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**White Paper on Resilience Management
Guidelines for Critical Infrastructures.
From theory to practice by engaging end-users:
concepts, interventions, tools and methods**

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White Paper on Resilience Management Guidelines for Critical Infrastructures. From theory to practice by engaging end-users: concepts, interventions, tools and methods

1. INTRODUCTION

This White Paper outlines a pathway towards the integration of the European Resilience Management Guidelines (ERMG) developed as part of the work performed by five Horizon 2020 DRS-07-2014 Projects. Resilience management addresses essential capabilities for Critical Infrastructure (CI) to adapt to an uncertain future and changing environment. Targeted at policy makers, it provides an overview of essential resilience concepts, methods and techniques to attain results from these Projects and to work towards an integrated guideline which could be implemented EU wide. It presents various identified issues and opportunities surrounding a potential integration process including: resilience concepts and understanding; terminology and standardisation aspects; the core challenges in reaching full integration; complementarities as well as possible incompatibilities among the processes, methods, tools and interventions, and where future research would be beneficial towards adoption of resilience management. It presents some practical examples from the Project pilots and demonstrations of how these guidelines may be adapted and adopted by numerous target users to a variety of CIs and other domains.

2. RESILIENCE CONCEPTS AND DIFFERENT UNDERSTANDINGS

Recent years have brought numerous disasters and crises that, in hindsight, clearly demonstrate the potential benefit of more resilient CIs and social processes (Woods, 2003; Adini, et, al, 2017, Birkland, 2006; de la Torre, et al., 2012; Comfort, et al., 2010; EUROCONTROL, 2013). Examples include the SARS and H1N1 pandemic outbreaks in 2003, Hurricane Katrina in 2005, Eyjafjallajökull eruptions in 2010, Fukushima Daiichi nuclear disaster in 2011, and Hurricane Sandy in 2012. Compared to the past, these disasters challenge society in terms of dealing with the unexpected, large-scale, highly interconnected society and trans-boundary nature of events involving different countries, many private and public stakeholders and high expectations from citizens.

The changing landscape of crises which governments and societies are confronted with requires governments to adapt their approaches and capacities (Baubion, 2013). In response, resilience has the potential to address the increased complexity of today's interconnected social systems, addressing survival and even prosperity when facing challenging situations (Longstaff, 2013, BSI, 2014).⁶

⁶ The latest Global Risks Report (World Economic Forum, 2017) observes that although, in theory, greater connectivity brings intrinsic resilience, the increasing dependencies among different infrastructure networks is increasing the scope for systemic failures – whether from cyberattacks, software glitches, natural disasters or other causes – to cascade across networks and affect society in unanticipated ways". World Economic Forum (2017). The Global Risks Report 2017 12th Edition, Insight Report, Switzerland. Available at <http://wef.ch/risks2017>

The concept of “resilience” has gained popularity, scientific articles using the term have increased exponentially in many scientific areas as show in Figure 2.1. It has been used over different research areas such as societal, organisational, urban, city, personal, human, socio-technical, ecology, and disaster research.

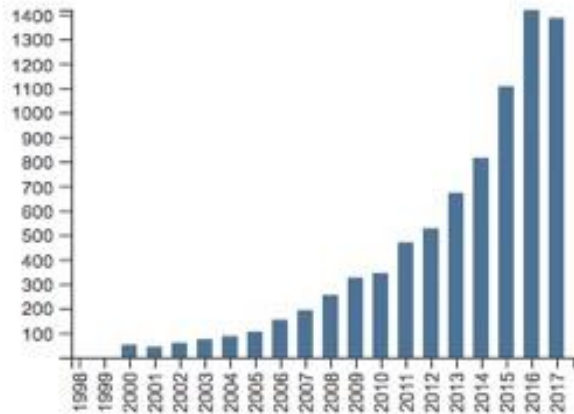


Figure 2.1. Resilience in scientific articles across CIs⁷

Hence, it is not a surprise that there is diversity, confusion, ambiguity and conflicting views on the scope and definition of “resilience”. This lack of clarity might hinder the operationalisation of resilience. To address this challenge, five H2020 European Projects have conducted world-wide literature reviews on resilience (DARWIN D1.1, 2015, RESOLUTE D2.1, 2016, SMR D1.1, 2016, IMPROVER, D1.2, 2016, RESILENS, 2015). One of these surveys identify over 300 different definitions - there are efforts to deal with these ambiguities. Survey findings show a lack of a clear definition of resilience, as well as gaps on information and understanding across agencies and CIs. It would be naïve to agree on a global definition; the different views are an invitation to remove silos and promote cross fertilisation and enrichment across domains. A possibility is to build on previous overviews and classifications of resilience understandings as illustrated in the table below (*adapted from Longstaff et al, 2013, Woods, 2015).

⁷ Prepared by Dr. Ivonne A. Herrera of DARWIN. Search for keywords: societal resilience, organisational resilience), resilience engineering, community resilience, city resilience, urban resilience and CIs Refined by categories social issues, sociology, ecology, environmental sciences, environmental studies, public environmental, public administration, occupational health, health policy services, health care services, water resources, telecommunications, transportation science technology, transportation, fisheries, multidisciplinary sciences, education scientific disciplines, management, computer science interdisciplinary applications, computer science information systems, automation and control systems, engineering manufacturing, construction building technology

Degree of Normativity Level of Complexity	Low: Descriptive Conceptual orientation: Outcome and capacity	High: Normative Conceptual orientation: Process and capability
Low: Reductionism Aspect of stability: Single state Characteristics: Linearity, predictability Dominant logic: Bounce back (absorb and recover)	I Resilience as capacity to rebound and recover Elasticity (capacity to absorb) Rapidity/rate (time required to return to predefined state)	II Resilience as ability to maintain desirable state Ability to absorb perturbations Maintaining functions
High: Holism Aspect of stability: Multiple states Characteristics: Non- linearity, uncertainty Dominant logic: Bounce forward (adapt and transform)	III Capacity to extend the adaptive capacity in the face of surprise Capability to stretch when events challenge boundaries of operation Transition between states Balanced contingency between system and contexts by adjustments	IV Sustain adaptability capability to adapt and thrive Adaptive responses Dynamic process encompassing both positive and negative adaptation Capability to self-organise, adapt and learn

Table 2.1 Multiple understandings of resilience*

There is common agreement in all projects that greater focus in disaster resilience is related to bouncing back. An example is the predominant definition of resilience from the United Nations Office for Disaster Risk Reduction (UNISDR): “The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management”, (Cocchiglia et al., 2012).⁸

⁸ The United Nations Office for Disaster Risk Reduction (UNISDR) definition of Resilience is available at: <https://www.unisdr.org/we/inform/terminology>

This definition can be connected to resilience of low level complexity, where the system can be described with sufficient detail. The definition comes short in terms of addressing complexity, under-specification, and emergence.

We argue that the different views of resilience have direct implications on the way the system is understood and improved. In short, resilience can be seen as a capacity to adapt to challenging situations whether expected or unexpected (changes, disturbances and opportunities). It is possible to map the DRS-7 Projects addressing different resilience understandings. The IMPROVER Project emphasises the preservation of key societal functions addressing concepts related to resistance, absorption and restoration. The RESILENS Project addresses organisational resilience including prevention, protection, mitigation, analysing current and future risks, building mechanisms for infrastructure hardening and incident response planning. Thus, we can see the IMPROVER and RESILENS Projects closely related in addressing a reductionism view on resilience (two upper quadrants). The SMR Project considers urban and city resilience, defining its scope as considering processes such as collaboration between stakeholders and social engagement. This Project sees a resilient city where human vulnerability is reduced because of appropriate infrastructure and is concerned with sustainability and continuity of critical services. It addresses ability to respond, recover and deliver timely restoration of basic services (quadrant II and III). The RESOLUTE and DARWIN Project addresses a view on holism and complexity, tackling the characteristics of non-linearity and emergence. These projects acknowledge that complexity generates emergent behaviours that cannot be solely understood by analysing the individual components. These Projects address themes related to understanding everyday operation, flexibility, self-organisation, brittleness, improvisation and sources of resilience. All projects address in different ways collaboration and coordination across multiple stakeholders. The surveys indicate a low level of maturity in terms of practical implementations and many resilience-related concepts are in early stages. After these surveys, all Projects have defined specific areas where resilience-related concepts evolve towards practical applications.

At a European level, the disaster management cycle addresses prevention, preparedness, response and recovery. It has emphasis on a risk management approach addressing national risk assessment and mapping considering a multi-hazard and multi-risk approach. Risk management deals with the coordinated activities to direct and control an organisation with regards to risk. It includes different forms of actions including structural, organisation and community measures to avoid (prevention) or to limit (mitigation, preparedness and response to) adverse events. While organisations need to maintain the capacity to deal with crises using a risk management approach, innovations are required to deal with new type of crises. These innovations are not seen as a replacement but as a complement to existing capacities. Therefore, organisations need to deal with the trade-offs preparing to crisis through predefined plans and procedures to address expected situations as well as developing adaptable and flexible capabilities to prepare to unexpected situations or situations that challenge established responses. The DRS-7 Projects propose strategies, methods and tools to support resilience management. The results include evidence of their added value with respect to established methods. More details on the relation between risk and resilience management are discussed below.

