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Realising European ReSILiencE for Critical INfraStructure

RESILENS

Start date of project: 2015-04-30
Duration: 36 months

Resilience Management Matrix and Audit Toolkit

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¹Public

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**RESILENS Deliverable Document Evolution**

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EXECUTIVE SUMMARY

Objectives
This Deliverable outlines how the RESILENS project addresses the objectives set out in Task 2.4. Of primary concern is the creation of a Resilience Management Matrix and Audit Toolkit (ReMMAT). The toolkit aims to provide an operational tool which can be adopted and implemented by Critical Infrastructure (CI) operators to meet their resilience management goals. The toolkit will be of a quality which will fulfil the CIs general resilience requirements and that of each of the pre-defined resilience management steps and will combine the outputs of the different methods put forward by the RESILENS project.

Description of the Work
Using the resilience assessment and management tools put forward in D2.2, the holistic resilience assessment and management toolkit (ReMMAT) was developed in Task 2.4 and is presented in this Deliverable report.

The web based ReMMAT which functions as a singular operational unit is designed to be comprised of three major parts; (1) a resilience matrix tool which will allow the CI operators to assess their system resilience levels across domains, (2) a resilience audit tool which incorporates a high level set of guidelines associated with the matrix scores that helps the CI operators interpret and use the obtained scores and provides steps that would support the CI operators in generating potential resilience enhancing strategies (3) a GIS mapping tool linked to the matrix and audit tool which allows for a hotspot visualisation of the resilience levels of the CI assets investigated as well as also highlighting CI system interdependencies and trans-boundary relationships that might be of importance.

Results and Conclusions
The toolkit presented in this Deliverable addresses the need for tools to support the operationalisation of resilience concepts. It thereby provides a tangible metric-based resilience assessment method which incorporates considerations from the societal, organisational and technical resilience domains. Furthermore, the toolkit also provides an audit function for contextualising the obtained scores and as a basis for developing potential actions aimed at building the CI resilience.

The initial ReMMAT will undergo table top exercises in Task 3.4, will be used for the development of the methodological framework for the ERMG, and the draft and final ERMG in WP3. The toolkit will be hosted in the RESILENS decision support platform (Task 3.5) which will be tested in the pilot demonstrations in WP4. The toolkit will also be considered for the development of the concept of operations (CONOPS) framework in WP 5 and the e-learning hub in Task 6.4.
PUBLISHABLE SUMMARY

Not applicable as the Deliverable is available for full distribution
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1. Introduction

1.1 Overview of the RESILENS project

Critical Infrastructures (CI) provides essential functions and services that support societal, economic and environmental systems at national and European scales. As disasters and crises, both natural and man-made, become more commonplace, the need to ensure the resilience of CI so that it is capable of withstanding, adapting and recovering from disruptive events, is paramount. Moving resilience from a conceptual understanding to applied, operational measures that integrate best practice from the related realm of vulnerability assessment and risk management is the focus of the RESILENS project.

RESILENS will develop a European Resilience Management Guideline (ERMG) to support the practical application of resilience to all CI sectors. Accompanying the ERMG will be a Resilience Management Matrix and Audit Toolkit (ReMMAT) which will enable CI systems (encompassing assets and organisations) to have their level of resilience quantitatively and qualitatively indexed. This toolkit is outlined in this Deliverable report. The developed toolkit will allow for the quantitative analysis of the resilience of the systems at different spatial scales (urban, regional, national and trans-boundary), which can then be iteratively used to direct users to aspects of their systems where resources could be concentrated in order to further improve their resilience levels. The ERMG and RESILENS resilience management methods will be tested and validated through stakeholder engagement, table-top exercises and three large scale pilots (transport CI, electricity CI and water CI). The ERMG and accompanying resilience methods will be hosted on an interactive web based platform - the RESILENS Decision Support Platform (RES-DSP). The RES-DSP will also host an e-learning hub that will provide further guidance and training on CI resilience.

Overall, RESILENS will aim to further advance the state of the art in CI resilience management and intends to increase and optimise the uptake of resilience measures by CI stakeholders.

1.2 Overview of Work Package 2

Work package (WP) 2 builds on the knowledge garnered from WP1 and further develops key elements of the quantitative resilience assessment and management approaches, and corresponding qualitative methods and measures aimed at expanding the state of the art with regards to operationalising resilience in CI. The Tasks in WP2 will methodologically integrate risk and resilience management methods and guidelines, and emergency response supporting guidelines into a functional resilience management tool. This developed tool can be applied for the scoring of the resilience levels of the CIs, as well as provide useful guidelines and support to the CI operators as to how they can interpret the resilience
scores. The overall aim of the use of the toolkit is to provide a basis for improving their overall system resilience.

To facilitate the above, key resilience management steps and sub-steps from the academic literature were identified and subsequently refined in Task 2.2 for the development of the RESILENS tools. Task 2.2 examined how to integrate risk management strategies into resilience management, and offers a description of the refined sub-resilience steps focusing on qualitative, quantitative and semi-quantitative assessments. The Task findings will be outlined in the Deliverable 2.1 report "Resilience Management Steps. Report and Templates. Version 2" and were considered for advancing the RESILENS tools put forward in Tasks 2.3 and 2.4.

Task 2.3 initially identified quantitative, semi-quantitative and qualitative methods previously applied in the literature for CI risk and resilience management (where available), using that as a foundation for mapping out the direction and development of the proposed RESILENS resilience management methods. Different operational qualitative, semi-quantitative and quantitative methods developed by the RESILENS project to assess and manage CI resilience were then put-forward in the Task. This was done on the basis of the resilience management steps put forward in Task 2.2. The outputs of this Task have been reported in Deliverable 2.2 (Qualitative, Semi-Quantitative and Quantitative Methods and Measures for Resilience Assessment and Enhancement. Version 2. Report and Templates), and served as the principal inputs in Task 2.4.

Task 2.4 is concerned with the creation of a ReMMAT which advances a functional web based application applied for the assessment of resilience in CIs. The developed toolkit aims to fulfil the general resilience requirements and total resilience management considerations of CI systems under investigation, taking into account and combining the refined resilience management steps (and sub-steps) and the different operational resilience assessment methods proposed in Task 2.2 and 2.3. To meet this goal, a web based toolkit was developed in this Task. In addition to the scoring and resilience audit function provided by the toolkit put forward in this Task, a GIS functionality which allows for the visualisation of the resilience levels of the CIs also incorporated in the developed web based toolkit. More details on the specific outputs of this Task which is the focus of this Deliverable report are presented in Section 1.3 below.

### 1.3 Overview of Task 2.4 and Deliverable 2.3

Specifically, this Task will:

- Develop a **Resilience Management Matrix Tool** that will permit organisations (CI operators, municipalities, CI end-users etc.) to score and quantitatively index their level of resilience and/or allow for a metric-based analysis of an overall system (from planning stage to recovery stage). The Matrix will evaluate resilience levels across
domains which apply to all CI sectors. A more detailed sector specific evaluation may also be carried out. The Matrix will allow for a quantitative analysis of an individual asset, entire region or country in terms of resilience measures. The output of this stage is a guiding score which can be used as baseline for the audit process.

- Develop a **Resilience Management Audit Tool** to incorporate a high level set of guidelines associated with the matrix. The audit tool will be applied across each of the stages of the resilience cycle. The user will have an indication of the most relevant stages of the resilience cycle to focus on based on the guiding score derived at the matrix stage. The audit tool will contain steps and guidance for various actions that will help build the resilience of an individual CI asset or the resilience of CI assets in a particular locale (e.g. local/urban, regional, national and trans-boundary).

- Develop GIS based tools and methods for **mapping and analysing** the resilience assessment and enhancement methods of Task 2.3 for CI of any sector within a standardised capacity as well as the interrelations across CI of other sectors; the performance of these tools will be validated with the aid of in-house expertise and key CI stakeholders. The visualisation will be interlinked with the Resilience matrix and audit tools.

- Explicitly link all process steps and methods refined in Task 2.3 to the resilience matrix and audit.

