Resilience Management Guidelines for Critical Infrastructures, Practical Solutions Addressing Expected and Unexpected Events

Expect the unexpected and know how to respond - DARWIN Project, February 2019

Resilience Management Guidelines for Critical Infrastructures, Practical Solutions Addressing Expected and Unexpected Events

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Abstract

Crises and disasters (Eyjafjallajökull and Deepwater Horizon 2010, Fukushima Daiichi 2011, and more recently the wildfire in Sweden 2018) have made it obvious that a more resilient approach to preparing for and dealing with such events is needed. This paper presents the results of the H2020 DARWIN project, which contributes to improving responses to expected and unexpected crises affecting critical infrastructures and social structures, whether man-made events (e.g. cyber-attacks) or natural events (e.g. earthquakes). The main result of the Darwin project is the creation of the DARWIN Resilience Management Guidelines (DRMG). The DRMG are evolving guidelines, designed to improve the ability of stakeholders to monitor, anticipate and learn from crises, and thereby allow them to adapt and respond more effectively and operate more efficiently during disasters. These guidelines are not prescriptive. Instead, they enable organizations to have a critical view of their own crisis management activities. The target beneficiaries of DARWIN are crisis management managers and practitioners responsible for public safety, such as critical infrastructures and service providers, which might be affected by a crisis, as well as the public and media.

The DRMG are not meant to be dust-collectors on a shelf. To this end, they have been made into a variety of formats to support their evolution, ease of use and maintenance. Within this paper, the reader is introduced to the DRMG in its different formats, as well as a host of innovative tools (e.g. DRMG Wiki, serious gaming, training packages) developed by the project to support resilience management learning and the uptake of the guidelines. A multidisciplinary approach is applied, involving experts in the field of resilience, crisis and risk management, social media, and service providers in the air traffic management and healthcare domains.

To ensure transnational, cross-sector applicability, long-term relevance and uptake of project results, the DARWIN Community of Practitioners (DCoP) has been established, with membership including experts and end users from different fields of expertise and from across multiple critical infrastructure domains. The DCoP has been involved in an iterative development and evaluation process to provide feedback on the results. The evaluation in pilot exercises and other activities involved 247 practitioners from 22 countries. The DCoP members contributed with knowledge and experience ensuring the feasibility of adapting them to other critical infrastructure domains. Our achievement is the current version of guidelines and associated innovative tools proposing practical interventions that end-users find useful. This paper includes testimonials of end-users within and outside the consortium. This document represents an invitation to explore the content of the guidelines, to encourage its use and further developments of the resilience management.

KEYWORDS: crisis management, resilience, critical infrastructures, air traffic management, healthcare

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ABBREVIATIONS

ATM	Air Traffic Management
CEN	European Committee for Standardization
CI	Critical Infrastructure
CC	Capability Card
DCoP	Darwin Community of Crisis and Resilience Practitioners
DRMG	Darwin Resilience Management Guidelines
D-TORC	DARWIN Training for Operational Resilience Capabilities
EC	European Commission
EMS	Emergency Medical Services
H2020	Horizon 2020 EU Research and Innovation Programme
ISO	International Organization for Standardization
OECD	Organisation for Economic Co-operation and Development
TORC	Training for Operational Resilience Capabilities
VR	Virtual Reality

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1. THE NEED FOR RESILIENCE MANAGEMENT

The changing landscape of crises highlight the limitations of the established risk management strategies. Examples of crises include the H1N1 pandemic outbreaks in 2003 and 2009, Hurricane Sandy and Thanksgiving holidays in 2005, Eyjafjallajökull and Deepwater Horizon in 2010, Fukushima Daiichi in 2011, and more recently the wildfires in Sweden and Portugal in 2018. Some trends that have influenced the need for a practical resilience approach are:

- The awareness of the limitations in prevalent risk management approaches that has focused on the predictability of the occurrence and impacts of risks and that has downplayed rare events, systemic risks, emerging risks and risk controversies [1], [2]. [3], [9];
- The changing regulatory and public view on societal safety to one where citizens no longer have the ability to manage the risks around them, where people are demanding actors to take greater responsibility, e.g. regulators to secure oversight, and operators to learn from events and to balance potential risks, time-to-market, and budgetary pressures [4], [5];
- The changing nature of crises and the increased need to address issues including: complexity and interdependencies across critical infrastructures, uncertainty, how crises may evolve, and their scale and pace [6], [7];
- Insufficient ability and increasing demands to learn and evolve from experience from crises and limitations of prevention and planning [8];
- The challenge of managing conflicting objectives, as typified by competition for limited resources in times of crises, or between safety and economic goals [10], [11], [12];
- The increase in real-time information flow to and from the public due to the complexity of the risks and crises as well, as the accessibility of data through social media, thus changing the role of the public in responding to the event and their expectations from governing and response entities [13];
- The challenge in security research of how to bridge the gap between research and market, and to encourage the exploitation of valuable and promising research results [14]; and
- The increase of connectivity and digitalisation which contributes to intrinsic resilience, and in turn, increased interdependency among different critical infrastructures. Hence, it increases the scope of systemic failures, for example cyberattacks, software glitches, and natural disasters cascading across networks and affecting the society in an unanticipated manner [15].

These trends highlight the need to move from crisis containment towards a non-linear approach to vulnerabilities [16]. The concept of 'resilience' has gained popularity in many scientific areas with diverse understandings. Therefore, it is not a surprise that there is diversity, confusion, ambiguity and conflicting views on the scope and definition of resilience, which may hinder the operationalisation of resilience. There is a lot of emphasis on disaster resilience as the capacity to 'bounce back' from adverse events. Our research shows that this view is not sufficient [17]. Inspired by the fields of community resilience and resilience engineering, we focus on resilience as the ability to 'bounce forward', adapt and transform. In practical terms, it is the ability of an organisation to monitor, to anticipate, to adapt and respond, and to learn and evolve.

DARWIN is a Horizon 2020 research project aiming to address the gap between the theoretical resilience knowledge and its practical use, as well as the aforementioned trends in resilience and crisis management. The purpose of the project is to propose a more resilient approach to prepare for and deal with both expected and unexpected events. In this context, the project developed state of the art DARWIN Resilience Management Guidelines (DRMG) and innovative tools for crisis management. The DRMG have the capacity to evolve to accommodate the changing nature of crises and constant growth of resilience knowledge. The DRMG are not prescriptive. Instead they enable organizations to

have a critical view on their own crisis management plans. In this way, organizations can easily integrate the guidelines into their own existing management practices and procedures.

It is possible to identify three different target users of the guidelines: primary, secondary and tertiary users:

- **Primary target users** are people or organisations who manage crises and emergencies. They are direct recipients of the guidelines and represent a high priority need. They directly influence the development of the guidelines. These are the most important professionals and end-users of the guidelines;
- **Secondary target users** are those affected by the guidelines. In our case, they represent operational roles, front line operators, policymakers, national and international committees. It is essential that their interests be considered for the proposed innovation to fit into existing arrangements, e.g. compatibility with existing procedures, practices and systems; and
- **Tertiary target users** are external actors who do not benefit directly or make decisions that affect the development of the guidelines, but have an influence of its success, e.g., consultant, other CIs.

The rest of this paper is dedicated to presenting main results concerning the development of the guidelines and associated innovative tools. A large community of 170 crisis management experts and researchers from 25 countries co-created of the DARWIN guidelines and provide inputs to the associated innovative tools. The document includes steps foreseen to ensure the use of the DARWIN guidelines will be sustained over the coming years. The overall conclusion is that the project, together with a community of practitioners, brings expertise and experience in an actionable body of knowledge. Therefore, this document is an invitation to for the reader to explore its broader use and development among diverse critical infrastructures.

