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

D2.2 Strategy for awareness and resilience of CIs V1

Document Identification			
Status	Final	**Due Date**	31/03/2024
Version	1.0	**Submission Date**	25/03/2024

Related WP	WP2	**Document Reference**	D2.2
Related Deliverable(s)	D1.1, D1.2, D2.1	**Dissemination Level (*)**	PU
Lead Participant	AIT	**Lead Author**	Stefan Schauer
Contributors	HB, HER, HZI, ICS, IHS, INS, UPM	**Reviewers**	Josip Radman (MZI)
			Miguel Martin Perez (ATS)

Keywords:
Pandemic Resilience, Pandemic-specific Critical Entity, Multi-criteria Risk Analysis, Consequence Simulation, Critical Infrastructure Protection

This document is issued within the frame and for the purpose of the SUNRISE project. This project has received funding from the European Union's Horizon Europe Programme under Grant Agreement No.101073821. The opinions expressed and arguments employed herein do not necessarily reflect the official views of the European Commission.

(*) Dissemination level: **(PU)** Public, fully open, e.g. web (Deliverables flagged as public will be automatically published in CORDIS project's page). **(SEN)** Sensitive, limited under the conditions of the Grant Agreement. **(Classified EU-R)** EU RESTRICTED under the Commission Decision No2015/444. **(Classified EU-C)** EU CONFIDENTIAL under the Commission Decision No2015/444. **(Classified EU-S)** EU SECRET under the Commission Decision No2015/444.

Document Information

List of Contributors	
Name	Partner
Manuel Egger	AIT
Martin Latzenhofer	AIT
Max Kesselbacher-Pirker	AIT
Stefan Schauer	AIT
Niklas Sommerer	AIT
Marianna Pedrazzi	HB
Maria Beatrice Versaci	HB
Laurens Bouwer	HER
Christine Nam	HER
Olga Hovardovska	HZI
Berit Lange	HZI
Isti Rodiah	HZI
Milan Tarman	ICS
Norman Fauster	IHS
Elisabeth Laa	IHS
Kerstin Plank	IHS
Hannes Zenz	IHS
Gilda de Marco	INS
Jose del Alamo	UPM

Document History			
Version	Date	Change editors	Changes
0.1	10/10/2023	Schauer (AIT)	First structure (ToC) of the document
0.2	08/01/2024	Latzenhofer, Schauer (AIT)	Structural changes, inputs on Vision, Mission and Objectives
0.3	31/01/2024	Latzenhofer, Schauer (AIT), Zenz, Plank, Laa (IHS), Nam (HER)	Update on various sections in the document
0.31	14/02/2024	Rodiah (HZI)	Update on Epidemiological Model
0.40	15/02/2024	Fauster (HIS)	Update on Economic Model
0.41	16/02/2024	Schauer (AIT)	Integration of Inputs, Update on Section 2
0.42	17/02/2024	Schauer (AIT)	Update of Section 2
0.43	21/02/2024	Schauer (AIT)	Update of Section 4
0.44	26/02/2024	Schauer, Egger, Kesselbacher-Pirker (AIT), Fauster (IHS), Versaci, Pedrazzi (HB)	Integration of new inputs
0.45	28/02/2024	Schauer (AIT)	Update of Sections 4 and 5

0.46	01/03/2024	Nam (HER), Rodiah (HZI), Kesselbacher-Pirker (AIT)	Updates on Sections 3 and 4; moved Section 5 to D2.3
0.49	02/03/2024	Schauer (AIT)	Integration of inputs from HER, HZI and AIT; extension of Section 4 and 5
0.50	04/03/2024	Schauer (AIT)	Update on Section 4
0.51	07/03/2024	Schauer (AIT)	Update on Sections 4 and 5
0.52	10/03/2024	Schauer (AIT)	Update on Section 5, reformatting and including references (Zotero)
0.6	11/03/2024	Schauer (AIT)	Producing clean version for review (eliminating change tracking)
0.85	18/03/2024	Radman (MZI), Perez (ATS), Sommerer, Schauer (AIT)	Review of the deliverable, integration of inputs from the reviewers, update of Section 5.2
0.90	20/03/2024	Latzenhofer, Schauer (AIT)	Internal review and respective updates, including missing references, polishing the overall text for SAB review
0.92	21/03/2024	Schauer (AIT)	Finalization of contents (Executive Summary, Introduction, Conclusion)
0.93	22/03/2024	Schauer (AIT)	Final polishing, submission to quality management and project coordination
0.94	25/03/2024	Juan Alonso (ATS)	Quality Assessment
1.0	25/03/2024	Aljosa Pasic (ATS)	Final version

Quality Control		
Role	Who (Partner short name)	Approval Date
Deliverable leader	Stefan Schauer (AIT)	22/03/2024
Quality manager	Juan Alonso (ATS)	25/03/2024
Project Coordinator	Aljosa Pasic (ATS)	25/03/2024

Table of Contents

List of Tables

List of Figures

List of Acronyms

Abbreviation / Acronym	Description
ABM	Agent-based Model
API	Application Programming Interface
AR1	Autoregressive Process of order One
CER	Critical Entities' Resilience
CFR	Case Fatality Rate
CI	Critical Infrastructure
CMIP	Coupled Model Intercomparison Project
CSV	Comma-separated Values
DSP	Digital Service Provider
D2.2	Deliverable number 2 belonging to WP2
EC	European Commission
ECDC	European Centre for Disease Prevention and Control
ECI	European Critical Infrastructure
ECMWF	European Centre for Medium-Range Weather Forecasts
ECSCI	European Cluster for Securing Critical Infrastructure
EISN	European Influenza Surveillance Network
ENISA	European Network and Information Security Agency
EPCIP	European Programme for Critical Infrastructure Protection
EU	European Union
GDP	Gross Domestic Product
HIV	Human Immunodeficiency Virus
HR	Human Resource
ICU	Intensive Care Unit
ICS	Industrial Control System
ICT	Information and Communication Technology
ILI	Influenza-like Illness
IRAT	Influenza Risk Assessment Tool
ISO	International Organization for Standardization
JSON	JavaScript Object Notation
MAARI	Medically Attended Acute Respiratory Illness
MONID	Modelling Network for Severe Infectious Diseases
MRSA	Methicillin-resistant Staphylococcus Aureus
MTPD	Maximum Tolerable Period of Disruption
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne (engl. Statistical classification of economic activities in the European Community
NIS	Network and Information Security
NPI	Non-Pharmaceutical Intervention

NUTS1	Nomenclature of Territorial Units for Statistic Level 1
OES	Operator of Essential Services
PDCA	Plan-Do-Check-Act
PHEIC	Public Health Emergency of International Concern
PHSM	Public Health and Social Measures
PI	Pharmaceutical Intervention
PIRM	Pandemic Influenza Risk Management
PISA	Pandemic Influenza Severity Assessment
PPE	Personal Protective Equipment
PSAF	Pandemic Severity Assessment Framework
PSCE	Pandemic-specific Critical Entity
RCP	Representative Concentration Pathways
REST	Representational State Transfer
SARS	Severe Acute Respiratory Syndrome
SEIR	Susceptible-Exposed-Infectious-Recovered
TIPRA	Tool for Influenza Pandemic Risk Assessment
UTCI	Universal Thermal Climate Index
WHO	World Health Organisation
WP	Work Package
XML	Extensible Markup Language

Executive Summary

The COVID-19 pandemic has highlighted the importance of the continuity of vital services and has proven that a pandemic is not only a health crisis but that it also has the potential to disrupt the operation of Critical Infrastructures. This showed the extremely important link between the resilience of Critical Infrastructures and the well-being of our society. Hence, all entities that can be considered critical in the context of a pandemic need to be more prepared to reduce or avoid the devastating and wide-ranging effects when facing a future pandemic.

This deliverable focuses on this challenge and describes the SUNRISE Strategy which aims at building a collection of activities that allow to capture these wide-ranging, multi-criterial effects and to build adequate response measures out of that. As a main result, the SUNRISE Strategy Process is defined, which gives critical infrastructures and critical entities the concepts to improve their awareness and resilience when facing future pandemics. Therefore, it consists of five major steps that range from the identification of pandemic-specific critical entities, the characterisation of the pathogen causing the pandemic, the assessment of consequences according to different criteria (health, economic, societal, etc.) as well as the evaluation and selection of protection and mitigation measures.

Besides that, this deliverable also provides an overview on possible solutions, i.e., methodologies and tools, that are provided by several project partners and can be used to implement the individual steps of the SUNRISE Strategy Process. In particular, these methodologies and tools include multi-domain simulation approaches, covering epidemiologic models, climate change models, socio-economic impact models and cascading effects models, for describing the potential consequences of a pandemic in all of these domains. Additionally, a risk assessment framework is described that integrates all of these approaches to provide a holistic risk estimation.

The target audience are operators of critical entities in general and critical infrastructures in particular as well as decision makers on a regional or national political level. For them, this deliverable serves as a basic guideline on how to prepare for, protect against or mitigate a pandemic future pandemic.

This deliverable represents a first version of the SUNRISE Strategy with the final version to be published in M33.

1 Introduction

1.1 Purpose of the document

The COVID-19 pandemic showed that a pandemic not only has direct effects, e.g., on the health of those people who get infected with the pathogen, but also has wide-ranging cascading effects in various sectors and parts of social life. These effects on vital services and organisations as well as the whole society make it much more complex to be prepared and to implement protection and mitigation actions since their effectiveness is unclear as the cascading (side-)effects are not well understood and captured by current risk assessment frameworks.

Therefore, the objective of this document is to describe a general strategy, i.e., the SUNRISE Strategy, which shall support operators of critical infrastructures or other critical entities as well as political decision makers on a regional or national level in their preparation for a pandemic. This strategy focuses on the diverse consequences a pandemic could have on society, affecting not only the health of people but also the capacities in the health sector, the availability of vital services as well as several functions of social life. Thus, it explicitly incorporates concepts and methodologies to evaluate and estimate such consequences and to provide a holistic view on the current situation together with an extrapolation of possible scenarios to support the decision makers.

The SUNRISE Strategy represents a core result of the SUNRISE project as it describes a framework and a step-by-step process on how the different concepts, methodologies and tools from the project can be applied in a structured way to improve the awareness, preparedness, response and resilience of critical infrastructure and critical entity operators. Additionally, it also provides a guideline for decision and policy makers from regional or national governmental bodies on how to use and integrate information and data coming from different sources (e.g., out of the critical infrastructures or entities) to evaluate and choose the optimal protection and mitigation actions to counter or contain a future pandemic.

This deliverable represents a first version of the SUNRISE Strategy with the final version to be published in M33. Hence, parts of this document might be restructured, adapted or changed based on the evaluation and validation process that will be carried out in the second half of the project.

1.2 Relation to other project work

The SUNRISE Strategy is a main outcome of WP2 and of the entire SUNRISE project. On the one hand, it takes information from Deliverable D2.1, where the first steps towards the strategy and the strategy process are sketched and important concepts already have been introduced., and provides information for D2.3, which covers the validation process for the strategy and the assessment framework coming out of it. On the other hand, the SUNRISE Strategy also builds upon the discussions and findings from the first national and international end user workshops in WP1 with their results being summarised in Deliverable D1.1 and D1.2. In the first workshops, some of the main requirements were already gathered and were fed into the design of the SUNRISE Strategy Process, whereas the later international workshop served as a first opportunity to already evaluate and discuss parts of the SUNRISE Strategy with relevant stakeholders. In this way, it goes hand in hand with the upcoming tasks planned in WP2 on the validation process and in WP1 on the next national and international workshops, which will be used to carry out parts of the validations.

Form an overall roadmap perspective of the SUNRISE project, the SUNRISE Strategy provides a high-level overview how the different results from the project can be brought together and complement each other. This also involves the specific tools that are built in the work packages WP4 – WP7. Although these tools provide solutions for specific problems, they have their place in the SUNRISE Strategy and the SUNRISE Strategy Process, too. For example, the risk-based access control from WP4 can be seen as a protective or preventive measure and influence the spreading of the pathogen (cf. Section 5.4.1 on the epidemiology model), the information on demand prediction and management (WP5) can be applied in several ways, e.g., when considering the pandemic's effects on other domains (cf. Section 5.4.3 on the cascading effects model) or the aspects of climate change (cf. the climate change model in Section 5.4.2). Furthermore, the approaches towards a cyber-physical resilience (WP6) as well as the tools for remote inspection of critical systems or infrastructures can be seen as protective measures for a specific aspect of the effects of the pandemic onto other sectors and thus can also influence the cascading effects simulation tool (cf. Section 5.4.3) and the socio-economic impact model (cf. Section 5.4.4).

1.3 Structure of the document

The aim was to structure this deliverable in the form of a guideline for decision makers within critical organisations and on a regional or national governmental level. Therefore, this document is structured in six major chapters:

Chapter 2 presents the main purpose of the deliverable, covering the vision, mission and objectives of the SUNRISE Strategy. In addition to the main vision of the strategy, five mission statements are introduced together with five objectives, each one related to one mission statement.

Chapter 3 introduces the main concepts that are used within the SUNRISE Strategy. In the beginning, the difference between an epidemic and a pandemic is covered as well as a definition and some explanation is provided for the concepts of weather and climate. As the strategy is mostly focusing on critical entities a definition for critical infrastructures and critical entities are given based on existing EU directives and from that the definition of pandemic-specific critical entities is derived. Finally, the concept of resilience in the context of critical entities is introduced.

Chapter 4 describes the SUNRISE Strategy Process, a step-by-step guideline on how to implement the SUNRISE Strategy and to achieve the objectives. The SUNRISE Strategy Process includes five main steps with several sub-steps, starting with the initial setup of the process' context together with the identification and analysis of the pandemic. The core part of the process involves the evaluation and assessment of the consequences based on multiple criteria as well as the analysis of available measures. The process closes with an estimation of the effects of these measures and the development of an implementation plan.

Chapter 5 focuses on the implementation of the SUNRISE Strategy Process from Chapter 4 and lists several methodologies and tools that can be used in the various steps of the process. These range from straight-forward methodologies to interact with operators of critical entities up to specific tools for the simulation of epidemiological models, cascading effects and economic impacts. This chapter also provides a high-level overview on potential protective and preventive measures that can be implemented to protect against, recover from or mitigate a pandemic

Chapter 6 provides a conclusion of the deliverable and sketches the main results and take-aways from the previous chapters.

Additionally, the document also has one **Annex**, which gives a detailed overview on a series of national workshops that were carried out in Slovenia, Italy and Spain. This complements the description in Chapter 5 and serves as an example how such workshops could look like.

2 Vision, Mission, and Objectives

2.1 Vision

European societies and economies depend on the reliable provision of vital services, especially during a pandemic. Such vital services are delivered through Critical Infrastructures (CIs) which include basic supply networks (water, electricity), networks of information and communication services, social services (e.g., care of children or elderly), as well as complex networks of essential supply to the population (e.g., medical supply, food supply). This means that European CIs must be resilient, i.e., able to accommodate constantly changing risks and recover quickly from expected or unexpected disruptions. However, infrastructure systems and their components are interdependent. If a disruption or failure occurs in one system, it can spread to other systems and subsequently amplify the impact of a disruption many times and impact further systems.

Due to the constant growth and increase in complexity of the connections between infrastructures, the interdependencies within the overall system also continue to increase, causing the system to become more susceptible to disruption [1]. A critical infrastructure system (e.g., public health system) comprises several sectors, with networks and components, interconnected at nodes. This creates a complex network of interconnections, whose characteristics determine how and with what intensity the effects of critical infrastructure system failures spread to dependent subsystems and society [2].

Dependencies of CIs can be documented, analysed, and investigated in multiple ways. Case studies (e.g., Schneidhofer & Wolthusen [3]) or incident reports (e.g., Hassanzadeh et al. [4]), document failures and their effects in real scenarios, while theoretical modelling and simulations (e.g., by Rinaldi [1], Setola [5], Oliva et al. [6], or Cavallini et al. [7]) investigate and envision what might be done in order to prepare responsible actors, processes and systems to protect critical infrastructures from potential threats. Different measures have been taken via the European Programme for the protection of CIs, such as EPCIP and the European CI Directive (ECI) [8]. Other actions have aimed at climate-proofing the CIs, increasing their cybersecurity (NIS Directive [9]), NIS2 Directive [10]), and defining/refining specific strategies at EU Member State level.

However, CI operators and competent authorities in Europe are still not adequately equipped to address pandemic risks due to the rapidly evolving threat landscape, the fact that the CIs in Europe have become deeply interconnected and digital, and gaps in existing legislation. Moreover, dependencies between CIs in different sectors and across different countries can be so substantial that disruptions in a single CI can multiply economic and societal impacts across other CIs, across other sectors, and across borders. In the future, CIs will more than ever have to be able to consider uncertainties, adapt to climate change and more often health crises, and ensure reliability of service provision across a range of potential future scenarios. Hence, the SUNRISE Strategy states the following vision:

> *The vision of the SUNRISE Strategy is to improve the* ***awareness*** *of critical infrastructure operators as well as decision makers on regional and national level for the* ***multi-criterial effects*** *of pandemics and thus to increase the resilience of the provision of vital services for the society against future pandemics.*

A single CI cannot factor in all the risks they are confronted with, cannot properly assess the scale of these risks, and cannot adequately address them on its own. Given the COVID-19 pandemic, the need for better cooperation and collective spirit in finding solutions has never been more obvious and urgent. However, due to the resource scarcity in a pandemic and since the impact of a pandemic varies across different CIs, there has been competition between Member States (even regions) and between different CIs, instead of cooperation. The SUNRISE Strategy will highlight where an active collaboration of European CIs will be beneficial for all participants and will show them how specific concept and methodologies can support the preparedness and resilience of CIs as well as equip them with tools and guidelines to adequately assess and jointly manage future risks created by pandemics.

2.2 Mission

If not addressed appropriately, the problems outlined above will become even more acute due to more frequent extreme weather events and more frequent pandemics. Increasing deforestation, land-use changes, and climate change will cause loss of habitat for animals, forcing them to migrate and encounter other animals they normally wouldn't, which will create more opportunities for illnesses, or more specifically, for pathogens to get into new hosts, spill over from animals to humans, cause more frequent disease outbreaks, and thus shorten the intervals between different pandemics. Consequently, and to achieve the Vision stated in Section 2.1 above, the SUNRISE Strategy foresees five missions.

> ***Mission 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.*

European Member States differ over the services, infrastructures, entities, and sectors that are formally recognised as critical. At EU level, there is no single recognised list of CI sectors. For example, the ECI Directive [8] covers two critical sectors whereas the first version of the NIS Directive [9] covers seven and the most recent second version covers eleven sectors of high criticality (plus seven "other critical sectors") [10]. Additionally, the CER Directive [11] also specifies eleven critical sectors, but leaving out "Information and Communication Technology (ICT) Service Management" and including "Production, processing and distribution of food" instead.

At national level, sectoral coverage also varies. Most Member States formally recognise energy, transport, and banking as critical sectors, but some do not formally recognise health, digital infrastructure, food, or public administration as critical, although these are some of the most important services in a pandemic. And since the heavily interrelated European CI network is only as strong as its weakest link, we must ensure that all pandemic-specific vital services across Europe are resilient, regardless of their formal status. Therefore, the SUNRISE Strategy states the second mission:

> ***Mission 2****: A deeper understanding needs to be established which* ***entities, services*** *and* ***people*** *are vital during a specific pandemic, where they have interrelations and what potential cascading effects due to pandemic-related threats could look like.*

As a consequence, there are vital services within the EU Member States that are not subject to the same risk assessment and mitigation processes, and thus do not adequately account for new threats created by the pandemic. In particular, the COVID-19 pandemic has shown that these new threats affect society, having consequences in a variety of fields. Besides the obvious implications on the health of the individual people and the health sector in general, the pandemic in combination with the protective measures taken had huge economic, societal, and even legal consequences. As measures that have been implemented in this crisis situation have not been used or evaluated before on a comparable (regional, national and global) scale, their full magnitude and implications were not clear to most of the decision makers. For future pandemics, this is a crucial point to solve, i.e., to establish a multi-criteria assessment of the consequences of a pandemic. Thus, the SUNRISE Strategy implements the third mission:

SUNRISE

> ***Mission 3**: Risk assessment and management as well as business continuity management methodologies on organisational, regional, and national level need to **consider the potential impacts and probabilities** of pandemic-related threats on the vital assets and services for society, taking societal, ethical, legal, economic and ecologic aspects into account.*

In order to implement such a risk assessment, most of the current approaches are not suitable as they are designed and tailored to only one or two dimensions, whereas the consequences of a pandemic need to be taken into account according to multiple criteria. Given the measures that can be implemented to prepare for, protect against or mitigate a pandemic, it has become obvious over the last years that also the effects of these measures need to be evaluated, ideally before they are set in place. As mentioned above, the effects of a pandemic as well as of the countermeasures need to be evaluated under medical, societal, ethical, legal, economic, and ecologic aspects. This can only be achieved if a respective methodology and toolset are at hand to support decision makers. However, such a methodology needs to be designed in a way that it combines the different aspects (medical, societal, ethical, legal, economic, and ecologic) in a comprehensive way and establishes a holistic picture of the overall situation. Therefore, the SUNRISE Strategy follows its fourth mission:

> ***Mission 4**: A high-level **collection of countermeasures**, i.e., a selection of pharmaceutical and non-pharmaceutical as well as economic and legal measures, needs to be established to support decision making and to effectively prepare for and counter the multi-criterial effects of pandemics.*

Although the COVID-19 pandemic has highlighted the importance of collaboration between CI operators, decision maker from regional and national government, it is still a big challenge to have the CI operators and authorities discussing and joining forces to better understand the needs of CIs in pandemics and how to meet them. This is a challenge because currently there is no such expert discussion environment for exchanging these important points. On the one hand, there are research networks on CIP on a European level [12], but they are missing the pandemic focus. There are even CI security gatherings (e.g., the European Cluster for Securing Critical Infrastructure – ECSCI [13]), but again, missing the focus on pandemics. On the other hand, there are ambitions to learn from the happening of the last years and to create a European partnership for pandemic preparedness [14] together with a strategic research and innovation agenda, but these approaches only focus on the medical and health aspects, leaving out the multiple influences on CIs and the consequences for society. In such emergency pandemic situations, the collaboration from experts coming from different fields is of utmost importance to improve the continuity and resilience of CIs and critical processes. This leads to the fifth and final mission of the SUNRISE Strategy:

> **Mission 5**: An **increased collaboration** among the operators of vital services, from different industry sectors and across regional and national borders, needs to be established or improved, in order to effectively share best practices and join forces during future pandemics.

The SUNRISE Strategy aims to implement these five missions to achieve an improved preparedness and resilience not only for CIs from different sectors but also for the whole society in face of future pandemics.

2.3 Objectives

The five mission statements from the previous section indicate the high ambition set by the SUNRISE Strategy and the SUNRISE Strategy Process, respectively. These mission statements are of a diverse nature and involve many different facets like the extension of existing processes such as risk assessment and business continuity management within the respective organisations, the implementation of hands-on activities such as the implementation of a toolset or the intensification of collaboration among CI operators and other relevant entities, as well as more subtle and soft achievements such as the creation of awareness and understanding for the potential future threats of a pandemic among the relevant stakeholders. To accomplish that, more precise objectives need to be defined, which characterise specific results to be achieved. In further detail, the SUNRISE Strategy defines the following five main objectives:

> **Objective 1**: Compile a **collection of pandemic-related threats** for critical infrastructures and the society based on the epidemiological characterization of pandemic risks and considering **climate change as a threat multiplier**.

The SUNRISE Strategy and the SUNRISE Strategy Process capture the epidemiological characteristics of a pandemic right in the beginning and all parts of the strategy and the process focus on these characteristics. Therefore, one step of the SUNRISE Strategy Process is entirely focusing on the epidemiological assessment of the pandemic (cf. Section 4.2) as well as its consequences (cf. Section 4.3). In this context, some parts of the consequences (e.g., on the population or on Pandemic-Specific Critical Entities – PSCEs) can be understood as pandemic-related threats and will be further dealt with in the strategy.

A detailed collection of pandemic-related threats will be provided in the second version of this deliverable. The threats will be related to the use cases that are defined in Deliverable D2.3 to highlight the practical relevance but will cover threats from a generic perspective such that they can be applied to different types of pandemics. This collection will then support decision makers within CIs and also on a regional and national level in future analyses.

> **Objective 2**: Identify **pandemic-specific critical entities and vital services**, describe the interactions and dependencies among them, and determine cascading effects based on the effects of pandemics on the society.

As part of the SUNRISE Strategy, we will provide a definition of Pandemic-Specific Critical Entities (PSCEs); these are organisations, people or even services and processes that will be highly relevant during a pandemic, either because they are directly affected by it or by the measures implemented to contain the pandemic. These PSCEs are of highest interest for the strategy as they have a huge effect on the population and on society. As part of the strategy, a methodology is sketched that supports the identification of these PSCEs.

In the second version of this deliverable, an overview on how to use that methodology in the use cases in Slovenia, Italy and Spain will be provided. Further, a list of PSCEs from these three regions will also be part of the second version of D2.2.

> **Objective 3**: Establish a comprehensive **risk analysis methodology** that considers multi-criterial impacts of disease spreading among employees of critical infrastructure operators and the whole society, considering also their cascading effects and including economic, ecologic, legal, ethical and societal aspects.

The SUNRISE Strategy Process as described in Section 4 is particularly designed to follow the core steps of a risk assessment approach. In particular, the Process is designed in a way such that a multi-criteria impact analysis is naturally integrated, i.e., multiple types of impacts are considered in the analysis (cf. Section 4.3). These involve impacts on the individual health of the population and on public health, effects on critical entities, infrastructures, and services as well as economic impacts on businesses within a region or on a national scale. In addition to the overall description of the SUNRISE Strategy Process, an example for a specific implementation as a software tool is sketched in Section 5.4.5. Whereas also other implementations would be possible, the one presented here already integrates several simulation approaches to capture the different types of consequences.

In the second version of this deliverable, it will be shown how the SUNRISE Strategy Process and the connected risk analysis methodology can be instantiated. Therefore, the use cases defined in Deliverable D2.3 will be applied to the demonstration regions in Slovenia, Italy and Spain and the information and data provided by the PSCEs involved will be integrated into the risk assessment tool.

Objective 4: Provide an overview on **potential activities and measures** to protect against as well as counter the effects of disease spreading and provide a framework to identify the best-fitting measure for specific pandemics.

As one part of the SUNRISE Strategy deals with the consequences a pandemic might have on various domains, another part of the strategy specifically covers activities and measures to prepare for, protect against or mitigate a pandemic (cf. Section 4.4). Such measures need to come from different domains since the consequences of a pandemic also affect different domains (as briefly sketched in the previous paragraph). During the COVID-19 pandemic, several of these measures have already been implemented such that there is also a good estimation on their effectivity.

A complete set of measures will be part of the second version of this deliverable, where we will discuss, which measures are most effective against which types of pandemics and describe the implicit societal consequences induced by certain measures (e.g., school closures or lockdowns).

Objective 5: Facilitate **active collaboration** among critical infrastructures as well as Pandemic-Specific Critical Entities (PSCEs) within and across European borders, within and across different sectors as well as between public and private sectors.

As a corner stone, the SUNRISE Strategy is building on an active and ongoing exchange among CI operators (or, more specifically, operators of PSCEs) and regional and national governmental bodies. This is reflected in the workshops that are organised in WP1 throughout the SUNRISE project as well as in the workshops that are suggested to be held as part of the first step of the SUNRISE Strategy Process (cf. "Establishing the Context" in Section 4.1). Such workshops bring together the experts from different organisations and domains, foster the exchange of information and encourage discussions among them. In this way, a comprehensive picture can be drawn, including the relevant entities, infrastructures, people, and services during a pandemic together with their dependencies among each other and the potential consequences stemming from a specific pandemic scenario.

During the second half of the project, more workshops are planned to be held in connection with WP1 (i.e., national and international workshops) but also in preparation and during the validation process that is implemented in Task T2.5 and is described in the first version of Deliverable D2.3 (with the execution and results being described in the second version of D2.3).

3 Definitions

As it has been described in the SUNRISE Strategy's vision, it focuses on *entities and infrastructures* that are considered *critical* because they are providing vital services for society; the strategy aims at improving their *resilience* against a potential *pandemic*, also considering future variations of pandemics due to the effects of *climate change*. Since most of these concepts are understood differently in various domains and sectors, it is important to define these terms and concepts, i.e., "pandemic", "climate change", "critical entity and infrastructure" and "resilience", for the context of the SUNRISE Strategy. The goal is to provide a brief overview on how these concepts are defined in the literature and, more importantly, how these concepts are understood in the context of the SUNRISE Strategy and the SUNRISE project in general.

3.1 Pandemic

Firstly, it is important to define what is meant by an epidemic and pandemic situation. The Dictionary of Epidemiology defines an epidemic as [15]:

> *An **epidemic** is the occurrence in a community or region of cases of an illness, specific health-related behaviour, or other health-related events clearly in excess of normal expectancy. The community or region and the period in which the cases occur must be specified precisely.*

In extension to that, the dictionary defines a pandemic as [15]:

> *A **pandemic** is an epidemic occurring over a very wide area, crossing international boundaries, and usually affecting a large number of people. Only some pandemics cause severe disease in some individuals or at a population level.*

Additionally, the World Health Organisation (WHO) does not use the term "pandemic" but rather the term Public Health Emergency of International Concern (PHEIC) and defines it as [16]:

> *A Public Health Emergency of International Concern is an extraordinary event which is determined to constitute a public health risk to other States through the international spread of disease and to potentially require a coordinated international response. This situation can be characterized as:*
>
> - *serious, sudden, unusual or unexpected;*
> - *carries implications for public health beyond the affected State's national border; and*
> - *may require immediate international action.*

The transmission route of a pandemic or, more precisely, of a pathogen is essential for assessing the possible consequences of a pandemic situation and for identifying potential protective and preventive measures. Possible methods of transmission of a pathogen (including some examples) are [17]:

- *Airborne (droplet and aerosols)*: Viral exanthems (measles), streptococcal diseases, various upper and lower respiratory tract diseases, tuberculosis, Legionnaire's disease, influenza (seasonal and H1N1), SARS, measles, mumps, rubella;
- *Physical contact*: Leprosy, impetigo, scabies, anthrax
- *Sexual contact*: HIV, syphilis, gonorrhoea, herpes genitalis, hepatitis B, chlamydia, human papilloma virus;
- *Blood and blood products*: HIV, hepatitis B, hepatitis C;
- *Faecal–oral*: Hepatitis A, poliovirus, enteroviruses, Shigella, rotavirus, adenoviruses, typhoid;
- *Foodborne*: Salmonella, Escherichia coli, Helicobacter pylori, Campylobacter, Listeria;
- *Waterborne*: Cholera, Giardia, Cryptosporidium, Helicobacter pylori;

- *Transcutaneous Vector-borne via insec*ts (arthropods): malaria, viral haemorrhagic fevers, schistosomiasis, plague + Animal bite (zoonoses): rabies;
- *Self-injected*: HIV, hepatitis B;
- *Congenital maternal-foetal*: Congenital rubella syndrome, congenital syphilis, gonorrhoeal ophthalmia, cytomegalovirus, HIV, rubella, syphilis, hepatitis B and C, gonorrhoea, chlamydia;
- *Healthcare-associated (e.g., hospital, long-term care facilities, community surgical centres, and community-acquired)*: Klebsiella pneumoniae, Clostridium difficile, Staphylococcus aureus including methicillin-resistant organisms (MRSA), HIV, hepatitis B, hepatitis C, fungal infections, central venous line-, ventilator-, and catheter-associated pneumonia, surgical site infections.

The specific pathogen and the transmission methods provide information about typical situations, behaviours and other influencing factors that favour or inhibit the infection of people. Hence, these transmission methods need to be considered when evaluating and estimating the consequences of a pandemic, in particular to identify the critical entities, infrastructures and services affected by the pandemic. However, these transmission methods and consequently the regions where specific pathogens are prevalent are influenced by the change of climate and other associated factors over time.