This document provides a report on the initial development of the web based GIS resilience management toolkit put forward by the RESILENS project that is aimed to be applied by CIs to facilitate the achievement of their resilience management goals. The Deliverable therefore outlines the outputs of Task 2.4, and provides an overview and the steps taken in the development of the resilience management and matrix audit toolkit, its use objective and the toolkit implementation. Potential limitations associated with the use of the toolkit for CI resilience monitoring are also highlighted.
2. Developing an Operational CI resilience toolkit

There is an increasing trend of incidents of man-made and natural disasters, and resultant economic costs associated with such events (Figure 1, and Leaning & Guha-Sapir, 2013). Therefore the development and application of practical resilience concepts which offer all encompassing, integrated approaches to planning for, responding to, and recovering from all manner of disasters and threats are required to ensure that affected societies can return to normal or an efficient operation level that guarantees the functioning and continuity of that society. This drive for resilience highlights the need to logically focus on systems whose functions provide those services and activities which can be considered to be deemed as essential for the community functioning and well-being (Bruneau et al. 2003).

These systems are what are regarded as "lifeline" or "critical" infrastructures. The critical infrastructures (CI) are therefore considered to be important for the ability of the society to respond and recover following disruptive events. Improving the resilience of these CIs can be seen as a crucial starting point for boosting the overall resilience of the considered society. Creating tools and methods which can assist in an increased understanding and uptake of resilience management concepts and the approaches in CI systems would therefore be beneficial and is the primary aim of the RESILENS project.

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As described in Leaning & Guha-Sapir (2013), the disaster effects on a local economy as described here consists of both direct and indirect consequences, with the estimated economic damage being for the year in which the disaster occurred and is given in billions of US dollars at 2012 value. The data used to generate this chart was obtained from EM-DAT international Disaster database (www.emdat.be). Biological events were not shown and included in this figure.
Research outputs aimed at addressing the need for such CI focussed resilience assessment and management tools\(^3\) have been described in the academic literature for a wide range of research disciplines ranging from engineering, computer science, social sciences, environmental science and ecology, operations research and management science, risks assessments, telecommunications, law and health. However, while these research outputs have addressed topics such as approaches to model or assess CI risks and failures (i.e. Moini, 2016; Rodriguez et al, 2015), proposed overview frameworks, methods and tools to facilitate CI protection/and resilience (i.e. Hosseini et al, 2016; Lebaka et al, 2016), or schemes for CI system interdependencies and interrelationships identification and impacts (and relationships with the society) (i.e. Emery & Schulman, 2015; van der Vleuten et al, 2013; Wu et al, 2016), a distinct lack of operable tools which can be easily adopted and implemented by CI operators appears to be conspicuously lacking.

Furthermore, a review of the state of the art with respect to resilience management in CI carried out in D1.3 and D2.1 highlighted a lack of standard approaches which are specific to CI systems resilience management, with traditional risk assessment more widely utilised. With an increased drive towards more resilient CI systems, more practical management systems which can be easily employed by CI operators to achieve potential resilience improvement goals are therefore needed.

The RESILENS project aims to contribute to this gap in the literature by developing and putting forward operable CI resilience management tools. Such tools were developed and are presented in D2.2 "Qualitative, Semi-Quantitative and Quantitative Methods and Measures for Resilience Assessment and Enhancement. Version 2. Report and Templates". How the developed standalone tools in D2.2 can be effectively adopted and used by the CI operators to meet their resilience objectives is the primary concern in this Deliverable. Here, a functional easy-to-use web-based resilience management toolkit with assessment and audit functions has been constructed using the tools developed by the RESILENS project for use by the CI operators.

An initial stakeholders survey carried out by the RESILENS project\(^4\) highlighted that the CI operators currently lack practical tools for monitoring, quantifying and scoring their levels of resilience. This finding strengthened the need for tools such as the outputs of this Deliverable. The EU H2020 DRS-07-2014\(^5\) call which funds the RESILENS project also alludes to this need, recommending that to address the research challenges associated with the

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\(^3\) An overview of such concepts and methods are presented in the RESILENS Deliverable 2.2.

\(^4\) Presented in D1.2 "Stakeholder Consultation Report"

The first step (step 1) relates to a survey of worldwide approaches on how to define, develop, implement and evaluate resilience concepts (including relevant EU sectoral approaches, was explored in the RESILENS project under WP 1 (with findings presented in D1.1, 1.2 and 1.3) and WP Task 2.1 and 2.3 (with findings presented in D2.1 and 2.2).
3. The RESILENS Resilience Management Matrix and Audit Toolkit (ReMMAT)

3.1 Overview

The web based RESILENS resilience management matrix and audit toolkit (ReMMAT) encompasses a suite of tools developed in the WP Task 2.3 and is designed to operate in logical progression as a "singular functional unit" to achieve the overall goal of providing a resilience assessment function, resulting in the scoring of the resilience level of the CI system evaluated. In addition to the main objective of assessing the overall resilience of the CI system evaluated, the toolkit also provides an indication of the most relevant stages of the resilience cycle that the CI operators can focus on, with regards to further improving their resilience levels. The ReMMAT also contains an audit tool aimed at providing guidance to the CI operators on the interpretation of their obtained resilience scores, how to use the scores, and to support the incorporation of organisational, societal and political considerations for developing implementable resilience enhancement strategies. A GIS visualisation of the resilience of investigated CI assets or systems is also provided in the ReMMAT toolkit which is linked to the resilience scores, and supports the CI operator with an overview of the resilience status of the different investigated assets in their CI system.

The tools which were integrated to form the web-based toolkit includes the semi-quantitative CI-RAT\textsuperscript{7} which was adopted and digitally incorporated as the main resilience assessment tool. This digitised semi-quantitative assessment tool is what comprises and will be subsequently referred to as the Resilience Management Matrix Tool (or Matrix tool) in this Deliverable and in the RESILENS toolkit. In addition to the overall score provided for the investigated CI, drilled down scores on specific CI components, stages and domains which may be of particular interest to the CI operator can also be obtained from the matrix tool results. However care needs to be taken in using specific CI component resilience scores as changes to the involved component may well have a wider impact than expected.

To address the requirements from the DRS-07 call description text and also those highlighted by surveyed stakeholders, for resilience assessment and management outputs to be useful, an understanding of resilience concepts and how these effect the CI operations is needed. This functionality is provided for in the toolkit via a qualitatively-based methodology audit tool which incorporates a high level set of guidelines associated with the matrix tool. The qualitative post assessment resilience enhancement tool (PARET) put forward as a supporting tool for the use of the obtained resilience assessment scores in D2.2 was adopted and digitised for use in the toolkit to provide an audit function. This tool will be

\textsuperscript{7}The semi-quantitative tool which was advanced in Task 2.3 and presented in D2.2 and forms the basis for the assessment function in the matrix tool draws inspiration from the UNISDR Disaster Resilience Scorecard for Cities.
applied across each of the stages of the resilience components, stages and domains identified in the Matrix tool and will contain steps and guidance for potential organisational actions that can be applied to help build the resilience of the investigated CI system or that of a particular asset. The digitised qualitative support tool developed and presented in Task 2.3 was therefore further refined to meet this goal and will be subsequently referred to as the Resilience management audit tool (or Audit tool) in this Deliverable.

An overview of the different component tools and their respective outputs in the ReMMAT are shown in Figure 2.
The combination of a semi-quantitative methodologically backed resilience scoring tool was selected for use in the RESILENS project since this would provide a tangible output which most CI operators (who usually have a technical background) can relate to. Supporting this assessment output, an in-depth qualitative method was employed since the analysis of the resilience scores will depend on the particular situational and subjective organisational human considerations which will be required for any decision making process related with intended resilience improvement actions in the CI.

Prior to the use of the resilience assessment tool of ReMMAT, a **CI system definition tool** is available in the toolkit. The CI system definition tool is aimed at helping to identify the scope and boundaries of the evaluated CI systems (including level of coverage), providing a description of the evaluated CI, an identification of the critical assets and functions of the CI, as well as highlighting CI system interdependencies with other CIs and existing trans-boundary relationships. More information on the tools and their functions and relevance is outlined in the following Chapter 4. This will include an introduction to the tool, its application and the outputs of this toolkit subset with regards to its contribution to an overall understanding of the resilience assessment scores attained using the resilience management matrix tool.

