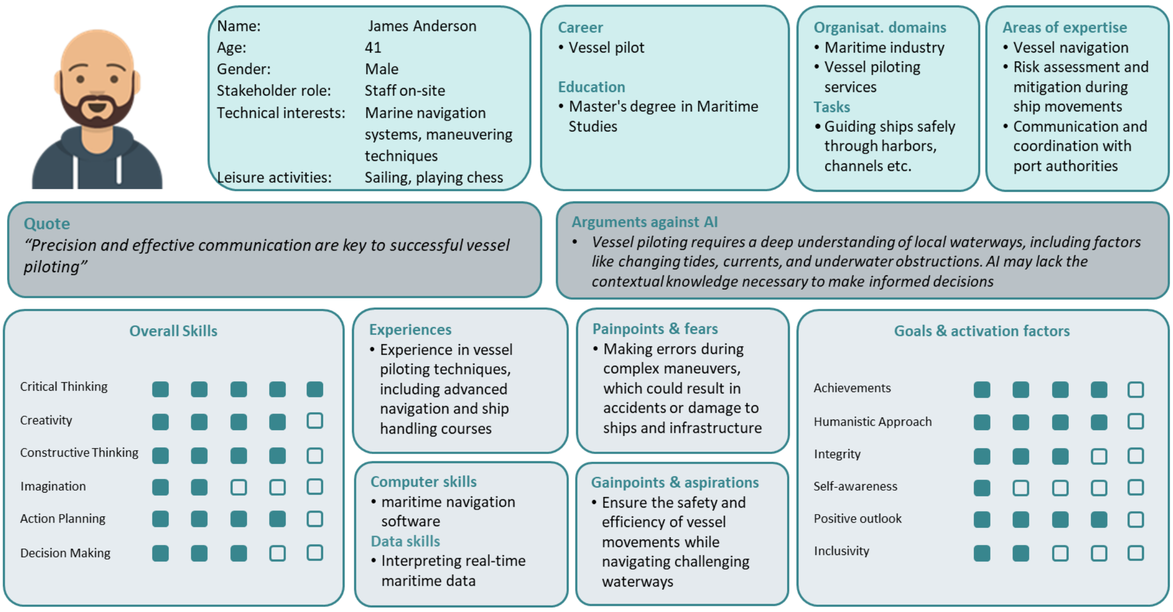


Figure 54: Persona of a vessel pilot

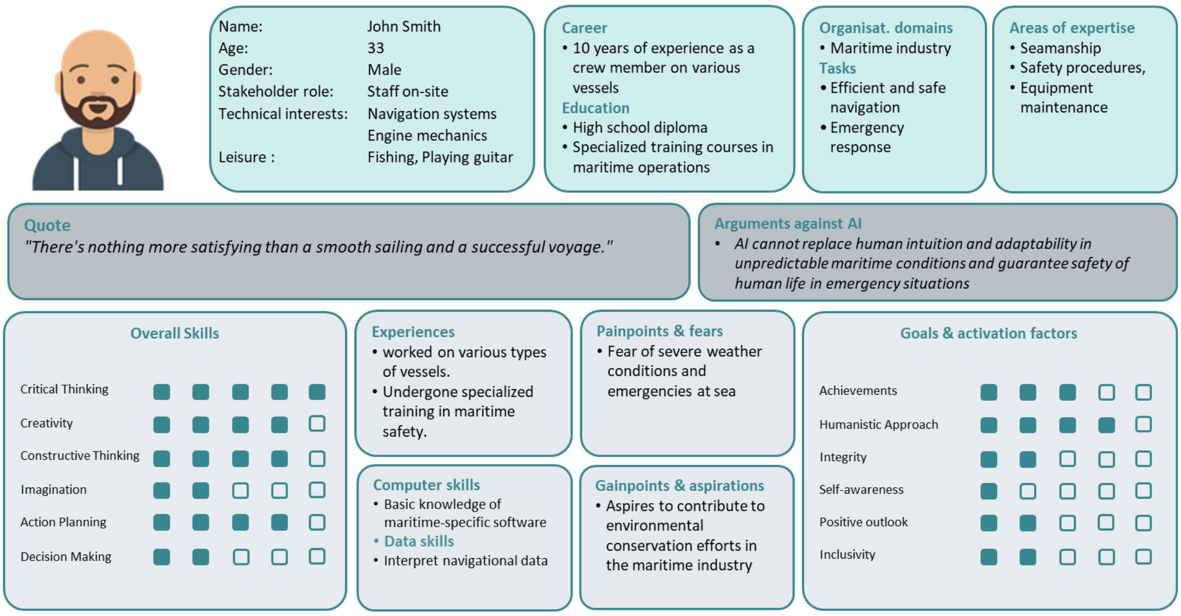


Figure 55: Persona of a vessel crew member

9.3.2 Data sources

Table 44: Data sources in the maritime case

Data sources	Data Source Volume (Vol), Velocity (Vel), Veracity (Ver), Characteristics/Description (Ch/D)
Data sources (local environment)	
MT IoT-Voyage Data Streamer – VDS [UoA vessel, RoBoat Race participating vessels]	Vol: 360 KB of data per hour with 1Hz update frequency per vessel Vel: 1Hz update frequency GSM 3G Ch/D: Collection of timestamp, longitude, latitude, couse, xyz accelerometer angles. Smart data acquisition based on: Time; Angle; Distance; Ignition or any other I/O event; Sending acquired data via GPRS; GPRS and SMS I/O events; Virtual odometer; Jamming detection, Configurable using Secured SMS Commands; Overvoltage protection. The module (FMB9YX) is designed to acquire records and send them to the server. Records contain GNSS data and I/O information. Module uses GNSS receiver to acquire GNSS data and is powered with three data acquiring methods: time-based, distance-based and angle-based. Note, that if the module loses connection to GNSS satellites, it continues to make records, however coordinate in these records remains the same (last known coordinate). All data is stored in flash memory and later can be sent via GPRS. GPRS and SMS settings are described in later Sections. It communicates with server using special data protocol. It can be managed by SMS commands. SMS Command list is described in Section. Module configuration can be performed only via SMS.
GPS (NEO V2 GPS module) [UoA autonomous vessel]	Vol: 10Hz (Max) Ver: Horizontal accuracy 2.5m, Speed accuracy: 0.05m/s Vel: 10Hz (Max) Ch/D: GNSS Services Beidou, Galileo, GLONASS, GPS
LIDAR (RPLidar A1) [UoA autonomous vessel]	Vol: 8K Sampling Frequency, Data output includes for each sampled point: distance (mm), heading angle (degrees), Quality level, new scan start flag Ver: Measuring Accuracy 1% Vel: Scanning Frequency 5.5Hz, Configurable Scan Rate from 2-10Hz Ch/D: The RPlidar A1 utilizes a ranging that rotates clockwise, enabling 360° full-scan detection of the surrounding