All projects have collaborated with each other and with other relevant initiatives. For example, the systematic literature reviews from DRS-7 have been provided as a starting point for future Projects (e.g. DRS-14 Smart Resilience). The Projects build on international terminology, standards and policies.

On-going H2020 Projects explore possibilities to build on results from DRS-7 Projects and example is IN-PREP using results from DARWIN Project. Standardisation activities conducted within SMR Project have received contribution from other DRS7 and DRS14 Projects. At its initial stages, IMPROVER has collaborated with the now completed FP7 Project CIPRNet (CIs Preparedness and Resilience Research Network), contributing with resilience related terms to the glossary of CI protection and resilience: www.cipedia.eu.

A conclusion concerning concepts is that, as good practice, resilience and related topics need to be explicitly defined so that the scope covered by the different studies, interventions, methods, approaches and practices is clarified. Another conclusion is that today, social systems and CIs implement numerous actions to manage crises, thus there is a need to understand and enhance existing resilience in systems and organisations.

Rather than providing a unique definition, the Projects contribute to highlighting the importance and complementarity between different resilience views as a way to enhance an understanding of resilience among CIs.

3. END USER INVOLVEMENT

3.1 Target end users

As noted in the previous section, each of the Projects address different understandings of resilience and different applications of the related concepts, from a direct application to CI to various applications to societies and cities. All were undertaken at different levels. As such, the target users of the different Projects' output would be expected to vary. Nevertheless, certain commonalities can be identified between the different Project's intended stakeholder groups. These include:

- First responders which contribute to the management of the type of incidents described in the previous section;
- National, regional or local governments and civil protection agencies (often as an umbrella organisation for civilian first response organisations) with a responsibility for not only crisis management, national or regional risk assessment and planning but also for policy making on various levels;
- CI operators, including the day-to-day operators, most importantly those persons within an organisation who play a complimentary role to the persons identified above for the managing organisation; and
- The research and standardisation communities since this is a direct route for the long-term uptake and impact of the Projects results.

There are some notable differences in the stakeholder groups between the Projects. For example, RESILENS, IMPROVER and RESOLUTE explicitly target the end users of CI services as stakeholders of the Project outcomes, and SMR's alternative focus on city resilience means that the main stakeholders of the Project are in fact cities in their functional role as part of Europe in a multi-level governance perspective.

DARWIN defines three different groups of stakeholders, a primary, secondary and tertiary group of stakeholders. The primary stakeholder group includes, for the most part, the groups identified and listed above (e.g. managers, NGOs and CI operators), although the groups responsible for policy making and standardisation on various levels are included in their secondary stakeholder group. Their tertiary stakeholder group includes consultants and other actors who do not directly benefit from, but who could influence the success of, the Project's outputs.

3.2 Mechanisms for inclusion

In all five Projects, mechanisms are in place to ensure that the various stakeholders are able to contribute to the creation, adaptation and adoption of the various versions of resilience management guidelines. DARWIN has its Community of Resilience and Crisis Practitioners (DCoP) which comprises 161 members from 22 countries in total who are co-creators of solutions, early adopter and potential end users of the Project results. IMPROVER has both a group of associate partners (comprising CI operators working in clusters around Europe) and the ERNCIP CI Operators network to which it has access via JRC. RESILENS, similar to IMPROVER, relies on end user Project partners (including the Water Sector in Ireland, Electricity and Municipal Government Sectors in Portugal and Transport Sector in Germany) to operationalise, evaluate and validate the Project outputs across a number of CI and public settings. Similar to the involvement of end users in the other four Project activities, partner cities in SMR have been central to the dissemination activities and implementation of their resilience management guidelines. These cities have formed a 'Circle of Sharing and Learning' with decreasing intensity of involvement and dissemination from the core circle (the three partners CITIES of Donostia/San Sebastian, Kristiansand, Glasgow) to the outer circles. In RESOLUTE has been created a User Forum composed by all city stakeholders interested in Urban resilience in general and Urban Transport System in particular has been created. The User Forum actively engages first responders, public transport operators, mobility departments, citizens, civil protection, educational institutions, etc. to incentive (big) data sharing, raise awareness and train people and operators on the ERMG and RESOLUTE technologies.

3.3 Presentation of outcomes to end users

All five Projects have undertaken continuous dissemination activities throughout their duration. This is often linked to the activities describing how the end users are involved in the creation, adaptation and adoption of the resilience management guidelines put forward by all of the Projects. All five Projects focus their dissemination activities on the specific backgrounds of the target groups addressing the potential motivation for their uptake of the Projects results. Specific techniques employed by the Projects include conferences and industry presentations, webinars, dedicated workshops, as well as experiments providing hands-on experience to engage end-users, together with educational and Continuing Professional Development (CPD) activities. All of these activities build upon the other stakeholder engagement activities with the aim of identifying key markets for the Projects and tailoring the Project outputs to these markets.

DARWIN has also included different training formats including a curriculum Master course for professionals, power point presentations, use of Emergo Train System, use of serious games such as

DARWIN Resilience Training for Operational Capabilities and a DARWIN serious game based on virtual reality (last one's prototypes).

Specific activities of the RESILENS Project include the development of the 'RESILENS Decision Support Platform' (RES-DSP), the RESILENS tools, incorporating a Resilience Management Matrix and Audit Toolkit (ReMMAT), an e-Learning Hub and a Concept of Operations (CONOPS) Approach.

SMR has implemented its tools in the seven city partners of the project and has implemented three additional regional clusters in Scandinavia, Spain and Greece to foster the use of the tools in more cities. IMPROVER collaborates with the European Commission's European Reference Network for CI Protection (ERNICIP, <https://erncip-project.jrc.ec.europa.eu>). Together, the two Projects co-organise a series of CI operators workshops on CI resilience to ensure that practitioners both inform and benefit from the work of IMPROVER on resilience (IMPROVER D1.4, 2016; D1.5, 2018).

Each of the Projects have a specific exploitation strategy which addresses individually the objective of encouraging uptake of the Projects' results by target users.

3.4 Key themes and synergies

Key themes in terms of stakeholder engagement in the different Projects include a targeting of CI operators, not only in the dissemination strategies of the different Projects but also in the actual development of the Project results. This is achieved largely through the inclusion of end users as participants either in the consortia or in workshops and other activities throughout the Projects and specifically in the final pilot implementations of the Projects' results.

Stakeholder surveys have been conducted by the Projects. For example, surveys were conducted at different stages, ensuring to meet user needs and expectations. This work has led to the identification of ten themes requiring improvements in terms of resilience management with the DARWIN Project (DARWIN D2.2 and D2.3):

SUPPORTING COORDINATION AND SYNCHRONISATION OF DISTRIBUTED OPERATIONS: 1 -Promoting common ground in cross-organisational collaboration; 2 - Establishing networks for promoting inter-organisational collaboration; 3 - Ensuring that actors involved in resilience management have a clear understanding of their responsibilities and the responsibilities of other involved actors;

MANAGING ADAPTIVE CAPACITY: 4 - Enhancing the capacity to adapt to both expected and unexpected situations; 5 -Establishing the capacity for adapting during crises and other events that challenge normal plans and procedures;

ASSESSING RESILIENCE: 6 -Identifying sources of resilience; 7 - Noticing brittleness; 8 - Assessing community resilience to understand and develop its capacity to manage crises;

DEVELOPING AND REVISING PROCEDURES AND CHECKLISTS: 9 - Managing policies involving systematically – policy makers and operational personnel for dealing with emergencies and disruptions;

INVOLVING THE PUBLIC IN RESILIENCE MANAGEMENT: 10 - Interacting with the public not yet affected by or involved in a crisis.

In addition to this end user involvement, all five Projects have identified the need to target policy makers either in the EU or in the individual Member States as stakeholders for the Projects' results. This is important as the long-term uptake of the concept of CI resilience relies on its adoption not only in CI, but also in national and international crisis planning and management activities (IMPROVER D5.1).

All five Projects have contributed to various activities together, attempting to achieve a synergy in terms of certain dissemination and communication activities. Shared events have been held and certain Projects have contributed to events held by some of the other Projects. Importantly, there seems to be significant overlap in terms of a focus on dissemination to stakeholders who will directly benefit from the Projects' results as opposed to dissemination via academic or research focussed industries.

