

User requirement and technical specifications of the decision-support tools

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Executive Summary

As part of the MIRACA project, one of the key outcomes is the development of two decision-support tools: A python workbench aimed at performing climate risk assessment and adaptation appraisal and an exploratory visualisation dashboard to showcase examples of MIRACA's climate risk assessment for critical infrastructure. The aim of these tools is to make the information generated within the project accessible to end-users, provide access to the data and models developed and show examples of use cases where the methodology is applied.

In order to create decision-support tools that are designed with the end-users in mind, the deliverable focuses on the identification of the main target audiences of the tools. This deliverable provides context on the current approaches that target audiences of the tools have towards climate risk assessment, their uncertainties, limitations and the potential needs that this project should address.

The input of this deliverable comes from a set of discussion sessions carried out during 2023 organised both within the MIRACA partners and the stakeholders that will be involved in the five Use Cases of this project. The outputs of these discussions are used to describe an initial set of requirements that the tools will need to address to meet the user needs. In addition, a description of the system's architecture is also presented for both tools, highlighting the back-end and front-end components and associated costs.



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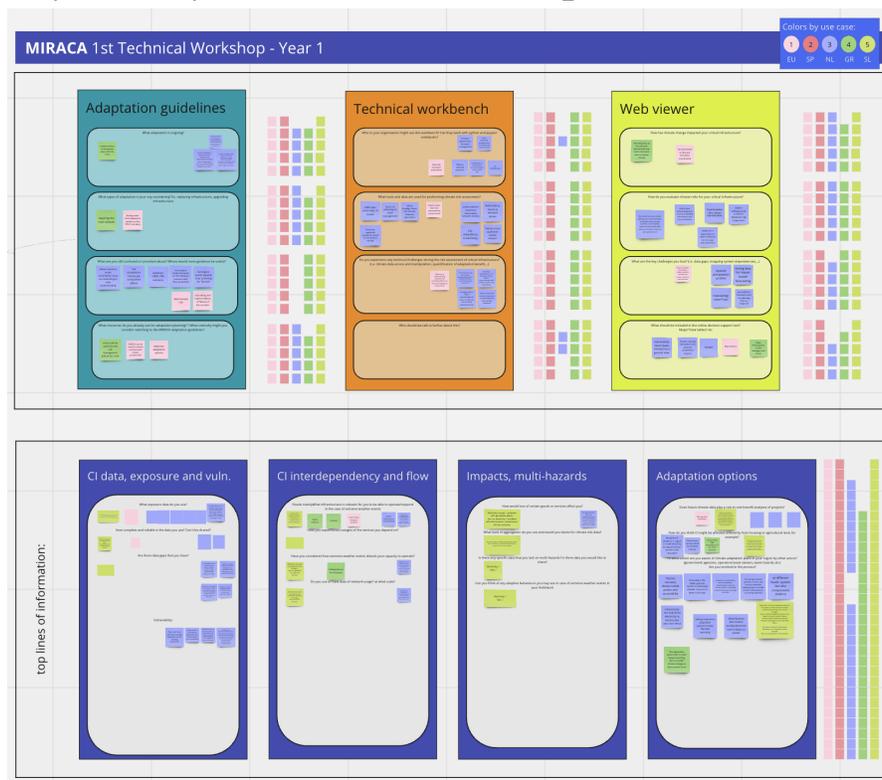
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1. Introduction and user research methodology

The purpose of this document is to define the main user-facing results of the project, namely the online exploratory Critical Infrastructure (CI) Climate Adaptation Decision-Support Tool and the developer-oriented CI Climate Adaptation Workbench.

This deliverable provides a starting point for the definition of the main requirements for the decision-support tools. The inputs of the deliverable are obtained from multiple discussions during 2023 both between the project partners (internal discussion sessions) and with the involved stakeholders of the Use Case. In particular, two major brainstorming sessions were organised: the 1st Stakeholder Engagement Session¹ which took place virtually on the 6th November 2023, and an Internal User Requirement Session² organised online on the 21st November 2023 (Figure 1). In Annex 1 we give more detail on the topics and questions addressed during the 1st Stakeholder Session.