In addition to the resilience assessment and evaluation functions provided by the Matrix tool, a **GIS based resilience mapping tool** (Mapping tool) was further developed and incorporated into the ReMMAT. This Mapping tool primarily serves as a visualisation function linked to the outputs of the Matrix tool, utilising the obtained score to provide a hot-spot indication of the resilience levels of investigated CI assets or systems in a given geographical area. The Mapping tool is therefore intended to assist the CI operators obtain a better overview of the resilience of their systems which is expected to in turn lead to a clearer understanding of potential impacts of disruptions of evaluated critical assets, as well as aid an overview visualisation of any available system interdependencies associated with the evaluated CI. Details on the technical specifications, operation and guidance functions provided by the Matrix tool and the Mapping tool in the ReMMAT will be elaborated in Chapter 5.

Further directions to tools and learning repositories that can be employed to address specific resilience related activities as well as to enhance the learning and training capacity of the CI operators who intend to use the toolkit are also embedded in the ReMMAT. A learning and education functionality will also be directly available at various stages in the toolkit, with the objective of providing the CI operators using the ReMMAT with general information on the toolkit, the meaning and relevance of the different terminologies, resilience domains, stages and steps that are used in the assessment as well as how to interpret the results obtained from the resilience assessment provided by the developed RESILENS toolkit. Directions to the e-learning hub of the RESILENS platform to meet other
resilience management training goals of the interested CI stakeholders will also be available using the links to e-learning and training tools from the toolkit.

### 3.2 Resilience Management Steps

Before describing the RESILENS ReMMAT (and its component tools), an introduction to the resilience management steps which underpin the operation and implementation of the RESILENS toolkit is useful in appreciating the reasoning behind the design and layout of the ReMMAT. This is especially since the defined resilience management steps form the basis for the positioning of the different components of the RESILENS toolkit.

As identified in section 3.4 of D2.1, the first three resilience management steps (and sub-steps) associated with the time period before a disruption were used as a basis for the development of the toolkit process flow.

Table 1. First three resilience management steps (and sub-steps).

<table>
<thead>
<tr>
<th>Step</th>
<th>Sub-steps</th>
<th>Explanation</th>
</tr>
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<tbody>
<tr>
<td>Define the System</td>
<td>Structure:</td>
<td>• To understand and identify the targeted CI systems (and their components), their critical functions and the processes which will be assessed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• To demarcate the boundaries of the interested system</td>
</tr>
<tr>
<td></td>
<td>Function:</td>
<td>• Identify appropriate scales and levels to examine resilience (including geographical considerations)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Identify the key players, system inter-relationships and dependencies, and involved stakeholders</td>
</tr>
<tr>
<td></td>
<td>Appropriate method selection:</td>
<td>• Identify the available methods and models in the suite of resilience assessment tools which</td>
</tr>
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- Qualitative methods
- Semi-quantitative methods
The above listed management steps were used as a basis for describing the objectives, function and operation of the component tools in the ReMMAT and were further aggregated and outlined in the following three chapters:

i. System Definition (Chapter 4)
ii. Resilience Assessment (Chapter 5)
iii. Resilience Enhancement (Chapter 6)
steps (and sub-steps) while being applied to provide an overview CI resilience assessment, as well as additional guidance and steps on how the adjudged resilience of the system can be improved. The use of the resilience management steps formed the basis for the toolkit phases as can be seen in Figure 2, which also highlights the linkages and overlap of functions between the tools. This is especially since the toolkit was designed so that information (as well as outputs) provided into (or from) one tool would feed into another tool where it is required.

The ReMMAT is therefore best presented and understood as a singular holistic toolkit which functions as a single unit (although made up of several component individual tools and methods) with the primary goal of helping with the assessment of the resilience levels of an evaluated CI, providing useful information on how the obtained results can be evaluated and the implications for the CI. The toolkit also provides information on supporting actions that the CI operators could consider to improve their overall resilience profiles or specifically at improving their resilience scores in a given domain where improvements can be made.

The use of this toolkit has the primary goal of informing the CI operators on their system preparedness with regards to relevant resilience requirements at different resilience stages. The toolkit is therefore intended to be periodically applied in CI systems in a "resting/quiet state" or before a disruptive event. Related resilience steps such as maintaining, restoring and transforming which assess active resilience activities during and after the disruption event are also supposed to be indicative of the CI operators’ capacity in the eventuality of such disruptions. Furthermore, the activities related to those active resilience steps are expected to be covered by the guidance provided by the outputs of this toolkit. This is since the organisational backing which informs the decisions made during such periods is expected to be supported by the audit (resilience evaluation and enhancement) functions of the toolkit.

3.3 Accessing the Toolkit

The web based ReMMAT is accessible directly by typing the address below on a web browser.

Web address: http://resilens.leute.server.de/ci-rat/

Alternatively, the toolkit can be accessed via the RESILENS website. Under the RESILENS output tab on the website home page.

A sign-in to the toolkit is required to access the toolkit functions. After signing into the ReMMAT (Figure 3), the targeted users of the tool can progressively go through the

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8This is further outlined in section 3.3 in D2.1 “Resilience Management Steps”. Reports and Templates. Version 2.
component tools which constitute the overall toolkit. A general introduction to the toolkit, including information about the tool, definition of terminologies and resilience concepts are provided in the pages following the log in process.

![Image: ReMMAT Resilience Management Matrix and Audit Toolkit]

Figure 3. Log in page of the ReMMAT

For first time users a "sign in as a new user" link is provided where some preliminary detail will be initially collected and access to the toolkit is requested by the intending user. After the access request is considered by the toolkit administrators, log-in details are sent to the CI operator, who can then log into the ReMMAT tool using this log-in detail.

Next, users (the CI operators, who are now the toolkit users) will be able to provide information to the different sections of the component tools which will be used for the assessment of the investigated CI resilience levels. The individual tools which deal with supporting the achievement of the individual objectives of the identified resilience steps, as well as the overall function of the toolkit are presented in chapters 4, 5 and 6.

Table 2 presents information regarding the use and some relevant design expectations associated with the deployment of the ReMMAT. The outputs of the toolkit might however be also useful for other stakeholders i.e. responders and government oversight bodies as identified in later chapters.
Table 2. Operator related questions and answers with the use of ReMMAT

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
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<tbody>
<tr>
<td>Who will use the tool?</td>
<td>CI operators (this includes managers or designated personnel who have been charged with resilience management in the CI system).</td>
</tr>
<tr>
<td>Skill levels required to use the toolkit</td>
<td>An understanding of the CI system organisation and operation will be useful before use of the toolkit. A set of criteria will be developed in Task 6.4 which will be used to ascertain if the intended user has the required organisational knowledge to be able to use the toolkit.</td>
</tr>
<tr>
<td>Is the toolkit to be used by a single or multiple users?</td>
<td>Both. The RESILENS project proposes that the toolkit is completed by a panel of relevant sectional CI managers or personnel in the CI system who have a good knowledge of the different organisational and operational aspects of the CI. Ideally the proposed panel will be made up of managers with organisational decision making capabilities as well as operational line managers with knowledge on particular department operations associated with the provision of the CI critical functions.</td>
</tr>
<tr>
<td>How will the toolkit be accessed?</td>
<td>Online. It is a web-based toolkit. The results and strategies decided on after its use can be downloaded and saved on the CI system servers for use offline.</td>
</tr>
</tbody>
</table>
4. **ReMMAT - System Definition Tool**

4.1 **System Definition Tools: An Introduction**

This EU directive (2008/114/EC)\(^9\) outlines a step procedure for the identification and designation of CI in EU member states, while outlining a common approach for the assessment of these infrastructures. The EU member states make use of the CI identification process and selection criteria outlined in the directive.

The cross-cutting criteria thresholds used for the designation of CI sectors are expected to be based on the severity of the impact of the disruption of an infrastructure, with the precise thresholds applicable to the criteria determined on a case-by-case basis by the member states concerned with a particular CI. Methods to aid the identification of CIs and assets are therefore a vital and logical first step in any process to secure and guarantee the protection of the services provided by the CIs. In Europe, several member states have established different initiatives regarding how this can be advanced, and are in the process of developing their own approaches.

As a starting point in the development of the RESILENS toolkit, an assumption was made that the CI sectors have been designated by the respective EU member states where in the CIs are located. The CI definition tool developed in the RESILENS project is therefore not concerned with sector designations and expects that the criteria outlined in the EU directive have already been applied by the member states. Furthermore, the 2008/114/EC directive additionally directs that the EU member states are also to implement an operator security plan (OSP) or an equivalent measure to facilitate the identification of critical assets of the CIs. The RESILENS project initially assumes that this section of the directive has also been implemented by the respective CI operators in the member states.

