SUNRISE

Strategies and Technologies for **Un**ited and **R**esilient Critical **I**nfrastructures and Vital **S**ervices in Pandemic-Stricken **E**urope

D2.3 Strategy validation report V1

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List of Acronyms and Abbreviations

Abbreviation / acronym	Description
ABM	Agent-Based Model
API	Application Programming Interface
BCM	Business Continuity Management
C&C	Communication and Collaboration
CFR	Case Fatality Rate
CIs	Critical Infrastructures
CIIG	Critical Infrastructures Interdependency Graph
CNPIC	Critical Infrastructure Protection National Centre
CORDEX	Coordinated Regional Climate Downscaling Experiment
COVID-19	Corona Virus Disease-19
CSV	Comma-Separated Values
D1.1	Deliverable number 1 belonging to WP1
D1.2	Deliverable number 2 belonging to WP1
D2.2	Deliverable number 2 belonging to WP2
DoA	Description of Action of the SUNRISE Project
EC	European Commission
ECDC	European Centre of Disease control
ECMWF	European Centre for Medium-Range Weather Forecast
ERA5	Fifth generation ECMWF reanalysis
EU	European Union
FVG	Friuli Venezia Giulia
HIT	Health Information Technologies
HR	Human Resources
ICU	Intensive Care Unit
ICT	Information and Communication Technology
ISO	International Organization for Standardization
ISS	Istituto Superiore di Sanità
IT	Information Technologies
JSON	JavaScript Object Notation
JWT	JSON Web Token
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
MIR	Ministerio Del Interior
MZI	Ministrstvo za infrastrukturo
NACE	Statistical Classification of Economic Activities in the European Community
NPI	Non-pharmaceutical Interventions
NUTS	Nomenclature of Territorial Units for Statistics
PDCA	Plan, Do, Check, Act
PSCE	Pandemic Specific Critical Entities

Abbreviation / acronym	Description
REST	REpresentational State Transfer
SARS-CoV	Severe Acute Respiratory Syndrome Coronavirus
UAV	Unmanned Aerial Vehicle
UTCI	Universal Thermal Comfort Index
WHO	World Health Organization
WP	Work Package
XLS	Excel Spreadsheet

Executive Summary

This document pertains to the SUNRISE Project, focusing on the validation of the Strategy enhancing the resilience of Critical Infrastructures against the backdrop of pandemics and climate change impacts.

At its core, the SUNRISE project seeks to address the pressing challenge of safeguarding CI providers against the threats posed by pandemics and climate change. The document serves as a blueprint for assessing the effectiveness of the devised Strategy and its associated tools within this context. The Strategy employs a systematic and collaborative approach, leveraging climate change scenarios and disease spread evaluations to gauge pandemic-specific risks and the economic repercussions of countermeasures. Validation has been undertaken with the validator entities identified in the Description of Action (DoA)[1] – the Slovenian Ministrstvo za infrastrukturo, the Spanish Ministerio Del Interior and the Italians Regione Autonoma Friuli Venezia-Giulia and Istituto Superiore di Sanità - and stakeholders across Europe facilitating a broad-based assessment and iterative refinement of the Strategy.

The validation process is articulated in two phases: an initial phase involving the analysis of outcomes from workshops and activities conducted, and a subsequent phase focusing on further workshops and validation events. This approach ensures a comprehensive evaluation of the Strategy's effectiveness, incorporating feedback from validating entities and stakeholders to refine and adapt the Strategy accordingly.

The first validation cycle is reported in this document, the next cycle will be reported in an updated version of this document (Deliverable D2.5). This first cycle highlighted several key insights. During this phase, an emphasis on the importance of a collaborative approach to Strategy development and validation has emerged underscoring the necessity of engaging a broad spectrum of stakeholders. This engagement facilitated the identification of information gaps and areas requiring enhancement allowing the refinement of the Strategy models and assuring that the to-be Integrated Tool (in which the models will converge as modules) meets the requirements defined by participants. Furthermore, the initial cycle demonstrated the critical role of integrating various models and tools to support CIs effectively, laying the groundwork for more a resilient infrastructure network.

This document outlines the plan defined by Work Package 2 (WP2) for the second validation cycle, aimed at deepening the analysis and broadening the Strategy's applicability. This second phase will involve additional workshops and dedicated validation events. These events will be focused in engaging with designated validating entities through the scenarios defined in this document and focused feedback mechanisms. Through the testing, which will be conducted by applying the scenarios, the outcomes will be processed and integrated into the Strategy. Subsequently, a new test will be proposed to the entities during the following workshop in a cyclical process. The objective is to incorporate this feedback systematically, further tailoring the Strategy to meet the evolving needs of CIs in the context of pandemics and climate change.

The SUNRISE Project represents a significant endeavour towards bolstering the resilience of critical infrastructures in the face of unprecedented challenges. The strategic framework and validation process outlined in the document underscore the Project's commitment to a proactive, inclusive, and adaptive approach. Key takeaways include the efficacy of collaborative planning and validation, the potential of integrated tools in enhancing CI resilience, and the imperative of ongoing refinement and adaptation of the Strategy. As the Project progresses into its second validation cycle, the foundation laid by the initial efforts promises a robust pathway towards achieving a resilient, responsive, and sustainable infrastructure ecosystem.

1 Introduction

1.1 Purpose of the document

The purpose of this document is to give an overview of the first cycle of the Strategy for Critical Infrastructure Awareness and Resilience validation, concluded in M18, and to outline the plan for the second cycle of validation for the Strategy for Awareness and Resilience of Critical Infrastructures.

In the context of the SUNRISE Project, the term "Strategy" should be understood not merely as operational and tactical guidance but also as an essential aid in comprehending fundamental risks, exploring potential decisions, and formulating countermeasures to enhance resilience of Critical Infrastructures.

For the first cycle of validation, a systematic and collaborative approach was implemented, aimed at assessing the effectiveness of the Strategy and its tools within the context of pandemics, focusing on projected climate change and disease spread, evaluating pandemic-specific risks, and the economic impact of measures to combat them. This activity includes the participation of four validating entities, respectively the Slovenian Ministry of Infrastructures, the Spanish Ministry of Home Affairs, the Italian Autonomous Region Friuli Venezia Giulia and the Italian National Institute of Health. The validation process is structured into two phases, with two anticipated cycles. The first phase involves analysing outcomes from national and Pan-European workshops and activities during the Strategy's formulation, through which initial tests of the Strategy models developed within WP2: climate and disease modelling, risk assessment (threat analysis) and impact analysis technologies have been conducted, in addiction to information gathering. The results were analysed for patterns, themes, and challenges at the national level. This has enabled the identification of informational gaps and areas for improvement, in real life scenarios, upon which the Strategy's tool can offer their support to CI providers. To fulfil this purpose, the integration of such models has been prepared. This phase aimed to understand the Strategy and the models' strengths and weaknesses and have been beneficial for the development of such models into modules and their subsequent integration.

The second phase includes additional workshops and validation events, testing the Strategy and the integrated tools with designated validating entities through case studies. During the second phase the initial step involves creating a comprehensive Strategy presentation, outlining key components, objectives, and methodologies. A structured questionnaire module is then formulated to solicit specific feedback systematically, addressing theoretical foundations, practical applicability, and alignment with industry best practices. Effective communication is established with validating entities, ensuring clear channels for information exchange. After communication channels are set up, the detailed Strategy presentation and structured questionnaire are dispatched to validators, serving as a reference guide, and prompting focused feedback. Collected feedback is to be compiled into Deliverable D2.5, encapsulating detailed insights, suggestions, and critiques in a structured format. The final step involves incorporating this feedback into the Strategy, addressing identified points of improvement. This iterative approach ensures the Strategy evolves based on valuable input received during the second validation phase.

1.2 Relation to other Project work

The objective of this subsection is to outline the correlation of the current document with the DoA, the Project roadmap, as well as with other deliverables already presented. Specifically, the deliverables with which the validation document has direct relations are Deliverable D2.2[2], Strategy for Awareness and Resilience of Critical Infrastructures, within which the defined Strategy and the models intended for use are outlined, and Deliverables D1.1 [3], Local meetings with Critical Infrastructure Stakeholders, and D1.2[4], Pan-European meeting with Critical Infrastructure Stakeholders. The latter two describe the first national workshop and the first international workshop, respectively, the outcomes of which have been utilized to support the validation of the Strategy tools, as described in the current document.

Regarding the SUNRISE Project roadmap, it sets milestones and specific goals aimed at achieving the expected results. The relationship between the activities carried out and the objectives set in the roadmap allows for the monitoring of Project progress and ensures that the actions taken are consistent with the overall purposes. This document fits into the implementation path of the roadmap as a tool to verify the effectiveness of the implemented strategies and as a basis for any adjustments. In accordance with the roadmap, the document illustrates the findings from the first Strategy validation cycle. In detail, it specifies the areas of intervention within which the tools developed in WP2 are inserted, shows how the results of the conducted workshops have contributed to defining the Strategy for Awareness and Resilience of Critical Infrastructures, and defines the integration between these tools.

In accordance with the roadmap, this Validation report also includes the plan that will be implemented during the second validation cycle.

1.3 Structure of the document

This document is structured in 7 chapters.

Chapter 1 is an introduction, containing background, purpose of the document and main objectives of the validation plan presented.

Chapter 2 focuses on practical application of the Critical Infrastructure Awareness and Resilience Strategy. It entails referencing the Strategy and Document D2.2[2], constituting the context for subsequent validation process.

Chapter 3 presents the Official Validators identified in SUNRISE's Description of Action [1] who will actively participate in the validation process. Validators encompass entities such as the Slovenian Ministry of Infrastructures, Spanish Ministry of Home Affairs, Italian Autonomous Region Friuli Venezia Giulia, and Italian National Institute of Health

Chapter 4 presents two use case scenario defined for the validation process: the Aerosol Scenario and the Vector Scenario. Each of this adheres to a structured format, covering contextual aspects, step-by-step descriptions, key focus points, and considerations of influences stemming from climate change.

Chapter 5 presents the application of the Strategy Tool, as a result of the integration among the models created by WP2 Partners. This chapter elucidates how validating entities, including the identified validators, may employ the Risk Assessment Tool. It delves into insights derived from the case study scenarios, highlighting the interconnections between the tool and decision-makers within the validating entities.

Chapter 6 presents a comprehensive overview of the validation methods, organized into two distinct phases. The initial phase incorporates an analysis of results from national and international workshops, which resulted in ensuring that the Strategy and its tools. The subsequent phase is expected to be closed in M31. The relative section delineates the detailed validation steps, incorporating the next workshops, the EU workshops, and specific validation events. It also addresses the processing of event results, result comparisons, and establishes a timeline for the validation process.

Chapter 7 synthesizes the document, encapsulating key findings and insights obtained throughout the validation process.

1.4 Glossary adopted in this document

- **Critical infrastructure:** Critical Infrastructure refers to essential assets or systems vital for sustaining crucial services and societal functions. This includes power distribution networks, transportation systems, and information and communication networks. Safeguarding these critical assets is imperative for maintaining the stability, security, and well-being of a state and its citizens, ensuring the normal operation of key societal functions.

- **Climate change:** Climate change refers to long-term changes in the average weather patterns that have come to define Earth's climate. This includes changes in temperature, precipitation, and other atmospheric conditions on a global or regional scale. Climate change can result from both natural processes and human activities, and it has become a significant environmental and societal concern with the increasing emission of greenhouse gasses.
- **Endemic:** the term “endemic” refers to the constant presence and/or usual prevalence of a disease or infectious agent in a population within a geographic area. CDC definition
- **Epidemic:** Epidemic is characterized by the swift and extensive outbreak of a specific infectious disease in a defined geographical area, community, or population over a limited timeframe.
- **Impact:** the potential consequences or effects that could result from the realization of a risk. Impact analysis is a critical component of risk management, focusing on identifying and assessing the severity of the outcomes that could occur if a risk event takes place. The impact can be quantified or qualified in various ways, depending on the nature of the risk and the context in which it is being analysed.
- **Lockdown:** is a restrictive measure implemented by authorities or organizations to limit people's movement and activities within a specific geographic area. It is often employed as an emergency response to contain the spread of a contagious disease, such as a pandemic. During a lockdown, individuals may be required to stay at home, non-essential businesses may be temporarily closed, and public gatherings or movements may be restricted. The goal of a lockdown is to minimize person-to-person transmission of a disease, protect public health, and alleviate the burden on healthcare systems.
- **Model:** representation of a structure or a process. Models can be used to describe the architecture of a system, design patterns, or business processes. A model serves as a blueprint or guide for the construction or understanding of complex systems. In this document, WP2 refers as models when describing analysis, projection and simulations conducted by the different partners.
- **Module:** in the context of this document and WP2, the term "modules" denotes the constituent elements of the Strategy Tool. These elements are crafted leveraging the models conceived and refined by the respective collaborating partners.
- **Non-pharmaceutical Interventions (NPIs):** refer to a set of public health measures and strategies that do not involve the use of pharmaceuticals or medical treatments. These interventions are implemented to prevent the spread of infectious diseases, particularly during pandemics or outbreaks. Non-pharmaceutical interventions aim to reduce the transmission of pathogens, protect individuals and communities, and mitigate the impact of the disease.
- **Pandemic:** is an outbreak of a contagious disease that occurs over a wide geographic area, affecting multiple countries or continents and spreading rapidly among populations. Unlike an epidemic, which is typically confined to a specific region or community, a pandemic involves the widespread dissemination of a disease across international borders and can have significant global impacts on health, society, and the economy.
- **Quarantine:** is a public health practice designed to prevent the spread of infectious diseases by isolating and restricting the movement of individuals who may have been exposed to a contagious pathogen. During a quarantine period, individuals are separated from others, even if they do not show symptoms of the disease, to monitor and prevent potential transmission.
- **Risk:** the likelihood or probability of a harmful event occurring, and it encompasses the potential for adverse consequences or loss. In various contexts, risk is evaluated by considering

the probability of an event's occurrence, the severity of its impact, and the ability to manage or mitigate its effects.

- **Social distance:** refers to the practice of intentionally maintaining a physical distance between individuals to reduce the risk of transmitting infectious diseases, especially in situations where close contact is more likely. The goal of social distancing is to minimize the spread of contagious pathogens, such as viruses, by creating space between people to prevent respiratory droplets containing the virus from easily passing between individuals.
- **Strategy Tool:** or Integrated Tool. This term refers to the Tool produced by all the WP2 partners, which consists in each partner's module integration.
- **Supply chain:** is a network of organizations, individuals, activities, information, and resources involved in the production, distribution, and delivery of goods or services from the point of origin to the end consumer. It encompasses the entire lifecycle of a product, including its design, production, transportation, storage, and eventual consumption or use.
- **Value chain:** is a strategic concept that represents the entire series of activities involved in the creation, production, and delivery of a product or service from its conception to the end consumer. It encompasses the full range of activities and processes required to design, produce, market, distribute, and support a product or service, adding value at each stage of the chain.
- **Vector-borne diseases**: human illnesses caused by parasites, viruses and bacteria that are transmitted by vectors, mainly bloodsucking insects - mosquitos, ticks, etc.
- **Vulnerability:** refers to the degree of susceptibility or exposure to potential harm, damage, or adverse effects. In various contexts, vulnerability can apply to individuals, systems, organizations, or communities. It often implies a state of being at risk or lacking the necessary defences or resilience to withstand or mitigate potential negative outcomes.

2 Application of the Strategy for Awareness and Resilience of CIs

The focus of the validation process described in this deliverable is the "Strategy for Awareness and resilience of CIs", i.e., the SUNRISE Strategy, which is compiled in Deliverable D2.2[2]. The SUNRISE Strategy aims at improving the understanding, preparedness of CI operators as well as decision makers on regional and national level for the multi-criterial effects that a pandemic might have on them. Further, the Strategy's goal is also to increase the resilience of vital services for the society against future pandemics. To achieve these goals, the SUNRISE Strategy consists of five distinctive missions that need to be implemented:

1) Critical infrastructure operators and decision makers on regional and national level need to become aware of the novel threat landscape related to and implied by pandemics. A core focus needs to be set on the effects of climate change and their implications on future pandemics in Europe.
2) A deeper understanding needs to be established which entities and services are vital during a specific pandemic and how their interrelations and potential cascading effects due to pandemic-related threats could look like.
3) Risk assessment and management as well as business continuity management methodologies on organisational, regional, and national level need to consider the potential impacts of pandemic-related threats on the vital services for society, taking societal, ethical, legal, economic and ecologic aspects into account.
4) A high-level toolset, i.e., a set of pharmaceutical and non-pharmaceutical as well as economic and legal measures, need to be collected to effectively prepare for and counter the multi-criterial effects of pandemics.
5) An increased collaboration among the operators of vital services, from different industry sectors and across regional and national borders, needs to be established to effectively share best practices and join forces during future pandemics.

2.1 SUNRISE Strategy Process

The SUNRISE Strategy is described in the form of an iterative, step-by-step guideline, i.e., the SUNRISE Strategy Process. This Process describes the individual actions that should be implemented to achieve the goals and missions set by the Strategy. Therefore, the Strategy Process is based on existing principles and standards such as the PDCA (Plan, Do, Check, Act) Cycle and the International Organization for Standardization (ISO) 31000 [5] standard for risk management. In this way, the Strategy Process implicitly builds on concepts, structures and mechanisms that are already existing within CIs as well as regional and national governmental organisations. The Strategy Process consists of the five major building blocks "Establishing the Context", "Assessing the Pandemic", "Analysing the Consequences", "Evaluating the Measures" and "Evaluating the Resilience" (see also Figure 1).

The first block, Establishing the Context, sets the scene for the SUNRISE Strategy and the core aspects for implementing the Strategy are defined. First, this includes the identification of the stakeholders, i.e., the people that are interested in and benefit from the Strategy in general and the results of the Strategy Process. Among them are also the relevant Pandemic-Specific Critical Entities (PSCEs), which are services, infrastructures or people that are mostly affected by the different consequences of a pandemic. As the relation among the PSCEs are of high interest in the Strategy, these relations and interdependencies are captured in the next part of the context establishment. These interrelations will later on be the basis for analysing the impacts and cascading effects a pandemic can have across different industry sectors and domains of social life. As final steps of this first block, the available data sources and general requirements are identified.

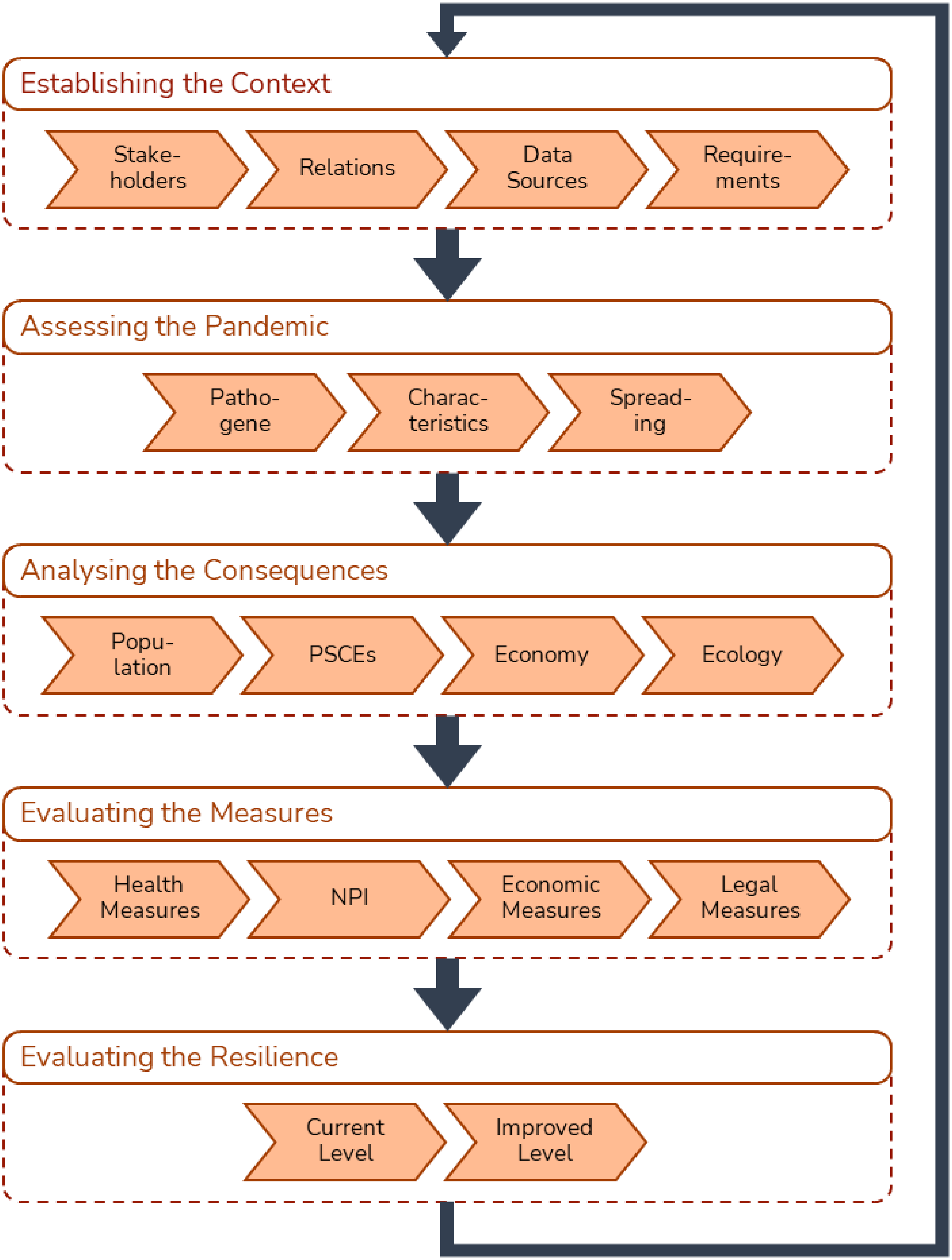

Figure 1: Illustration of the SUNRISE Strategy Process

The second block is dedicated to gather information about the main threat, i.e., the pandemic that the CI or the regional or national government is facing. Therefore, the pathogen must be identified in the beginning, which can be done, for example, by using national or international surveillance and monitoring systems. Once it is clear which pathogen is causing the pandemic, more information about its characteristics is required, such as transmissibility, exposure, seriousness of disease, Case Fatality Rate (CFR) and others. These characteristics are essential to obtain a better estimation on the spreading of the pathogen and to decide on possible measure to protect from infection or reduce the spreading. The second block concludes with the definition of potential scenarios that the organisation implementing the Strategy could be facing.