4. INTERVENTIONS, TOOLS AND BENEFITS

This section provides an overview of the key Project outputs of the DRS-7 Projects. Each Project output has been classified into 8 categories: definition, strategy, analysis, evaluation, training, implementation, simulation, and other.

Definition:

- E-Learning Hub (RESILENS): An interactive platform containing e-learning resources and repository of supporting documentation, to support academic and vocational learning and CPD.
- Terminology (DARWIN): It describes terms used in the resilience management guidelines. Definitions come from standards or literature, references are included.
- Lexicon (IMPROVER): The IMPROVER lexicon has evolved over the course of the Project, with a draft presented at the end of the first year following completion of the international survey. A final version was delivered half way through the Project. It represents key definitions related to resilience agreed upon by the Project partners and stakeholders. All definitions will be transferable across borders, infrastructures and between the asset level and the policy level.
- Semantic Aware Taxonomy (RESOLUTE): the terms used in the project have been managed through a dedicated tool (SIDOC) where lemmas are disambiguated, semantically connected with other lemmas and then reused for buildings indicators. Thus, SIDOC tool supports a collaborative, consensus driven and not ambiguous common language and indicators definition.

Strategy:

- RMM (Resilience Maturity Model), (SMR): The RMM is a strategic tool that provides an ideal roadmap for how the resilience building process should be. It enables the identification of areas that have to be improved in each city, related to policymaking and planning. This tool also helps to enhance the communication among stakeholders which increases their awareness, engagement and commitment on the resilience building process.
- Method to adapt guidelines to specific CI (DARWIN): Method to adapt resilience concept to specific domains. It consists of two main phase assessments of adaptability of the generic

resilience concepts and adaptation of concepts to specific domains. The Project presents adaptation of resilience concepts to two domains such as air traffic management and health care.

- ERMG - European Resilience Management Guidelines (RESILENS): It provides a comprehensive guide to measuring and understanding the resilience of individual and interconnected CI systems, through a series of structured sections that address the key concerns and considerations through an ongoing and iterative process. The guide promotes greater flexibility, foresight, organisational learning and collaboration.
- ERMG - European Resilience Management Guidelines (RESOLUTE): it provides a number of guidelines with the aim improving the ability to cope with system performance variability, through the dampening and management of its operational impacts. In particular, a FRAM-based (Functional Resonance Analysis Method) “desired” model is provided, and for each function and interdependences identified a number of recommendations to dampen functional variability are identified. For each function in the model are reported general recommendations, common performance condition (CPC) – based recommendations, interdependencies management recommendations, real word examples, references. The ERMG aims at supporting a self-evaluated multilevel gap analysis in respect to the state of the affairs of the CI considered (D3.5 European Resilience Management guidelines, 2016).
- ERMG – UTS (Urban Transportation Systems) (RESOLUTE): it provides an adaptation of the ERMG that are generic of the all the transport infrastructures, to the UTS case.

Analysis:

- Triggering questions associated with resilience concepts (DARWIN): The DARWIN Resilience Management Guidelines (DRMG) are developed around the concept cards (CC) which represent sets of interventions including triggering questions proposed in order to develop and enhance specific resilience management capabilities
- Critical Infrastructure Resilience Index (CIRI) – (IMPROVER): It is a holistic, easy-to-use and computable methodology for analysing and assessing resilience which is based on other existing methodologies – e.g. the Repair & Maintenance, Inc. (RMI) developed by Argon labs in the US or the methodology developed by the Italian association of CI operators. It has been developed with a focus on the crisis management cycle and incorporates multiple domains of resilience. The methodology is applicable to all types of CI, including a possibility to tailor it to the specific needs of different sectors, facilities and hazard scenarios. The proposed methodology is especially suitable for organisational and technological resilience evaluation but also permits elements of societal resilience indicators in the evaluations.
- IMPROVER Technological Resilience Analysis (ITRA) – IMPROVER Technological Resilience Analysis (IMPROVER): ITRA combines a performance loss and recovery function, which indicates long term recovery for a given infrastructure, with an emergency response model which is used to determine the short-term recovery. Using this approach interdependencies can be identified and their impact on the recovery can be accounted for. Using the emergency response model also helps to priorities different recovery operations which can improve the overall ability of the infrastructure to adapt in the short term and to provide an immediate minimum functionality. Finally, the emergency response model also helps to identify the role of first responders in contributing to the resilience of CI.

- IMPROVER Organisational Resilience Analysis (IORA) – (IMPROVER): The IORA is a narrative based methodology for analysing organisational resilience. The purpose of the analysis is to promote resilient performance. This is based on identifying a hierarchy of functions, forms and processes which contribute to this purpose. The IORA process requires collection and processing of information about how an organisation’s processes contribute to this. Within the IMPROVER Project this is done via in-depth interviews based on narratives of historical events. Functions, forms and processes during this event form the basis for the analysis and the subsequent evaluation.
- IMPROVER Societal Resilience Analysis (ISRA) - (IMPROVER). ISRA is a methodology structured similarly to CIRI which focusses on societal resilience. It focusses on different social capitals, and includes the results of CI resilience assessment as part of a societies physical capita
- Quantified Functional Resonance Analysis Method (RESOLUTE)- Q-FRAM aims at extending the expressiveness of FRAM approach formalising the methodology and connecting (Big) data related to each function in the model to quantify variability and system resonance (Bellini et al. 2017; Bellini, Nesi Ferreira, 2016; Bellini et al 2016).

Evaluation:

- Risk Systemicity Questionnaire (RSQ) - (SMR): It is an Excel based tool where users are asked to consider the relative likelihood of a broad range of risks in their cities. These risks are spread across ten topics and are considered as networks of interrelated risks. These networks of risks are presented as risk scenarios, some of which result in vicious cycles. Users progress through the tool by completing questions.
- Evaluation method (cases) pilot trial (DARWIN): Pilot cases provide evidence of potential benefits of the guidelines. It combines a quantitative and qualitative evaluation assessment.
- ReMMAT - Resilience Management Matrix and Audit Toolkit (RESILENS): ReMMAT is designed to help CI operators have a better understanding of how resilient their entities are to potential disruptions (man-made or natural). ReMMAT allows CI operators to quantitatively score the resilience of their entities, assets or systems and provides a platform for them to qualitatively assess strategies that can be put in place to improve resilience.
- Criteria for evaluation of CI resilience (IMPROVER): The evaluation criteria for CI resilience in IMPROVER are based on user needs, physical needs or needs built into legislation, or on user tolerances. A methodology has been developed for elaborating these evaluation criteria in a way that they can be compared with the results of an analysis carried out using ITRA to inform engineering decision making.
- The system resilience is assessed through a FRAM-Driven approach, where a number of Key Performance Indicators (KPIs) has been identified for each function of the system. These KPIs are valorised through a mixed approach of expert judgment/data analysis. Synthetic indicators have been also defined to quantify the variability in the system related to each of the 4 resilience capacities: anticipate, respond, monitor, learn.

Training:

- Training material for operational resilience (DARWIN, prototype): D-TORC is a game-based training for operational resilience capabilities. It can be applied to specific DRMG Concept

Cards (CCs) and the scenarios. It includes operational, managerial and integrated training arenas.

- Academic course on resilience management (DARWIN): It was written by content experts in both arenas of disaster resilience, as well as in the field of academic teaching. Each module includes relevant CCs according to the DARWIN Project, an abstract describing the summary of the module, and learning outcomes.
- Serious game using virtual reality (DARWIN, prototype): Players conduct exercises to improve their understanding of the DARWIN resilience concepts, and to have memorable experiences that are beneficial in real crises. These exercises should present the main concepts, constraints, and guidelines so everyone involved in a large crisis has a better understanding and course of action. It is aimed to be an entertaining medium to introduce anyone to the DARWIN guidelines.
- E-Learning Hub (RESILENS): An interactive platform containing e-learning resources and a repository of supporting documentation, to support academic and vocational learning and CPD.
- Game-Based Training App (RESOLUTE): It is a tool to improve the preparation of citizens. It is motivated by its teaching potential: interactive, engaging and immersive. The learning is happening due to intrinsic motivation to play. Game-based learning has become an optimal training tool for soft skills development since it fulfils the following five criteria: Compelling content; Clear emphasis on practical application; Interactivity and experimentation; Genuine skills development through practice and feedback; Motivation for people to learn and, above all, to complete the course they begin.
- CI Resilience training material (IMPROVER): The training material from IMPROVER is currently under development, and includes a series of modules on the themes of: Introduction to resilience; the Improver CI REsilience Framework (ICI-REF); Technological resilience concepts and their implementation to CI (ITRA); Organisational resilience concepts and their implementation to CI (IORA); Holistic resilience assessment using the CIRI; Societal resilience concepts and their implementation to CI (ISRA); Implementation of resilience concepts (could also include e.g. expert elicitation and scenarios); and finally resilience evaluation and treatment. This training material will be made available on the IMPROVER website when it is finalised.