Data sources	Data Source Volume (Vol), Velocity (Vel), Veracity (Ver), Characteristics/Description (Ch/D)
	environment and producing a map of the area. Using a modulated pulse type low-power infrared laser emitting light source, RPlidar A1 meets the Class 1 laser safety standard.
Camera (Luxonis OAK Camera) [UoA autonomous vessel]	Vol: H.264, H.265, MJPEG - 4K/30FPS, 1080P/60FPS Ver: Common video stream data rates Vel: 4K/30FPS, 1080P/60FPS Ch/D: IR illumination LED allowing operation in low-light or no-light environments, 12MP central RGB with auto-focus
Accelerometer (ICM-20689) [UoA autonomous vessel]	Vol: Accelerometer with programmable FSR of ±2g, ±4g, ±8g and ±16g Ver: Accel FSR ±2/4/8/16, Accel Sensitivity Error ±2%, Accel Noise 150µg/√Hz Vel: Digital-output X-, Y-, and Z-axis accelerometer with a programmable full-scale range of ±2g, ±4g, ±8g and ±16g and integrated 16-bit ADCs – 500Hz Ch/D: 6-axis Motion Tracking device that combines a 3-axis gyroscope, 3-axis accelerometer, in a small 4x4x0.9mm (24-pin QFN) package
Gyroscope (BMI055) [UoA autonomous vessel]	Vol. Gyroscope programmable FSR of ±125dps, ±250dps, ±500dps, ±1000dps and ±2000dps (degrees per second) Ver: Gyro Sensitivity Error ±2%, Gyro Rate Noise 0.006dps/√Hz Vel: Digital-output X-, Y-, and Z-axis angular rate sensors (gyroscopes) with a user-programmable full-scale range of ±250, ±500, ±1000, and ±2000°/sec and integrated 16-bit ADCs – 500Hz Ch/D: 3-axis gyroscope of the ICM-20689 Accelerometer
Barometer (MS5611) [UoA autonomous vessel]	Vol: Several KB of data per hour depending on update frequency Ver: altitude resolution of 10 cm, Accuracy 25°C, 750 mbar -1.5 +1.5 mbar, temperature accuracy -0.8 +0.8 °C Vel: 0.5 / 1.1 / 2.1 / 4.1 / 8.22 ms Ch/D: The sensor module includes a high linearity pressure sensor and an ultra-low power 24 bit DC ADC with internal factory calibrated coefficients. It provides a precise digital 24 Bit pressure and temperature value and different operation modes that allow the

Data sources	Data Source Volume (Vol), Velocity (Vel), Veracity (Ver), Characteristics/Description (Ch/D)
	user to optimize for conversion speed and current consumption. A high resolution temperature output allows the implementation of an altimeter/thermometer function without any additional sensor
Data sources (global environment)	
AIS	Vol: 2,500 position messages per ship per day; approximately 70 GB per day. Vel: Updates every few seconds Ver: Affected by coverage and other issues (GPS errors, spoofing, equipment malfunctions)
Copernicus Marine Service: Global Ocean Physics Analysis and Forecast	Vol: max 282.17 MB per API Request depending on number of selected features, time period and area size Ver: Spatial resolution 0.083° × 0.083° Vel: Update frequency, Daily – 12:00 UTC Monthly, Temporal resolution: Hourly / Daily / Monthly, Ch/D: The Operational Mercator global ocean analysis and forecast system at 1/12 degree is providing 10 days of 3D global ocean forecasts updated daily. The time series is aggregated in time in order to reach a two full year's time series sliding window. This product includes daily and monthly mean files of temperature, salinity, currents, sea level, mixed layer depth and ice parameters from the top to the bottom over the global ocean. It also includes hourly mean surface fields for sea level height, temperature and currents. The global ocean output files are displayed with a 1/12-degree horizontal resolution with regular longitude/latitude equirectangular projection. Variables: Age of sea ice (SIAGE) Cell thickness Eastward sea ice velocity (SIUV) Eastward sea water velocity (UV) Model level number at sea floor Northward sea ice velocity (SIUV) Northward sea water velocity (UV) Ocean mixed layer thickness defined by sigma theta (MLD) Sea floor depth below geoid Sea ice albedo (SIALB) Sea ice area fraction Sea ice speed Sea ice surface temperature (IST) Sea ice thickness (SIT) Sea surface height above geoid (SSH) Sea surface wave stokes drift x velocity (UV, VSDXY) Sea surface wave stokes drift y velocity (UV, VSDXY) Sea water potential temperature (T) Sea water potential temperature at sea floor (bottomT) Sea water pressure at sea floor Sea water salinity (S) Surface snow thickness (SNOW) Upward sea water velocity (UV)

Data sources	Data Source Volume (Vol), Velocity (Vel), Veracity (Ver), Characteristics/Description (Ch/D)
Copernicus Marine Service: Global Ocean Waves Analysis and Forecast	Vol: max 299.83 MB per API Request depending on number of selected features, time period and area size Ver: Spatial resolution: 0.083° × 0.083° Vel: Update frequency: Daily – Twice per day (00:00 UTC and 12:00 UTC), Temporal resolution: Hourly Ch/D: The operational global ocean analysis and forecast system of Météo-France with a resolution of 1/12 degree is providing daily analyses and 10 days forecasts for the global ocean sea surface waves. This product includes 3-hourly instantaneous fields of integrated wave parameters from the total spectrum (significant height, period, direction, Stokes drift...etc), as well as the following partitions: the wind wave, the primary and secondary swell waves. Variables: Sea floor depth below geoid Sea surface primary swell wave from direction (SW1) Sea surface primary swell wave mean period (SW1) Sea surface primary swell wave significant height (SW1) Sea surface secondary swell wave from direction (SW2) Sea surface secondary swell wave mean period (SW2) Sea surface secondary swell wave significant height (SW2) Sea surface wave from direction (VMDR) Sea surface wave from direction at variance spectral density maximum (VMDR) Sea surface wave mean period from variance spectral density inverse frequency moment (MWT) Sea surface wave mean period from variance spectral density second frequency moment (MWT) Sea surface wave period at variance spectral density maximum (MWT) Sea surface wave significant height (SWH) Sea surface wave stokes drift x velocity (UV, VSDXY) Sea surface wave stokes drift y velocity (UV, VSDXY) Sea surface wind wave from direction (WW) Sea surface wind wave mean period (WW) Sea surface wind wave significant height (WW)
NOAA Global Forecast System (GFS)	Vol: MB – GB depending on dataset Ver: 13-km horizontal resolution. The GFS is built with the GFDL Finite-Volume Cubed-Sphere Dynamical Core (FV3) and the Grid-Point Statistical Interpolation (GSI) data assimilation system. The current operational GFS is run at 64 layers in the vertical extending from the surface to the upper stratosphere and on six cubic-sphere tiles at the C768 or 13-km horizontal resolution. 28-km grid horizontal resolution for out to 16 days predictions. 70-km between grid horizontal resolution for forecasts between one week and two weeks.

Data sources	Data Source Volume (Vol), Velocity (Vel), Veracity (Ver), Characteristics/Description (Ch/D)
	Vel: 4 times a day, every 6 hours starting at midnight UTC Ch/D: The Global Forecast System (GFS) is a weather forecast model produced by the National Centers for Environmental Prediction (NCEP). Dozens of atmospheric and land-soil variables are available through this dataset, from temperatures, winds, and precipitation to soil moisture and atmospheric ozone concentration. The entire globe is covered by the GFS at a base horizontal resolution of 18 miles (28 kilometers) between grid points, which is used by the operational forecasters who predict weather out to 16 days in the future. Horizontal resolution drops to 44 miles (70 kilometers) between grid point for forecasts between one week and two weeks.