When the scenarios are described in detail, the consequences of the pandemic are analysed in the third block of the SUNRISE Strategy Process. Since one major objective of the Strategy is to capture multi-criteria impacts, the consequences are analysed according to four domains, i.e., the effects on the population, on PSCEs, on the economy in general and on the society as a whole. In this way, the Strategy makes sure that the impacts of a pandemic together with the available countermeasures are not only analysed according to the effects on individual and public health but also effects on vital services, economic processes and the societal well-being is captured as well. This multi-criteria approach is of particular importance for governmental organisations on a regional and national level to make sure that they obtain a holistic overview on the impacts of a pandemic and can also identify the best countermeasures not only according to one indicator but to several indicators.

After getting an estimation on the consequences, the fourth block of the Process deals with the identification and evaluation of possible measures to prevent of, protect against or mitigate the pandemic. As the SUNRISE Strategy is focusing on a multi-criteria analysis, also the countermeasures are gathered from different domains: protective health measures, non-pharmaceutical interventions (NPIs), economic measure and legal measures. Whereas the first group, the protective health measure, focus mainly on the health of individual people, i.e., how to protect someone from getting infected with the pathogen or curing their illness, the NPIs focus on reducing the spreading of the pathogen in the general society. Hence, some NPIs such as school closures or lockdowns potentially have huge effects onto the society and implications for the daily life, which need to be taken into account. Since most of the NPIs (but also the protective health measures) come with a high cost that cannot be covered by individual organisations, the economic measures describe actions how a state can help in this context, e.g., by providing funds or financial support. All of the measures taken also need to be set within a legal framework as laws and directives are still valid in the course of a pandemic.

The final block of the Strategy Process now covers the estimation of the risk level and the resilience level of the services, infrastructures and population in the focus of the analysis. Therefore, the data coming from the consequence analysis is gathered and compiled into one abstract level representing the risk for a given scenario, e.g., a value between 1 and 5 on a semi-quantitative risk scale. The same is done for the resilience level; here, the resilience of individual services and infrastructures is compiled into a resilience level for an entire region or nation. As a second step in this block, the various countermeasures from the previous block are taken into account and a "what-if" analysis is carried out. This analysis assumes that one or several of the measures are implemented and re-calculates the consequences with these measures in place. This will result in a new risk and resilience level, giving the decision makers an estimation, on which set of measures will be most effective according to the criteria from the different domains.

2.2 SUNRISE Strategy Process Implementation and Validation

The Deliverable D2.2[2] provides an overview of the concepts, methods and tools that can be used to implement each step of the Strategy Process. For example, several simulation approaches for analysing and assessing the consequences in the different domains are outlined in Deliverable D2.2[2] together with a risk assessment approach and tool that integrates these simulation tools. Additionally, a list of protective health measures and NPIs are covered in Deliverable D2.2[2] to give decision makers on various levels, e.g., within a CI or a regional or national governmental organisation, an overview on which measures are available.

The following sections of this deliverable now capture, how the SUNRISE Strategy and, accordingly, the SUNRISE Strategy Process are validated. Firstly, this includes the general setup of the Strategy Process, i.e., "Establishing the Context", which is defined by the four organisations that validate the process (i.e., the Ministrvo za Infrastrukturo in Slovenia, the Ministerio del Interior in Spain as well as the Regione Autonome Friuli Venezia-Giulia and the Instituto Superiore di Sanità in Italy as described in Section 3). Secondly, the scenarios sketched in Section 4 provide all details that are necessary and usually collected in the second phase of the Strategy Process, "Assessing the Pandemic". Then, the four simulation approaches illustrated in Deliverable D2.2[2] (cf. Section 5.4.1 to 5.4.4 in D2.2) are instantiated according to the scenarios and are integrated into the risk assessment framework described in Section 5 further below. In this way, the multi-criteria consequences can be analysed for the scenarios. Additionally, the risk assessment framework also incorporates a "what-if" analysis that allows to evaluate the effectiveness of the countermeasures as illustrated in the last block of the Strategy Process, "Evaluating the Risk and Resilience".

The validation process is then carried out in several phases, including a more theoretical overview on information on the SUNRISE Strategy and the SUNRISE Strategy Process as well as more hands-on evaluation and validation events where the developed tools are used by representatives of the validator organisations (details are given in Section 6). This will provide an overview on open issues and missing aspects in the SUNRISE Strategy Process itself but also with regards to the tools implementing the different steps within the Process.

3 Official Validators Involved

This section presents the CI representative identified in the SUNRISE's DoA[1] to be involved into the Strategy Validation process.

The aforementioned entities are as follows: Ministrstvo za infrastrukturo (MZI), the Slovenian Ministry of Infrastructure; Ministerio Del Interior (MIR), the Spanish Ministry of Home Affairs; Regione Autonoma Friuli Venezia-Giulia (FVG), Italian Autonomous Region; and Istituto Superiore di Sanità (ISS), the Italian National Institute of Health.

These validating entities, as defined in the Project DoA, have been identified to take charge of validating the Strategy and its tools for climate change impacts and disease spread, specific pandemic risk assessments, and the evaluation of the economic impact of measures to combat pandemics. Each validating entity will be responsible for validating, in relation to its assigned sector, the Strategy, the alignment of business continuity plans, and the WP2 tools. Specifically, regarding the Ministry of the Interior, it is involved in the security sector of the Project during the Strategy validation phase of SUNRISE and the alignment of Business Continuity Plans to it. The Istituto Superiore di Sanità, in turn, is involved in the validation of the Strategy and the alignment of Business Continuity Plans in the healthcare sector. Similarly, the Autonomous Region of Friuli-Venezia Giulia is involved in the healthcare sector. Lastly, regarding the Ministrstvo za infrastrukturo, it provides its expertise in the energy and transport sectors.

3.1 MZI - Ministrstvo za infrastrukturo

The Ministry of Infrastructure ensures the continuous improvement of Slovenian transport infrastructures by providing maintenance, planning, regulation, and enhancement of the country's railway, road, air, cableway, maritime, and inland waterway transport. It is also responsible for transport policies and infrastructures. In this context, the Directorate for Aviation and Maritime Transport in particular performs expert and administrative tasks for setting strategic guidelines and policies in aviation, maritime transport, and navigation on inland waterways. It ensures conditions for the safe implementation of air and maritime transport and inland navigation, overseeing services of general economic interest and agreements to obtain collaboration licenses with the Ministry. Additionally, it handles drafting and implementing legislation in its field, participates in European Union institutions, collaborates with international organizations, and conducts supervisory activities within the Ministry or the Civil Aviation Agency of the Republic of Slovenia.
In relation to the SUNRISE Project, the Ministry provides significant legal and strategic contributions from public authorities regarding strategic cooperation and coordination activities characteristic of WP1. It also performs relevant legal assessments, acting as a validating entity for validating strategies related to the assessment and mitigation of pandemic-specific risks and climate change-related risks; it is also involved in validating risk analysis tools and What If analyses included in WP2. As a pilot partner, it adopts the proposed technologies and initiates pilot trials for the tool developed by WP5, demand prediction and management, in coordination with the Slovenian National Transmission System Operator and a consulting and engineering company in the electricity sector, providing services to operators and authorities in Southeastern Europe. Furthermore, through the Directorate for Aviation and Maritime Transport, it supports demonstration and utilization activities for the tool developed by WP7, which in the Slovenian case corresponds to inspection activities along a 110 kV transmission line and an electrified railway line in the northeast part of the country, characterized by varied vegetation, bridges, overpasses, signalling equipment, and covered by a 5G mobile network. Moreover, it provides support for managing legal aspects related to autonomous Unmanned Aerial Vehicle UAV flights as well as consultancy and data for understanding the parts of the infrastructure to be monitored, their normal conditions and potential anomalies, and the requirements for physical inspection.

3.2 MIR - Ministerio Del Interior

The Spanish Ministry of Interior is responsible for public safety, law enforcement oversight, national security, and civil protection. In particular, the department of the Ministry involved in the SUNRISE Project is the Critical Infrastructure Protection National Centre (CNPIC). The CNPIC is the organisation in charge of promoting, coordinating, and supervising all critical infrastructure protection, activities for which the Secretariat of State for Security is competent at national level. The CNPIC depend on the Secretary of State for Security, of Spanish Ministry of Interior, principal responsibility of critical infrastructure protection system. In this regard, CNPIC manages a network of more than 300 entities and up to 1200 security plans at both, strategic and operative levels. This network, regulated under Spanish law, consists of a number of public and private agents that ensure that the CIs are able to provide the essential services for the society with warranties and without interruptions, creating a preventive system that can overcome crisis situations. The different entities of the network come from multiple sectors including, but not limited to, telecommunications, energy, transport, banking, etc. As these infrastructures are of vital importance, they are often the target of criminal activities. Because of this, they need a constant optimization of their security measures against deliberate aggressions.

With this in mind, CNPIC is in charge of ensuring that there is mechanism in place that will help different CIs to provide their services even in the worst situations. CNPIC relates to entities from the public and private sectors that are responsible of the correct operation of the essential services for the citizens. In this sense, CNPIC is also the Spanish contact point for the protection of CIs in the European Union (EU), as well as third countries. This is enforced by regular meetings with governmental institutions from multiple neighbouring countries, as to have constant contact to ensure that the interdependencies are up to date in the different strategic sectors.

Regarding the Work Packages, CNPIC is to actively participate in work groups related to the collaboration of critical infrastructure providers, critical infrastructure awareness, and resilience Strategy. This is due to its roles in overseeing critical infrastructure protection within the national territory. Specifically, in addition to being involved in the validation process of the Strategy undertaken within WP2, this entity will provide significant legal and strategic contributions from public authorities regarding the cooperation and coordination activities characteristic of WP1. Lastly, in WP8, it must establish the appropriate business plan and how it should be implemented in the market, and refine, execute, and monitor exploitation, dissemination, communication, collaboration, standardization, and policy-making activities.

3.3 FVG - Regione Autonoma Friuli Venezia-Giulia

The Autonomous Region of Friuli Venezia Giulia is one of the 20 Italian regions into which the Italian national territory is divided. The regional territory has an extension of 7,924 km² and a population of approximately 1,200,000 inhabitants. The main cities are Trieste, the regional capital, Udine, Gorizia and Pordenone, and other smaller 214 municipalities. The organization of the Regional Authority at a political level is made up of the President of the Regional Council, the Regional Council, the Regional Ministries, President of the Regional Government. In particular, the Regional Ministries are:

- (i) infrastructure and territory,
- (ii) Productive activities and tourism,
- (iii) heritage-state property-general services and information systems,
- (iv) local autonomies-public function-safety and immigration
- (v) work-training-education-university and family,
- (vi) culture and sport,
- (vii) environment-energy and sustainable development,
- (viii) agri-food-forestry and fishery resources,
- (ix) finances,
- (x) health-social policies-disability.

Each Ministry has a central department, within which there are different sub-areas with specific responsibilities. Furthermore, the regional health Minister is also delegated for the management of the Civil Protection of the FVG Region. As part of the SUNRISE Project, the direction most involved Department refers to the Health, Social Policies and Disability Ministry. During the pandemic, this department faced the challenge of protecting public health and supporting the resilience of the regional health system.

As described above, each direction is structured into different thematic areas. One of the areas within the Health, Social Policies and Disability Department is the "Information Systems and Privacy" area, which collaborates jointly with Insiel on the activities of SUNRISE. This area is responsible for the planning and management of the digitalization within the social and health sector on the entire regional territory, as well as communications and interactions with the central government. During the pandemic, the digital aspect played a crucial role in the management of internal and external information flows and in the management of relations with national authorities and citizens. In light of this role, the Information Systems and Privacy area of the Health Directorate will be the validator of the SUNRISE Strategy.

3.4 ISS – Istituto Superiore di Sanità

Istituto Superiore di Sanità, the Italian National Institute of Health, is a public institution that serves as the leading technical-scientific body of the Italian National Health Service (Servizio Sanitario Nazionale). It is engaged in research, trials, control, counselling, documentation, and training in the field of public health. This makes the ISS a central entity in Italy's healthcare system, contributing significantly to the promotion and protection of public health through scientific and technical expertise.

The organizational structure of the technical-scientific operational area of the Italian National Institute of Health is comprised of 6 Departments, 16 National Centers, 2 Reference Centers, and 5 Technical-Scientific Services. The Departments are engaged in research, control, consulting, and training within the Institute's activities. The National Centers are specialized structures dedicated to creating national and international scientific networks and serve as operational references for the health system's structures. The Reference Centers conduct similar activities but focus on specific sectors. The Technical-Scientific Services provide operational support to ensure efficiency and effectiveness in the missions of the Departments and Centers. Regarding the SUNRISE Project, the Institute is expected to make significant contributions through the National Center for Innovative Technologies in Public Health, in WP2 with support activities corresponding to the provision of wastewater data and disease spread analysis, necessary for the development of the Disease Spread Modelling Tool. Additionally, it participates in the validation of the tool as a validating entity. The National Center for Innovative Technologies in Public Health aims to improve public health status through the research, development, optimization, and evaluation of innovative technologies that contribute to public health protection. Utilizing multidisciplinary expertise, the Center addresses various areas, including medical devices, biomedical engineering, radiological health, nuclear medicine, nanotechnologies, and innovative therapies. Through its research, control, and training activities, the Center operates in fields such as radiobiology, quality assurance in radiological sciences, nuclear medicine, bioengineering, medical devices, regenerative medicine, electron microscopy, nanotechnologies, and innovative therapies.

4 Scenarios

This section follows a recurring structure to describe the scenario in order to help the reader.

4.1 Aerosol Scenario

Until the COVID-19 pandemic caused by the virus SARS-CoV-2 (Severe Acute Respiratory Syndrome Coronavirus), influenza was predicted to be the most likely pathogen to cause the next pandemic due to its high rate of mutation and transmission. Many past pandemics were flu-related; the 1918 influenza pandemic was caused by an H1N1 virus, and smaller-scale influenza pandemics occurred in 1957, 1968, and 2009.

As was described in D2.1[6], climate change due to greenhouse gas emissions, is projected to lead to changes in the weather that can have direct and indirect effects on respiratory pathogens. Direct impacts occur because of influences of weather and climate on pathogen transmissions. Indirect effects include weather changes, affecting people's behaviour, and this in turn influences the contacts among people thereby changing the likelihood of transmissions, morbidity and mortality. Climate change and weather factors can be included in the scenario of respiratory infection resulting in direct or indirect impacts on the transmission of pathogens, contact patterns, and other behavioural characteristics of people. Additionally, extreme weather events impact critical health infrastructure escalating negative health outcomes through impeding health service provision. Based on the multivariate analysis performed in WP2 — see D2.2[2], temperature is a driver of respiratory infections such as SARS-CoV-2.

Step 1:

Imagine the following scenario:

15 November 2029. An HxNx pandemic was declared a month ago and your region currently is in a large infection wave. There are no specific antiviral drugs for treatment. There is no available vaccine to prevent infection from HxNx.

Transmission and clinical course: Health professionals know that the virus is transmitted via airborne transmission, both with aerosols and with droplet transmission. The incubation period is approximately 4 – 7 days but can vary, depending on individual status. Around 40-50 % of infected people will have an asymptomatic course of the disease but can spread infection. Symptoms of mild and non-severe cases include fever, sore throat, running nose, cough, shortness of breath, diarrhea, vomiting, headache, and body aches, whereas severe cases have to be given oxygen or treated with invasive ventilation. It is also clear that if HxNx enters a household at least half of the persons in that household will be affected.

Severity of disease:

Of 100 children who have HxNx, 30 will have to go to the hospital, 15 will have to go to Intensive Care Unit (ICU) and 10 will die.

Of 100 persons between 20 and 50, 40 will have to go to hospital, 10 will have to go to ICU and 5 will die.

Of 100 persons between 50 and 90, 30 will have to go to hospital, 10 to ICU and 5 will die.

Current situation in your region including responses and restrictions from the government side: From epidemiological surveillance data you know that currently in your region 5% of the whole population is testing positive and this is predicted to double in 10 days, the peak is only expected in 3-4 weeks and no further measures to contain this are currently planned from the governmental side.

Current situation at your CI: 80% of employees are currently coming to work, 10% are sick for different reasons (some with HxNx) and 10% are not responding to contact anymore.

Step 2:

30 November 2029.

<u>Transmission and clinical course:</u> It was reported that the virus also can be transmitted from fomites infected by excretions of infected persons with a severe course of disease. It was identified that healthcare workers and family members of infected persons have a high risk of getting an infection. 21 days of isolation is recommended for an infected person.

<u>Characteristics of clinical course and severity of diseases</u> are the same.

<u>Current situation in your region including responses and restrictions from the government side</u>: From: A massive testing company to detect asymptomatic cases of HxNz infection was opened in hospitals, schools, and other large institutions in your region. Around a quarter of the region's population was tested for two weeks. 7% of the region's population got positive testing results and were recommended to be isolated, a low number of detected cases had symptoms and required hospitalization. Around 3% of the population has a severe course of the disease and is hospitalized. The lack of hospital beds is noted, especially in hospitals/departments for children.

10 deaths are registered in all age groups.

Risk groups were identified by international specialists:

- for HxNx infection: children, healthcare workers, close contacts with severe cases of infection (household members);
- for a severe course of disease: children, people with immunodeficiency, non-compensated diabetes mellitus.

The government recommends using personal protective equipment (face masks, gloves, etc.), physical distancing in crowded areas, and closure of schools and not essential facilities.

<u>Current situation in your CI:</u> 75% of employees are currently coming to work, 10% are sick, isolated as an asymptomatic case or quarantined with their sick children or family members, due to HxNx infection, 5% are sick for other reasons, and 10% are not responding to contact anymore.

Step 3:

15 December 2029. The peak of infection is expected for this period.

<u>Transmission and clinical course:</u> are the same.

<u>Characteristics of clinical course and severity of diseases:</u> are the same.

<u>Current situation in your region, including responses and restrictions from the government side</u>: From the epidemiological surveillance data it is known that from the start of the outbreak around 20% of the population was infected by the new respiratory virus. A quarter of them are already cured, not infected anymore, and can't transmit the HxNx virus to other people, also healthcare specialists suppose that they have a natural immunity that will protect them from new infections. 3.5% of the population has a severe course of the disease and is hospitalized.

25 deaths were registered in the region, 10 of them were children younger than 5 y.o., 5 adults 20-50 with co-morbidities (immunodeficiency, diabetes mellitus, etc.), and 10 adults 50-90.

The lack of hospital beds is noted, especially in hospitals/departments for children. The lack of healthcare staff is noted due to the high rate of infection and the necessity of further isolation in this group.

In addition to the previous recommendations of the government restriction to travel to other regions of the country, because of worth epidemiological situation, is applied during the Christmas period (20 December – 10 January).

<u>Current situation at your CI:</u> 70% of employees are currently coming to work, 10% are sick, isolated as an asymptomatic case or quarantined with their sick children or family members, due to HxNx infection, 5% are sick for other reasons, 5% have a vacation because of fear to be infected, and 10% are not responding to contact anymore.

Step 4:

30 December 2029. The decrease in new cases of infection is noted. Some vaccine candidates for the prevention of HxNx infection are testing in other countries.

Transmission and clinical course: are the same. International experts found that reinfection is possible after 3 months of primary infection, course of the disease is often more severe.

Characteristics of clinical course and severity of diseases: are the same.

Current situation in your region, including responses and restrictions from the government side: From the epidemiological surveillance data is known that the detection of new cases decreased to 20 %, including symptomatic and asymptomatic cases. Hospitalization also decreased, and currently, 2.5 % are hospitalized with a severe course of disease.