Implementation:

- Resilience Policies Tool (SMR): It is an extension of the online version of the RMM. It combines custom ways to view policies contained in the RMM with detailed information and examples from initiatives identified in the RSQ as well as case studies from SMR cities and further details from scientific literature. It is adaptable and interactive through the SMR Policy Wiki, where cities can request login details to contribute their own case studies to the tool.
- Resilience Information and Communication Portal (SMR): It serves as a toolbox that can complement and enhance the platforms and software that cities already have in place. It allows cities to display data internally or publicly that are already available to the city as it applies to resilience, vulnerability and crisis situations. The portal allows for different levels of users to allow for city managers, CI providers, citizens or other stakeholders to be able to contribute information as applies to a given city context.

- DARWIN Wiki (DARWIN): A DARWIN Wiki platform has been used to develop and manage the guidelines. The content is the result of co-creation between DARWIN partners and members of the DARWIN resilience and crisis community of practitioners.
- Critical Infrastructure Resilience Management Framework (ICI-REF) - (IMPROVER): The ICI-REF is a framework which lays out the relationship between CI risk management and CI resilience management. It formalises the steps needed to undertake a CI resilience assessment and describes where various tools could fit into this. The intention with the ICI-REF is that it could also take advantage of other Project outputs and methodologies to enrich the risk management process with information about resilience.
- Societal Resilience Management Framework (IS-REF) - (IMPROVER): The IS-REF is a framework similar to the ICI-REF, which enriches societal risk assessment with the results of resilience assessment.
- Collaborative Resilience Assessment and Management Support System – (CRAMSS) - (RESOLUTE). The CRAMSS is primarily a concept or an idea of a collaborative workspace in which DSS operators can share their outputs of or information about their operations among each other. Thus, the CRAMSS is a frame to gather, integrate, analyse and display information from separate legacy systems or Decision Support Systems (DSS) managed by different operators (e.g. mobility managers, civil protections, fire brigade). The CRAMSS consists of a backend that establish a bi-directional communication environment and it is built up on a Big Data layer that collects and fuse heterogeneous data from a sensorised urban environment and makes them available through dedicated APIS for further analysis. The CRAMSS is also composed by:
 - Resilience Dashboard: it supports reference actors at the UTS, such as infrastructure managers, with their decision making under both, standard operating conditions and emergency conditions displaying in real-time information from different sources such as: car accidents, presence of the people in city areas, etc.;
 - Evacuation DSS: The eDSS supports a quick and effective evacuation of the civilians taking into account how safe spots or paths may change with continuously evaluation of the situation exploiting the data in collected in real time by the Big Data layer;
 - Resilience DS: it allows the modelling of a complex system according to the FRAM approach. The tool supports the connection of the FRAM model with data collected by the Big Data Layer and formalise the variability propagation through a Tree Value Logic decision tree.
- Emergency Mobile App (ESSMA) - (RESOLUTE): ESSMA aims to assist the resilience of a community keeping civilians updated and guided for their reactions under danger situations. The main objective of the ESSMA application is to give the opportunity to civilians to be aware of emergencies and to know the most appropriate way to take in order to be safe.

Simulation:

- City Resilience Dynamics Tool (SMR): It is an online serious game, which represents the evolution of the City Resilience, depending on the policies cities implement. The simulation model allows the cities to understand the precedence relationship of the policies included in the RMM. It also provides the possibility of calibrating the model to every city particular characteristics.

- Discrete Event Simulation tool for specific situations (DARWIN): It is specifically tailored for a DARWIN scenario. The simulation supports the domain expert in assessing a particular strategy of resource deployment or the implications of a particular set of initial conditions.
- RES-DSP (RESILENS Decision Support Platform) (RESILENS): The RESILENS tools will be hosted on an interactive platform that allows users to access the guidelines and associated tools.

Others:

- Stakeholder analysis (DARWIN): This questionnaire is used to identify individuals, groups and organisations that are affected directly or indirectly by the resilience guidelines. It also identifies needs, priorities, barriers as well as opportunities for implementation of the guidelines.
- Association of European Schools of Planning (AESOP) Communication guidelines for CI operations (IMPROVER): Communication guidelines for CI operators to improve their interaction with communities, creating a sense of shared ownership with regards to the capabilities of CI in the event of a crisis.
- IMPROVER Web based resilience analysis tool (IMPROVER): this is a tool which is intended to facilitate the completion of indicator-based analyses, such as CIRI or ISRA.

5. POLICY, STANDARISATION AND CURRENT NEEDS

Policy

Context

The concept of Resilience has been reflected in recent EU policies with increasing rate and in various priorities. The EU has been working in various areas that aim in improving the Resilience of the Members States. Examples include the Digital Single Market⁹, the European Security Agenda¹⁰, the Joint Framework on countering hybrid threats¹¹, the Joint Communication on Resilience, Deterrence and Defence: Building strong cybersecurity for the EU¹² and the Communication on Launching the European Defence Fund¹³. Such recent policies indicate a shift from a reactive to a proactive approach.

While Member States remain responsible for national security, the scale and cross-border nature of the threats, such as cyber-attacks or hybrid threats, make a powerful case for EU action providing incentives and support for Member States to develop and maintain more and better national

⁹ Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 'A Digital Single Market Strategy for Europe', COM (2015) 0192 final, Brussels, 6.5.2015

¹⁰ Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, 'The European Agenda on Security', COM (2015) 185 final, 28.4.2015.

¹¹ Joint Communication to the European Parliament and the Council 'Framework on countering hybrid threats a European Union response', JOIN/2016/018 final, Brussels, 6.4.2016

¹² Joint Communication to the European Parliament and the Council 'Resilience, Deterrence and Defence: Building strong cybersecurity for the EU', JOIN (2017) 450 final, Brussels, 13.9.2017

¹³ Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 'Launching the European Defence Fund', COM (2017) 295 final, Brussels, 7.6.2017

capabilities, while at the same time building EU-level capacity. This approach is designed to galvanise all actors – the EU, Member States, industry and individuals – to build resilience.

Moreover, the EU Global Strategy for EU Foreign and Security policy elaborated the need for an integrated approach to link internal resilience with EU's external actions and called for synergies between defence policy and policies covering the internal market, industry, law enforcement and intelligence services.

The EU is already working under Horizon 2020 to develop a sound evidence base to strengthen resilience, in various areas such as:

- Climate Adaptation;
- Civil Protection;
- CI Protection;
- Cyber-Security;
- Security of critical transport infrastructure; or
- Energy security.

Policy recommendations arising

Based on the experience and findings of the Projects, focusing especially on CI (CI) resilience, it is proposed that:

- 1) The paradigm shift from protection to resilience would be reflected more in the EU/Member States policy documents;
- 2) The recommended direction in the EU/Member States would be to move from mere risk assessment/management towards resilience management, that is, focusing more on recovery capabilities (without losing the efforts to enhance prevention and preparedness); and
- 3) The EU/Member States should develop a strategy on how to balance between regulation and voluntary efforts by the private CI operators to enhance CI resilience.

Below follows a more detailed argumentation for the above policy objectives.

1) From protection to resilience

Although the concept of resilience has deep roots in many disciplines, in its contemporary meaning it may be appropriate to trace it back to the ecological debates of the early 1970s. The concept was popularised in unofficial policy and scientific analyses in the mid-2000s in the context of crisis and disaster management. Before long, it also entered the academic field of, for instance, CI studies, replacing the earlier focus on protection.

After some years, this paradigm shift became visible at the policy level as well, first and foremost in the US. As was the case with the concept of CI Protection (CIP), the EU followed the same trajectory after lagging behind for some years. While the concept of resilience was not even mentioned when EPCIP, the European Programme for Critical Infrastructure Protection, was launched in 2005-2008, in the 2012 Commission review of EPCIP it already plays a role, albeit a small one. As an alternative concept to protection, resilience didn't start to appear in the EC institutions in earnest until about 2014. The more recent Network and Information Systems (NIS) Directive (2016) reflects such a change as among its key objectives is to ensure the continuity of essential services against incidents affecting the security of the network and information systems used for the provision of such essential services¹⁴.

¹⁴ 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.

This development reflects the acknowledgment that complete protection can never be guaranteed, and that achieving the desired level of protection is not cost-effective as a rule in relation to the actual threats.

The exact boundaries of the resilience discourse in the context of CI or vital societal functions remains still rather blurred. Nevertheless, certain sub-discourses have emerged, and have even become institutionalised. Consequently, we can differentiate between at least three separate, albeit partially overlapping domains of CI resilience that show potential for policy change: organisational, technological and societal. When defining the CI resilience domain, in principle we can approach the issue from the perspective of the organisations or institutions that are in charge of taking the appropriate actions before, during or after a harmful and unwanted event affecting CI service provision. In organisational resilience, the actors are the businesses, especially those responsible for CI and supply chains, i.e. CI operators or operators of essential services. In technological resilience, the actors include CI systems and the respective facility operators, and, to some extent, safety and security manufacturers and vendors. In societal resilience, the important actors are national and local governments, communities and households, and it is in these contexts that CI resilience often overlaps with normal civil protection or crisis management efforts. This is where CI resilience also links to city resilience.