9.3.3 Specific focus for the uptake of technologies (WP3-WP5)

Table 45: Required focus of requirements elicitation with regard to simulation

T2.4 Simulation and Tools			
Simulated effect	**Relevancy**	**Derived needs**	**Examples/ references**
Forecasted collision position(s) of the involved vessels	Collision mitigation. Simulation of the collision event using the fore-casted vessel paths in VR for supporting decision making in a dynamic environment and reducing uncertainty in action planning Depending on the uncertainty of the fore-casted collision prediction the decision maker(s) may opt to disregard the forecasted collision event or perform mitigation actions that do not sufficiently ensure the avoidance of the collision event in time Decisions include: Which collision mitigation actions should be performed, what is the	The use and visualization of metrics or variables which quantify and interpret the uncertainty of the collision prediction to the end users has the potential to facilitate informed decision making and accurate action planning by the decision makers and the action planners respectively	[40] [41]

	available time horizon to perform them and the possible cooperation with nearby involved vessels through communication <u>Actions include:</u> The change of the vessel course The change of the vessel speed through acceleration or deceleration The route change of the vessel		
Collision mitigation (Rerouting)	In case of a forecasted collision event alternative route suggestions will be provided through a path planning solution. Simulation of the suggested solutions in VR to support decision making in a dynamic environment and reduce uncertainty in action planning. Since path planning takes place in a dynamic environment, it needs to consider the influence of external factors (e.g. model inaccuracies, changing environmental conditions etc.) on the accuracy of the path planning solution. Simulation in VR will verify the validity of the proposed solution and aims to allow the end user to make any necessary corrections. <u>Decisions include:</u> Which alternative route should be selected to avoid a forecasted collision with another	The use and visualization of metrics or variables which quantify and interpret the uncertainty of the path planning solution to the end users has the potential to facilitate informed decision making and accurate action planning by the decision makers and the action planners respectively	[40] [42] [43]

	vessel, how the influence of other factors might affect or alter the decision making and the sequence of required actions to be completed in real time <u>Actions include:</u> The selection of an alternative route The change, monitoring and adaptation of the vessel course The change, monitoring and adaptation of the vessel speed The monitoring of the involved vessel positions, course and speed		
Hazardous Weather Rerouting: Uncertainty in path planning	In case of a hazardous weather event alternative route suggestions will be provided through a path planning solution. Since path planning takes place in a dynamic and changing weather environment, it needs to consider the influence of external factors (e.g. model inaccuracies, continuously changing environmental conditions etc.) and conditionally update the path planning solution. Decision making on vessel rerouting should take place considering the effects of prediction uncertainty especially in long term forecast horizons. The simulation of the different alternatives using VR supports decision making and serves as a basis to verify the validity of the proposed solutions.	The use and visualization of metrics or variables which quantify and interpret the uncertainty of the path planning solution and overlay weather forecast data to the end users has the potential to facilitate informed decision making and accurate action planning by the decision makers and the action planner(s) respectively	VesselAI [44] [45]

The system architecture requirements for performance, scalability, availability and usability are derived from the CREXDATA Maritime Use Case questionnaire survey where the quality-of-service measurement for each of the service-level requirements are defined (see: 4.3.5 Stakeholder requirements).

Table 46: Required focus of requirements elicitation with regard to system architecture

T3.1 - System Architecture		
System quality characteristics	**Collision mitigation (Rerouting) Service Level Significance**	**Hazardous Weather Rerouting Service Level Significance**
Performance	• Update frequency: minute latency • Computation performance: Very important • Prediction accuracy: Very important	• Update frequency: hour latency • Computation performance: Very important • Prediction accuracy: Very important
Scalability	Very important	Very important
Availability	Very important	Important
Interoperability	Important	Important
Personalizability	Moderately important	Moderately important

Table 47: Required focus of requirements elicitation with regard to graphical workflow specification and data fusion

T3.2 - Graphical Workflow Specification and Data Fusion		
RM Operators	**Relevancy**	**Derived needs**
Fusion	Development of new Kafka streams for RapidMiner for fusing different sources of input data from the vessel IoT device, external vessel sensors and weather data sources. Fused data streams will be used for forecasting hazardous maritime events considered in CREXDATA for all involved vessel actors.	Distribution of fused data streams to different AKKA vessel actors for supporting the forecasting and rerouting RM operations.
Forecasting	RM operator for forecasting hazardous maritime events considered in CREXDATA for all involved vessel actors.	Deployment of the forecasting operator to each vessel actor based on event type (collision/hazardous weather). According to the forecasted event parameters rerouting options will be provided to the end user for each vessel actor.

Rerouting	RM operator for rerouting the vessel actors based on the forecasted hazardous maritime events.	Deployment of the rerouting operator to each vessel actor based on event type (collision/hazardous weather).

Table 48: System integration and released software stacks

T3.3 – System Integration and Released Software Stacks	
Components	**Derived needs**
APIs	Integration of all components related to the Maritime Use Case
Security	Security for data at rest and in transit
AKKA	Integration of AKKA with the related Maritime Use Case components
System	System deployment in premises

Table 49: Required focus of requirements elicitation with regard to critical events

T4.1 Complex Event Forecasting			
Complex event type	**Relevancy**	**Derived needs**	**Examples/ references**
Collision Forecasting and Rerouting	Collision avoidance, rerouting	IoT vessel device streams AIS data from Kafka topics data from external onboard sensors (e.g. camera, wind) weather data Route forecasting and collision event predictions for several vessels at the same time up to the next 15min Handling and fusion of data from different sources, arriving inconsistently	VesselAI, INFORE, BigDataOcean [46] [47] [48] [49] [50] [51] [52] [53] [42]
Hazardous Weather Rerouting	Rerouting	IoT vessel device streams	VesselAI, INFORE [54]

		AIS data from Kafka topics Hazardous weather data Handling and fusion of data from different sources, arriving inconsistently	[55] [56] [57] [58] [59]

Table 50: Required focus of requirements elicitation with regard to interactive learning for simulation exploration

T4.2 Interactive Learning for Simulation Exploration		
Complex event type	**Relevancy**	**Derived needs**
Collision and Hazardous Weather Rerouting	Avoidance of the exhaustive search of the solution space for vessel path planning for rerouting purposes Retraining of the path planning model with user defined adjustments and corrections of the suggested path planning solution Cross comparison of the differences between suggested vs. actual rerouting path selected by the decision makers	Deployment of a retraining mechanism Provision of visual analytics tools and functions to the end users for exploring the solution space

Table 51: Required focus of requirements elicitation with regard to distributed computing

T4.4 Optimized Distributed "Analytics as a Service"			
Resource type	**Relevancy**	**Derived needs**	**Examples/ references**
Hardware resources	Optimization of resource deployment for the Maritime Use Case	Detailed technical requirements and goals will be defined at a later stage.	INFORE

Table 52: Required focus of requirements elicitation with regard to uncertainty

T5.3 Visual Analytics for Decision Making under Uncertainty			
Typical uncertainties that might benefit from VA	**Relevancy**	**Derived needs**	**Examples/ references**
Uncertainty of the forecasted collision position(s) of the involved vessels	Collision mitigation. Depending on the uncertainty of the forecasted collision prediction the decision maker(s) may opt to disregard the forecasted collision event or perform mitigation actions that do not sufficiently ensure the avoidance of the collision event in time Decisions include: Which collision mitigation actions should be performed, what is the available time horizon to perform them and the possible cooperation with nearby involved vessels through communication Actions include: The change of the vessel course The change of the vessel speed through acceleration or deceleration The route change of the vessel	The use and visualization of metrics or variables which quantify and interpret the uncertainty of the collision prediction to the end users has the potential to facilitate informed decision making and accurate action planning by the decision makers and the action planners respectively	-

	Communication with the involved vessels and port authorities to mitigate and resolve the collision event through cooperation (by external communication means, not implemented in CREXDATA)		
Collision mitigation (Rerouting): Uncertainty in path planning	In case of a forecasted collision event alternative route suggestions will be provided through a path planning solution. Since path planning takes place in a dynamic and changing environment, it needs to consider the influence of external factors (e.g. model inaccuracies, changing environmental conditions etc.) on the accuracy of the path planning solution <u>Decisions include:</u> Which alternative route should be selected to avoid a forecasted collision with another vessel, how the influence of other factors might affect or alter the decision making and the sequence of required actions to be completed in real time <u>Actions include:</u> The selection of an alternative route The change, monitoring and adaptation of the vessel course The change, monitoring and adaptation of the vessel speed The monitoring of the involved vessel positions, course and speed	The use and visualization of metrics or variables which quantify and interpret the uncertainty of the path planning solution to the end users has the potential to facilitate informed decision making and accurate action planning by the decision makers and the action planners respectively	-