¹ MIRACA 1st Stakeholder Session - https://miro.com/app/board/uXjVNyligYc=

² Internal User Requirement Session - https://miro.com/app/board/uXjVNet7Dpw=



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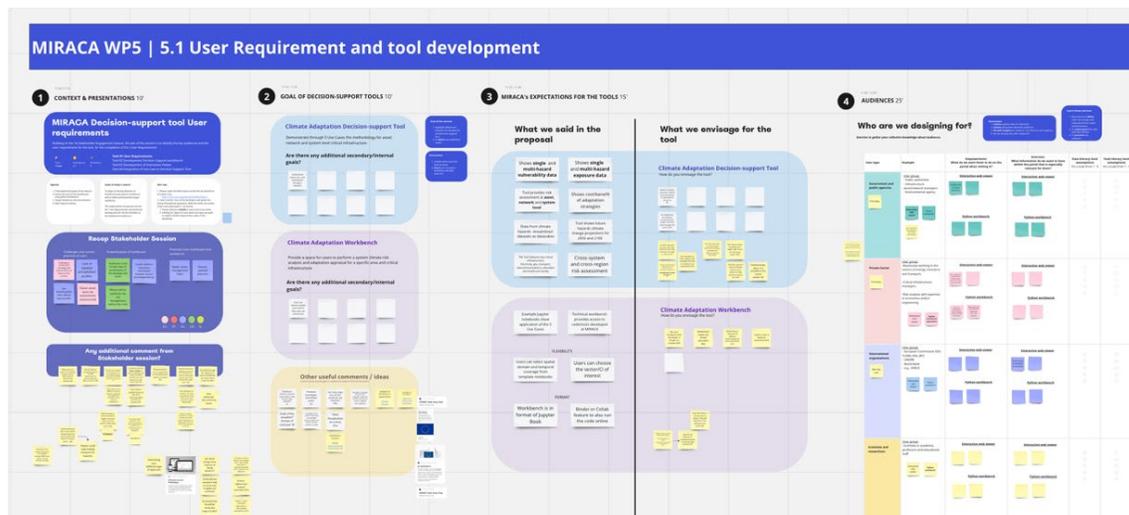


Figure 1. Screenshot of the two brainstorming sessions with key stakeholders (top image) and with the MIRACA consortium (bottom image).

The technical requirements set in this deliverable will be the foundation of the next deliverable D5.2 - Development of the decision-support workbench that will start from January 2023 onwards, which will go deeper into the features that the decision-support tool will have.

The document is organised in six sections:

1. **Purpose of decision-support tools:** Revisit the original goal of the decision-support as described in the project description and its evolution since the start of the project.
2. **Stakeholder identification:** This includes an overview of the key stakeholders, their role in the project, and how the project will engage with them.
3. **User persona and stories:** This provides an end-to-end description of specific user stories to show, through specific examples, the interactions of the users with the decision-support tools.
4. **Functionalities of the tools:** After taking into consideration the project objectives and the stakeholders needs, this section gives a preliminary overview of the key features that the decision-support tools should include to respond to the user needs. This is meant to be refined over time, as the tool is developed and reviewed during the project duration.



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5. **System architecture:** Provides an overview of back-end and front-end of the system.
6. **Operating costs:** Based on the technical requirements and system architecture, a preliminary estimate of the potential costs is provided.

2. Purpose of the decision-support tools

There are two distinct decision-support tools that will be generated as part of the MIRACA project, which aim to address different needs:

- **Technical workbench:** Python-based notebooks combining the models and code development from the project into a unified open-access Jupyter Book.
- **Exploratory online viewer:** User-friendly online interactive tool, to assess single and multi-hazard risk and adaptation strategies on an asset, network and system level for Europe.

The purpose of the **technical workbench** is to provide a space for users to perform a climate risk assessment and adaptation appraisal for a specific area and critical infrastructure levels. In addition, the aim of the workbench is to allow users to access and download the data and models developed as part of the MIRACA framework, being not only a place to carry out climate risk assessment, but also a place to retrieve data generated within the project, such as hazard, exposure, vulnerability data and models.

The purpose of the **exploratory viewer** is to demonstrate through 5 Use Cases the methodology for asset, network and system level climate risk assessment for critical infrastructure. For this, the goal is to go beyond the visualisation of data, and use the viewer to describe the MIRACA methodological framework through examples.

3. Identification of targeted user communities

There is a wide range of stakeholders that will use the exploratory dashboard and python workbench, each one having their own challenges and needs that this project aims to cover. Based on the initial discussions with stakeholders, there will be two specific groups of users, some with more technical expertise that aim to have access to the datasets and models developed in great detail, and users with less technical



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expertise who will primarily use the project outcomes to make informed decisions from the outcomes of the climate risk assessment.

To focus the tool development to the specific user needs, in this section, we describe the key target audiences and examples of potential users. Then, for each audience we make an initial differentiation of what their main decision-support tool will be of interest. This classification is meant to provide an initial overview of which of the target audiences will be more inclined to use each of the two decision-support tools. Overall there are six main target audiences (Table 1):

Table 1. *Target audiences and potential users of the decision-support tools*

Target audience	Main users	Technical workbench	Exploratory viewer
Government agencies and policymakers	<ul style="list-style-type: none"> - Public authorities - Environmental agencies at a local, national and regional level - Local authorities and infrastructure development departments 		x
Asset and network managers	<ul style="list-style-type: none"> - Critical infrastructure and network managers for telecommunications, gas, transport,... 	x	
Private sector	<ul style="list-style-type: none"> - Businesses working in the sectors of energy, insurance and transport. - Risk analysts with expertise in economics and/or engineering 	x	x
International organisations and NGOs	<ul style="list-style-type: none"> - European Commission (DG-CLIMA, DG-ECHO, EEA, JRC); - UNFRR, UNFCCC - Development Banks - NGOs (e.g., Resilience shift, Coalition for Disaster Resilience Infrastructure) 	x	x
Science and research	<ul style="list-style-type: none"> - Scientists - Risk analysts in private & public institutes 	x	
Wide audience	<ul style="list-style-type: none"> - General public 		x



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	- People living in Use Case regions		
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Government and public agencies

Government agencies have a role in policy making. Their main interest is in identifying key actionable insights that they can use to inform policy decisions and strategies on climate adaptation. They will benefit from the project if they have accessible information, such as the location of hotspots of critical infrastructure or different adaptation options available for critical infrastructure systems. Therefore, their main interest will be in the exploratory viewer, as it provides more easy-to-understand information with a complete climate risk methodology.