From the start of the pandemic 40 deaths were registered in your region. 12 of them were children younger than 5 y.o., 3 children 5-12 y.o. with non-treated diabetes, 2 adolescents, 11 adults 20-50 with co-morbidities (immunodeficiency, diabetes mellitus, etc.), and 12 adults 50-90.

Lack of healthcare staff is noted.

Government recommendations are the same.

Current situation at your CI: 70% of employees are currently coming to work, 10% are sick, isolated as an asymptomatic case or quarantined with their sick children or family members, due to HxNx infection, 5% are sick for other reasons, 10% have a vacation, and 5% are not responding to contact anymore.

Step 5:

15 January 2030. The stable epidemiological situation is noted in the country.

Transmission and clinical course: are the same.

Characteristics of clinical course and severity of diseases: are the same.

Current situation in your region, including responses and restrictions from the government side: A slight decrease in new cases of infection HxNx is noted, including symptomatic and asymptomatic cases. From the start of the outbreak around 30% of the population was infected by the new respiratory virus. Half of them is already cured, not infected anymore. 2% of the population has a severe course of the disease and is hospitalized. The average hospitalization period is 14 days, for cases which were admitted to ICU – 21 days.

50 deaths were registered in the region, 15 of them were children younger than 5 y.o., 3 of them had severe immunodeficiency, 3 children 5-12 y.o., 2 adolescents with non-treated diabetes, 15 adults 20-50, the majority of them had co-morbidities (immunodeficiency, diabetes mellitus, etc.), and 15 adults 50-90.

The workload in hospitals is normalized, and beds are available.

Travel restrictions have been lifted. All other recommendations are relevant.

Current situation at your CI: 70% of employees are currently coming to work, 7% are sick, isolated as an asymptomatic case or quarantined with their sick children or family members, due to HxNx infection, 5% are sick for other reasons, 13% have a vacation, due to necessity to stay with children at home or because of fear to get an infection, and 5% are not responding to contact anymore.

Step 6:

30 January 2030. A stable epidemiological situation is noted in the country. New waves of infection HxNx are predicted by epidemiologists in March-April 2030.

A vaccine with 60%-80% protection from infection is introduced and recommended by international experts to use for small children to 5 y.o. and healthcare workers. It will be available in your region in 2 weeks.

<u>Transmission and clinical course:</u> are the same.

<u>Characteristics of clinical course and severity of diseases:</u> are the same.

<u>Current situation in your region, including responses and restrictions from the government side</u>: A slight decrease in new cases of infection HxNx is noted, including symptomatic and asymptomatic cases. Around 20 % of the population already recovered from infection HxNx. 2% of the population has a severe course of the disease and is hospitalized.

60 deaths were registered in the region, 18 of them were children younger than 5 y.o., 4 of them had severe immunodeficiency, 4 children 5-12 y.o., 3 adolescents with non-treated diabetes, 18 adults 20-50, the majority of them had co-morbidities (immunodeficiency, diabetes mellitus, etc.), and 17 adults 50-90.

The workload in hospitals is normalized, and beds are available.

Government recommendations are the same.

<u>Current situation at your CI:</u> 70% of employees are currently coming to work, 7% are sick, isolated as an asymptomatic case or quarantined with their sick children or family members, due to HxNx infection, 5% are sick for other reasons, 13% have a vacation, due to necessity to stay with children at home or because of fear to get an infection and school closure, and 5% are not responding to contact anymore. Around 20% have already recovered from infection HxNx. 2 deaths from the staff of your institution due to infection HxNx were registered.

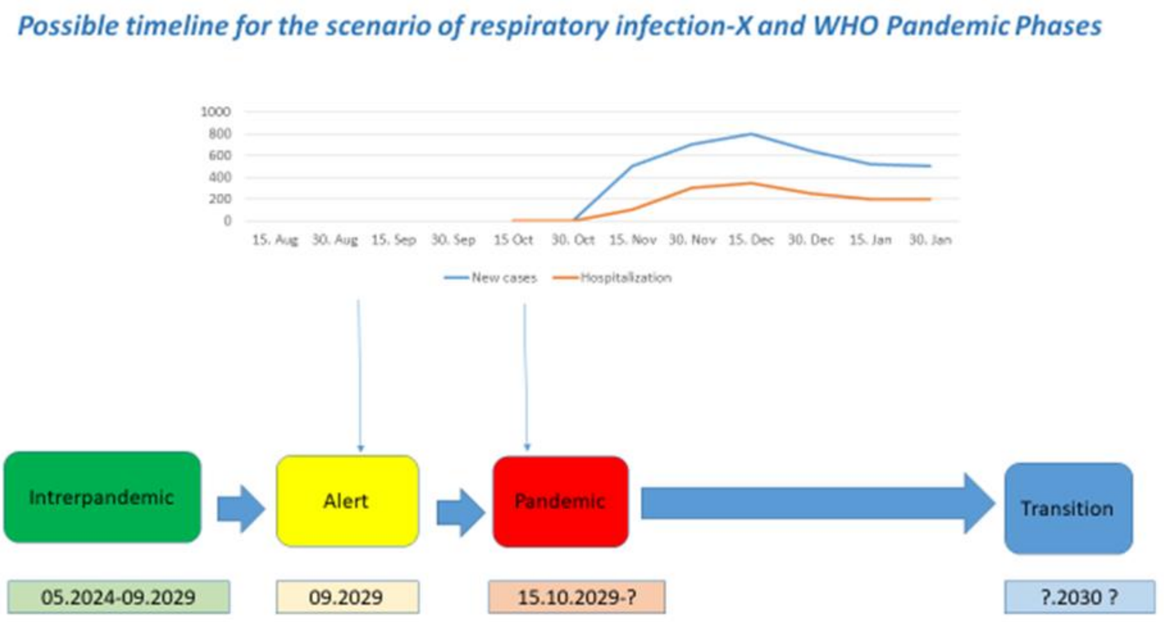

Figure 2: Possible timeline for the scenario of respiratory infection-X and WHO Pandemic Phases

<u>NPIs that can be suggested in case of respiratory virus outbreak:</u>

- Personal measures: physical distancing (1 – 2 meters), respiratory hygiene, and hand hygiene are measures reducing the transmission of pathogens. Personal protective equipment, like face masks, respirators, gloves, etc.
- Environmental measures like ventilation are additionally required to reduce the transmission of pathogens transmitting through aerosols.
- Population level NPIs include the limiting of close physical interpersonal interactions, which can be reached by isolation of symptomatic cases not requiring hospitalisation, quarantining of contacts, shielding medically- and socially-vulnerable populations, recommending 'social bubbles', limiting the size of indoor and outdoor gatherings, measures in long-term care

facilities, migrant and refugees centers, prisons, also measures at the workplace, including remote working, closure of non-essential businesses, school closures, and stay-at-home measures. Furthermore, population NPIs include mobility-related measures, such as international travel restrictions and border closures, measures on conveyances and travel hubs, travel advice, screening at points of entry at national borders, quarantine of passengers, and domestic travel restrictions.

4.2 Vector Scenario

Higher temperatures and changes in precipitation patterns in EU countries will affect the transmission of some vector-borne diseases, depending on the affected region and degree of projected climate changes for the future. Vector-borne diseases are mainly transmitted by arthropod vectors such as mosquitoes, which are particularly sensitive to changes in climatic conditions because they are cold-blooded. Infectious disease impacts from climate change comprise a complicated interplay of climate and pathogens or vectors. The prevalent area of endemic pathogens can change in response to changes even in local climate. Transmission of infections can thus change spatially, but also temporally as changes in climate affect seasonal weather patterns and in turn seasonality of infectious agents and their vectors. Furthermore, temperature impacts the rate of pathogen maturation and replication in mosquitoes and increases the likelihood of infection. For diseases transmitted by vectors that have aquatic developmental stages, precipitation also exerts a very strong influence on vector-borne disease dynamics.

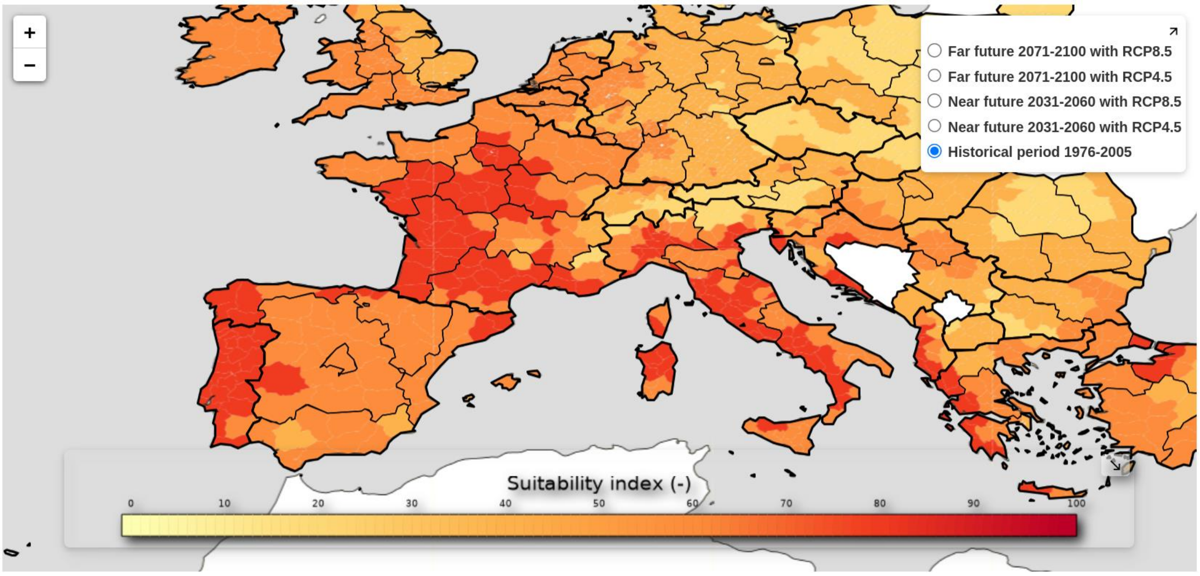

Figure 3: Copernicus projections for e.g. Aedes albopictus 1

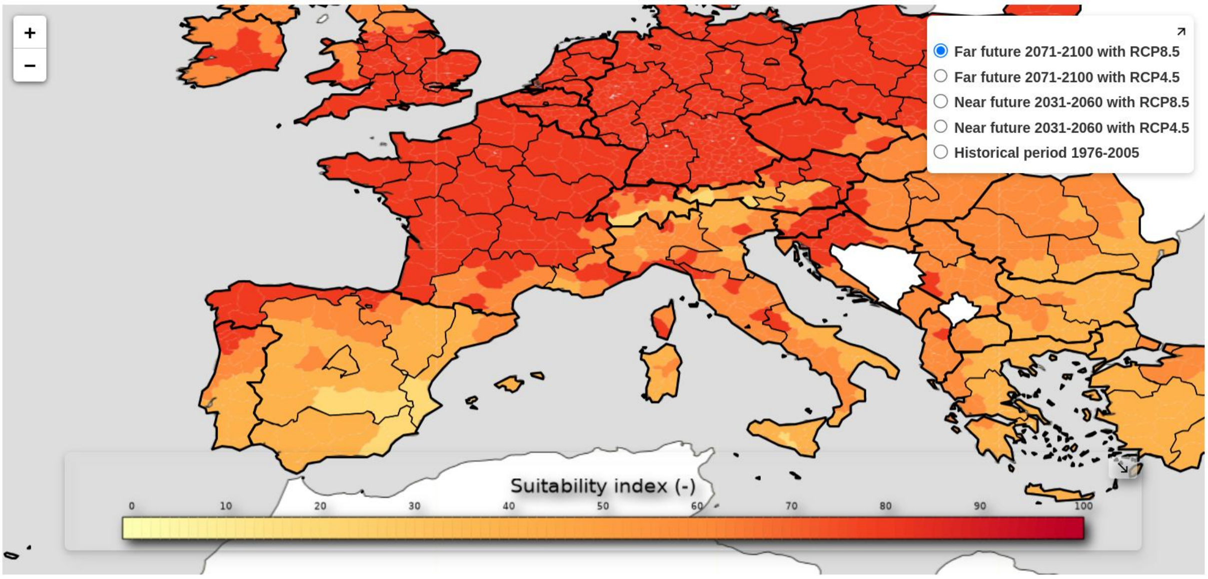

Figure 4: Copernicus projections for e.g. Aedes albopictus 2

The Copernicus Climate Data Store shows how the suitability index of the Aedes albopictus mosquito is projected to change as precipitation and temperature patterns change under different climate change scenarios [7].

Pathogen with predominantly vector-borne transmission include the Crimean-Congo haemorrhagic fever, Zika virus, West Nile fever, Dengue virus, etc. Zika virus cases transmitted by the Aedes (Stegomyia) genus mosquitoes were reported in 89 countries and territories, mainly in the Americas. However, surveillance remains limited globally. In EU countries numerous cases of travel-associated Zika virus infections were reported in 2015-2018. In 2019 autochthonous, mosquito-borne transmission of Zika virus was identified in South-eastern France. Complications include Guillain-Barré syndrome in adults and increased incidence of microcephaly associated with transmission of virus from mother to foetus during pregnancy [8][9]].

The global incidence of Dengue virus has increased dramatically in recent decades and reached 5.2 million cases in 2019. The virus is endemic to more than 100 countries in the World Health Organization (WHO) regions of Africa, the Americas, the Eastern Mediterranean, South-East Asia and the Western Pacific. Local transmission in Europe was reported for the first time in France and Croatia in 2010 and imported cases were detected in 3 other European countries. Based on these findings, a possible pandemic-like outbreaks of these diseases in Europe, with potential impacts on Cis, is projected.

Step 1:

Imagine the following scenario:

May 2026. Your region becomes endemic to mosquitos that can transmit new virus X to humans.

<u>Transmission and clinical course:</u>

Health professionals know the virus is transmitted from infected mosquitos that usually bite during the day.

Most people with infection X have a mild or asymptomatic course.

20% of infected persons will develop symptoms. Typical manifestation of diseases is 4–10 days after infection and lasts for 2–7 days. Symptoms may include high fever (40°C/104°F), severe headache, pain behind the eyes, muscle and joint pains, nausea, vomiting, swollen glands, and rash. Individuals infected for the second time are at greater risk of severe dengue.

10% of symptomatic cases have severe symptoms that often come after the fever has gone away: severe abdominal pain, persistent vomiting, rapid breathing, bleeding gums or nose, fatigue, restlessness, blood in vomit or stool, being very thirsty, pale and cold skin, and feeling weak.

Pregnant women are a vulnerable group population, usually having a severe course that leads to death in 20% of cases in this group.

Tests for identification with high sensitivity and specificity are available.

There is no specific medicine to treat infection X.

Severe infection X is a medical emergency, that requires ICU beds with a high level of infection control.

No vaccines are available.

Severity of disease:

Of 100 children who have infection X, 10 will have to go to hospital, 5 will have to go to ICU and 1 will die.

Of 100 persons between 20 and 50, 20 will have to go to hospital, 5 will have to go to ICU and 1 will die.

Of 100 persons between 50 and 90, 30 will have to go to hospital, 10 to ICU and 2 will die.

Of 100 pregnant women who have infection X, 80 will have to go to hospital, 40 will have to go to ICU and 20 will die. Complications for the foetus and childbirth are unknown.

Current situation in your region, including responses and restrictions from the government side:

From local public health authorities, it is known that in your region a total of 200 infected suspected individuals were examined, out of which 40 (20%) patients were infected with virus X. 2 adult patients are currently in ICU, 2 pregnant women died.

In the infection X-positive patients, 24 (60%) were male and 16 (40 %) were female. More than 60% of cases are in the age group 20-50 y.o., children (0-18) - 15%.

Epidemiologists predict an increase in the number of cases in the future.

No further measures to contain this are currently planned from the governmental side.

Current situation at your CI:

85% of employees are currently coming to work, 10% are sick for different reasons, half are suspected cases of infection X and 5% are not responding to contact anymore.

Step 2:

June 2026. The epidemic of infection X is continuous in your region, as in the neighbouring regions.

Transmission and clinical course:

Health professionals from the national level found cases of transmission from mother to child. No evidence of sexual transmission.

Characteristics of clinical course and severity of diseases: are the same.

Current situation in your region, including responses and restrictions from the government side:

1600 suspected cases were examined from the start of the outbreak, out of which 400 were positive. Only 80 of them had a symptomatic course, and 50 were hospitalized, 15 of them needed ICU. 5 deaths were registered, 3 pregnant women and 2 men aged between 50 to 90, one of them had severe immunodeficiency.

In the infection X-positive patients, 240 (60%) were male and 160 (40%) were female. More than 60% of cases are in the age group 20-50 y.o., children (0-18) - 15%.

Epidemiologists predict a peak in two months.

The government recommends using repellent as an individual measure and mosquito nets as a population NPI.

Current situation at your CI:

80 % of employees are currently coming to work, 15% are sick for different reasons, 5% have a symptomatic course of infection X or positive test, 5% are suspected cases of infection X, and 5% are not responding to contact anymore.

Step 3

July 2026. The epidemic of infection X is continuous in your region, as in the neighbouring regions.

Transmission and clinical course:

Health professionals from the international level found that 20% of severely symptomatic patients have negative test results. No evidence of sexual transmission.

Characteristics of clinical course and severity of diseases: are the same.

Current situation in your region, including responses and restrictions from the government side:

3000 suspected cases were examined from the start of the outbreak, out of which 700 were positive. Only 140 of them had a symptomatic course, and 100 were hospitalized, 30 of them needed ICU. 10 deaths were registered, 5 pregnant women and 3 men aged between 50 to 90, one of them had severe immunodeficiency, and 2 women of the same age group without comorbidities.

In the infection X-positive patients, 490 (70%) were male and 210 (30%) were female. More than 60% of cases are in the age group 20-50 y.o., children (0-18) - 15%.

Epidemiologists predict a peak in one month.

The government recommends using repellent as an individual measure and mosquito nets, international travel restrictions, and closure of schools as a population NPI.

Current situation at your CI:

75% of employees are currently coming to work, 15% are sick - 5% have a symptomatic course of infection X or a positive test, 5% are suspected cases of infection X, 5% for other reasons; 5% take a leave or home office because of school closure; and 5% are not responding to contact anymore.

Step 4

August 2026. The epidemic of infection X is continuous in your region, as in the neighbouring regions. Peak is predicted on this month.

Transmission and clinical course:

International health authorities report possible transplant transmission of infection.

The average period of stay in ICU is 10-14 days, which can reach 1 month for pregnant women.

Characteristics of clinical course and severity of diseases: are the same.

Current situation in your region, including responses and restrictions from the government side:

4500 suspected cases were examined from the start of the outbreak, out of which 1100 were positive and 25 had clinical diagnoses based on severe symptoms without laboratory confirmation of infection X. 260 cases of them had a symptomatic course + 120 in last month, and 190 were hospitalized, 40 of them needed ICU. 14 deaths were registered - 6 pregnant women, 4 men aged between 50 to 90, one of them had severe immunodeficiency, and 4 women of the same age group without comorbidities.

In the infection X-positive patients, 490 (70%) were male and 210 (30%) were female. More than 60% of cases are in the age group 20-50 y.o., children (0-18) - 15%.

The government recommends using repellent as an individual measure and mosquito nets, international travel restrictions, and closure of schools as a population NPI.

A lack of ICU beds is observed.

Current situation at your CI:

55% of employees are currently coming to work, 20% are sick - 5% have a symptomatic course of infection X or a positive test, 10% are suspected cases of infection X, 5% are sick for other reasons; 15% take a leave or home office because of school closure; and 10% are not responding to contact anymore.

Step 5

September 2026. The epidemic of infection X is continuous in your region, as in the neighbouring regions. The peak of infection X was on a last month. A decrease in incidence is predicted for this month.

Transmission and clinical course: are the same.

Characteristics of clinical course and severity of diseases: are the same.

Current situation in your region, including responses and restrictions from the government side:

7000 suspected cases were examined from the start of the outbreak, out of which 2000 registered as infection X cases. Of them, 1900 were confirmed by test and 100 had clinical diagnoses based on severe symptoms without laboratory confirmation of infection X. 420 cases had a symptomatic course + 160 in the last month. From the beginning of the outbreak, 290 cases were hospitalized, 58 of them needed ICU. 19 deaths were registered, 10 pregnant women and 5 men aged 50 – 90, one of them had severe immunodeficiency, and 4 women of the same age group without comorbidities.

In the infection X-positive patients, 1330 (70%) were male and 570 (30%) were female, 45 of them were pregnant. More than 60% of cases are in the age group 20-50 y.o., children (0-18) - 15%.

The government recommends using repellent as an individual measure and mosquito nets, international travel restrictions, and closure of schools as a population NPI.

Because of the lack of hospital beds, not all cases can be hospitalized. Telemedicine is used for those, who need to be treated at home. A lack of ICU beds is observed.