Table 53: Augmented reality at the field

T5.4 Augmented reality at the field			
Situations to be supported by AR	**Relevancy**	**Derived needs**	**Examples/ references**
Vessel route prediction visualization in real-time	Collision avoidance, rerouting	Visualization of (a) vessel traffic in the area, (b) trip and vessel details (speed, MMSI etc.) from AIS messages, (c) sensor data from the vessel, (d) predicted route, (e) notifications for potential collisions. The visualization of the aforementioned parameters in near real time may facilitate and support the decision-making during collision avoidance actions.	-

Table 54: Required focus of requirements elicitation with regard to AR

T5.5 Uncertainty Visualization in Augmented Reality			
Situations to be supported by AR	**Relevancy**	**Derived needs**	**Examples/ references**
Vessel route prediction visualization in real-time	Collision avoidance, rerouting	Visualization of the uncertainty in vessel route prediction and rerouting suggestions. The visualization of the aforementioned parameters in near real time may facilitate and support the decision-making during collision avoidance actions.	INFORE

9.3.4 Stakeholder requirements

Table 55: Requirement Attribute MAR_1_1 of the Maritime Use Case

Req Attribute	Description
ID	MAR_1_1
Version	0.01
Date_Created	02.06.2023
Author_CreatedBy	MarineTraffic
Date_LastChange	28.08.2025 01:13
Author_LastChangeBy	MarineTraffic
Name	Maximum acceptable latency
Description	Maximum acceptable latency of the collision forecasting service for maritime users. This value refers to the time intervals the system checks and updates its state for route and collision prediction Maximum acceptable latency: Minute latency
State	M
Category	Functional
Ref_Pilot	maritime
Ref_Stakeholder	Data Science and Maritime Users
Ref_Associated	Result of the User Requirements Survey (see: 4.3.5)
Discussion	-
ID_ParentReq	MAR_2
ID_ConflictReq	-
ID_TraceToReq	-
ID_DerivedFromReq	-

Table 56: Requirement Attribute MAR_2_1 of the Maritime Use Case

Req Attribute	Description
ID	MAR_2_1
Version	0.01
Date_Created	02.06.2023
Author_CreatedBy	MarineTraffic
Date_LastChange	28.08.2025 01:13
Author_LastChangeBy	MarineTraffic

Req Attribute	Description
Name	Maximum acceptable latency
Description	Maximum acceptable latency of the hazardous weather routing service for maritime users. This value refers to the time intervals the system checks and updates its state for route and collision prediction Maximum acceptable latency: Hour latency
State	M
Category	Functional
Ref_Pilot	maritime
Ref_Stakeholder	Data Science and Maritime Users
Ref_Associated	Result of the User Requirements Survey (see: 4.3.5)
Discussion	-
ID_ParentReq	MAR_2
ID_ConflictReq	-
ID_TraceToReq	-
ID_DerivedFromReq	-

Table 57: Requirement Attribute MAR_1_2 of the Maritime Use Case

Req Attribute	Description
ID	MAR_1_2
Version	0.01
Date_Created	02.06.2023
Author_CreatedBy	MarineTraffic
Date_LastChange	28.08.2025 01:13
Author_LastChangeBy	MarineTraffic
Name	Provided information features to the end-users
Description	The provided information features to the end-users of the collision forecasting service. This value refers to the specific features users require in order to make informed decisions for mitigating maritime collision events. The three most important features that need to be provided are: ETA (Estimated Time of Arrival) to conflict point Prediction confidence Rerouting information with path suggestion
State	M

Req Attribute	Description
Category	Quality
Ref_Pilot	maritime
Ref_Stakeholder	Data Science and Maritime Users
Ref_Associated	Result of the User Requirements Survey (see: 4.3.5)
Discussion	-
ID_ParentReq	MAR_1
ID_ConflictReq	-
ID_TraceToReq	-
ID_DerivedFromReq	-

Table 58: Requirement Attribute MAR_2_2 of the Maritime Use Case

Req Attribute	Description
ID	MAR_2_2
Version	0.01
Date_Created	02.06.2023
Author_CreatedBy	MarineTraffic
Date_LastChange	28.08.2025 01:13
Author_LastChangeBy	MarineTraffic
Name	Provided information features to the end-users
Description	The provided information features to the end-users of the hazardous weather routing. This value refers to the specific features users require to make informed decisions for rerouting the vessel in order to avoid hazardous weather conditions at sea. The three most important features that need to be provided are: ETA to destination port Prediction confidence Rerouting information with path suggestion
State	M
Category	Quality
Ref_Pilot	maritime
Ref_Stakeholder	Data Science and Maritime Users
Ref_Associated	Result of the User Requirements Survey (see: 4.3.5)
Discussion	-
ID_ParentReq	MAR_2

Req Attribute	Description
ID_ConflictReq	-
ID_TraceToReq	-
ID_DerivedFromReq	-

Table 59: Requirement Attribute MAR_1_3 of the Maritime Use Case

Req Attribute	Description
ID	MAR_1_3
Version	0.01
Date_Created	02.06.2023
Author_CreatedBy	MarineTraffic
Date_LastChange	28.08.2025 01:13
Author_LastChangeBy	MarineTraffic
Name	Suggestions for possible courses of action
Description	The collision forecasting service must provide suggestions for possible courses of action. This refers to providing specific instructions in the form of a new path or route for the vessel to avoid an oncoming collision with another vessel.
State	M
Category	Quality
Ref_Pilot	maritime
Ref_Stakeholder	Data Science and Maritime Users
Ref_Associated	Result of the User Requirements Survey (see: 4.3.5)
Discussion	-
ID_ParentReq	MAR_1
ID_ConflictReq	-
ID_TraceToReq	MAR_1_2
ID_DerivedFromReq	MAR_1_2

Table 60: Requirement Attribute MAR_2_3 of the Maritime Use Case

Req Attribute	Description
ID	MAR_2_3
Version	0.01

Req Attribute	Description
Date_Created	02.06.2023
Author_CreatedBy	MarineTraffic
Date_LastChange	28.08.2025 01:13
Author_LastChangeBy	MarineTraffic
Name	Suggestions for possible courses of action
Description	The hazardous weather routing service has to provide suggestions for possible courses of action in case of hazardous weather conditions along the current route. This refers to providing specific instructions in the form of a new path or route for the vessel to avoid entering a hazardous weather sea area.
State	M
Category	Quality
Ref_Pilot	maritime
Ref_Stakeholder	Data Science and Maritime Users
Ref_Associated	Result of the User Requirements Survey (see: 4.3.5)
Discussion	-
ID_ParentReq	MAR_2
ID_ConflictReq	MAR_2_2
ID_TraceToReq	MAR_2_2
ID_DerivedFromReq	-

Table 61: Requirement Attribute MAR_1_4 of the Maritime Use Case

Req Attribute	Description
ID	MAR_1_4
Version	0.01
Date_Created	02.06.2023
Author_CreatedBy	MarineTraffic
Date_LastChange	28.08.2025 01:13
Author_LastChangeBy	MarineTraffic
Name	Frequency of updating mitigation actions
Description	The frequency of updating mitigation actions for the end-users of the collision forecasting service. This value refers to the specific time frequency users demand in case a possible collision is detected for the mitigation actions to be controlled and readjusted by the system

Req Attribute	Description
	Frequency of updating mitigation actions: Every minute
State	M
Category	Functional
Ref_Pilot	maritime
Ref_Stakeholder	Data Science and Maritime Users
Ref_Associated	Result of the User Requirements Survey (see: 4.3.5)
Discussion	-
ID_ParentReq	MAR_1
ID_ConflictReq	-
ID_TraceToReq	-
ID_DerivedFromReq	-