Therefore, it was assumed that European CI operators already possess a list of the critical assets\(^10\) and a clear understanding of their critical functions\(^11\). This is especially since such exercise would have been carried out to meet their OSP obligations.

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\(^10\)The critical assets are those physical or virtual assets which are directly required or are key to providing the critical function associated with the infrastructure. The critical assets are designated on a basis of the function as well as the business relevance to the CI. This is opposed to those assets which are not considered core to aiding the primary service or product provision. For example, in a water utility a major sewage pumping station could be considered a critical asset while the accounting offices of the same utilities while providing an important support function would not be considered a critical asset.

\(^11\)Critical functions refer to the core service, process or activity provided by the critical infrastructure. The critical function underpins the business and organisational processes of the CI, with the function being the reason or driver for the existence of that infrastructure. When the ability to provide this critical function is disrupted or ceases, the continued existence of the infrastructure could be endangered or risk sustaining a severe economic loss. The earliest possible restoration of such functions after a disruption will be of the main
The tools associated with first resilience management step of the toolkit uses such information already in place in the member state for CI, and is mainly concerned with the overall identification of the investigated CI system and setting the study boundaries associated with the resilience assessment process. The CI definition tool of the ReMMAT was developed to meet the objectives of this step and aims to achieve the goal of aiding an understanding and identification of:

- the CI sectors and systems being evaluated;
- the critical functions of the CI;
- the critical assets and components of the evaluated CI;
- and the interdependency relationships that exist with other CI systems that affect the provision of the CI critical functions;

The tools associated with the system definition will also help establish the appropriate scales and levels of the CI system under investigation in terms of the resilience level to be assessed. For example, if the consideration is on a standalone asset or an evaluation of the entire CI system in a geographical area (owned by a single operator or as a collective of several operated and owned CIs in the same sector).

### 4.2 Specifics on the CI System Definition Tool

After the CI operator (or user) enters the ReMMAT, the system definition tool is presented as a series of question sets, with the CI operator providing the requested information on the CI particulars, geographical location and coverage, and CI interdependencies and trans-boundary relationships (Figure 4).
Figure 4. Screenshots of CI definition tool pages of ReMMAT.

The inputs required in this aspect of the ReMMAT are mainly aimed at extracting specific details of the investigated CI (including its name, physical address and brief overview), its critical functions, critical assets and the geographical boundaries of the CI system and/or assets. The relationships with other CIs (service supplies and dependencies) as well as knowledge of the CI trans-boundary relationships are also gained with this questions posed in this tool.

The CI definition aspects of the toolkit, will therefore specifically request that the CI operators provide the following inputs:

1. the critical sector that the investigated CI falls under: this is provided as a drop down function in the RESILENS toolkit. The critical sectors indicated in the definition tool
were extracted from principal functions associated with the 11 critical sectors identified in the EPCIP12

(2) The critical functions of the CI: this is also available as a drop down function and draws from the identified critical functions usually related with the CIs under the selected CI sectors. This entry provides for the insertion of multiple critical functions for a singular CI system. As described under footnote 11, a particular CI under investigation might have more than one function.

(3) Where an entire system is being examined, a listing of the critical assets/elements of the CI system.

(4) The level of coverage of the investigated system: i.e. if the resilience of a particular asset or installation or of an entire CI system operated by one provider or a combination of several CIs in a particular CI sector is being considered. This was considered an important addition since the outputs of such evaluation can be used to reflect on the resilience state of a particular installation of concern (important to CI operators and oversight government agencies) or can be used to gather knowledge on the overall state of resilience of an entire CI sector (relevant to government response emergency and oversight agencies). The toolkit user indicates using a drop down menu if the resilience assessment is aimed to reflect the status of an entire CI system or targeted at a specific CI installation.

(5) A description of the critical assets of the system, including the name of the asset, a brief description, and the address/location of the asset. Where more than one asset is covered during the assessment, the CI operator using the tool can also add other assets to the list

(6) System interconnectivities; This aspect of the tool identifies any known CI systems designated by the member states to which the investigated CI directly supplies its services, or is directly dependent on their service. Here a brief description of services received or delivered from or to dependent CI systems is provided, as well as the physical location (if available) of the assets providing those services. The periodicity of the service supply is also noted. In some cases, the CI operator might need to discuss this with the member state oversight body since some of these dependencies might not be transparent to either party.

(7) Trans-boundary relationships: This tool aspect requires inputs from the CI operators regarding any trans-boundary relationships that might be available. The trans-boundary relationships were strictly restricted to the critical service transfer between identified geo-political member state boundaries, and not those of internal

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regional boundaries within the EU member state. Here the service provided, location of the trans-boundary CI service provider and receiver as well as the impact and periodicity of the service supply is also inputted.

After completing the required inputs related to the CI definition aspects of the toolkit, the target users can then click on the “proceed to survey” tab (as seen in Figure 5). This directs them to the RESILENS resilience assessment question sets, which will be used to semi-quantitatively evaluate the resilience levels of the investigated CI system.

Figure 5. Screenshot of end of CI definition tool.
5. ReMMAT - Resilience Assessment Tool

5.1 Resilience Assessment Tools: An Introduction to RESILENS Resilience Management Matrix Tool

The RESILENS resilience management matrix tool is primarily a digitisation of the CI-RAT developed in Task 2.3 of the RESILENS and is presented in D2.2. The application of this semi-quantitative method was deemed useful for the toolkit goals since it is focussed on addressing CI resilience preparedness to both natural and man-made disasters, specifically with regards to identified resilience components in CI systems. With the Matrix tool, the CI’s resilience preparedness is viewed as the totality of different pre-defined system components and interactions. The assessment components and items in the Matrix tool incorporates the two resilience qualities of systems: inherent (functioning during normal operation, non-crisis periods) and adaptive (response flexibility capacity during disaster/disruption processes) capacities.

To index the CI resilience, relevant assessment criteria (using a Likert type assessment criteria scale of 0-5) linked to the component items which are reflective of the current state of the CI system are then selected and constitutes the resilience score for that item.

As outlined in D2.1 and 2.2 for the CI-RAT, the Matrix tool (and other tools in ReMMAT) also use a grouping of the resilience stages/phases to establish RESILENS resilience “requisites”:

- Requisite 1: Prepare, Prevent and Protect (Before the disruption)
- Requisite 2: Mitigate, Absorb and Adapt (During the disruption)
- Requisite 3: Respond, Recover and Learn (After the disruption)

It must be noted that while this time phase dependent grouping provides the main considerations supporting the specific choices made for the RESILENS project, the characterisation of resilience stages into relevant disruption time periods is still a heavily contentious issue since some of the resilience stages can be considered to not squarely fit into a specific period. The Matrix tool (and the evaluation functions that will be later provided with the ReMMAT) recognises this limitation, views some of the resilience stages as having an overlap between the designated disruption time phases and also integrates the inter-relation and cyclicity of the requisites stage grouping i.e. with the Requisite 3 component stages (i.e. Respond, Recover and Learn) feeding into Requisite 1 stages (Figure 6).
The components put forward in the matrix tool were therefore designed to specifically address the requisites as highlighted below in Table 3.

Table 3. Overview of the matrix tool requisites and components.

<table>
<thead>
<tr>
<th>Requisites</th>
<th>Components covered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requisite 1</td>
<td></td>
</tr>
<tr>
<td>Prepare, Prevent and Protect</td>
<td>Organisation and co-ordination</td>
</tr>
<tr>
<td></td>
<td>Identification, analysis and management of current and future risks</td>
</tr>
<tr>
<td></td>
<td>Budget allocation for CI protection, redundancy and resilience enhancement and the organisation’s financial capacity</td>
</tr>
<tr>
<td></td>
<td>Responsiveness - incident response and business continuity planning</td>
</tr>
<tr>
<td></td>
<td>Safeguarding CI assets with electronic and physical means</td>
</tr>
<tr>
<td>Requisite 2</td>
<td></td>
</tr>
<tr>
<td>Mitigate, Absorb &amp; Adapt</td>
<td>Building codes and infrastructure hardening</td>
</tr>
<tr>
<td></td>
<td>Robustness of communication networks, mission critical systems, power / energy supply, supply chain and core services</td>
</tr>
</tbody>
</table>
The described components and items are used as the basis for advancing the assessment criteria scales in the resilience management matrix tool. The CI operators can then establish a baseline measurement of their current level of resilience with regards to each of the resilience component items.