Current situation at your CI:

50% of employees are currently coming to work, 20% are sick - 5% have a symptomatic course of infection X or a positive test, 10% are suspected cases of infection X, 5% for other reasons; 20% take a leave or home office because of school closure or need to treat relatives at home; and 10% are not responding to contact anymore.

Step 6

October 2026. The epidemic of infection X is continuous in your region and country. A decrease in incidence is predicted for this month, absence of new cases is predicted for next month.

Transmission and clinical course: are the same.

Characteristics of clinical course and severity of diseases are the same.

Current situation in your region, including responses and restrictions from the government side:

10.000 suspected cases were examined from the start of the outbreak, out of which 2600 registered as infection X cases. Of them, 2450 were confirmed by test and 150 had clinical diagnoses based on severe symptoms without laboratory confirmation of infection X. 550 cases had a symptomatic course, of them 130 for the last month. From the beginning of the outbreak, 370 cases were hospitalized, 70 of them needed ICU. 23 deaths were registered, 13 pregnant women and 5 men aged 50 – 90, one of them had severe immunodeficiency, and 5 women of the same age group without comorbidities.

The government recommendations are the same, except for international travel restrictions.

All severe cases can be hospitalized, and no lack of ICU beds is observed.

Current situation at your CI:

60 % of employees are currently coming to work, 20% are sick - 5% have a symptomatic course of infection X or a positive test, 5% are suspected cases of infection X, 10% for other reasons; 15% take a

leave or home office because of school closure or need to treat relatives at home; and 5% are not responding to contact anymore.

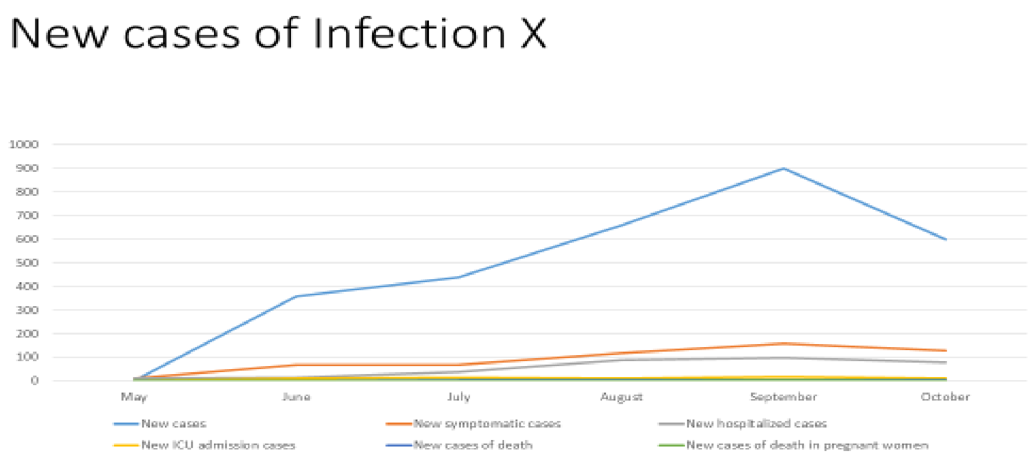

Figure 5: Total cases of infection 1

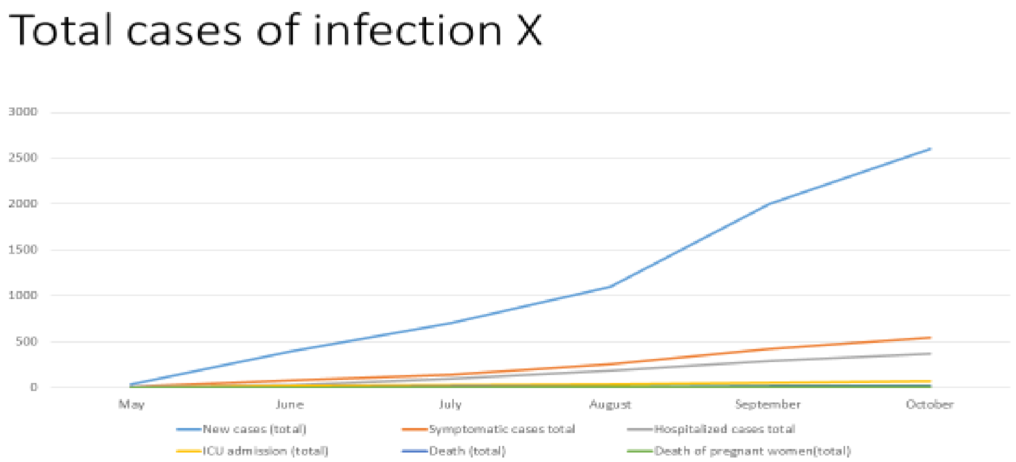

Figure 6: Total cases of infection 2

NPIs that can be suggested in case of vector-borne infection outbreak:

- Personal level NPIs for protection from vector-borne infectious diseases contains an application of repellents to exposed skin or clothing, wearing clothing that minimizes skin exposure to mosquito bites during periods, when mosquitoes are most active, using window screens, door screens, and air-conditioning in buildings to discourage day-time entry of mosquitos and using long-lasting insecticidal mosquito nets when sleeping or resting during the day. Furthermore, infected individuals should protect themselves from mosquito bites to prevent further transmission.
- Environmental measures include reducing vector populations through residual and space spraying and NPIs targeting eggs, larvae, and pupae appropriate to the water reservoirs used for breeding. For small water receptacles such as discards and other waste, measures include community clean-up campaigns to remove or destroy small discards that are serving as water receptacles, such as plastic containers, tin cans, or scrap metal, to ensure tires are stored

properly, removed to landfill sites or recycled, to clean roof gutters and home coolers. For medium to large containers that hold water for domestic use recommendations are to empty, clean and scrub to remove eggs and other immature stages each week before refilling, place tight-fitting covers and introduce larvicides. For other large containers such as ornamental pools, wells and cisterns, here one should introduce native larvivorous fish or other larvivorous aquatic insects. For irrigation and storm water canals or other relevant waters stores efficient irrigation practices such as weekly flushing, improved drainage, use of temporary pools, and ensuring free-flowing gutters without any stagnant pools are implemented.

- Population NPIs present a surveillance system (epidemiological and entomological) and travel-related measures.

5 Application of the Risk Assessment Tool

In this chapter, the various interactions between modules outlined in deliverable D2.2[2] are illustrated, where they will engage with each other, serving both as sources and receivers of information. These interactions will be realized using the Risk Assessment Module, described in section 5.2.1 of this document, as a gatherer.

Within this tool, the models of climate modelling and disease spread, CIs interdependence and evaluation of economic impacts will be implemented as simulation modules. Through this integration, it will be possible to offer a novel tool to the end-users, which it will be referred to as the Integrated Tool (or Strategy Tool). This tool will not only serve as a vehicle for implementing the SUNRISE Strategy but will also aid CI providers in their decision-making processes related to pandemic and climatic risks.

5.1 General Overview

The different simulation modules interact with each other through the bidirectional exchange of data and information, forming a network of connections aimed at integrating and compensating for the intrinsic limitations of each model. This synergy arises from each module's focus on a single aspect of the pandemic crisis, which, if considered in isolation, would offer a partial and fragmented view of the crisis. The integration of these modules thus enables the creation of a comprehensive and multidimensional framework, essential for the effective and efficient management of pandemic emergencies. The result is the development of an integrated, advanced risk management tool that provides an integrated view of the multiple challenges associated with pandemic crises, positioning itself as a strategic resource for the development of realistic and data-based intervention policies.

End users derive benefits from the use of this tool in terms of response capability and strategic planning as well as gaining support during the decision-making process. This support reflects the specific needs of critical infrastructure providers identified during the management of pandemic emergencies and the conduct of the first national workshop. Specifically, incorporating this tool into the decision-making process allows for:

- Ensuring management aligns with the real needs identified during critical phases of the emergency.
- Providing a comprehensive assessment of the strengths and vulnerabilities of the organization or system considered.
- Offering a detailed analysis of the impacts and consequences of specific events on the supply chain.
- Assessing the economic implications of interdependencies among the various sectors involved, crucial for the resilience and sustainability of the supply chain.

Figure 7, in the next page, shows a graphic representation of the modules' integration.

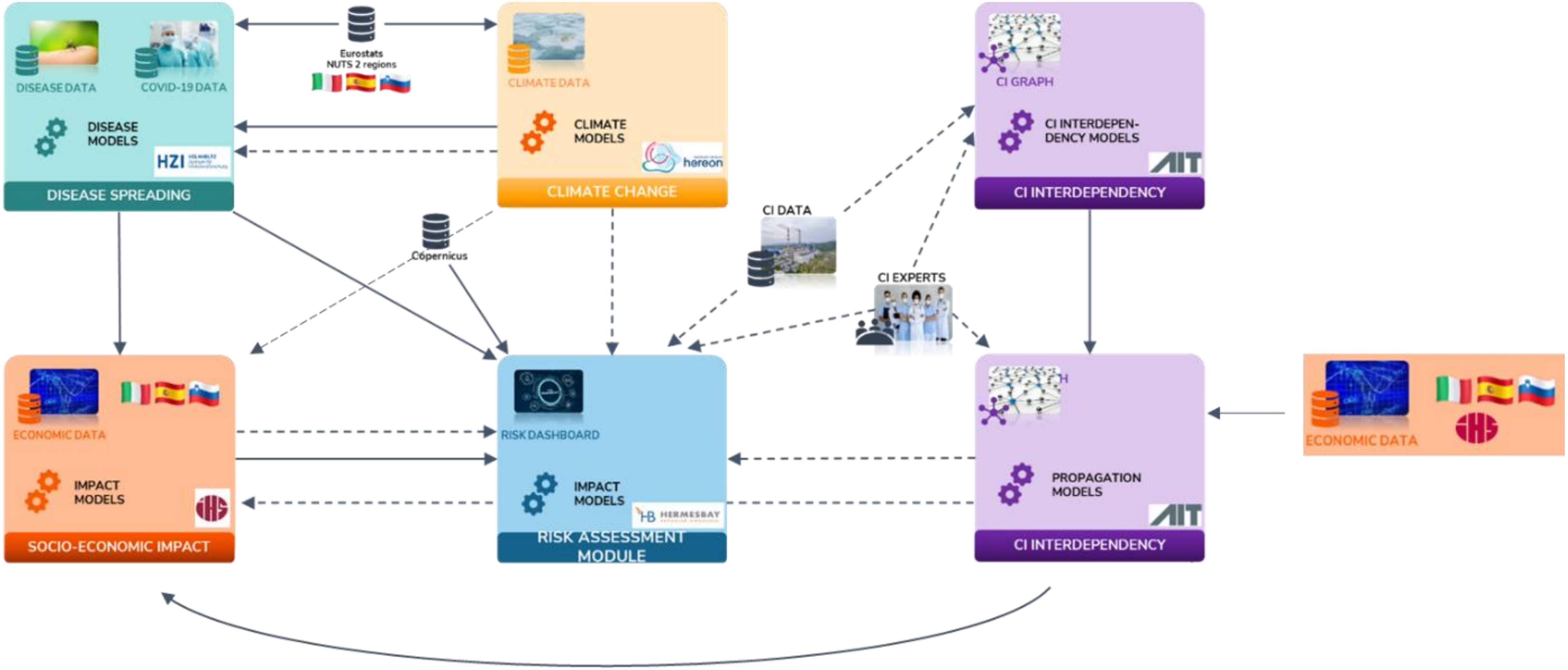

Figure 7: High-level overview on the architecture model for the simulation approaches

The interaction among simulation modules unfolds through a network of interdisciplinary collaborations, where each module contributes its uniqueness to the overall understanding of the dynamics at play. Within this framework, the Climate and Disease Spreading modules closely cooperate to examine how climate changes affect disease spread and the resulting health and environmental impacts. This analysis is critical for predicting and mitigating public health risks in climate change scenarios, underscoring the importance of a multifaceted approach to crisis management and response strategies.

Concurrently, the Disease Spreading modules supplies essential data to the Socio Economic and Risk Assessment modules to decode the economic repercussions of epidemics. This information exchange is vital for designing intervention strategies that are not only effective from a health perspective but also sustainable for the economy and society. Additionally, the models of Critical Infrastructure Interdependence and Propagation enrich both the Risk Assessment and Socio-Economic modules by factoring in potential cascading effects that might arise from disruptions in one of the infrastructure network nodes. This enhances understanding of how interruptions in one sector can spread through the economic and social network, impacting even seemingly distant or unrelated sectors.

The Socio-Economic modules feeds into both the risk assessment modules and those of interdependence and propagation. This creates a feedback loop that not only integrates but also amplifies the understanding of the phenomena under study, enabling further refinement of mitigation strategies and public policies. This multidirectional interaction among the modules ensures an integrated approach to crisis management, crucial for devising effective responses to complex risk scenarios. This dynamic interconnection establishes the Risk Assessment module as the core of an advanced analytical ecosystem, facilitating the application of the SUNRISE Strategy outlined in document D2.2[2], allowing for the planning of targeted interventions based on a deep understanding of the pandemic crisis and its various dimensions.

5.2 Detailed Components

The following section provides a brief summary of the WP2 modules described in D2.2[2], chapter 5, to provide a more in-depth understanding of the interfaces that will be created between the different modules.

5.2.1 Risk Assessment Module

The Risk Assessment Module, developed for the SUNRISE Strategy, aims to bolster the resilience of CIs against pandemics and extreme climate scenarios. This platform uses historical and CI-provided data for customized risk evaluations, grounded in a meticulous risk analysis methodology. It starts with an extensive context analysis identifying CIs' operational environments, networks, and threats, underlining the heightened risks from intricate interdependencies and potential cascading effects within the European CI network. CI operators enhance this analysis by inputting data through platform questionnaires, essential for delineating the complex web of interconnections.

The Risk Assessment categorizes threats into pandemic-epidemic and extreme climate events, further detailed by specific occurrences like avalanches or heatwaves, and identifies direct and indirect threats. Utilizing open datasets, the model quantifies threat probabilities and assesses impacts across economic, operational, manpower, reputational, and service quality domains, assigning scores to these impacts for a nuanced risk understanding.

Functionally, the tool supports CIs in risk monitoring, impact prediction, and decision-making for business continuity, featuring threats, impacts and interdependency analyses to examine threats, countermeasures, and interdependencies. A significant update introduces a predefined list of countermeasures for each threat, simplifying operator processes and aiding in proactive risk management and resilience enhancement for European CIs.

5.2.2 Disease Spreading Module

The multi-patch Disease Spreading Module is a sophisticated computational framework developed to simulate infectious disease spread in spatially heterogeneous environments, transcending the limitations of simpler models by incorporating the diversity of population distributions into multiple interconnected compartments or patches. These patches represent distinct geographic or demographic areas, each with unique disease transmission dynamics, managed through differential equations that integrate critical parameters like transmission, recovery, and inter-patch movement rates. This approach provides insights into disease propagation across different locations and communities.

A key feature of the model is its ability to illustrate the effects of spatial connectivity on disease spread, capturing the potential for infected individuals moving between patches to introduce or amplify infections in new areas. This aspect is particularly relevant for diseases with long incubation periods or those spread by mobile vectors.

The model also explores spatial heterogeneity in factors affecting disease transmission, such as population density and environmental conditions, underpinning the development of nuanced epidemiological models and control strategies. In the SUNRISE Project, the model employs a meta-population approach and a SEIR model framework, allowing for detailed disease transmission simulations within and across sub-populations.

Furthermore, the model integrates climate change impact analysis, assessing how changes in weather variables could affect infection rates and pandemic patterns. Inputs include epidemiological, demographic, and climate data, enabling the model to predict disease outcomes and the indirect impact of epidemics on critical infrastructure, thus highlighting its comprehensive approach to addressing the challenges of infectious disease spread in the context of global changes like climate change.

5.2.3 Climate Module

A multi-variate analysis utilizing current meteorological data from the ECMWF, European Centre for Medium-Range Weather Forecasts' reanalysis (ERA5) aims to determine how weather variables impacted SARS-CoV-2 infection risk in Germany. The study examines temperature, precipitation, and the Universal Thermal Comfort Index (UTCI) to understand their effects on the virus's spread. Additionally, the analysis explores the influence of regional climate projections on the transmission routes of respiratory and vector-borne pandemics, particularly focusing on the role of the Aedes albopictus mosquito. The climate data, sourced from the EURO-CORDEX (Coordinated Regional Climate Downscaling Experiment) dataset [10], includes regional model projections based on global climate model projections from the 5th Coupled Model Intercomparison Project, covering Europe with high-resolution projections for historical and future periods under three emission scenarios. These projections, especially under the high-emission scenario, indicate a significant temperature increase, potentially enhancing the habitat suitability for Aedes albopictus, a carrier of diseases like dengue and chikungunya. The findings underscore the growing environmental conditions conducive to the mosquito's spread, pointing to an urgent need for integrated health and environmental policy responses.

5.2.4 Socio Economic Impact Module

The Socio-Economic Impact Module leverages an Agent-Based Model (ABM) to evaluate the economic repercussions of diverse disaster scenarios across various sectors. This approach, grounded in a detailed macro-economic framework that differentiates 64sectors according to the Eurostat Figaro tables classification, is tailored to capture the intricate dynamics of critical infrastructures and their capital stocks. Initially calibrated to Austria's economy, the model operates on a quarterly basis, projecting up to three years ahead to manage uncertainty and predict economic outcomes.

Agents within the model represent a spectrum of economic entities including firms, households, government bodies, banks, and international actors. They interact based on predefined rules and autoregressive processes, facilitating dynamic simulations of macroeconomic variables such as income, demand, and Gross Domestic Product (GDP) growth without relying on rational or model-consistent expectations, which is in most instances closer to empirical observations.

The model's flexible structure allows for the simulation of various economic shocks — from supply chain disruptions and demand shifts to productivity changes and capital stock damages due to natural disasters. It utilizes data from Eurostat for accurate scenario simulations, including input-output tables and national accounts. Additionally, it considers climate-induced labour productivity variations, with sector impacts evaluated against sun exposure and, work intensity, building on related literature in health economics.

Output indicators include sector-level and macroeconomic metrics like gross value added, employment, GDP, and unemployment rates, enabling a thorough analysis of socio-economic impacts. This comprehensive assessment aids in informing policy and planning, particularly in addressing the challenges posed by pandemics, climate change and other environmental and economic disruptions.

5.2.5 CI Interdependency Module

The CI Interdependency module provides two services to the architecture model.

CI Interdependency models

The CI Interdependency module provides a technical interface to the risk assessment module. This interface supports the synchronization of risk assessment data and interdependencies (that are added by the end users) to technical representations of this data in a CI interdependency graph (CIIG) (cf. D2.2[2] Section 5 on simulation models). The synchronization also includes pandemic scenario configurations (like disease spreading and climate change models). The end users do not directly interact with the technical representation of the CI interdependency graph. In this interface, the risk assessment module acts as a data hub and service requester.

Propagation models

The CI Interdependency module also provides a technical interface to run cascading effects simulations (cf. D2.2[2] Section 5 on simulation models) on interdependency models. These simulations will be used in two ways in the architecture model and can be visualized via the risk assessment module.

1. The propagation models provide simulation results on interdependency graphs with socio-economic and pandemic dependencies, describing a baseline of interdependent effects in pandemic scenarios. This data will be available on the level of NACE [11]sector classifications and can also be broken down to individual service providers and critical infrastructures participating via the risk assessment module. In this use case, the cascading effects simulation represents a forecast model that transforms modelled data from multiple sources into an impact model that is suitable for implementation by end users.
2. The propagation models provide data to the What-If analysis of the risk assessment module in the form of simulations of possible interdependent effects in pandemic scenarios, including simulated forecasts of possible intervention scenarios. In this use case, the cascading effects simulation represents an interactive model that is suitable for interactive usage by end users.

5.3 Interfaces

The purpose of this section is to provide an in-depth analysis of the interactions between various modules, thoroughly examining the data exchanged among them and, where already definable, to outline the communication protocols used for integrating these modules. The evolution of these interactions and the realization of combining all interfaces to the Risk Assessment module towards the Integrated Tool will form the core of the Project's second phase. In this context, the integration strategies and technologies to be adopted will be detailed, aiming to facilitate synergy among the different models, ensuring an efficient and secure data flow, in alignment with the Project's predefined objectives.

5.3.1 Risk Assessment Module – Disease Spreading Module

The Disease Spreading Module interacts with the Risk Assessment Module in two main ways, outlined as follows:

- Validation Scenarios: This configuration aims to provide detailed epidemiological scenarios used as a basis for the Strategy's validation. These scenarios allow the validating entity to apply and verify the effectiveness of both the adopted Strategy and the integrated support tools within a simulation environment that mimics realistic conditions. These specific scenarios are elaborated upon in chapter 4 of this document.
- Threat Configuration: This setup involves developing a customized list of threats associated with specific pandemic events, such as an influenza epidemic. This approach enables end users to gain a detailed understanding of various indirect threats, formulated by industry experts, which may arise from a pandemic event. The added value of this "customized list" lies in offering end users the expertise and perspectives of specialists, highlighting indirect threats that might not be immediately apparent in the initial stages of crisis management but could have significant long-term effects if not adequately addressed.