Table 62: Requirement Attribute MAR_2_4 of the Maritime Use Case

Req Attribute	Description
ID	MAR_2_4
Version	0.01
Date_Created	02.06.2023
Author_CreatedBy	MarineTraffic
Date_LastChange	28.08.2025 01:13
Author_LastChangeBy	MarineTraffic
Name	Frequency of updating mitigation actions
Description	The frequency of updating mitigation actions for the end-users of the hazardous weather routing. This refers to the time window in case hazardous weather conditions are detected along the vessel's current route for the service to update the rerouting suggestions. Frequency of updating mitigation actions: Every hour
State	M
Category	Quality
Ref_Pilot	maritime
Ref_Stakeholder	Data Science and Maritime Users
Ref_Associated	Result of the User Requirements Survey (see: 4.3.5)
Discussion	-
ID_ParentReq	MAR_2

Req Attribute	Description
ID_ConflictReq	-
ID_TraceToReq	-
ID_DerivedFromReq	-

Table 63: Requirement Attribute MAR_1_5 of the Maritime Use Case

Req Attribute	Description
ID	MAR_1_5
Version	0.01
Date_Created	06.06.2023
Author_CreatedBy	MarineTraffic
Date_LastChange	28.08.2025 01:13
Author_LastChangeBy	MarineTraffic
Name	Data sources/Datasets for evaluation
Description	The data sources/datasets for the development of the collision forecasting service. • Sea trial/experimental data
State	M
Category	Quality
Ref_Pilot	maritime
Ref_Stakeholder	Data Science and Maritime Users
Ref_Associated	Result of the User Requirements Survey (see: 4.3.5)
Discussion	-
ID_ParentReq	MAR_1
ID_ConflictReq	-
ID_TraceToReq	-
ID_DerivedFromReq	-

Table 64: Requirement Attribute MAR_2_5 of the Maritime Use Case

Req Attribute	Description
ID	MAR_2_5
Version	0.01
Date_Created	06.06.2023
Author_CreatedBy	MarineTraffic

Req Attribute	Description
Date_LastChange	28.08.2025 01:13
Author_LastChangeBy	MarineTraffic
Name	Data sources/Datasets for evaluation
Description	The data sources/datasets for the development of the hazardous weather routing service. • Real-time/Streaming AIS data • Real-time/Streaming IoT vessel data • Historical AIS and weather data
State	M
Category	Quality
Ref_Pilot	maritime
Ref_Stakeholder	Data Science and Maritime Users
Ref_Associated	Result of the User Requirements Survey (see: 4.3.5)
Discussion	-
ID_ParentReq	MAR_2
ID_ConflictReq	-
ID_TraceToReq	-
ID_DerivedFromReq	-

Table 65: Requirement Attribute MAR_1_6 of the Maritime Use Case

Req Attribute	Description
ID	MAR_1_6
Version	0.01
Date_Created	06.06.2023
Author_CreatedBy	MarineTraffic
Date_LastChange	28.08.2025 01:13
Author_LastChangeBy	MarineTraffic
Name	Data sources/Datasets for evaluation
Description	The data sources/datasets for the evaluation of the collision forecasting service. • Sea trial/experimental data
State	M
Category	Quality

Req Attribute	Description
Ref_Pilot	maritime
Ref_Stakeholder	Data Science and Maritime Users
Ref_Associated	Result of the User Requirements Survey (see: 4.3.5)
Discussion	-
ID_ParentReq	MAR_1
ID_ConflictReq	-
ID_TraceToReq	-
ID_DerivedFromReq	-

Table 66: Requirement Attribute MAR_2_6 of the Maritime Use Case

Req Attribute	Description
ID	MAR_2_6
Version	0.01
Date_Created	06.06.2023
Author_CreatedBy	MarineTraffic
Date_LastChange	28.08.2025 01:13
Author_LastChangeBy	MarineTraffic
Name	Data sources/Datasets for evaluation
Description	The data sources/datasets for the evaluation of the hazardous weather routing service. • Historical vessel and weather data
State	M
Category	Quality
Ref_Pilot	maritime
Ref_Stakeholder	Data Science and Maritime Users
Ref_Associated	Result of the User Requirements Survey (see: 4.3.5)
Discussion	-
ID_ParentReq	MAR_2
ID_ConflictReq	-
ID_TraceToReq	-
ID_DerivedFromReq	-

Table 67: Requirement Attribute MAR_1_7 of the Maritime Use Case

Req Attribute	Description
ID	MAR_1_7
Version	0.01
Date_Created	23.06.2023
Author_CreatedBy	Stavroulakis Alexios, Katerina Mania
Date_LastChange	26.06.2023
Author_LastChangeBy	Stavroulakis Alexios, Katerina Mania
Name	AR visualization
Description	This is a draft scenario description to be discussed in subsequent CREX-DATA meetings. The user/captain on board wears head-worn Augmented Reality (AR) glasses such as the Hololens 2 device which transforms their field of view into a holographic overlay of the maritime environment. The AR glasses display a dynamic map with a recommended navigation path based on real-time data. The confidence level of the prediction algorithm showcasing which route to follow to avoid a potential collision is shown, indicating the reliability of the path. The glasses also provide an Estimated Time of Arrival (ETA) of collision, continually updated using ship and traffic data. In cases of data uncertainty, the glasses show alternative routes and cautionary indicators. Once reliable data is available, the display is seamlessly updated. The data required for the AR visualization • Map with recommended navigation path • Confidence of the prediction algorithm in relation to route to follow to avoid a collision event • ETA of collision AR interface features and visualization • Interactive navigation map superimposed on the sea, with dynamic route visualization [60, 61] • Displaying confidence level of the collision • ETA of collision displayed as a countdown timer or distance indicator

Req Attribute	Description
	• Real-time AIS data integrated into the AR display, showing nearby vessels' positions, headings, and speeds [62] • Real-time collision alerts: audible alerts and virtual indicators for risk identification • Alternative navigation paths dynamically calculated to avoid collisions • In cases of data uncertainty, the AR visualization shows alternative routes and cautionary indicators • Fail-safe visualization mode in case of data connection loss, displaying simplified navigational information • Seamless transition back to full AR display when data connection is restored. • Integration with manual navigation tools, experience, and visual observations during data connection loss • Integration of data derived from ship controls as input to the prediction model for routing concerning collision avoidance (maps, sonar, propeller movement and velocity, weather information, ship weight, satellite data, ECDIS, AIS), at different spatial locations of the AR visualization • Exploratory add-ons: Potential transfer of AR visualization to users at land, to aid decision making in real-time in collaboration
State	M
Category	Functional
Ref_Pilot	Maritime
Ref_Stakeholder	Data Science and Maritime Users
Ref_Associated	Result of the User Requirements Survey (see: 1.1.6)
Discussion	-
ID_ParentReq	MAR_1
ID_ConflictReq	-
ID	MAR_1_7
Version	0.01

10 Appendix 3: Uptake of technologies – reference documentation

10.1 WP3 technologies

T3.2 Graphical Workflow Specification

- Enable the graphical design of data processing workflows to facilitate the data analyst correctly process the data.
- Enable different visual analytic tools and interfaces to be easily plugged in.