3.2 Weather and Climate

Some diseases are more (or less) likely to spread within the population depending on outside factors such as the weather. For example, influenza-like illnesses and other respiratory viruses are more common in winter than in summer. Similarly, there are various regions on earth, where pathogens are more likely to spread due to the weather or climate conditions. Due to the ongoing climate change, these regions can expand, and parts of the world might be affected by and experiencing new diseases in the future. In this context, it is important to distinguish between Weather and Climate [18]:

> ***Weather** refers to the atmospheric condition at a given time in a given location, and is measured by meteorological variables such as temperature, humidity, precipitation, cloudiness, wind, and visibility.*
>
> ***Climate** refers to the average of weather patterns over an area for a long period of time, typically 30 years or more, which represents the overall state of the climate system.*

This definition already makes it obvious that climate has a much longer time span attached to it. Accordingly, we can define Climate Change and, in relation to that, Weather Prediction as [18]

> ***Climate change** refers to long-term changes in the Earth's climate that are warming the atmosphere, ocean and land.*

The balance of ecosystems supporting life and biodiversity, and impacting health is changing with increasing temperature. More extreme weather events, in terms of frequency and intensity, such as hurricanes, floods, heat waves, and droughts are projected to occur. Climate change also leads to sea level rise and coastal erosion as a result of ocean warming, melting of glaciers, and loss of ice sheets.

Due to the difference between climate and weather, the prediction of climate change goes far beyond the prediction of weather [19]:

> ***Weather predictions** use the current weather observations to forecast future weather over the next few hours and days. **Climate predictions** are also initialised from observed conditions and cover the coming weeks, months and years (seasonal to decadal predictions).*

The climate predictions also account for different assumptions in concentrations of greenhouse gases, aerosols, and other atmospheric constituents that affect the planet's radiative balance which are represented by different "**climate scenarios**". **Climate projections** span until the end of the century and are influenced largely by the climate scenario rather than the initial weather conditions.

3.3 Critical Infrastructures and Critical Entities

The concept of a Critical Infrastructure (CI) describes those companies and organisations that are crucial to the maintenance of society and daily life. The term was initially specified in 2008 by the European Commission as part of the European Programme for Critical Infrastructure Protection (EPCIP) in Directive 2008/114/EC [8]:

> ***Critical infrastructure*** *means an asset, system or part thereof located in Member States which is essential for the maintenance of vital societal functions, health, safety, security, economic or social well-being of people, and the disruption or destruction of which would have a significant impact in a Member State as a result of the failure to maintain those functions.*

The EPCIP was transferred to national law in the Member States, which led to a slightly different interpretation of the concept of "critical infrastructures". In particular, the sectors that are characterized as "critical" differ from state to state and the methodology to identify the individual CIs (e.g., based on their size, number of customers they provide their service to, etc.) vary as well, which leads to a slightly different interpretation of the concept in the individual Member States.

With the development and publication of the first version of the Directive on Security of Network and Information Systems (NIS Directive) [9], the European Commission fostered the (re-)harmonisation of the concept of "critical infrastructures". Therein, specific sectors were defined that were considered as "critical" all over the European Union; the methodology and process to identify the individual CIs within these sectors was left to the Member States. The NIS Directive had a stronger focus on communication and information systems, i.e., on the cyber-aspects, etc. Additionally, the NIS Directive also introduced the terms "operator of essential services" (OES) and "digital service provider" (DSP), which replaced the concept of the "critical infrastructure". In this way, it was possible to broaden the concept of "critical infrastructures" a little more.

In 2022, the NIS directive was extended to a second version, i.e., the NIS2 Directive [10], which defines a larger number of critical sectors and integrates a stronger focus on the supply chain of these sectors. In this way, not only the security of the operators of essential services themselves are at the focus of the NIS2 Directive but also the security of their suppliers and customers. The NIS2 Directive keeps the concept of "essential services" but defines "essential entities" and "important entities" instead of the operators in the first version of the NIS Directive. The focus of the extension was a broader scope on the economy and thus includes more sectors which are important for the European society and economy. It should strengthen the cooperation and information exchange between the Member States and their authorities and organisations in case of cybersecurity incidents. Furthermore, it should enforce a more stringent cybersecurity culture even on management level and in supply chains.

At the same time, the Critical Entities Resilience Directive (CER Directive) was established [11], which extended the NIS2 Directive from a content perspective by focussing more on aspects besides communication and information systems; in this way, the CER Directive can be understood as focussing more on the physical aspects. Following the concept of terms of the NIS2 Directive, the CER Directive defines "critical entity" instead of "essential entities" and "important entities" and defines the term of a "critical entity" as [11]:

> ***Critical entity*** *means a public or private entity which has been identified by a Member State such that:*
>
> *(a) the entity provides one or more essential services;*
> *(b) the entity operates, and its critical infrastructure is located, on the territory of that Member State; and*

(c) an incident would have significant disruptive effects, on the provision by the entity of one or more essential services or on the provision of other essential services in the relevant sectors.

With this more high-level approach and stronger focus on the physical domain rather than the cyber domain, the definition of "critical entities" as provided in the CER [11] will be the most relevant for the SUNRISE Strategy. Hence, we will build onto this definition in the following sections.

One of the problematic shortcomings in both national and European legislation was that different sectors were classified as "critical" across the individual Member States and therefore different organisations were identified as critical infrastructure. In general, this means that the term critical infrastructure, the relevant criteria used to decide whether organisations and their services are identified as critical infrastructure in the member state, and the relevant sectors in which the critical infrastructure providers operate, were not sufficiently standardised.

This was accompanied by a lack of comparability and inconsistencies from a European perspective, particularly where there were dependencies between the individual member states, for example where the service of a critical infrastructure was not considered sufficiently relevant by the resident member state but was essential for the supply in another member state. The NIS2 and CER directives now seek, among other things, to harmonise the existing differing perspectives in the member states and at the same time significantly expand the sectors addressed to reflect the real situation better.

3.4 Pandemic-Specific Critical Entities

Given the regulations and definitions presented in Section 3.2, it is easy to see that there are several slightly different definitions of Critical Infrastructures (CIs) or Critical Entities (CEs) but there is no final version that is valid across all Member States. Rather, each Member State can specify the thresholds according to which they will identify CEs among the organisations and companies within their borders. Additionally, it is easy to see that the definitions in these EU directives are on a rather high level and only going into more detail on the security of communication and information systems in case of the NIS2 Directive. Hence, it becomes obvious that practicable definitions and criteria need to be developed to characterize CIs or CEs according to their relevance in the course of a specific pandemic, i.e., the Pandemic-specific Critical Entities (PSCEs).

It is evident that during a pandemic, possible countermeasures should be focussed on specific focal points in social life. Critical entities – and even more specific for a pandemic situation – PSCEs can represent such a focal point. Hence, we define Pandemic-specific Critical Entities in the SUNRISE Strategy as follows:

Pandemic-specific Critical Entity (PSCE) *means a public or private entity that is considered:*

a) an "essential entity" under Article 3 of the Directive (EU) 2022/2555 EC, or
b) an "important entity" under Article 3 of the Directive (EU) 2022/2555 EC, or
c) a "critical entity" under Article 2 of the Directive (EU) 2022/2557, or
d) an important supplier of services or goods to one of the organisations mentioned in a), b), c) or d)

and

e) is immediately involved in the implementation of measures for detecting, preventing, or mitigating the effects of a pandemic; or
f) is directly affected by the measures for detecting, preventing, or mitigating the effects of a pandemic.

The explanation of the terms "essential entity", "important entity" and "critical entity" are already covered in Section 3.2; hence, we only need to specify the term "important supplier" used in *d)* above in some more detail. An important supplier is characterised as an organisation that provides goods or services that are "critical" (using the definition established in Section 3.2). In other words, the organisation is providing tangible goods (i.e., concrete objects such as materials), intangible goods (i.e., immaterial objects such as intellectual property rights, IPRs) or services (i.e., provision of technology, knowledge, or skills); a shortage or failure of this good or service would pose an existential threat to the consuming organisation and thus have a similar effect on social life.

Additionally, the items *e)* and *f)* characterise the relation to a specific pandemic scenario. In detail, if an organisation is essential for preparing against or dealing with a pandemic (e.g., most organisations in the healthcare sector or specific authorities) or it is heavily affected by a specific pandemic (e.g., supermarkets as part of the food supply or the public transportation since a high number of people are getting together there), they qualify as "pandemic-specific".

3.5 Resilience of PSCE

From the previous two sections, we can see that the concept of criticality is not well-defined in the context of infrastructures and their importance to social life. Another concept that has even more different meanings depending on the domain that is considered, is the concept of resilience. Whereas resilience can be considered, in general, as the ability or capacity of a system to recover (to an acceptable level of functionality or operation) from a perturbation or disruption, there are numerous definitions in different areas of application. From a technical point of view, resilience can be understood in construction as the ability of buildings and infrastructure to absorb assaults without suffering complete failure, or in computer systems as the ability of a computer network to maintain service in the face of faults. From a psychological point of view, resilience can be interpreted as an individual's ability to adapt in the face of adverse conditions; from an organisational point of view, it can be interpreted as the ability of an organisation to withstand changes in its environment and still function. From a community or societal point of view, resilience can be understood as the adaptive capacities of communities and societies to manage change and adversities over time.

As all these concepts and definitions have their reason to exist in their respective domains (and also do have their individual ways and methods to measure the resilience), for the context of the SUNRISE Strategy, a definition that is closer to the context of critical entities and pandemics is required. Therefore, the context of the CER Directive seems to be reasonable, where resilience is defined as follows [11]:

> ***Resilience** means a critical entity's ability to prevent, protect against, respond to, resist, mitigate, absorb, accommodate, and recover from an incident.*

Due to the fact that the CER Directive is focusing on a broad variety of threats, we can refine the definition of resilience in the SUNRISE Strategy a little more towards the specific threat of a pandemic, such that we say:

> *The **resilience** of a critical entity in general, or a PSCE in particular, is understood as the entity's ability to prevent, protect against, respond to, resist, mitigate, absorb, accommodate and recover from the direct or indirect effects of a pandemic.*

In this way, resilience is not only limited to the ability to recover or "bounce back" from a perturbation such as a pandemic, i.e., involving post-incident activities, but also captures the ability to prepare for and resist a pandemic, i.e., involving pre-emptive activities and measures before the incident as well as concurrent activities while the incident is happening. Although this provides a much broader understanding of the concept of resilience, it makes it harder to estimate or assess the resilience of individual critical entities, of a community or the whole society.

4 Strategy Process Definition

The different steps of the SUNRISE Strategy are collected in a general process description, the SUNRISE Strategy Process (cf. Figure 1). This supports not only a structured overview on the SUNRISE Strategy but also provides a step-by-step guidance for CI operators, municipalities, and regional as well as national governmental bodies to implement the strategy.

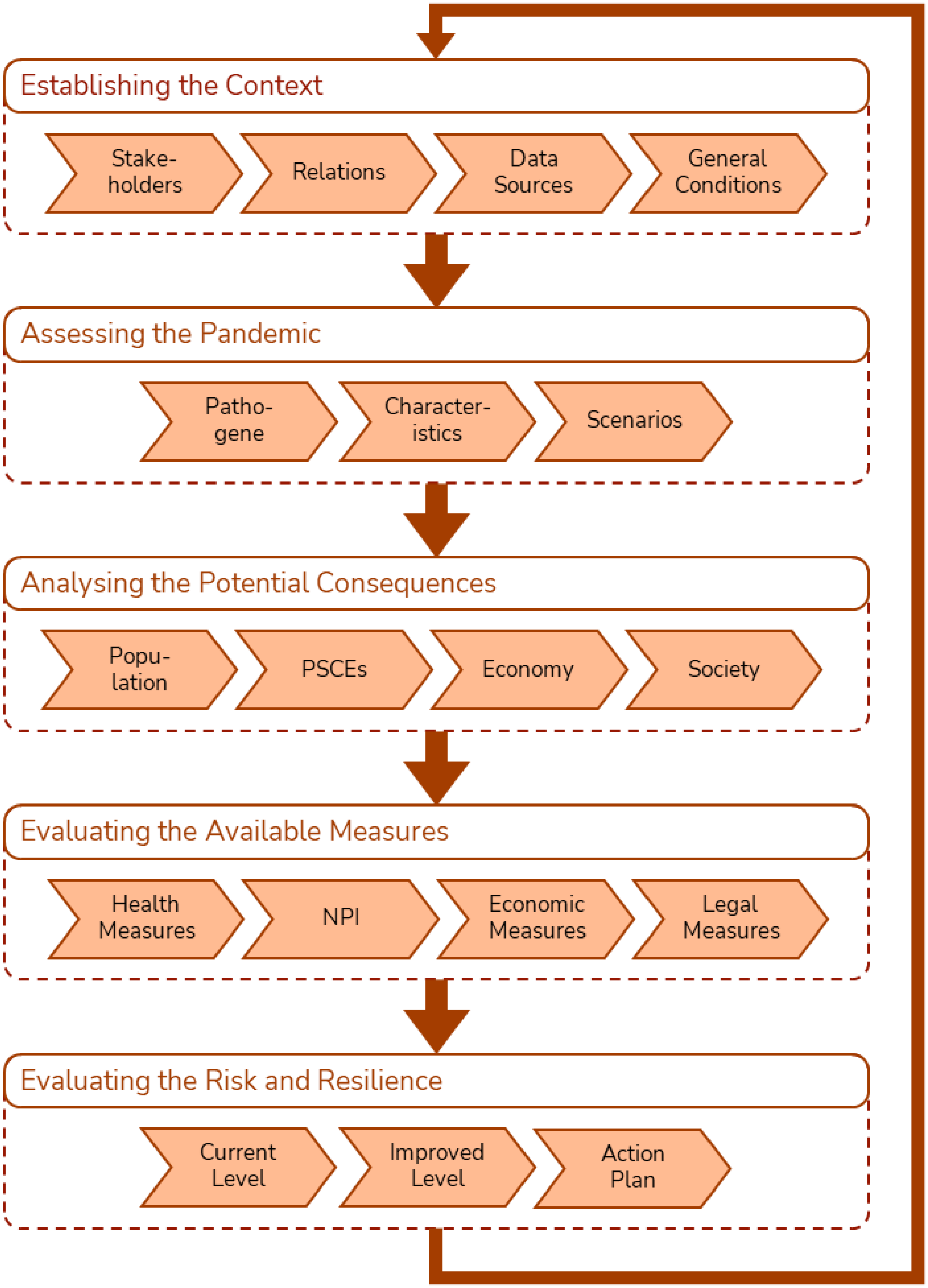


Figure 1: Illustration of the SUNRISE Strategy Process.

The SUNRISE Strategy Process is building on the cornerstones of the Plan-Do-Check-Act (PDCA) cycle and strongly relates to the generic risk management process as defined in the ISO 31000 [20] and ISO 27005 [21]. In detail, the first step, "Establishing the Context", corresponds to the "Plan" part in the PDCA cycle and can easily be integrated in the beginning of any general risk or security management process. "Assessing the Pandemic" and "Analysing the Consequences" cover the "Do" part in the PDCA cycle; these two steps can directly extend the corresponding steps in any risk or security assessment where threats are identified and analysed. With "Evaluating the Measures" and "Evaluating the Risk and Resilience", the SUNRISE Strategy Process goes beyond current risk or security assessment processes, as it combines the risk analysis and the resilience analysis for pandemic scenarios. Thus, it integrates the different impact areas and addresses both risk as well as resilience from a holistic point of view and analyses relevant countermeasures according to both aspects. Hence, these steps directly relate to and extend the evaluation steps in any risk or security assessment process and can also be understood as the "Check" part of the PDCA cycle. Finally, one output of the step "Evaluating the Risk and Resilience" is a treatment or action plan containing a set of measures that need to be implemented and a schedule when and where these measures need to take place. This can be understood as the "Act" part of the PDCA cycle.

A large fraction of CIs, municipalities and regional as well as national governmental bodies already implement processes for risk or security management or processes following the PDCA cycle in general. Therefore, the structure of the SUNRISE Strategy Process facilitates and supports a straightforward integration into already existing processes within these end user organisations.

In the following subsections, the individual steps of the SUNRISE Strategy Process are described from a general perspective, i.e., highlighting the core concepts behind each step and indicating the most important activities that need to be taken. A more detailed guideline on how to implement the individual steps is provided in Section 5.

4.1 Establishing the Context

As a first step into the SUNRISE Strategy Process, it is important to get an overview on the current situation and the context, in which all further steps will be set. This step initiates with the definition of the general conditions under which the strategy process will operate, including organisational, structural, and legal aspects. Further, it involves an overview on the entities (people as well as organisations) that are or need to be involved in the strategy process, the relations and dependencies among them and the data sources that are available (or that are already used) to obtain the required information.

4.1.1 Identify the Relevant Stakeholders

A crucial part of the Context Establishment is to identify the stakeholders that are relevant for the SUNRISE Strategy Process. This can be done rather agnostic of the pandemic situation under evaluation since it primarily focuses on the entities, people, processes, and organisations that are critical for any pandemic situation. In this way, the stakeholders include first and foremost the people within the organisation implementing the process, e.g., a CI, municipality, or other governmental body, that are interested in the results of the process. In general, this includes decision makers on various levels that will use the information and data gathered and created throughout the process to choose relevant measure to contain the pandemic. Depending on the type of organisation, the focus of these decision makers will vary from very detailed aspects within a CI up to a rather broad aspects from a (regional or national) government perspective. Hence, the identification of stakeholders already provides an indication at which level of detail the consequences and protective measure need to be analysed.

Additionally, the stakeholders also include those people and entities that are outside the organisation implementing the strategy process but are still interested in the results of the process or affected by a reduced resilience of the organisation. This includes regional or national government, suppliers, or customers of the organisation and – depending on the organisation – parts of the population. With regards to the suppliers and customers but also to the population, the relations and dependencies are or particular importance and are specifically evaluated in the following step.

4.1.2 Identify the Important Relations and Dependencies

Based on the identified stakeholders, it is important to get an overview on the various relations and dependencies among them as a next step. These relations can mostly be seen as supplier-consumer relations, since many of the organisations implementing the strategy process either provide a good or a service to another entity or are using a good or a service provided by another entity. In this way, the entirety of identified stakeholders can be represented in a graph-like structure where the entities are the nodes and the relations among them are the edges. In this way, the relations are captured in a formalised way and can also be augmented, if necessary, e.g., by using different types of nodes or edges to bring additional semantics into the abstract representation. The resulting graph will then later be used as a basis for several of the approaches used for analysing the consequences.

4.1.3 Identify the Available Data Sources

One aspect that also needs to be clarified in the beginning of the SUNRISE Strategy Process is to identify the available data sources that are needed in the later steps of the process, e.g., the Assessment of the Pandemic or the Analysis of the Consequences. For example, to be able to monitor both epidemiological situation, vulnerable groups, effect of interventions and functions of critical infrastructures, relevant research infrastructures needed are networks of dynamic modelling groups. Both need to be well connected to relevant public health agencies and institutes. Relevant examples of such networks include the European COVID-19 Forecast Hub [22] as well as the German Modelling Network for Severe Infectious Diseases (MONID) [23]. Throughout different epidemic phases estimates and information from these groups will inform decision makers regarding who to target interventions to (see also 4.3.1).

Due to the various sectors and dimensions that are considered in the strategy process, the data from the different dimensions will not be available in a condensed or pre-processed way. Rather, several data source from different organisations are needed to be integrated into one single source that then feeds the different steps of the process. This will include not only the identification of the various sources but also the technical integration (possible access, available formats and interfaces as well as the possibility for a continuous update. Furthermore, it might be possible that throughout the strategy process, an update of the available data sources is necessary, in case additional data is required or new sources are being identified.

4.1.4 Identify the General Conditions

As a last part of the initial step into the SUNRISE Strategy Process, it is necessary to establish the general conditions under which the process will be carried out. On the one hand, this covers the people from the organisation who will carry out the activities in the process and how they are supported by their organisation and management, respectively. On the other hand, the scope and boundaries of the strategy process need to be defined as well as the laws and directives relevant to the organisation during a pandemic need to be evaluated.

4.1.4.1 Organizational Conditions

In the initial phase to start off the strategy process, the organisational aspects need to be defined. Fore and foremost, this includes the definition or identification of the relevant stakeholders that are involved in the process. The hierarchical level and the background of these stakeholders can differ depending on whether the process is implemented for an individual organisation or within a municipality, regional or national governmental organisation. In more detail, the stakeholders can include the crisis manager or the managing board of an organisation such as a CI, the crisis managers of a regional or national governmental body as well as high-level politicians and decision makers on a national or even supra-national level. To know exactly who the stakeholders are is of crucial importance since the results of any following step will be communicated to them and this needs to be done in a way and in the language of these stakeholders, i.e., keeping their requirements in mind.

Furthermore, the organisational aspects also include the group of people implementing and carrying out the strategy process within any organisation, e.g., the crisis management team. In that context, it is important to have a well-defined team with clearly stated duties and responsibilities to avoid any conflicts with other processes running in parallel within the organisation. In addition to that, resources also need to be defined and communicated such that the crisis management team does have the necessary time, personnel efforts, and budget available to implement the strategy process.

4.1.4.2 Structural Conditions

As a next part of the General Conditions, the scope and boundaries of the strategy process need to be clearly defined. This has to be done with regards to the competences and restrictions of the organisation implementing the strategy process. Here, the process is designed such that it can be enacted on different levels, i.e., by an individual organisation such as a critical infrastructure, by a municipality or any other regional governmental organisation or also by a governmental body on a national scale. Accordingly, the scope of the process can include only the systems, people and processes running with a critical infrastructure, or it includes all the relevant organisations (e.g., CIs but also others) within a city or a region, or it covers all relevant infrastructures, organisations, and aspects on a national scale. It has to be noted that, the more organisations are in the scope of the process, i.e., the higher the process is set on a governmental or political scale, the higher also the level of abstraction will be, i.e., it might not be possible to capture technical details of individual organisations, but organisations might need to be treated as single entities.

In addition to the scope and boundaries of the process, it is necessary to agree and set the basic criteria for the evaluation that are done throughout the process. In detail, the crisis management team together with the stakeholder need to agree on how the two main aspects of the strategy process, the risk, and the resilience for individual critical entities and – depending on the scope – also for all entities within a city, region or nation can be defined and measured. Although many of the organisations involved in the strategy process already have their own interpretation of risk and resilience, this part becomes particularly challenging when this needs to be defined for several organisations, maybe even from different sectors. Additionally, one specific goal of the strategy process is to bring together different points of view to enable decision making on holistic information. Therefore, the analysis of the consequences in the different areas (e.g., health, infrastructure, economy, society) results in different indicators that need to be aligned to get a concise estimation of the risk stemming from a specific pandemic scenario as well as the resilience of the organisations and the society due to that pandemic scenario.

4.1.4.3 Legal Conditions

Since the evaluation of a pandemic together with the implementation of possible preventive, protective or mitigative measures usually also involves regulations and laws, getting an overview on the legal framework is an important part of the General Conditions as well. In general, all organisations and people involved in the strategy process should be aware of the current legal framework. However, in the context of a crisis such as a pandemic, some aspects might change due to specific directives and regulations that are issued in an emergency situation (as it has been the case during the COVID-19 pandemic). Based on the scope in which the strategy process should operate, the situation regarding the current legal framework can be different with respect to how much the individual entities might influence the framework.

In other words, on the level of an individual organisation, e.g., a CI, the set of laws and regulations is quite fixed and usually well-defined based on current legislation. On the level of a municipality or regional governmental organisation, the current legislation will be the same; however, it could be seen as a bit more flexible since these bodies might have the possibility to update or change regulations in a crisis. The highest flexibility is given on a national level, where not only existing laws and regulations can be adapted but new directives and regulations can be issued (not necessarily directly by the team running the strategy process but maybe by the stakeholders that are using the outcomes of the process as a support for their decision making). Hence, the legal framework also influences the preventive, protective and mitigative actions that can be set during the strategy process.

4.2 Assessing the Pandemic

As the details of the pandemic are at the heart of the entire strategy process, the second step of the process covers the collection of information and data on the pandemic. This includes the relevant information on the pathogen and its characteristics together with details on how it is spreading. Depending on where the SUNRISE Strategy Process is implemented, i.e., in which organisation, or on which management level it is implemented, i.e., what is the focus of the decision makers, detailed medical information might not be required but a high-level overview on the main aspects of the pandemic could be sufficient.

4.2.1 Identify the Pathogen

In order to identify a new virus or pathogen as it is emerging and starting to circulate in the human population, it is important to have a network of monitoring systems at hand. Such systems provide an overview on illnesses in the population, can analyse the pathogens and collect relevant data on the characteristics of these pathogens. Further such monitoring systems can be used to identify cyclic phases of epidemics or pandemics. A very popular example is the Global Influenza Program [24] powered by the World Health Organisation (WHO) and installed in most of the nations across the globe. Therein, data on influenza and other respiratory viruses (influenza-like illnesses) are collected on a national level and brought together on a global scale. This provides an overview on the current influenza season, helps to identify peaks on a national and trans-national scale and supports the identification of upcoming influenza strains to prepare vaccines. For the EU and other European countries, the European Centre for Disease Prevention and Control (ECDC) [25] is maintaining European Influenza Surveillance Network (EISN) [26] that is based on reports from the national sentinel influenza surveillance systems installed in the respective countries.

4.2.2 Analyse the Pathogen's Characteristics

For most of the epidemics and pandemics that are known and are monitored by various surveillance systems, their characteristics are rather well-known, and it is easy to define different potential scenarios for these pandemics. However, once a new virus or pathogen has been identified, it is necessary to analyse its characteristics to be able to describe the possible effects the pandemic might have on the population. Therefore, several characteristics and indicators are evaluated such as the transmissibility, exposure, seriousness of disease, case fatality rate (CFR) or the general impact on society. In more detail, the transmissibility indicates how easy a virus can move from one infected person to another. Different ways of transmission are known, e.g., over the air, food, water, or a vector, i.e., an animal (cf. also Section 3.1 for a detailed definition) and these also influence the dynamics of a pandemic and exposure of people. In connection to the transmissibility, the exposure of people is also a core indicator as it also characterizes the incubation period, i.e., the time it takes until a person shows symptoms after being exposed to the pathogen. When a person falls ill, the seriousness of disease indicates the state in which a person gets sick after being infected. This usually covers a classification of "mild", "moderate" and "severe" and can be accompanied with detailed clinical symptoms. Usually, a pathogen affects some parts of the population more than other, e.g., during the COVID-19 pandemic, older people had a higher chance of dying after an infection. The CFR is also an important characteristic of a pandemic as it describes the severity of the disease in terms of lethality, i.e., it is the ratio of people who have been diagnosed with the disease and in the end die because of it. At last, another indicator is the impact on society. This indicator already considers the measure that are implemented, mostly the Non-Pharmaceutical Interventions (NPIs), and their effects on the society. As it has been evident from the COVID-19 pandemic, the NPIs such as closure of schools or entire lockdowns had a significant impact on day-to-day business as well as on social life and thus on the whole society. In particular when dealing with a new pathogen, these characteristics might not be known in the beginning and have to be reevaluated over time to get to a good estimation.

4.2.3 Define Possible Scenarios

With the detailed information on the pathogen and its characteristics, the effects of an epidemic or pandemic on the population and on society can be described. However, since the pathogen does not affect all parts of the population equally and the transmission paths are more amplified in some areas or situations than others, it is important to define a set of scenarios that describe different conditions in which people are exposed to the pathogen. These scenarios should cover a time frame for the events of the pandemic (e.g., in Summer or Winter or, in case a short-term analysis is required, the next two or three weeks), a location where the pandemic takes place (e.g., in a metropolitan or rural area), and whether there are already some protective measures in place. In such a scenario, the spreading of the pandemic can be analysed based on the characteristics collected in the previous step (cf. Section 4.2.2) and the effects on the population, the society or the economy can be assessed. To achieve that, different analytical tools are required, e.g., a simulation for the disease spreading or an economic analysis to capture the financial implications, because the effects an epidemic or pandemic might have on the population and the society can only be assessed by analysing the impacts and consequences in several different areas (e.g., on people, infrastructures or the economy, cf. Section 4.4 for further details) according to these scenarios. Afterwards, the overall risk and resilience of the population and the society can be assessed by bringing together the results from the individual scenarios (cf. Section 4.5).

4.3 Analysing the Potential Consequences

After the details about the pandemic are collected, it is relevant to identify the potential consequences. In that context, the strategy aims to capture a variety of areas that can be affected by the pandemic. This covers the parts of the population that are influenced the most by the pathogen (which can be directly related to the characteristics defined in Section 4.2.2). Another perspective is focusing on the PSCEs that are directly or indirectly affected by the pandemic. Additionally, the economic consequences (i.e., effects on the economy on a regional or national level) need to be analysed.

4.3.1 Analyse the Potential Effects on the Population

In any epidemic or pandemic, vulnerable populations will have to be particularly considered. Hardly any pathogen will target each person equally, but specific population groups will be more prone to either exposure, infection or severe course of diseases. To understand and be able to quickly mitigate consequences for these population groups, sustainable and effective research infrastructures monitoring and assessing pathogen emergence are crucial [27]. Hence, the first dimension of the consequence analysis needs to cover these immediate effects on the population. This is usually done by epidemiological models that provide an estimation and a prognosis on the number of people that will be infected, that will need some medication and either can stay at home or need to go to the hospital. In the hospital, it can be further distinguished between the patients that need some medical treatment and the ones that need to go to the intensive care units (ICU). In the end, the epidemiological models also provide an estimation on the deaths due to a pandemic.

In many regions in Europe, these research infrastructure for infectious disease medicine and epidemiology are now being built up. In particular, networks of dynamic modelling groups and of population-based research are essential in this context and have shown to be able to provide relevant benefit in the targeting of measures [28], [29]. Both need to be well connected to relevant public health agencies and institutes. Relevant examples of such networks include the European COVID-19 Forecast Hub [22] as well as the German Modelling Network for Severe Infectious Diseases (MONID) [23]. Throughout different epidemic phases, estimations and information from these groups are an important source for decision makers on where and for which groups to plan and implement measures and interventions. The main challenge is to integrate this information into consistent and comprehensible estimation on the consequences for the general health of the population. In detail, it needs to be decided which indicators weigh more, i.e., is the number of deceased more important compared to the patients going to the ICU, and the hospital.

For the functioning of CIs (including research CIs) the knowledge who is vulnerable, who is contributing most to the transmission of a pathogen and how to mitigate consequences for both groups is very relevant and can be directly translated into action. For example, early in the planning of making CIs resilient to pandemics, this needs to be considered in building redundancies among critical workers. If critical workers are made up mainly of the same demographic groups that will put functioning of this infrastructure in danger if that demographic group becomes vulnerable.

In this context, the strategy is focusing on the identification of these vulnerable groups and an estimation of the number of affected people within them, as these numbers will go as an input value into the other consequence analyses, e.g., when the number of people that need to stay at home or need to go to the hospital influence the available critical workers or when a high number of ICU patients or deaths has a strong influence of the social well-being in general.

4.3.2 Analyse the Potential Effects on the PSCEs

In most cases, a pandemic might not directly affect organisations or critical entities in the same way as it affects people. However, critical entities are affected in a transitive way, i.e., when their employees are affected by the pandemic. For example, when a lot of people are ill and need to stay at home or even in the hospital for a longer period of time, this has an influence on the available work force in companies and organisations. In particular, if these people are working in critical infrastructures and the overall productivity could be reduced or some services might not be available anymore. An obvious example for a sector that is heavily affected by a pandemic is the health sector. Not only can nurses, doctors and other personnel in a hospital become ill but also the workload will increase due to a pandemic.

Another way how PSCEs can be affected by a pandemic is due to the fact that people might not be able or do not want to use the service provided by the PSCEs and thus these organisations are losing customers and, consequently, some parts of their revenue. As these services usually are (per definition) essential to the society, people might not have the choice to use them. However, people might use a service in a different way, e.g., more food delivery than going into shops, or the service is only used by a much smaller percentage of people, e.g., people are leaning more towards individual transportation that public transportation. All of this can influence the organisation's revenue and cash flow and thus, in case these effects are long-lasting, the economic situation of the organisation (see also the next Section 4.3.3).