Asset and network manager

Critical infrastructure asset and network managers have the main task to ensure the reliability, security, and resilience of critical infrastructure, such as roads, and telecommunications. Related to MIRACA, their main task is to develop and implement resilience plans to mitigate and adapt to the impact of natural disasters. Each manager has specific levels of in-house development. Some obtain data from public datasets and government sources and combine it with information of the asset. For others, there are systems in place for performing climate risk assessment. For this audience, the technical workbench allows them to extract data and models from the MIRACA framework to complement their existing approaches.

International Organisations and NGOs

Similarly to government and public agencies, the EU Commission and international organisations will use the MIRACA project to support evidence-based policymaking and inform people on the existing methodology for climate risk assessment. For them, their interest is in the wider picture of the project.

For international organisations, specially development banks, they have in-house technical expertise. As part of their work, they have specific datasets, from impact-based indicators and the KPIs of climate adaptation projects. For them, having access to the technical workbench would be useful, as it would allow them to integrate for knowledge transfer and capacity building activities.

The primary goal of non-governmental organisations (NGOs) is to raise awareness on the impacts of climate change. Their main interest is in showing visual narratives and stories to communicate complex climate science to a broad audience. For them, the exploratory viewer is also the main interest tool, as it will give them a platform with developed examples of how the MIRACA climate risk methodology can help (i) map climate risks and (ii) drive adaptation action.



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Private sector

The private sector comprises a wide range of users from managers of critical infrastructure, engineers, asset managers and spatial planners. Overall they have the task of maintaining critical infrastructure as well as carrying out risk assessment. There are different levels of expertise in climate risk assessment; some companies will already have climate risk assessment methodologies in place, as well as access to specific datasets, whereas others will rely on external organisations for the climate risk assessment.

For them, the main benefit of the MIRACA project will be in complementing their current knowledge and work on climate risk assessment adaptation appraisal. This includes accessing and downloading additional datasets for hazard and vulnerability and improving the risk assessment by accessing models developed as part of the MIRACA framework. For this audience, the python workbench will be the main decision-support tool.

Science and research

Researchers in the field of climate change risk assessment and adaptation have high data literacy. Since MIRACA covers the full climate risk assessment approach, the outcomes of the project will be of interest to many different disciplines, from climate modellers, climate adaptation researchers, structural engineers, etc... Within this group, there is a high technical expertise, and most have knowledge on existing datasets related to their field. For them, the main benefit from the project will come from the Python Workbench. Having access to additional datasets identified and developed as part of the MIRACA project, and selecting specific models that they can integrate into their current research.

Wider audience

The general public represents a diverse group of people with varying levels of expertise in climate. They are individuals interested in understanding the impacts of climate change and their main interest is in engaging with interactive and visual stories showing the climate risk assessment. For them, it is expected that their main interest will be the exploratory viewer.

The description of the target audiences is meant to inform on the wide range of users that are expected to use the decision-support tools. By classifying each target audience into each of the main decision-support tools, we aim to facilitate the identification of user needs and the tool requirements. It is important to highlight that this classification is not exclusive, as it assumes any user can access both of the



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decision-support tools. During the development of the decision-support tools, the user needs of each target audience will be refined.

4. User persona and stories

In order to define the features and functionalities of the online exploratory viewer and python workbench, three user personas and stories have been developed from stakeholders that have different levels of technical expertise and needs of the project:

- Private Sector: Spatial planner from a telecommunications company in The Netherlands
- Public sector: Asset manager of the Rhine-Alpine TEN-T corridor
- Regional authority: Technician at the Department of Territory and Sustainability of Catalonia

User Persona	Spatial planner from a telecommunications company in The Netherlands
Data literacy	High data literacy. Experience in processing specific climate hazard data from public sources.
Objectives and responsibilities	
<ul style="list-style-type: none"> • Asset management: Maintain inventory of telecommunication assets, including the network infrastructure and its condition. • Risk management: Identify and assess risks associated with telecommunications assets. • Mitigation and Adaptation: Implement risk mitigation and adaptation strategies to ensure the continuity of services. • Business continuity: To avoid disruptions and reduce maintenance and repair costs. 	
Challenges	
<ul style="list-style-type: none"> • For some hazards, current tools only provide information on the current climate (historical). 	



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- Identify what are the hotspots of critical infrastructure at a network and system level.
- How to move from asset-level vulnerabilities to network and system level risks.
- Understand the risk for other infrastructure that is not theirs (e.g. electricity).