For example, on the EU level, the EU “Adaptation Strategy to Climate Change”¹⁵ formed a turning point in the understanding of the concept of resilience within the EU. It also acknowledged the essential role played by infrastructures and the need for climate-proofing. The concept of city resilience is wide and covers CIs, climate change, but also social dynamics. It still lacks widespread operationalisation and is only partially reflected in relevant policies. Challenges to be addressed are among others the engagement of multiple stakeholders with conflicting priorities and objectives, but also financial, practical, political, reputational, or other opportunities and constraints that the cities need to take into account when developing resilience strategies. Some examples on how cities are currently using public policy to integrate resilience thinking into their activities have been identified by the 100 resilient cities initiative¹⁶, in the three areas, namely Project design, land use planning, and budgeting and capital planning. Another institutional change can be the formalisation of the Chief Risk Officer (CRO).

2) From risk management to resilience management

The approaches of resilience assessment and management are overlapping with, and indeed a more generic concept than, risk assessment and management. While risk assessment is commonplace in corporations, most governments also carry out risk assessments. In recent years, in Europe risk assessment has become more important in such fields as civil protection and emergency planning. In the context of the Union Civil Protection Mechanism (UCPM)¹⁷, most European and neighboring

¹⁵ Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions ‘An EU Strategy on adaptation to climate change’, COM (2013) 216 final, Brussels, 16.4.2013

¹⁶ <https://www.100resilientcities.org/cities-changing-policy-trends-developing-urban-resilience/>

¹⁷ Decision No 1313/2013/EU of the European Parliament and of the Council of 17 December 2013 on a Union Civil Protection Mechanism Text with EEA relevance

countries¹⁸ have prepared National Risk Assessments (NRAs), generally following guidelines provided by the European Commission¹⁹. These guidelines follow closely the ISO 31000 family of standards.²⁰

The European Commission has summarised these NRAs into an overall overview of risks, emphasising risks that are shared by many countries, in 2014 and in 2017.²¹ Since 2013, Member States have committed to produce a new or updated national risk assessment every three years, starting from December 2015²². NRAs identify and assess the natural and man-made disaster risks which would, if faced, require a response at a national or supra-national level. According to the overview of risks published in 2017, “disaster risk types range from meteorological (flooding, extreme weather), climatological (forest fire, drought), geo-physical (earthquake, landslide, volcano) and biological (pandemic, epizootic, animal and plant diseases) natural disaster risks, to non-malicious man-made disaster risks of technological origin (industrial accident, radiological accident, CI disruption), and malicious man-made disaster risks and security threats (cybercrime, terrorism) closely associated with the European Agenda on Security”.²³ Finally, in collaboration with participating states, the European Commission has developed guidelines for the assessment of risk management capability (Commission Notice 2015/C 261/03).²⁴ Participating states must complete an assessment of their risk management capability by August 2018.

Should resilience become the dominant paradigm and strategy, this would basically entail the need of moving from the current (national, local, CI operator and facility-based) risk assessment/management toward resilience assessment/management when it comes to CI or, more generally, vital societal functions or essential services. In practice, this would mean clearly adding the recovery factor and respective preparatory issues to the risk management approach (risk assessment, prevention, and to some extent preparedness). The difference is that the occurrence of a crisis is assumed.

But how should resilience management be carried out? While in the field of risk management one can find several standards and best practices, there are no standards when it comes to performing resilience management. How do we know whether a CI (or any entity or community) is resilient or not? Can resilience be measured? How can it be enhanced?

In fact, a number of models do exist, some of which are only theoretical applications while others are already in operational use and designed for resilience assessment. No such models are in operative use in Europe, however. This is the issue that the current Project(s) have dealt with. The results include blueprints of resilience assessment and, to a lesser extent, management models.

¹⁸ These include across the EU 28 Member States and the six non-EU countries participating in the UCPM (Iceland, Norway, Serbia, Montenegro, former Yugoslav Republic of Macedonia, and Turkey).

¹⁹ Commission Staff Working Paper, 'Risk Assessment and Mapping Guidelines for Disaster Management', SEC (2010)1626 final, 21.12.2010

²⁰ <https://www.iso.org/iso-31000-risk-management.html>

²¹ Commission Staff Working Document on Overview of Natural and Man-made Disaster Risks in the EU, SWD (2014) 134 final, Brussels, 8.4.2014

Commission Staff Working Document on Overview of Natural and Man-made Disaster Risks the European Union may face, SWD (2017) 176 final, Brussels, 23.5.2017

²² Decision No 1313/2013/EU of the European Parliament and of the Council of 17 December 2013 on a Union Civil Protection Mechanism Text with EEA relevance.

²³ Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, 'The European Agenda on Security', COM (2015) 185 final, 28.4.2015.

²⁴ Commission Notice 2015/C 261/03 - Risk Management Capability Assessment Guidelines, 8.8.2015.

Resilience is already being explored within international and European standardisation levels. Some of the DRS-7 Projects are working towards *Comité Européen de Normalisation*/European Committee for Standardisation (CEN) Workshop Agreements (see section on Standardisation). In the field of CIs, the working groups of the ERNCIP Project could also be a means to perform pre-normative research that could inform such standardisation processes at a later stage.

3) Regulation or public-private partnership?

So where do private actors fit into the picture? This is an important question when it comes to CI in particular. Governments are usually legally responsible for safeguarding CI, and yet most of it is owned, administered and operated by the private sector. This is why public-private partnership (PPP) is regarded as a major issue in safeguarding national infrastructure.

While in the United States, private industry traditionally owns most of what is defined as national infrastructure (its share being estimated at 85 per cent),²⁵ in many European countries infrastructures such as water, energy, and railway transportation have previously been the sole remit of the government.

The rapid development of the predominantly privately owned and operated information and communication technology sector, and other sectors' dependence on it, has complicated the situation. This, coupled with other CI interdependencies, has led to a rather ambiguous situation in terms of the real authority, as government authorities may have, either formally or informally, overall responsibility for the reliable provision of services, but they lack the authority, resources and skills to actually fulfil that responsibility.

Hence, private industry is supposed to be able to exert extensive self-regulation because, in practice, only they have access to the necessary technical capabilities and information pertaining to most of the CI.

Added to this, globalisation, with its tendency to move private companies outside the nation state, has made the situation more complex from the perspective of government control. The fact that national CI are dependent not only on other sectors but on the situation in other countries complicates the situation because no single country is either immune to the effects, or able to predict the outcomes, if its neighbours suffering from serious CI disruptions.

Here we face the dilemma of the common good. Some have proposed that the solution lies in the concept and practice of Corporate Social Responsibility (CSR). However, while CSR and PPP may seem self-evident and are celebrated by all parties, this shallow consensus is usually broken when it becomes clear that governments expect the private sector to make considerable investments beyond their cost-benefit calculations. Thus, this dilemma leaves governments with only two options: to provide the necessary resources itself, funded out of the public budget, or to increase regulation.

In the US, the approach is clearly based on voluntary private sector cooperation with the federal government. This is largely due to the country's anti-regulation traditions, and the private sector's willingness to do their share precisely in order to avoid regulation. Compared with the US, the EU approach, referring to national rather than EU legislation, seems to mark a step towards regulative efforts instead of mere voluntary compliance, although both the US and the EU put emphasis on the importance of PPP.

²⁵ Government Accountability Office, The Department of Homeland Security's (DHS) CI Protection Cost-Benefit Report, June 26, 2009.

None of the EU Member States has thus far arrived at any clear solution to this dilemma. Undeniably, CI operators usually do prepare all kinds of regulatory and voluntary risk assessments, but the regulation is rather light, and often outdated. The field of cyber security, for instance, is for the most part owned by the private sector and companies tend to follow commercial logic, which creates a challenge for cyber security preparedness. The implementation of the NIS Directive tries to ensure a minimum level of security for operators of essential services.

There is, of course, rather detailed regulation in all countries related in particular to so-called high-risk industries, such as nuclear power plants, as well as organisations connected to critical public services, such as hospitals. They should have updated risk assessments as well as the respective capacities and capabilities, which are monitored in principle by certain independent state or municipal agencies. In many privately-owned CI cases, however, this regulation is also rather vague from the perspective of resilience.