In addition to the resilience quantification provided by the resilience matrix tool, a visualisation of the obtained CI resilience scores will also be provided by a GIS based mapping tool included in the ReMMAT. This visualisation of the resilience of the investigated CI was a functionality which some of the CI Stakeholders consulted in Task 1.4 “Multi-disciplinary Stakeholder Consultation” highlighted would be a very useful inclusion in potential resilience management methods which are intended to be applied in the CI systems. Using a pre-defined colour coded system, the GIS tool in ReMMAT will present an overview of the “resilience status” of investigated CIs and assets in a defined geographical area which are linked to the results obtained from the resilience assessment provided by the matrix tool, and will also highlight the critical function interdependencies that exist between the CI and other CI systems in the defined space.

5.2 Description of the Resilience Management Matrix Tool

The resilience components and issues assessed in the semi-quantitative resilience method presented in D2.2, is digitised in the ReMMAT and is what primarily constitutes the aspects of the Resilience Management Matrix Tool concerned with conducting the CI resilience evaluation and for computing the resilience scores.

After the toolkit user completes the sections on the CI system description in the ReMMAT as outlined in chapter 4, the ReMMAT user normally the CI operator, seamlessly proceeds to the Matrix tool.
At the start of the assessment process, an estimate of the total number of questions that makes up the assessment and the average amount of time to complete the assessment is provided. The definitions of the terminology used in the Matrix tool is also provided in the opening pages.

The user is then directed to the overview page where all the main resilience components and items which underpin the resilience assessment in the Matrix tool are outlined. Here, the user can directly select or deselect specific components that they intend to address during the assessment process (Figure 7). This was done since an extra consideration was that not all the resilience issues put forward in the Matrix tool might be of particular interest or some scoring criteria not directly applicable to the evaluated CIs. The possibility to choose relevant resilience assessment components was therefore incorporated in the tool design to afford a more tailored assessment tool where desired. The default setting however provides for all component issues to be addressed.

![Figure 7. Screenshot of the overview page](image)

The user proceeds to provide responses to a set of assessment questions on different component items or issues. A description of the component and the specific issue assessed is provided on each page (see example screen shot presented in Figure 8).

The Matrix tool consists of 55 resilience evaluation items, with each evaluation criterion broken down to set out the specific component item being measured, an indicative measurement and a Likert type criteria assessment scale (from 0 to 5, where 5 presents best practice).
Figure 8. Screen shot of a requisite assessment page.

The user is expected to indicate a relevant criteria assessment scale which best reflects the state of the evaluated system with respect to the item being measured. The user also provides backing comments (and possibly documents) which underscore the verification of the criteria scale selected and is intended to provide a justification for the scores chosen. The comments provided here (or the attachment of relevant documents) is therefore expected to be evidence based, relates to the considered assessment criteria and support the levels selected by the CI operators. The comment section must be filled in before the user can move on to subsequent pages or away from the current page. In addition to providing verification, the documentation or rationale behind the scores can subsequently serve as a benchmarking purpose in the evaluation phase regarding activities to improve the CI resilience. This will be explained further in the following chapter 6.

The Matrix tool comes equipped with a “progress tracker” at the top right hand corner of the page which provides a tracking of the overall progress of the user with regards to completing the overall assessment process, as well as an indication of the level of progress regarding the extent of completion of a specific component section (i.e. section progress) by the end user (as seen in Figure 8).

After the completion of the question sets the user then clicks the “Evaluate” link (indicated in the red dashed line circle in Figure 8) and is directed to the overall resilience score of the CI, presented as an overall percentage score (i.e. 0-100%) (Figure 9).
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Figure 9. Screenshot of the result page of the Matrix tool.

As highlighted in D2.2 for the developed CI-RAT tool, the main approach of the Matrix tool is to set high thresholds for the assessment of CI resilience (CIR), so that it is very unlikely that CI owners and operators will receive scores higher than 75% for their investigated systems. This is done with the intention of ensuring that the CI owners and operators continue to apply the appropriate level of management to ensure CIR.

After the user gets the overall CI resilience result, further drived down scores on the of the different resilience components and also of the resilience domains (i.e. social, organisational, information and technical) will also be provided. Such results as shown in Figure 9 can be viewed by scrolling down the assessment results page. This additional tool output uses the same inputs provided by the users in the Matrix tool.
At the end of the Matrix tool, the users is therefore presented with the overall scores associated with the CI system resilience, as well as individual scores which allows the CI operators to appraise their resilience status with regards to the different resilience domains, the resilience requisites (stages) or specific resilience components covered during the assessment process.

To get a visualisation of the obtained resilience scores using the Matrix tool, the user can proceed to the GIS mapping tool which is also incorporated in the ReMMAT by clicking on “Map Results”. A description of the GiS mapping tool is provided in the following section (5.4).

5.3 Description of the GIS Based CI Resilience Mapping Tool

The GIS mapping tool component of REMMAT provides an additional analytic level for the outputs of the CI definition tool and the results of the Matrix tool, using the information obtained from those tools as inputs for mapping the quantified resilience levels of the CI systems evaluated using the toolkit.

As the GIS mapping tool is already connected with the CI definition and Matrix tool of the toolkit (which it is dependent on for information), no direct inputs into the tool are required. The geographical location, system interdependencies and trans-boundary relationship will be those which had already being specified in the CI definition tool.

After the users has gone through the resilience assessment scores and the drilled down scores associated with the different CI resilience requisites and components, and domains, they can proceed to the mapped results using the "Enter Map tool" tab (Figure 10).

Figure 10. Screenshot of the GIS mapping tool entry function
The user is taken to a general information page, where information on the GIS based mapping tool can be obtained. An explanation of the GIS symbology and icons, as well as the definition of the colour coding used in the mapping tool output is provided here. The user can then proceed to accessing the GIS mapping outputs by clicking on the "Enter Map Tool". To enable a standardisation of the GIS symbolologies used in EU projects (FP 7 and H2020), where relevant, the use of the GIS symbols and symbology as put forward by the FP 7 INDIGO (Innovative Training and Decision Support for Emergency Operations) D4.3.2 European Emergency 2D/3D Symbology was applied in the GIS mapping tool.

The resulting screen presents a geographical overview of the resilience status of particular asset, assets or CI system covered in the resilience assessment using a pre-defined colour coding system(Figure 11). The colour system is drawn from an aggregation the overall resilience score and the resilience status of the evaluated CI system is based on defined percentage ranges of the overall resilience score obtained for the investigated CI using the Matrix tool. An overview of the colour code system used in the identification of the resilience status of the CI systems in the GIS overview page is presented in table 4.

Table 4. Colour coding used for indicating the resilience levels of investigated CI assets.

<table>
<thead>
<tr>
<th>Resilience score (%)</th>
<th>100-80</th>
<th>80-60</th>
<th>60-50</th>
<th>50-40</th>
<th>40-30</th>
<th>30-20</th>
<th>20-10</th>
<th>10-0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour code</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Designated status</td>
<td>Excellent</td>
<td>Very Resilient</td>
<td>Resilient</td>
<td>Average</td>
<td>Resilience enhancement required</td>
<td>Urgent enhancement required</td>
<td>Poor</td>
<td>Very Poor</td>
</tr>
</tbody>
</table>

The geographical boundaries of the tool are automatically defined on the basis of capturing the locations of the investigated CIs and interdependent systems. In addition to the overview visualisation of the different CI assets in a given geographical area, the individual resilience score of specific assets can be further identified (including their composite resilience domain scores). A function which visualises the existing interdependencies with other CI systems function is also included in the mapping page.

The information that drives this function is provided by the users in the CI system definition tool of the ReMMAT. System interconnectivities can therefore be viewed using the mapping tool, with CI systems which might suffer the biggest impacts following a service disruption identified.

After the use of the GIS mapping tool, the user can then proceed to the resilience evaluation and enhancement aspects of the ReMMAT. Here, the evaluation of the resilience scores

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emanating from the Audit tool (which were also displayed in the mapping tool) are provided with the aim of furnishing the user with a step by step guidance on what to do with the scores with the view of enhancing the overall resilience standing of their CI systems.