Tool Requirements

- Historical climate hazard data available both at a single and multi-hazard level.
- Projections of future climate scenarios for the main climate hazards.
- Information about what are the key climate hazards that can affect telecommunication critical infrastructure.
- Information and access to available open-source hazard and vulnerability datasets.
- Option to download datasets and models developed within MIRACA.

User Persona	National transport authority of the Rhine-Alpine TEN-T corridor
Data literacy	Technical expertise for the transport field. Not expertise in climate change data analysis.
Objectives and responsibilities	
<ul style="list-style-type: none"> ● Risk assessment: Identify what are the hotspots of critical infrastructure at a network and system level. ● Adaptation appraisal: Identify the different adaptation options that they have to address climate risks. 	
Challenges	
<ul style="list-style-type: none"> ● Identify the cascading and indirect effects of failure of the corridor. ● How multi-hazard risk can impact the TEN-T corridor. ● Current adaptation planning focuses mainly at an asset-level. ● Difficulty in interpreting complex climate models. 	
Tool Requirements	



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- Integration of multi-tier adaptation options.
- Provides how critical infrastructure systems can fail due to cascading and indirect effects.
- Addition of specific risk metrics tailored to the day-to-day risk assessment activities.

User Persona	Technician in the Transport Planning and Sectoral Development Group of the Catalonia's Department of Territory and Sustainability.
Data literacy	Technical expertise for the transport field. Not expertise in climate change data analysis.
Objectives and responsibilities	
<ul style="list-style-type: none"> ● Regulation: Plan, coordinate, execute and monitor the general policy of road, rail and cable transport, ports and airports. ● Sectoral development: Plan and, where appropriate, design and build the infrastructure and equipment specific to the service. ● Asset management: Prioritise and perform maintenance of the infrastructure. 	
Challenges	
<ul style="list-style-type: none"> ● Data Interpretation: Difficulty to interpret complex climate data, such as multi-hazard and cascading events. ● Hotspot identification: Lack of awareness of the critical hotspots due to physical climate risks. ● resources measures: Need to identify key hotspots from high exposure and vulnerability assets. ● Adaptation appraisal: Difficulty in understanding the positive impact that different adaptation measures will have on the asset. 	
Tool Requirements	
<ul style="list-style-type: none"> ● Users can visualise the infrastructure shapefile in the viewer. ● The tool provides clear, easily understandable visualisations of climate hazards and summaries to aid decision-making. 	



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- The tool provides, at a generic level, the guidelines to develop effective adaptation strategies.
- Climate risk assessment allows for prioritisation of repair/maintenance activities in hotspot areas based on climate stress tests.
- Different climate hazards can be shown to the viewer together with the asset to understand the implications of climate risks on the transport network.
- Storylines in the viewer allows users to formulate practical adaptation strategies based on identified risks.

The User Personas in this document will be regularly updated and refined upon the feedback with the real users, in order to ensure that the decision-support tools address their needs over the project duration.

4. Functional requirements

The functional requirements outline the core features and capabilities that the decision-support tool should include. These requirements are essential for achieving the intended functionality and providing a comprehensive user experience.

Table 2. *Key functional requirements of the tool based in identified issues of the stakeholders*

Topic	Identified issues	Requirements
Data availability	Some users are not aware of the availability of other hazard and vulnerability data sources.	The python workbench provides information of the most-recent hazard and vulnerability datasets available at the European level.
Data availability	Some users have in-house climate risk assessments. In addition, some have infrastructure data that can't be shared.	The tool (mainly the python workbench) has the option to download the datasets and models developed within MIRACA.



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Climate change Scenarios	Not all hazard datasets currently used incorporate climate change projections.	The tools shows hazards for the future due to climate change for 2050 and 2100 according to guidelines set by the European Commission ³ .
Climate change Scenarios	Frequency of extreme phenomena has increased due to climate change and is experienced by CI managers.	Visualisation tool shows the historic trends in climate hazards and how it will change into the future.
Interdependency of Critical infrastructure	Critical infrastructure managers want to know how their infrastructure interacts with other CI	The exploratory viewer shows the interaction between different critical infrastructures, such as electricity and gas.
Climate hazard assessment methodology	Some operators don't know which climate hazard is most relevant for their CI	The use cases cover a variety of critical infrastructure systems to show what key hazards affect each CI.
Climate risk assessment methodology	Some users don't have expertise in carrying out climate risk assessment across users	The exploratory viewer shows easy-to-follow examples of the application of the MIRACA climate risk methodology
Climate hazard assessment methodology	There is uncertainty on how to incorporate multi-hazard risk assessment into current risk assessment	Tools provides multi-hazard footprint datasets
Climate adaptation options	Some users mainly focused on asset-level adaptation options	Tools differentiate risk assessment at asset, network and system level

³ Commission Notice — Technical guidance on the climate proofing of infrastructure in the period 2021-2027 (OJ C, C/373, 16.09.2021, p. 1, CELEX: [https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021XC0916\(03\)](https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021XC0916(03)))



5. System architecture

The visualisation support tool and the python workbench are conceived as two different outcomes of the MIRACA project, with relation to the system architecture.