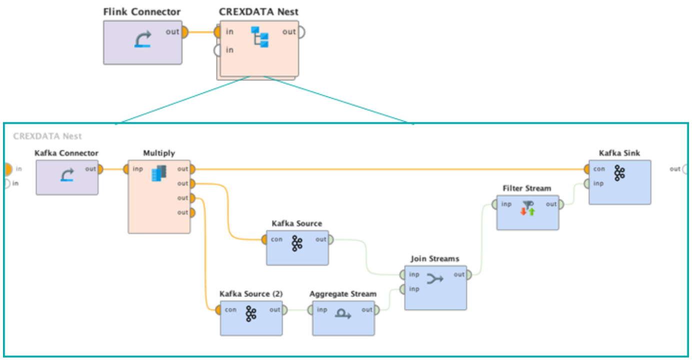


Figure 56: Exemplary screenshot of the Graphical Workflow Specification tool

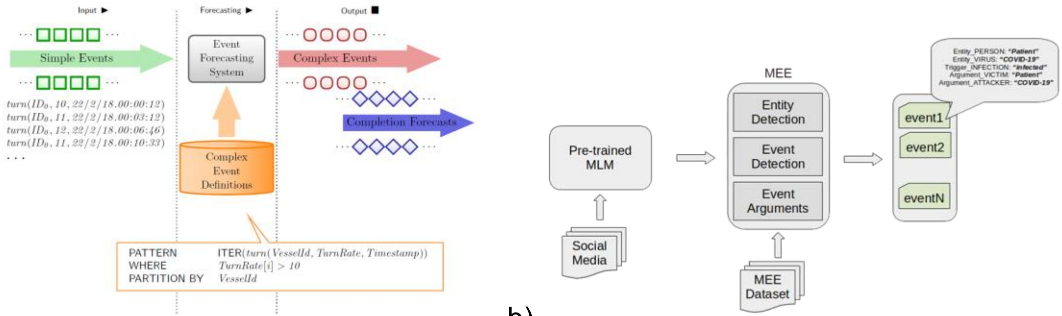
10.2 WP4 technologies

T4.1 Complex Event Forecasting

- Logical description of complex events composed from simple events
- Goal: Long-term forecasting under uncertainty (short-, medium-, long-term) with explainable forecasts

T4.5 Text Mining for Event Extraction

- Identification of the entities mentioned in the text, such as people, organizations, locations, and dates.
- Identification of event triggers
- Identification of event arguments, i.e. entities participating in the corresponding event trigger.



a) b)

Figure 57: Exemplary visualisations for T4.1 and T4.5

T4.2 Interactive Learning for Simulation Exploration

- Develop algorithms for guiding large-scale simulations towards desired ends
- Learning through parametrization, adapting to changing environments
- Combine interactive learning, i.e., advanced visual analytics tools to support experts

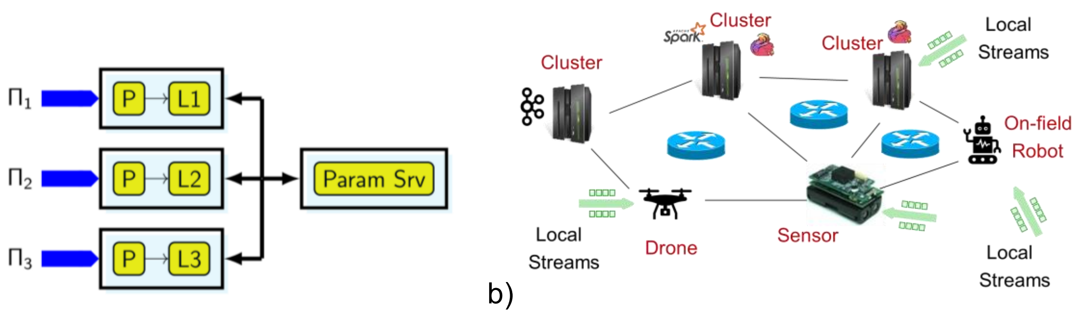
Figure 58: Exemplary visualisations for T4.2

T4.3 Federated Machine Learning

- Idea: Keep data local (do not centralize), Bring the model to the data, not the data to the model.
- Challenges: learning speed, network cost.

T4.4 Optimized Distributed "Analytics as a Service"

- Avoid communication (data transfer) as long as no relevant events occur
- Expand the performance of the entire system using distributed resources



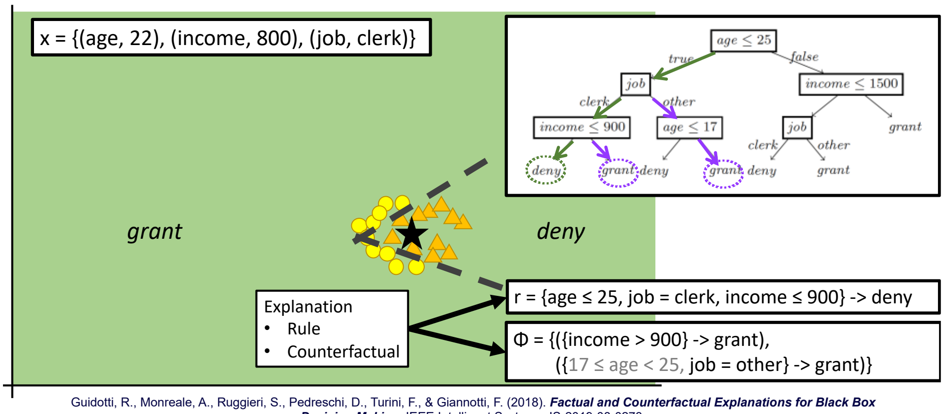
a) b)

Figure 59: Exemplary visualisations for T4.3 and T4.4

10.3 WP5 technologies

T5.1 Explainable AI

- Presenting in a human-comprehensible way the results of computations
- Explaining the internal logic of the models
- Interactive exploration by means of visualization and exploration



Guidotti, R., Monreale, A., Ruggieri, S., Pedreschi, D., Turini, F., & Giannotti, F. (2018). ***Factual and Counterfactual Explanations for Black Box Decision Making***. IEEE Intelligent Systems, IS-2019-08-0273.

Figure 60: Exemplary visualisations for T5.1

T5.2 Visual Analytics supporting XAI

- generalize, summarize, and organize output so that the user can grasp the overall logic and proceed to more specific information on demand
- organize and represent information at an appropriate level of abstraction by means of domain concepts

T5.3 Visual Analytics for Decision Making under Uncertainty

- make users aware of various kinds of uncertainties present in the information they receive and to allow them to deal with these uncertainties in reasoning and decision making
- representation of forecasts with integrated uncertainty markers and measures

T5.4 Augmented reality at the field

- Off and on site AR visualization for collaboration and single use, in mobile or head-word AR.
- Data streaming /prediction of future state in an emergency directed to the AR user in real-time.
- The AR user will concurrently and on-site provide data to a control room and get instructions.
- Collaborative data sharing.

T5.5 Uncertainty Visualization in Augmented Reality

- Appropriate visual or multimodal cues to extend the visualization past a deterministic feature of the data.
- Based on data and forecasts, deploy animation, data vis for uncertainty visualization, not a deterministic feature of the data.