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2. RESILIENCE MANAGEMENT GUIDELINES: KNOWLEDGE, INTERVENTIONS AND TOOLS

2.1 Main results

This section presents a summary of the main results of the DARWIN project. These results have been developed with active practitioners in such a way that they can be considered building blocks for enhancing resilience. These results include:

Updated knowledge on resilience for crises management
- Comprehensive consolidation of resilience concepts and practices;
- Practitioners and academic requirements for the development and evaluation of resilience management guidelines;

Operationalization of resilience concepts
- DARWIN Resilience Management Guidelines (DRMG, latest issue updated after evaluation activities);
- Methodology and adaptation of the guidelines to healthcare (HC);
- Methodology and adaptation of the guidelines to air traffic management (ATM);

Innovative tools that support evolution: development and use
- DRMG includes the DARWIN Wiki and DRMG Book;
- Training tutorials, simulation and serious games;

Enabling co-creation and relevance for end-users
- The DARWIN Community of Practitioners will now continue after the conclusion of the project to support expertise exchange, as well as the practical application and further development of the DRMG (DCoP Terms of Reference);
- Interactive workshops and webinars involving the DCoP members;

Providing evidence of advances and benefits on realistic cases
- Evaluation activities including pilot exercises provide evidence on the progress achieved in terms of translating the body of conceptual knowledge on resilience into practical interventions including degree of achievement with respect to the requirements.

These results are also illustrated in Figure 1 as follows: Updated knowledge (Result 1); resilience management guidelines and adaptations to HC and ATM (Result 2), DARWIN Wiki and DRMG Book (Result 3), Simulation and serious games (Result 4), Training modules (Result 8), Interactions with Community of Practitioners - DCoP (Result 6 and Result 7) and Evaluation activities (Result 5).

2.2 Integrating knowledge and experiences from end-users

The inclusion, interaction and collaboration with end-users was central to the success of the DARWIN project. End-users became co-creators of the DRMG who were actively involved throughout the project. In the early stages of DARWIN, the end-users were essential in identifying the needs, practices and requirements to be considered in the development of the guidelines. The end-users also evaluated the DRMG and tested the tools developed by the project through a series of exercises. The end-users were one of the primary audiences for the adoption of the guidelines. Figure 1 also provides an overview of the interactions and contributions between end-users participating in the DCoP and the project results.

In reality, the process for end-user involvement was not that neat. For example, there were many iterations of the DRMG developed during the pilot exercise phase. This was necessary to ensure the correct translation of theoretical knowledge into practical interventions that could be used in the pilots.
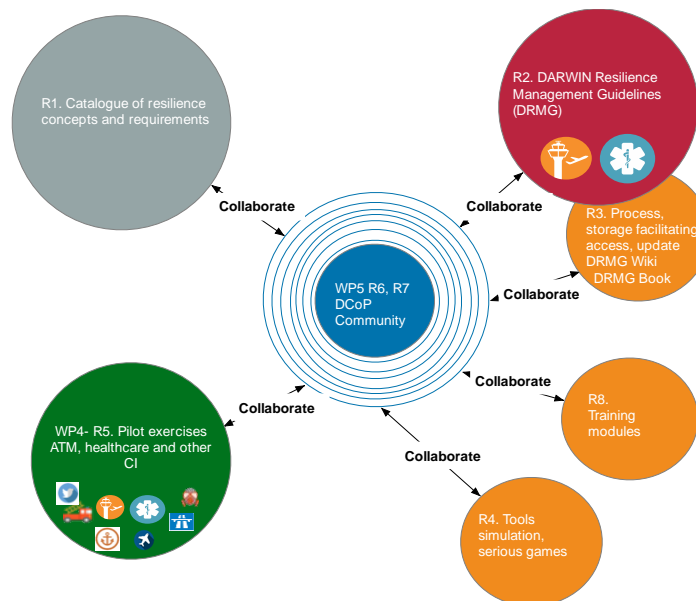
Figure 1 DARWIN Results co-created and co-evaluated involving end-users

Overall, the evaluation process was successful in involving a considerable number of resilience practitioners, coming from a large variety of countries and crisis management sectors. If we consider all the different contexts and diverse activities in which the DRMG was evaluated, about 247 participants were directly involved in the evaluation of the Capability Cards (CC). Almost half of them were involved during the different DCoP workshops. Then 61 were involved in the pilot exercises and 25 participated to an additional small-scale evaluation focusing on emergencies following mass casualty accidents on the highways. The practitioners came from 22 different countries (including non-European ones) and although the majority of them came from the healthcare and aviation domains, many other sectors were involved, for example water and waste, economics and finance, fire and rescue, CBRNE and energy. See Figure 13 for an overview of domains involved.

Here are some examples of the engagements undertaken:

- The results of the project were presented to and discussed with members from the Community of Users for Safe, Secure and Resilient Societies. Members of this community also enrolled as DCoP members;
- The project team included end-users from healthcare and air traffic management. These end-users led adaptation process in terms of definition and also enriching the guidelines with operational, managerial and contextual content. This provides both end-user and expert perspectives. These end-users contributed to the design of relevant scenarios for evaluation of the guidelines; and
- The DCoP complements the development and evaluation of the guidelines providing a transnational perspective, applicability to critical infrastructures beyond healthcare and air traffic management, long term relevance and uptake.

2.3 World-wide review of existing knowledge

The DARWIN project started generating input to the DRMG mainly through an extensive world-wide literature survey, covering several hundred journal articles related to resilience, and interviews on resilience with relevant practitioners from various critical infrastructure domains as illustrated in Figure 2.

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Figure 2 Map illustrating geographical places covered in the literature survey

Common topics in the form of concepts, theories and practices emerged from the literature and interviews. The literature revealed an emphasis on the phases before and during the event when addressing needs and issues, and on both planning and responding when discussing solutions and practices. The interviews also highlighted the practices that indicate a degree of resilience, flexibility and adaptability to circumstances in practice. Important elements to consider included: cultural aspects of various groups and organisations, variations in reliance on and adaptation of procedures, the use of domain-specific working groups, aspects of everyday work versus crisis situations, dynamics of events and the need to stay flexible, learning practices, and the use of training exercises and drills. Central themes identified in both literature and interviews included: the need to facilitate coping with complexity, managing dynamics of events and potential cascading effects, and the importance of adaptive capacity. Furthermore, a number of methods, strategies and tools to assess resilience, models of resilience, operational practices, and needs and difficulties relating to resilience, were also identified.

2.4   Resilience management guidelines needs and requirements

The identified concepts, approaches, and practices were subjected to a Delphi consensus-seeking process, to let subject experts (internal and external to the project) agree on a prioritization of the most important concepts to include in the project. The selection process resulted in 51 prioritized resilience concepts to be considered for the content and subjects of guideline implementation in 11 categories [17]:

- Collaboration;
- Planning;
- Procedures;
- Training;
- Infrastructure;
- Communication;
- Governance;
- Lessons learned;
- Situation understanding;
- Resources; and
- Evaluation.

The process used for the work was based on a requirement engineering process [26]. The use of a structured process was aimed to support the communication and transfer of knowledge between consortium partners and work packages, as well as guiding the process of later development and evaluation tasks, integrating both academic and practitioner perspectives. The requirements elicitation was, where appropriate, supported by the identification of stakeholder needs as a foundation.

The requirements were categorized as either concept requirements or non-concept requirements. Concept requirements (derived from the Delphi process) specify the conceptual basis that the guidelines should use, while non-concept requirements specify how the guidelines should be developed, structured, and evaluated. The non-concept requirements were further separated in five different categories: (1) form requirements related to the design or appearance of guidelines, with regard to ease of use, (2) quality requirements related to the internal consistency or soundness, and fitness for purpose of the guidelines, (3) target requirements setting the scope of the guidelines as in primary recipients and type of crisis that are covered, (4) process requirements guiding how to develop and evaluate the guidelines, and (5) context requirements clarifying in which environment and settings the guidelines are aimed to be applicable. The requirements were documented textually to facilitate the communication, common ground, and coordination of work within the multi-disciplinary DARWIN project team. In line with this aim, the requirements were formulated as guiding principles, rather than strict requirements that the guidelines must adhere to.