5.1. Python Jupyter Workbench

The technical workbench architecture is based on the Jupyter Book⁴. A Jupyter Book is an open-source tool used to create interactive, web-based books and documentation from Jupyter notebooks and text files. For MIRACA, It is where all the workflow and data notebooks will be presented, together with other relevant documentation needed for the climate risk assessment.

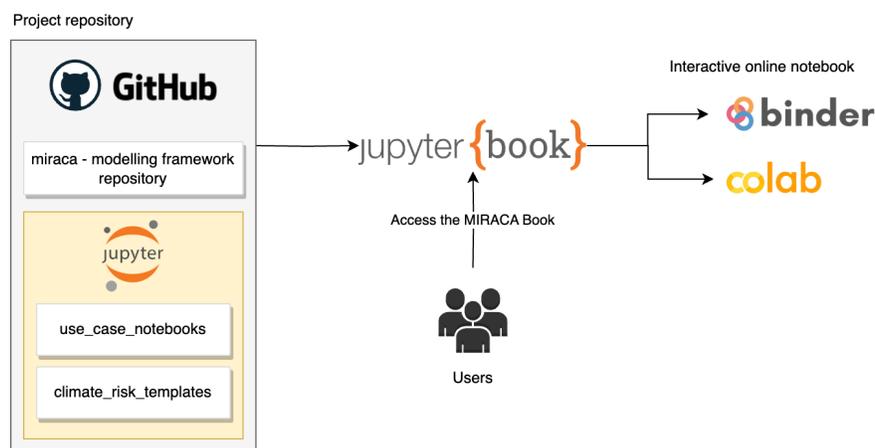


Figure 2. *Workflow of the proposed MIRACA Python workbench book*

The Jupyter Book allows the creation of sections with text, code examples and jupyter books. While the specific sections of MIRACA will be established during the first design of the workbench as part of the deliverable D5.2, overall the book will contain at least:

- Introduction: This page presents the MIRACA project, the current status of the work and the guidance to the different sections in the Jupyter Book. This section will be updated as the project progresses.

⁴ Executable Books Community. (2020). Jupyter Book (v0.10). Zenodo. <https://doi.org/10.5281/zenodo.4539666>



- **Case Studies:** A section presenting Jupyter notebooks of the 5 use cases that will be developed within MIRACA. The information will be updated as the climate risk assessment advances.
- **Resources:** The section will include access to specific datasets, models or project outputs.

5.1.1 MIRACA GitHub repository

A specific MIRACA GitHub page will be set up to host the code and models developed as part of the project (Figure 3). In the Github page, the Jupyter Notebooks for the use cases and templates for running the climate risk assessment and adaptation appraisal will be included. Also, during the development of the Work Packages, this GitHub will also be a space for the partners of the project to co-develop the models.

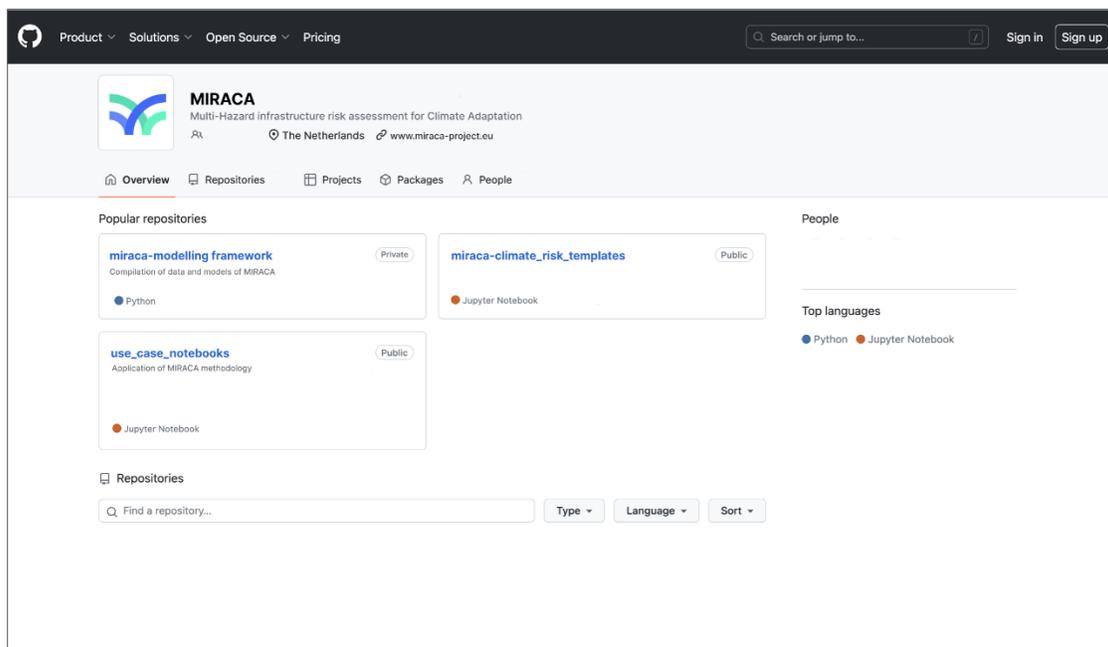


Figure 3. Mock-up of the MIRACA Github with the main repositories considered as starting point.