As a third part, a pandemic can have even more indirect and complex effects on PSCEs and other organisations based on the measures that are taken to counter the pandemic. Depending on the severity of the pandemic, drastic measures need to be taken, such as the closing of different shops, complete lockdowns, or the closing of borders. Such measures can have a huge effect on the daily routines and thus on the services provided by PSCEs and other organisations.

Taking all that into account, it is obvious that describing and analysing the consequences of a pandemic on the PSCEs can be complex but is of high importance to make predictions on the economic and societal effects (see Section 4.3.3 and Section 4.3.4). Due to the complexity and the lack of information and data from the PSCEs, a very detailed analysis might not be possible. Therefore, the strategy focuses on capturing a more generic "Level of Operation" for the PSCEs, which indicates how severely affected an entity is by the pandemic. Although this is just an abstract estimation, it can help to analyse the consequent effects on the economy and the society (see Section 4.3.3 and Section 4.3.4).

4.3.3 Analyse the Potential Effects on Economy

Similarly to the PSCEs, the economy in general will not be directly affected by the pandemic; rather, the cascading effects stemming from the lack of employees or customers as well as from potentially severe countermeasures will have an effect on the economy. In particular, these countermeasures that are implemented to contain the pandemic pose heavy influence on the economy. These measures can have wide-ranging effects on the economy by limiting or shutting down individual services or entire sectors as well as national or international commerce and trade agreements. Accordingly, these effects are very complex to identify and measure and need to take macro-economic indicators into account, as it is not possible to generate a detailed model of all companies and organisations within a region or on a national scale.

Nevertheless, the analysis of the effects on the economy can directly build upon the results of the effects on the PSCEs (see Section 4.3.2), i.e., on their abstract level of operation. In general, the more the level of operation of the PSCEs decreases, the higher the effect on the economy will be. This can be directly translated to companies and organisations other than the PSCEs. If these organisations are lacking workforce, customers or have to close down for some time due to a lockdown or similar measures, their level of operation also degrades, which has a negative implication on the economy. Furthermore, economic, and epidemiological assessments also need to go hand in hand to understand which measures and interventions are required. Thus, a relevant understanding and collaboration between these two groups is necessary.

4.3.4 Analyse the Potential Effects on Society

A fourth dimension of consequences that needs to be taken into account are the potential effects on the society as a whole. Although a pandemic (depending on the severity of the pathogen and its health impacts) as an isolated event can already influence the well-being of society, the combination with cascading effects, countermeasures and economic implications can have an even higher impact.

Compared to the other dimensions previously described here, the consequences on the society are the softest and thus might be the most complex to measure. The effects on the health of the population will have an influence as well as the impacts on the critical services and PSCEs and on the economy. Therefore, the analysis can build upon the results from the previous steps; however, there might not be a direct connection, but additional influences also need to be taken into account. This includes, for example, how classical and social media are covering the pandemic or how regional or national government communicates decisions in the context of the pandemic.

4.4 Evaluating the Available Measures

With the consequences being analysed, the next step involves the identification and evaluation of possible countermeasures to prevent of, protect against or mitigate from the pandemic in the focus of the analysis. Therefore, countermeasures from different areas are covered, including the health sector (i.e., measures involving medicine or vaccination acting directly in the infection), non-pharmaceutical interventions (i.e., activities and regulations in society to reduce the large-scale spreading of the pathogen), economic measures (i.e., monetary support for organisations that are fighting the pandemic or that are affected by it) as well as legal and political measures (i.e., regulations or directives granting special benefits or advantages to organisations that are fighting the pandemic or that are affected by it).

4.4.1 Identify and Evaluate the Available Protective Health Measures

The first set of measures to directly combat a pandemic can be found in the health domain. These measures are focusing on protecting against the infection with the pathogen in the first place or to reduce the consequences for a patient once they are infected. There is a broad variety of such measures, e.g., using of protective gear, in particular when dealing with or treating infected patients in hospitals, or avoiding the way of transmission, e.g., by keeping a safe distance or not using contaminated water, to reduce the likelihood of getting infected. Additionally, medication and vaccination are used once a person is infected to alleviate symptoms, fight the pathogen or to prepare and strengthen the immune system. The detailed measures can vary depending on the pandemic and the way of transmission of the pathogen.

4.4.2 Identify and Evaluate the Available Non-pharmaceutical Interventions

Besides the purely medical countermeasures, non-pharmaceutical interventions (NPIs) can also be used to reduce the spreading of a disease. These are measures that people individually and communities as a whole can take to slow down the spreading of a pathogen. NPIs for respiratory infectious diseases are organized into three levels - individual, environmental, and population [30]. During the COVID-19 pandemic, NPIs have shown to be a vital set of tools for governments and populations in reducing the spread of the virus.

Regarding mostly droplet-based transmission, physical distancing (1 to 2 meters), respiratory hygiene, and hand hygiene are measures for reducing the transmission of pathogens from an individual perspective. Personal Protective Equipment (PPE), e.g., face masks, respirators, and goggles, as well as environmental measures, e.g., 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 hospitalization, 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.

4.4.3 Identify and Evaluate the Available Economic Measures

Whereas protective measures from the health domain and NPIs mainly focus on preventing or slowing down the spreading of the pathogen, additional measures need to be considered to address the economic effects of a pandemic. Such measures have the goal to support PSCEs or, in general, any organisation that is directly affected by the pandemic or by the (non-pharmaceutical) measures taken to contain the pandemic. In detail, if a large part of the critical workers within an organisation needs to stay home due to infection or quarantine, this can affect the productivity of the organisation and, in the ultimate consequence, and lead to financial losses. Similarly, if the core business of an organisation is affected by the pandemic or the organisation is closed as a protective measure, this also results in a reduction of the turnover or profit. In this situation, economic measures such as financial support or infusion of capital by a governmental body might help the affected organisation to maintain their financial stability and thus increase their resilience.

4.4.4 Identify and Evaluate the Enabling Legal Measures

Most of the countermeasures discussed above need to have a respective legal framework that goes along with them. In particular, this accounts for NPIs focusing on groups of people or the community as well as economic measures where organisations receive funding to cover for losses due to the pandemic. To implement such measures, specific directives and laws need to be designed and brought into force. However, if such directives or laws are not prepared in advance, it can be difficult to compile them during a crisis due to the lack of time of availability of experts. Additionally, legal, and governmental processes need to be followed to put them into force, which also need to be prepared to work in such a crisis situation. Taking into account the set of measures that are identified in the steps described in Section 4.4.1, Section 4.4.2 and Section 4.4.3, the legal requirements to bring them into force can be identified right away and the legal framework can be already prepared at this point.

4.5 Evaluating the Risk and Resilience

Given the set of available countermeasures from the previous step, the final step of the SUNRISE Strategy Process focuses on the effectiveness of the individual measures. This is done by considering the consequences of the pandemic according to the different categories defined in Step 3 (Section 4.3) and integrating that into a resilience level for one individual organisation or a network of organisations. This is done first without any measures implemented (i.e., providing a baseline) and then with any set of countermeasures in place. In this way, the improvement (or deterioration) gained by the measures from the various areas is assessed. By considering various impact categories, a more holistic view is provided compared to the evaluation of only one singe aspect. This also represents the main outcome of the process and serves as an input to any further decision process.

4.5.1 Assess the Current Risk and Resilience Level

As a first part, the results from the previous step on analysing the consequences need to be integrated into a concise representation of the current risk level of the respective scenarios. Therefore, the results from the analyses on the potential effects on the population, on the PSCEs, on the economy as a whole and on the society for one specific scenario need to be combined. One of the main challenges here is that the various outcomes from the analyses are describing the consequences according to different dimensions, for example, the epidemiological modelling is focusing on the effects on the population, i.e., infected people, patients on the ICU or deaths, the effects, and the consequences from the economic modelling are described in monetary values. Harmonizing these dimensions needs a coordinated approach that can take the different dimensions into account. The goal is to condense the different dimensions into one number that in the end summarises the overall consequences in the different dimensions. In general, it is not necessary to represent the various consequences by a single number; however, it is beneficial since the overall consequences of one scenario will mostly be used as input for a (two-dimensional) risk matrix bringing them into relation to the likelihood of that scenario.

According to the risk level, also a resilience level needs to be estimated at this stage. The general notion of resilience with regards to PSCEs has been described in Section 3.5; however, the resilience of parts of the population or the whole society is rather difficult to assess. Hence, some high-level indicators will be used to capture an estimation of the resilience level of these aspects. Additionally, the resilience of the PSCEs and the population needs to be considered over time, whereas the risk can be understood as a snapshot at a certain point of time. Therefore, the indicators compiling the estimation of the resilience level are extrapolated to several points into the future using different simulation models (see also Section 5.4 for details on possible simulation models). In the end, the results for the current risk level and resilience level are combined and treated equally to obtain a more comprehensive and precise overview on the current situation.

4.5.2 Assess the Potential Risk and Resilience Level

Once a set of available measures is identified for a specific scenario, their positive effects can be integrated into the estimation of the risk and resilience level. Therefore, the consequence analyses according to the four different dimensions in Step 3 (cf. Section 4.3) need to be reiterated with the new parameters given by the implementation of the measures, implementing a type of "what-if" analysis. As described in the previous section, the various types of measures have different implications on the pandemic and its consequences. For example, the protective health measures aim at reducing the transmissions and infections of people with the pathogen; hence, these measures will directly affect the effects on the population, i.e., the number of infected, ICU patients and deaths. Further, the economic measures have the goal to minimize the financial burden for companies and organisations that might be affected by the pandemic or by other circumstances (e.g., a lockdown); hence, these measures will directly affect the economy and the monetary consequences (in this way, either positively or negatively). Similarly to the consequences, also the resilience needs to be re-calculated with the available measure in place. Since the resilience indicators are directly related to the different dimensions of consequences, the new resilience can computed based on the simulation results gathered for the risk level.

When the individual consequences based on all different dimensions are evaluated and integrated into the overall consequence score (see above), a new risk level for the scenario can be computed together with the already captured likelihood of that scenario. In the same way, the resilience indicators are integrated into a new resilience level for the given scenario. This re-analysis and re-calculation of the risk level and resilience level can be done for each available measure individually or for combinations of them. In this way, it is possible to identify the best combination of measures, i.e., this combination that reduces the risk level the most and, at the same time, increases the resilience level. Since consequences from various dimensions are captured in the risk and resilience level, the identified measures will not be overly emphasising one of these dimensions but provide a holistic view on which measures to take.

5 Strategy Process Implementation

This section will provide an overview on potential concepts, methodologies and tools that can be used to implement the various steps of the SUNRISE Strategy Process described in the Section 4. They should support the understanding of the general concepts of the strategy process and give some guidance, which already existing methodologies and tools could be used in the process.

5.1 Workshops for Identifying Stakeholders, Relations and Data Sources

A core aspect of the initial phase "Establishing the Context" of the SUNRISE Strategy Process is to gather necessary information on the relevant stakeholders, the relations, and dependencies among them and on available data sources to be integrated into the process. Although some of this can be done using desk research, the best way to gather information is to involve experts from the CIs and PSCEs of the region where the strategy process is implemented. Whereas desk research can provide a high-level overview on the established processes and interrelations between organisations, a series of workshops with employees from different organisations allow for more detailed insights into these organisations. For example, these workshops can provide knowledge on how particular processes are really implemented and carried out in the day-to-day business or can reveal implicit dependencies among organisations as well as between people that are not documented anywhere. However, such workshops need to be planned in sufficient detail and apply proper methodologies that are tailored to the setting and the participants.

From a methodological point of view, two approaches have been shown to be successful when bringing together CI operators and experts from different domains: the World Café Method [31] and moderated discussion groups. The World Cafe Method is organized around a set of small groups, either tables in a physical setting or break-out session in an online setting, with a small number of participants in each table. Additionally, one facilitator is required for each group to pose questions and lead the discussion; one person to take notes can also be helpful but is not required. Questions are posed by the facilitator for each group to maintain a conversation. Once a predefined amount of time is over, each participant moves to a different group, while the facilitator and the minute-taker stay with one topic. After all participants had the chance to discuss on all topics or in all groups, the participants are invited to share insights or other results with all the other participants. The results are usually reflected visually, most often using graphic recording in the front of the room.

In addition to the World Café, the 5-D format can also be applied to have the discussion in each group structured in a similar way. This helps to guide the discussion among the participants a bit and to make sure no important parts are missed. The 5-D format is based on the appreciative inquiry theory, taking the participants through the steps of [32]:

- *Defining the topic*, i.e., clarifying the area of interest to be considered in the group. Main question: "What needs to be achieved?"
- *Discovering best practices*, i.e., talking about success stories and strengths from the past. Main Questions: "What are the strategies that have worked?"
- *Dreaming the preferred future*, i.e., describing the expected future in a given time frame (in 6, 12, 24 or 36 months) in an ideal setting. Main question: "What could the future look like if we succeed in improving?"
- *Designing the required activities*, i.e., identifying the precise steps and activities that need to be taken to realize the dreaming from the previous step, including initiatives, prototypes, projects, meetings and so on. Main question: "What should be done?"
- *Developing an implementation plan*, i.e., putting the design initiatives into practice such that a real difference can be made, and the progress and results can be measured. Main question: "What needs to be done?"

In case a bigger and/or more diverse group is involved in the workshop, the World Café might be too extensive and take too much time to be fully carried out. Hence, moderated discussion groups are a better way to gather the participant's views and opinions on a series of discussion topics. Similar to the World Café, several discussion topics are defined, and the participants are divided into usually larger groups for one topic. Each group has a moderator (equal to the facilitator in the World Café) who leads the discussion in the group, usually by having a list of prepared questions or opinions. The participants in the group discuss these questions and share their expertise and opinions on it. In this way, the moderated discussion groups are less creative and explorative than the World Café, since many of the topics or statements are prepared beforehand. After a certain amount of time, the participants might be able to switch groups to discuss also on other topics; however, usually not every participant will be able to discuss each topic, but they would have to decide on one or two topics in the beginning. Hence, at the end of the session, the results from the discussion do not reflect the opinion and inputs from all participants.

For both methodologies, the World Café and the moderated discussion, the preparation before the workshop, the introduction to the workshop and the summary of results at the end of the workshop are central aspects to guarantee the success. During the preparation of any type of workshop, it is important to specify the main topics that need to be discussed early on. Based on these topics, the best methodology needs to be chosen to be carried out during the workshop (of course, there are several other creative techniques that can be used). Further, also the participants are chosen based on the topics since the people with the most experience and the highest expertise should participate; the list of participants also determines whether the workshop can take place in a physical format or needs to be carried out online (which again influences the methodology used in the workshop).

In the beginning of the workshop, an introduction to the main topic is essential to set the scene for all participants and to bring all of them to the same level of knowledge. Further, also the main goals of the workshop and even of the processes behind it need to be highlighted. This will help the participants to focus on the relevant aspects during the rounds of discussion. It is equally important to have a closing session where the results of the individual discussion rounds are presented (this is usually done by the facilitators or moderators of the individual groups). At this point, it could be beneficial to open the plenum again for final thoughts or comments by the participants, especially in case not everybody had the chance to discuss on each topic (as, for example, in the moderated discussion setting). Finally, the participants need to be kept informed on what will be happening with their inputs and whether they will have the chance to hear about or see the results of the later stages; the next steps should be highlighted at this point.

As part of the SUNRISE project, several workshops have already been carried out (cf. Deliverables D1.1 and D1.2 for details on them), either bringing together CI operators from a region in a national setting or involving cross-border CI operators in an international setting. In detail, two rounds of national workshops have been organised so far, bringing together CI operators and experts from each of the demo regions (Slovenia, Italy, and Spain). These workshops were using the World Café Method and were held in a physical setting and in the local language to make it easier for participants to share their ideas without the need to switch to English. An overview on the second workshop can be found as a detailed exampled in Annex I. Additionally, one international workshop was organised so far that brought together CI operators and experts from all over Europe (with a focus on the demo regions from the SUNRISE project). This workshop was carried out in an online format and used moderated discussion groups due to the larger number of participants. The focus was laid on cross-border topics, such as dependencies and international cooperation among infrastructures and organisations from different countries.

Similar workshops are also planned for the next months of the SUNRISE project; their results will be used to improve and validate the SUNRISE Strategy and thus they will be reflected in the second version of this deliverable.

5.2 Decision Framework for Identifying PSCEs

Pandemic-specific critical entities (PSCEs) provide essential goods and services that are vital to a functioning society during a pandemic, such as health or energy organizations. Moreover, the disruption of such entities could have cascading effects, which might lead to devastating consequences. In general, there are various ways in which entities or organizations could be impacted during a pandemic. For example, entities could be affected directly due to a reduced workforce caused by increased illness or indirectly by supply chain disruptions. Thus, it is necessary to have a process that allows for the quick identification of pandemic-specific critical entities to take proactive measures and minimize this pandemic's societal and economic impacts. However, developing such an identification process presents many difficulties since various potential scenarios exist in which different organizations will be considered as a PSCE. For example, the identification of PSCEs might depend on the transmission route of the infection. Besides, other factors, such as the density of today's supply chains, also make it difficult to predict organizations' dependencies correctly. Subsequently, it is necessary to account for a plentitude of factors to develop a suitable identification process, which this section aims to accomplish.

5.2.1 Criteria

In order to characterize an entity as critical in the context of a specific pandemic, distinct criteria are required to obtain a comprehensive picture of the pandemic, the examined organization and its environment. A first criterium is the transmission method of the pathogen causing the pandemic. The transmission method indicates how an entity is impacted by the pandemic. A second criterium is the entity’s resilience towards the pandemic, i.e., how resilient the entity’s operations or functionality is in the context of the pandemic and whether that entity can implement measures to mitigate the pandemic’s impact. A third criterium is whether an entity is already considered critical (or “essential” or “important, respectively) according to the NIS2 Directive or the CER Directive. In case the entity is not considered critical, its importance from a supply chain perspective or for the region where it is located in needs to be considered as well. Hence, the fourth criterium is whether the entity is an important supplier for a critical (or essential or important) entity on a regional or national level (as defined in Section 3.3). To sum it up, PSCEs can be identified according to these four criteria:

1. Impact by the Transmission Method
2. Operational Resilience of the Entity
3. General Criticality of the Entity
4. Importance for Critical Supply Chains

5.2.1.1 Impact by the Transmission Method

As discussed in Section 3.1, an infectious disease can spread via various transmission methods, such as airborne transmission, physical contact, blood and blood products, food, water, or others. Based on the transmission method, people and organizations will be affected differently by the effects of a pandemic as there will be a difference in the exposure to the pathogen. Therefore, it is important to consider the transmission method of a pathogen to determine whether an organization and its employees might be exposed to the pathogen in their daily business. Thus, considering the transmission methods provides an indication on how much a specific pandemic impacts an entity.

In order to give an example, if a pathogen is transmitted over the air, several sectors like the financial sector might be less impacted in their operation since it is easier for employees to work remotely. This would be different for other sectors where employees need to be on premise or are providing specific services to other people, such as in food production or in the health sector. However, if the pathogen spreads via food or water transmission, organizations and people in the financial sector and the health sector might have the same exposure to the pathogen but people and organizations in food production might be more severely affected.

In general, people and organizations in the health sector will be most likely highly affected in all pandemic scenarios, i.e., considering any transmission method, and thus will be considered as PSCEs due to the fact that they are the first to provide protection, prevention and mitigation measures for people that get infected and fall ill.

5.2.1.2 Operational Resilience of the Entity

Once the organization is aware that its employees are at risk of becoming infected as part of their daily work routines, the next aspect would be to assess, how resilient the organization is when a respective part of their work force is not available anymore. In other words, it has to be assessed how much the operational or functional capacity is reduced and for how long it would take to get back to an (almost) normal operation. In this context, it also needs to be identified if there were mitigation actions that would help to reduce these effects, e.g., reduce the risk of infection or to maintain the operational capacity with fewer people. Additionally, it is essential to figure out if those mitigation actions allow the organization to remain fully operational or if those mitigation tactics prevent business continuity. Thus, this step is required to estimate further a specific pandemic's impact on an entity or organization.

Continuing the example form above, if we are considering an airborne transmission method, the chance for an infection could be reduced by wearing protective gear (e.g., masks, etc.). In this way, the daily business in the financial sector or the food production could be maintained. However, if there is a minimum number of employees required to keep production lines operational, wide-ranging infections could reduce the operational capacity of an organization in the food sector; a similar argument hold for the number of people required to keep a control room in the transportation sector (e.g., for trains, undergrounds or airplanes) operational. In this way, the people in the financial sector and the transportation sector might have the same exposure and means of protection, but the transportation sector could be more severely affected.

5.2.1.3 General Criticality of the Entity

After it is evaluated if (and to which degree) the pandemic is affecting an entity, it is necessary to determine its criticality. As already pointed out in Section 3.3, the concept of criticality is strongly related to the definition in the NIS2 Directive and the CER Directive, respectively. Therein, a list of sectors is defined, such as energy, ICT, transport, wastewater or others, and entities within these sectors that fulfill certain criteria (which are individually specified by the Member States) are defined as critical (or essential or important, respectively). In other words, if an entity is characterized as critical, it operates in a vital sector and plays an important role in maintaining the crucial functions of society. All these entities can, in principle, also be considered critical in the course of a pandemic. However, depending on the characteristics of the pandemic and the respective pathogen, some entities might be more critical than others.

Considering the financial, food or health sector as in the examples before, many of the large organizations therein, e.g., a bank, a dairy factory, or a hospital, might be characterized as critical according to the NIS2- and CER Directive and the threshold values defined in the individual Member State where the bank, dairy factory or hospital is located. Accordingly, these organizations would then also be critical in the context of a pandemic; on the contrary, some smaller organizations might not fall into this classification.

5.2.1.4 Importance for Critical Supply Chains

The last step of the identification process is targeted towards those entities that are not characterized as critical (or essential or important, respectively) according to the NIS2 and CER Directive because they are too small and are below the official threshold to be characterized as critical themselves. However, these entities also need to be considered in case they do have a significant role in the supply chain for one of those critical entities. Significant in this context can be understood such that the critical entity's operational capacity is reduced if the smaller entity is not available any more or also has to reduce its capacity, e.g., due to the impacts of the pandemic.

Following along with the examples from above, an organization in the health sector that is providing sterilization services for surgical instruments might be too small to be considered as critical entity according to the NIS2 or CER Directive. However, if this organization is significant for big hospital, e.g., since it carries out all the sterilization services for that hospital, it should also be considered as PSCE.

5.2.2 Decision Process

Based on the criteria defined above, a decision process is designed which helps to decide whether a given entity is considered a PSCE. This decision process is kept simple and therefore only involves four questions, one for each criterion. As several answers are possible, each answer (and accordingly each path in the decision process) has a specific score, i.e., a weight attached to that answer. The most important criterion is the general criticality of an entity, because if an entity has a high relevance for society, this entity most probably will also have a high priority during a pandemic. The second most significant criterion is the entity's operational resilience, since a highly resilient entity will also be able to cope with a pandemic and will have a lower priority compared to other entities. The questions together with the scores of the answers are given in Table 1.

Table 1: Overview on questions from the decision process and their scoring

Criteria	Questions	Scoring
Impact by the Transmission Method	▪ Is the entity impacted by the transmission method?	▪ Low: 10 Points ▪ Medium: 15 Points ▪ High: 20 Points
Operational Resilience of the Entity	▪ Is the entity resilient against the effects of the pandemic?	▪ High: 10 Points ▪ Medium: 20 Points ▪ Low: 35 Points
General Criticality of the Entity	▪ Is the entity classified as critical, essential, or important?	▪ Important: 30 Points ▪ Essential: 45 Points ▪ Critical: 45 Points
Importance for Critical Supply Chains	▪ Is the entity significant for a critical supply chain?	▪ Yes: 15 Points

The first question covers the different transmission methods and how much an entity is impacted by the respective method. The answer can be either “Low”, “Medium” or “High”; a water- or foodborne pathogen might have low impact on an entity in the financial sector whereas an airborne pathogen will have a medium to high impact. In case there is no impact of the transmission method on the entity, the decision process can be terminated, and the entity is not considered a PSCE.

The second question deals with the entity's resilience in the pandemic situation and depends on whether mitigation actions can be implemented to keep the entity operational. Also, there are three possible answers, i.e., “High”, “Medium” and “Low”; if the entity's resilience is low, this would implicate that it is not well-prepared, and the pandemic will have a strong effect on the entity.

The third question addresses the criticality of the entity and therefore refers to concepts defined in the NIS2 and CER Directive. Since entities that are classified “important” according to NIS2 are considered less critical than “essential” entities, this is also reflected in a lower score. In case the entity is not classified in either of the categories, the fourth question determines whether the entity is significant for a critical supply chain, i.e., it is supplier for a critical entity (or an essential or important entity, respectively). If the answer is yes, the score is lower compared to an entity that is officially classified as "important". Figure 2 visualizes the decision process with all questions, answers, and their respective score.

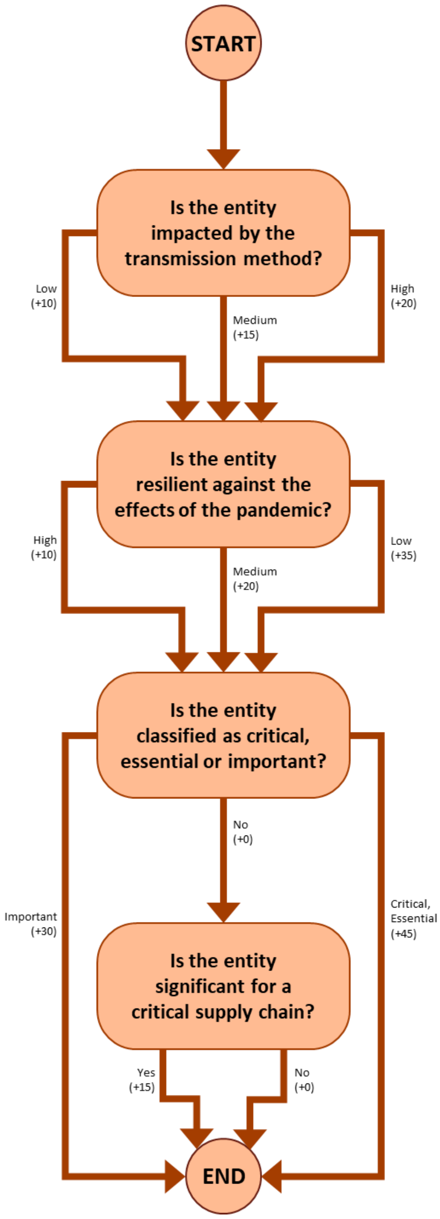


Figure 2: Decision process for identifying PSCEs.

Following the process, it is easy to see that several scores between 0 and 100 are possible such that there will be no clear decision on whether an entity is a PSCE. Rather, a distinction can be made among entities that do not qualify as PSCE, entities that would need special consideration, entities that can be qualified as PSCEs and, among them, entities that can be understood as high-priority PSCEs (see Table 2 for details).

Table 2: Characterization of PSCEs according to their score

	Entity does not qualify as PSCE	Entity needs special consideration	Entity qualifies as PSCE	Entity is a high-priority PSCE
Score	0 – 35 points	36 – 60 points	61 – 75 points	76 – 100 points

As a result, an entity that is neither classified as critical (or essential or important, respectively) and is not part of a critical supply chain is most likely not qualified as PSCE. However, an entity that is fairly impacted by the transmission method and is operationally not sufficient resilient would need a further inspection and might be considered as PSCE in a certain situation. Moreover, an entity that is strongly impacted by the transmission method, has a medium to low resilience against the effects of the pandemic and is either critical (or essential or important, respectively) or part of a critical supply chain will be considered as PSCE according to the decision process and scoring scheme. The stronger the impact and the lower the entity's resilience, the higher the priority of the PSCE gets, i.e., indicating that such a PSCE requires a strong protection or immediate mitigation action.

5.3 International Frameworks for Assessing a Pandemic

Once a novel respiratory virus has emerged and started circulating in human populations, the severity of and the risk posed by the epidemic/pandemic can be assessed on different levels. Pandemic severity assessments provide information to determine the timing, scale, and intensity of pandemics and to support decisions on the urgency of pandemic response actions and on implementing and lifting control measures. Several tools were developed by responsible organizations to guide the assessment process at different levels (regional, national, global) such as PISA [33], PIRM [34], TIPRA [35], Rapid Risk Assessment of Acute Public Health Events [36], IRAT [37], PSAF [38], and others.

WHO pandemic phases are based on virologic, epidemiologic, and clinical data. WHO uses the phases to describe evolving situations about the circulation of novel influenza viruses. WHO strongly advises countries to use local circumstances and information to develop their national risk assessments. The first phase presents a period between influenza pandemics. During the alert phase, identification of the pathogen (a new subtype of Influenza virus in the human population) is observed. The third phase encompasses the global spread of the pathogen. During the final transition phase, a reduction in global risk and response activities, or progression toward recovery actions is observed [34].

In 2014, the **CDC** updated the preparedness and response framework for Influenza pandemics, outlining 2 additional phases for respiratory pathogens [39]. The **investigation interval** is initiated by the identification and investigation of a novel influenza [A] infection in humans or animals anywhere in the world. The **recognition interval** starts when increasing numbers of human cases or clusters of novel influenza infections are identified anywhere in the world, and the virus characteristics indicate an increased potential for ongoing human-to-human transmission. The **initiation interval** begins when human cases of a pandemic influenza virus infection are confirmed anywhere in the world with demonstrated efficient and sustained human-to-human transmission. The next interval is characterized by the **Acceleration** of a pandemic wave and is accordingly termed the Acceleration interval. The **deceleration interval** is indicated by a consistently decreasing rate of pandemic influenza cases. The **preparation interval** is characterized by low pandemic influenza activity, although outbreaks might continue to occur in certain territories. Figure 3

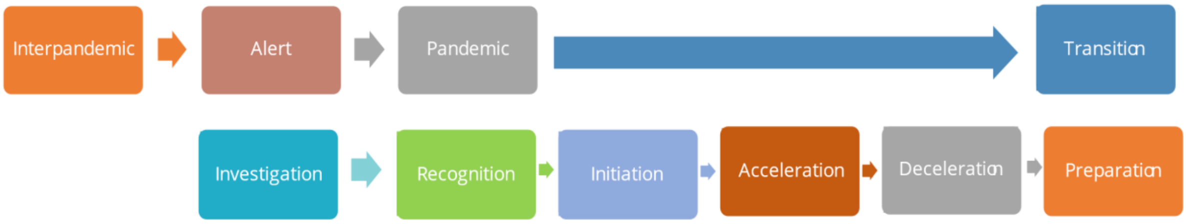


Figure 3: Pandemic intervals, according to preparedness and response framework for Influenza pandemics [34].

The Pandemic Influenza Severity Assessment (PISA) is focused on the national level and aims to describe the epidemiological situation and assess the severity of an epidemic/pandemic, to inform national and global risk assessments, and, also, public health preparedness, response, and recovery measures, as well as resource allocation. In the PISA framework (respiratory) pandemic severity is defined in terms of three indicators: transmissibility of the virus, seriousness of influenza disease, and impact [33].

The **transmissibility** indicator reflects the ease of movement of the influenza virus from person to person and inside communities. Transmissibility depends on the ability of the virus to spread from person to person, the dynamics of the spread, and the susceptibility of the exposed population. Otherwise, transmissibility is influenced by social contact patterns and climatic factors.

The **seriousness of disease** indicator describes the state in which a person gets sick when infected with the virus. It describes the frequency of clinical symptoms, complications of illness, and outcomes following infection. The seriousness of the disease depends on the virus and the human. An infection is likely to be much more severe for some segments of a population than for others, and descriptions of the groups that are at increased risk are an important part of this indicator.

The **impact** indicator generally describes how the epidemic/pandemic affects society. The impact is affected by the implementation of NPIs, public concern, and the behavior of the affected population.