The final requirements specification encompassed 124 requirements for consideration by subsequent work in the DARWIN project. Of these, 92 requirements addressed the final guidelines product, the DRMG; 26 requirements addressed the process of developing the DRMG; and 6 requirements addressed the process of evaluating the DRMG. The requirements specification served as an essential reference document to guide the development and evaluation of the DRMG.

2.5   Resilience management guidelines

2.5.1   Development and adaptation

The development of the DRMG involved various partners from diverse backgrounds. The process was established to be collaborative and iterative, each main step involving multiple iterations through internal feedback and revisions. The process was inspired by user-centred design and agile development principles and includes end-user input early and as often as possible to generate new iterations and improve the applicability of the guidelines created.
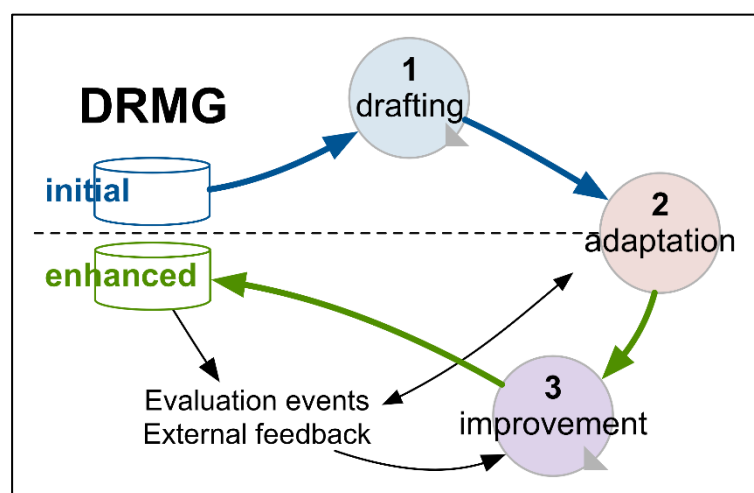
Figure 3. Overview of the DRMG development process

The guidelines are initially of generic nature and were piloted in the specific domains of healthcare and air traffic management (ATM), as two representative types of critical infrastructures (CI). An adaptation process as illustrated in Figure 3 developed and lead by end-user partners enriched the generic content of the CCs drafted previously (described in detail in DARWIN Deliverables 'D2.2 Generic Resilience Management Guidelines Adapted to Healthcare' and 'D2.3 Generic Resilience Management Guidelines Adapted to ATM'). This adaptation process can be a source of inspiration to adapt the DRMG to other critical infrastructures. The process provided a more operational perspective with domain-specific illustrations, practices and strategies, and contextual and implementation elements. While not explicitly an evaluation process, the adaptation of the guidelines is the process during which potential end-users had the most detailed look at the content of the guidelines developed and provided input and feedback from the perspective of CI domains. The adaptation therefore played a key role in transitioning the CCs from initial drafts mostly based on literature and researchers' experience to enhanced cards more grounded in crisis and resilience management practices.

The parallel development of the DARWIN Wiki (see Section 2.5.1) as the supporting content management platform had a significant impact on the capacity of the team to follow the various steps of this process.

2.5.2   Content

The resulting guidelines represent 13 topics belonging to 6 higher-level themes, captured below[1].

Table 1. Themes and topics covered in the DARWIN Resilience Management Guidelines

Themes	Topics
Supporting coordination and synchronisation of distributed operations	- Promoting common ground for cross-organisational collaboration in crisis management - Establishing networks for promoting inter-organisational collaboration in the management of crises - Ensure that the actors involved in resilience management have a clear understanding of roles and responsibilities in own and other organisations involved in the management of the crisis
Managing adaptive capacity	- Enhancing the capacity to adapt to both expected and unexpected events - Establishing conditions for adapting plans and procedures during crises and other events that challenge normal plans and procedures - Managing available resources effectively to handle changing demands
Assessing resilience	- Assessing community resilience to understand and develop its capacity to manage crises - Identifying sources of resilience: learning from what goes well - Noticing Brittleness
Developing and revising procedures and checklists	- Systematic management of policies involving policy-makers and operational personnel for dealing with emergencies and disruptions

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[1] The DARWIN Resilience Management Guidelines are available online at: https://h2020darwin.eu/wiki/ (accessed on 01/04/2019)

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Themes	Topics
Involving the public in Resilience Management	- Communication strategies for interacting with the public - Increasing the public's involvement in resilience management
Managing system failures	- Supporting development and maintenance of alternative working methods

For each topic, the DRMG and the associated DARWIN Wiki are design as a portfolio of approaches, methods and tools, organised in the form of CCs. In this way, the DRMG achieves the flexibility and scalability that is required to capture common and specific aspects of crisis management in different regions in Europe while also allowing the cards to evolve to include new knowledge and experiences. Figure 4 illustrates how these CCs are interrelated. It also indicates potential ways to implement the guidelines e.g. starting from assessing resilience. This figure is a complement to Table 1 showing relations among themes and topics. The boxes in grey colour relate to CCs that have been developed through rapid prototyping while the other CCs have been developed through the adaptation process described in Section 2.4.1. See DARWIN Deliverable 'D2.4 DARWIN Resilience Management Guidelines' for a description of the rapid prototyping process.
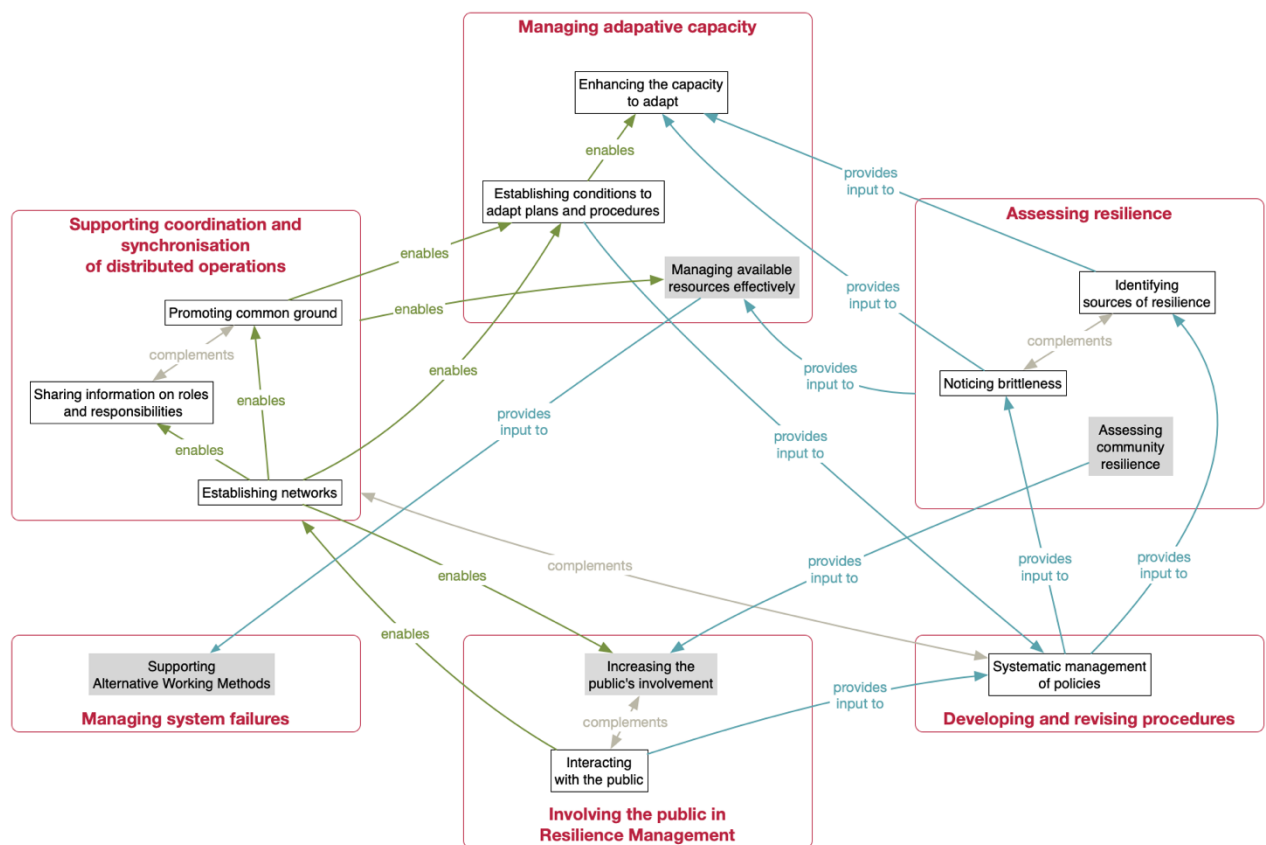
Figure 4. DARWIN Resilience Management Guidelines Map