In response, the Risk Assessment Module provides essential data to enrich the Disease Spreading Module, including:

- An exhaustive catalog of indirect threats and their relational networks, with "indirect threat" encompassing any threat precipitated by the manifestation of a direct threat. Given the vast and diverse body of literature on the exact likelihood of indirect threats materializing, a qualitative analysis was undertaken. Utilizing an ontological framework, each indirect threat is linked to either direct threats or other indirect threats that may instigate its emergence. Notably, the genesis of indirect threats is not limited to direct threats alone; they can also emerge as a result of other indirect threats, in a multi-layer taxonomy.
- Information gathered from Critical Infrastructures during the profiling phase described below in section 5.4, conducted by the Risk Module.

The outcome of this interaction is a tailored profile for Critical Infrastructures, providing them with a case study on the implementation of strategies by a multidisciplinary team of experts, as well as a comprehensive overview of the threats and impacts stemming from an epidemiological crisis. This approach aims to enhance preparedness and response to crisis scenarios, leveraging interdisciplinary collaboration and the integration of data and analysis.

The technical modalities for data exchange between the two models are currently being defined, and the potential use of APIs, JSON formats, or solutions involving CSV or XLSX files will be jointly evaluated.

5.3.2 Risk Assessment Module - Socio-Economic Impact Module

The Socio-Economic Impact Model plays a pivotal role in enriching the Risk Assessment Model by providing a comprehensive array of quantitative data and graphical visualizations. This data set encompasses:

- Sectoral Interdependence Analysis: By employing the NACE code during the profiling phase, this module quantifies the economic interdependence between the end-user's sector and other sectors. It calculates an economic value that reflects the significance of each sector within the user's supply chain, thereby offering an estimation of the economic impact resulting from the disruption or absence of specific sectors.
- Financial Evaluation of Countermeasures: This involves an analysis of the financial effects associated with implementing countermeasures against a pandemic, aimed at assessing their impacts both economically and socially. This includes NPI, especially the temporary lock-down

of sectors. Such analysis aids in understanding the consequences of these measures, enabling a balanced evaluation of public health benefits versus the economic burdens incurred.

In response, the risk assessment model further augments this knowledge base with specific data, including:

- A detailed enumeration of indirect threats and their interconnections, illustrating how certain events can cascade and affect other areas.
- Information gathered from critical infrastructures during their profiling phase, contributing to a holistic understanding of the risk landscape.

The outcome of this interaction is a complex set of information that enhances and extends the impact analysis already integrated into the tool. This methodology allows end-users to leverage economic data as a metric to evaluate available strategic options and identify vulnerabilities. Consequently, users can make informed decisions, weighing the economic and social impacts of their choices in response to pandemic scenarios and other crises, thereby ensuring a more effective and informed risk management approach.

The technical modalities for data exchange between the two models are currently being defined, and the potential use of APIs (Application Programming Interface), JSON (JavaScript Object Notation) formats, or solutions involving CSV (Comma-Separated Values) or XLSX (Excel Spreadsheet) files will be jointly evaluated.

5.3.3 Socio-Economic Impact Module – CI Interdependency Module

The Socio-Economic Impact Module provides data to the CI interdependency module in the form of an interdependency graph configuration. This configuration includes:

- Graph nodes in the form of 64 defined economic sectors (following the NACE[11] sector classification) on the territorial units for statistics (NUTS) 2 level of Italy, Slovenia, and Spain. Depending on actual sector data, some sectors might be grouped for less overall nodes.
- Interdependencies between these graph nodes. These interdependencies represent economic dependencies on other sectors' goods and / or value generation.
- A heuristic to model state transitions of the graph nodes based on economic interdependencies and different pandemic scenarios. This heuristic will be developed over the course of the SUNRISE Project.

In turn, the CI interdependency module returns data in the form of cascading effects simulation results. These results include the following data:

- Possible cascading effects of pandemic scenarios to economic sectors, modelled as the individual state of affectedness of each economic sector.
- The simulation runs are non-deterministic and will run in batches. Therefore, the simulation results include individual simulation results, cause-and-effect relationships between economic sectors, simulated distributions of affectedness, and aggregated results like mean state of affectedness.

Data will be exchanged in JSON format via a REST (REpresentational State Transfer) Web API in both directions. A solution with CSV or XLSX files could be implemented if necessary.

5.3.4 Risk Assessment Module – CI Interdependency Module

The risk assessment module provides data to the CI interdependency module in the form of risk assessment data of CIs and other relevant regional service providers. This data is used as input data for simulations, and includes:

- Economic sectors (NACE[11]) and regional information (NUTS) of the service providers and of suppliers they are dependent on, estimated climate and pandemic threats that impact the service providers and estimated economic loss in relation to the threats.

- Pandemic scenario configurations (disease spreading and climate change, and respective input data) for specific cascading simulation runs. This data includes regional pandemic effects, differentiated by population groups and CI sectors.

In the CI interdependency module, the graphs will be automatically transformed to facilitate the cascading effects simulations. Transformation steps include:

- Forming interdependencies between modelled CIs. There will be a technical interface to exchange risk assessment data of the CIs using the risk assessment module. For cascading effects simulations, dependent CIs will be automatically connected in the CI interdependency graph based on their economic sectors and geographic regions.
- Adding population nodes (dependent on the disease spreading and climate change projections) to the modelled CIs or affected NACE[11] sector. This step is needed to properly simulate the cascading effects of pandemic scenarios.
- Adding a heuristic to model state transitions of the graph nodes based on the risk assessment and service dependencies of the modelled CIs and the pandemic scenario effects. These heuristics will be developed over the course of the SUNRISE Project.

The CI interdependency module provides data in the form of cascading effects simulation results. These results will be used in the What-If analysis of the risk assessment module, and include the following data:

- Possible cascading effects of pandemic scenarios to the CIs, modelled as both individual states of affectedness of the CIs as well as an estimated economic impact (in absolute monetary value, estimated by the CIs).
- The simulation runs are non-deterministic and will run in batches. Therefore, the simulation results include individual simulation results, cause-and-effect relationships between CIs and their economic service dependencies, simulated distributions of affectedness, and aggregated results like mean state of affectedness.

Data will be exchanged in JSON format via a REST Web API in both directions. A solution with CSV or XLSX files could be implemented if necessary.

It is recognized that the data exchange in question handles highly sensitive information. Unauthorized access to Critical Infrastructure (CI) interdependencies would potentially enable adversaries to comprehend methods for incapacitating the CI network. In order to safeguard this data, the REST Web API utilized for the data exchange is secured through JSON Web Token (JWT) authorization, employing the symmetric signing algorithm HS256 on the server side, whilst refraining from sharing the secret key with API clients. Consequently, this ensures that valid authorization tokens can only be generated by the server. Furthermore, authorization tokens are designed to expire after a predetermined duration, and mechanisms for secret key rotation can be implemented server-side, enhancing the overall security posture.

5.4 Critical Infrastructure Profiling

In order to actualize the objectives outlined in the preceding chapter, it is crucial to solicit and gather data representing the real needs and peculiarities of the involved critical infrastructures. For these reasons, the profiling phase within the Risk Assessment Module is essential, as it allows for the collection of non-sensitive information directly from end users, ensuring results consistent with the needs identified during the pandemic and highlighted by CI providers during the SUNRISE Project workshops. Additionally, this section enables the gathering of fundamental information to feed all modules and facilitate their integration into a single tool. Therefore, it is crucial that the profiling section be included in the validation plan, as without it, the functionality of the integrated tool cannot be guaranteed.

The following sections will present the different requests submitted to critical infrastructures during the profiling phase.

5.4.1 Basic Information

In this section, CI providers are asked to provide their basic information, such as NACE[11] codes and the geographical distribution of their various locations.

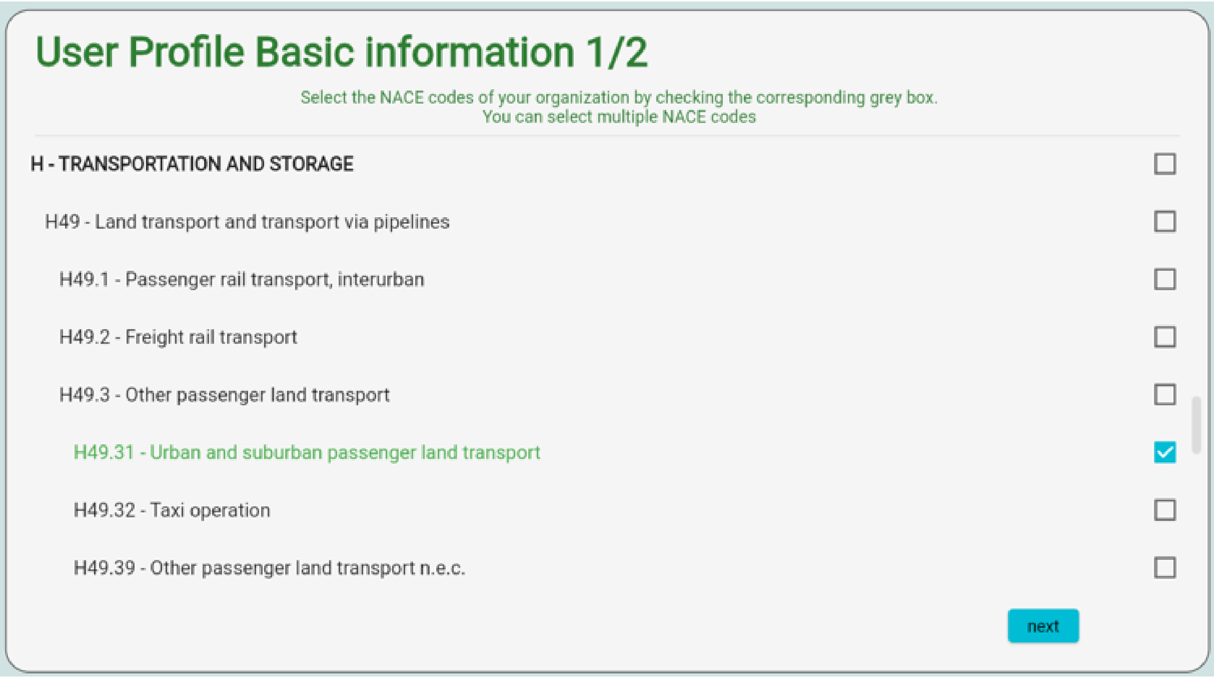

Figure 8: User profile basic information section 1/2

Figure 9: User profile basic information section 2/2

5.4.2 Threat Analysis

In this section, end users are required to specify the direct and indirect threats they intend to monitor.

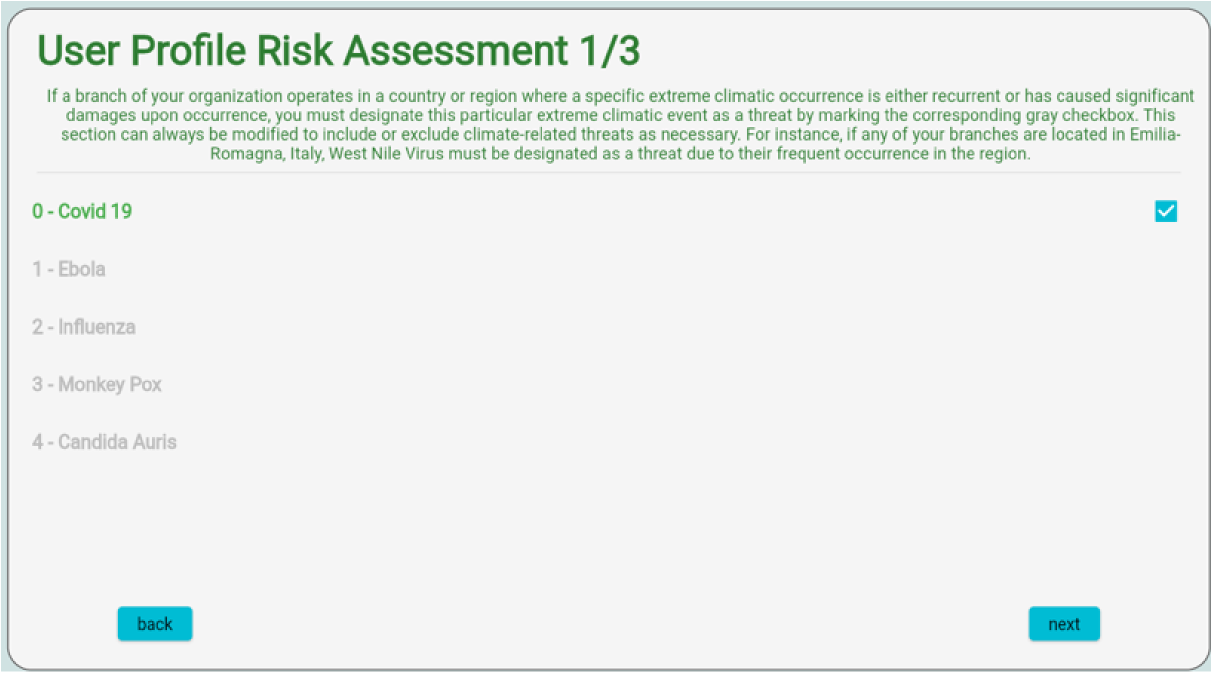

Figure 10: Risk assessment section 1/3

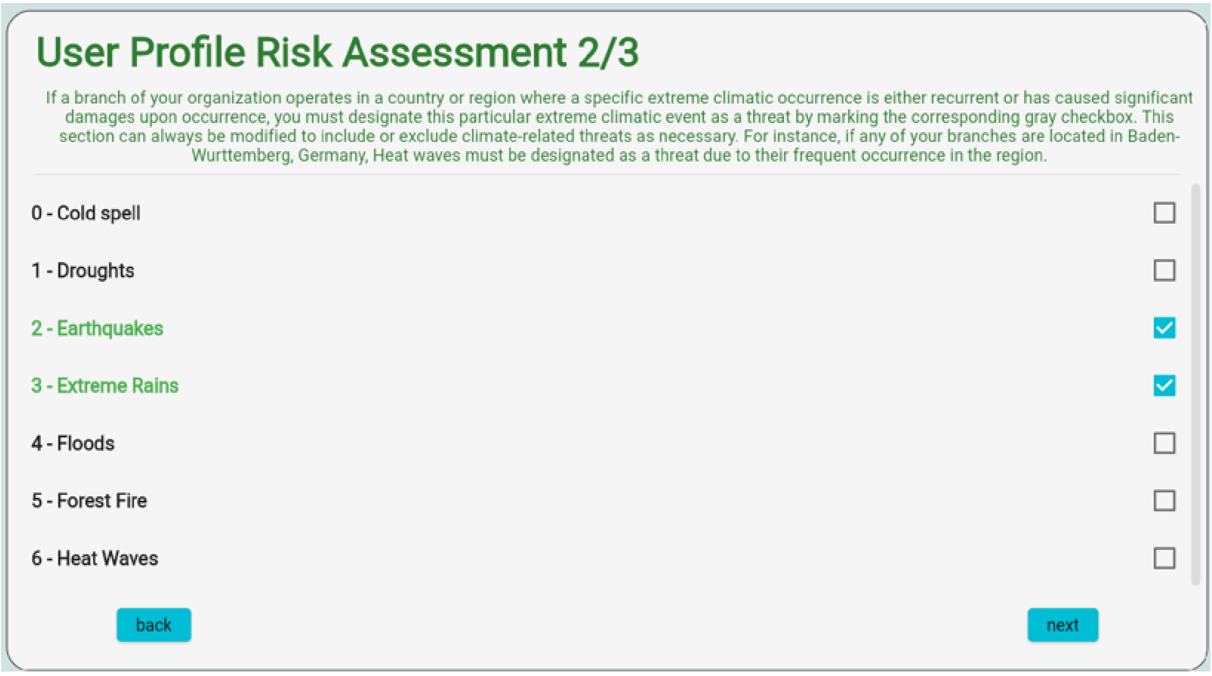

Figure 11: Risk assessment section 2/3

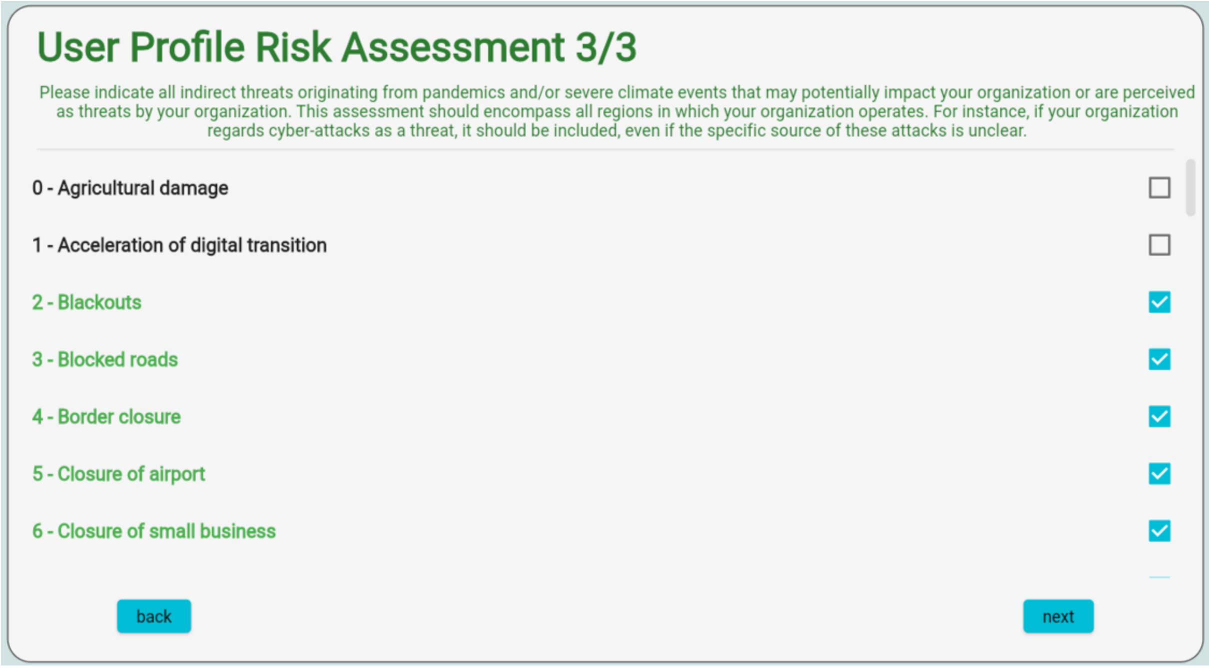

Figure 12: Risk assessment section 3/3

5.4.3 Impact Analysis

In this section, the end user is required to define their own impact metric to subsequently assess the type and severity of the impact generated by the previously selected threats in their branches.