To provide an assessment each of the three indicators should be evaluated according to parameters that are available in certain countries. For example, weekly influenza-like illness (ILI) or medically attended acute respiratory illness (MAARI) cases as a proportion of total visits, or incidence rates can be used to evaluate transmissibility indicator. To know how serious the infection is, cumulative death or ICU admission and hospitalization ratio can be calculated. A parameter of the weekly number of confirmed influenza cases admitted to the ICU or hospitalized patients can be used to assess the impact indicator. Other possible parameters that may reflect the impact on society are school closures, hospital beds occupied, work absenteeism, and school absenteeism.

Historical data has high importance in defining the start of an epidemic/pandemic and further assessment of its severity. It should be used to establish national thresholds for each parameter and qualitative evaluation (no activity or below the seasonal threshold, low, moderate, high, extraordinary).

The Pandemic Influenza Risk Management (PIRM) [34] aligns more closely with the disaster risk management structures already in place in many countries and underscores the need for appropriate and timely risk assessment for evidence-based decision-making. Risk characterization has three components: hazard, exposure, and context. For pandemic influenza, the hazard is the influenza virus of concern. Key virological, epidemiological, and clinical information is reviewed as part of the **hazard** assessment. Exposure defines the population groups known to have been or likely to be exposed so that a profile of the susceptibility in terms of immunity can be determined. **Exposure** assessment incorporates epidemiological and susceptibility factors such as incubation period and potential for transmission. **Context** assessment involves the evaluation of the environment in which the event takes place with social, scientific, economic, ethical, political, and policy factors considered. Although hazard, exposure and context are assessed separately, there is some overlap in the information required to assess each component.

The Tool for Influenza Pandemic Risk Assessment (TIPRA) [35] enables risk assessment of animal influenza viruses that have not caused human infection but are still of public health importance. TIPRA was developed to provide a standardized and transparent approach to support the risk assessment of influenza viruses with pandemic potential. TIPRA enables the identification of gaps in knowledge so that attention and resources can be dedicated to addressing those needs. The tool can also feed into comprehensive risk assessments that characterize all three components: hazard, exposure, and context.

The objectives of TIPRA are to: 1. support a timely and updatable hazard risk assessment for influenza viruses with pandemic potential; 2. transparently document features of the virus and the infections they cause; 3. identify knowledge gaps and prompt further investigations including research and surveillance; and 4. facilitate sharing of information between scientists, policymakers, and other stakeholders.

The ten risk elements used to characterize the virus risk:

A. Properties of the virus:
   • receptor binding properties • genomic characteristics • transmission in animal models • susceptibility to antiviral treatment.
B. Attributes in the human population:
   • human infection • disease severity • population immunity (likelihood) • population immunity (impact).
C. Virus ecology and epidemiology in non-human hosts:
   • geographic distribution in animals • infections in animals.

Figure 4: Steps for conducting a risk assessment using TIPRA [35].

5.4 Simulation Models for Impact and Effect Analysis

A core part of the SUNRISE Strategy Process is to capture and evaluate the potential consequences of a pandemic from multiple domains. Therefore, simulation models and tools for each domain are required that can describe the potential consequences a pandemic might have on the respective domain. In the following, a few examples are provided to show how such simulation models and approaches can be defined and to highlight already existing approaches.

5.4.1 Epidemiological Model

5.4.1.1 Theoretical Background

The multi-patch epidemiological model is a computational framework used to simulate the spread of infectious diseases in a spatially heterogeneous environment. Unlike simple models that assume homogeneity in population distribution, the multi-patch model acknowledges the spatial heterogeneity in populations, dividing them into multiple interconnected patches or compartments.

Each patch represents a distinct geographic area or population subgroup where disease transmission can occur.

At the core of the multi-patch model are differential equations that describe the flow of individuals between patches and the transmission dynamics of the disease within each patch. These equations incorporate parameters such as transmission rates, recovery rates, and movement rates between patches, which are crucial in understanding how the disease spreads across different locations and populations.

One key aspect of the multi-patch model is its ability to capture the effects of spatial connectivity on disease transmission. By considering movement between patches, the model can account for the flow of infected individuals from one location to another, potentially leading to the introduction or amplification of the disease in new areas. This spatial perspective is particularly relevant for diseases with long incubation periods or those transmitted by mobile hosts, such as humans or animals.

Furthermore, the multi-patch model allows for the exploration of spatial heterogeneity in factors influencing disease transmission, such as population density, contact patterns, and environmental conditions. These variations can have significant impacts on the spread and persistence of infectious diseases, making it essential to consider spatial dynamics in epidemiological modelling and control strategies.

5.4.1.2 Model Setup

The model is typically set up as a system of differential equations, where each patch is represented by a set of state variables describing the population dynamics within that patch. For the SUNRISE project, each patch within the model corresponds to a Nomenclature of Territorial Units for Statistic Level 1 (NUTS1) subdivision. Within each patch, a meta-population framework is employed to account for the heterogeneity of populations across different critical infrastructures (Table 3). This approach considers various demographic factors, such as age distribution and contact patterns, to capture the nuances of disease transmission within and between subpopulations.

Table 3: List of meta-population in the model

i	Subpopulation
1	Hospital
2	Transportation
3	Energy/Water
⋮	⋮
n	The rest population

The epidemiological dynamics within each patch are developed by adapting a deterministic SEIR (Susceptible-Exposed-Infectious-Recovered) model, including those transmitted through direct contact or vector-borne transmission. This model distinguishes between healthy (susceptible) individuals, infected but not yet infectious (exposed) individuals, and infectious patients. Moreover, depending on the nature and severity of the disease, it is possible to introduce additional compartments. In the case of severe illness, compartments for hospitalized patients and individuals in ICUs can be integrated into the model. Subsequently, patients may either recover or die from the disease. Furthermore, an additional compartment is introduced to account for the indirect impact of the epidemic on critical infrastructures, represented as an absence compartment. The model structure within each patch is illustrated in Figure 5. Therein, an individual on meta-population i is classified either as susceptible (S_i), absence (A_i), exposed (E_i), infectious (I_i), hospitalized (H_i), in intensive care (U_i), recovered (R_i), or dead (D_i).

In scenarios involving vector-borne transmission, the model incorporates additional compartments and parameters to represent the dynamics of the vector population, as well as the transmission dynamics between vectors and humans. This entails introducing compartments for susceptible vectors, exposed vectors, and infectious vectors, alongside parameters governing transmission rates between vectors and humans. The model integrates the interactions between human and vector populations to simulate the spread of the disease in such transmission scenarios. Figure 6 illustrates the model structure for vector-borne transmission, where a human individual on meta-population i is classified either as susceptible (S_{h_i}), exposed (E_{h_i}), infectious (I_{h_i}), or recovered (R_{h_i}). A vector on meta-population i is classified either as susceptible (S_{v_i}), exposed (E_{v_i}), or infectious (I_{v_i}). Transmission between human and vector represents by red dash line.

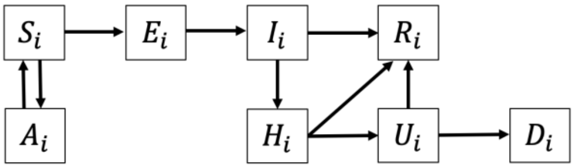


Figure 5: Structure of model for direct transmission within each patch (region).

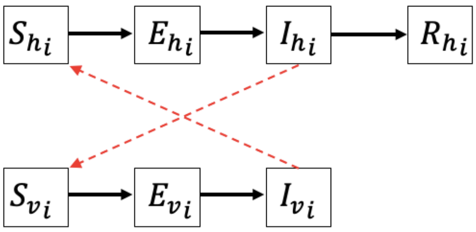


Figure 6: Structure of model for vector-borne transmission within each patch (region).

In recognition of the evolving threat posed by climate change, the model integrates a comprehensive analysis of its impact on disease transmission dynamics. Specifically, the effects of changing meteorological variables on infection parameters, such as transmission rate, are incorporated into the model framework. To evaluate how the projected climate change will impact the development of respiratory pandemic events, we take a two-step approach: (i) a multi-variate analysis is performed to assess the potential impact of individual weather variables, such as temperature, UTCI (Universal Thermal Climate Index), and precipitation (described in Section 5.3.2); and (ii) we study how the model accounts for the potential modulation of disease spread patterns in response to changing environmental conditions from the recognition to acceleration stages of a pandemic. To evaluate how the projected climate will impact the development of an infectious disease pandemic, we investigate the impact of regional climate change projections on the environmental suitability of vectors and the occurrence of transmissions of vector-borne infectious diseases.

Table 4: Variables for multivariate regression analysis

Infection parameter	• Seasonal index
Climate variables	• Temperature • Universal Thermal Climate Index (UTCI) • Precipitation

Additional control variables	- Holidays - Population density - Median age - Income

Input of model

- Epidemiological data
  - Reported new cases
  - Hospitalization number
  - ICU admitted
  - Deaths
- Demographic data
  - Population (by age): EUROSTAT
  - Social contact pattern: COVIMOD, POLYMOD
  - Mobility between countries: approx. by EUROSTAT
- Climate data
  - Temperature
  - UTCI
  - Precipitation
  - Climatic suitability of Aedes albopictus
- Critical infrastructures data
  - Meta-population: survey on critical infrastructure
  - Contact pattern: survey on critical infrastructure

Output of model

- Prediction of epidemiological outcomes
  - New cases number
  - Hospitalization number
  - ICU admitted
  - Deaths
- Prediction of absence on CIs

5.4.1.3 Software and Development

The model simulation was originally developed by Rodiah [40], [28] using Python. Parameters, initial conditions, and connectivity matrices can be specified in standard data formats such as Excel, CSV, or custom text files. Simulation results are typically saved as time-series data or visualizations, including graphs and heatmaps. Output formats may include CSV files for data analysis, image files for visualizations.

The computational resources required depend on the complexity of the model and the scale of the simulation. Simulations involving many patches or detailed spatial resolution may require significant computational resources, including high-performance computing clusters or cloud-based infrastructure. Memory and processing power are essential considerations, particularly for simulations with a large number of compartments.

5.4.1.4 Implementation

Simulation of a multi-patch model with age structure and varying critical infrastructure involves several key steps. Firstly, the population is divided into different patches, each representing a NUTS1 region. Within each patch, meta-populations are defined based on critical infrastructure, such as hospital, transportation, or energy/water, to capture variations in disease transmission dynamics and resource availability. Additionally, age structure is incorporated to account for demographic variations and susceptibility to the disease across different age groups. The model parameters, including transmission rates, incubation periods, and recovery rates, are calibrated based on epidemiological data and derived by scenario pandemic. Simulation of the model involves solving a system of differential equations numerically to project the spread of the disease over time, taking into account interactions between patches, age groups, and critical infrastructure dependencies. Model outputs can then be used to assess the effectiveness of various intervention strategies and inform public health decision-making. Figure 7 represent an illustrative view of the model output depicting the incidence of new cases during the H1N4 pandemic scenario across different CI sectors and age groups. This visualization gives an idea of how the disease is spreading across different critical infrastructure sectors.

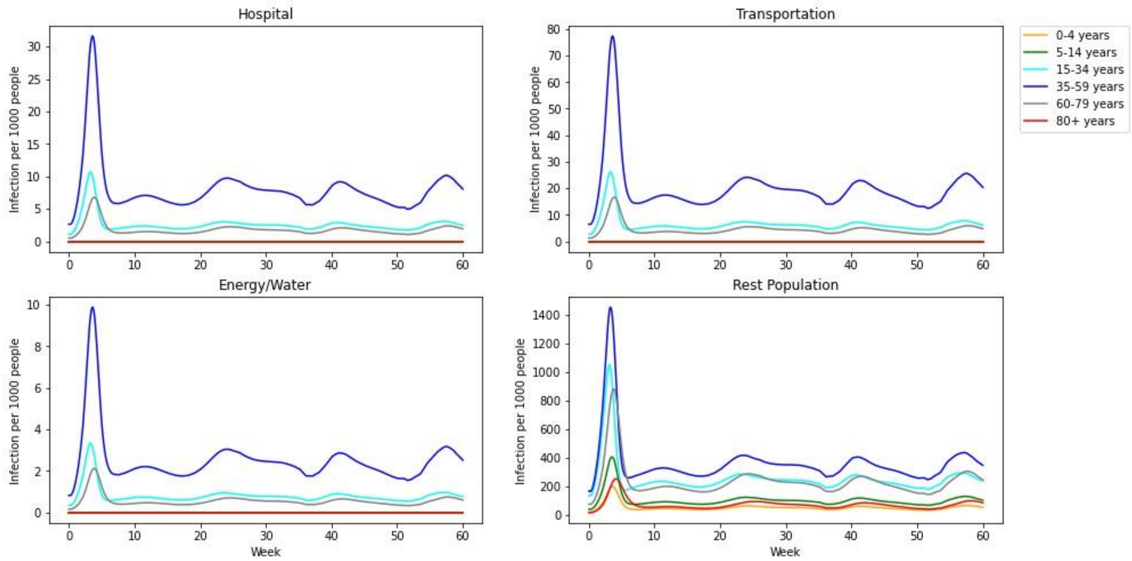


Figure 7: Simulation results of the epidemic model for scenario H1N4 pandemic for different CIs across age groups.

5.4.2 Climate Change Model

A multi-variate analysis is being performed for present day meteorological variables from the European Centre for Medium-Range Weather Forecasts (ECMWF) Reanalysis v5 (ERA5) [41], a proxy for observed atmospheric conditions, to identify meteorological variables which influence the infections risk of SARS-CoV-2 (aka COVID-19) over Germany. Meteorological variables tested include temperature, precipitation, and the Universal Thermal Comfort Index [42].

We will investigate how regional climate projections of temperature and climatic suitability of the Aedes albopictus (tiger mosquito) may impact the root of transmissions of a respiratory and vector-borne driven pandemics. The regional climate model temperature projections over Europe come from the EURO-CORDEX dataset [43]. It contains an ensemble of regional climate models driven by the 5th Coupled Model Intercomparison Project (CMIP5) [44] global climate models. The EUR-11 CORDEX ensemble covers the European domain with a spatial resolution of approximately 12.5km x 12.5km for a 'historical' period (1970 – 2005) and the projected period (2006 – 2100) for three climate scenarios

(RCP 2.6, RCP 4.5, RCP 8.5). The high-emission scenario (RCP 8.5) has a temperature increase of about 4.3˚C by 2100, relative to pre-industrial temperatures, compared to the low-emission scenario (RCP 2.6), which has a global warming of about 1.8˚C by 2100. These climate projections are also the basis of the Copernicus C3S European Health service dataset of climatic suitability of the Aedes albopictus which transmits vector-borne diseases such as dengue and chikungunya [45]. Changing environmental factors in temperature and precipitation are becoming more favourable for the presence of Aedes albopictus.

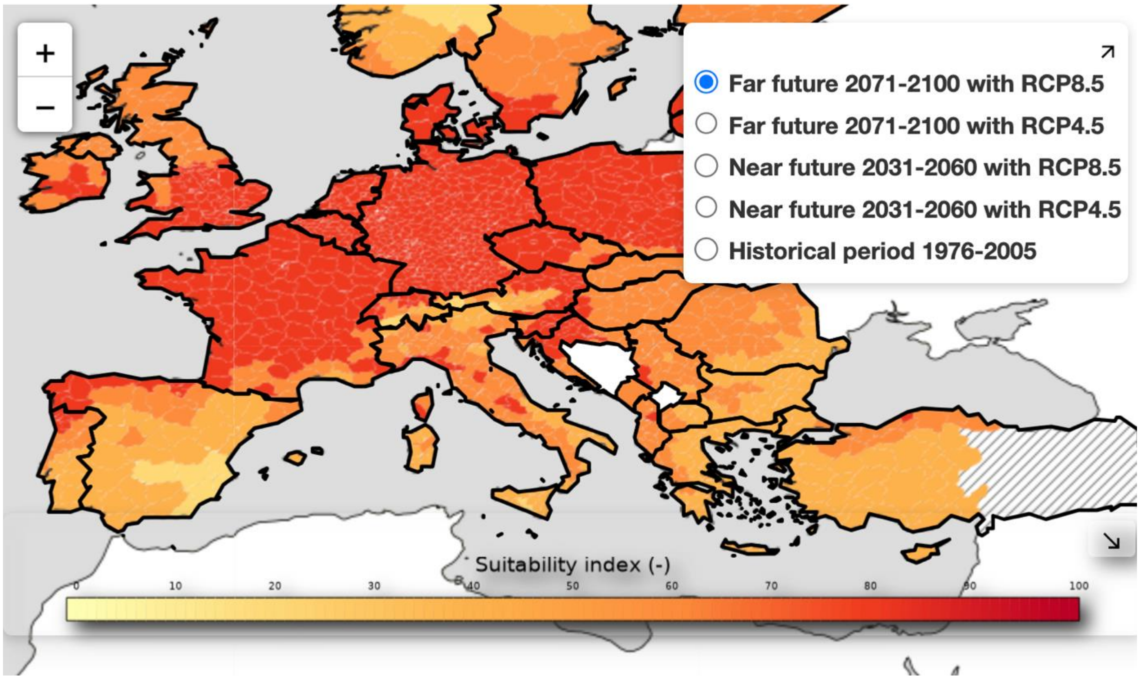


Figure 8: Copernicus Climate Data Store application showing the suitability index of the Aedes Albopictus mosquito over Europe in the far-future. The suitability index takes into the account increasing temperatures and rainfall amounts. [46]

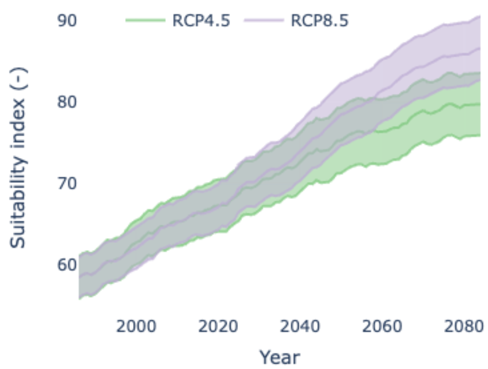


Figure 9: Copernicus Climate Data Store application showing changes in suitability of the Aedes Albopictus mosquito under two climate change scenarios compared to the reference period over Slovenia. [46]

5.4.3 Cascading Effects Model

Critical infrastructures (CIs) are interdependent in many ways. First and foremost, CIs provide goods and services that are used by other CIs, e.g., a hospital needs electricity and water for operation, but also depends on the transportation system for staff and medication. In recent years, digitalization induced further dependencies, e.g., by electronic control systems for physical processes. Due to these interdependencies, CIs cannot be treated as isolated entities. In particular, any risk analysis carried out by an individual CI needs to take the interdependencies with other CIs into account, since those relations affect the operation of the CI itself.

Furthermore, when looking at the complex network of CIs within a city or metropolitan area it is important to consider this entire network of CIs because the interdependencies affect not only risk level (i.e., the impact of particular threats on all CIs) but also the resilience (i.e., how fast all CIs can recover from an incident) of the entire network.

A natural high-level model for a network of CIs is a graph, where nodes represent CIs (or their specific assets), and edges represent dependencies between them. Since the model is used for risk analysis, a directed graph is used where an edge $X \rightarrow Y$ means that a problem in X may affect Y.

For a more detailed analysis, refinements of this high-level model are needed. For that purpose, the interdependency graph is enhanced in the sense that nodes have an inner model describing their local dynamic [47]. The form of this inner model depends on the problem at hand. An automata model proves to be useful for analysing an incident's consequences as it reacts to triggers, such as an incoming event. More specifically, Mealy automaton are used since they also send notifications to neighbouring nodes if the threat affects the node. Section 5.4.3.3 gives more details on this inner model used here.

5.4.3.1 Identification of Interdependencies

The first step in the analysis of cascading effects is to formally describe the network of CIs or by creating the interdependency graph. This breaks down to two tasks: identification of relevant components and identification of the dependencies between these components. In the considered interdependency graph model, an edge describes how a problem propagates, e.g., how limited availability of one component may affect other components.

Relevant Components

The identification of the relevant components depends on the purpose of the analysis. If the focus lies on raising awareness of various existing dependencies, a high-level diagram is sufficient where each CI is represented as one node. If the big picture is known and the focus lies on a deeper understanding, it is required to model a CI in more detail, i.e., represent all its relevant (critical) components as nodes. In this case, the nodes are sometimes also called assets or components of the network. The granularity depends on the purpose of the analysis, and in some cases also on the availability of data. For example, if the purpose is to evaluate a cyber-attack on a power provider, the most relevant components will often be the power network, the transformer stations, the Industrial Control System (ICS) supervising both, and the staff using the ICS, since many cyber-attacks target either the systems directly or employees using it. If the focus lies on the impact of such an attack, power network and power station should be modelled in more detail.

Dependencies between Components

When focusing on the effects of an incident, and particularly on cascading effects within a CI network, it is necessary to understand the direction of the propagation of these effects. In the interdependency graph, this is realized by using a directed graph. In the context of the interdependency graph, an edge $X \rightarrow Y$ means that a problem in component X may influence component Y. For example, hospital Y needs drinking water from water utility X.

Dependencies can be of various kinds, including (but not limited to) the following:

- Physical dependencies: a physical connection between components (e.g., a wire); exchange of goods or resources (e.g., water)
- Cyber dependencies: connections in a computer network, e.g., a server holding databases; exchange of data or information (e.g., ICS control data)

- Logical dependencies: devices may be connected through shared networks in a company, multiple users may have (remote) access.

The type of dependency may influence the propagation in the sense that the probability that the problem affects other components may depend on it [48]. An alternative modelling approach classifies the nodes of the networks as physical, cyber, process, human etc. and characterizes the propagation through the node's behaviour [49].

Multiple dependencies of the same kind are usually represented through a single edge, and the strength of the dependency is described through the node model (see Section 5.4.3.3). In case of the hospital depending on multiple products of the water provider, drinking and cooling water, this dependency is represented as one physical dependency. If this dependency is important, e.g., if the hospital is in the focus of the analysis, a more detailed representation is preferred.

5.4.3.2 Identification of Threats

Another important input for the analysis of CI networks is the kind of threats that are relevant. There are several sources to identify potential threats to one or several of the CIs in the network. Two of the main sources are openly available threat databases such as the ENISA threat landscape for Internet Infrastructures [50] and the experience of threats (what and how it happened) that already happened in the same or in related industrial sectors, e.g., cyber-attacks on ports [51]. In some domains, standards may provide information on generally known issues (e.g., the ISO standard 62443 [52] for the automotive domain).

Relevant Threats

Besides information on the CI network, the threats to be considered in the upcoming analysis need to be identified. This is a list of threats faced by one or more of the CI operators that may yield to reduced functionality or availability of at least one of the CIs. Here it is crucial to not only include threats that affect all CIs (e.g., a blackout), but also more specific threats (e.g., local shortage of electricity) since the realization of such a threat may have far reaching consequences (e.g., cause a blackout in neighbouring areas, as in Italy in 2003 [53]).

5.4.3.3 Models of Local Dynamics

The main purpose of the interdependency graph is to gain information about the global behaviour of the CI network based on the local behaviour of CIs. These local dynamics are described through a model inside each node, describing how a threat affects this specific node.

The first task is therefore to measure this effect. Due to the complexity of the modelled systems (be it entire CIs or their critical components), it is not feasible to use specific and detailed measures of loss for each node. Instead, a qualitative scale to characterize the state of the node is more favourable, e.g., ranging from 1 (best) to 5 (worst). Depending on the type of the node, the levels represent functionality or availability of a component. Some possible interpretations are provided in Table 5.

Table 5: Interpretation of states of a node

State	Functionality	Availability	Loss / Damage
1	Full functionality	Normal	No or negligible
2	Slightly reduced	Slight delay	Some minor damage, repairable
3	Some limitations - but still operating	Some interruption or delay, but still satisfactory	Some severe damage or multiple smaller problems, repair takes considerable time or money
4	Strong limitations	Strong interruption or delay, not satisfactory	Severe or long-lasting damage, repair time consuming or expensive
5	Not working at all	Not available	Failure, needs to be replaced or substituted (at least temporarily)

Characterization of Local Dynamics

In the context of CIs or their crucial components, data is often sparse or vague, which makes a precise and detailed description of the local dynamics almost impossible. With the choice of a qualitative state, specification of the node's dynamic boils down to describing when it changes its state, i.e., when the condition gets better or worse. Such a change is triggered by an incident, either directly or indirectly through the state of a node it depends on. Further, the reaction to a threat may depend on the circumstances, i.e., on the current state of the node. Such behaviour is best modelled through a Mealy automaton, as it changes its state upon a given input and returns an output.

The reaction of a node to an input is influenced in real life by manifold factors that can hardly be captured in full detail in a practical abstract model. Therefore, it is appropriate to model a node's behaviour by adding probabilities to the state changes of the automaton model, i.e., through a probabilistic Mealy automaton [47]. Figure 10 illustrates an example of a probabilistic Mealy automaton for 3 states.

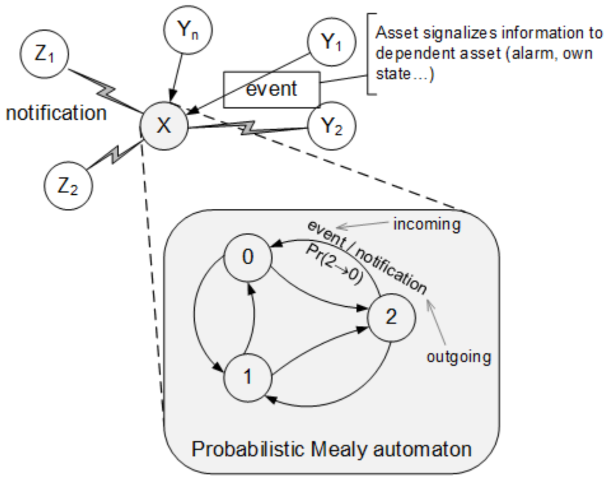


Figure 10: Interdependency graph with probabilistic Mealy automaton model.

Formally, the local dynamics in a node are described through a tuple $M = (S, \Sigma_{\text{in}}, \Sigma_{\text{out}}, \delta, \lambda, s_0)$ where:

- S is a finite and non-empty set of states, e.g., $S = \{1,2,3,4,5\}$
- Σ_{in} is a finite and non-empty input alphabet encoding the threats, where $\Sigma_{\text{in}} \subset \{0,1\}^*$
- Σ_{out} is a finite and non-empty output alphabet
- $\delta: S \times \Sigma_{in} \to \Delta(S)$ is a transition function that maps a pair of state and input word to a probability distribution over the states (i.e., an element of the simplex $\Delta(S)$)

- $\lambda: S \times \Sigma_{in} \rightarrow \Sigma_{out}$ is an output function that maps a pair of state and input word to an output word
- $s_0 \in S$ is the initial state

It is recommended to choose the same set of states S for all nodes as it allows comparing the condition of different components. Further, it is convenient, and in most cases sufficient, to set $\Sigma_{\text{in}} = \Sigma_{\text{out}} =: \Sigma$. The strings describing the alarms contain information such as the kind of threat, its criticality, a timestamp, and any other relevant information.

The transition function δ can be described through a table as shown in Table 6. Each row describes a state change including the input and output messages that are relevant for the detection of cascading effects. The situations where the state is not changed are defined implicitly through the fact that the sum of all transition probabilities being 100% but could also be added explicitly. Whenever the node goes to a new state, it notifies its neighbours through the output.

Table 6: Transition table (example)

Input	Current State	Next State	Output	Probability
Fire	1	2	Fire	20%
Fire	1	3	Fire	70%
Fire	2	3	Fire	80%

5.4.3.4 Simulation of Global Dynamics

Based on the local dynamics of the individual CIs within the interdependency graph, a simulation approach can be used to describe the global dynamics, i.e., the behaviour of the entire CI network upon a specific incident happening at one of the nodes. This is realized by sending notifications from one node to all its neighbours if a problem has occurred. The Mealy automata inside the nodes reacts to an input α and returns an output β if it changes the state (i.e., if it is affected by the trigger). All neighbouring nodes receive this output as new input and may react accordingly. Through this transmission of messages which can be interpreted as alarms, the impact of an incident can propagate through the entire network.

For example, if a CI is affected by the threat "fire", it might suffer a complete breakdown. The output sent by the automaton is used as the input for all nodes depending on the CI. Hence, another CI (e.g., a telecom provider) is also affected by the fire, suffering a complete breakdown. In this case, the output could be different than the input (e.g., indicating that the telecom network is down, or the provider's cloud storage is not available anymore).

Following this path of events through all possible dependencies modelled in the interdependency graph describes the potential cascading effects of the threat affecting the initial node in the entire CI network. This simulation is carried out by a tool developed by AIT [54], which implements this stochastic process. Because of the probability distributions of the state transitions in the individual nodes (cf. Section 5.4.3.3), each simulation could lead to a different result. The overall impact of the cascading effects on the entire CI network is then measured by the resulting states of the individual CIs. Hence, the tool runs numerous iterations of the simulation to get a statistical overview on the results.

5.4.3.5 Implementation

The implementation for SUNRISE, called CASSANDRA (**Cas**cading Effects **S**imulation **and R**isk **A**nalysis) consists of three main components:

1. Simulation Core: A NodeJS-based package covering the stochastic simulation. This module can be integrated and reused in different projects while expanding it with specific functionalities, like in SAURON [55], ODYSSEUS, PRAETORIAN [56] and PRECINCT [57]

2. Backend API[1]: For SUNRISE, the simulation core is wrapped within a NestJS application providing a REST-API supporting HTTP-based endpoints that are accessible for all projects partners. The API documentation can be accessed via a dedicated Swagger endpoint.
3. Web Frontend[2]: To support in the modelling phase of the interdependency graph, starting simulations and viewing the results, there are also project specific frontends available. They are developed as a web application with Angular and provide customized views and feature sets for projects.

Figure 11 summarises the dataflow for cascading effect simulations: First the interdependency graph must be modelled as detailed in Sections 5.4.3.1, 5.4.3.2 and 5.4.3.3 using the CASSANDRA web application. Adding further simulation parameters to the interdependency graph, like how much simulations should be executed and what initial event triggers the simulation (i.e., starting the global dynamics, see Section 5.4.3.4) creates the simulation request, which is sent as a JSON structure to the backend API. The simulation core, expanded with project-specific features computes the simulation output, which consists of the full simulation request (interdependency graph and simulation parameters), results of each individual simulation run, and aggregated simulation results, transmitted as a JSON structure via the backend API. In the web application, the most frequently used simulation results are visualized.