The CCs capture a significant amount of information, structured around five main sections:

- **Purpose,** highlighting the overall objective and scope of the CC;
- **Implementation,** describing the interventions proposed during different phases of crisis management, i.e. before, during and after a crisis. They include 'triggering questions' that capture

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essential resilience-oriented issues users should think of or try to address. The implementation fields represent the most essential content of the guidelines;

- **Background and context information**, describing the objectives and rationale underlying the resilience management capability addressed, as well as associated benefits, challenges, relevant actors, illustrative examples, etc. Such content facilitates the understanding of the guidelines;
- **Relevant material**, describing selected strategies, practices, methods and tools from the implementation section, and providing references for further reading. Relevant material gives interested users the opportunity to explore further the ideas presented in the guidelines; and
- **Navigation,** providing ways to navigate the content of the guidelines through indicating relationship of topic with themes or categories (resilience abilities, functions of crisis management). Direct links between topics are also made.

2.6   Innovative tools and training

2.6.1   DARWIN Wiki

The iterative and collaborative nature of the guidelines' development process emphasises the need for actual knowledge management capabilities to support the distributed storage, versioning, variants, representation and delivery of guidelines' content. A specific knowledge management platform was created to facilitate the development of and use of the DRMG. The solution is the DARWIN Wiki knowledge platform offers opportunities to reconsider common views on the nature of guidelines, their necessary evolution and their multi-faceted, multi-purpose content. Furthermore, the DARWIN Wiki contributes to development, easy use and evolution of the DRMG, avoiding the guidelines becoming outdated, dust collectors on a shelf.

The DARWIN Wiki provides the following advantages:

- Provides a single, centralised resource;
- Provide tools for managing versioning and data storage across potential large amounts of collaborators;
- It does not require extensive technical expertise for content contributors, as support exists through online resources such as tutorials, books, user forums, etc; and
- The use of templates to control the representation of content allows defining various output formats   for   various   uses.

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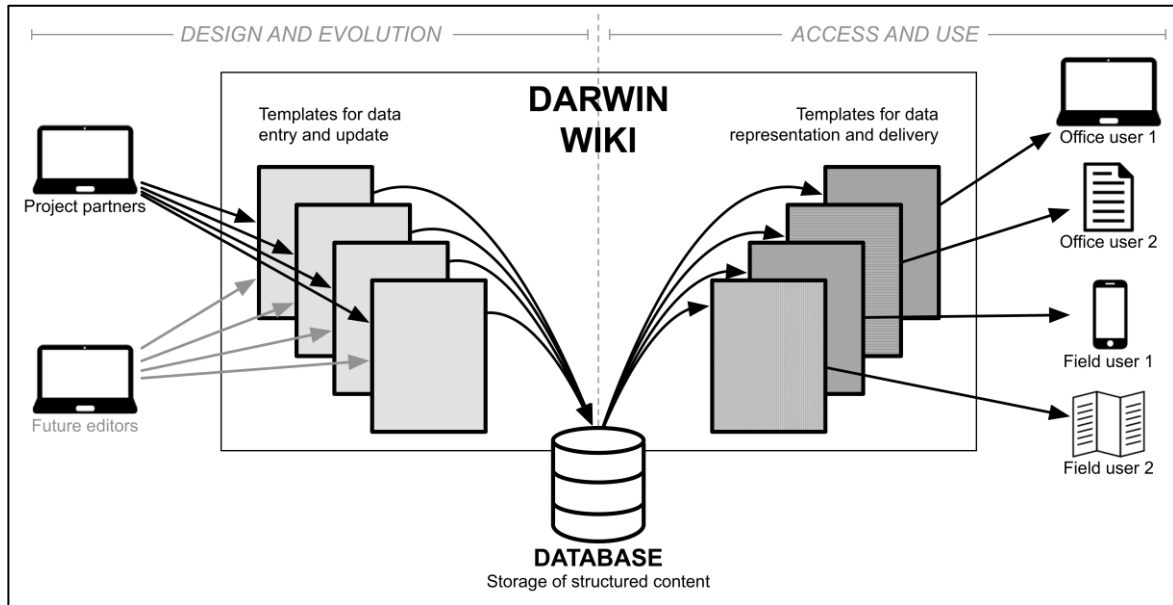
Figure 5. DARWIN Wiki supporting development and use

Figure 6. Extract from the DRMG Book

CAPABILITY CARD HANDOUT 4.2: Identifying Sources of Resilience

ABOUT THIS CAPABILITY CARD

One of the aims of Resilience Engineering is to learn from the everyday performance and from successful operations, rather than by only through lessons learned after failures. In line with this, identifying **Sources of Resilience** means investigating the mechanisms by which organizations successfully handle expected and unexpected conditions. Such mechanisms (e.g., strategies, processes, tools) allow the organization to adapt, perform and deliver required services in spite of the variability and complexity they experience in their operations. This *adaptive capacity* can be recognized by looking at the **work-as-done**, both in daily operations and unusual or exceptional scenarios, in order to identify sources of resilience and to **learn from what goes well**.

Actors targeted by the capability card

Actors that may benefit from this topic include actors involved in safety, security, and change management activities, audits, safety assessments, concept development sessions, debriefing sessions, after-action reviews, exercise analyses, and incident investigations. This may include policy makers, middle and line management, operational management, and a variety of operational roles.

INTRODUCTION

What is needed to identify sources of resilience

- Build the necessary skills to understand and identify sources of resilience at different levels of the organization.
- Select methods for the identification of possible sources of resilience with the involvement of roles and actors at different levels in the organization, making sure to account for an adequate diversity of perspectives. In order to achieve such diversity, combine individual interviews and workshop-based techniques, taking into account time constraints and availability of resources.
- Plan the methods around triggering questions to be used as guide for defining and describing margins and couplings in daily operations (triggering questions before) or looking back at past events to identify successful skills, strategies, and procedures (triggering questions after).
- Use the outcome of your analysis to revise your internal guidelines, training or to create ad-hoc ones.

CAPABILITY CARD HANDOUT 4.3: Noticing Brittleness

ABOUT THIS CAPABILITY CARD

The interventions proposed here aim to support organisations in identifying sources of *brittleness* in order to invest in their correction.