Adding regulation would force the private sector to invest more resources in dealing with the protection or resilience of the systems they own or operate. This would be an unwelcome change for many CI operators because markets are externalising CI risks at present, whereas state regulation would mean establishing liability rules based on the notion that organisations should internalise the costs of the risks they produce and that by internalising them, they will make wiser choices about the technologies they use. This in essence would necessitate a well-functioning tort liability legislation, which would make it easy for consumers, both public and private, to subsequently demand compensation for losses incurred by CI failures, which in turn would force industry to pay more pre-emptive attention to security and protection out of self-interest.

In any case, the issue demands a solution. Again, the existing ERNCIP might become a part solution, providing a pilot case, based on its established series of “CI Operators Workshops”. While the EU might be too large to be involved to develop best practices, such entities as the Nordic countries or another selected group of countries (organised in sectorial CI operators and authorities’ cooperation, such as energy and transport) could test different voluntary solutions, at least.

Standardisation – needs and potentials

This section gives an overview of the standardisation activities of the SMR, RESOLUTE and DARWIN Project. The process on how to identify standardisation potentials, the development of a standardisation strategy of the SMR and DARWIN Project are described. All three research Projects took part in standardisation activities, because an early presence in the field of standardisation can lead to the following benefits:

- leading role in emerging technologies and innovations in general;
- public availability of relevant Projects results even having finished the project; and
- being part of the European Standardisation Community and thereby linking with relevant stakeholders.

Identification of Standardisations Potentials

In order for the SMR Project to identify standardisation potentials; existing standards and ongoing standardisation activities were identified and assessed. The so called ‘supply side’ is the amount of existing standards and ongoing standardisation activities as well as the developed results out of the SMR Project.

However, developed solutions can only be transferred into standards, if the stakeholders identify a matching need for these solutions. In this regard a survey and several standardisation sessions were conducted in order to receive the stakeholder's point of view and to assess their needs. These activities have been summarised as the 'demand side'. The survey consisted of 10 questions and was answered by city representatives from Bristol, Glasgow, Kristiansand, Riga, Rome San Sebastian and Vejle. The following four questions give an insight into the survey and the given answers:

What are your needs regarding new Standards?

- Steps on how to build a robust cross-sectorial and holistic collaboration in the city;
- Simplify cross-sectorial cooperation;
- Guidance on the creation of a responsive structure within the city which embeds resilience-building and breaks down sectoral boundaries;
- Clear and transparent action plan which will not increase bureaucracy;
- Standards who help create the breathing space (avoid being overly prescriptive).

What should be part of a standard on resilience management?

- Description on the difference between risk management and resilience management;
- Explanation why resilience management is important;
- General goals, action directions, evaluation scales, reporting templates;
- Information and knowledge sharing among municipal administrations, research institutions;
- civil protection services at local and national level as well as concerned citizen associations;
- A manual, a checklist or some informal standard for how initiatives should be prioritised organised and launched; and
- Good practices.

What are the reasons for not using formal standards?

- Every municipality is doing their own thing;
- Sometimes local/national guidance are preferred;
- Knowledge sharing issues and siloed skills as well as resources;
- Growing criticism that all of the additional administrative burden is placed on employees; and
- Often experienced as a control function and a lack of confidence that employees solve the task in a professional manner.

Which Format should a resilience related standard have?

- Toolbox for each city to 'pick and choose' the most appropriate issues for them;
- Helpful if the standard was provided as a framework of steps or stages; and
- Quantifiable values can be described (e.g. indicators on climate change).

Finally, the 'supply side' and 'demand side' have been brought together to identify the standardisation potential. The SMR Project evaluated four out of the six tools to have a significant potential for standardisation - the Resilience Maturity Model (RMM), the Risk Systemicity Questionnaire (RSQ), Resilience Information and Communication Portal (RP), and the European Resilience Management Guideline (ERMG).

CEN Workshop Agreement

The identified standardisation needs can be met through the development of a European Committee for Standardisation (CEN) Workshop Agreement. A CEN Workshop Agreement (CWA) is described in the CEN (European Committee for Standardisation) - CENELEC (European Committees for Electrotechnical Standardisation) Guide 29. The guide details the characteristics and the development process of a CEN Workshop Agreement. A CEN Workshop is basically a working platform open to the participation of any interested party. The proposal of a new CWA leads to the creation of a new Workshop. Next, the proposer of a CWA shall prepare a draft Project plan, a self-assessment and undertake an analysis of the degree of interest in the subject across different European countries and amongst different stakeholders.

The Project Plan of a CEN Workshop Agreement contains the CEN Workshop background, a description of the scope, the objectives, the time schedule of development and the contact persons. After one month of publication of the Project Plan on the CEN website, a Kick-off Meeting needs to be organized. During the Kick-off Meeting of the CEN Workshop, the Project Plan is confirmed and the chairperson as well as the secretariat elected.

In the development phase of the CWA, the participants need to agree on the content of the document. Public consultation is mandatory, if the CWA deals with a safety aspect (the draft CWA will be posted on the CEN website for a minimum of 60 days). For any other CEN Workshop, it is recommended, but not mandatory.

A CWA is valid for 3 years, after which the participants of the CEN Workshop are asked to make a choice to reconfirm, revise, upgrade into a standard/ technical specification or withdraw the CWA.

Strategy for Standardisation

The initiation of the standardisation activities depends mainly on the outcome of the standardisation research and the identification of standardisation potentials. The SMR tools that have been considered as most practical to transfer into a standard were the RMM, the RP and ERMG.

The standards series initiated through the SMR Project has the general title of 'City Resilience Development' – as all Project activities are referring to resilience building activities of cities – and as a subtitle of each CWA of the corresponding tool.

In summary the following three standardisation activities have been initiated:

- City Resilience Development – Operational Guidance;
- City Resilience Development – Maturity Model; and
- City Resilience Development – Information Portal.

As DIN, the German Institute for Standardization, is the only national standardisation body within the funded Projects under the same call (DRS-7 – DARWIN, RESOLUTE, RESILENS, IMPROVER), it was agreed with the funding authority that SMR will serve as a focal point for the other DRS-7 Projects. This was already approved and initially fostered by the SMR consortia within the European Workshop on Resilience in Cities and Communities that took place on 4th April 2017 at DIN in Berlin. All Projects

and cities that attended were actively invited to join the development process of the standardisation activities of the SMR Project.

When the three CWA's are finalised, it is proposed to actively advertise these standards within the relevant standardisation committees and to consider the possibility to adopt it on different national levels (e.g. in Germany as DIN SPEC (CWA)). In particular, the promotion of the CWAs within the following technical committees is envisaged:

- CEN-CENELEC-ETSI Sector Forum on Smart and Sustainable Cities and Communities;
- CEN/TC 391/WG3 Crisis Management/Civil Protection;
- ISO/TC 268 Sustainable Cities and Communities (mainly the International Organisation for Standardisation Technical Committee (ISO/TC) 268/SC 1 Smart community infrastructures); and
- ISO/TC 292 Security and Resilience.

From the beginning of the development of the CWAs, these technical committees were kept informed about the development process. Furthermore, SMR became a liaison organisation type D of the ISO/TC 268.

DARWIN also contributed to the standardisation activities of ISO/TC 292 Security and Resilience and CEN/TC 391 Societal and Citizen Security. The Project supported the development of 'ISO 22300 Security and Resilience – Vocabulary' and 'FprCEN/TS 17091 Crisis Management – Guidance for developing a strategic capability'. DARWIN has attended standardisation activities providing expert comments on standard formulation. These comments used knowledge gained through the Projects e.g. DARWIN literature survey.

City Resilience Development – Operational Guidance

The CEN Workshop was initiated in September 2017 through the preparation of the corresponding Project plan. The chairperson of this CEN Workshop is Vasileios Latinos from ICLEI (Local Governments for Sustainability, European Secretariat). The draft Project plan for this CEN Workshop was published on the CEN website for approx. two months and the kick-off took place on 8th November 2017 in Thessaloniki. The development team consists of 22 organisations from 12 different countries.

The envisaged CWA defines an operational framework for cities that provides guidance on local resilience planning and supports their efforts in building resilience.

The standard is primarily targeted towards policy and decision makers at city level and councillors working for climate adaptation and urban resilience, as well as to other city stakeholders working on resilience in their cities, (e.g. - examples but not limited to - CI managers, service providers, emergency services, individuals, media, non-governmental organisations, academic and research institutions, consultancies).

City Resilience Development – Maturity Model

The CEN Workshop was initiated in September 2017 by the preparation of the corresponding Project plan. The chairperson of this CEN Workshop is the Project coordinator of SMR - Jose Maria Sarriegi

from TECNUN (University of Navarra). The draft Project plan was published on the CEN website for approx. two months and the kick-off was taking place on 8th November 2017 in Thessaloniki. The development team consists of 23 organisations from 11 different countries.

The scope of the CEN Workshop is to develop a CWA that defines a framework to show the ideal path in the resilience building process of a city. This framework will be based on maturity stages a city should go through.