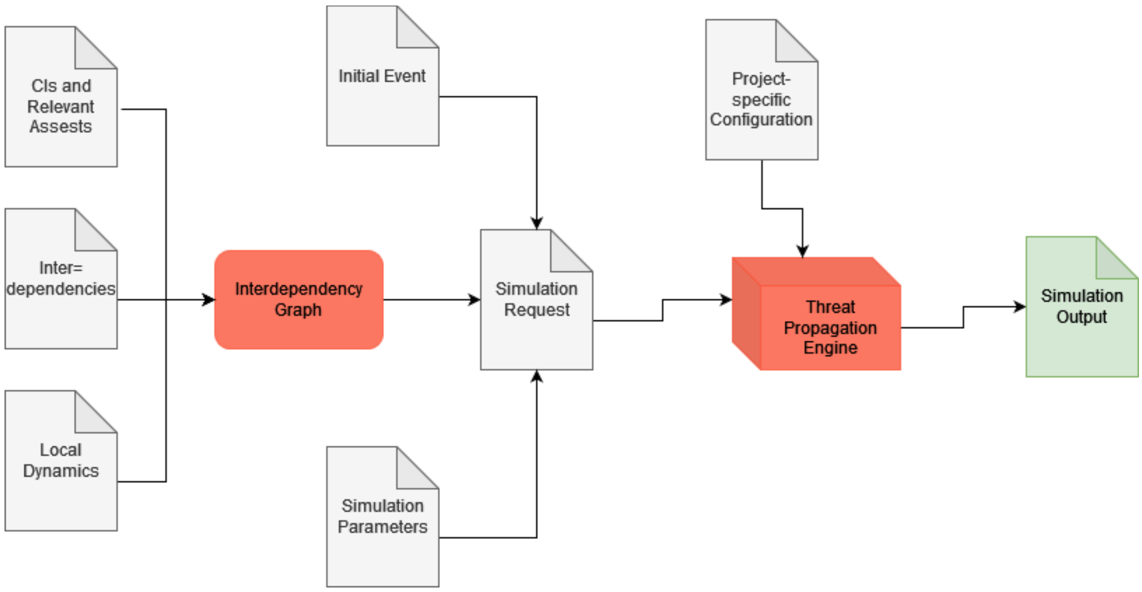
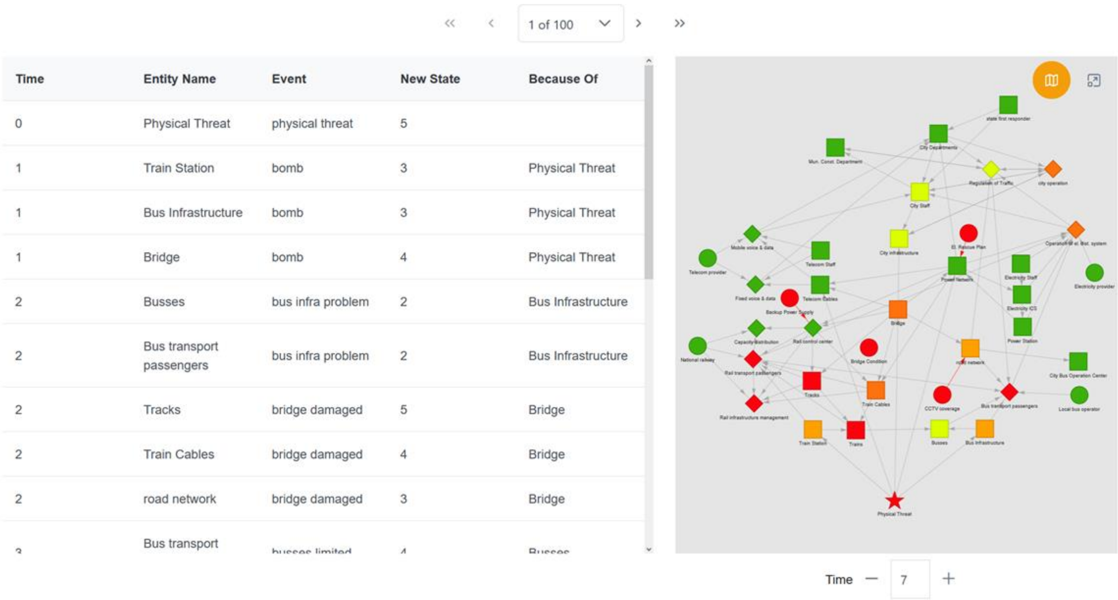


Figure 11: High-level dataflow in CASSANDRA.

In general, the web application visualizes provides two main results: first, it shows the propagation steps for each individual simulation run (cf. Figure 12) indicating for each affected node in the graph the event that affected it, the state that it was brought into, and which other node triggered the event. This allows tracing of the path of the effects from the initial event (i.e., the threat scenario the simulation was started with) to the final state of each node.

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

1 of 100

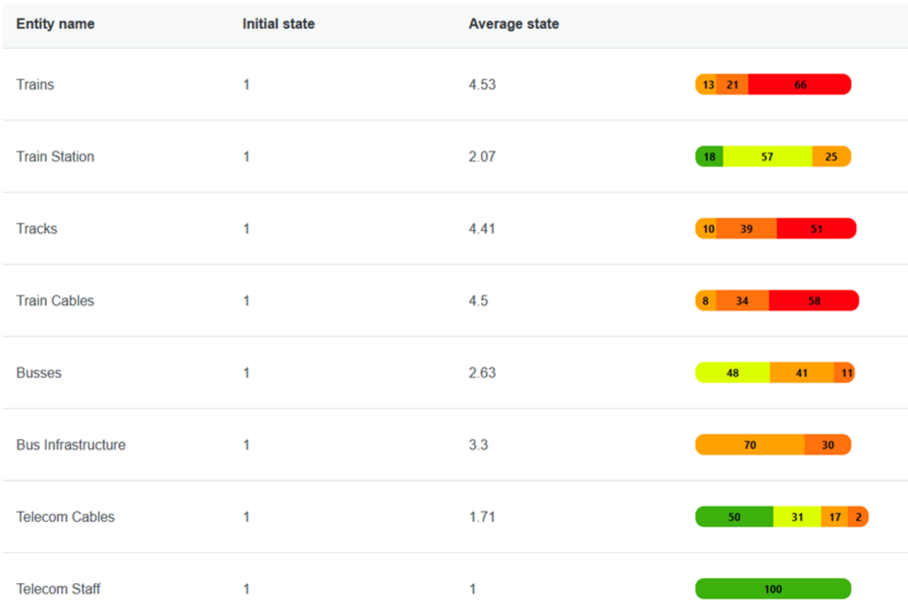


Time	Entity Name	Event	New State	Because Of
0	Physical Threat	physical threat	5	
1	Train Station	bomb	3	Physical Threat
1	Bus Infrastructure	bomb	3	Physical Threat
1	Bridge	bomb	4	Physical Threat
2	Busses	bus infra problem	2	Bus Infrastructure
2	Bus transport passengers	bus infra problem	2	Bus Infrastructure
2	Tracks	bridge damaged	5	Bridge
2	Train Cables	bridge damaged	4	Bridge
2	road network	bridge damaged	3	Bridge
3	Bus transport	busses limited	4	Busses

Time 7

Figure 12: Screenshot of the CASSANDRA tool showing results of an individual simulation run.

Second, the web application shows an overview of the effects of all simulation runs, indicating for each node in the graph how often it ended up in one of the possible states. This indicates how much the entire CI network is affected by the cascading effects of the initial event (i.e., how many nodes end up in the worst state, in some mediocre state or stay unchanged). From all these results, the tool then also calculates one single number for the entire network (by using the median) indicating the overall average state or the possible worst-case state.



Entity name	Initial state	Average state	
Trains	1	4.53	13 21 66
Train Station	1	2.07	18 57 25
Tracks	1	4.41	10 39 51
Train Cables	1	4.5	8 34 58
Busses	1	2.63	48 41 11
Bus Infrastructure	1	3.3	70 30
Telecom Cables	1	1.71	50 31 17 2
Telecom Staff	1	1	100

Figure 13: Screenshot of the CASSANDRA tool visualising final node states of an entire simulation run.

Depending on the use cases in different projects, CASSANDRA is customizable to meet specific requirements. This applies to the backend API by providing customized statistics and analyses and to the web frontend with different views and modelling capacities.

5.4.4 Socio-Economic Impacts Model

5.4.4.1 Theoretical Background & Technical Implementation

A wide range of different models has been used for the economic impact assessment of different types of disasters, including inoperability input-output models, CGE models or specifically tailored frameworks, each with different advantages and drawbacks (see for example Okuyama & Santos [58], Galbusera & Giannopoulos [59] or Okuyama [60]). A crucial issue regarding SUNRISE is flexibility, since the model should be able to potentially cover a wide range of sectors and disasters. For that reason, we build on the sector-disaggregated macro-economic agent-based model (ABM) developed by Poledna et al. [61]. The ABM can account for critical infrastructures and related capital stocks of sectors at the NACE level (Nomenclature statistique des activités économiques dans la Communauté européenne, Statistical classification of economic activities in the European Community) of the Figaro tables (Full international and global accounts for research in input-output Analysis) provided by Eurostat. The model is thus based on an input-output framework and originally calibrated for the small open economy of Austria. A detailed model description can be found in [61]. The model agents form expectations in each simulation period regarding income, demand, and growth of the Gross Domestic Product (GDP) amongst others based on an autoregressive process of order one (AR1). Thus, the agents are not equipped with rational nor model-consistent expectations.

5.4.4.2 Model Setup

The ABM considers the following sectors: firms, private households, the general government, banks including the central bank, and the rest of the world. Each sector consists of heterogeneous agents representing either natural persons or legal entities that interact according to predefined rules (see Figure 14). The firm sector is made up of 64 industries, each producing a perfectly substitutable good with labour, capital, and intermediate inputs from other sectors with a fixed-coefficients (Leontief) technology. The model is based on quarterly data and typically runs simulations for up to three years. This implies a forecasting period of 12 quarters, after which uncertainty becomes too large. The model architecture is flexible and allows for several types of simultaneous shocks on a sectoral level. Examples include supply shocks (e.g., due to disruptions in the supply chain), demand shocks (e.g., travel restrictions), changes in productivity (e.g., heatwave effects) or destruction of capital stock (e.g., by flooding). It is further easy to change parameters to assess the implications and impacts throughout the modelled economy.

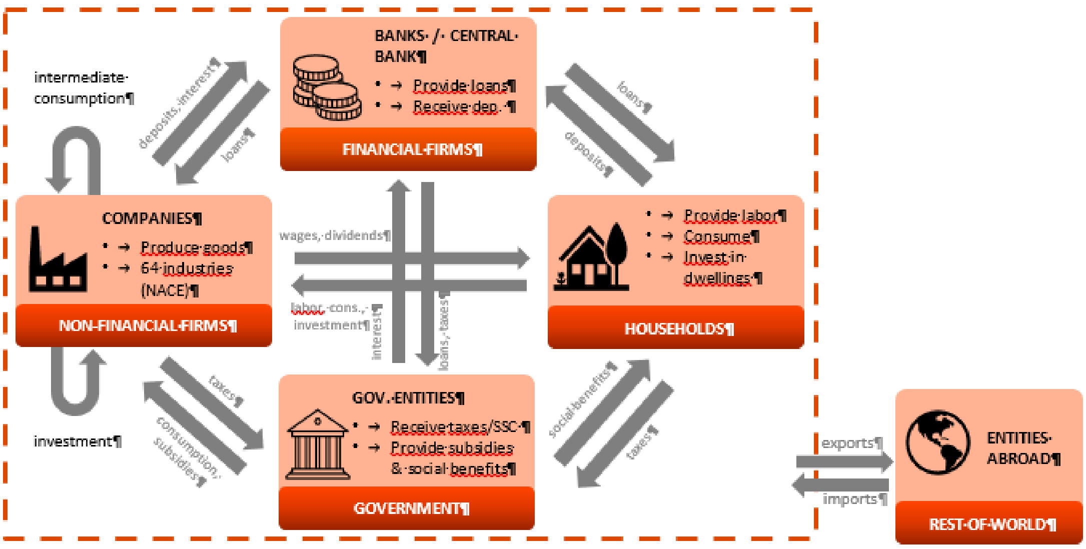


Figure 14: Model Agents and Interactions.

5.4.4.3 Required Inputs

The main data source of the ABM is economic data including input output tables, national accounts, capital stocks, business demography, government statistics and population data mainly provided by Eurostat, which are described in Table 7.

Table 7: Eurostat data tables based on [61], p.10.

Datasets	Eurostat Code
Population by current activity status, NACE Rev. 2 activity and NUTS 2 region	cens_11an_r2
Business demography by legal form (from 2004 onwards, NACE Rev. 2)	bd_9ac_1_form_r2
Symmetric input-output table at basic prices (product by product)	naio_10_cp1700
Cross-classification of fixed assets by industry and by asset (stocks)	nama_10_nfa_st
Government revenue, expenditure, and main aggregates	gov_10a_main
General government expenditure by function (COFOG)	gov_10a_exp
Quarterly non-financial accounts for general government	gov_10q_ggnfa
Quarterly government debt	gov_10q_ggdebt
Financial balance sheets	nasq_10_f_bs
Non-financial transactions (annually)	nasa_10_nf_tr
Non-financial transactions (quarterly)	nasq_10_nf_tr
GDP and main components (output, expenditure, and income)	namq_10_gdp
Money market interest rates – quarterly data	irt_st_q

For the simulation of various shock scenarios, additional inputs are required for shock implementation. A variety of variables could be used for that purpose, e.g.

- Heatwaves: climate projections and the resulting impact of the heatwave on varied sectors through labour productivity losses (see Table 8 as an example)
- Pandemic scenario: information on the number of persons absent from work, estimated reduction of sectoral output, changes regarding the service level, counter-measures like lockdowns or travel restrictions, etc.
- Natural disasters: amount or share of destroyed capital stock, data on the regional impact, etc.

Table 8 provides an illustrative example regarding data on the average loss in labour productivity due to climate change, which was used as the main input parameter for the economic impact model when analysing heat shocks. The data on labour productivity losses is based on the Climate Chip website[3] work intensity and exposure to sun were assigned to each NACE sector based on literature and additional assumptions.

Table 8: Average loss in labour productivity by sector due to climate change in %, Vienna region, by quarters, 2041-2070, based on http://climatechip.org/

NACE Sector	Sun/ Shade	Work Intensity	Avg. loss in Q1	Avg. loss in Q2	Avg. loss in Q3	Avg. loss in Q4
A01 Crop and animal production, hunting and related service activities	Sun	Heavy	0,00%	1,37%	4,37%	0,00%
A02 Forestry and logging	Sun	Heavy	0,00%	1,37%	4,37%	0,00%

[3] http://climatechip.org/

NACE Sector	Sun/ Shade	Work Intensity	Avg. loss in Q1	Avg. loss in Q2	Avg. loss in Q3	Avg. loss in Q4
A03 Fishing and aquaculture	Sun	Heavy	0,00%	1,37%	4,37%	0,00%
B Mining and quarrying	Sun	Heavy	0,00%	1,37%	4,37%	0,00%
C10T12 Manufacture of food products; beverages and tobacco products	Shade	Light	0,00%	0,07%	0,37%	0,00%
C13T15 Manufacture of textiles, wearing apparel, leather and related products	Shade	Light	0,00%	0,07%	0,37%	0,00%
C16 Manufacture of wood and of products of wood and cork…	Shade	Moderate	0,00%	0,23%	1,17%	0,00%
C17 Manufacture of paper and paper products	Shade	Heavy	0,00%	0,50%	2,17%	0,00%
C18 Printing and reproduction of recorded media	Shade	Light	0,00%	0,07%	0,37%	0,00%
C19 Manufacture of coke and refined petroleum products	Shade	Heavy	0,00%	0,50%	2,17%	0,00%
C20 Manufacture of chemicals and chemical products	Shade	Moderate	0,00%	0,23%	1,17%	0,00%
:	:	:	:	:	:	:
S96 Other personal service activities	Shade	Light	0,00%	0,07%	0,37%	0,00%

5.4.4.4 Provided Outputs

The ABM provides the standard outputs of a macroeconomic model. Below is a (non-exhaustive) table of economic indicators on which the socio-economic impacts will be assessed, see Table 9.

Table 9: Economic output indicators

Level	Indicator
Sector-level indicators	Nominal and real gross value added in each considered sector
	Employment in each considered sector
Macroeconomic indicators	GDP (nominal and real)
	Total gross value added (nominal and real)
	Total employment
	Unemployment rate

Figure 15 and Figure 16 plot trends of different macroeconomic and sectoral output variables due to effects on labour productivity in different climate change scenarios for Austria as produced by the economic impact model. The period of analysis is 3 years or 12 quarters, seasonality is due to higher impacts in the summer months.

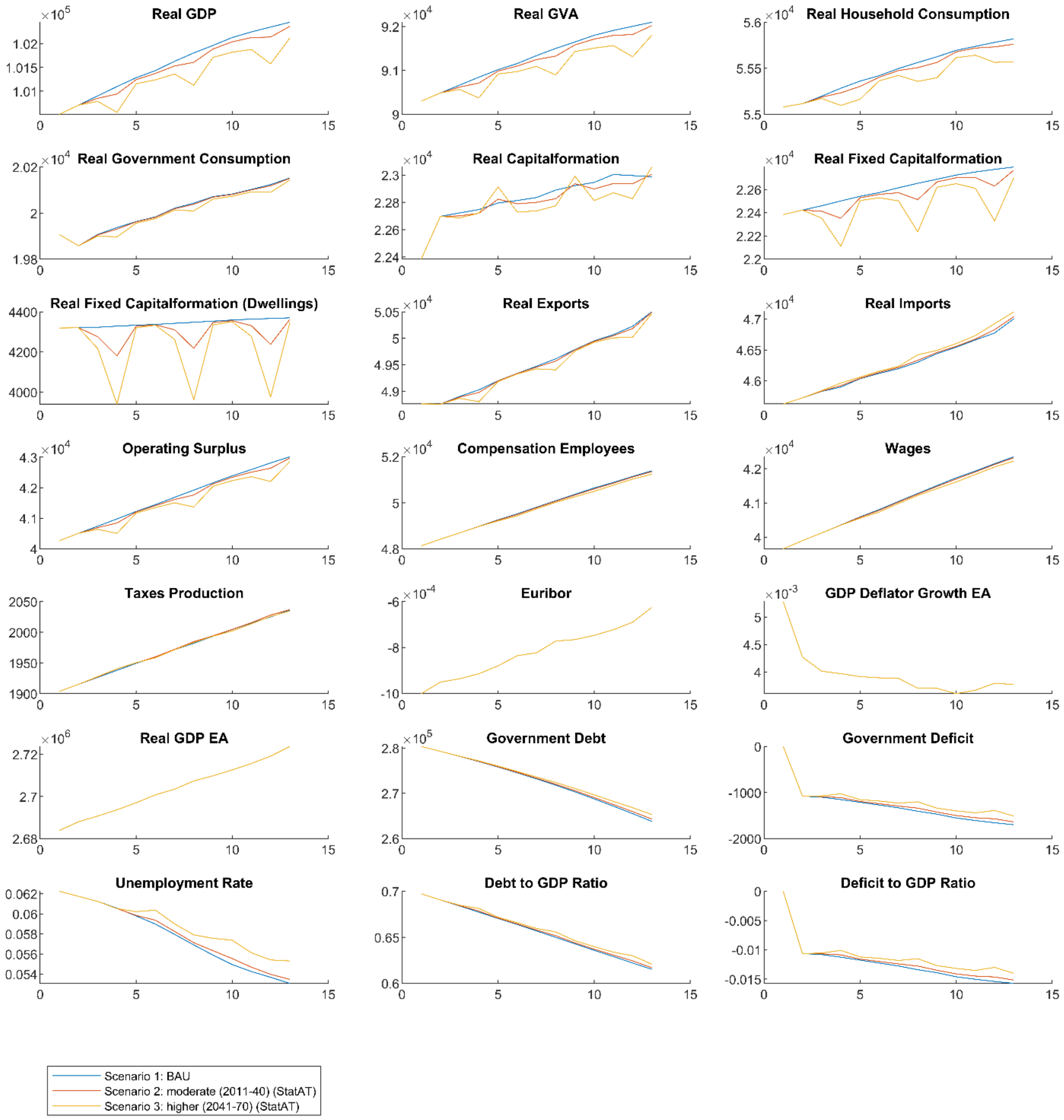


Figure 15: Trends of various macroeconomic variables in different climate change scenarios for Austria.

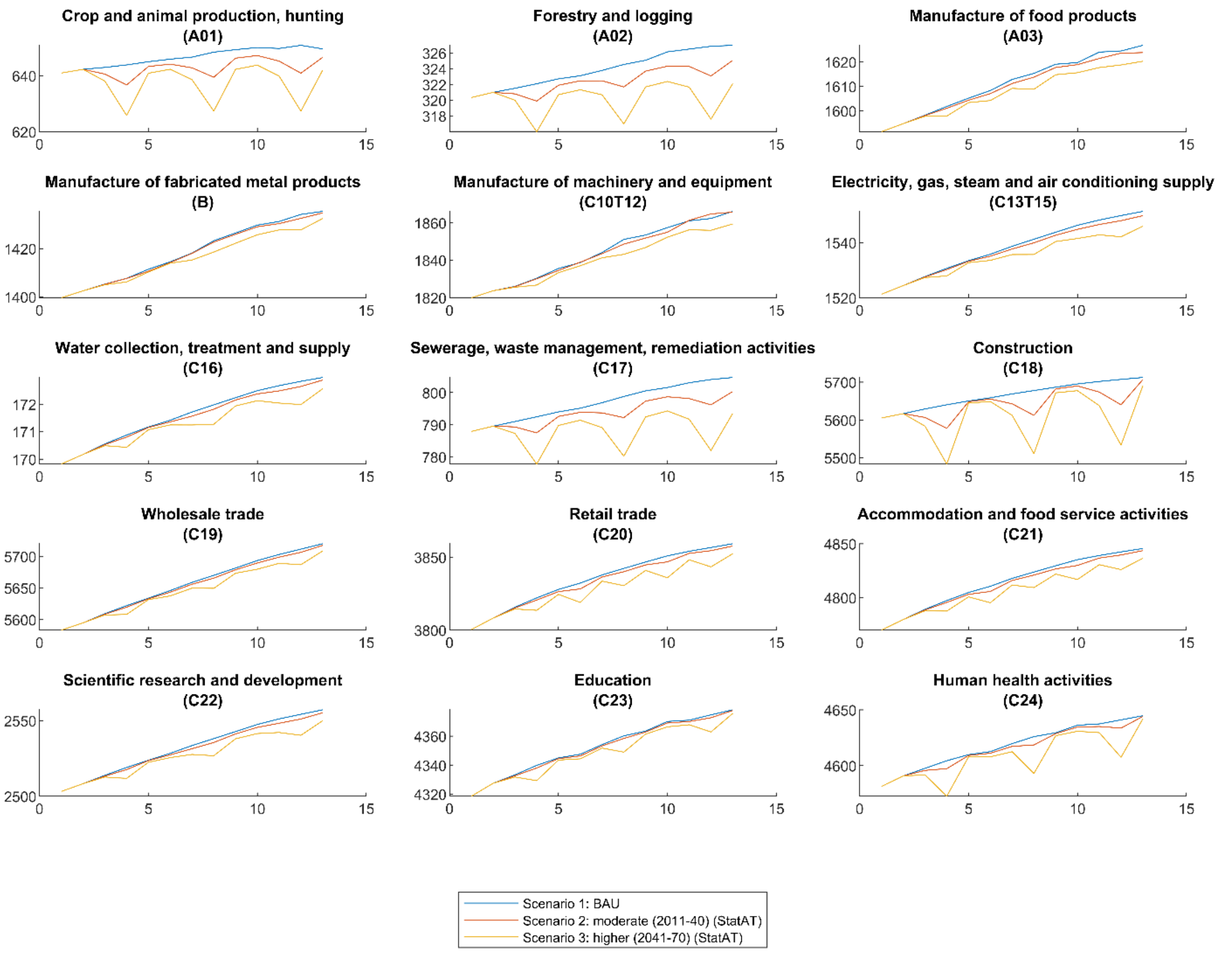


Figure 16: Trends of the sectoral gross value added in different climate change scenarios for Austria.

However, given the model architecture, it is easy to define new economic output variables and have them displayed or printed in addition to the standard macroeconomic outputs. This possibility will likely be exploited to tailor new output indicators for specific scenario simulations.

5.4.4.5 Adaption for Various National Economies

The ABM has previously been applied to assess the medium-run macroeconomic effects of lockdown measures taken in Austria to combat the COVID-19 pandemic [61], and to estimate the economic impacts of flood events in Austria [62].

For the SUNRISE project, the model is being continuously refined. A crucial part of development is dedicated to adapting the model to other national economies. With the given model architecture, data for other European countries can be used for calibration. Thus, simulations are possible for those economies as well. This model characteristic is highly relevant within the SUNRISE Project, given that simulations should be run for Italy, Spain, and Slovenia. This work on the adaptation is close to be completed and simulations for those countries will soon be possible.

5.4.4.6 Technical Implementation

The ABM is coded as a Matlab simulation and was originally developed by [61] in an open-access manner. Inputs listed in Table 7 are read from a local database using SQL commands and are mainly used for model calibration. Data required for model runs are stored as Matlab objects. This is to speed up computation for repeated model runs. For this pre-processing of the tables, separate code is available. Disaster- or model-specific inputs like shocks can be considered in several ways. One possibility are hard-coded values in the model based on external computations or elicitations. For example, this data can also be read from Excel or csv (or similar) tables. In this case, small adjustments to the code may be required to for loading of the data.

A complete model computation corresponds to a Monte Carlo simulation of individual model runs. One single model run consists of the iteration through the pre-set timesteps (in quarters), computing all prices/investments/expenditures etc. Random processes are added to the expectations of economic growth and prices, imports, exports, government consumption, and shocks. For each Monte Carlo step, new random elements are drawn. Usually, 500 Monte Carlo runs are specified. As those simulations are used to average out the effects of the random components, no burn-in phase has to be considered. Then, for each run, the aggregated macroeconomic and disaggregated sectoral indicators are computed.

The output variables specified in Table 9 are obtained by averaging over the results of the Monte Carlo runs. A script is available which runs all the described steps automatically and produces the figures as shown above. Besides the graphical output, the results are also exported as Excel files. Other graphical or non-graphical output formats can be implemented. The most useful case will be table-like data structures, but XML or JSON are also viable options.

The computation time heavily depends on the selected representation of the individual economy. In its original (i.e. complete) configuration for Austria, the model depicts the entire economy on a one-to-one basis with almost 9 million agents. This model version requires large computational resources, exceeding the capabilities of average personal computers. Therefore, a scaled-down version with only a thousandth of the agents exists and is used for our simulation purposes. Still, the model run for one single scenario takes about eight minutes on a 6-core Intel Core i5-8500 at 3GHz. Therefore, the ABM is primarily used for the simulation and evaluation of pre-defined scenarios.

5.4.5 Risk Assessment Model

This subsection aims to outline he theoretical background and the technical implementation of the risk assessment model to be implemented in the context of SUNRISE Strategy for Awareness and Resilience of Critical Infrastructures. The risk assessment will be executed by Hermes Bay through a proprietary computer platform. This platform, utilizing historical data and information inputted by the Critical Infrastructures themselves, will perform a customized risk assessment that these infrastructures face in the event of a pandemic or extreme climate situation.

5.4.5.1 Theoretical Background

In this section will be conducted an exploration of the theoretical foundation supporting the functionality of the mentioned platform. This is grounded in the risk analysis methodology utilized by Hermes Bay, as detailed below.

The initial phase of the above-mentioned methodology consists in a preliminary context analysis that aims to identify and define the environment in which Critical Infrastructure operates, the operational network they are located in, and the threats that they will potentially face.

As outlined in deliverable D1.1 "Local Meetings with Critical Infrastructures Stakeholders", the landscape surrounding CIs is becoming increasingly intricate due to rising natural disasters and the emergence of pandemic threats like COVID-19.

The increasing interdependency between European Critical Infrastructures makes clear the need for a comprehensive crisis management strategy. In fact, the interconnection between Critical Infrastructures makes them vulnerable to the propagation of cascading effects that amplifies the impact of the different threats, leading to global and cross-sectoral consequences that transcend individual entities or regions.

In order to get a representation as comprehensive as possible of the interconnections between various Critical Infrastructures in the European context, it has become necessary to draw upon information provided by the critical infrastructures themselves. Closed-ended questionnaires have therefore been developed, which operators will be required to complete. The completion of these questionnaires can be carried out within the profiling interface of the computer platform developed by Hermes Bay, as described in Section 5.4.5.2 of this document. This information will contribute to establishing the context upon which the risk analysis will be initiated. The risk analysis relies upon two primary metrics: one for potential threats and another for their associated impacts.

Regarding threats, an ontology has been developed to identify and classify potential threats that may impact Critical Infrastructures. In accordance with the objectives of SUNRISE, in this phase these threats have been categorized into two groups: Pandemic-Epidemic threats and threats related to extreme weather events. The extreme climate events threat set is additionally categorized according to the typology of climate-related event: avalanches, forest fires, droughts, heat waves, hurricanes, storms, floods, etc.

With the scope of elaborating a systemic propagation projection, it is also necessary to individuate the indirect threats, generally generated by the occurrence of a direct threat. There have been identified a maximum of five layers of indirect threat. The following Table 10 and Table 11 outline the first layer for each of the aforementioned categories, i.e., threats due to pandemics and extreme climate events.

Table 10: Potential threats due to pandemics or epidemics.

Pandemic-Epidemic	
Hospitals congestion	Mandatory vaccination
Shortage of medicine and medical device	
Mandatory social distancing	
Lack of manpower	
Mandatory mask wearing	
Mandatory quarantine for tested positive	
Border closure	

Table 11: Potential threats due to extreme climate events.

Avalanches	
Blocked Borders	Deaths
Blocked Roads	Missing People
Damaged Buildings	Injured People
Damaged Ski Infrastructure	
Forest Fires	
Damage To Power Lines	Smoke
Blocked Roads	Preacutionary Stop of Nearby Infrastructures
Damaged Roads	Wildstock Distress
Damaged Industrial Sites	Agricultural Damage
Injured People	Loss Of Wood
Closed Industrial Sites	Loss Of Biodiversity
Displaced People	Deaths
Droughts	
Agricultural Damage	Loss of Water for Civil Use
Reduction Of River Flows	
Irrigation Problems	
Wildstock Distress	
Water Rationing	
Loss Of Water for Livestock	
Loss Of Water for Industrial Uses	

Heat waves	
Damaged Industrial Sites	Increased Use Of Ac
Damage To Railroads	Wildstock Distress
Failure Of Cold Chain	Agricultural Damage
Increased Maintenance Cost	Less Electricity from Pv
Failure Of Cold Chain	Damaged Transport Means
Damaged Roads	
Heat Stress	
Hurricane	
Blocked Roads	Deaths
Overproduction Of Wind Electricity	Missing People
Communication Breakdown	Low Visibility
Damage To Power Lines	Injured People
Damaged Buildings	Global Internet Connections Damage
Damage To Railroads	Slippery Roads
Damaged Industrial Sites	Destroyed Bridges
Internet Outage	
Storms	
Blocked Roads	Lightnings
Communication Breakdown	Slippery Roads
Deaths	Less Insolation
Destroyed Bridges	Agricultural Damage
Destroyed Dams	
Damaged Industrial Sites	
Internet Outage	
Floods	
Blocked Roads	River Trasportation's Problems
Damaged Roads	Lost People
Destroyed Bridges	Flooded Agricultural Fields
Destroyed Dams	Damaged Industrial Sites
Destroyed Embankments	
Displaced People	
Flooded Building	

Each threat will be associated to a number, which quantifies the probability of it. In this case, the concept of probability must be understood as the likelihood of a threat to generate an impact on a CI or an organization. The threat indicator associated with each category originates from a list of open datasets, agreed among SUNRISE WP2 partners.

These datasets allow evaluation of pandemics through three primary metrics: the fatality rate, the incidence of confirmed positive cases, and the rate of hospital admissions. Systematic data collection and categorization are undertaken across different regions within designated member states, specifically encompassing France, Germany, Italy, Slovenia, and Spain. Regarding the assessment of Extreme Climatic Events, it involves a structured categorization process based on the abovementioned types of climatic occurrences. The dataset aggregates historical data pertaining to these events within designated states, further categorized by distinct regions.

To obtain a valuable result, each threat indicator will undergo a normalization process, yielding a threat score on a scale of 1 to 5. Concerning the pandemic threat, the regional threat score is derived from a weighted average of three indicators. In the case of extreme climate events, the threat score is determined through the normalization of individual indicators on a 1 to 5 scale. These scores represent the probability of direct threats impacting CIs and its associated supply chains at the time the analysis is conducted.

For what concern the impact, assessing the potential ramifications of various threats on the system involves categorizing them into five distinct domains: economic, reputational, operational, service quality and manpower. By examining the possible extent of damage or disruption, the user can better understand the impact at both the individual CI level and the systemic level.

The identified impact categories and their definition are listed below:

- **Economic impact:** The main impact registered after the occurrence of the selected threat is due to economic or financial losses. It should be considered the loss of profits and the actual damage caused by the selected threat.
- **Operational impact**: The main impact registered after the occurrence of the selected threat is due to organizational issues related to inefficacy/ disruption of internal procedures, lack of equipment, working teams' organization and management.
- **Manpower (HR) impact**: The main impact registered after the occurrence of the selected threat is due to lack personnel, sick-leaves, HR management problems…
- **Reputational impact:** The main impact registered after the occurrence of the selected threat is due to an "image" damage on the organization detected on social media, newspaper, and social network. Because of the registered impact the following topics should be considered: costumer reduction, drop in demand for service, discontent of clients.
- **Impact on service quality/service level:** The main impact registered after the occurrence of the selected threat is due to a reduction or disruption of service level that could lead to a contractual non-compliance, penalties or sanctions and lowering of service quality.