Brittleness is experienced in situations of goal conflicts and trade-offs, or when there is a competition for resources and a need to establish priorities under time pressure. Other difficulties emerge when an organisation struggles to manage functional interdependencies between different parts of the same organization, or when there is insufficient buffer capacity to provide additional resources. Noticing brittleness also means observing operational variability and comparing work-as-done with work-as-imagined, so to reveal how the system might be operating riskier than expected. In addition, brittleness manifests itself when the organization is unable to learn from past events, such as near misses and accidents.

Actors targeted by the concept card

Managers are expected to implement the interventions in two ways:

setting up regular activities that lead to discussions about brittleness and its identification,

involving actors at all levels of the organisation, in particular team leaders and other operational personnel who are engaged in crisis management activities.

In addition, members of the organisation familiar with resilience notions (e.g., resilience or safety managers), possibly with the help of external experts, play a key role in conducting events, leading and moderating discussions about brittleness.

INTRODUCTION

What is needed to notice brittleness

- Engage personnel at all levels of the organisation in understanding and noticing brittleness.
- Create the conditions for personnel across the organisation to expose and discuss things that do or might not go well in crisis situations.
- Implement recommended activities regularly to facilitate personnel's capacity to notice and discuss brittleness.
- Rely on external experts if resilience or safety managers familiar with notions of resilience are not available.
- Select methods for the identification of possible sources of brittleness with the involvement of roles and actors at different levels in the organisation, making sure to account for an adequate diversity of perspectives. In order to achieve such diversity, combine individual interviews and workshop-based techniques, taking into account time constraints and availability of resources.
- Plan the methods around triggering questions to be used as guide for the analysis (see examples of triggering questions below for the phases 'Before', 'During' and 'After' a crisis).
- Use the outcome of your analysis to revise your internal guidelines or to create ad-hoc ones.

Note Brittleness is a useful concept because it can be easier to describe and notice when systems can break down. However, this focus on "what goes wrong" is complementary to the approach described in Capability Card 4.2 Identifying Sources of Resilience. It would actually be counter-productive to only focus on the negative aspects of systems and operations: it is fundamental to also understand the nature and characteristics of resilience and how it exists in the organisations considered.

Figure 7. Examples - Extract from CCs handouts for workshops

The latest and most up-to-date version of the Wiki can be found here, it contains the DRMG Book[2] and the handouts (specific handouts for workshop are also available through the DCoP). It is easily available and released under the Creative Commons CC-By 4.0 license. Thus, people using the DARWIN Wiki can: share, copy and redistribute the material in any medium or format, and adapt, remix, transform, and build upon the material for any purpose, even commercially. People using the guidelines must give credit to the DARWIN project and EC support.

2.6.2   Simulation tool

Currently at a prototype stage, SimEnv is a simulation tool that provides the means to evaluate different strategies of resource deployment and patient allocation applied during the Swedish pilot exercises. The tool is used to simulate and evaluate a scenario where the user needs to evacuate differently wounded patients from a damaged ferry to the nearest available hospitals. A detailed description of the approach can be found in DARWIN Deliverable 'D3.3. Resilience Management Guidelines Toolkit'. The simulation is based on detailed descriptions of the availability of particular transport vehicles (buses, rescue ships, helicopters and ambulances), their respective technical characteristics and the different patient allocation plans at numerous hospitals.

SimEnv can be fed with real data obtained from actual rescue operations. Based on different initial conditions, the different resource utilization and patient distribution policies can be examined with respect to selected values of interest. These values (or performance indices) such as transport durations for patients, throughput at assembly points, utilization of transport vehicles or waiting periods, can be easily customized by the simulation environment. Practitioners in crisis management can use SimEnv to assess different strategies and initial conditions by means of performance indices adapted to their individual requirement. Here, bottlenecks due to resource limitations, unfavourable strategies and difficult initial conditions can be revealed. Thus, supporting the concept of noticing brittleness, in case of revealing a substantial degradation of a selected performance index during the course of the simulation.

For example, the overall transport duration of triaged patients is an important performance index, which is influenced by the initial distribution of available ambulances with regards to the assembly points across the affected region. These particular first routes of the ambulances are not defined. Whilst the evacuation of patients from the ferry itself (performed by rescue ships and helicopters) shows a relatively good utilization of transport resources, thus not affecting the aforementioned performance indicator significantly, the currently unbalanced initial distribution of ambulances reveals significant impact on that performance. Specific initial distributions towards distinct assembly points might cause the system to experience stark losses in transportation performance. At this time, different initial solutions of ambulance routes are examined in order to optimize the present configuration of the Swedish trial.

Since SimEnv can be used for emergency preparedness and debriefing, the latter by evaluating historic data, a new, interacting functionality is currently under development. It aims to support the practitioner in evaluating different decisions during the course of the scenario and mainly affects transport distribution and generation, strategy changes and availability at hospitals.

For example, Figure 8 and Figure 9 below illustrate the implications of different initial distributions of ambulances among distinct assembly points. The calculations are made for three different patient allocation schemes and a specific resource deployment and depict the arrival times of red and yellow

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[2] DARWIN (2018) 'DRMG Book'

triaged patients at the hospitals. A skewed distribution towards the assembly point, closest to the ferry during the final stages of the operation, suggests achievable benefits with regard to the transportation performance.
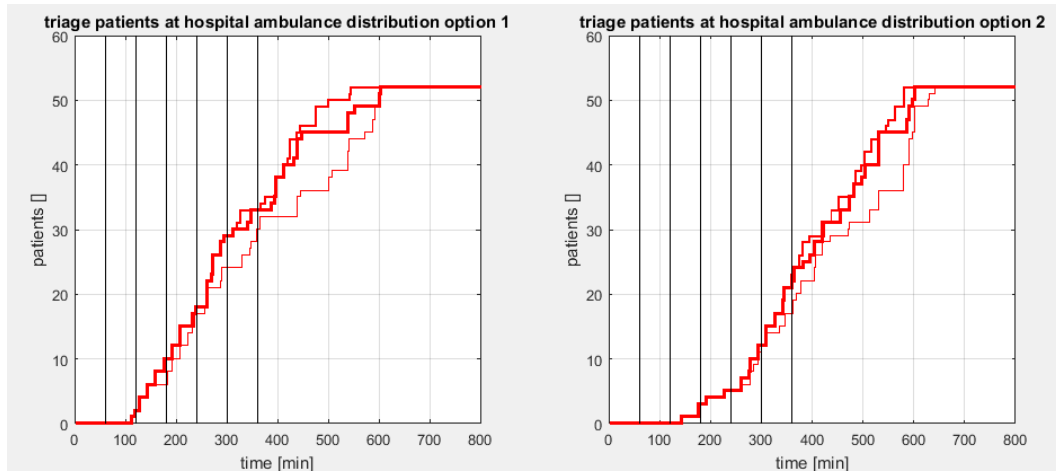
Figure 8. Red triaged patients arriving at hospitals, depending on three different patient allocation schemes and a given resource deployment, preferring the first assembly point during initial ambulance distribution
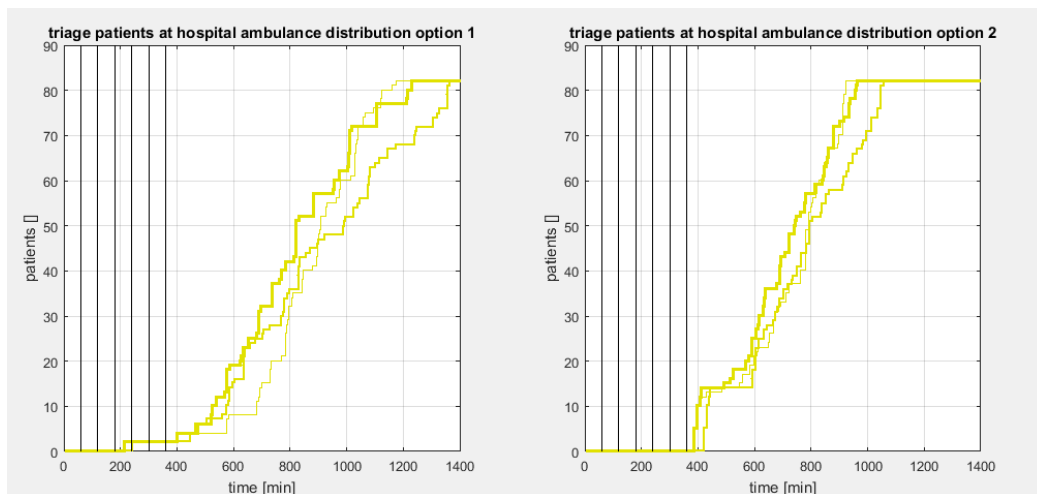
Figure 9. Yellow triaged patients arriving at hospitals, depending on three different patient allocation schemes and a given resource deployment, preferring the last assembly point during initial ambulance distribution