Once the GitHub page is created, three repositories will be initially created:

- **miraca_modelling framework:** This repository will host the existing modelling code from the partner universities involved in the project. The repository will



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serve also as a common space for co-development of the upcoming Work Packages WP1-WP4.

- **use_case_notebooks:** 5 Jupyter Notebooks, one for each of the use cases developed within the MIRACA project. The notebooks provide the examples of how to carry out the MIRACA climate risk methodology
- **miraca_climate_risk_templates:** Jupyter notebooks for specific activities, for example performing climate risk assessment of a critical infrastructure, computing the multi-hazard risk or calculating the cost-benefit of adaptation options.

5.1.2. Interactive computer interfaces

One of the features of the python workbench will be the possibility to run reproducible examples implementing the MIRACA methodology. For that, executable online environments will be available. There are several services available. In this document we inform about two of the most common, Binder and Google Colab. The main difference between them is that Google Colab allows users to save the work and replicate the jupyter notebook whereas Binder has mainly capabilities for executing notebooks.

5.1.2.1 Binder

MyBinder⁵ is a public online service that allows users to open jupyter notebooks in an executable environment, making the code immediately reproducible by anyone, anywhere. It is free to use and powered by BinderHub⁶. There are several benefits from using Binder in the MIRACA project:

- **Accessibility:** Notebooks that are shared in GitHub can be run by anyone in a reproducible environment, without need to clone or download the notebooks on the local machine.
- **Reproducibility:** The Binder allows the notebooks developed to be reproducible. By providing a specific environment, the notebooks provide the same outputs regardless of the local machine where they are run.

⁵ <https://mybinder.readthedocs.io/en/latest/>

⁶ <https://binderhub.readthedocs.io/en/latest/>



If a Binder user clicks on a Binder link, the mybinder.org deployment will run the linked repository. While running, users are guaranteed at least 1GB of RAM, with a maximum of 2GB. During the development of the Python Workbench, the system requirements and RAM consumption will be evaluated to see if the performance is adequate. In the case where this is not possible, the notebooks would be hosted by BinderHub with Kubernetes in an external Cloud provider.

5.1.2.2 Google Colaboratory

An alternative to Binder for running notebooks online is the Google Colab⁷. This normally takes less time to load and gives the user the possibility to be taken to the execute and edit the code displayed in the Jupyter Book.

Within the MIRACA Jupyter Book, the users will have different ways to execute the code:

- **GitHub repository:** By accessing the notebooks and models in the Github repository. Users will be able to clone the repositories and use it in their own computers.
- **Jupyter Notebook:** By downloading specific jupyter notebooks and executing the code.
- **Collaborative notebooks:** By executing the jupyter notebooks from Binder or Google Colab.

5.2 Exploratory online viewer

The exploratory online viewer will be created with a specific website url, separate from the MIRACA project website. The viewer link will be shared from the MIRACA website. The exploratory online viewer will let users assess single and multi-hazard risk and adaptation strategies on an asset, network and system level for the five selected use cases. Its user interface will be designed to offer a user-friendly experience, by carefully presenting the information in increasing levels of detail as users request it, and by providing meaningful summaries in the overview panes.

Depending on the outcome format of the climate risk and adaptation appraisal, additional features apart from the visualisation of raster and vector data will be included, for example through simple storylines. This will be used to support the

⁷ <https://colab.google/>



description of how the MIRACA framework can be used to visualise, perform and interpret the results of the climate risk assessment and adaptation appraisal.

In terms of application architecture, this viewer will be fully serverless. All the data consumed by the viewer will have been pre-generated and optimised to offer high-performance of the user interface.

5.2.1 Back-end services

The input data needed for the exploratory viewer will be pre-generated and stored in the cloud, using the Zarr format⁸. This format is designed to store multi-dimensional data arrays and is cloud-optimised: data is divided into smaller chunks and each of these chunks is stored in a binary file, and the metadata is stored in JSON files. The chunked nature of the Zarr format makes it suitable for web-based exploration, given that browsers can fetch only the needed chunks of data to display the current viewer state, and fetch subsequent data chunks as users dive into the data (e.g. navigate in time, select a scenario, or pan or zoom a map). In addition to the Zarr data, ancillary files with the definition of the asset geometries will be stored in the same cloud bucket.

The cloud storage bucket containing all the datasets will be publicly available via HTTPS, and directly consumed by the exploratory viewer. Additionally, notebooks in the Python Jupyter workbench can have access to these data cubes if needed.

5.2.2 Front-end architecture

The exploratory viewer is built using the React UI framework and the Next.js⁹ web development framework. Next.js is a React framework for building full-stack web applications. React Components are used to build user interfaces, and Next.js for additional features and optimizations.

The mapping engine is based on two key components built by Lobelia: TeroMaps is in charge of rendering the base maps and data layers on top of them, and TeroZarr is in charge of fetching the needed portions (chunks) of the Zarr datacubes depending on

⁸ <https://zarr.readthedocs.io/en/stable/>

⁹ <https://nextjs.org/>



the state of the application, ensuring that only the minimal information is retrieved from the cloud storage, and thus offering a highly performant UI.