In regard of the impact metrics, it has been necessary to establish a comprehensive global impact severity metric scoring system grounded in an economic perspective. This entails the assignment of monetary values to five distinct metrics, thereby facilitating a nuanced evaluation of their respective influences.

The following scheme outlines the established impact levels. For each of these levels, the user can input the corresponding thresholds based on its own evaluation.

- Very Low/NA Impact
- Low Impact
- Medium Impact
- High Impact
- Critical Impact

In order to define the regional risk score for a given threat is necessary to multiply the probability score and the impact value associated with that threat. In instances where a threat results in multiple impacts, the highest impact category is selected. Furthermore, the risk outcomes undergo normalization on a scale ranging from 1 to 5. This systematic approach yields a distinct risk value for each direct and indirect threat chosen by the user. The user's comprehensive risk assessment is then established as the weighted average of all the individual risk scores corresponding to the selected threats.

The subsequent step in the risk assessment methodology involves evaluating the interdependencies among the Critical Infrastructures under analysis. The initial phase of this assessment entails reconstructing the network of interdependencies within which the infrastructure being assessed is situated. To conduct this activity, it is necessary for the operator to specify the corresponding NACE codes for each of their suppliers or for each sector deemed to be dependent. This will enable the determination of how many and from which sectors the operation of that critical infrastructure depends.

For identifying the criticality of each dependency link for the functioning of the infrastructure, the operator must specify, for each supplier, their Maximum Tolerable Period of Disruption (MTPD) following the unavailability of that service. This evaluation will be carried out by assigning a score from 1 to 5 to each indicated NACE code, as shown below:

1. **Very low dependency** - in case of supplier disruption business continuity is guaranteed for more than 1 month.
2. **Low dependency** - in case of supplier disruption business continuity is guaranteed from 2 weeks to 1 month.
3. **Medium dependency** - in case of supplier disruption business continuity is guaranteed from 5 days to 2 weeks.
4. **High dependency** - in case of supplier disruption business continuity is guaranteed from 1 day to 5 days.
5. **Critical dependency level** - in case of supplier disruption business continuity is guaranteed for less than 1 day.

Upon the determination of the global risk score and assessment of dependency extent, the computation of the What-if index becomes feasible. This index is derived by multiplying the user-defined dependency level with the supplier's risk score, normalized within a 1 to 5 score range. In instances where an infrastructure lacks a connection with a specific supplier in a sector, the supplier's risk score is computed as the average of the risk indices of users within that sector in the region.

The risk assessment methodology outlined above serves as the theoretical foundation upon which the functionality of the risk assessment tool has been defined. In the following section, the features of the model will be elaborated in detail.

5.4.5.2 Tool Functionality

The primary objective of the Risk Management Tool is to furnish Critical Infrastructure Operators and their Supply Chain Organizations with valuable insights in two key areas:

Monitoring and Prediction of Impacts:

- In the monitoring section, the tool assesses the likelihood of direct threats impacting a Critical Infrastructure and its supply chains.
- In the forecasting period of up to one week, the predictive score is influenced by factors including elapsed time, climate indicators, and measures such as Non-Pharmaceutical Interventions (NPI) and Pharmaceutical Interventions (PI), building upon real-time indicators.

Supporting Decision-Making for Business Continuity:

- The tool facilitates a comprehensive What-if analysis through structured processes, encompassing risk analysis (threat analysis and impact analysis), countermeasure assessment, and interdependencies evaluation.

The operativity of the Tool is based on the direct integration of data from relevant entities within critical infrastructures. These data, detailed in the previous section, are input into the model by operators themselves through the profiling section, the first interface users encounter after registering on the platform. Following the input of essential elements by each user, such as the geographical distribution of their facilities and suppliers at a regional level, along with corresponding NACE codes, the tool requires a series of user inputs including threat characterization, definition of impact metrics, and detailed information on the supply chain, including supplier details, industry specifications, location specifics, and dependency levels.

Once the required data input is completed by the user, they can access interfaces allowing them to monitor the risks they face individually and those arising from their supply chain. The tool performs additional functions, including providing datasets to enable real-time and forecasting modes, specifically in the threat and risk sections. It displays threat and impact scores on maps of countries and regions, along with declared values of supply chain interdependencies. The tool also lists possible countermeasures to enhance organizational security.

Based on the information provided by the user, the tool enables the creation of connections between the organizations' suppliers, providing users with specific assessments of the risk level for the connected organizations. This process is initiated through a request transmitted to the supplier once the user profiling is completed. This request must be accepted by the counterpart. If not accepted, the tool displays the average risk in the supplier sector. Upon receiving and confirming a connection request, suppliers gain access to information detailing the specific customer's dependency on them. This process is not confined to companies initiating connections; suppliers can also initiate connections with companies. Conversely, for suppliers with established connections, the user can explore their supplier network (suppliers of suppliers).

In evaluating risks, the regional risk score for each threat is determined by multiplying the probability score of the threat with its associated impact value. Subsequently, the risk results are normalized on a scale from 1 to 5, yielding a comprehensive risk value for each direct and indirect threat chosen by the user. Furthermore, the user's global risk value is derived as the weighted average of all the individual threats' risk scores, providing a consolidated assessment of overall risk. Simultaneously, the What-If index is computed by multiplying the user-defined dependency level with the supplier's risk score, and this index is normalized on a scale from 1 to 5. This metric aids in gauging the potential impact of dependencies within the organization. The tool offers a visually intuitive representation of dependencies through a cascading effect tree. This visualization illustrates direct suppliers, supplier sectors, and second-level suppliers in the supply chain, providing a holistic view of the network. In essence, the tool empowers organizations with the insights needed to proactively assess and mitigate potential disruptions, fostering a comprehensive risk management approach.

5.4.5.3 Countermeasures

This subsection outlines how the Risk Assessment Tool can assist users in identifying countermeasures to mitigate the effects of threats considered in the risk assessment. Currently, the tool allows users to manually input countermeasures that they intend to apply for each threat in a dedicated section. These countermeasures are then saved within the model and made visible to other users. Consequently, users can view the countermeasures implemented by others, along with the corresponding NACE codes. This functionality was initially designed to facilitate the identification of measures to be implemented for a specific threat for every Critical Infrastructure employing the tool.

However, during the WP2 workshop held in Vienna from January 30 to February 01, 2024, it was mutually agreed among partners that, to streamline the process for operators, the tool should include a predefined list of countermeasures for each threat already present in the system and outlined in the preceding section of this document. Users can then select the specific countermeasures they intend to implement from this predefined list.

5.5 Overview on Protective Measures

5.5.1 Non-pharmaceutical Interventions and Public Health Measures

Respiratory pandemics, including Influenza, affect a large proportion of the population and require rapid but continuous multisectoral response. For this reason, countries are engaged to develop pandemic plans describing their strategies for responding to a pandemic supported by operational plans at national and subnational levels. Preparing for an influenza pandemic is a continuous process of planning, exercising, revising, and translating into action national and subnational pandemic preparedness and response plans.

Resilience can be reached by systematic revision and updating of pandemic plans, depending on local and global changes, for instance, changes in global guidelines, new experience from other countries, trends on migration and climate change, etc.

According to the ECDC recommendations [63], pandemic preparedness is most effective if it is built on general principles that guide preparedness planning for any acute threat to public health. This includes the following:

- Pandemic preparedness, response and evaluation should be built on generic preparedness platforms, structures, mechanisms and plans for crisis and emergency management.
- To the extent possible, pandemic preparedness should aim to strengthen existing systems rather than developing new ones, in particular components of national seasonal influenza prevention and control programmes.
- New systems that will be implemented during a pandemic should be tested during the inter-pandemic period.
- Adequate resources must be allocated for all aspects of pandemic preparedness and response.
- The planning process, implementing what is planned, testing, and revising the plan in order for key stakeholders to familiarise themselves with the issues at hand, may be even more important than the pandemic plan itself.
- Pandemic response requires that business continuity plans and surge capacity plans be developed for the health sector and all other sectors that could be affected by a pandemic to ensure sustained capacity during a pandemic.
- The response to a pandemic must be evidence-based where this is available and commensurate with the threat. Planning should be based on pandemics of differing severity while the response is based on the actual situation determined by national and global risk assessments.
- Not all countries will be able to contribute to global risk assessment, nor conduct evaluations such as pandemic vaccine effectiveness. They must all have the capacity to access and interpret data for risk assessment provided by WHO, ECDC, and from other countries or sources.

During the COVID-19 pandemic public health and social measures or NPIs reduced the burden of the pandemic and other directly transmitted respiratory virus infections in many countries by reducing their transmissibility and susceptibility in the community. Timeliness of NPIs implementation and their effectiveness depend on various factors such as the phase of the pandemic, socio-economic and political context, behavioural insights, socio-economic impacts, and levels of uncertainty, etc. Behavioural factor was studies in large number of studies from different countries. The COVIMOD study from Germany [64] found general reduction in contact numbers in the German population and also a differential response to contact restriction measures based on risk status for severe COVID-19. People at higher risk of developing a severe outcome from a SARS-CoV-2 infection due to age or an underlying health condition had on a population level, fewer daily contacts during the pandemic than people at lower risk. Interestingly, the difference in the number of contacts between people at higher risk due to old age and those was not smaller during the pandemic than before. Furthermore, persons at higher risk due to their age increased their contacts less than those not when contact restriction measures were lifted. These differences should be considered when parametrising infectious disease models in pandemic settings. Experience from COVID-19 pandemic support different level of adherence to personal protective measures. It was found that a prior known infection of SARS-CoV-2 confirmed with a positive PCR test and vaccination against SARS-CoV-2 may have influenced compliance with certain behaviours during the pandemic in Germany [65].

The Public health and social measures (PHSM) Severity Index is composed of six indicators: (i) wearing of masks; (ii) school closures and adaption measures; (iii) offices, businesses, institutions and operations closures and adaptation measures; (iv) restrictions on gatherings; (v) restrictions on domestic movement; and (vi) limitations to international travel. These six indicators were chosen because they represent common categories of large-scale measures that have been implemented by a considerable number of countries throughout the WHO European Region. These measures aim to reduce the personal risk of infection or spread and the risk of acquiring or spreading COVID-19 infection in various community settings [66].

The PHSM Severity Index explicitly focuses on public health and social measures, its methodology and the countries covered. A standardized data-collection process, ordinal scales, a revised formula, indicator-specific data-coding principles and a unique coding validation method all distinguish the PHSM Severity Index from other government COVID-19 response trackers. The PHSM Severity Index sources its data from the WHO Regional Office for Europe's PHSM database, which provides detailed data on government responses across the 53 Member States of the WHO European Region. PHSM Severity Index data-collection principles ensure standardized data capture.

The PHSM Severity Index draws on several aspects of the Oxford COVID-19 Government Response Tracker (OxCGRT), which collects data on 23 indicators concerning government containment and closure policies, as well as economic, health system and vaccine policies [67] (9).

Evidence for effectiveness of some measures during COVID-19 pandemic are known. Some of PHSM indicators that are mentioned above were evaluated during retrospective observational study in Germany 2020-2022. Authors observed that open schools under hygiene measures and testing strategies contributed up to 20% of population infections during the omicron wave early 2022, and as little as 2% during vacations/school closures; about a third of students and teachers were infected during the omicron wave in early 2022 in Germany [68]. Mandatory mask wearing during class in all school types and reduced attendance models were associated with a reduced infection risk in schools.

In this subsection, available Influenza pandemic plans for European countries are evaluated as an example for using of a multi-faceted approach to controlling the spread of the virus. NPIs for the population include isolation and quarantine, hygiene measures, closures of educational facilities and mass events as well as general lockdowns. Table 12 provides a comprehensive overview of the pandemic plans and NPIs that 20 countries of EU, Norway and UK have in place to respond to an influenza pandemic.

Table 12: NPIs planned in European Influenza pandemic plans (updated from D2.1)

#	Country, year	Quarantine	Hygiene	Closure of shops/ venues	Closure of education facilities	Closure of mass events	General lockdown
1.	Austria (2006)						
2.	Belgium (2006)						
3.	Croatia (2005)						
4.	Cyprus (2005)						
5.	Czech Rep. (2006)						
6.	Finland (2012)						
7.	France (2011)						

8.	Germany (2016)	Green	Green	Red	Green	Green	Red
9.	Greece (2009)	Green	Green	Red	Green	Green	Red
10.	Hungary (2008)	Green	Green	Red	Green	Green	Red
11.	Iceland (2016)	Green	Green	Red	Green	Green	Red
12.	Ireland (2007)	Yellow	Green	Red	Red	Red	Red
13.	Italy (2021)	Yellow	Green	Red	Green	Yellow	Red
14.	Latvia (2015)	Yellow	Green	Red	Green	Red	Red
15.	Lithuania (2016)	Yellow	Green	Red	Yellow	Yellow	Red
16.	Luxembourg (2006)	Yellow	Green	Red	Green	Green	Red
17.	Norway (2016)	Yellow	Yellow	Red	Yellow	Yellow	Red
18.	Poland (2009)	Green	Green	Yellow	Green	Red	Red
19.	Portugal (2006)	Green	Green	Red	Yellow	Yellow	Red
20.	Slovakia (2012)	Green	Green	Red	Green	Red	Red
21.	Spain (2006)	Yellow	Yellow	Red	Red	Red	Red
22.	UK (2011)	Green	Green	Red	Green	Green	Red

Yellow - measures that have been mentioned but not described in detail.

Green - measures that are thoroughly explained and detailed.

Red - measures that have not been mentioned or discussed in any way.

The data shown indicates that the countries' pandemic plans differed in terms of details and content. The measures that have been marked in green suggest that in their plans the countries laid out a clear and comprehensive understanding of the measures they plan to implement and how. Yellow marking suggests that countries have plans in place, albeit rather lacking in detail. The measures that have been marked in red suggest that countries have not discussed or mentioned these measures in the pandemic plans assessed.

The majority of evaluated pandemic plans suggest a detailed plan of implementation and a comprehensive understanding of for quarantine, hygiene measures and closure of education facilities, as a population NPIs. Regulations for closure of mass events are provided only in one-third of countries. At the same time, the closure of shops and venues and the general lockdown are not anticipated.

Overall, we show that European countries are taking the threat of an influenza pandemic seriously and have response plans. However, it also highlights the need for more detailed and comprehensive plans to be developed and communicated to the public.

Table 13 presents findings of evaluation of Influenza pandemic plans and maintenance of CIs in European countries. Key infrastructures such as health, education, transport, energy, water, were assessed. Population NPIs mentioned above were qualitatively described in plans of countries exclusively for Health sector. Only plans from Czech Republic and Latvia suggest full regulations for Educational and Transport sectors of CIs, from Luxemburg – for Transport and Energy sectors. Countries, like France, Belgium, Norway mentioned that NPIs also should take place in another sectors, but do not provide details and clear explanations.

Table 13: Interactions between NPIs and CIs in European Influenza pandemic plans (updated from D2.1)

#	Country, year	Health	Education	Transport	Energy	Water
1.	Austria (2006)	Green	Red	Red	Red	Red
2.	Belgium (2006)	Green	Yellow	Yellow	Red	Yellow
3.	Croatia (2005)	Green	Red	Red	Red	Red
4.	Cyprus (2005)	Green	Red	Red	Red	Red
5.	Czech Rep-c (2006)	Green	Green	Green	Red	Red
6.	Finland (2012)	Green	Red	Red	Red	Red
7.	France (2011)	Yellow	Red	Yellow	Yellow	Yellow
8.	Germany (2016)	Green	Red	Red	Red	Red
9.	Greece (2009)	Green	Red	Green	Red	Red
10.	Hungary (2008)	Green	Red	Yellow	Red	Red
11.	Iceland (2016)	Green	Red	Red	Red	Red
12.	Ireland (2007)	Green	Red	Red	Red	Red
13.	Italy (2021)	Green	Red	Red	Red	Red
14.	Latvia (2015)	Green	Green	Green	Red	Red
15.	Lithuania (2016)	Green	Green	Red	Red	Red
16.	Luxembourg (2006)	Green	Red	Green	Green	Red
17.	Norway (2016)	Green	Yellow	Yellow	Yellow	Yellow
18.	Poland (2009)	Green	Red	Red	Red	Red
19.	Portugal (2006)	Green	Red	Red	Red	Red
20.	Slovakia (2012)	Green	Red	Red	Red	Red
21.	Spain (2006)	Green	Red	Red	Red	Red
22.	UK (2011)	Green	Red	Green	Red	Red

Yellow - measures that have been mentioned but not described in detail.
Green - measures that are thoroughly explained and detailed.
Red - measures that have not been mentioned or discussed in any way.

Our findings show that pandemic plans for respiratory infection outbreaks inadequately anticipated the measures taken and mainly focused on the healthcare system. Recommendations for the implementation of PNPIs for other critical infrastructures, except healthcare, and essential services were mentioned only partially in the pandemic plans; a general lockdown was not anticipated. Changes in existing pandemic plans are needed to strengthen the preparedness of European countries for future respiratory pathogen outbreaks.

5.5.2 Economic Measures and Legal Support

Within the course of the COVID-19 pandemic governments across the globe introduced a variety of measures aiming to keep the negative repercussions on the economy in check. This subchapter provides a brief overview over governments' responses providing economic support that were in place between during the pandemic between 2020 and 2021 and discusses, which protective measures might be suitable in advance to prepare for a similar crisis. Special attention is given to Austria, which serves as a case study.

5.5.2.1 Economic Measures During the COVID-19 Pandemic

Most countries introduced special economic policies to tackle the effect of the pandemic on the economy. Hale et al. [67], [69] distinguish between four different categories of economic responses: income support, debt or contract relief for households, fiscal measures and international support. These indicators comprise the Oxford COVID-19 Government Response Tracker (OxCGRT) "economic support index", which covered the policies of more than 180 countries, and does not claim completeness. It does not, for instance, include economic support given directly to companies. Overall, Hale et al. [67] note a large overlap in the implemented measures and timeframes across their sample of countries in the first few months of the pandemic and increasingly diverging paths afterwards.

Income support refers to direct cash transfers to people who lost their jobs or were unable to work during the pandemic. In these cases, the government replaced a certain percentage of the lost income. Within the year 2020, over 80 percent of the 183 countries in [69] introduced some kind of income support, roughly half of them reduced the policy during the year and about 10 percent of countries reimposed income support after a previous reduction. Over 20 percent of countries replaced at least 50 percent of the lost salaries. Some countries introduced income support on a national level, while others targeted specific regions. Austria, for instance, introduced lump-sum payments for the unemployed and increased the financial assistance for long-term unemployed people [70].

A vast majority of countries launched economic policies that provided temporary relief of financial obligations to households, such as not cutting water or electricity access despite unpaid bills or temporarily stopping mortgage payments and other loans. Almost 90 percent of countries aided households with their debts or contracts during 2020 in some shape or form, though not necessarily on a national level. Around 30 percent of the 183 sample countries reduced the support during the year and less than 10 percent reintroduced the policy [69].

Fiscal measures refer to financial stimuli via government spending or tax cuts. Hale et al. [67] note that this indicator is ambiguous, because they sometimes included ill-defined bundles of policies in this category. Austria lowered the taxes on wages and increased the tax-deductible amount for transportation and social insurance [70]. Apart from providing relief for their own respective economies, some governments also supported other countries with aid spending. Beyond the OxCGRT index, there were various economic policies targeted especially at the firm-level. Austria, for example, sought to stimulate investment activities of companies by offering an investment bonus and creating the option of a degressive deprecation. Another economic measure was a loss carryback to increase the liquidity of companies. A rather special construct was the introduction of "Short-time work", which was based on an agreement between employers, employee representatives and the Austrian government and aimed at preventing layoffs [70].

5.5.2.2 Potential Preparatory and Protective Economic Measures

To achieve a better preparation for future pandemics or similar events, it is crucial to reflect upon the lessons learnt and consider potential protective measures that can be taken before the next crisis strikes.

While we cannot predict when the next pandemic or similar event will take place, we could focus on laying the legal foundations. It is advisable to continue to inspect the costs and benefits of all the economic (and other) measures that were taken during the COVID-19 pandemic, assess their usefulness and create the statutory framework to ease a swift deployment of the best measures whenever needed again. Returning to the case of Austria, one of the stabilizing economic measures that has proven its worth is "short-time work" [70]. A cost-benefit analysis of short-time work would be comparably easy to calculate, as it is already partly implemented in the IHS agent-based model.

Another protective measure that needs a long time to prepare is the diversification of supply chains. A reduced dependency on a single or only a few supplier(s) would, of course, be beneficial with and without the context of a pandemic. Furthermore, increased inventory stocks of non-perishable goods could reduce economic damages in case of delivery problems. Diverging from the “just in time” concept, however, will not be feasible in all industries.

6 Conclusions

This deliverable describes the SUNRISE Strategy for improving the awareness and resilience of PSCEs, i.e., critical entities that are particularly affected by a pandemic. Therefore, the SUNRISE Strategy Process is defined, a generic step-by-step guideline to and to achieve the SUNRISE Strategy's vision and mission statements. The strategy process is inspired by classical risk and resilience management frameworks but has a strong focus on the combined assessment of the consequences and effects a pandemic might have on the various aspects of social life. To achieve that, the process designed in this deliverable includes five main steps with several sub-steps.

It starts with the initial setup of the process' context, which involves a strong collaboration and exchange with CI operators. One step is dedicated to the identification and analysis of the pandemic, which includes the characteristics of the pathogen and the development of potential threat scenarios. The core part of the process involves the evaluation and assessment of the consequences based on multiple criteria, which include the effects on the population (i.e., peoples' health), on PSCEs (i.e., how much vital services and CIs are affected), on the economy (i.e., the monetary costs of induce by the pandemic and the respective countermeasures) and on the society (i.e., psychological and societal effects). Additionally, available measures are evaluated, which are effective in the consequence domains defined before. The process closes with an estimation of the effects of these measures and the development of an implementation plan.

In addition to the SUNRISE Strategy Process, the deliverable also describes a collection of methodologies and tools that can be used in the various steps of the process. These range from straight-forward methodologies to interact with operators of critical entities up to specific tools for the simulation of epidemiological models, cascading effects and economic impacts. Additionally, a risk assessment model is described that integrates all of these individual approaches into one framework to provide operators and political decision makers with a holistic overview on potential consequences of the pandemic and the optimal methods to counter them.

In this first version of the Deliverable D2.2, the strategy's mission statements from Section 2.2 are already completely covered by the structure of the strategy process. Mission 1 on the awareness of the novel threat landscape is achieved by the assessment of the pathogen described in Section 4.2 and the detailed analysis of the multi-criterial consequences described in Section 4.3 (and achieved by the various simulation approaches in Section 5.4). With the integration of the climate change model (cf. Section 5.4.2) also the aspect of novel pathogens coming to Europe in the future is included. The definition of PSCEs as provided in Section 3.4 together with the identification process described in Section 5.2 fully supports Mission 2 on deepening the understanding about vital services during a pandemic.

The strategy's Mission 3 , which is dealing with the risk assessment dedicated to pandemic threats, is accounted for on a conceptual level by the entire strategy process (particularly by analysis of potential consequences in Section 4.3, the evaluation of available measures in Section 4.4 and the combined evaluation of the risk and resilience in Section 4.5) and on a technical level by the integrated risk assessment tool described in Section 5.4.5. Accordingly, also Mission 4 of the strategy, which is focusing on the different countermeasures, is covered with the explanations on NPIs, public health measures and economic measures given in Section 5.5. Finally, the realization of Mission 5, an increased collaboration among the operators of PSCEs, is ensured by the continuous involvement of stakeholders throughout the SUNRISE Strategy Process in the form of workshops.

With regards to the objectives from Section 2.3, some still remain open and will be fully covered in the second version of the deliverable that is due in M33. For example, the detailed collection of pandemic-related threats will be developed and extended as part of the scenario definition for the validation process and of the workshops carried out in WP1. Similarly, a list of PSCEs for the individual regions in

Slovenia, Italy and Spain will be provided as part of the second version of Deliverable D2.2 by applying the identification process described in Section 5.2. However, Objective 3, Objective 4 and Objective 5 can be seen as achieved since the risk assessment methodology and an indicative list of available countermeasures is provided in Section 5.4.5 and Section 5.5, respectively. As already mentioned in the previous paragraph, the active collaboration among PSCE operators and decision makers from regional or national governmental bodies is achieved by their involvement in national and international workshops in the second half of the project.

The results of this deliverable will be used twofold: first, they are directly used in Deliverable D2.3, as this deliverable describes the process that will be implemented to validate the SUNRISE Strategy; as part of that, the different tools presented in Section 5.4 will be tested and evaluated. Second, the results are used in WP1 to support the design of the next national and international workshops with end users and other stakeholders that will take place during the second half of the project in Slovenia, Italy and Spain as well as online. Therein, the concept of the SUNRISE Strategy, its structure and the general process will be discussed with the participants and their feedback will be integrated into the Strategy, where possible.

References

[1] S. M. Rinaldi, J. P. Peerenboom, and T. K. Kelly, ‘Identifying, understanding, and analyzing critical infrastructure interdependencies’, IEEE Control Syst. Mag., vol. 21, no. 6, pp. 11–25, Dec. 2001, doi: 10.1109/37.969131

[2] K. A. Pesch-Cronin and N. E. Marion, Critical Infrastructure Protection, Risk Management, and Resilience: A Policy Perspective. Boca Raton: CRC Press, 2016. doi: 10.1201/9781315310657

[3] C. Scholz, S. Schauer, and M. Latzenhofer, ‘The emergence of new critical infrastructures. Is the COVID-19 pandemic shifting our perspective on what critical infrastructures are?’, Int. J. Disaster Risk Reduct., vol. 83, p. 103419, Dec. 2022, doi: 10.1016/j.ijdrr.2022.103419

[4] A. Hassanzadeh et al., ‘A Review of Cybersecurity Incidents in the Water Sector’, J. Environ. Eng., vol. 146, no. 5, p. 03120003, May 2020, doi: 10.1061/(ASCE)EE.1943-7870.0001686

[5] R. Setola, ‘Analysis of Interdependencies Between Italy’s Economic Sectors’, in Critical Infrastructure Protection, E. Goetz and S. Shenoi, Eds., in IFIP International Federation for Information Processing. Boston, MA: Springer US, 2008, pp. 311–321. doi: 10.1007/978-0-387-75462-8_22

[6] G. Oliva, S. Panzieri, and R. Setola, ‘Agent-based input–output interdependency model’, Int. J. Crit. Infrastruct. Prot., vol. 3, no. 2, pp. 76–82, Jul. 2010, doi: 10.1016/j.ijcip.2010.05.001

[7] S. Cavallini et al., ‘A System Dynamics Framework for Modeling Critical Infrastructure Resilience’, in Critical Infrastructure Protection VIII, J. Butts and S. Shenoi, Eds., in IFIP Advances in Information and Communication Technology. Berlin, Heidelberg: Springer, 2014, pp. 141–154. doi: 10.1007/978-3-662-45355-1_10

[8] European Commission, Council Directive 2008/114/EC of 8 December 2008 on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection (Text with EEA relevance), vol. 345. 2008. Available: http://data.europa.eu/eli/dir/2008/114/oj/eng. [Accessed: Mar. 10, 2024]

[9] European Commission, ‘Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union’. Available: https://eur-lex.europa.eu/eli/dir/2016/1148. [Accessed: Mar. 10, 2024]

[10] European Commission, ‘Directive (EU) 2022/2555 of the European Parliament and of the Council of 14 December 2022 on measures for a high common level of cybersecurity across the Union, amending Regulation (EU) No 910/2014 and Directive (EU) 2018/1972, and repealing Directive (EU) 2016/1148 (NIS 2 Directive)’. Available: https://eur-lex.europa.eu/eli/dir/2022/2555. [Accessed: Mar. 10, 2024]

[11] European Commission, ‘Directive (EU) 2022/2557 of the European Parliament and of the Council of 14 December 2022 on the resilience of critical entities and repealing Council Directive 2008/114/EC’. Available: https://eur-lex.europa.eu/eli/dir/2022/2557. [Accessed: Mar. 10, 2024]

[12] ERNCIP, ‘ERNCIP Website’. Available: https://erncip-project.jrc.ec.europa.eu/. [Accessed: Mar. 10, 2024]

[13]ECSCI, 'ECSCI Website'. Available: https://www.finsec-project.eu/ecsci. [Accessed: Mar. 10, 2024]

[14]BeReady, 'BeReady Website'. Available: https://beready4pandemics.eu/. [Accessed: Mar. 10, 2024]

[15]M. Porta, 'A Dictionary of Epidemiology', in A Dictionary of Epidemiology, Oxford University Press, 2016. Available: https://www.oxfordreference.com/display/10.1093/acref/9780199976720.001.0001/acref-9780199976720?btog=chap&hide=true&skipEditions=true&source=%2F10.1093%2Facref%2F9780199976720.001.0001%2Facref-9780199976720. [Accessed: Mar. 17, 2024]

[16]World Health Organization (WHO), 'Emergencies: International health regulations and emergency committees', 2019. Available: https://www.who.int/news-room/questions-and-answers/item/emergencies-international-health-regulations-and-emergency-committees. [Accessed: Mar. 17, 2024]

[17]T. H. Tulchinsky and E. A. Varavikova, 'Communicable Diseases', New Public Health, pp. 149–236, 2014, doi: 10.1016/B978-0-12-415766-8.00004-5

[18]UNDP, 'The Climate Dictionary: An everyday guide to climate change', UNDP Climate Promise. Available: https://climatepromise.undp.org/news-and-stories/climate-dictionary-everyday-guide-climate-change. [Accessed: Mar. 10, 2024]

[19]Deutscher Wetterdienst, 'Climate prediction'. Available: https://www.dwd.de/EN/climate_environment/climateresearch/climateprediction/climateprediction_node.html. [Accessed: Mar. 10, 2024]

[20]International Organization for Standardization (ISO), ISO/IEC 31000:2018 Risk Management - Principles and Guidelines. Geneva, Switzerland, 2018. Available: https://www.iso.org/iso-31000-risk-management.html

[21]International Organization for Standardization (ISO), ISO/IEC 27005:2022 Information technology - Security techniques - Information security risk management. Geneva, Switzerland, 2022. Available: http://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/07/52/75281.html. [Accessed: Mar. 10, 2024]

[22]K. Sherratt et al., 'Predictive performance of multi-model ensemble forecasts of COVID-19 across European nations', eLife, vol. 12, p. e81916, Apr. 2023, doi: 10.7554/eLife.81916

[23]MONID, 'German Modelling Network for Severe Infectious Diseases'. Available: https://webszh.uk-halle.de/monid/?page_id=873&lang=en. [Accessed: Mar. 10, 2024]

[24]World Health Organization (WHO), 'Influenza surveillance outputs'. Available: https://www.who.int/teams/global-influenza-programme/surveillance-and-monitoring/influenza-surveillance-outputs. [Accessed: Mar. 10, 2024]

[25]ECDC, 'Surveillance for seasonal influenza', Jun. 11, 2010. Available: https://www.ecdc.europa.eu/en/seasonal-influenza/surveillance-reports-and-disease-data. [Accessed: Mar. 10, 2024]

[26]ECDC, ‘European Influenza Surveillance Network (EISN)’, May 19, 2017. Available: https://www.ecdc.europa.eu/en/about-us/partnerships-and-networks/disease-and-laboratory-networks/eisn. [Accessed: Mar. 10, 2024]

[27]S. Beermann, M. Dörr, E. Grill, A. Karch, B. Lange, and H. Zeeb, ‘Die Rolle epidemiologischer Forschung in Gesundheitskrisen’, Dtsch Ärztebl., vol. 119, no. 7, pp. 753–757, 2022.