A parallel work effort is the validation and calibration of the model to reach a higher maturity stage. This will be done in close cooperation with the respective practitioners. Currently, SimEnv is at too early a stage to support the training of the noticing brittleness CC, or to illustrate and explore different DARWIN concepts or CCs in a broader, more illustrative and accessible way. A first step towards this has been made by a second dataset, which is slightly altered concerning the real data and was implemented subsequently. It can be used for illustrative purposes and represents the basis for further discussion due to the confidential nature of the real data.

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The simulation environment will be made available only as part of consultancy projects as the detailed handling and modelling of the needed processes is too complex to provide it on an open source platform. Additionally, a MATLAB® Simulink commercial license is needed as the event driven models are implemented in this software package.

2.6.3 Serious games based on virtual reality

The DARWIN serious games create a virtual environment to test specific tasks performed during rescue operations. This approach provides a new level of immersion to train newly developed resilience concepts. The games are produced to provide training opportunities by posing a challenge for the actor during generic and typical crisis management situation. In this serious game, the players conduct exercises in order to have a memorable experience and to improve their understanding of the DRMG. Since training for disaster management can be costly as it can be focused on highly context specific environments involving several actors and resources. It has been argued that lower fidelity training also can support competence development with pedagogical and economic advantages. In line with this argument, the DARWIN VR game does not try to simulate a crisis in a perfectly realistic fashion but aims to be an effective training tool. Most of the situations presented to the user are highly simplified, to allow focus on the important resilience concepts represented by the scenario.

The virtual environment is a prototype which provides an enjoyable and user-friendly experience comprising two main components: a virtual reality game with one player ('resilience manager') and a mobile game for including other players. The serious game is set up in the following way. One participant acts as the resilience manager, he or she uses the VR goggles whilst the other participants can connect themselves to the game by using their mobile devices.

The session starts by familiarizing with the different elements of the game and the VR space. Within the game, a generic town, 'Wedgewood', is created which represents an undisturbed everyday situation for the actors. The 'resilience manager' in the VR has a complete overview of the situation and all resources, such as airplanes, helicopters, cars, etc. The other players represent available agencies such as airports, hospitals, bus stations, car-depots and fire agencies.

During the gameplay, a crisis is initiated. The current scenarios are: the flooding of a part of the city, the evacuation of a hospital, a disaster site which has multiple victims of varying damage and bad weather which causes all air-based vehicles to be grounded. The participants of the mobile game dispatch their resources to the 'resilience manager' in the virtual reality world, so that the manager can utilize those resources in an effective manner to save as many victims as possible. A detailed description of the DARWIN mini game is available in [Darwin Deliverable D3.5 Resilience Management Guidelines Toolkit](#).

Figure 10 depicts the virtual environment of the DARWIN VR game that deals with a flooding event. So far, the game has received positive feedback from representatives of the aviation community which invited SINTEF to customize the game according to their needs. As, the relation between VR and resilience management has not achieved a conclusive answer yet, the following is proposed for further work:

- Conduct more tests including both the minigames based on VR and Capability Cards with end-users;
- Update the software to create generic reusable components focusing on maximizing viability for end-users; and
- Propose the DARWIN VR games to students and/or within new research projects to continue its development.
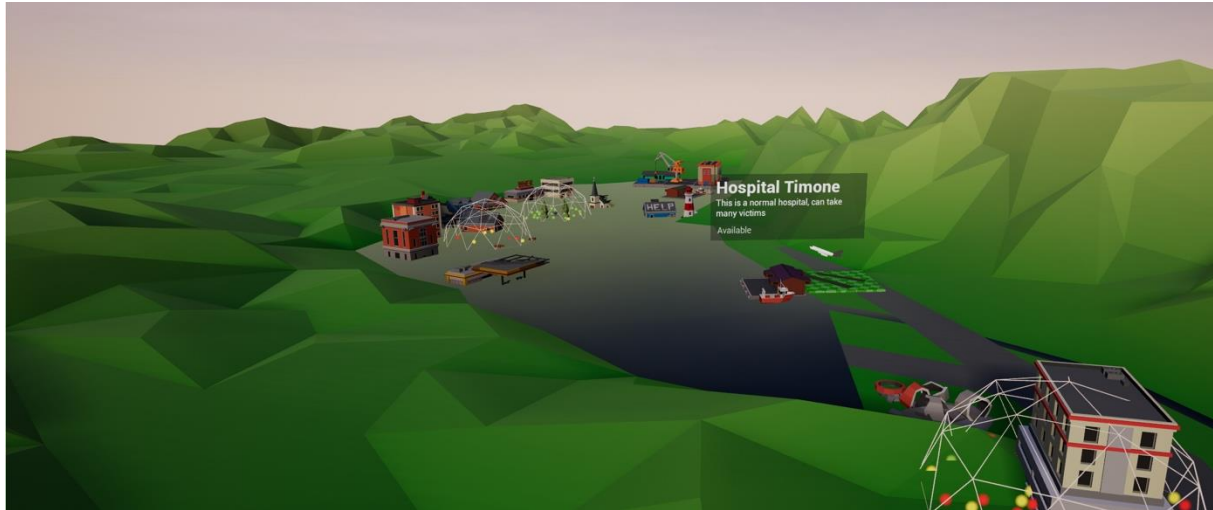
Figure 10. DARWIN VR mini game - flooding situation

The DARWIN serious games are released under the Creative Commons CC-By 4.0 license. Thus, people using the DARWIN serious games can: share, copy and redistribute the material in any medium or format and adapt, remix, transform, and build upon the material for any purpose, even commercially. People using the guidelines must give credit to the DARWIN project and EC support.

No warrants are given. However, the DARWIN serious games contain assets and software components owned by third-parties with different licensing models. These assets and software components are not necessarily released under the Creative Commons CC-By 4.0 and their sources are not released within the DARWIN serious games sources. Compiled versions of the DARWIN serious games contain compiled version of these assets and software components and anyone can share, copy, redistribute, adapt, remix, transform, and use the compiled serious games commercially.

2.6.4 Training for Operational resilience Capabilities board game

Besides the virtual environment, a second serious game was developed during the project. This game is an adaptation of Training for Operational Resilience Capabilities (TORC) called the DARWIN TORC (D-TORC), explained in detailed in DARWIN Deliverable 'D3.4 Resilience Management Concepts and Application Tutorials'. The TORC is a board game that can be structured around diverse scenarios with different triggers as resources to solve the scenario. It is addressed to managerial and operational levels. The DARWIN project enhances this game including the DRMG Capability Cards as an integrated part of the game, as illustrated in Figure 11.