According to the serverless architecture mentioned earlier, the viewer fetches the portions of the data cubes directly from the cloud bucket, using HTTPS requests, and renders client-side the raster information with contextual data and polygons representing the assets.

6. Operating costs

The operating costs of the decision-support tools depend largely on the size of the datasets that will be stored in buckets for the exploratory viewer. Overall, a proxy estimate of the cost of the resources needed for data storage is 15€/TB/month (the providers we are in contact with offer between 12 and 15€/Tb/month).

To calculate the total storage needed, the volume of the datasets to be shown in the visualisation dashboard from MIRACA should be multiplied by 3 (1 copy for the native raw data in NetCDF, and other 2 for the actual arco datacubes, the map-optimised and the time-series optimised capabilities that do in the viewer). As an example, for a 1TB dataset, an approximation of the cost would be ~45€/month. With regards to the front-end component, the website will be developed serverless and hosted in Vercel's Frontend Cloud, so the associated costs are negligible.

With regards to the python workbench, datasets from public sources will be accessed through APIs, when available, so not required to store the data in a server. The developed code will be hosted in GitHub which is also free of charge. As described in Section 5.3.2, there is a potential cost associated with the Binder if RAM requirements are exceeded; In case the notebook computing power exceeds 2GB, the notebooks will have to be hosted in an external cloud provided. For an example of the costs, there is a cost of 200€/month/server. For ~3-5 servers, the potential cost of hosting notebooks to run online would be ~ 600-1000€/month. Alternatively, the Google Colab provides free access to computing resources, including GPUs and TPUs.



7. Conclusions

One of the main goals of MIRACA is to facilitate the understanding and implementation of the MIRACA methodology for climate risk assessment and adaptation appraisal. As part of this first year, the focus has been on contacting potential end users of the tool. This has given useful insight on the main challenges they face when carrying out climate risk assessment, their limitations, needs and interests. The highlight of this discussion has been the organisation of the 1st Stakeholder session which set the foundations of this User Requirement document.

Table 3 below gives a summary of the technical workbench and the exploratory online viewer, with a focus on the overarching goal, the potential users and the features that should be included based on the interaction with the target audiences. Future deliverables within Work Package 5 will expand these requirements, specifically for each decision-support tool, refining the work presented in this deliverable and validating the needs identified.

Table 3. Summary table with overview of the decision-support tools.

	Technical workbench	Exploratory online viewer
Goal	Provide access to the data and models developed as part of the MIRACA project for climate risk and adaptation appraisal.	To visualise climate risk impact to critical infrastructure at asset, network and system level and to provide adaptation and cost benefit appraisal in an easy-to understand and visual way.
Target user	<i>Users that need access to the data and models to use within the MIRACA workbench or for their in-house climate tools.</i> Scientists, developers, engineers and asset managers.	<i>Users that want to visually see the implementation of the climate risk and adaptation methodology.</i> Public authorities, critical infrastructure managers, international organisations and the general public.
Usage and	The workbench includes	Visualisation dashboard exemplifies



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legacy of tool	<p>templates to carry out climate risk for different infrastructure replicating the MIRACA methodology.</p> <p>This allows users to go beyond the case studies presented, and actually carry out a similar assessment in their own region.</p>	<p>climate risk assessment following the European Commission Technical Guidance on the climate-proofing of infrastructure.</p> <p>This serves as a “living template” for users to see the potential integration of MIRACA into their climate risk approaches.</p>
Technology	<p>Jupyter Book</p>	<p>Next.js - React web portal</p>
List of key features	<p>Access to models Users can access the main Github repository to see models developed within MIRACA.</p> <p>Data export Capability to download hazard and vulnerability datasets and models described in the research.</p> <p>Customization Users can select a specific region of interest for assessing climate risk and adaptation of a specific critical infrastructure.</p> <p>Reproducibility Binder launcher gives the option to execute certain notebooks online.</p> <p>Case studies integration 5 Jupyter notebooks that show an end-to-end climate</p>	<p>Visualisation of spatial data Map-based interface to visualise raster and vector data of hazard, multi-hazard, exposure and vulnerability datasets.</p> <p>Climate Scenario Analysis Users can select hazards for historical and future climate projections.</p> <p>Climate risk assessment at varying Critical Infrastructure levels Users can see the climate risk at an asset, network and system level.</p> <p>Adaptation appraisal options Integration of the cost benefit of different adaptation options for the most vulnerable critical infrastructure.</p> <p>Storylines For a specific Use Case, show the implementation of the MIRACA methodology through visual storyline.</p>



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	<p>risk and adaptation methodology are implemented.</p> <p>Documentation and Help Jupyter book with introductory page with the structure of the MIRACA book and its workflow.</p>	<p>Applications for different critical infrastructure system Viewer shows examples of the MIRACA framework for the main infrastructure systems: Electricity, gas, transport, telecommunications, education and healthcare facilities.</p>
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Annex 1. Content of the 1st Stakeholder Session

This Annex provides more information on the questions addressed during the brainstorming session carried out during November 2023 with the main Use Case stakeholders.