[28]M. Harries et al., ‘Bridging the gap - estimation of 2022/2023 SARS-CoV-2 healthcare burden in Germany based on multidimensional data from a rapid epidemic panel’, Int. J. Infect. Dis., vol. 139, pp. 50–58, Feb. 2024, doi: 10.1016/j.ijid.2023.11.014

[29]B. Lange et al., ‘Estimates of protection levels against SARS-CoV-2 infection and severe COVID-19 in Germany before the 2022/2023 winter season: the IMMUNEBRIDGE project’, Infection, vol. 52, no. 1, pp. 139–153, Feb. 2024, doi: 10.1007/s15010-023-02071-2

[30]CDC, ‘Nonpharmaceutical Interventions (NPIs)’, Oct. 04, 2022. Available: https://www.cdc.gov/nonpharmaceutical-interventions/index.html. [Accessed: Mar. 10, 2024]

[31]TWCCF, ‘World Cafe Method’, The World Cafe, Jul. 04, 2015. Available: https://theworldcafe.com/key-concepts-resources/world-cafe-method/. [Accessed: Mar. 10, 2024]

[32]Champlain College, ‘5-D Cycle of Appreciative Inquiry’, The Appreciative Inquiry Commons. Available: https://aicommons.champlain.edu/learn/appreciative-inquiry-introduction/5-d-cycle-appreciative-inquiry/. [Accessed: Mar. 10, 2024]

[33]World Health Organization (WHO), ‘Pandemic Influenza Severity Assessment (PISA): A WHO guide to assess the severity of influenza epidemics and pandemics’, Geneva, Switzerland, 2017. Available: https://iris.who.int/bitstream/handle/10665/259392/WHO-WHE-IHM-GIP-2017.2-eng.pdf?sequence=1&isAllowed=y

[34]World Health Organization (WHO), ‘Pandemic Influenza Risk Management’, Geneva, Switzerland, 2013. Available: https://www.who.int/publications-detail-redirect/pandemic-influenza-risk-management. [Accessed: Mar. 19, 2024]

[35]World Health Organization (WHO), ‘Tool for Influenza Pandemic Risk Assessment (TIPRA)’, Geneva, Switzerland, 2020. Available: https://cdn.who.int/media/docs/default-source/influenza/tipra_guidance_version-2_20211008.pdf?sfvrsn=88132b6c_6&download=true

[36]World Health Organization (WHO), ‘Rapid Risk Assessment of Acute Public Health Events’, Geneva, Switzerland, 2012. Available: https://iris.who.int/bitstream/handle/10665/70810/WHO_HSE_GAR_ARO_2012.1_eng.pdf?sequence=1

[37]CDC, ‘Influenza Risk Assessment Tool (IRAT)’, Jun. 30, 2023. Available: https://www.cdc.gov/flu/pandemic-resources/national-strategy/risk-assessment.htm. [Accessed: Mar. 19, 2024]

[38]CDC, ‘Pandemic Severity Assessment Framework (PSAF)’, Jul. 11, 2023. Available: https://www.cdc.gov/flu/pandemic-resources/national-strategy/severity-assessment-framework.html. [Accessed: Mar. 19, 2024]

[39]R. Holloway, S. A. Rasmussen, S. Zaza, N. J. Cox, and D. B. Jernigan, ‘Updated Preparedness and Response Framework for Influenza Pandemics’, MMWR, vol. 63, no. RR-6, pp. 1–9, 2014.

[40]I. Rodiah et al., ‘Age-specific contribution of contacts to transmission of SARS-CoV-2 in Germany’, Eur. J. Epidemiol., vol. 38, no. 1, pp. 39–58, Jan. 2023, doi: 10.1007/s10654-022-00938-6

[41]H. Setchell, ‘ECMWF Reanalysis v5’, ECMWF, Feb. 19, 2020. Available: https://www.ecmwf.int/en/forecasts/dataset/ecmwf-reanalysis-v5. [Accessed: Mar. 19, 2024]

[42]Climate-ADAPT, ‘Universal Thermal Climate Index, 1979-2020’, 2024. Available: https://climate-adapt.eea.europa.eu/en/metadata/indicators/thermal-comfort-indices-universal-thermal-climate-index-1979-2019?set_language=en. [Accessed: Mar. 19, 2024]

[43]Hereon, ‘Euro Cordex EURO-CORDEX Data’, 2024. Available: https://euro-cordex.net/060378/index.php.en. [Accessed: Mar. 19, 2024]

[44]Lawrence Livermore National Laboratory, ‘Coupled Model Intercomparison Project Phase 5’, 2024. Available: https://pcmdi.llnl.gov/mips/cmip5/. [Accessed: Mar. 19, 2024]

[45]H. Hooyberghs, E. Ducheyne, J. Berckmans, F. Lefebre, K. De Ridder, and G. Hendrickx, ‘Climatic suitability for the presence and seasonal activity of the Aedes albopictus mosquito for Europe derived from climate projections. Copernicus Climate Change Service (C3S) Climate Data Store (CDS)’, 2019. Available: https://cds.climate.copernicus.eu/cdsapp#!/dataset/sis-health-vector?tab=overview. [Accessed: Mar. 10, 2024]

[46]ECMWF, ‘Climatic suitability and seasonal activity of the tiger mosquito for Europe’. Available: https://cds.climate.copernicus.eu/apps/c3s/app-health-aedes-albopictus-projections?variable=Suitability%20index. [Accessed: Mar. 10, 2024]

[47]S. König, S. Rass, B. Rainer, and S. Schauer, ‘Hybrid Dependencies Between Cyber and Physical Systems’, in Intelligent Computing, K. Arai, R. Bhatia, and S. Kapoor, Eds., Cham: Springer International Publishing, 2019, pp. 550–565.

[48]S. König, S. Schauer, and S. Rass, ‘A Stochastic Framework for Prediction of Malware Spreading in Heterogeneous Networks’, in Secure IT Systems: 21st Nordic Conference, NordSec 2016, Oulu, Finland, November 2-4, 2016. Proceedings, B. B. Brumley and J. Röning, Eds., Cham: Springer International Publishing, 2016, pp. 67–81. doi: 10.1007/978-3-319-47560-8_5. Available: https://doi.org/10.1007/978-3-319-47560-8_5

[49]S. König, A. Gouglidis, S. Rass, N. Adams, P. Smith, and D. Hutchison, ‘Analyzing Disaster-Induced Cascading Effects in Hybrid Critical Infrastructures: A Practical Approach’, in Guide to Disaster-Resilient Communication Networks, J. Rak and D. Hutchison, Eds., in Computer Communications and Networks. Cham: Springer International Publishing, 2020, pp. 769–789. doi: 10.1007/978-3-030-44685-7_31. Available: https://doi.org/10.1007/978-3-030-44685-7_31. [Accessed: May 10, 2022]

[50]C. Lévy-Bencheton, L. Marinos, R. Mattioli, T. King, C. Dietzel, and J. Stumpf, ‘Threat Landscape and Good Practice Guide for Internet Infrastructure’. European Union Agency for Network and Information Security (ENISA), Jänner 2015. Available: http://www.enisa.europa.eu/activities/risk-management/evolving-threat-environment/threat-landscape-of-the-internet-infrastructure/iitl. [Accessed: Jan. 23, 2015]

[51]C. Cimpanu, ‘Port of San Diego suffers cyber-attack, second port in a week after Barcelona’, ZDNet, Sep. 27, 2018. Available: https://www.zdnet.com/article/port-of-san-diego-suffers-cyber-attack-second-port-in-a-week-after-barcelona/

[52]ISA, The 62443 series of standards. 2016. Available: http://isa99.isa.org/Public/Information/The-62443-Series-Overview.pdf

[53]R. Bacher and U. Näf, ‘Report on the blackout in Italy on 28 September 2003’. Nov. 2003. Available: http://www.bfe.admin.ch/php/modules/publikationen/stream.php?extlang=en&name=en_109363212.pdf. [Accessed: Jan. 23, 2015]

[54]S. Schauer, T. Grafenauer, S. König, M. Warum, S. Rass, and S. Rass, ‘Estimating Cascading Effects in Cyber-Physical Critical Infrastructures’, in Critical Information Infrastructures Security, in Lecture Notes in Computer Science. Linköping, Sweden: Springer International Publishing, 2020, pp. 43–56.

[55]S. Schauer et al., ‘Conceptual Framework for Hybrid Situational Awareness in Critical Port Infrastructures’, in Critical Information Infrastructures Security, E. Luiijf, I. Žutautaitė, and B. M. Hämmerli, Eds., Cham: Springer International Publishing, 2018, pp. 191–203. doi: 10.1007/978-3-030-05849-4_15. Available: http://link.springer.com/10.1007/978-3-030-05849-4_15. [Accessed: Jan. 23, 2019]

[56]PRAETORIAN, ‘H2020 PRAETORIAN – Protection of Critical Infrastructures from advanced combined cyber and physical threats’. Available: https://praetorian-h2020.eu/. [Accessed: Mar. 10, 2024]

[57]PRECINCT, ‘H2020 PRECINCT - Preparedness and Resilience Enforcement for Critical INfrastructure Cascading Cyberphysical Threats and effects with focus on district or regional protection’. Available: https://www.precinct.info/. [Accessed: Mar. 10, 2024]

[58]Y. Okuyama and J. R. Santos, ‘Disaster Impact and Input–Output Analysis’, Econ. Syst. es., vol. 26, no. 1, pp. 1–12, Jan. 2014, doi: 10.1080/09535314.2013.871505

[59]L. Galbusera and G. Giannopoulos, ‘On input-output economic models in disaster impact assessment’, Int. J. Disaster Risk Reduct., vol. 30, pp. 186–198, Sep. 2018, doi: 10.1016/j.ijdrr.2018.04.030

[60]Y. Okuyama, ‘A few good models for economic analysis of disasters: can your model handle the truth?’, Chapters, pp. 30–49, 2022.

[61]S. Poledna, M. G. Miess, C. Hommes, and K. Rabitsch, ‘Economic forecasting with an agent-based model’, Eur. Econ. Rev., vol. 151, p. 104306, Jan. 2023, doi: 10.1016/j.euroecorev.2022.104306

[62]G. Bachner, N. Knittel, S. Poledna, S. Hochrainer-Stigler, and K. Reiter, ‘Revealing indirect risks in complex socioeconomic systems: A highly detailed multi-model analysis of flood events in Austria’, Risk Anal., vol. 44, no. 1, pp. 229–243, 2024, doi: 10.1111/risa.14144

[63]ECDC, ‘Why is pandemic preparedness planning important?’, Nov. 17, 2017. Available: https://www.ecdc.europa.eu/en/seasonal-influenza/preparedness/why-pandemic-preparedness. [Accessed: Mar. 10, 2024]

[64]J. Walde et al., 'Effect of risk status for severe COVID-19 on individual contact behaviour during the SARS-CoV-2 pandemic in 2020/2021—an analysis based on the German COVIMOD study', BMC Infect. Dis., vol. 23, no. 1, p. 205, Apr. 2023, doi: 10.1186/s12879-023-08175-2

[65]R. Kettlitz et al., 'Association of known SARS-CoV-2 serostatus and adherence to personal protection measures and the impact of personal protective measures on seropositivity in a population-based cross-sectional study (MuSPAD) in Germany', BMC Public Health, vol. 23, no. 1, p. 2281, Nov. 2023, doi: 10.1186/s12889-023-17121-5

[66]World Health Organization (WHO), 'A systematic approach to monitoring and analysing public health and social measures in the context of the COVID-19 pandemic', Copenhagen, Denmark, 2022. Available: https://iris.who.int/bitstream/handle/10665/357854/WHO-EURO-2022-1610-41361-65165-eng.pdf?sequence=2

[67]T. Hale et al., 'Variation in government responses to COVID-19', Var. Gov. Responses COVID-19, 2023, Available: https://www.bsg.ox.ac.uk/research/publications/variation-government-responses-covid-19. [Accessed: Mar. 10, 2024]

[68]T. Heinsohn et al., 'Infection and transmission risks of COVID-19 in schools and their contribution to population infections in Germany: A retrospective observational study using nationwide and regional health and education agency notification data', PLOS Med., vol. 19, no. 12, p. e1003913, Dec. 2022, doi: 10.1371/journal.pmed.1003913

[69]T. Hale et al., 'A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker)', Nat. Hum. Behav., vol. 5, no. 4, pp. 529–538, Apr. 2021, doi: 10.1038/s41562-021-01079-8

[70]J. Baumgartner et al., 'Wirkung der wirtschaftspolitischen Maßnahmen zur Abfederung der COVID-19-Krise. Mikro- und makroökonomische Analysen zur konjunkturellen, fiskalischen und verteilungspolitischen Wirkung', WIFO Stud., 2020, Available: https://ideas.repec.org//b/wfo/wstudy/66958.html. [Accessed: Mar. 10, 2024]

[71]European Commission, 'EU Taxonomy Navigator', 2024. Available: https://ec.europa.eu/sustainable-finance-taxonomy/assets/documents/CCM%20Appendix%20A.pdf. [Accessed: Mar. 19, 2024]

Annex I – SUNRISE 2nd Workshop Summary

The SUNRISE project organized a 2nd round of national workshops in Italy, Slovenia, and Spain in May 2023, with a focus on three topics:

- Preparedness for epidemiological threats.
- Preparedness for climate-related threats.
- Preparedness for other threats.

This annex describes the main outcomes of the workshop to serve as input to the works being carried out within SUNRISE WP2 – STRATEGY: Strategy for Awareness and Resilience of CIS.

Methodology

The workshops were organized around three technical sessions, one session devoted to each topic.

Session 1: Preparedness for Epidemiological Threats

Session 1 was devoted to showing the organization's preparedness for epidemics given a theoretical disease spread by mosquitoes in Europe (see Figure 17). According to this scenario, many regions have become endemic to mosquitos that can transmit a new virus to humans. Health professionals know the virus is transmitted from infected mosquitos that usually bite during the day. Most people with the disease have mild or no symptoms. If symptoms occur, they usually begin 4–10 days after infection and last 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 who are infected for the second time are at greater risk of a severe course of the disease. Severe symptoms 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. There is no specific medicine to treat the disease. A severe case is a medical emergency since it can lead to death.

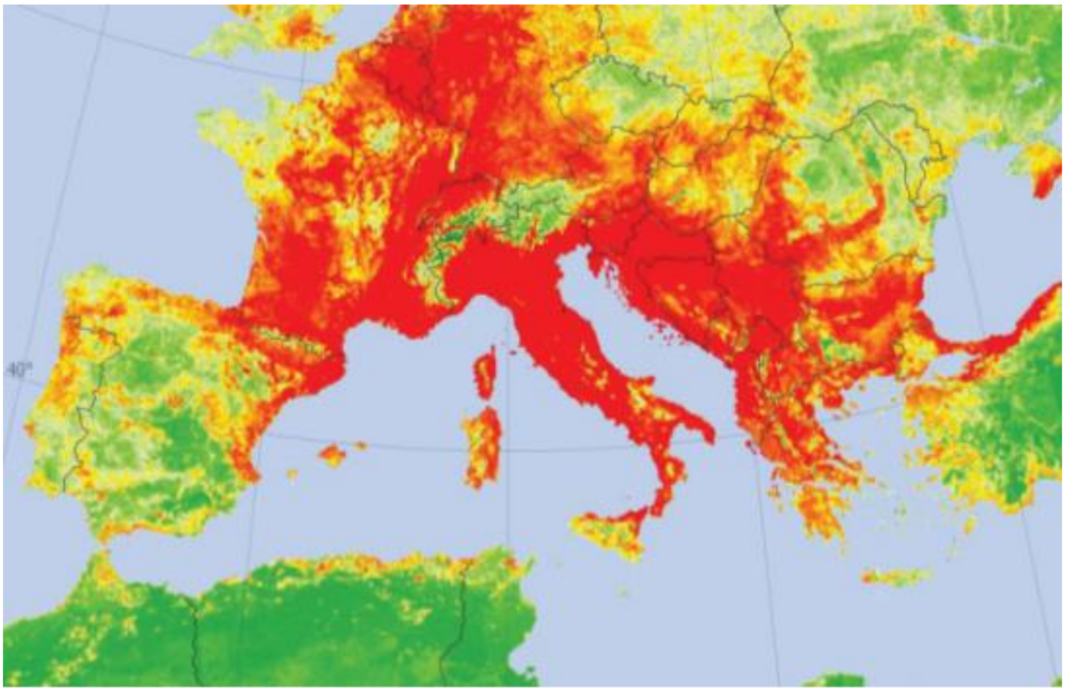


Figure 17: Simulated disease spread in Europe.

The severity of the disease is as follows:

1 Of 100 persons 0-20 years old who have the disease: 20 will have to go to a hospital, 10 will have to go to ICU, 2 will die.
2 Of 100 persons between 20 and 50 years old: 40 will have to go to a hospital, 10 will have to go to ICU, 2 will die.
3 Of 100 persons between 50 and 90 years old: 60 will have to go to a hospital, 20 will have to go to ICU, 8 will die.

From local public health authorities, it is known that in your region a total of 200 disease-suspected individuals were examined, out of which 80 (40%) patients were infected with a new virus. Epidemiologists predict an increase in cases in the future. No further measures to contain this are currently planned from the governmental side. Of the disease-positive patients, 60 (75%) were male and 20 (25%) were female. More than 60% of cases are in the age group 20-50 years old, and about 25% are children (0-20). 50 % have a symptomatic course of the disease. At each organization, 60 % of employees are currently coming to work, 20 % are sick for different reasons, half of them are suspected cases of the disease, and 20 % are not responding to contact anymore.

The participants were asked to answer several questions that would come to show how ready they are to actually tackle a realistic pandemic situation of which most of the data is known. These questions relate to the identification of both, directly and indirectly, vulnerable workers, the impact on human resources, and the preparedness for personal and environmental interventions. At the end of the session, each table shared its perspective, and the participants were invited to discuss the solutions that had been found within the initial discussion of the table.

Session 2: Preparedness for Climate-related Threats

Session 2 goal was to address the preparedness of the actors regarding climate hazards that were introduced in detail. The question was twofold: On the one hand, they were asked about their preparedness against acute threats that happen once and with little to no time to react, and on the other hand, they were asked about their preparedness against climatic threats that are becoming either cyclical or are just chronic (cf. Figure 18). Afterwards, they were asked to choose their top 3 hazards and rank them. Sharing the results with other tables at the end provides a way to identify which are the more common and worrisome threats.

	Temperature-related	Wind-related	Water-related	Solid mass-related
Chronic	Changing temperature (air, freshwater, marine water)	Changing wind patterns	Changing precipitation patterns and types (rain, hail, snow/ice)	Coastal erosion
	Heat stress		Precipitation and/or hydrological variability	Soil degradation
	Temperature variability		Ocean acidification	Soil erosion
	Permafrost thawing		Saline intrusion	Solifluction
			Sea level rise	
			Water stress	
Acute	Heat wave	Cyclone, hurricane, typhoon	Drought	Avalanche
	Cold wave/frost	Storm (including blizzards, dust and sandstorms)	Heavy precipitation (rain, hail, snow/ice)	Landslide
	Wildfire	Tornado	Flood (coastal, fluvial, pluvial, ground water)	Subsidence
			Glacial lake outburst	

Classification of climate-related hasards by the EU Taxonomy

Figure 18: EU taxonomy of climate-related hazards [71].

Session 3: Preparedness for Other Threats

Session 3 had the participants choose the threats that they have faced in the past as a consequence of climatic and pandemic threats. The following threats were introduced:

1. Forced remote working and acceleration of digital transition.
2. Agricultural damage
3. Social distance/limited access to public and private space
4. Blackouts/damage to power lines/electricity congestion
5. Blocked roads
6. Border/airport /other public transportation closure or decrease
7. Lockdown (activities)
8. Communication breakdown
9. Lockdown/curfew (customer segment)
10. Damage to railroads, roads, transportation means
11. Damaged buildings /industrial sites and machinery
12. Hospitals congestion and healthcare system distress
13. Safety threat
14. Increase of cyber-attacks
15. Decrease or disruption of productivity/ service level
16. Increased use of ac and heating
17. Decrease of tourism and consequences on tourism facilities
18. Delays in logistic/deliveries/saturation of e-commerce shops
19. Lack of primary supplies or energy sources prices increase
20. Lack of manpower/ personnel
21. Shortage of medicines and medical devices
22. Mandatory quarantine for tested positive
23. Loss of water for civil use/industrial uses/livestock
24. Organization and creation of "testing point"/"vaccination hub"
25. Problem in food management and supply
26. Waste management disruption

They selected among these threats which ones had affected them in the past and how much with regard of certain aspects which include operational, economic, human resources, reputational, and quality of service. Once they have selected the threats and classified them, they presented them to the other participants by displaying them on boards (Figure 19) and mentioning how they dealt with them in the past as well as the lessons learnt.

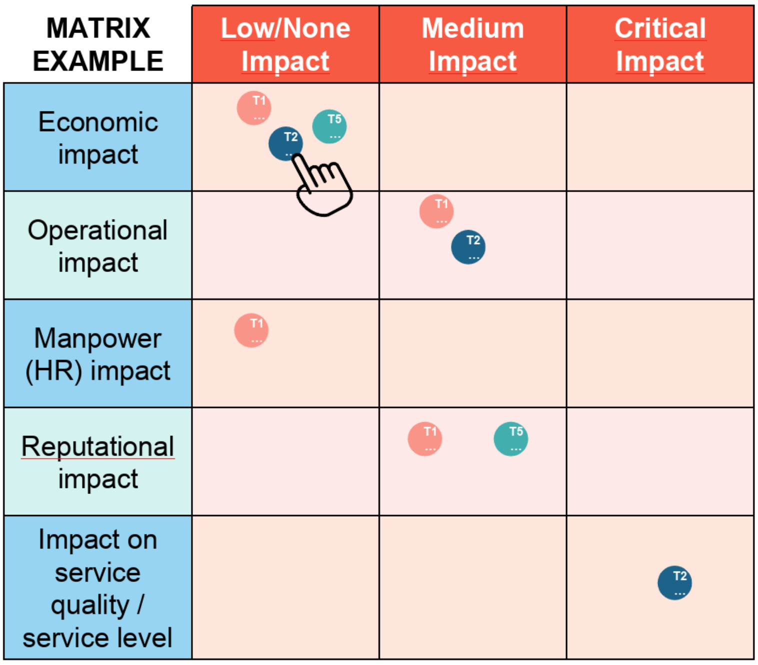


Figure 19: Impact matrix for the selected threats.

Results from National Workshops

The workshops were held in Spain, Slovenia, and Italy. The following sections detail the results per country.

Results from Spain

The Spanish workshop was held on 9th of May 2023 at the Universidad Politécnica de Madrid (UPM), in Madrid, Spain. It was led by UPM, who is the Spanish cluster lead, with the support of Atos (ATS), who is the vice-leader of the Spanish cluster. All the Spanish Critical Infrastructure (CI) operators participating in SUNRISE, including Acosol (ACO, water sector), Quirón Salud and Hospital Quirón Madrid (QS/HQM, healthcare sector), Consorcio Regional de Transportes Públicos Regulares de Madrid (RTM, transport sector), and Telefónica (TLF, telecommunications sector) and the Spanish CI supervisory authority (MIR, Ministerio del Interior) participated in the workshop. Additionally, there were actors from the Banking sector, Energy sector, Industrial Association, and Health Authorities.

16 participants were distributed among four tables (five participants per table) doing their best not to match with any of their own sector/organization. One facilitator joined each table. The participants hold management positions in the following areas:

- Telecommunications (4),
- Healthcare (3),
- Water Distribution (3),
- Transport (2),
- Supervision Authority (2),
- Banking (1), and
- Industrial Association (1).

Session 1: Preparedness for Epidemiological Threats

As mentioned above, Session 1 versed about the threat that a disease transmitted by mosquitoes would pose and how prepare the actors are against it.

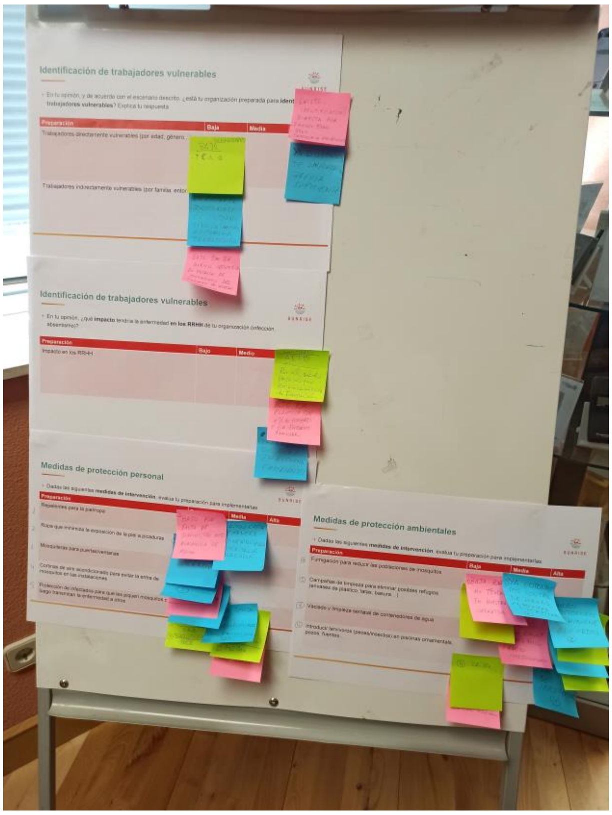


Figure 20: Results from Session 1.

Regarding the identification of vulnerable workers, there was a unanimous response from all the actors stating that the identification of those that are directly vulnerable would be easy given the data that is available for Human Resources. On the other hand, most of them also seem to point out that finding those that are indirectly vulnerable (because they might live with some dependents at risk, e.g., infants or the elderly) would prove to be much more difficult. This is partially due to some legislation, like the GDPR, forbidding them to obtain more information from their employees. There is also a trend in which actors point out that finding out about those employees who are indirectly vulnerable because of children should be easy, as that is something that is registered, e.g., for tax calculation purposes. Nevertheless, the same actors point out that finding right away those employees in charge of elder people would prove to be almost impossible. Something that was brought to the table was the idea of reusing certain tools from COVID's pandemic to gather information, such as surveys before joining work every day. The actors in the healthcare system were less concerned since most of their employees are female and those are less prone to the theoretical threat. Some actors, as those in the transport domain, raised their concerns regarding the difficulty of collecting information from the outsourced employees.

The consensus was unanimous again for declaring that the impact on human resources would be high, although all of them raised concerns regarding the location. For them the location of the workers was key, as some of the actors operate in a distributed manner and have employees in multiple and far away locations.

The last question of the session, regarding their preparedness for intervention at the personal and environmental levels, was received by most actors with low expectations for it to work properly. Most of them referred to the situation during COVID's pandemic and how difficult was to get supplies, especially when factoring in the idea of international shipping and the possibility of other countries' interference. Some of the actors proposed the idea of developing a way to have factories dedicated to produce the required supplies, while others suggested the option of having a national reserve that could be accessed by any actor in need of supplies. The only actor that felt completely ready to deal with such an outbreak was the one of water distribution, as they already deal with the kind of hazards that the theoretical sickness was presenting. In that regard they already have all the required supplies as well as protocols to deal with such a threat. Finally, the actors that had bigger infrastructures were confident on the ability of the maintenance teams to make the buildings secure. This is because mosquito nets would not be required, as windows cannot be opened, and the latest technology is available for them to shield out the doors. It was proposed that the air con system would be used to distribute products that would be able to deal with the threat of propagation.

Session 2: Preparedness for Climate-related Threats

Session 2 had the participants choosing among some climate threats the most impactful for them and how they are prepared to deal with those.

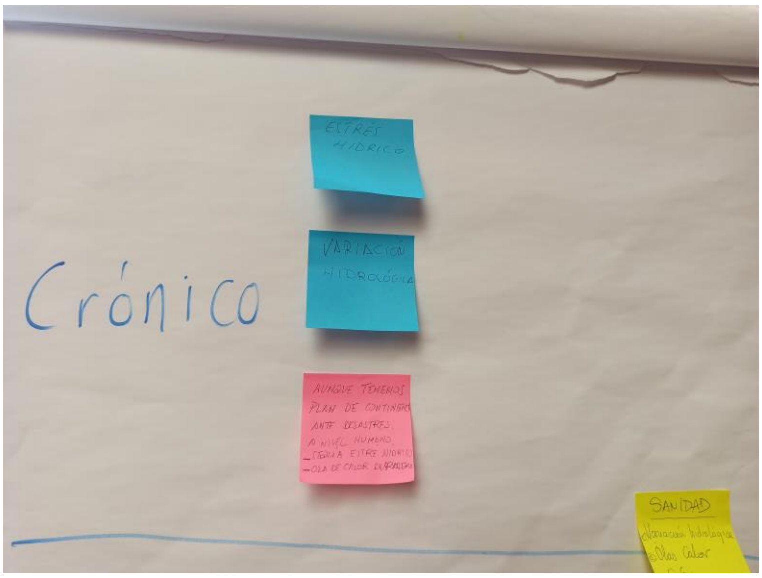


Figure 21: Results from Session 2.

Most of the actors revealed that they had no interest in climate hazards as their contingency plans revolve around the idea of targeting the effect, they are not hazard-based, but rather aftermath-based. They develop their contingency plans based on the idea that they can solve the outcome with disregard of what caused it. It means that they can solve issues like employees not being able to get to work, or malfunction of equipment, with disregard of what might have caused it. Also, all the actors, except for water distribution, were more concerned about the acute hazards than the chronic ones. They assume that only acute hazards have a real impact, while chronic hazards, while disruptive on a small scale, are something to which they must adapt as time goes by. In particular, they point out that there is nothing that they are doing to battle climate change's impact, as it is something to adapt to rather than stay inflexible and maintain their current plans and organization; in their own words "You cannot plan against climate change".

As mentioned above, water distribution actors were the only ones that cared about chronic hazards and their impact. This is because they are already feeling the impact of the chronic hazards in many different situations. This has led them to provide solutions and plan ahead of peak-season to actually be able to provide their services with the least number of issues. This kind of hazard has also forced them to do some extra work on the maintenance of the infrastructure as, for example, they mention that a big portion of the pipelines that were close to the coast lie underwater nowadays. They also mention that most acute hazards get chronicled and again they need to plan, just as in the case of droughts. Finally, water distribution actors also mention that most chronic hazards become much bigger as they compound with each other, and what used to be just a simple issue of maintenance and planning requires a bigger effort to solve all the possibilities that lie ahead.

Session 3: Preparedness for Other Threats

Session 3 dealt with the participants going through a list of threats and choosing the ones they have dealt with in the past. Afterwards they were presented to the other actors alongside with an explanation on how they dealt with it.

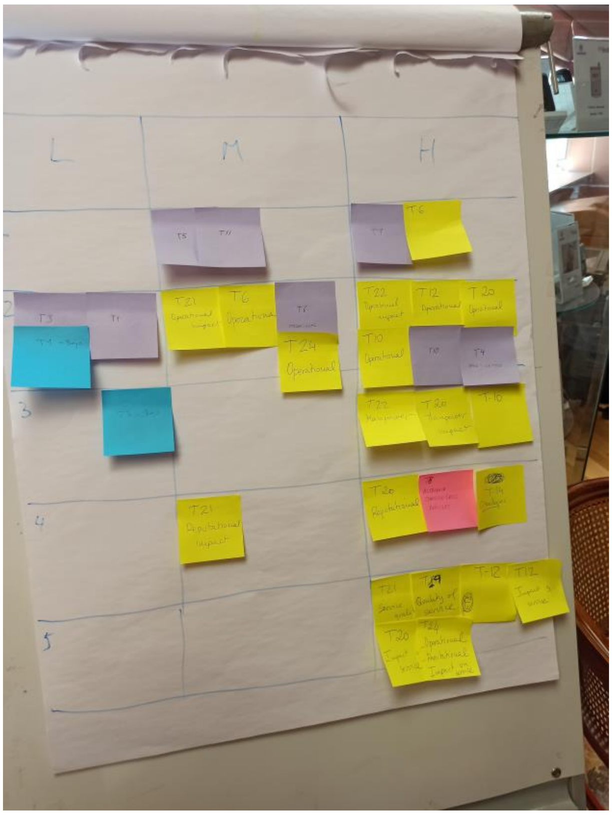


Figure 22: Results from Session 3.