At the end of the project, the D-TORC is still a prototype. We foresee evolutions of the D-TORC project towards a more practical application and have plans to propose this approach in future research and innovation projects at national and international level. The games present diverse modes, and the emulation mode (use an actual event for the game) is currently being adapted within the H2020 project Stop-It as a stress test for water infrastructure.
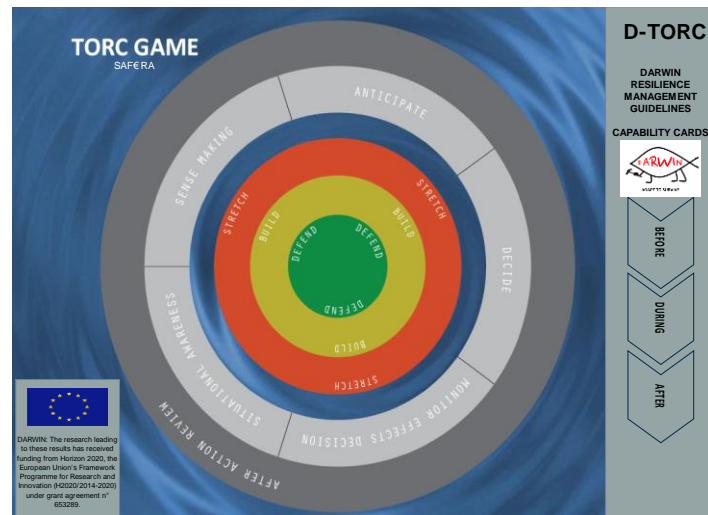
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Figure 11. DARWIN Training for Operational Resilience Capabilities

2.6.5 Courses and training material

The DARWIN resilience courses and tutorials aim to increase awareness and knowledge of the DRMG training material. The latest issue of the training material is available on request through the DCoP. The following sections shortlists the training courses and tutorials which were developed within the project:

- The DRMG are available in DARWIN Wiki format, the Wiki tutorial is directly available within the guidelines to support end-users to navigate the guidelines. In 2018, an associated webinar 'DARWIN Wiki Webinar: What is in it for me' was also created.
- Tutorials associated with specific capability cards, previously called concept cards are described in DARWIN Deliverable 'D3.4 Resilience Management Concepts and Application Tutorials';
- Resilience management master academic course modules for professionals; and
- Specific lectures on resilience management and workshops based on the DRMG [20, 21, 22], evaluation workshops [23].

The lectures listed above enable students to learn about different views on societal safety, in particular resilience management as a complement to risk management. These lectures have been elaborated initially early in 2016 and delivered in Sweden (attended only by professionals from representing critical infrastructures and roles e.g. transportation and firefighting). Afterwards, the lectures have been updated in autumn 2016 and 2017, with the latest edition delivered in autumn 2018 in Norway as part of a course called 'Risk Governance, Societal Safety and Critical Infrastructures'. The 2016-2018 editions have been presented mainly to Master students at the Norwegian University of Science and Technology, NTNU TIØ 4201. During 2018, only specific lectures on resilience management and a workshop using the DARWIN Wiki were conducted as a training exercise.

The DARWIN material used for those lectures was based on:

- Essential concepts for resilience management [24];
- Complementary activities and functions between risk and resilience management [33]; and
- Scenarios to discuss and reflect on resilience capabilities [28, 29].

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As an opportunity, a workshop was conducted with participation from the Libra consortium (oil and gas industry) and students as well as professors from three Brazilian universities. The workshop builds on material produced for previous events. The workshop included 30 participants and a fictional scenario on an air crash on Fiumicino airport was used a case for the discussion. The following three CCs were used for the workshop:

- Promoting Common Ground for Cross-Organisational Collaboration in Crisis Management;
- Identifying Sources of Resilience: Learning From What Goes Well; and
- Noticing Brittleness.

The lectures and workshops highlighted the importance of knowing the target and having scenarios that are relevant and realistic as a baseline to discuss and to increase understanding on resilience management. The DARWIN resilience courses have already proven to be an added value for students interested in resilience concepts and approaches. Most of the participants agree the workshops and the Capability Cards allowed the identification of new things and new issues. As shown, the audiences are quite diverse, so it can be assumed that future adaptions to other groups and listeners can easily be made. The diversity of target audiences reaches from students becoming engineers and political scientists who need to know more about resilience concepts in the development of systems up to aspects related to management and governance of critical infrastructures. Different training material and workshops have been implemented and are available to the wider audience. This material can be used as a source of knowledge for further implementation. The feedback of the courses has not been used to evaluate the Capability Cards itself, as the feedback was received after the evaluation process concluded.

2.7 Evaluation of resilience management guidelines

2.7.1 Evaluation approach

The evaluation addressed two parts: the DRMG as a whole, with focus on the DARWIN Wiki, and the individual CCs. The focus on individual CCs represented the core of the evaluation and was performed at different stages. An initial evaluation was conducted when only a first set of CCs was available. We organized two focus groups – one in Italy and one is Sweden – involving only representatives from the DARWIN consortium members, including domain experts from the three end-user organizations: ISS, ENAV and KMC. This first stage served to collect initial feedback for the improvement of the already existing CCs and for the other cards going to be developed. Then, after one year of the project, the evaluation started to involve a large variety of potential users and stakeholders external to the consortium. The idea was to assess both the possibility to adapt the CCs to the healthcare and air traffic management domains and the feasibility of generalizing them to other critical infrastructure domains.

The evaluation combined two perspectives that aimed to achieve different goals, but supported one each other. On the one hand, the *formative perspective* focused on identifying the necessary improvements to the guidelines, in order to generate a set of recommendations for the guideline developers. It consisted of a qualitative analysis of the feedback collected from critical infrastructure practitioners during four Pilot Exercises. Three of them were organized in Italy and on one in Sweden, and detailed information on the exercises can be found in DARWIN Deliverable 'D4.3 Pilots Implementation and Evaluation'.

On the other hand, the *summative perspective* aimed at assigning a specific score to each CC, in order to facilitate a quick identification of the areas requiring more improvements in the final part of the project. It focused on the assessment of the DRMG compliance with respect to the design requirements identified at the beginning of the project (see Section 2.3), as well as on an analysis of

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
how the practitioners perceived the potential impact of the CCs in enhancing the resilience capabilities of their respective organizations. The perceived impact was assessed with a questionnaire administered both at the end of each Pilot Exercise and during other evaluation events organized with the DCoP.

The questionnaires can be retrieved from the DARWIN Wiki in the top right corner of each CC page, at the link 'provide feedback on this topic'. All the questionnaires had the same format. The content was the same, except for the references to the specific CC. For example, the online version of the questionnaire administered for the DARWIN Capability Card 'CC2.1 Promoting Common Ground for Cross-Organizational Collaboration in Crisis Management' can be accessed here. Figures below show the evaluation activities such as pilot exercises, DCoP workshops and small-scale evaluations as well as the critical infrastructure involved in the exercises. The evaluation activity includes 247 practitioners from 22 countries directly involved in the pilot exercises.