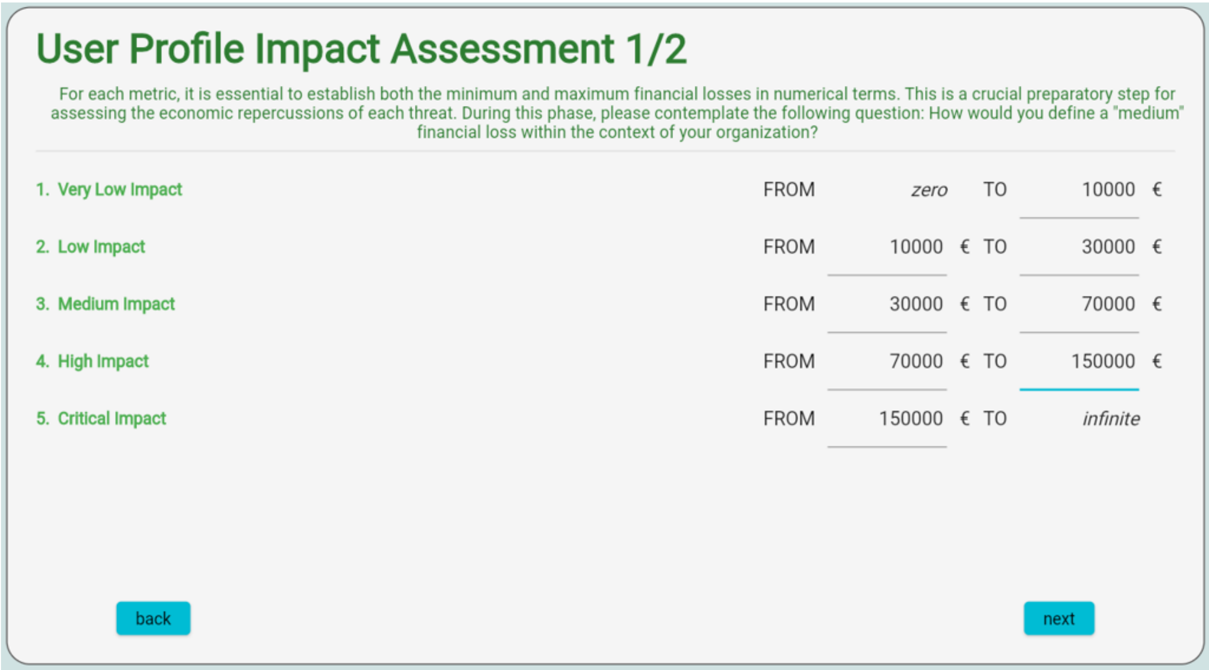

Figure 13: Impact assessment section 1/2

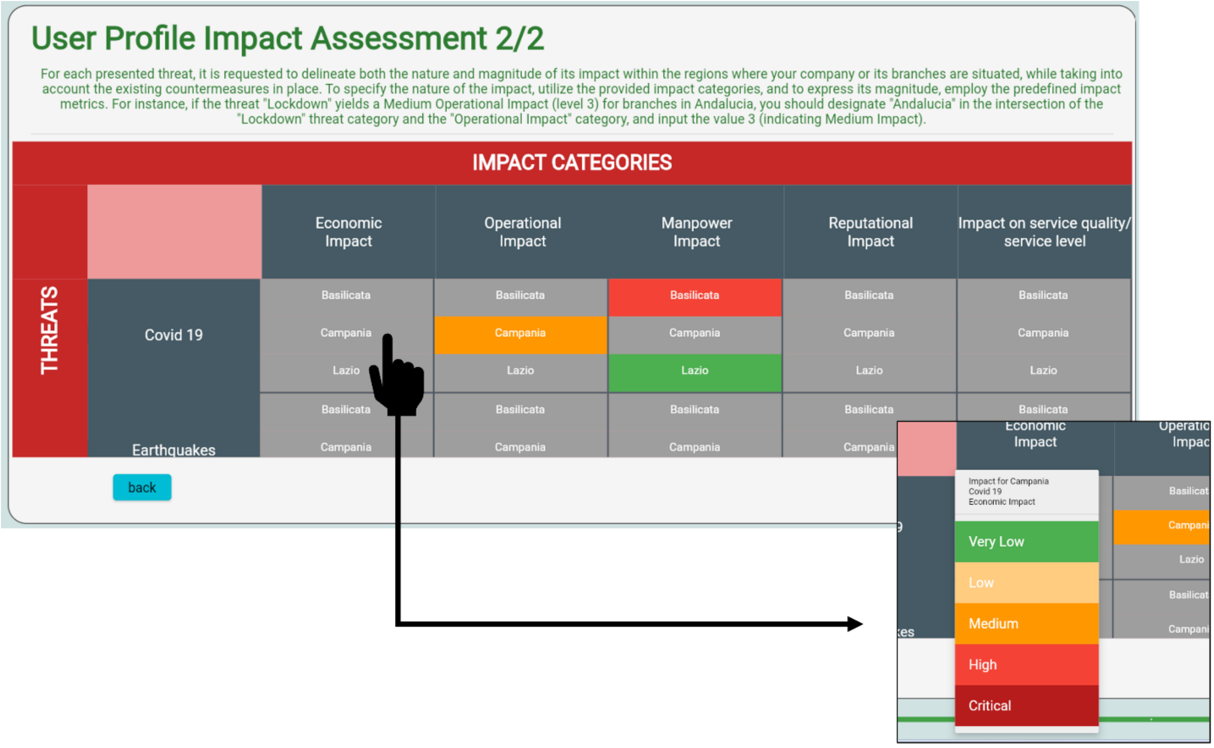

Figure 14: Impact assessment section 2/2

5.4.4 Countermeasure Analysis

In this section, the end user must outline the countermeasures implemented during a pandemic crisis to address the selected threats across their branches.

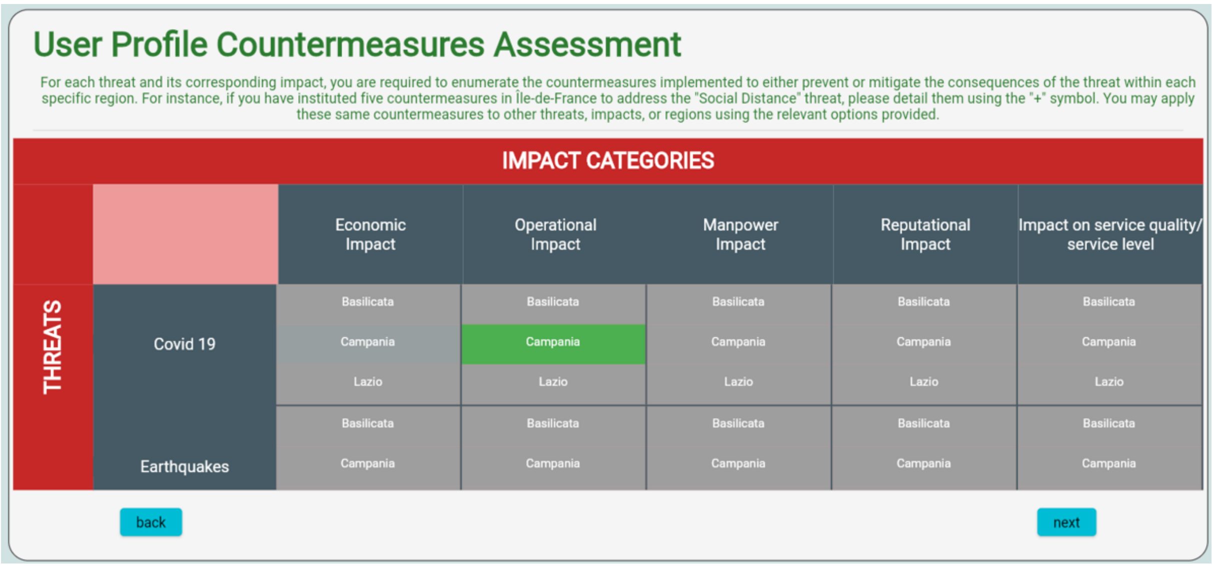

Figure 15: Countermeasures assessment section

5.4.5 Supply Chain Information

In this section, the end user is required to provide information regarding their suppliers, such as their economic sector, level of interdependence with suppliers, and country of origin.

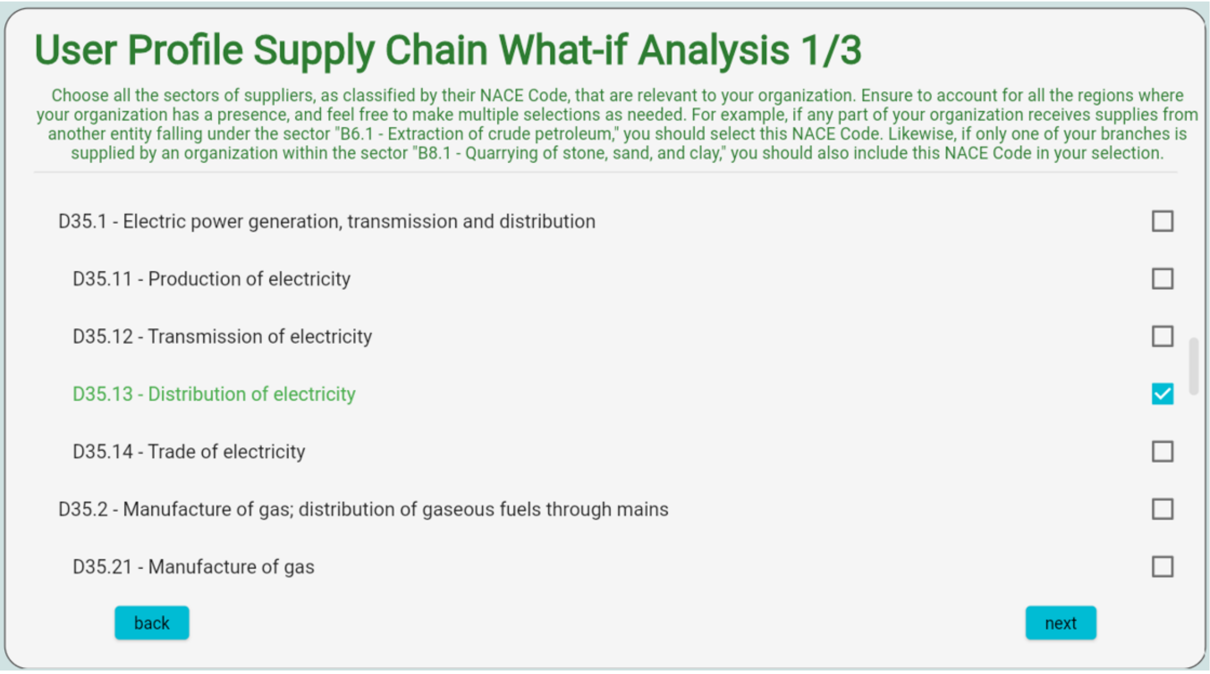

Figure 16: Supply chain section 1/3

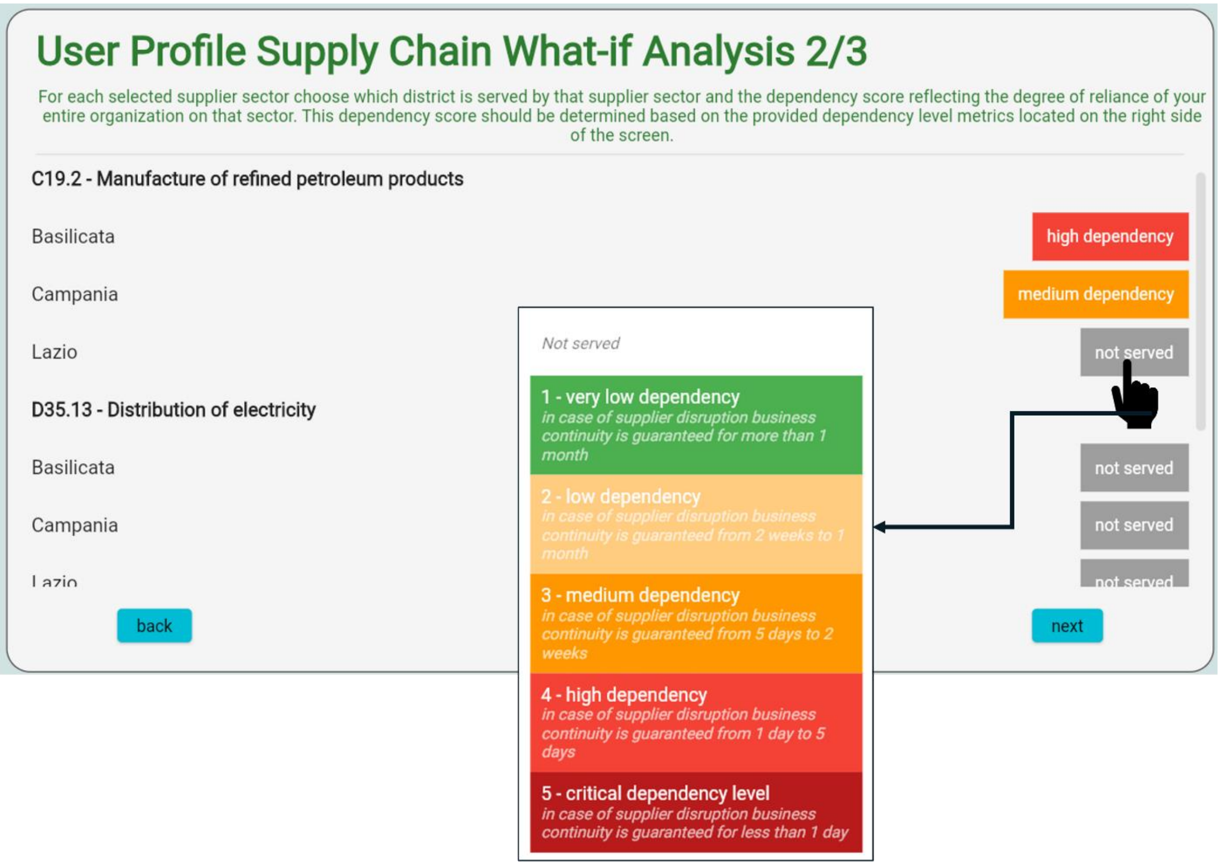

Figure 17: Supply chain section 2/3

Figure 18: Supply chain section 3/3

6 Validation methods

This chapter aims to elucidate the methods devised by the WP2 for validating the Strategy for Awareness and Resilience of Critical Infrastructures outlined in Chapter 2 of this document. In accordance with the Project DoA[1], two validation cycles are anticipated: the current cycle, slated for completion by M18 of the Project – which result are described in this section – and the second cycle, projected to start in M18 and to conclude by M34.

To facilitate this endeavour, the WP2 Partners structured by mutual agreement the validation process into two phases.

The first phase comprised three complementary actions: The analysis of outcomes from the SUNRISE national workshops, conducted in Months 2 and 7, and the pan-European workshop conducted in M8, in relation to the Strategy and the analysis models developed by partners; The commencement of the integration process for the aforementioned models, described in chapter 5 of the document; The drafting of the plan for the second validation cycle, which included identifying features to be tested, determining the methods for conducting tests, and establishing a timeline to sequence the process.

The second phase of the Validation process involves the next national workshop, to be done in M20 and EU Workshop, forwarded for M22. During these events, according to the Project DoA[1], the Strategy will be presented to the SUNRISE partners and stakeholders, that will be able to engage with it. In addition to these, it has been established to organize two additional Validation events, proposed to be done respectively in M25-26 and M31-32. During these events, the Strategy and the finally integrated Tool will be tested with the support of the designated validating entities, as outlined in Chapter 3 of this document. The testing will be conducted through the scenarios outlined in Chapter 4. At the conclusion of each event comprising the second validation cycle, a thorough analysis of the results will be conducted, and all the data collected will be used to measure the effectiveness of the Strategy by comparing the achieved results with the identified needs of CI providers and, if necessary, consequently update the Strategy itself in accordance with the results of the comparison. The result of this process will be serving as the basis for producing the Deliverable D2.5 the final version of the Strategy validation.

6.1 First phase

This section delves into the first phase of the validation process, following the structure mentioned in the previous section.

6.1.1 Workshop analysis

The **workshops** (see details below) have been valuable forums for gathering insights and feedback from key stakeholders within each of the countries involved. Participants included experts, professionals, and relevant stakeholders who provided diverse perspectives that have been useful for the development of the proposed Strategy and for the validation of the models. In fact, these events served as platforms for defining the area of action of the Strategy under consideration and to conduct a first test for the models the Strategy tools are based on. During the workshops, an initial testing of the methodology behind the climate and disease modelling and the threat assessment and impact analysis technologies has been conducted with CI authorities, enabling the WP2 partners to gather information about the needs to be fulfilled by the Strategy and to ensure that the models presented are beneficial for the CI in a crisis context. It also involves examining the activities undertaken during the formulation of the Strategy. By doing so, the workshops served as a real-time environment to validate the applicability of the tools against specific scenarios and challenges faced by the CIs. The feedback collected has been instrumental in identifying gaps, usability issues, and potential enhancements, ensuring that the tools not only meet the theoretical requirements, but also deliver tangible benefits. Furthermore, this collaborative approach facilitated the alignment of the tools with the operational realities and strategic needs of the CIs, making them more adaptable and effective in supporting decision-making processes during crises. The insights gained from this engagement have been fundamental for the iterative development and refinement of the Strategy tools, ensuring they are fully aligned with the needs and expectations of the critical infrastructure sectors they aim to support.

By synthesizing the results from both national and international workshops, this phase of validation provided a comprehensive understanding of the Strategy's strengths, weaknesses, and potential areas for enhancement. The collective input from diverse stakeholders enriched the validation process and laid the foundation for subsequent phases, ensuring a robust and globally relevant Strategy.

6.1.1.1 First National Workshops

The first national workshop, held in Slovenia, Italy, and Spain in November 2022, and detailed in Document D1.1[3], gathered a total of 66 participants from 15 critical infrastructures and two authorities across the three countries. The participants were representatives from different sectors such as Health Information Technologies (HIT), water, transport, energy, national healthcare authority, Information and Communication Technologies (ICT), etc. The primary aim of this workshop was to understand the challenges faced by CI operators and authorities at the onset of the COVID-19 pandemic, capturing valuable insights on practices that proved helpful and identifying existing gaps requiring attention. Participants highlighted common issues, such as challenges in communicating with authorities, ambiguous information received, and the need for quick, yet sometimes unclear, strategic decisions. Additionally, the lack of pandemic preparedness and difficulties in identifying and protecting essential workers were recognized.

The workshop focused on five key themes: operational continuity management, human resources, information and communication technologies, collaboration with other actors, and communication with stakeholders. It included four sessions: introduction, problem identification, problem analysis, and identification of good practices, followed by a reflection and conclusion session. Participants engaged in identifying issues, analysing root causes, sharing good practices, and reflecting on the sessions.

The outcomes of the workshop enabled WP2 to incorporate relevant, feedback-based information into its models and laid the groundwork for Strategy formulation, in line with the indications provided in D1.1[3]:

WP2 will benefit from the definition of problems faced in the pandemic and their suggested solutions, to be discussed for inclusion in the SUNRISE Strategy for awareness and resilience (D2.2[2]). The description of the CIs' dependencies will be particularly useful for T2.2, which aims to identify CIs, services and entities, their interactions, and interdependencies.

Further details on the execution of the event and the aforementioned feedback will be provided below. Participants identified common challenges faced during the pandemic: the need for effective communication with responsible ministries, particularly regarding information dissemination and communications; a shortage of resources and infrastructure; the absence of strategic communication and rapid changes in state-level strategic decisions.

In Slovenia, participants highlighted that the national plan was not activated appropriately, leading to decentralized crisis management and hindering preventive actions and the response to crisis symptoms. The rationalization of material resources, inequality of plans at various levels, and the lack of a realistic assessment of critical processes for society's functioning were also noted. The workshop underscored the need for better coordination between state plans and real-life situations. The necessity to rapidly develop policies due to changes in government decrees during the crisis was also identified.

The workshop also pinpointed good practices, such as inter-sectoral communication, positive effects of digitalization (e.g., telemedicine, remote work), and the importance of understanding the interdependence of critical functions within critical infrastructure.

In Italy, participants identified and shared key issues related to communication, relationship with suppliers, changes in demand and supply, remote work, security (regarding working from home), reorganization of processes and services, availability of experts, and lack of infrastructure.

The communication challenges were multifaceted, including difficulties in communicating with customers, workers, and high-level authorities. Proposed solutions included the establishment of decision-making committees, improving communication flows, supporting people through change, providing clear information on vaccination campaigns, and offering additional services to staff.

Supplier-related issues were tied to disruptions in the supply chain, leading to challenges in delivery times and financial aspects. Diversification of suppliers was suggested as a potential solution. The reorganization of processes and services during the pandemic called for solutions like lower taxes for hiring new technicians, replanning internal communication flows, monitoring and updating procedures, and redistributing skills within the operational unit.

The workshop also highlighted broader issues, including the absence of pandemic emergency plans in CIs and challenges in implementing ad-hoc national decrees.

In Spain, the focus was on identifying critical problems faced by organizations during the pandemic, categorized into four key areas: Business Continuity Management (BCM), ICT, Communication and Collaboration (C&C), and Human Resources (HR). Participants then collectively prioritized and selected the most significant issues for further analysis.

Among the highlighted issues was the failure to anticipate – and consequently prepare for – the pandemic scenario in certain sectors. Health-related entities had started preparations as early as December 2019, while larger organizations gained early insights due to their scale and geographical scope. The common challenge was the lack of reliable information from authorities, leading to decisions not aligned with the evolving reality.

Participants proposed regulatory measures enforcing contingency plans, defined activity protocols, and cultural integration through simulations to address future uncertainties.

Supply chain bottlenecks, especially in the healthcare sector, were identified as a challenge to continuity. The transition to remote work posed ICT-related challenges, such as the sudden need for computers, stressing Information Technologies (IT) departments. The rapidly changing context required adaptability to digital transformations, collaborative mechanisms, and government policies.

In addition, the following section presents sector-specific insights that were identified.

In the telecommunication sector, which played a pivotal role during the pandemic due to the surge in demand for digital services, the workshops revealed remarkable resilience. Despite an unprecedented increase in the request for ICT services across critical infrastructure organizations, the telecommunications sector encountered minimal difficulties in managing operations during the pandemic. This resilience can be attributed to key enablers, including oversized infrastructure in hardware, software, and network capabilities, the existence of Business Continuity Plans in telecommunication services, a wide network of suppliers for procurement needs, and the substantial size of telecommunication organizations. Early preparation, triggered by uncertainties about international events, further contributed to their readiness. However, human resources management challenges included workforce overload, psychological or behavioural issues, and the need for increased awareness regarding the proper use of corporate and personal resources to mitigate cyber risks.

In the water sector, managing the pandemic presented complexities, particularly in identifying essential services and dealing with non-essential workers. The lack of equipment for remote working posed challenges, leading to the utilization of personal devices, introducing associated cyber risks. Increased domestic water consumption during lockdowns also heightened communication challenges with end-users, resulting in a surge in inquiries about water quality and infection concerns.