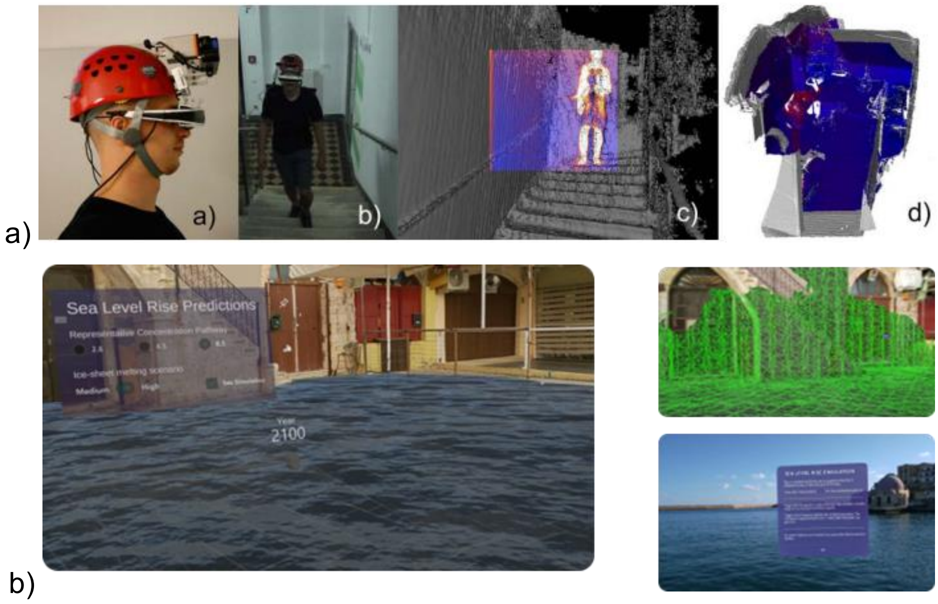


Figure 61: Exemplary visualisations for T5.4/T5.5

11 Appendix 4: Maritime Use Case: User Requirements Survey

The Annex includes the questionnaires distributed to Data Scientists and Maritime Users in order to extract the user requirements for the Maritime Use Case.

11.1 CREXDATA Maritime Use Case: Data Science Requirements Questionnaire

CREXDATA Maritime Use Case: User Requirements Survey

Project Overview

CREXDATA is a three-year EU-funded H2020 research project aiming to develop a generic platform for real-time critical situation management, flexible action planning and agile decision using extreme scale and complex data.

Three use cases will be used to evaluate project results. These use cases include:

- **Maritime domain, for forecasting hazardous situations at sea.**
- Weather emergency management, to allow authorities and first responders proactively act in the case of natural disasters.
- Health crisis management, to limit pandemic outbreaks and come up with non-pharmaceutical means of patient treatment.

Maritime Use Case

The purpose of this use case is to develop the first solution, combining hardware and software development, that will be able to use data coming from a vessel's VDR, which will be fused with global views of data creating reliable digital twins of vessels. It will develop the first weather and emergency routing and route forecasting solutions that will be performed for all vessels of a fleet simultaneously (instead of on-demand requests per vessels) and that will rely on big data and AI technologies.

Purpose of this Survey
This questionnaire will take about 5 minutes to complete and your answers will help us better understand the requirements of different stakeholders in designing the maritime use case of the CREXDATA project in the context of hazardous situation forecasting and mitigation at sea.

More information can be found in the project's website: crexdata.eu

* Indicates required question

1. Email *

Privacy statement

The answers provided will be collected by MarineTraffic and will be shared with the CREXDATA consortium for research purposes solely, within the context of the CREXDATA project.

The data provided will be recorded and preserved in our archive for a period of up to six months. All data will be treated confidentially, within the boundaries of the CREXDATA consortium. Anonymized information will be aggregated, processed and may be presented in public project reports. No personal data will be shared to third parties. You can request that your information be deleted at any time, without giving a reason. If you wish to do so, please submit your request in the following form and the requested data clearance will take place within 10 business days: CREXDATA Survey data removal

Your participation in this study is only possible if you freely and independently agree to authorize the CREXDATA consortium to use the data you provide.

2. Consent *

Check all that apply.

☐ I agree to proceed to the survey.

Respondent Information

3. Country *

Mark only one oval.

4. Type of organisation *

Mark only one oval.

◯ Industry
◯ Academia/Academic Research
◯ Public Authority
◯ Non-governmental Organisation
◯ Other: ____________________

5. Domain of expertise *

Mark only one oval.

- ◯ Shipping industry (ship owners, brokers, charterers)
- ◯ Shipbuilding, naval engineering
- ◯ Vessel tracking/mobility
- ◯ Logistics operators
- ◯ Operations management
- ◯ Insurance
- ◯ Civil Security
- ◯ Environment
- ◯ Machine learning, AI
- ◯ Big data technologies & infrastructure
- ◯ Software engineering
- ◯ Other: ______________________

6. Name of organisation *

____

7. Website of organisation *

____

Maritime Use Case: Hazardous Event Forecasting

The following maritime hazardous events have been identified by the consortium during the project appraisal phase:

1. Collision
2. Hazardous weather

For these hazardous events, forecasting and routing services will be developed and assessed. The forecasting services may address either short-term or long- term prediction horizons:

1. Short-term prediction horizon: =< 30 minutes
2. Long-term prediction horizon: > 30 minutes (e.g. 1hr, 12hr day etc.)

The output of these algorithms will be visualized to the end-users. The end-users will be able to view the forecast motion of vessels in the future, together with the confidence level of each predicted/suggested route.

In the following questions the main goal is to quantify and assess the significance of the proposed services for the maritime industry as well as define the requirements of the end-users for the respective services.

9. How would you rate the importance of forecasting the following maritime hazardous events? *

Mark only one oval per row.

	Not at all important	Not important	Neutral	Important	Very important	No opinion
Collision forecasting (=<30 minutes)	⬭	⬭	⬭	⬭	⬭	⬭
Hazardous weather routing	⬭	⬭	⬭	⬭	⬭	⬭

10. What is the maximum acceptable latency of forecasting the following maritime hazardous events in order to make informed decisions? *

Mark only one oval per row.

	Sub-second latency	minute latency	15-minute latency	30-minute latency	hour latency	12-hour latency	No Opinion
Collision forecasting (=<30 minutes)	⬭	⬭	⬭	⬭	⬭	⬭	⬭
Hazardous weather routing	⬭	⬭	⬭	⬭	⬭	⬭	⬭

11. Which information would you expect to receive from the corresponding forecasting service (short-term/long-term)? *

Check all that apply.

	ETA to destination port	ETA to conflict point	Prediction confidence	Trajectory prediction of nearby vessels	Trajectory prediction of own vessel	Rerouting information with path suggestion	Forecasted energy consumption/CO2 emission	No Opinion
Collision forecasting (=<30 minutes)	☐	☐	☐	☐	☐	☐	☐	☐
Hazardous weather routing	☐	☐	☐	☐	☐	☐	☐	☐

12. Which type of information is relevant for developing services for the prediction of the following maritime hazardous events? *

Check all that apply.

	Vessel position	Vessel speed	Vessel course	Vessel acceleration	Wind speed	Wind direction	Wave height and direction	Bathymetry	Other weather data	Data from sensors onboard (radar, ECDIS, cameras, engine sensors, etc.)	No Opinion
Collision forecasting (=<30 minutes)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Hazardous weather routing	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

13. Which additional information would you expect to receive from the corresponding service that was not listed in the previous question (short-term/long-term)?

14. Based on your experience in Data Science briefly list and describe the most critical data processing challenges for developing services for predicting maritime hazardous events. *

15. Which different data sources would you use to develop the following services (choose max 3 options)? *

Check all that apply.

	Historical AIS data	Real-time/Streaming AIS data	Historical IoT vessel data	Real-time/Streaming IoT vessel data	Historical weather data	Real-time/Streaming weather data	No Opinion
Collision forecasting (=<30 minutes)	☐	☐	☐	☐	☐	☐	☐
Hazardous weather routing	☐	☐	☐	☐	☐	☐	☐

16. Which data source would you prefer to use to evaluate the following services efficiently? *

Mark only one oval per row.

	Historical hazardous event data	Historical vessel data	Simulated/Augmented data	Sea trial/experimental data	Realtime vessel data	No Opinion
Collision forecasting (=<30 minutes)	◯	◯	◯	◯	◯	◯
Hazardous weather routing	◯	◯	◯	◯	◯	◯

17. Collision forecasting (=<30 minutes): Please rate your expectations regarding the service quality and usability features (1 to 10 scale. 1= least important, 10=most important). *

Mark only one oval per row.