The standard is primarily targeted towards policy and decision makers at city level and councillors working for resilience in their city, as well as any other city stakeholders working on resilience (e.g. - examples but not limited to – CI providers, service providers, emergency services, citizens, individuals, media, non-governmental organisations, academic and research institutions, consultancies).

City Resilience Development – Information Portal

The CEN Workshop was initiated in May 2017 by the preparation of the corresponding Project plan. The chairperson of this CEN Workshop is Tim A. Majchrzak from Centre for Integrated Emergency Management (CIEM) (University of Agder). CIEM has been responsible for the development of the Resilience Information and Communication Portal (RP). The draft Project plan was published on the CEN website for one month and the kick-off took place on the 21st of June 2017 in Brussels. In total 9 organisations from 5 different countries are participating in the development of the corresponding CWA. Particular the research Project RESOLUTE is a big contributor of this CWA.

The CWA provides a list of requirements for how municipalities can equip an information system that facilitates resilience building through collaboration, communication, and engagement. This marks the functional specification of an RP. The portal is a platform for communication within a local government, between a local government and its overall stakeholders, and between a local government and citizens. Requirements aim towards a broad-purpose, easy-to-use platform that provides versatility and flexibility.

This document is intended to be used by information technology professionals and information technology decision-makers. It provides them with support in planning municipal information technology as well as operative help for the development process. The functional specification does not impose any specific paradigms, technological frameworks or third-party programs. The specification takes into account existing information technology infrastructure and following the recommendations can complement it. The specification provides for significant freedom and room for customisation. This facilitates a technological solution that aligns with political decisions, particularly deriving from a local government's information technology strategy.

Status and Further Needs

Resilience has raised a substantial interest across many industry sectors. This interest has been motivated by a wide variety of perceived needs and challenges. The changing nature of risk, related to an increased operational complexity and uncertainty, can be found at the core of most investments in resilience. However, resilience perspectives remain quite diverse, which inevitably results in the pursuit of equally diverse solutions and approaches. Definitions and understanding of resilience concepts remain very diverse and the five DRS-7 Projects here discussed offer considerably different

approaches to the implementation and management of resilience. Although some variances emerge from the different Project conceptual frameworks, they can essentially be considered the consequence of different sector needs and scopes of intervention.

The far-reaching nature of resilience as a concept leads to the possibility of valid contributions from many different approaches. While these can be complementary, the challenges for integration are as important as the different objectives and scope adopted by each of the Projects, and other industry needs potentially not addressed by these Projects.

A coherent and organised body of knowledge and methods cannot exist without conceptual clarity, in the same way that conceptual robustness is demonstrated by the coherency and consistency of the applied knowledge and methods that are derived from it. Thus, progress on resilience understanding and application should be addressed from two perspectives:

- The clarification of factors and aspects that are conceptually coherent within the scope of a resilience definition, and of the resulting tools and methods. This involves the identification of clearer boundaries between what it is and is not consistent with resilience as an organisational characteristic that must be managed;
- The development of an organised structure of knowledge and methods on resilience that supports the application of conceptual elements and tools according to a suitable methodological approach and within relevant contextual settings. As no single approach to resilience can be considered valid across the wide diversity of domains and organisational needs, a comprehensive mapping of resilience knowledge and methods to relevant domains and scope of application is needed.

Significant progress has been achieved in terms of the conceptual clarification. Section 2 of this paper offers a comprehensive overview of the perspectives on resilience across the five Projects. Keeping in mind that each of these perspectives were distilled from extensive literature reviews and research work, it can be argued that DRS-7 achievements are considerably robust in this domain.

The development of validated models of resilience are needed to support further progress on applied tools. Models are particularly relevant for the demonstration of indicators and assessment tools. A model provides traceability and meaningfulness for tools in view of different contexts of application, which becomes a fundamental support to decision-making in the scope of resilience management. The broadness of resilience concepts and practices are likely to render the integration of all relevant aspects within a single model an unrealistic endeavour, as the obtained model may become too complex to support resilience management needs. DRS-7 Projects provide considerable progress towards this endeavour, namely through the different sets of guidelines developed. However, integration and further validation work is needed before work on comprehensive modelling can be carried out.

Further work is needed to systematically relate concepts and methods to their relevant scope and domain of application. Practical applications of resilience have been demonstrated and the corresponding approaches have been validated, showing an improved level of maturity of the proposed solutions. Still, further work is needed towards their implementation. The rolling out of interventions, methods, tools and indicators across different domains and scenarios are needed to test the validity and the applicability of their output to the management of resilience. This will also give way enhancing the understanding of resilience and identification of aspects of resilience that are not yet addressed by the approaches offered by these five Projects and which domains or industry sector specificities require additional effort in terms of the development of dedicated tools and

methods. The roadmap towards integration here proposed addresses the priorities and requirements previously mentioned.

6. ROADMAP TO INTEGRATION

The roadmap proposed aims to produce a path for the integration of DRS-7 Project and achievements, and for future research and development on resilience. Three specific objectives should be considered for the development of the work plan laid out by this road map:

- The integration of all DRS-7 Projects, namely guidelines, resilience assessment and monitoring tools, and resilience management interventions and approaches, by mapping onto a resilience model and disaster management life cycle the relations between these outputs.
- The identification of resilience conceptual and applied aspects that may require further work, namely through the identification of gaps between the different Project contributions and the outcome of the taxonomy and conceptual framework to be developed, where such Project contributions may overlap, and potential additional clarification and refining may be needed.
- The outline of requirements for future work for the development of resilience management.

A possible path could be approach grounded on the development of a taxonomy, which will produce a systematic description of the relations between the different contributions and output from the DRS-7 Projects. A conceptual framework will support the definition of the descriptors for the taxonomy. classification criteria. The taxonomy work will then support modelling activities, based on which Project tools and methods can be mapped in view of their scope and context of application, and from which future work on resilience enhancement can be identified.

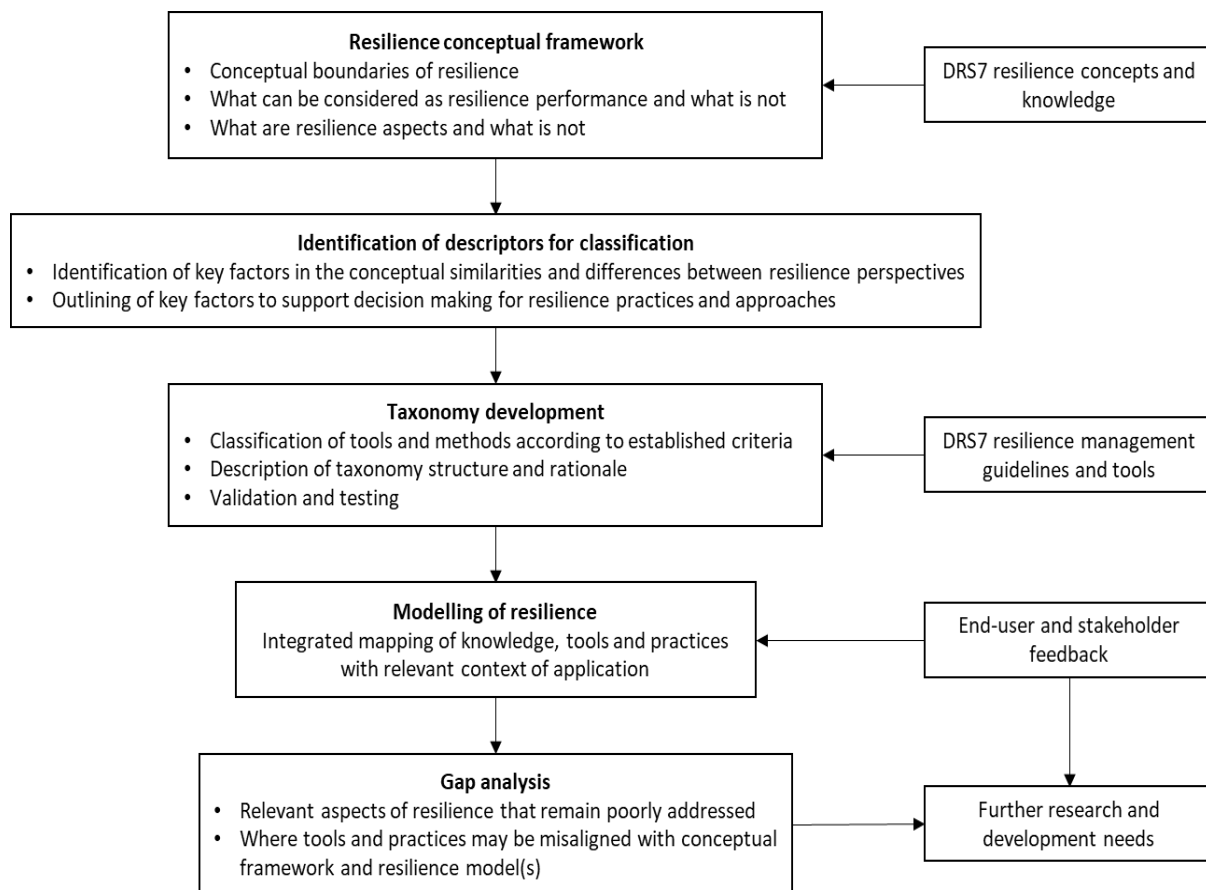


Figure 7.1 Resilience Roadmap Approach

The contributions and achievements of DRS-7 Projects respond to different steps described in the roadmap. The following aspects are particularly relevant as contributions to the roadmap:

- The different sets of **guidelines produced and work on standardisation**, not only contribute to the conceptual framework through the research and literature review work from which they were developed, but also provide an extensive support for the definition of the taxonomy descriptors. They are also one of the key inputs from the Projects to be mapped onto a resilience model.
- **Assessment, metrics and monitoring tools and the various validation and testing approaches** that were undertaken by each of the Projects, in particular involving end-users and other relevant stakeholders, will feed the core of the taxonomy work and support its validation.
- The **contacts and networks** developed throughout the duration of the Projects will provide the means to generate end-user and stakeholder feedback.