The energy sector, specifically gas pipeline operators, navigated uncertainties at the pandemic's onset, emphasizing the importance of communication and information reliability. Crisis groups were established to adapt risk assessments and implement measures swiftly. International cooperation among gas pipeline operators showcased solidarity, effective crisis planning, and risk assessments. Challenges in procuring protective equipment were addressed by defining work-from-home possibilities and supplying necessary equipment. In electricity distribution, continuous adjustments to plans and measures, cooperation with external organizations, and remote working challenges, including trust issues and cybersecurity risks, were highlighted.

The health sector, on the frontline of the pandemic, faced initial challenges in providing ICT equipment for remote work. Public procurement issues, redundancy in equipment, and increased cyber risks due to expanded ICT usage were notable. Collaboration with Italian colleagues, though focused on immediate actions, increased after the first wave. Differences in communication and collaboration between public and private health care organizations were evident, revealing the lack of protocols for essential activities during lockdowns.

Within the transport sector, passenger traffic interruptions led to surplus labour, challenges in retraining, and complexities in maintaining service levels despite reduced demand. Freight transport excelled, but infrastructure interventions faced administrative obstacles and legal constraints. Unlike other sectors, transport operators, unaccustomed to remote work, encountered difficulties in enabling it, including the lack of personal equipment and infrastructure.

These insights from the workshops provide valuable data for WP2, contributing to the definition of pandemic-related challenges and potential solutions for inclusion in the SUNRISE Strategy for awareness and resilience. The telecommunications sector's exemplary resilience and challenges faced across sectors underscore the need for adaptable strategies addressing diverse critical infrastructure dependencies and interactions.

6.1.1.2 Contribution of the First National Workshop to the Validation process

The data stemming from the workshops play a pivotal role in the very first phase of definition of the Strategy and the understanding of the module’s applicability. Firstly, they unveiled sector-specific challenges encountered by critical infrastructure organizations amid the pandemic, ranging from workforce management intricacies to communication hurdles and cybersecurity risks. This nuanced understanding is indispensable for tailoring resilience strategies that effectively address the distinctive needs of each sector.

Furthermore, the workshops shed light on key enablers and best practices that significantly contributed to the resilience of certain sectors, such as the telecommunications industry. These insights not only provide valuable benchmarks, but also serve as potential models for other sectors, enhancing the necessity of anticipating crisis events by planning their response mechanisms.

The cross-sectoral insights garnered from diverse challenges and experiences underscore the interconnected nature of critical infrastructure. These observations emphasize the need for an integrated approach to resilience planning, one that takes into account the intricate interdependencies among various infrastructure components.

The challenges faced by different sectors also offer insights into potential vulnerabilities and risks that may emerge during crises. This information is instrumental in developing effective risk mitigation strategies, ensuring their seamless integration into the broader resilience framework.

Additionally, the workshops provide a real-world validation of resilience measures implemented across sectors. Understanding the effectiveness of these measures during a crisis allows for refinement and improvement, ensuring that the strategies devised for critical infrastructure resilience are not only theoretical but also practical and impactful.

Importantly, the data contribute to informing policy and regulation related to critical infrastructure resilience. They offer tangible evidence of what worked well and where gaps exist, guiding policymakers in creating a regulatory environment conducive to supporting resilience initiatives.

Lastly, by analysing the challenges faced and lessons learned from the pandemic, the workshops contribute to the continuous improvement of preparedness strategies. This forward-looking approach aids in anticipating and addressing potential future challenges, ultimately making critical infrastructure more resilient to a spectrum of disruptions.

6.1.1.3 Second national workshop

The second national workshop, described in Annex I of D.2.2[2] was organized in May 2023, and it led to the scheduling of three meetings held in Spain, Italy, and Slovenia.

The Spanish workshop involved, in addition to the Ministry of the Interior, a broad representation of operators from Spanish Critical Infrastructures in the sectors of water, health, transport, and telecommunications.

The Italian workshop saw the participation of the Italian partners of the SUNRISE Project and other actors from various critical infrastructure sectors.

The Slovenian workshop involved all the partners of the Slovenian Project, the Ministry of Infrastructure, and other stakeholders.

The aim of this workshop was to analyse the level of preparedness of CI providers to face certain threats, with specific attention to the epidemiological and climatic threats. The cross-sectoral participation of actors from various sectors allowed for a comprehensive assessment of the response capacity of each of the three countries to the challenges under examination. This enabled the identification of blind spots in understanding pandemic-specific risks and cascading effects across interconnected CIs.

The discussion on pandemic-specific risks allowed for the testing of the practicality of the epidemiological model, the IC Interconnection model, and the Risk Management Module. For this purpose, three topics were defined: climatic threat, pandemic threat, and other threats, each dedicated to one of the three sessions into which the workshop was divided.

Session 1 explored the theme of organizational preparedness in the face of epidemics, using as an example a hypothetical spread of mosquito-borne disease in Europe based on a first version of the scenario described in Chapter 4 of this document. The scenario analysis highlighted an increase in endemic areas for mosquitoes capable of transmitting an emerging virus to humans. The virus considered had a severity picture varying by age. Within the presented scenario, it was defined that in organizations, 60% of employees are currently on duty, 20% absent due to illness, with a suspected share of infection from the new virus, and 20% not reachable.

Participants were encouraged to reflect and respond to questions aimed at assessing the response capacity to a realistic pandemic, with particular emphasis on identifying vulnerable workers, both directly and indirectly, the impact on human resource management, and the predisposition towards personal and environmental protection interventions. At the end of the activities, the various discussion tables shared their analyses, opening up a collective debate on the initially proposed solutions.

In the case of Spain, despite the difficulties highlighted in identifying indirectly vulnerable workers due to regulatory restrictions such as the General Data Protection Regulation (GDPR), this session highlighted the importance of proactive strategies and data collection tools, such as those used during the COVID-19 pandemic, to improve organizational preparedness.

In Italy, this session highlighted a good capacity of organizations to identify directly vulnerable workers thanks to data available at HR departments. But even in this case, the identification of indirectly vulnerable workers must take into account the provisions of the GDPR. The measures proposed to reduce the risk of infection and ensure operational continuity include the adoption of night shifts, the digitalization of services, and the reduction of outdoor work, demonstrating an adequate but improvable level of preparedness in relation to operational complexity and the availability of essential goods on the market.

In Slovenia, the session revealed a general awareness of organizations about the need to identify vulnerable workers, with particular emphasis on measures to ensure operational continuity in case of a significant reduction in the workforce. Although organizations have the necessary data for identifying vulnerable workers, the main challenge remains identifying those who are indirectly at risk. The discussion highlighted the importance of proactive and flexible strategies, capable of adapting to different situations and protecting all personnel.

The aim of Session 2 was to assess the preparedness of the actors involved in facing climatic hazards. The issue addressed had a dual nature: on the one hand, it investigated the readiness to react to acute threats, characterized by a sudden onset and a limited time margin for intervention; on the other hand, it explored preparedness with respect to cyclical or chronic climatic threats. Participants were asked to select and rank the three climatic hazards they perceived as most significant, allowing for the identification of the most common hazards among those discussed. This exchange of information not only allowed for mapping a panorama of shared concerns and risk perception among the different actors, but also to concretely assess their actual preparedness in the face of variable climatic risk scenarios.

This approach contributed to the validation purposes by offering a platform for direct comparison of experiences and adaptation strategies implemented or planned by the involved actors. Through the analysis of responses and the classification of climatic threats, it was possible to further refine the Strategy, directing it towards areas of greatest urgency and relevance, and strengthening the resilience of communities and critical infrastructures in the face of climate change. Delving into such aspects allowed for highlighting gaps and strengths in current risk management policies, offering concrete insights for refining the Strategy in terms of effectiveness and applicability.

In Spain, participants revealed an approach generally focused on consequences rather than the hazards themselves. The discussion highlighted a tendency to consider acute threats more impactful than chronic ones, except for the water distribution sector, already sensitive to the effects of climate change. This session emphasized the need for greater attention to persistent climatic threats and their management.

In Italy, the second session showed that CI providers tend not to incorporate climate risk into their emergency plans, relying on traditional contingency plans. The perception of climate risk varies by sector, with transportation and logistics particularly exposed to thermal stress, precipitation, flooding, and tornadoes. The general interest in including climatic effects in planning underscores the need to develop a culture of prevention more oriented towards sustainability and adaptation to climate variations.

In Slovenia, the second session highlighted the level of preparedness of Slovenian organizations regarding specific climatic hazards. Most organizations declared themselves relatively prepared to face their "Top 3" climate risks, although some threats, such as landslides and heatwaves, require further actions and improvements in preparedness. This session emphasized the importance of integrating climate change data into risk planning and preparing for combinations of risks, as well as for consecutive extreme climate events.

In Session 3, participants were asked to identify threats they had faced in the past, stemming from climate changes and pandemics. A list of potential threats was introduced, including challenges such as imposed remote work, damage to agriculture, social distancing, damage to power lines, closures of roads and borders, lockdowns, communication disruptions, hospital congestion, increased cyberattacks, productivity interruptions, and many other issues related to emergency management and the impact on human, economic, and operational resources.

Participants selected the threats that had impacted their operations in the past and assessed the extent of such impact on various aspects, such as operability, economy, human resources, reputation, and service quality. After choosing and ranking the threats, they shared their experiences with other participants, presenting the information on illustrative panels and discussing the strategies adopted to address these challenges, as well as the lessons learned.

In Spain, the distribution of highlighted threats shed light on predominant concerns for economic and operational aspects, with particular emphasis on the lack of personnel and medical resources as the most pressing challenges.

In Italy, the last session introduced a board game for identifying threats and assessing their impacts, simulating data input into the risk management model. This activity resulted in the selection of a wide variety of threats, most of which were defined as having a medium or critical impact intensity. Transportation and water distribution infrastructures emerged as the most affected, underscoring the importance of improving risk management in these sectors. The discussion highlighted the need for greater cohesion and comparison between procedures and threat management among the different national sections of the companies.

In Slovenia, the last session offered participants the opportunity to collaboratively identify and prioritize potential threats, contributing to a more comprehensive risk analysis. The exercise highlighted the impact of threats mainly in the HR, operability, and service level categories, with an impact level assessed as medium for the first two categories and high for the last.

This last session provided a contribution to improving the risk management module, allowing for testing the data input phase and impact definition, and integrating some of the identified threats into the taxonomy present in the module.

Offering a thorough overview of how different organizations have responded to a wide range of climatic and pandemic threats, the workshop allowed for identifying a series of additional countermeasures to be included in the model. In this way, it was possible to ensure that the proposed model reflects real scenarios, but also its applicability in such contexts.

The sharing of experiences and solutions adopted in response to such threats allowed for identifying best practices and areas of vulnerability, contributing to strengthening the overall strategic approach. The comparative analysis of different responses to threats also facilitated the identification of common and sector-specific priorities, guiding further development and refinement of the SUNRISE Strategy to ensure optimal preparedness and resilience in the face of future climate and health crises.

6.1.1.4 Contribution of the second National Workshop to the Validation process

The outcomes of these sessions provided significant contributions to the validation of the SUNRISE Strategy, highlighting critical areas that required attention and strengthening. Sharing experiences and adopted strategies has allowed for the identification of effective practices and common areas of vulnerability, contributing to the creation of a more resilient and adaptable Strategy. The following are the areas of improvement identified within the workshop:

Identification and Protection of Vulnerable Workers: The difficulty in identifying indirectly vulnerable workers, due to regulatory constraints such as GDPR and the lack of suitable tools, highlighted the need to develop more effective methodologies for collecting and analysing sensitive data, while ensuring privacy and information security. There emerged a necessity for organizations to develop more effective systems for identifying and protecting vulnerable workers, both directly and indirectly at risk. In this regard, a better understanding of infection spread patterns, affected population segments, and the severity of these diseases, provided by the infection propagation module, allows for more accurate identification of at-risk employee categories, aiding organizations in the development of their business continuity plans.

Preparedness and Response to Epidemiological Threats: Despite some organizations demonstrating readiness to face disease outbreaks, the session revealed concerns about the capacity to respond effectively, especially regarding the availability of critical supplies and the implementation of personal and environmental prevention measures. This underscores the need to strengthen emergency plans and supply chains to ensure timely and effective responses. The outcomes of Session 2 provided empirical insights which enriched the development of an enhanced version of the Vector Scenario. This refined scenario is poised for implementation during the forthcoming second Validation Cycle.

Management of Climatic Threats: The predominantly reactive approach to climatic threats and the tendency to underestimate the chronic impacts of climate change suggest the need to develop proactive strategies, which include adaptation and mitigation plans based on a holistic assessment of climatic risks, both acute and chronic. It is essential for organizations to improve their ability to anticipate, prepare for, and respond to a wide range of climatic risks, integrating more accurate forecasting data and planning for combined and extreme scenarios. The risk analysis model addresses this need by allowing organizations to conduct a risk analysis that considers threats from extreme climatic events, proposes mitigation measures for each threat, and allows for the visualization of mitigation measures implemented by infrastructures sharing the same NACE[11] code.

Planning and Adaptability: The inability to plan against climate change, highlighted by some actors, underlines the need to develop flexible and adaptable strategies that can be quickly updated based on evolving environmental conditions and scientific knowledge. The climate event analysis model, combined with the risk management model, meets this need by enabling the identification and mitigation of potential threats before they significantly impact operations and services.

Focus on Economic Impacts: A significant element that emerged from the workshop is that the threats considered are quantifiable based on the economic impact they produce. Indeed, it was found that operators participating in the workshop consider threats as dangerous or impactful in term of their possible economic impact. In this context, the risk management model is once again relevant, as it allows users to define impacts on an economic basis and set custom metrics.

6.1.1.5 First Pan-European workshop

The first Pan-European workshop, conducted virtually in June 2023, engaged discussions on key elements addressed by the SUNRISE Strategy tools: operational continuity management, human resources, information dissemination, and collaboration with stakeholders. This collaborative effort was crucial for ensuring the Strategy's effectiveness in protecting critical services and infrastructures across European borders. By facilitating cross-border collaboration among EU Member States, the workshop enabled the identification of pandemic-specific essential services and CIs, understanding their interactions, and assessing dependencies. These insights were pivotal for refining the models, demonstrating how the Strategy tools meet the real-world needs of Critical Infrastructures, considering the network of interdependencies and threats they face, and highlighting the importance of a comprehensive view of the network's strengths, vulnerabilities, and potential cascading effects.

Below are reported the key points emerged during the workshop, presented in greater detail within Deliverable D1.2[4].

The first Slovenian virtual session focused on the pandemic's impact on cooperation among CIs in Europe and the challenges encountered during this period. Various points were raised, emphasizing the importance of EU institutional collaboration among CIs. Building relevant communication networks and inter-sectoral dialogues was deemed crucial for effective collaboration. Operational continuity management emerged as a fundamental necessity, ensuring effective preparation, response, and recovery from disruptive events. The session also highlighted the need to improve the communication infrastructure network. Remote work, which has become a significant component in CI sectors, was discussed. Dependencies, including inter-sectoral and cross-border collaboration, with a focus on their vulnerability elements in crisis times, were examined. Lastly, the need for better operational continuity planning was identified.

Similarly, in the second Slovenian Virtual Table session participants delved into the pandemic's impact on cooperation among CIs in Europe. The challenges in crisis contexts identified during the session include the spread of contradictory instructions, supply issues, and the rapid transition to remote work. Concerns about cybersecurity were also expressed, highlighting vulnerabilities in services like Zoom and Google.

In response to these issues, collaboration emerged as a key aspect: success stories of cooperation among hospitals, data providers, and communication networks were shared with partners.

The Italian Virtual Table brought together authorities, operators, stakeholders, and others from CIs.

The session began with a focus on Operational Continuity Management, emphasizing the significant shift to remote work during the pandemic, requiring changes to existing policies. This necessitated a complete overhaul of risk assessments, especially in terms of cybersecurity policies aligned with the new approach to work. The discussion highlighted that while remote work is applicable to some activities, specific worker groups require alternative routines to mitigate infection risks during a pandemic.

CIs with pre-existing operational continuity plans had to adapt them to the specific challenges posed by COVID-19. The experience enhanced their pandemic preparedness, mainly due to the adoption of remote work. Information from the epidemiological model highlighted the importance of early identification of vulnerable workers and the adoption of preventive measures.

The overview of sectoral interdependencies, essential components of risk management models, and interdependencies among ICs underscored the crucial role of the energy sector, highlighting its dependence on a complex supply chain involving multiple sectors. The challenge posed by this network of interdependencies will be effectively addressed by integrating the risk management model with the interdependencies model among critical infrastructures. This approach will allow for a more precise identification and assessment of potential risks to various network nodes, understanding not only direct risks but also indirect risks arising from connections between different sectors. Moreover, the model will facilitate the identification of critical points and vulnerabilities within the network, enabling the implementation of proactive strategies for risk mitigation and resilience strengthening, ensuring more informed and targeted risk management.

In the Spanish Virtual Table session, the focus was on classifying critical workers. The discussion emphasized the need for rapid determination of critical needs, facilitating the identification of essential workers for in-person operations in facilities. The importance of preserving key knowledge in operational continuity plans was highlighted.

Additionally, a series of elements that emerge in a crisis situation like the COVID-19 pandemic were identified, such as organizations receiving inaccurate or insufficient information from authorities, leading to sudden procedural changes and hindering performance. Therefore, better communication between sectors, particularly transportation and government, was recognized as essential for future resilience.

6.1.1.6 Contribution of the First Pan-European workshop analysis to the Validation process

The outcomes of this initial pan-European meeting hold substantial significance for the validation of the SUNRISE Strategy tools for Awareness and Resilience of CIs. The challenges and needs that emerged from the discussions demonstrate that the proposed models, relying on actual epidemiological and climatic data and information directly provided by critical infrastructures providers, are capable of meeting the planning and information exchange requirements articulated within the context of these work sessions.

Specifically, the contributions provided by the Strategy tools are as follows:

Expansion of Collaboration: The need to expand collaboration among Critical Infrastructures, essential service operators, and institutions finds a solution in the risk management model. This model enables a risk analysis contextualized within a real scenario, informing suppliers about the mitigation measures implemented, and quantifying the potential risk posed by each element of the supply chain.

Interdependencies and Business Continuity Management (BCM): The analysis of interdependencies has been highlighted as a crucial aspect of BCM. Understanding and managing these relationships and connections is vital for effective operational continuity planning. In this regard, the CI Interdependency model allows the examination of these relationships and the simulation of cascading effects resulting from the compromise of a node across the entire network, facilitating the development of predictive analyses.

6.1.2 Modules Integration

The definition of the modules integration is an integral part of the Strategy validation mechanism, since it subjects the Strategy to real-world applicability, facilitating a holistic examination of the multifaceted aspects that define CIs while simultaneously encompassing diverse crisis scenarios. This methodical approach ensures that the Strategy's theoretical foundations are rigorously tested against practical, operational challenges, thereby affirming its effectiveness in enhancing the resilience and adaptive capabilities of CIs in the face of emergent and evolving threats.

In the first validation cycle, the foundations for structuring the integration of models were established. The details of this integration have been detailed in Chapter 5 of this document.

6.1.3 Definition of the Validation Plan

At the end of the first cycle of validation, WP2 partners collaboratively established a plan of action to be implemented during the next validation cycle. This plan, meticulously detailed in subsequent discussions, was finalized during the workshop held in Vienna from January 31 to February 1, 2024. The consensus reached underscored a multi-faceted approach, incorporating direct feedback from the initial validation phase to refine the strategies and tools further. The validation plan for the second cycle, described in Section 6.3 of this document, was crafted to address identified gaps, enhance the resilience Strategy's applicability, and ensure its effectiveness across different critical infrastructure contexts. This comprehensive plan integrates rigorous testing scenarios, stakeholder engagement, and dynamic feedback mechanisms to validate the SUNRISE Strategy's efficacy, ensuring alignment with real-world operational challenges and the diverse needs of CI providers.

6.2 Second phase

This section outlines the structured approach undertaken for the second cycle of validation of SUNRISE Strategy for Awareness and Resilience of Critical Infrastructures, giving a description of the Validation Plan developed to implement this process and the process timeline, defined in accordance with the Project's roadmap.

6.2.1 Methodology

The initial step in the validation process involves the development of a comprehensive presentation of the Strategy. This presentation serves as a detailed document outlining the key components, objectives, and methodologies embedded in the Strategy. The document will be meticulously crafted, providing a clear and concise overview for the validators.

Following the creation of the Strategy presentation, a structured questionnaire module will be formulated. This module is designed to solicit specific and detailed feedback from the validators. The questionnaire encompasses targeted inquiries addressing various aspects of the first version of the Strategy presented in D.2.2[2], including its theoretical foundation, practical applicability, and alignment with industry best practices. The structured questionnaire ensures that feedback is collected systematically, enabling a comprehensive understanding of the validators' perspectives.

The questionnaire will be presented to the validator entities during the third SUNRISE national workshop to be done in M20. Effective communication is established with the validating entities during this step. The Strategy presentation serves as a reference guide, providing context and insights into the proposed resilience Strategy. Simultaneously, the structured questionnaire prompts validators to offer specific feedback, ensuring a focused and constructive evaluation process.