![GIS resilience mapping](image)

**Figure 11.** Sample screenshots of the GIS resilience mapping pages of the ReMMAT.

Users who do not want to use the mapping function of the toolkit after the Matrix tool results can proceed directly to the Audit tool of the toolkit where guidelines on how to use the obtained scores are provided.
6. ReMMAT- Resilience Enhancement Tool

6.1 Resilience Enhancement Tools: An Introduction

The resilience assessment function of the ReMMAT described above is provided by the Matrix tool which uses a semi-quantitative approach for the scoring of the CI system resilience using pre-defined resilience assessment criteria.

Using this resilience quantification method based on the system’s critical functionality can prove beneficial for facilitating resilience management in technical systems, since the scoring method is designed to provide a measure of a concept which otherwise has an ambiguous and contested definition to one with a tangible output which the CI operators can relate to. This, with the resulting resilience management definition and quantification, is reduced to only a few clearly defined variables which can be easily ranked and monitored.

The method of obtaining the quantified CI resilience score as provided by the Matrix tool primarily use a modular approach for ease of standardisation and operation, and can be considered as initially useful for operation by CI operators to gain an understanding of resilience concepts and how they relates to their CI systems. By reducing potential resilience improvements of the CI to single separate component criteria issues and scores this approach however has limitations. It does not explicitly consider how CIR can be potentially influenced by interactions between the different resilience requisites or components and does not incorporate other important component cross-linking factors, internal and external factors which might affect the CI resilience and the particular system situation and conditions. In addition, this approach might not allow the usefulness (or success) of different alternative resilience strategies to be considered.

The danger exists that CI operators may simply seek to improve their system resilience by targeting the achievement of a criteria assessment scale higher than that which was identified. Resilience might therefore be viewed solely as a “sum of its parts” by CI operators, with CI resilience deemed to be enhanced by an improvement in the score of any of the component items, regardless of the particular CI situation, due consideration of other external influences, or the minimum service thresholds of the CI critical function provision.

The PARET tool presented in D 2.2 was therefore designed to help CI operators interpret the score obtained from the preceding resilience assessment, provide guidelines for using this score as a basis of understanding their system’s resilience and to support the development of strategies and actions to enhance their overall resilience. It also enables external societal, political and environmental considerations potentially influencing their CI operation, which may not have been examined in the focused resilience assessment but are critical for the subsequent resource allocation, to be factored into CI operator’s decision making.
With regards to the development of resilience-building interventions to improve the resilience levels of the CI, using the toolkit, such intended actions should ideally begin with a problem and situational analysis using the assessment criteria put forward in the Matrix tool as an initial guide. This action determines which assessment criteria is intended to be improved, why and how it is to be brought about, and the eventual implications for the CI. All interventions should be based on a documented analysis which provides a rationale for addressing the intended criteria change, explaining the importance of the change to the CI's ability to continue its critical function provision, and how the intervention will interact with the different CI aspects (organisational, technical and information) and external influences. Using such analysis, a change in "resilience" will therefore not only assess changes in the end state as indicated by the assessment criteria, but will also capture as much of the internal and external influences (i.e. social and political) as possible. This will significantly help avoid a narrow focus limited to the use of the pre-identified assessment criteria as the main indicator for the intended changes. Such an approach is useful in understanding whether and how these criteria changes contribute towards the larger objective of aiding the CI to be better able to cope with any potential threats and continue its service provision with minimal time disruptions. The specificity of the intended resilience objectives further prevents any abstract articulation of why the CI is investing in resilience management strategies.

To address this requirement in the toolkit, a qualitative approach which supports an understanding of the CI system operations and resilience components, and how they relate to achieving the resilience enhancement goals of the CI was deemed a highly useful accompanying tool to the Matrix tool. Its use will provide valuable context to the overall resilience scores obtained from the Matrix tool. The resilience management audit toolkit of the ReMMAT was therefore specifically designed to meet this goal.

Using the Audit tool, supporting steps and guidelines in relation to improving the resilience levels of the investigated CI system based on the obtained scores and the different resilience component evaluated during the assessment process will be provided. Furthermore, the Audit tool steps are designed to be broad enough to capture innovative strategies which are not solely confined to addressing the component items identified in the resilience assessment tool. The Audit tool component of the ReMMAT will be elaborated in the following section of this chapter.

**6.2 Description of the RESILENS Audit Tool**

The RESILENS resilience Audit tool component of the ReMMAT is specifically developed to facilitate the ability of CI operators and end users to effectively use the resilience scores and information garnered on their CI resilience states obtained from the Matrix tool to potentially enhance their CI resilience. The Audit tool presents a set of guideline steps associated with the obtained scores, which are applicable across each of the resilience
stages (as indicated by the matrix tool requisites). The qualitative RESILENS post assessment resilience enhancement tool (PARET) which was developed in Task 2.3 and presented in Deliverable D2.2 is what is principally adopted and digitised and forms the basis for the Audit tool in the ReMMAT.

With the use of the Audit tool, the user (normally the CI operator) will be provided with a useful indication of the most relevant resilience components (and stages) which the CI operator can focus on, the minimal component criteria levels to support its critical function provision and a priority resilience components list. The tool also provides an identification of where improvements might be targeted in the CI system and the best use of the CI operators’ resources to meet its resilience enhancement goals. The outputs of the audit tool are also expected to potentially contribute to the development of future resilience strategies in the investigated CI.

After the user has completed using the GIS mapping pages, clicking on the "proceed to resilience audit tool" tab will bring the user to the audit tool home and information page. The options to go directly to the audit tool is also possible from this page for users who want that option.

![RESILIENCE MANAGEMENT AUDIT TOOL](image)

Figure 12. Initial mock-up of the audit tool home page

Furthermore, to support the users with information on the resilience components applicable to their CI systems as indicated during the resilience assessment processes of the ReMMAT, links are also provided on the audit tool home page that allow the user to generate a list of the individual component scores obtained during the resilience
assessment exercise. The user can also view and print a summary of the scoring and the indicated assessment criteria associated with their systems (Figure 12).

After printing out the necessary pages (containing a summation of the preceding resilience assessment steps) which are expected to be used to guide the implementation of the audit tool, the users can proceed to the audit tool evaluation by clicking the "Start CI Resilience Audit" tab.

The Minimal Resilience criteria selection page is the first page to be completed by the user. Here the CI operator is presented with the different resilience component items and the obtained scores from the Matrix tool. On this page, after a careful deliberation an indication of the minimum criteria level they deem will be needed to allow for the provision of the minimal level of their critical functions to their clients will be put forward. A justification for the choice of the selected criteria level will also be filled in by the user.

The user then proceeds to the resilience component cross-links page of the audit tool (Figure 13). Here using the resilience assessment summary pages, the user can identify other resilience components regarded as linked to the identified component. The page uses a four scale system i.e. High, Medium, Low and Negligible- with "High" indicating that the particular resilience component is recognised as very significant to the CI system considerations and "Negligible" highlighting that actions related to the specific component will not require urgency from the CI operators. The component cross link ranking is achieved via a drop down function. The resilience assessment print-out from the audit tool home-page page will be highly useful here since it will provide some background information on the different resilience components.
After completing the resilience cross-linkages page, the user proceeds to the component priority list page, where a ranking of the different resilience components is carried out. If further actions are needed for the identified components this is indicated on this page. Initially, the component priority list is automatically generated using the obtained resilience scores integrated with the number and priority scale of the identified cross-link with other resilience components. However, the user can alter the ranking of components manually. This is done on the basis of perceived importance of the components to the ability of the CI system to prepare for, or continue, providing its critical function in the face of a potential disruption.

The next page "Internal and External Considerations" in the audit tool, provides an avenue for the users to carefully consider and outline potential internal and external factors which can hinder the achievement of higher resilience criteria for the different resilience components. After completing this section, the user proceeds to the "Resilience Improvement Page".

In the Resilience Improvement Page, the users can deliberate on the prioritised resilience components, and provide potential improvements required to enhance the resilience of the identified component. This will also specifically indicate the target criteria assessment scale they would like to attain and address how important potential societal and political factors can affect the CI system resilience decision making and should be considered for the different resilience components. An identification of resources (human, economic and time)
which will be required to achieve the outlined proposed resilience strategies will also be carried out here. This page will also detail the relevance of the targeted improvement on the overall CI operation (Figure 14).