The roadmap outlined offers ample opportunity for the enhancement of Project achievements and for the further exploitation of their output. It also highlights the consistent and integrated continuity of work in terms of resilience related research and development within the scope of improved societal security.

7. CONCLUSION

This White Paper delineates the productive activity of the five DRS-7 Projects. It answers the invitation “to link the on-going efforts and share EU-wide risk assessment and mapping *approaches*” outlined in the original DRS-7 call topic.²⁶ The research activity of the five Projects has resulted in a community of resilience scholars actively participating in and monitoring the EU effort to create and sustain smarter responses to adverse man-made and environmental events. There is a consensus in all Projects that greater focus in disaster resilience is related to bouncing back. The Projects have broadened this perspective with complementary perspectives and concepts. CIs, cities and society are not only expected to respond and recover but to look for ways to thrive in the new ecology of adversity. To facilitate this goal, the DRS-7 Projects have provided extensive literature reviews, guidelines, interventions and toolkits to garner end user input and to provide practical resources for policy advisors, CI users, and owners. The interdependency²⁷ of critical resources leads to a cascading effect during and subsequent to an adverse event. This infrastructural reality is a common theoretical thread among the DRS-7 consortia and in practice, all five Projects produce cascading effects on each other, from enriching the scholarly baseline to symbiotically developing each other’s standardisation and integration strategies.

The consortia aim to improve policy and implementation strategies across the EU and beyond. The DRS-7 consortia recommend a paradigm shift from protection to resilience and that this be reflected more in the EU/Member States policy documents. This leads to the conclusion that EU CIs need to be regulated across state, semi-state, and private providers. The question of Regulation or public-private partnership has risen to the top of all five project conclusions and the consortium call for further investigation into how best to protect EU CI and plan for liability and compensation strategies in the event of loss and/or damage to said CIs. The roadmap for integration demonstrates a robust strategy for exploitation of the combined expertise of the DRS-7 consortia and provides a tangible resource for securing a more resilient future for Europe.

REFERENCES

Adini, B., Cohen, O., Eide, A., Nilsson, S., Aharonson-Daniel, L., Herrera, I. (2017) Striving to be resilient: What concepts, approaches and practices should be incorporated in resilience management guidelines? *Technology Forecasting and Social Change*. In Press.

BSI British Standard (2014). Guidance on organisational resilience BS 65000:2014. Available at: <https://shop.bsigroup.com/ProductDetail/?pid=000000000030258792>.

Baubion, C. (2013), “OECD Risk Management: Strategic Crisis Management”, OECD Working Papers on Public Governance, No. 23, OECD Publishing. <http://dx.doi.org/10.1787/5k41rbd1l7r7-en>.

²⁶ TOPIC: Crisis management topic 7: Crises and disaster resilience – operationalizing resilience concepts Research and Innovation Specific Challenge. Available at: <https://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/drs-07-2014.html>

²⁷ O’Rourke, T.D (2007), (‘CI, Interdependencies, and Resilience’, *The Bridge – Linking Engineering and Society*, 37(1), pp. 22-30).

Bellini, E., P. Nesi, P. Ferreira, A. Simoes, L. Cocone, E. Candelieri, A. and Gaitanidou Towards resilience operationalisation in urban transport system: The RESOLUTE Project approach. DOI:10.1201/9781315374987-320. pp.2110-2117. In Risk, Reliability and Safety: Innovating Theory and Practice - ISBN:978-1-138-02997-2.

Bellini E. Ceravolo P. Nesi, P. Quantify resilience enhancement of UTS through Exploiting Connect Community and Internet of Everything Emerging Technologies - *ACM Trans. Internet Technol.* 18, 1, Article 7 (October 2017), 34 pages.

Bellini E. Nesi P, Ferreira P. Operationalize Data –driven resilience in Urban Transport System in Florin, M.-V., & Linkov, I. (Eds.). (2016). *IRGC resource guide on resilience*. EPFL Lausanne.

Birkland, T. A., 2006. Lessons of disaster. Washington: DC: Georgetown University Press.

Cocchiglia, Letizia, Patrick J. Purcell and Mary Kelly-Quinn, 2012. A critical review of the effects of motorway river-crossing construction on the aquatic environment. *Freshwater Reviews* 5, pp. 141-168. <https://www.fba.org.uk/journals/index.php/FRJ/article/viewFile/489/329>

Colten, E. C., Hay, J. & Giancarlo, A., 2012. Community resilience and oil spills in coastal Louisiana. *Ecology and Society*, 17(3), p. 5.

Comfort, L. K., Boin, A. & Demchak, C. C. e., 2010. Designing resilience: Preparing for extreme events. Pittsburgh PA: University of Pittsburgh Press.

DARWIN, 2015. Deliverable D1.1 Consolidation of resilience concepts and practices for crisis management. Available at: <http://www.h2020darwin.eu/Project-deliverables>.

de la Torre, L. E., Dolinskaya, I. S. & Smilowitz, K. R., 2012. Disaster relief routing: Integrating research and practice. *Socio-economic planning sciences*, 46(1), pp. 88-97.

EUROCONTROL, 2013. Challenges of growth 2013 Task 8: Climate change risk and resilience. [Online] Available at: <https://www.eurocontrol.int/articles/challenges-growth> [Accessed 19 February 2016].

IMPROVER, 2016. Deliverable D1.1 International Survey <http://improverProject.eu/2016/06/23/deliverable-1-1-international-survey/>.

IMPROVER, 2016. Deliverable D1.3 Final lexicon of definitions <http://improverProject.eu/2017/05/31/final-version-of-the-lexicon/>.

IMPROVER, 2016. Deliverable D1.4 Report of operator workshop 1 <http://improverProject.eu/2016/06/23/deliverable-1-4-first-operators-workshop/>.

IMPROVER, 2018. Deliverable D1.5 Report of operator workshop 2 <http://improverProject.eu/2018/02/16/deliverable-1-5-second-operator-workshop/>.

Kitchenham, B., 2004. Procedures for performing systematic reviews, Keele, UK: Keele University, p. 8.

Longstaff PH, Koslowski TG, Geoghegan W. (2013) Translating Resilience: A Framework to Enhance Communication and Implementation. In: Proceedings of the fifth Symposium on Resilience Engineering, resilience engineering association.

RESILENS, 2015. Deliverable D1.1 Resilience Evaluation and SOTA Summary report. Available at: <http://resilens.eu/wp-content/uploads/2016/08/D1.1-Resilience-Evaluation-and-SOTA-Summary-Report.pdf>.

RESOLUTE, 2016. Deliverable D2.1 State of the Art Review.

RESOLUTE, 2016 Deliverable 3.5 European Resilience Management guidelines http://www.resolute-eu.org/files/D3.5_European_Resilience_Management_Guidelines.pdf.

RESOLUTE, 2016 Deliverable 3.7 ERMG adaptation http://www.resolute-eu.org/files/RESOLUTE_UTS-D3-7_final_v1-15_no-rk.pdf.

SMR Smart Mature Resilience (2016). Deliverable D1.1 Survey report on worldwide approaches. Available at: http://smr-Project.eu/fileadmin/user_upload/Documents/Resources/WP_1/D1.1.SMR_Final.pdf.

Woods, D. D., 2003. Creating Foresight: How resilience engineering can transform NASA's approach to risky decision making, s.l.: US Senate Testimony for the Committee on Commerce, Science and Transportation.

Woods, D. D., 2015. Four concepts for resilience and the implications for the future of resilience engineering. *Reliability Engineering & System Safety*, Volume 141, pp. 5-9.