Following the collection of feedback from the validators, the results are compiled into a dedicated document in which will be presented in a structured format, highlighting key themes, common observations, and noteworthy recommendations.

The next step involves the incorporation of the collected feedback into the Strategy. The implementation process is meticulous, addressing each identified point of improvement or enhancement.

A similar process of Strategy and Integrated Tool evaluation and testing, questionaries for feedback and feedback integration in the Strategy will be applied in the following events. Comparative analyses between the workshop results will be conducted to discern any disparities or convergence in feedback. This iterative approach ensures that the resilience Strategy evolves in response to the valuable input received during each event of the second validation phase.

The outlined methodology underscores the commitment to a rigorous validation process, fostering collaboration with external entities and refining the resilience Strategy for critical infrastructures. This approach ensures that the Strategy not only meets industry standards but also benefits from the diverse perspectives and expertise offered by the validating entities.

6.2.2 Survey example

In this section is presented an example of the structured questionnaires designed for the validators to be used in the workshop and the validation events. The primary goal of this questionnaires is to systematically collect comprehensive feedback on the SUNRISE Strategy for Awareness and Resilience of Critical Infrastructures as presented in the Deliverable D2.2[2] and the Integrated Tool defined in Chapter 5 of this document. The questionnaires serve as a preliminary survey, accompanied by a brief presentation offering validators insights into the Strategy's methodology and key components.
The questions are crafted to cover various dimensions of the resilience Strategy and its Integrated Modules. For example, for what concern the Modules, the parameters to be evaluated in this phase are the following:

- Usability of the Strategy's integrated tool
- Comprehensibility of the tool's key outputs
- Alignment with Industry Standards
- Effectiveness of the Strategy

The survey is structured to elicit specific insights on the Strategy's effectiveness, potential areas of improvement, and overall suitability for diverse critical infrastructure contexts. The mentioned survey is accessible in Annex I for reference.

Once the survey questions are finalized, they are ready to be presented to the identified validators during the first national workshop. The questionnaires will be accompanied by a detailed Strategy presentation, offering contextual information to aid in the evaluation process. Clear instructions and guidelines for completing the survey will be also prepared to ensure consistency in feedback collection.

6.3 Validation Plan

6.3.1 National workshop

The national workshop will be organized in May 2024 (M20). During the event, there will be a dedicated time to furnish the Validators with an all-encompassing understanding of the Strategy. This will be achieved through the presentation of a concise description provided on a written document.

During the workshop, the Validators will also be introduced to the profiling section of the risk analysis tool. After an explanation of how it works, they will be required to register into the system and input their risk analysis. This interactive session will allow them to actively engage with the tool, enabling the generation of information about critical infrastructure and their supply chain interconnections.

After the session, once the profiling is complete, they will be requested to fill the survey described in the previous section.

Validators are encouraged to provide detailed and constructive feedback based on their expertise. The Project team will then review the feedback systematically, categorizing responses, and identifying recurring themes or concerns. The objective is to gain a nuanced understanding of the validators' perspectives on the first version of the Strategy's strengths and areas for improvement.

The feedback obtained through the survey process informs an iterative refinement of the resilience Strategy. Each identified point of feedback is carefully considered, and modifications are made to enhance the Strategy's effectiveness. This iterative approach ensures that the Strategy evolves in response to the diverse insights provided by the validators.

The data collected during this hands-on exercise will subsequently be incorporated into the risk analysis process.

6.3.2 Second Pan-European Workshop

Similar to the first pan-European workshop, the second workshop planned for July 2024 (M22) will also see the participation of the validator entities and numerous European entities, both related to critical infrastructure and other essential service operators, in addition to the consortium members. This event marks the first opportunity to provide validators with not only a comprehensive but also an applicative view of the first version of the SUNRISE Strategy, as described in deliverable D2.2[2] and mentioned in chapter 2 of this document. The aim of this initial meeting is to broaden the discussion on the Strategy for Awareness and Resilience of Critical Infrastructures presented, sharing visions and feedback not only from the validator entities but also from a broad spectrum of stakeholders. Participants will also be asked to test the Risk Analysis Tool integrated with the cascading effects assessment model. The goal is to ensure that it effectively meets the needs of various sectors and national contexts. In line with the national workshop, at the end of this phase, participants will be asked to complete an evaluation questionnaire. The workshop serves as a platform to explore synergies, identify potential common challenges, and discuss innovative solutions for pandemic management and preparation for future crises.

6.3.3 First validation event

The first event specifically dedicated to validation planned for the second cycle will be scheduled for October-November 2024 (M26-M27).

This event will be tailored for the four validator entities, key figures in the process of reviewing and approving the SUNRISE Strategy. During the event, the Strategy – including modifications and improvements resulting from the two previous workshops – will be detailed, with a particular focus on the developed risk analysis tool. Validators will have the opportunity to "play" with the tool, exploring its functionalities and assessing its effectiveness in modelling and managing specific risks related to pandemics. This hands-on phase aims to ensure that the tool is intuitive, effective, and suitable for the needs of critical infrastructure operators. At the end of the event, a questionnaire will be administered to participants to gather detailed feedback, suggestions for improvements, and general perceptions of the Strategy and tools presented.

6.3.4 Second validation event

The second event specifically dedicated to validation, planned for the second cycle, will be scheduled for April-May 2025 (M31-M32).

The public validation event will follow a structure similar to that of the event with the validators, but it will be open to a broader audience. This includes, in addition to the four validating entities, external stakeholders, representatives from the public sector, and industry experts.

They will be provided with the updated version of the Strategy based on the feedback collected during the first validation event. The presentation of the SUNRISE Strategy and the risk analysis tool aims to solicit even broader feedback, valuing diverse perspectives and experiences. The "playtime" phase allows participants to directly interact with the tools, offering user experience-based feedback that will be crucial for the final refinement phase. A survey will also be distributed on this occasion to gather the latest impressions, critiques, and suggestions from a variety of viewpoints, contributing to an overall evaluation of the SUNRISE Strategy's effectiveness and applicability.

6.3.5 Results comparison

The comparison of results from the different workshops and validation events described above is a crucial step in ensuring that the SUNRISE Strategy is robust, effective, and adaptable to various needs and contexts. This process unfolds in several phases:

1. Data Collection and Aggregation: Initially, all feedback, outcomes from interaction sessions, and observations produced during the validation events (EU Workshop, First Validation Event with Validators, Second Public Validation Event) will be collected and aggregated. This includes questionnaire responses, notes from playtime sessions with the tools, discussions, and any other significant input.
2. Analysis and Identification of Trends and Discrepancies: The gathered data will undergo a qualitative analysis focusing on observations, suggestions, and comments to understand stakeholders' perceptions of the Strategy and its integrated tools. Special attention will be paid to identifying common trends and discrepancies across feedback from different stakeholder groups. This will help discern which aspects of the Strategy are universally accepted, which raise doubts or concerns, and if there are significant perceptual differences across sectors or groups.
3. Evaluation Based on KPIs: The events outcomes will also be evaluated in relation to the key performance indicators (KPIs) defined earlier in the Project DoA[1] (Table 1 - Strategy goals). This will enable the quantitative measurement of the SUNRISE Strategy's effectiveness, providing a solid foundation for comparing results.
4. Results Comparison Report: Drafting a detailed report documenting the results comparison process, the analyses conducted, identified trends, discrepancies, and final recommendations. This report will form the core part of Deliverable D2.5.

Table 1 - Strategy goals

Result	Type	KPI	Target	TRL
Upgrade of the SORMAS system (epidemiological characterisation of pandemic risks)	Innovative solution	# of pathogen- and region-specific quantitative pandemic scenarios produced	≥ 10	7
		# of pathogen-specific control measures produced	≥ 5	
		# of lists of pathogen-specific data sources, indicators and surveillance systems produced	≥ 15	
List of pandemic-specific critical services and entities	Policy recommendation	# of sectors covered	≥ 6	n/a
		# of entities covered	≥ 20	
		# of countries covered	≥ 8	
Risk analysis system	Innovative solution	# of sectors covered	≥ 5	7

Result	Type	KPI	Target	TRL
Guideline for CIs' compliance with relevant legislation (CER, NIS2)	Guideline	# of considered legislation frameworks (national and European)	≥ 5	n/a
Economic impact analysis models for pandemicspecific measures	Innovative solution	# of impact categories included	≥ 3	7
		# of countries covered	≥ 5	7
SUNRISE Strategy for CI resilience	Guideline	# of CIs reviewing it	≥ 4	8
		# of CIs aligning their business continuity plans	≥ 10	

6.4 Timeline

The following image describe the chronological sequence through which the Validation Plan unfolds:

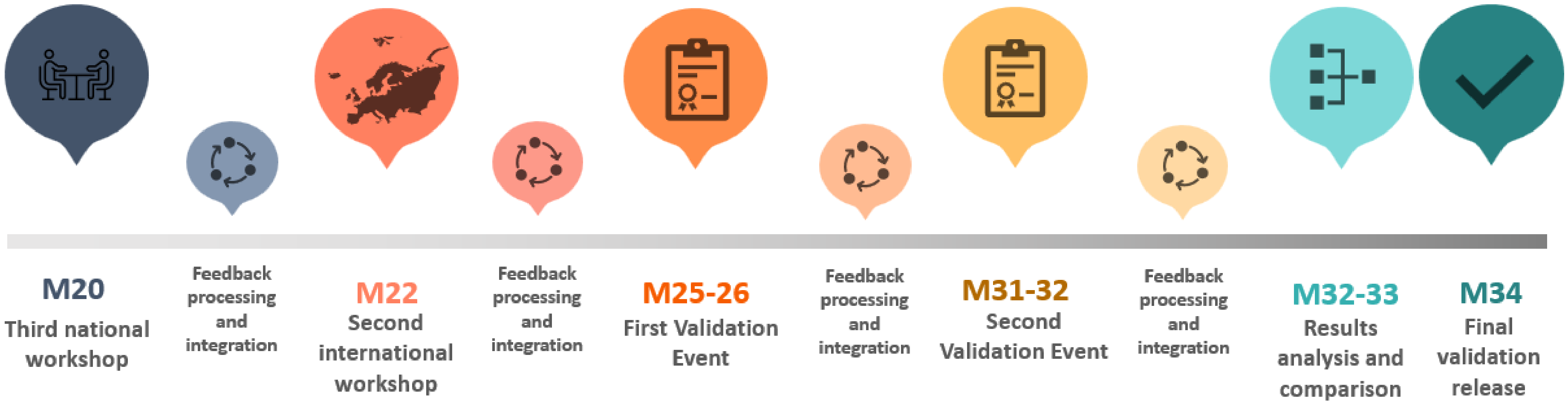

Figure 19: Validation Plan Timeline

7 Conclusions

The document's validation Strategy for enhancing the resilience of Critical Infrastructures against pandemics and climate change impacts has reached several pivotal conclusions through its first validation cycle, particularly highlighted in Chapters 4, 5 and 6. These chapters are instrumental in detailing the scenarios, the application of risk assessment tools, and the comprehensive overview of validation methods, respectively, thereby providing a thorough understanding of the Strategy's efficacy and areas for improvement. Moreover, the document define the Validation Plan agreed within the WP2 Partners in order to satisfy the requirement of the Project DoA[1] and Roadmap.

The purpose of the use case scenarios (Aerosol and Vector) in the validation context will be to demonstrate the practical application and relevance of the Strategy in real-world settings. These scenarios allowed for the assessment of the Strategy's tools in identifying, analysing, and mitigating the risks associated with pandemics influenced by climate change. The main conclusion drawn from this chapter is the critical need for adaptable and dynamic models that can accurately predict and respond to the complexities of pandemic spread and climate impacts on CIs.

Chapter 5 outlines the bidirectional data and information exchange among simulation modules, creating an integrated framework that leverages the strengths of individual models for a comprehensive understanding of pandemic crises. It provides in depth description of the functional requirements of the modules' integration. The purpose of this activity is to offer to the end-users comprehensive perspective on pandemic-related challenges and enabling CI providers to make informed decisions on pandemic and climatic risks. This tool enhances decision-making by aligning management with real needs during emergencies, assessing strengths and vulnerabilities, and understanding economic implications. Future steps include refining integration strategies, defining technical modalities for data exchange, expanding the tool's users base, engaging stakeholders, and supporting policy development.

The methodology defined in Chapter 6 highlights the approach to validating the Strategy through workshops, stakeholder feedback, and scenario-based testing. The main conclusion here is the invaluable role of stakeholder engagement in the validation process, which ensures the Strategy remains aligned with the actual needs and challenges faced by CIs. Additionally, the methodology proposed by WP2 underscores the importance of iterative validation cycles to progressively refine the Strategy based on feedback and changing environmental conditions.

The insights and findings from the validation process, as detailed in this document, are instrumental for subsequent tasks and deliverables within the SUNRISE Project. Specifically, the results will inform the development of tailored intervention within the Strategy for Awareness and Resilience of CI (Deliverable D2.4). Moreover, the application of the defined validation plan will be a core contribution to the second validation cycle (Deliverable D2.5).

In alignment with the Project roadmap, the immediate steps involve addressing the identified gaps and challenges through the second validation cycle. This includes testing the Strategy effectiveness, incorporating broader stakeholder feedback, and enhancing the Strategy. The next cycle will also focus on increasing the collaboration between CI operators and governmental bodies to ensure the Strategy's recommendations are actionable and grounded in practical realities.

In conclusion, the validation plan outlined in this document has laid a solid foundation for enhancing the resilience of critical infrastructures against pandemics and climate change. The comprehensive validation process highlights the importance of continuous refinement, stakeholder engagement, and adaptability in developing effective resilience strategies. As the SUNRISE Project progresses, these principles will guide the further development and implementation of the Strategy, ensuring that European Critical Infrastructures are better prepared to face future challenges.

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Annex I - Example of Survey on SUNRISE Resilience Strategy for Critical Infrastructures

Dear Validator,
Thank you for participating in the validation process for the SUNRISE resilience Strategy for critical infrastructures. Your valuable insights will contribute significantly to refining and enhancing the Strategy's effectiveness. Please take your time to provide thoughtful responses to the following questionnaire.

Section 1: Introduction and Background

1. Have you participated in similar validation processes for strategies in the past?
    a. Yes
    b. No

Section 2: Overview of SUNRISE Strategy Tool

2.1. From a user point of view, how would you rate the usability of the Strategy's tool as presented in the accompanying brief?
    a. High
    b. Medium
    c. I have doubts about it
    d. Low
    e. Low in this matter _____

2.2. Please rate the comprehensibility of the tool's key outputs.

	Very comprehensible	Comprehensible	Barely comprehensible	Not comprehensible at all
Risk score	☐	☐	☐	☐
Threats Probability	☐	☐	☐	☐
Potential Impact	☐	☐	☐	☐
Suggested Countermeasures	☐	☐	☐	☐

2.3. Highlight any challenges or limitations you foresee in implementing the tool presented within diverse critical infrastructure contexts.

____

Section 3: Alignment with Industry Standards

3.1. From your perspective, how well does the SUNRISE resilience tool – once it is implemented – align with established industry standards and best practices?
    a. aligned
    b. partially aligned

c. partially not aligned
d. not aligned at all
e. Other_____

3.2. Suggest any adjustments or enhancements needed to better align the tool with industry standards.

____

Section 4: Effectiveness and Areas of Improvement

4.1. In your opinion, how effective would you see the SUNRISE Strategy Tool – once it is implemented – in enhancing the resilience of critical infrastructures?

a. Very effective
b. Effective
c. Barely effective
d. Not effective at all
e. Other_____

4.2. Identify specific areas where you believe the tool could be improved for better outcomes.

____

Section 5: Overall Suitability

5.1. Considering diverse critical infrastructure contexts, what is your feeling on the overall suitability of the tool presented:

a. Suitable for all CI
b. Suitable for the majority of CI
c. Suitable for some CI
d. Not suitable for any CI
e. Other_____

5.2. Provide any additional comments or recommendations regarding the tool's overall suitability.

____

Section 6: General Comments and Suggestions

6.1. Share any general comments, suggestions, or additional insights not covered in the previous sections.

____

Your feedback is crucial to the refinement and success of the SUNRISE resilience Strategy. Thank you for your time and expertise in contributing to this validation process.

Annex II - What-If Analysis: Cascading Effects of Pandemic Scenarios

The What-If Analysis aims to improve the understanding of the impact on pandemic scenarios from countermeasures or interventions. In the COVID-19 pandemic we have seen that it is not a trivial task to estimate and predict the versatile impacts of NPIs, especially when it comes to the interplay between different domains that are not directly the target of an NPI. As an example, while closing schools to prevent disease spreading within a high-risk young age group might be an effective intervention, it is also forcing parents to supervise their children at home, having further economic impacts. To improve the understanding of these highly varying impacts of interventions and countermeasures, it is not only important to understand a specific domain well (as domain experts do), but also to consider interplays between domains. The What-If Analysis works on a combined model using information gathered from the Risk Assessment Tool, Disease Models, Climate change projections and Socio-Economic Impact Models as introduced in Chapter 5.2.

The CI Interdependency module (cf. Figure 1) provides the necessary data for the What-If analysis via a cascading effects simulation. In a first step to simulate cascading effects of pandemic scenarios a Critical Infrastructure Interdependency Graph (CIIG) must be build. This modelling process and simulation logic is explained in more detail in Deliverable D2.2[2]. Simulations running on this CIIG can be interpreted as baseline simulations without any countermeasures or other interventions being placed. Since the cascading effect simulation runs on a stochastic model there is not a single output as a forecast available, that gives insights to what will happen if no interventions are taken. Instead, the simulation returns a set of possible outcomes, which can be further analyzed to give more information like best- and worst-case scenarios or likelihoods of final node states.

The baseline from the initial simulation output is then used for comparisons to outputs from models with integrated interventions or countermeasures. The propagation model includes interactable elements making it possible for end users of the Risk Assessment Tool to simulate different interventions to pandemic scenarios and get an overview of their cascading effects, exploring cause-and-effect relationships between CIs and service providers of different economic sectors.

The What-If graph can be accessed from the CI Interdependency module via a REST Web API[1] delivering JSON data, or by directly incorporating parts of its web app via URL as an inline frame.

CI Interdependency

We provide a technical interface between the risk assessment module and the CI interdependency module that automates the construction of the CI interdependency models while end users fill and update their profiling (supply chain dependencies, assessments of threats and countermeasures). During the SUNRISE Project, we envision the construction of three separate CI interdependency models, one for each country of service providers (Italy, Spain, Slovenia), due to the necessary data of economic sector dependencies. In the future, this process can be extended to also include additional countries or even trans-national models.

The technical interface consists of the following parts:

- CI interdependency module: a dedicated REST Web API callback endpoint, accepting data in the JSON format, that is responsible for accepting profile changes and transforming them into the internal graph structure of the critical infrastructure interdependency graph (CIIG, cf. D2.2[2] Section 5 on simulation models).

[1] https://risk-mgmt.ait.ac.at/cassandra-api/api/

- Risk assessment module: sending any service provider profile creations and updates (supply chain dependencies, assessment of threats and countermeasures) to the callback endpoint.
- Both modules: providing necessary means of authentication and authorization to ensure secure data transmission and data access. A potential Strategy to achieve secure data access is to provide a single sign-on interface between the modules, and to restrict the authenticated users' access to CIIGs and simulation possibilities to only those necessary in the SUNRISE Project.

The resulting CIIG that is persistently stored by the CI interdependency module in a database is comprised of the following elements. These elements are updated whenever a profile update is received from the risk assessment module.

- Nodes representing modeled entities of different abstraction levels. This includes economic sectors (NACE classification, can be on multiple hierarchical levels to facilitate result aggregation), critical infrastructure providers and other regional service providers.
- Edges representing dependencies of affectedness between nodes of the graph. Edges between economic sectors will be created based on the NACE classification levels. Edges between economic sectors and service providers will be created based on risk assessment profile information (applicable economic sectors of each service provider). We also consider creating edges between different service providers based on the supply chain dependency information in the profiles. However, when we do not receive enough of this detailed dependency information, we plan to use a fallback method of creating edges between the service providers and the generic economic sectors they depend on.
- To capture pandemic scenarios of disease spreading, nodes representing parts of the population (partitioned by age groups) will automatically be added to the graph and connected to economic sectors and service providers via edges.
- General economic and pandemic state transitions will be added to the nodes based on heuristics embedded in the CI interdependency module transformation code, facilitating cascading effects simulations for the baseline forecast. In this case, general state transitions mean that they do not include modeled behavior to respond to specific pandemic interventions. More specific transitions are part of the What-If analysis simulation runs.

For cascading effects simulations in the context of the What-If analysis, the CI interdependency module provides input possibilities for graph and simulation parameters that correspond to the pandemic scenarios and the interventions the end user wants to simulate. Based on these inputs, the economic and pandemic state transitions are transformed in the CI interdependency module as part of a preprocessing step before the simulation to more accurately reflect the interdependent cascading effects in the specific forecasts. Again, the heuristics for how to transform the nodes' state transitions are embedded in the CI interdependency module.