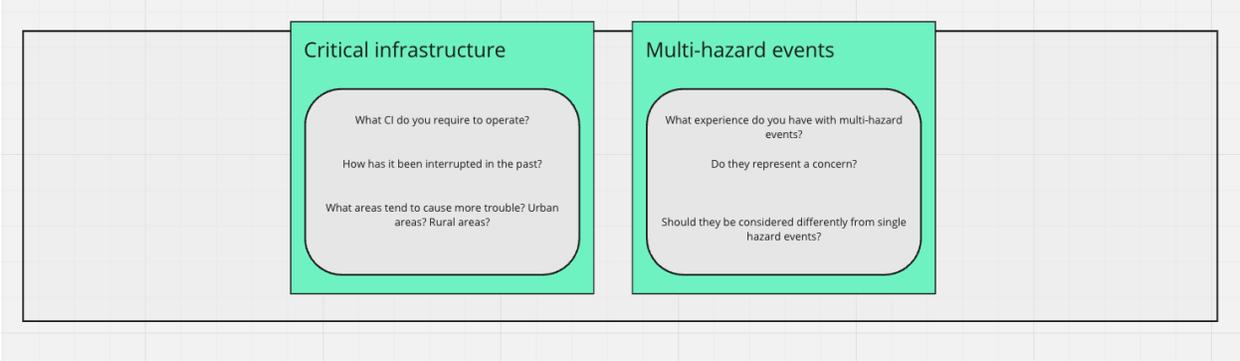
MIRACA 1st Technical Workshop - Year 1

Adaptation guidelines	Technical workbench	Web viewer	<div style="background-color: #4a7ebb; color: white; padding: 2px; text-align: center; font-size: 8px;"> Colors by use case: </div> <table style="margin: 2px auto; border: 1px solid black; text-align: center; font-size: 8px;"> <tr> <td style="background-color: #e91e63; color: white; border-radius: 50%; width: 15px; height: 15px;">1</td> <td style="background-color: #e91e63; color: white; border-radius: 50%; width: 15px; height: 15px;">2</td> <td style="background-color: #42a5f5; color: white; border-radius: 50%; width: 15px; height: 15px;">3</td> <td style="background-color: #42a5f5; color: white; border-radius: 50%; width: 15px; height: 15px;">4</td> <td style="background-color: #42a5f5; color: white; border-radius: 50%; width: 15px; height: 15px;">5</td> </tr> <tr> <td style="font-size: 8px;">EU</td> <td style="font-size: 8px;">SP</td> <td style="font-size: 8px;">NL</td> <td style="font-size: 8px;">GR</td> <td style="font-size: 8px;">SL</td> </tr> </table>	1	2	3	4	5	EU	SP	NL	GR	SL
1	2	3	4	5									
EU	SP	NL	GR	SL									
<p>What adaptation is ongoing?</p> <p>What types of adaptation is your org considering? Ex. replacing infrastructure, upgrading infrastructure</p> <p>What are you still confused or uncertain about? Where would more guidance be useful?</p> <p>What resources do you already use for adaptation planning? When and why might you consider switching to the MIRACA adaptation guidelines?</p>	<p>Who in your organization might use this workbench? Can they work with python and jupyter notebooks?</p> <p>What tools and data are used for performing climate risk assessment?</p> <p>Do you experience any technical challenges during the risk assessment of critical infrastructure? (i.e. climate data access and manipulation, quantification of adaptation benefit,...)</p> <p>Who should we talk to further about this?</p>	<p>How has climate change impacted your critical infrastructure?</p> <p>How do you evaluate climate risks for your critical infrastructure?</p> <p>What are the key challenges you face? (i.e. data gaps, mapping system dependencies,...)</p> <p>What should be included in the online decision-support tool? Maps? Data tables? etc</p>											

CI data, exposure and vulnerability	CI interdependency and flow	Impacts, multi-hazards	Adaptation options
<p>What exposure data do you use?</p> <p>How complete and reliable is the data you use? Can it be shared?</p> <p>Are there data gaps that you have?</p> <p>Vulnerability:</p>	<p>What infrastructure is relevant for you to be able to operate/respond in the case of extreme weather events</p> <p>Have you experienced outages of the services you depend on?</p> <p>Have you considered how extreme weather events disturb your capacity to operate?</p> <p>Do you use or have data of network usage? at what scale?</p>	<p>How would loss of certain goods or services affect you?</p> <p>What level of aggregation do you use and would you desire for climate risk data?</p> <p>Is there any specific data that you lack on multi-hazards? Is there data you would like to share?</p> <p>Can you think of any adaptive behaviours you may see in case of extreme weather events in your field/work</p>	<p>Does future climate data play a role in cost-benefit analyses of projects?</p> <p>How do you think CI might be affected differently from housing or agricultural land, for example?</p> <p>To what extent are you aware of climate adaptation plans in your region by other actors?(government agencies, operators/asset owners, water boards, etc) Are you involved in the process?</p>



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