	1	2	3	4	5	6	7	8	9	10
Computation performance	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭
Prediction accuracy	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭
Scalability	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭
Update frequency	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭
Easy integration with existing workflows	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭
API availability	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭
Attractive UI/UX	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭
Graphical personalization and parameter adaptation	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭

18. Hazardous weather routing: Please rate your expectations regarding the service quality and usability features (1 to 10 scale. 1= least important, 10=most important). *

Mark only one oval per row.

	1	2	3	4	5	6	7	8	9	10
Computation performance	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Prediction accuracy	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Scalability	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Update frequency	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Easy integration with existing workflows	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Task automation	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
API availability	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Attractive UI/UX	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯
Graphical personalization and parameter adaptation	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯

19. Are there specific hazardous events that you would like to forecast in real-time, which you currently cannot forecast and were not considered in this survey? (Please describe them briefly)

20. Please feel free to add any other comments you may have. Thank you for your participation!

11.2 CREXDATA Maritime Use Case: Maritime Users Requirements Questionnaire

CREXDATA Maritime Use Case: User Requirements Survey

Project Overview

CREXDATA is a three-year EU-funded H2020 research project aiming to develop a generic platform for real-time critical situation management, flexible action planning and agile decision using extreme scale and complex data.

Three use cases will be used to evaluate project results. These use cases include:

- **Maritime domain, for forecasting hazardous situations at sea.**
- Weather emergency management, to allow authorities and first responders proactively act in the case of natural disasters.
- Health crisis management, to limit pandemic outbreaks and come up with non-pharmaceutical means of patient treatment.

Maritime Use Case

The purpose of this use case is to develop the first solution, combining hardware and software development, that will be able to use data coming from a vessel's VDR, which will be fused with global views of data creating reliable digital twins of vessels. It will develop the first weather and emergency routing and route forecasting solutions that will be performed for all vessels of a fleet simultaneously (instead of on-demand requests per vessels) and that will rely on big data and AI technologies.

Purpose of this Survey
This questionnaire will take about 5 minutes to complete and your answers will help us better understand the requirements of different stakeholders in designing the maritime use case of the CREXDATA project in the context of hazardous situation forecasting and mitigation at sea.

More information can be found in the project's website: crexdata.eu

* Indicates required question

1. Email *

Privacy statement

The answers provided will be collected by MarineTraffic and will be shared with the CREXDATA consortium for research purposes solely, within the context of the CREXDATA project.

The data provided will be recorded and preserved in our archive for a period of up to six months. All data will be treated confidentially, within the boundaries of the CREXDATA consortium. Anonymized information will be aggregated, processed and may be presented in public project reports. No personal data will be shared to third parties. You can request that your information be deleted at any time, without giving a reason. If you wish to do so, please submit your request in the following form and the requested data clearance will take place within 10 business days: CREXDATA Survey data removal

Your participation in this study is only possible if you freely and independently agree to authorize the CREXDATA consortium to use the data you provide.

2. Consent *

Check all that apply.

☐ I agree to proceed to the survey.

Respondent Information

3. Country *

Mark only one oval.

4. Type of organisation *

Mark only one oval.

◯ Industry
◯ Academia/Academic Research
◯ Public Authority
◯ Non-governmental Organisation
◯ Other: ____________________

5. Domain of expertise *

Mark only one oval.

- ◯ Shipping industry (ship owners, brokers, charterers)
- ◯ Shipbuilding, naval engineering
- ◯ Vessel tracking/mobility
- ◯ Logistics operators
- ◯ Operations management
- ◯ Insurance
- ◯ Civil Security
- ◯ Environment
- ◯ Machine learning, AI
- ◯ Big data technologies & infrastructure
- ◯ Software engineering
- ◯ Other: ____________________

6. Name of organisation *

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7. Website of organisation *

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Maritime Use Case: Hazardous Event Forecasting

The following maritime hazardous events have been identified by the consortium during the project appraisal phase:

1. Collision
2. Hazardous weather

For these hazardous events, forecasting and routing services will be developed and assessed. The forecasting services may address either short-term or long- term prediction horizons:

1. Short-term prediction horizon: =< 30 minutes
2. Long-term prediction horizon: > 30 minutes (e.g. 1hr, 12hr day etc.)

The output of these algorithms will be visualized to the end-users. The end-users will be able to view the forecast motion of vessels in the future, together with the confidence level of each predicted/suggested route.

In the following questions the main goal is to quantify and assess the significance of the proposed services for the maritime industry as well as define the requirements of the end-users for the respective services.

9. How would you rate the importance of forecasting the following maritime hazardous events? *

Mark only one oval per row.

	Not at all important	Not important	Neutral	Important	Very important	No opinion
Collision forecasting (=<30 minutes)	⬭	⬭	⬭	⬭	⬭	⬭
Hazardous weather routing	⬭	⬭	⬭	⬭	⬭	⬭

10. What is the maximum acceptable latency of forecasting the following maritime hazardous events in order to make informed decisions? *

Mark only one oval per row.

	Sub-second latency	minute latency	15-minute latency	30-minute latency	hour latency	12-hour latency	No Opinion
Collision forecasting (=<30 minutes)	⬭	⬭	⬭	⬭	⬭	⬭	⬭
Hazardous weather routing	⬭	⬭	⬭	⬭	⬭	⬭	⬭

11. Which information would you expect to receive from the corresponding forecasting service (short-term/long-term)? *

Check all that apply.

	ETA to destination port	ETA to conflict point	Prediction confidence	Trajectory prediction of nearby vessels	Trajectory prediction of own vessel	Rerouting information with path suggestion	Forecasted energy consumption/CO2 emission	No Opinion
Collision forecasting (=<30 minutes)	☐	☐	☐	☐	☐	☐	☐	☐
Hazardous weather routing	☐	☐	☐	☐	☐	☐	☐	☐

12. Which type of information is relevant for informed decision making in the following maritime hazardous event scenarios? *

Check all that apply.

	Vessel position	Vessel speed	Vessel course	Vessel acceleration	Wind speed	Wind direction	Wave height and direction	Bathymetry	Other weather data	Data from sensors onboard (radar, ECDIS, cameras, engine sensors, etc.)	Other local data (e.g., image data from drones, cameras)
Collision forecasting (=<30 minutes)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Hazardous weather routing	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

13. Which additional information would you expect to receive from the corresponding service that was not listed in the previous question (short-term/long-term)?

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14. Would you like to also receive suggestions for possible courses of action? *

Mark only one oval per row.

	Yes	Maybe	No	No Opinion
Collision forecasting (=<30 minutes)	⬭	⬭	⬭	⬭
Hazardous weather routing	⬭	⬭	⬭	⬭

15. In case of a maritime hazardous event detection that dynamically changes over time, how often would you need to be able to adapt or reevaluate your mitigation actions? *

Mark only one oval per row.

	1 time after detection (no further action is possible)	every second after detection	every minute after detection	every hour after detection	No Opinion
Collision forecasting (=<30 minutes)	⬭	⬭	⬭	⬭	⬭
Hazardous weather routing	⬭	⬭	⬭	⬭	⬭

16. Collision forecasting (=<30 minutes): Please describe the typical action task workflow and decision making process after this maritime incident has been detected in a maritime scenario. *

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17. Hazardous weather routing: Please describe the typical action task workflow and decision making process after this maritime incident has been detected in a maritime scenario. *

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Further information

18. Are there specific hazardous events that you would like to forecast in real-time, which you currently cannot forecast and were not considered in this survey? (Please describe them briefly)

19. Please feel free to add any other comments you may have. Thank you for your participation!