Figure 14. Initial mock-up of the resilience improvements pages.

The user then proceeds to the CI resilience enhancement actions pages where specific actions which the users have put forward as useful to meet the resilience enhancement goals for the different component items will be outlined.

The relevant parties in the CI organisation who will take charge of providing the management actions supporting the potential strategies page will also be put forward on this page.

After completing the CI resilience enhancement actions page, the user can then proceed to the CI resilience assessment overview page where a summary of the resilience assessment scores as well as the resilience management considerations taken with regards to the different resilience components in the Matrix tool can be viewed. The summary page can then be distributed amongst those responsible for carrying out the actions and used to monitor the resilience enhancement and future improvement processes in the CI system.

6.3 Further Resilience Learning Actions
To further advance the understanding of resilience concepts in CI operators seeking to improve the different aspects of the system resilience, the ReMMAT further points the CI user to the RESILENS resilience E-learning hub. This tool, which will be developed in WP 6 of the RESILENS project, will aim to provide an avenue to facilitate the education and training of CI stakeholders on resilience concepts and the factors that underscore CI resilience. The E-learning hub will also highlight what resilience concepts mean for the CI organisation and the society to which it provides services, as well as lessons on applied resilience strategies from other CI sectors which may provide some support for future resilience enhancing strategies that the CI operators can apply in their systems.

This open resilience repository can therefore provide a means of learning from others to create a level of analysis and understanding of resilience concepts that is greater than the sum of its parts, and would have tremendous value in the continued propagation and operation of resilience management in CI.

The link to the e-learning hub which is hosted in the RESILENS decision support platform (RES-DSP) is provided in the CI resilience assessment overview page.

In addition to the e-learning functions provided as a supporting tool to the CI operators who want to learn more about resilience and enhancing their CI's operational and organisational resilience levels, other support tools were also developed by the RESILENS project. These can be applied by the CI operators to gain some better understanding of their systems can also be accessed via the toolkit.

Although housed in the RES-DSP under "Other Resilience Management Methods" these tools, i.e. the quantitative resilience assessment tool and the CI critical asset identification tool, will also be provided as direct links on the actions page of the toolkit. This was done so that the CI operators can have a quick link to these methods as well as providing an entry to the RES-DSP where other useful resilience enhancing support (i.e. the European Resilience Management Guideline (ERMG)) can be obtained.

With this Deliverable dealing solely on the ReMMAT, more information on the RES-DSP (and its contents) and the ERMG will be provided in D3.4 "Delivery of the RESILENS Decision Support Platform" and D3.5 "Final ERMG".

### 6.4 Testing of the ReMMAT in Case Study CIs

In addition to its use for the assessment of CI resilience, the contents of the web based ReMMAT described in this Deliverable and available as a standalone tool will be used in the development of the ERMG in this project. Along with the developed ERMG, the ReMMAT will also be hosted in the RES-DSP and will undergo initial table top exercises in Task 3.4 "Tabletop Testing of the Draft ERMG", with an iterative review prior to being tested and validated in the pilot demonstrations in WP4. Furthermore, the WP5 harmonisation Tasks
will ensure that the resilience management assessment and audit functions of the ReMMAT are efficient, functional and can be operationalised in a wide range of contexts, across various domains and at different stages of the resilience life-cycle.
7. Technical Specifications, Security issues and further toolkit amendments

The details of the development of the software and technical specifications supporting the web based Resilience Management and Audit Toolkit described in this Deliverable are omitted. This is due to this Deliverable being positioned as an introductory descriptive guide to the function and operation of the toolkit. Also, although the primary aim of the toolkit has been clearly defined, the technical specifications used to achieve the achievement of the set goals associated with the toolkit use are being continuously adjusted and improved.

A document which delves into a detailed description of the technical and design details regarding the development of the web based toolkit (including the construction scheme behind the different toolkit components, the integration and linkages of the different components and how a digitisation of the paper based methods put forward in D2.2 was achieved) will be put in the appendix section of D2.1 “Resilience management Steps. Report and Templates. Version 2.”

It must also be highlighted that the ReMMAT outlook and functionality as described and presented in this Deliverable is expected to be further improved. Additional toolkit functions as well as an alteration to the toolkit optics reflect the changes made to the ReMMAT. The screenshots provided in this document are therefore intended to be viewed as serving illustrative purposes to reflect the current toolkit visuals. Following amendments to the toolkit after its initial and subsequent review, additions to the functionalities of the toolkit will be presented as appendices attached to future RESILENS Deliverables.

Owing to the sensitivity issues associated with the use of valuable information which can be deemed to expose potential vulnerabilities in the investigated CI which can be exploited by competitors, several security considerations were implemented in the design of the toolkit. This was to ensure that the uptake of the use of the toolkit by CI was encouraged based on a trust that they have control over the data inputs to the toolkit as well as its outputs. These security design considerations will be presented in the appendix section of D2.1.
8. Gap analysis and Toolkit value beyond the State Of The Art (SOTA)

8.1 Addressing the identified gaps with CI resilience operationalisation.

<table>
<thead>
<tr>
<th>Gaps Identified – D1.1, 1.2 &amp; 1.3,</th>
<th>How does the ReMMAT address these identified gaps?</th>
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</thead>
<tbody>
<tr>
<td>A lack of a clear, practical, holistic, multi-sector understanding of resilience to CI stakeholders.</td>
<td>The ReMMAT provides a singular functional mechanism aimed at promoting an appreciation of CI resilience management in CI systems. The toolkit does this by providing the CI operators with a means of quantitatively scoring their CI resilience and using the obtained score as a basis to improve their systems resilience. This is expected to help the CI stakeholders with an understanding and familiarisation of resilience concepts especially with regards to their CI systems. Currently, many of the tools used by stakeholders to enhance the security of their systems and component assets are mainly based on probabilistic risk assessment principles and have not been properly expanded to cover resilient management. Such tools are usually fragmented and are often hazard or discipline specific. In order to address the current disparate nature of such tools the ReMMAT explicitly addresses resilience as an integrated concept which draws from the different resilience domains and stages, and brings together different resilience management tools developed in the RESILENS project to enable. The toolkit presents the CI operators with different resilience assessment criteria in pre-defined resilience components which aim to highlight the need for consideration of all stages of the resilience cycle. The ReMMAT presents an additional value beyond the SOTA, since, although several resilience assessment methods have been outlined in the academic literature, the concept of resilience has not been operationalised within normal practice in CI systems. The tool helps to mainstream and operationalise resilience management in CI systems so that resilience is considered as an inherent aspect of operational and organisational planning and as an important factor which should be incorporated in the CI security design principles and measures.</td>
</tr>
<tr>
<td>Non-use of common</td>
<td>The toolkit provides and uses easy-to-understand terminology that</td>
</tr>
<tr>
<td>platforms and lexicon</td>
<td>is already expected to be used by CI stakeholders for the day-to-day management of the business continuity of their systems.</td>
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<td>-------------------------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| Current methods which can be employed within a CI resilience management processes | A number of useful but disparate tools have been developed in recent years which seek to address some of the issues specifically around CI resilience specifically. However, the existence of such tools is often not widely known and building awareness around the availability of such resources is a key area which this toolkit (and RESILENS as a project) can contribute to. This is since the toolkit brings together several resilience management assessment and enhancement tools in an easy to use format which is expected to be easier to grasp and adopted by CI stakeholders.

The methods can then be easily employed in potential resilience management processes in interested CI systems. |
| An appreciation of social and political factors considered in CI resilient management processes by CI operators. | The design of the resilience assessment criteria used to quantitatively score the resilience of the CI systems in the considered components in the Matrix tool initially draws from several societal influences on the CI system. In addition to this, the audit tool clearly calls for a careful consideration of the social and political, as well as environmental and economic external factors which can potentially affect the CI resilience especially during the process of developing strategies to enhance the CI resilience levels. |
| A requirement for greater organisational resilience | The ReMMAT provides a functional basis for considerations in organisational resilience which have previously not been properly treated in previous resilience methods. This is since most resilience models in the academic literature aimed at CI have been mainly focused on the technical/physical resilience domains. The toolkit described in this Deliverable provides a holistic resilience management approach which encompasses not only the physical/technical domain of the CI resilience, but also strongly addresses the organisational and societal domains.