The threats were distributed across all aspects and intensities. In total, 133 threats were assigned to the different levels and aspects. Low intensity at the reputational aspects was assigned no threats by the participants. On the other hand, the category that got assigned the most threats was the high intensity of the economic aspect with 23 threats (17% of the grand total).

Similarly, both low impact in the economic aspect and low impact in the human resources aspect both got assigned 17 threats (12% of the grand total). On the lower side of the spectrum, setting aside the category with zero elements, we have both low and medium impact on the quality-of-service aspect, with just 1 threat each (0.7% of the grand total). The distribution of the threats by sector shows that the sectors that have suffered more threats in the past are Water Distribution, with 24 threats (18% of the grand total), and Healthcare with 23 threats (17% of the grand total).

On the other side of the spectrum, we have the Banking sector and Industrial Association, with 5 threats each (4% of the grand total). Looking at the distribution of threats, we find out that the Healthcare sector classifies most of the threats of high intensity, as 20 (86%) of their selected threats were set in such level. On the opposite side, we have 10 threats selected by the Transport sector (58%) that sit on the low impact level.

Additionally, it seems that no sector thought that the threats they faced were mostly situated on the medium impact, as most of them tend to be on the high intensity level. Finally, looking at the threats by aspect, we see that the economic aspect is the one that gets the most threats with 37 (27% of the grand total), followed closely by the 33 (24% of the grand total) threats of the Human Resources aspect and the 31 (23% of the grand total) threats of the operational aspect. On the opposite side we have the Reputational aspect with barely 6 (4% of the grand total) threats.

Looking at the specific threats, we find out that the threat that appears the most is T20 and T21 with 9 appearances each (6% of the grand total) and relating to the lack of staff due to confinement and the lack of medical drugs. On the other hand, we have T2 with no appearances whatsoever, relating to agricultural damage, something to be expected since no one of the participants had any direct interest on the topics. It is worth mentioning that T16 is the threat with the most appearances in one category with 4 in the low impact/economic aspect. T16 relates to higher use of the air con and the heating of the buildings.

Key Takeaways from the Spanish Workshop

As a results from the Spanish workshop, the following key takeaways can be drawn:

- Almost no CI is ready to take on a new pandemic.
- There are too many variables to consider when preparing for an unknown threat.
- The CI are not preparing for climate changes and have a reaction policy rather than a prevention one.
- All the threats that have been dealt with in the past are of high impact.
- The previous threats are considered as dangerous because of their economic impact.

Results from Slovenia

The Slovenian National workshop of the EU project SUNRISE (Strategies and Technologies for United and Resilient Critical Infrastructures and Vital Services in Pandemic-Stricken Europe) was successfully implemented. The workshop took place in the Crystal Palace conference room in Ljubljana, organized by the Institute for Corporate Security Studies - ICS Ljubljana. It was led and moderated by Denis Čaleta, Milan Tarman, and Marko Potokar (ICS), as well as Daniel Vladušič (XLB).

All Slovenian project partners and invited partners with 22 participants were present at the workshop. In addition to ICS Ljubljana, these are XLAB, MZI the Ministry of Infrastructure, UKC Ljubljana, Plinovodi, ELES, Slovenske železnice, Slovenske železnice-infrastruktura (SŽ-I), Prometni Institut Ljubljana, Telekom Slovenije as project partners also Vodovod Maribor (MBV), DARS, NKBM, URSIV and NIJZ as invited partners.

After the welcoming address of the organizers and the mutual introduction of the participants, the purpose of the productive discussion was to gather experience, identify shortcomings, expectations and good practices formulating answers on how we can support each other, and how we can collaborate better in crises related to:

- Epidemiological scenarios
- Climate change scenarios and
- Threats scenarios.

The focus was on creating answers, how we can support others and how we can better cooperate in crises related to the pandemic situations. Special emphasis was placed on understanding the public-private partnership and what is already in the operational environment, what is missing and how we can achieve strategic and system improvements. The collected information, experience and good practice will support the continuation of discussions, analyzes and research of the EU project SUNRISE in the national and international environment.

Figure 23: Opening of the workshop in Slovenia.

Session 1: Preparedness for Epidemiological Threats

When asked whether organizations are able to identify vulnerable workers based on age and other risk factors, participants generally rated that they can identify vulnerable workers as HR departments have records of age and other data. In the event of a 40% workforce reduction, everyone would have difficulties, so they would focus on the most urgent tasks.

URSIV, MBV, SŽ-I, and NKBM assessed that they can identify vulnerable workers with a focus on the most urgent tasks. At ELES, measures are very strict, especially at key points such as control centres, and certain technologies are used to reduce the engagement of maintenance staff in monitoring dispersed infrastructure. UKC LJ is highly exposed, and reducing the workforce means reducing the necessary medical teams. They assess risks as HIGH. DARS warned that they have many older workers who are frequently on the road, so they focus on the most urgent tasks and organize work in smaller groups. Currently, they have an older population that is now beginning to get younger. SŽ has a problem protecting those who provide activities in public passenger transport.

In short, organizations are aware of the importance of identifying vulnerable workers and have appropriate records for identification, but all emphasize the importance of focusing on the most urgent tasks.

During the discussion on identifying and assessing risks for indirectly endangered workers (e.g., due to children or elderly people at home), organizations agreed that it is difficult to determine the level of risk, as they do not have all the data on the family and living circumstances of employees. During the coronavirus outbreak, organizations used informal questionnaires, which could also be done in this case. All organizations found that the risk was low or possibly medium. Nevertheless, organizations should take measures to protect indirectly endangered workers and ensure appropriate working conditions. All participants agreed that it is difficult to determine the level of risk since they do not have all the data on family circumstances.

Figure 24: Presentation of the scenario.

Regarding the impact of disease X on personnel (e.g., infections, absences), the general finding was that the consequences would be high. The disease would have a major impact on work, especially for field workers, where it is very difficult to protect and replace them. Organizations such as ELES, SŽ, and MBV will have to decide who will go to the front line, while UKC LJ will face risks of infection due to work with patients.

Organizations are aware that disease X would have a significant impact on their personnel and will have to take appropriate measures to protect employees and manage associated risks.

Regarding the preparedness for personal and environmental interventions, organizations assessed their level of preparedness for protecting staff as moderate. Regarding personal protective equipment (sunscreen, hat), DARS, SŽ, and ELES assessed that they have equipment and are partially prepared. These organizations were assessed as moderately prepared in this area. UKC LJ, MZI, and MBV are less exposed and therefore did not assess the need for personal protective equipment.

Regarding environmental measures, SŽ, ELES, and UKC LJ assessed that they are not necessary as they are not exposed to environmental risks. Generally, none of the organizations have the necessary measures for environmental protection. Therefore, they were assessed as poorly prepared in this area.

Organizations generally recognize the need for appropriate personal protective equipment, but due to different levels of exposure, they assess preparedness for measures differently.

Session 2: Preparedness for Climate-related Threats

In the second workshop, participants answered questions about climate hazards they face and how prepared they are to deal with them. From a range of climate and weather events, individual representatives identified three that they believe have the greatest impact on their organization and answered the question of how well prepared they are to face them.

SŽ-I feels prepared for its "Top 3" hazards, which are fires, heavy rain/snow/ice/freezing rain, and landslides. The organization has equipment for cleaning the track area and special attachments on locomotives to combat winter hazards such as ice and snow. However, according to the organization's statements, landslides are still a challenge that requires project work to address.

MBV faces risks of heatwaves, floods, and landslides. The key risk for the organization is contamination of one of the local water sources, so they are prepared to act in the event of floods and other water hazards.

NKBM feels prepared for its "Top 3" hazards, which include freezing, storms, and floods.

UKC LJ is located in an old building where infrastructure is slowly being renovated. The organization specifically highlighted the problems that occur during storms due to floods and meteoric water but did not indicate how it prepares for these hazards. DARS faces risks of heatwaves, cold, storms, and snow. The organization has systems for power outages, such as redundant power supply and generators, as well as measures for removing snow and ice with salt and plowing. In the event of storms and other weather hazards, the organization can close highways and workers work at night. MZI feels prepared for its "Top 3" hazards, which include freezing, storms, and floods. ELES faces risks such as heat waves, cold weather, storms, and snow. However, the biggest challenge they face is freezing rain. Therefore, they specifically reinforce transmission towers and heat wires with additional electricity transmission to prevent them from freezing. This is necessary to ensure a stable supply of electricity, as freezing rain could cause major problems in the distribution network. Nevertheless, ELES remains prepared for all possible weather conditions and risks they face.

In general, organizations feel relatively prepared for their "Top 3" hazards, but they are still exposed to certain challenges and risks that require further action and preparedness improvement.

Regarding the question of how they incorporated data on climate change to prepare for risks, the responses from organization representatives were varied. Generally, they are prepared for typical weather conditions, but not for all possible weather events. MZI is somewhat moderately prepared, as they have rules for working from home in case of extreme weather conditions. SŽ-I somewhat considered some weather data, but they are mainly prepared for typical weather conditions. MBV is moderately prepared, while NKBM and UKC LJ did not fully consider climate change data but included weather impact scenarios in their policies and plans. DARS and ELES are prepared for typical weather conditions, but they have not prepared for all possible weather events, such as freezing rain, which occurred on such a large scale a few years ago. In response to the question of how organizations have prepared for combined risks, the answers were varied.

Generally, organizations are prepared for typical weather conditions, but not for all possible combinations of hazards. URSIV and SŽ-I are not prepared for combined risks but, like everyone else, are prepared for typical weather conditions. MBV has low preparedness for combined risks. NKBM is not prepared for combined risks, while DARS is prepared for typical combinations of hazards.

The answers on the question how well organizations are prepared for consecutive heat waves are mixed. Together, they have no alternative for offices if the air conditioning fails, they can only close them. DARS carries out outdoor work at night. MZI has no problem with heat waves, but if the air conditioning fails, there are issues. They disperse people to their homes, but there is no alternative for offices, as they are poorly insulated. SŽ-I has problems if the temperatures are high, as the tracks can bulge. Without air conditioning, they go home from offices. MBV has the biggest problem in that local wells can run dry, so they have to use firefighters to supply water. NKBM and UKC LJ generally do not have problems with heat waves, but there is a problem if the air conditioning fails, as there is no alternative for offices. DARS and ELES only carry out necessary work late in the afternoon or at night.

Regarding the question of changes in daily work, companies in general do not need to make significant changes to their daily work due to heat waves. Office work would continue as usual, except in cases where air conditioning fails. For field workers, schedules may need to be adjusted due to the heat. However, SŽ-I, ELES, and DARS face risks for their employees due to the heat, and changing schedules is not always easy. They also have concerns about their infrastructure, as they are not always sure if it can withstand more than the specified tolerances. However, they know that their sensors are protected in some way. They also have old pipes under the railway that cause drainage problems, and these are replaced with larger pipes during reconstruction. There can also be difficulties with drainage during heavy rainfall due to dry ground not absorbing water as well as moist soil. MBV could reduce risks by connecting multiple water sources and could also provide larger hats for employees to reduce heat exposure. NKBM reports that no changes would be necessary for their daily work. DARS is facing issues with drainage on old highways with small pipes, which are replaced with larger ones during reconstruction. Maintenance personnel are aware of problem areas and have additional sensors and collection tanks to monitor and clean all drains regularly. However, when 100-year floods occur, there is no solution. UKCLJ reports that severe storms with heavy rainfall pose significant problems due to outdated infrastructure, such as problematic underground passages between buildings and proximity to the Ljubljanica river. ELES is experiencing issues with heat, as the stretching of transmission cables reduces the amount of electricity that can be transmitted.

Overall, while companies do not need to make significant changes to their daily work, some infrastructure investments could help mitigate risks associated with extreme weather events.

The last discussion of the session was about obtaining weather information. The responses indicate that most companies rely on Google and other private applications to obtain climate information for risk analysis, except for DARS, which has access to information from ARSO and the university. ELES also has its own weather stations on transmission poles. MZI and SŽ-I also use Google to obtain the necessary information. MBV reports that they do not have a specific method for obtaining climate information and rely on Google. NKBM uses both Google and the Hydrometeorological Institute to obtain climate information. Overall, it appears that companies heavily rely on internet sources for obtaining climate information for risk analysis.

Figure 25: Group setting during the workshop.

Session 3: Preparedness for Other Threats

During the last session, each participant was tasked with identifying potential threats and writing them on cards provided by the organizers. Each table was given seven cards, and individuals were instructed to select a maximum of three threats, write their ID and organization and place them on the board. Game Master was responsible for inviting each person to contribute their cards to the board. This process was repeated three times, with each table receiving a new set of seven cards to work with. Overall, this exercise allowed participants to collaboratively identify and prioritize potential threats, ultimately contributing to a more comprehensive risk analysis.

Figure 26: Result from the Slovenian workshop.

The results of the analysis showed that most of the threats can be categorized into HR Impact, Operational Impact, and Service Level Impact. The level of impact was mostly rated as Medium for HR Impact and Operational Impact categories, and High for Operational Impact, HR Impact, and Service Level Impact categories.

The analysis highlights the importance of addressing the identified threats to minimize their impact on the organization's operations and service delivery. It is recommended that measures are taken to mitigate the high impact threats and to monitor and manage the medium impact threats to prevent them from escalating.

Furthermore, the results suggest that there may be vulnerabilities in the HR and operational systems of the organization, which require further investigation and improvement. Additionally, the findings can be used to inform the development of a comprehensive risk management strategy that considers the identified threats and their potential impact on the organization.

Overall, the analysis provides valuable insights into the organization's risk profile and highlights the need for proactive risk management measures to ensure the continued success and sustainability of the organization.

Participants in the event provided positive feedback regarding the game-like approach used to identify potential threats, which allowed for active participation and engagement from all involved. However, due to time constraints, there was not enough opportunity for in-depth discussion and exchange of opinions regarding the identified threats and their underlying reasons. Overall, while participants appreciated the method used for identifying threats, there is room for improvement in allowing for more thorough discussion and exploration of the identified risks.

Key Takeaways from the Slovenian Workshop:

As a results from the Slovenian workshop, the following key takeaways can be drawn:

- Organizations are aware that new pandemic of unknown disease would have a significant impact on their personnel and will have to take appropriate measures to protect employees and manage associated risks.
- Organizations generally recognize the need for appropriate personal protective equipment in case of disease, but due to different levels of exposure, they assess preparedness for measures differently.
- In general, organizations feel relatively prepared for their "Top 3" hazards regarding climate changes, but they are still exposed to certain challenges and risks that require further action and preparedness improvement.
- While organizations do not need to make significant changes to their daily work, some infrastructure investments could help mitigate risks associated with extreme weather events.
- Organizations heavily rely on internet sources for obtaining climate information for risk analysis.
- The analysis of preparedness for other threats provides valuable insights into the organizations risk profile and highlights the need for proactive risk management measures to ensure the continued success and sustainability of the organization.

Results from Italy

The Italian workshop was held on 18th of May 2023 at Insiel, in Trieste, Italy. It was led by INS, who is the Italian cluster lead, with the support of Hermes Bay (HB), who is the vice-leader of the Italian cluster. The Italian Critical Infrastructure operators participating in SUNRISE were: Insiel (INS digital sector), Consorzio Acquedotto del Friuli Centrale (CAF water sector), Trieste Trasporti (TT transport sector), Hydro Dolomiti Energia (HDE energy operator), Istituto Superiore della Sanità (ISS health sector). Additionally, there were actors, no SUNRISE partners, from Energy sector, Transport sector, Roads Infrastructure, Logistics Infrastructure, Rail Logistic Infrastructure.

15 participants, 4 facilitators and 1 workshop coordinator were distributed among three tables doing their best not to match with any of their own sector/organization. The areas covered by all participants were:

1. Telecommunications (2),
2. Healthcare (1),
3. Water Distribution (2),
4. Transport (3),
5. Energy (3)
6. Logistics Infrastructure – Interport (1)
7. Roads Infrastructure (2)
8. Rail Logistics Infrastructure (1)

Session 1: Preparedness for Epidemiological Threats

As mentioned above, Session 1 versed about the threat that a disease transmitted by mosquitoes would pose and how prepare the actors are against it.

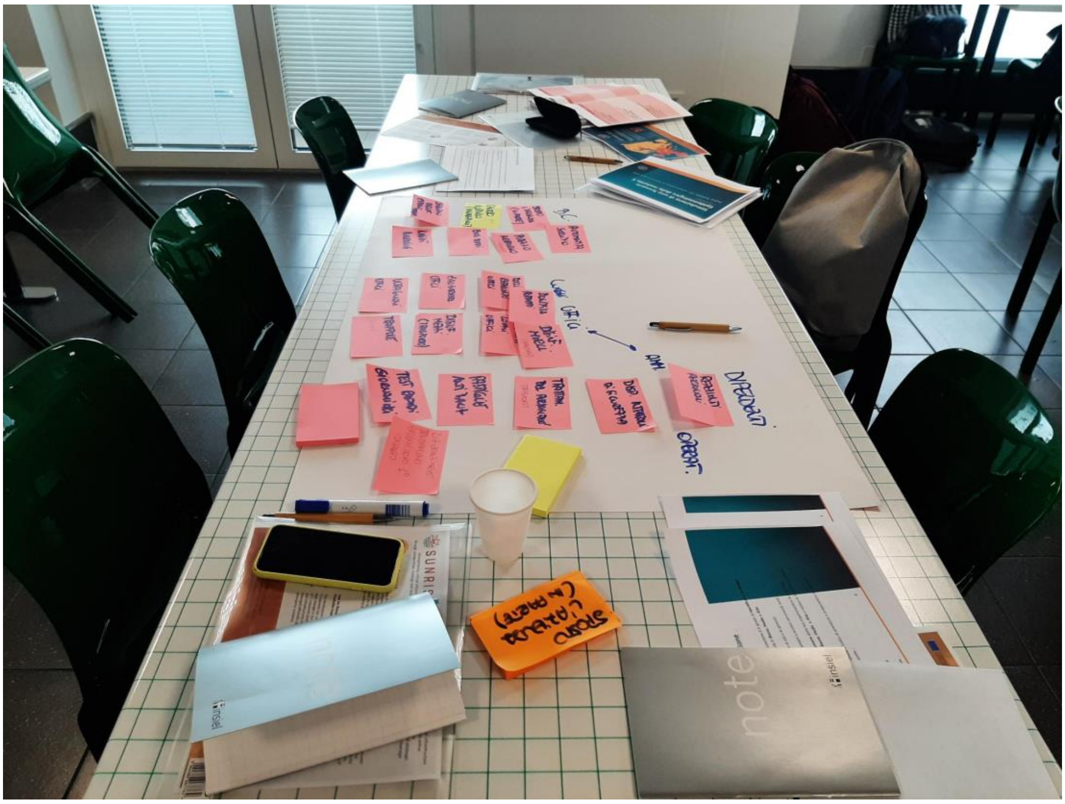


Figure 27: Results from Session 1.

Regarding the identification of vulnerable workers, there was a unanimous response from all the actors stating that the identification of those that are directly vulnerable would be easy given the data that is available for Human Resources. On the other hand, the identification of worker that are indirectly vulnerable is not applicable due to legal constraints, such as GDPR.

Concerning the measure to avoid infection risk due to mosquito, the crucial factor is the type of activity and the location. For those critical infrastructure that have a significant amount of work that must be done physically, the main priority is to protect the workers. The actions proposed to reduce the exposure to mosquito are divided in four main categories.

For the business continuity are the adoption of night shift for some activities, such as maintenance of infrastructure, digitalization of services, reduce the work outdoor work; for the workplaces are disinfestation of workplaces, use of repellents, installation of mosquito net, devices against mosquito, remediation of area around workplaces; for the workers are personal protection devices (special workwear), change of the workwear colour, repellents, test; for the communication are cooperation with healthcare authority, establishment of emergency committee, awareness campaign and incentives

In general, the level of preparedness is good for the set of essential activities but related to all operations the critical infrastructure needs time to organize their work. Moreover, a key factor that can impact the preparedness is the availability in the market of all needed goods and it is also crucial the action of Public Authority to avoid speculation of the prices.

Session 2: Preparedness for Climate-related Threats

Session 2 had the participants choosing among some climate threats the most impactful for them and how they are prepared to deal with them.

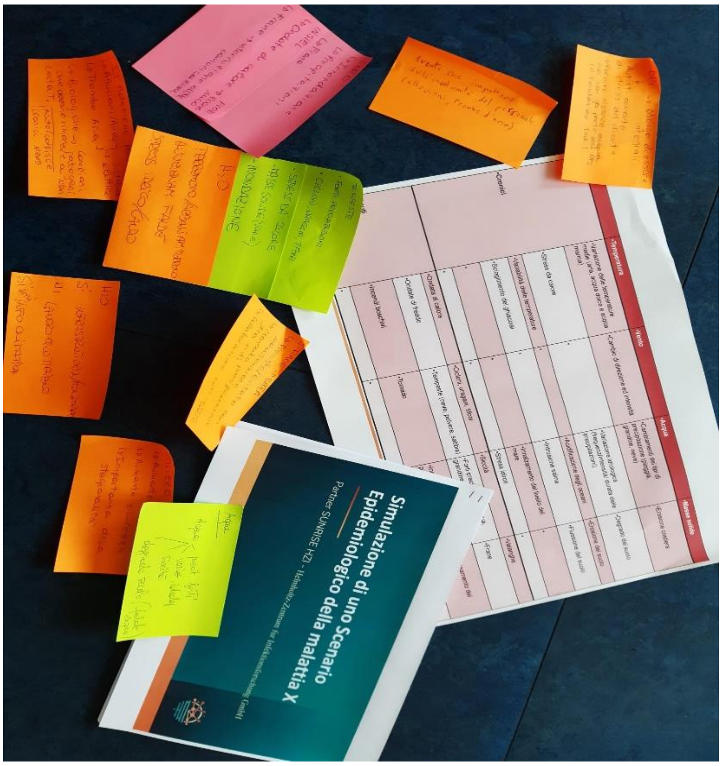


Figure 28: Results from Session 2.

In general, the Critical Infrastructures don't have a specific focus on climate change. In case of emergency, Critical Infrastructure decisions are based on traditional contingency plan. There isn't any culture or approach to add the climate change risk in their planning. Anyway, the perception of the climate changes risk depends on the type of sector. For transport and logistics sectors the top risks are heat stress, precipitations, flood, and tornado.

The main actions to prevents damages or business interruption consist in increasing of monitoring and maintenance, adoption of addition protection personal workwear or reinforce the use of air conditioned in case of heat stress. A general interest-need is to start to include the climate effects on the planning process. For the transport infrastructure sector some analysis on historical data related to type of works, due to disruptive events. The road infrastructure operator proposed to define a sustainability balance sheet at European level to have some common standard to face the climate changes. For the energy sector the top risks are earthquake, hydrological variability and in addition the fire. The impacts of the extreme events, such as floods, must be considered not only at operational level, but also during the infrastructure design.

For the water sector the main important climate changes are drought, hydrological variability and subsidence. The acute climate changes are considered dangerous for the functioning of the infrastructure, but the remediation to some events, such as drought cannot be addressed so easily. The only thing is to improve the water management at infrastructure level by improving monitoring and maintenance to avoid water waste.

Session 3: Preparedness for Other Threats

The last part of the second national workshop was related to mixed threats and their impacts on critical infrastructure. The purpose was to identify the threats that each infrastructure was affected by during the emergency scenarios and the related impacts that had been registered. This goal has been achieved through a tabletop game based on 26 cross-field selected threats, 5 categories of impacts and 3 levels of impact severity. The tabletop game was divided into three parts: threat selection, table of impacts and debriefing.

Threat selection: The goal of this first phase was to identify the threats that affected the critical infrastructure. For this reason, the 26 threats were divided among three tables, to enable each participant to choose the ones that they had to dealt with in the past years. This first phase was divided in "rounds". At the end of each round the sets of cards given to each table has been exchanged with the cards of the other tables. In this way each participant had the possibility to analyse the whole 26 threats' list. During this phase, the participants selected a total of 132 threats.

Table of impacts: In this phase, each participant discussed on the typology and the severity of the impacts that each selected threat had generated within their organization. At the end of this phase, only the "low intensity" slot of the reputational impact category was not filled with any threats by the participants. On the other hand, the impact slot that achieved the highest number of threats, was the "medium intensity" of the "operational" impact category, with 24 threats (31% of the grand total). Similarly, both the "critical intensity" slots of the "operational" impact category and the "critical intensity" slot of the "service quality and service level" impact category were assigned 19 threats each (25% of the grand total). On the lower side, other less selected impact categories and related intensity levels were: "low intensity" of the "service quality and service level" impact category and the "medium intensity" of the "reputational" impact category, both with only one threat assigned.

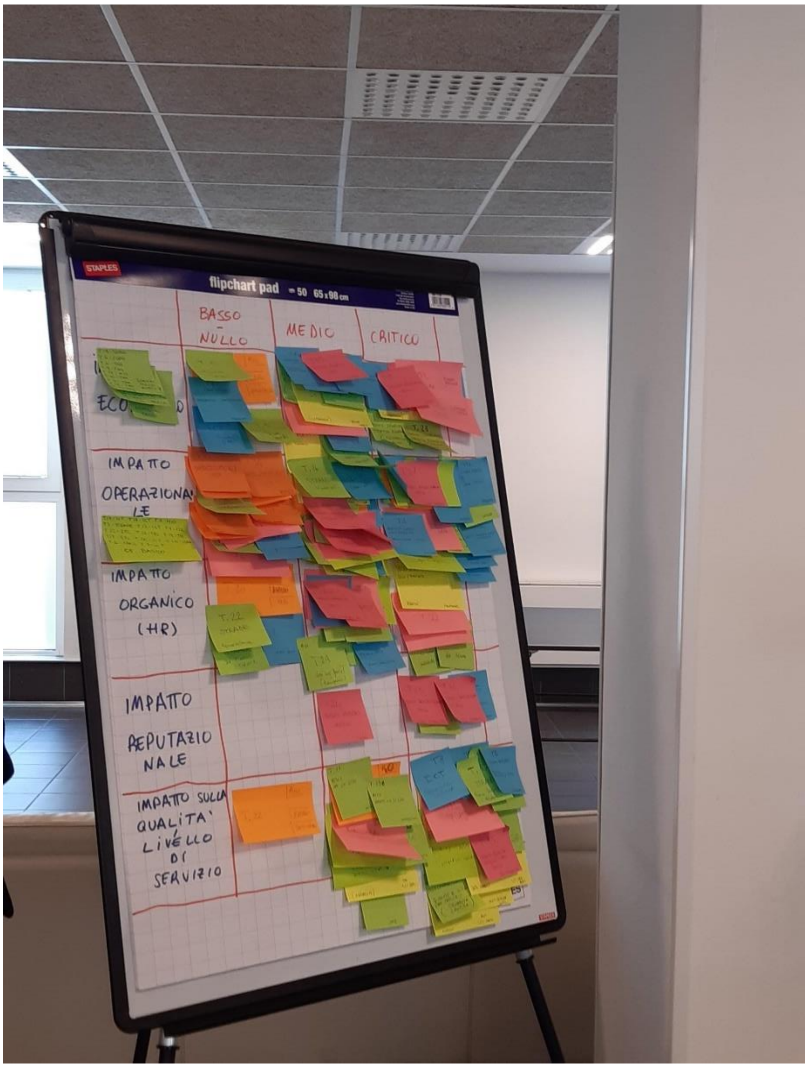


Figure 29: Results from Session 3.

Following the results for the other categories:

1. Economic Impact - low intensity: 5 threats
2. Economic Impact - medium intensity: 9 threats
3. Economic Impact - critical intensity: 10 threats
4. Operational Impact - low intensity: 14 threats
5. Manpower (HR) Impact - low intensity: 4 threats
6. Manpower (HR) Impact - medium intensity: 13 threats
7. Manpower (HR) Impact - critical intensity: 5 threats
8. Reputational Impact - critical intensity: 4 threats
9. Impact on service quality and service level - medium intensity: 10 threats

It can be noticed that most of the threats caused impacts on CIs with medium or critical intensity.

The results can also be evaluated from the point of view of the critical infrastructure. Indeed, the distribution of the threats by sector shows that the sectors that have suffered the most are the transport sector, with 40 selected threats, and the water distribution sector, with 27 selected threats. On the other end of the spectrum, the infrastructure management sector registered only 5 threats and the information and communications technology sector selected only 10 threats.

Finally, looking at the individual threats, it has been noticed that the most common threats were T.3 - Social distance/limited access to public and private spaces, with 12 occurrences and T.19 - Lack of primary supplies or increase in energy prices, with 11 occurrences.

On the other hand, "T.2 - Agricultural damage" never appeared, and "T.16 - Increased use of AC and heating", and "T.12 - Hospitals congestion and healthcare system distress" appeared only once.

Debriefing: During this final phase, participants had the opportunity to briefly comment on their choices. The most interesting discussion was led by the hydroelectric company, which highlighted the differences in procedures and management between the Italian section of the company and the Slovenian one.

Key Takeaways from the Italian Workshop:

As a results from the Italian workshop, the following key takeaways can be drawn:

- After COVID they are prepared to re-organize the activities, at least the essential services.
- CIs are not totally ready to face a new pandemic.
- The climate changes are not considered in the strategy of CI.
- They highlighted the importance to add the "climate change" in their process, they expected some regulation from EU.
- They impact of mixed threats are economic.

Overall Summary

With all the above, we can have some takeaways from the workshops, looking at them from a more general perspective.

As a first note, we can point out that in Session 1, all the participants from the different workshops answered unanimously at the idea of identifying vulnerable employees. All actors point out that identifying directly vulnerable employees is something that can be done on the spot and without issues thanks to the employee's data that the participants collect. On the other hand, the identification of indirectly vulnerable employees proves to be difficult because of regulations such as GDPR. Regarding the preparedness to deal with a new pandemic, most critical infrastructures point out that they can implement some of the lessons learned from COVID's pandemic, although the circumstances might not be the same. Another point that was stressed by all the participants is that the context, such as location of the work done (indoors or outdoors) might be an impediment when trying to come up with a global strategy.

Regarding Session 2, the workshops of both, Spain, and Italy, come to show that the critical infrastructures that participated are, overall, not ready to deal with climate change. But not only they are not ready, they also do not plan to solve the impending threats. On the other hand, while some of Slovenia's participants are not ready, some of them have begun to implement countermeasures regarding climate change impact. This difference could be explained by Slovenia dealing with a harsher weather in comparison and having had some previous crisis, such as freezing rain a few years ago. In the overall perspective, we find out that most of the critical infrastructures do not plan ahead for climate change and is not taken into account in the future development, thus disregarding the challenge that it might present and assuming that it can be dealt with in a traditional manner. Nonetheless, those participants that do work towards their resiliency against climate change effects, do take it very seriously as they already can feel its impact.

As per Session 3, there is a diversity of approaches, as most Spanish participants centered their attention on the economic aspect, while both, Slovenian and Italian participants, did focus on the operational aspect. On the other hand, something that was common, was the disregard for the reputational aspect. Also, the critical infrastructures of the three countries did mention none or very few threats with a low impact, most of them did focus mostly on the critical impact, with the medium impact following close.

Finally, we can point out some common ground that was established throughout the three workshops. The main takeaway is that almost no CI is totally ready to take on a new pandemic, although they are aware that a new pandemic could have a potentially disruptive impact on their activities. Because of that they know that they can reuse some of the previous strategies. Regarding climate change, CIs are not preparing for it as it is not part of their strategy, and while they might be able to react to acute events, they are not ready for chronic ones. One element that could be key in solving this, is the data acquisition, as most participants have to rely on publicly available data that is not suited for analysis to be carried by specialists. Finally, they consider the threats as dangerous or impactful, only because of their possible economic impact.