Most existing methods in the literature tended to mainly address only one of these domains. This toolkit therefore contributes to the existing knowledge base on CI resilience by demonstrating how these domains can be incorporated to facilitate a practical tool built from important issues from these domains which can affect the overall CI resilience. |
| The need for more robust quantification, evidence and methods for CIR; Difficulty in evaluating impact | The toolkit and the resilience quantification tool component in it provides an excellent platform that allows for the CI stakeholders to obtain a robust and tangible resilience quantification output which is then further used to form the basis for designing and proposing resilience enhancement strategies for the CI.

For the integration and eventual success of potential resilience concepts in CIs, such robust quantification evidence is deemed necessary especially with its use in highly technical systems such as the CI systems which are the focus of the RESILENS project. To address this gap and meet this goal, a resilience scoring function applicable to the investigated CI system is obtained in the Matrix tool of the ReMMAT. The obtained resilience scores along with the defined resilience components and stages then form an evidence base which can then be used by the CI operators to support subsequent potential resilience building decisions in the CI system and subsequent resilience reviews using the documented supporting evidence.

The availability of such quantifiable, evidence based methods as put forward with the use of the ReMMAT provides the CI operator with a more improved understanding of their systems, with the considered strategies and future resilience scores used to monitor and gauge potential improvement in their systems resilience.

Integrated learning, training and knowledge transfer for resilience practice | In addition to the information pages in the different sections of the toolkit, which provides useful information to the CI operators on the concepts underscoring the resilience concepts applied in the toolkit, the ReMMAT was designed to enable the CI operators gain an appreciation of resilience principles especially with regards to how it affects their CI systems.

The audit toolkit builds on this by providing a means for a detailed consideration of the inter-linkages between the different resilience components, the interconnectivities with other CI and external factors (i.e. social, economic and political) by the CI user. This exercise aims to advance the understanding of CI resilience past viewing it as a singular aim of improving one system resilience component, but as a holistic goal with the overall improvement of CI resilience targeted by the CI operators.

The ReMMAT therefore integrates a learning function in its use, so
that even without a deep understanding of resilience concepts, a novice CI user after the use of the Matrix and Audit tools can possess a good understanding of the factors that potentially contribute to their CI resilience and how these might be improved.

8.2 Addressing the roadmap actions from D1.3

<table>
<thead>
<tr>
<th>Roadmap actions – D1.3</th>
<th>How does the ReMMAT address these actions?</th>
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<tbody>
<tr>
<td>Outline how the steps from CI protection to CI resilience management can be operationalised.</td>
<td>The ReMMAT demonstrates a functional tool which can be operationalised in practical CI systems. The toolkit integrates principles drawn from current business continuity, assets and risk management and emergency preparedness practices which are commonly applied in CI protection management in the development of the resilience assessment components in the Matrix tool and also forms key considerations in the audit tool. The outputs of the toolkit therefore highlight how such CI protection considerations can be extended and refined to facilitate the emergence and operationalisation of resilience management concepts in the CI.</td>
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<tr>
<td>Identify which metrics assist a shared understanding of current resilience; identify what universal metrics are needed and outline development.</td>
<td>The development of a resilience score in the ReMMAT which represents an overview of the resilience status of the CI system on the basis of the pre-defined different resilience assessment criteria provides a good basis for an understanding of the resilience concept and what it means to the investigated CI. The ReMMAT was designed in such a way so that it can be expanded to incorporate other resilience components which the CI operators later identify as key to their systems. So for example, if the CI operators decide to include a new societal criterion in the Matrix tool, this can be easily integrated into the existing tool with the definition of the associated assessment scales used to measure the component. Assessment components and metrics deemed as useful can therefore be included as suits the particular CI, but with the overall</td>
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<tr>
<td>Give detailed consideration to how societal implications can be measured and mapped.</td>
<td>The societal factors and implications of the CI resilience are addressed in the formulation of the resilience component criteria issues in the Matrix tool and are explicitly considered for the development of potential resilience enhancement strategies in the audit tool of the ReMMAT. The use of the ReMMAT therefore provides clear details of how such societal considerations are examined and integrated in the eventual resilience management and resource allocation approaches that will be put forward and implemented in the CI systems.</td>
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<tr>
<td>scoring system, as well as the score interpretation and enhancement guideline steps in the audit tool remaining the same, the use of the score outputs from the Matrix tool will always provide the CI operators with a shared understanding of the aspects of their systems where resilience improvements would be required.</td>
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Project Number: 653260  
Project Acronym: RESILENS  
D2.3 Resilience Management Matrix and Audit Toolkit
9. Summary, Limitations and Further Work

One of the major difficulties encountered in the operationalisation of resilience concepts is the practicality of combining the diverse research fields which must be considered to achieve a holistic resilience measurement and management tool, which can serve a dual function as both a diagnostic tool and as a way of assessing the impact of efforts to support and improve the systems resilience. This is especially since, as outlined in the WP 1 Deliverables, many definitions for the term "resilience" abound. Any objectives associated with the need for resilience quantification in investigated systems would therefore be often heavily reliant on the individuals or organisation’s specific understanding of the definitions. With the RESILENS project focused mainly on CI, a working definition for CIR was put forward in D1.3\textsuperscript{14} as:

’a transformative, cyclical process, that builds capacities in technical, social and organisational resources for critical system function, so as to mitigate the impacts of disruptive events and long-term incremental changes, thus guaranteeing the continued provision of its basic functions. CIR is based upon new forms of risk management, adaptability and the assessment of potential trade-offs between parts of a system’.

Using this definition, the development of a resilience management toolkit principally targeted for use by CI operators and managers for understanding their system resilience and facilitating potential resilience management was put forward by the RESILENS project and is presented in this Deliverable. This developed RESILENS resilience management toolkit as presented largely draws from the range of quantitative, semi-quantitative and qualitative resilience management tools developed in Task 2.3 which have the aim of aiding CI operators assess the different components, domains and situational contexts around their systems, quantitatively score their resilience levels, as well as effectively use the scores obtained from the assessment process to devise resilience enhancing strategies which could potentially improve the overall resilience of the investigated CI systems.

After using the web based ReMMAT, the CI operator is expected to have a first-hand understanding of the resilience levels of different organisational, technical and societal components of their CI systems (represented by the resilience scores), a priority list of which components might demand more attention, a list of actions which can be taken to improve the CI resilience levels and an idea of the resource demands to meet those resilience improvement needs (as well as the responsible parties who have been allocated to oversee the implementation of the resilience enhancing strategies).

\textsuperscript{14}Deliverable 1.3 of the RESILENS Project "Emerging Findings Report on knowledge, Current Practice, SOTA, GAP Analysis and Road map of Key Actions to Advance SOTA. Submitted 1 February 2016.
The different resilience assessment criteria components presented in the Matrix tool of the toolkit are not intended to be rigid in its composition. It is expected that the CI assessment function can be easily expanded to suit the resilience management demands of CI systems, with the concerned CI operators of such systems having the ability to identify new resilience assessment component criteria, with the proposition of suitable relevant criteria scales which will be used to score and monitor the new criteria. The toolkit can then be refined to fit the exact needs of the CI operator using it.

The RESILENS ReMMAT thereby provides an easy to use operational toolkit which goes beyond the current SOTA with regards to resilience tools and methods, and can be readily applied in CI systems for their resilience management objectives.

The results obtained from the Matrix tool are mainly proposed as an exploration of deliberated CI focused parameters which are associated with different component issues related to the resilience stages which have been put forward as requisites in D2.2 and used in the toolkit development. With the toolkit results being quite CI-specific in its evaluation approach, it does not pretend to present an unabridged inventory of resilience components and issues which extensively covers every potential factor in the organisational, physical, social and information domains with which a CI system is involved. The overall resilience scores obtained from the RESILENS resilience management toolkit are therefore not meant to form a basis for a direct comparison of the resilience of individual CI systems or assets, since the organisational and situational grounding for these CIs will be different. The toolkit and the outputs obtained from it are also not intended to support competitive goals i.e. as a measure of what infrastructure is better than the other with resilience used as a metric. The main goal of the resilience management matrix and audit toolkit is to highlight criteria issues which could be further probed by the CI stakeholders to enhance their individual preparedness capacity to be able to respond and recover with the goal of a continued provision of their critical functions to their end users.
References