Figure 12. Overview of the evaluation activities
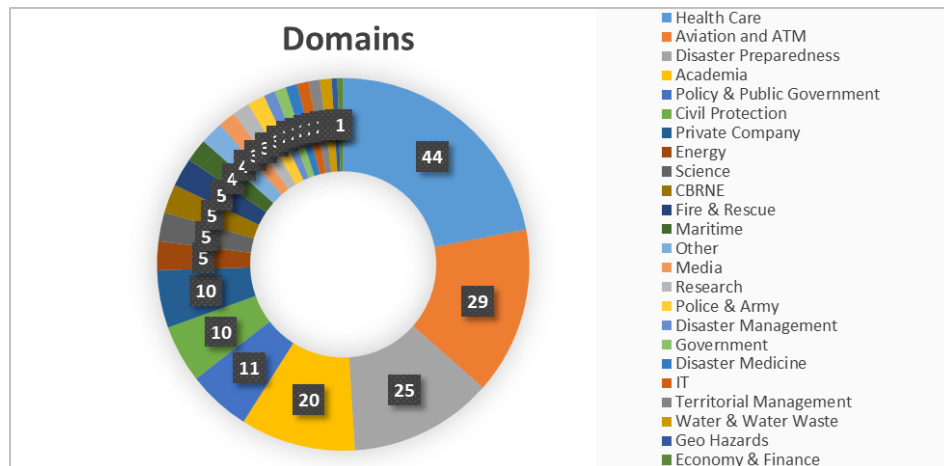
Figure 13. Distribution of user´s domains involved in the different evaluation activities

2.7.2 Outcome of the Evaluation

The outcome from the evaluation process showed that the progress made with the development of the DRMG and CCs was very promising, although some areas required improvements in the final part of the project. The 75% of concept requirements identified at the beginning of the project were considered covered by the DRMG. While for what concerns the non-conceptual requirements, seven out of ten CCs reached at least a partial level of compliance. Only three CCs scored below this threshold and required important improvements. According to questionnaire responses by the practitioners, all the CCs were expected to have an impact in enhancing the resilience capabilities of their respective organizations. Actually, none of the CCs were considered below the threshold of 3 (Agree nor Disagree), while four out of ten fell in the interval between 4 (Partially Agree) and 5 (Totally Agree). For more information on analytical results see DARWIN Deliverable 'D4.4 Final Guidelines Evaluation Report'.

The qualitative analysis produced 105 recommendations on ways to improve the DRMG. However only 16 of these recommendations were classified as critical, making the plan for improvement in the final phase of the project quite realistic. Another 48 recommendations were considered important, while all the others were just classified as nice-to-have.

The most significant experience in terms of impact on the resilience practitioners were the pilot exercises which allowed the achievement of two main goals:

- Raising awareness among crisis management stakeholders of the possibilities offered by the DRMG for improving the level of resilience of their organization; and
- Enabling concrete implementation examples of the actions suggested by the CCs.

The lessons learnt from such experience, as well as the analysis of the perceived impact of the DRMG elaborated in this deliverable, suggests that future adopters should consider different strategies for introducing the DRMG in their organizations, after careful considerations of available resources and time constraints. Some suggestions can be found in DARWIN Deliverable 'D4.4 Final Guidelines Evaluation Report'.

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3. TESTIMONIALS: END-USERS AS EARLY ADOPTERS

3.1 *Testimonials: discovering ways to use the guidelines*

The DRMG and the tools are being adapted and adopted by DARWIN project partners, end-users and members of the DCoP. When asked to give a written testimonial they have answered as follows:

VIEWS FROM END USERS ON RESILIENCE MANAGEMENT GUIDELINES

This practitioner plans to use the Capability Cards to adjust to different scenarios. The practitioner particularly identified the simulation tool as an application that could be used in their organization, highlighting its usefulness in examining the micro and macro aspects of complex disasters.

Practitioner – Ministry of Health, Israel

The guidelines were taken into account to rethink and evolve scenarios for exercises but also to review and update operation plans.

Practitioner - Ministry of Defence, Greece

This practitioner plans to use the DARWIN guidelines as a baseline for a future project on improving the resilience of an European City. He also plans to investigate how to incorporate the tools and Capability Cards into this plan.

Practitioner, Safety and Security Advisor/Emergency and Disaster Manager, European City

This practitioner plans to integrate the DARWIN Capability Cards into the Emergency Medical Services (EMS) service assessment process to facilitate the debriefing of major incidents. She believes that the cards will provide a structure to the debrief process, which will make the it easier. She thinks that the cards will also help to implement any results from the debrief.

Practitioner, Head of the Emergency Medical Services, European City

Istituto Superiore di Sanità (ISS, Italy) is currently engaged in using the DAWIN results in two ways. Firstly, through the inclusion of DARWIN in projects funded by the Central European Initiative (CEI), such as the Know-How Exchange Programme. The beneficiaries are the Public Institutes of the Western Balkans, i.e. the National Institute of Public Health of Albania, FYRM (Macedonia), Montenegro and Serbia. The title of this project is 'Improving Disaster Risk Reduction Skills and Resilience-Building Practices in the Western Balkans: EMS WeB'. One of the modules of this project concerns the implementation of DARWIN results in a master course on Disaster Risk Reduction and resilience building practices in the Western Balkans. The project team through a study visit participated on the presentation of the DRMG and DRMG Wiki, during the conference addressing European resilience management guidelines for crisis and emergencies in healthcare and critical infrastructures, held on 21 September 2018. This meeting was organized as the showcase of DARWIN project to the Italian National Healthcare Regional representatives.

Secondly, ISS plans to offer the guidelines to researchers and healthcare providers at a national and international level. It would consist in a check of procedures currently used and suggestions on how to improve them in order to take into account the specific guidelines produced in DARWIN.

Dr. Giuseppina Mandarino, Researcher, ISS

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We are currently in the process of developing our own strategies and crisis plans within the Swedish Red Cross. I am involved in the development of a guide about need assessment in crisis. I have found the DARWIN guidelines, especially the Capability Card about noticing brittleness very helpful.Sharing information with others working in the crisis management arena has many benefits: knowledge, networking, and sharing of practical experience. In the long run we are interested in strengthening our strategies and our work in crisis management, community resilience building, community engagement and accountability and gender and diversity.

Practitioner from Red Cross, Sweden

I used a combination of Capability Cards to identify a weak area of operation and produce a pocket guide for staff to help with any ambiguity in this area. The guide was originally designed for use by EMT personnel, to help as a quick guide when they take patients' vital parameters, with different sections for normal parameters and not normal: Green, Yellow, Orange and Red parameter measurements. It was found to be useful to other staff too, particularly new and summer staff.

Practitioner from Ambulance Service, Sweden

One of the noteworthy outcomes of the project, from ENAV's point of view, is that we discovered more uses than we expected at the beginning of the project. We found out that the guidelines are useful, they can be adapted and adopted to be used in many occasions such as training courses, workshops and meetings. They can help to start discussions, facilitating moderation while dealing with significant topics.
Moreover, they can be used to:
1. Check, survey or update current procedures and guidelines (if already existing) or define new procedures and guidelines (if not existing) through periodical coordination activities and training;
2. Identify and develop possible indicators for resilience assessment/management and evaluation of trends (to do possible benchmarking);
3. Prepare plans;
4. Identify each company's risks and perform risk assessment and management.
5. Assess the effectiveness of roles and responsibilities during a crisis;
6. Increase their knowledge in identifying brittleness in the system;
7. Start to reflect on "what went well" and not only "what went wrong";
8. Get to know practices, methods and tools applied by other ATM stakeholders;
9. Test and improve plans of communication with public during emergencies

Valentina Cedrini, Safety Expert, ENAV

We are working on the crisis management plan, and we use the DARWIN guidelines to improve it

Practitioner from an airport, Italy

The guidelines can be used for comparison and discussion about already existing protocols and instructions especially regarding the civil protection field.

Practitioner - Emergo Train System Italian Faculty, Italy

This practitioner plans investigate how to adapt the cards to his work in the ambulance service, particularly to facilitate the day to day work of frontline operatives. The cards can help to develop a 'go-to-guide' of what to do in particular scenarios, such as terrorist attacks.

Practitioner, Swedish Ambulance Service

The guidelines can support designing and conducting simulation exercises.

Practitioner, Emergency Training System Italian Faculty, Italy

The DRMG will be used during 2019 when evaluating and updating the regional and local disaster management plans for the county council of Sörmland. The DRMG will also be used when building scenarios to train Local and Regional Command and Control set-ups during future exercises, closing the gap between theory and practice.

Practitioner – Regional County Council of Sörmland, Sweden

4.   ENABLE SUSTAINABILITY THROUGH AN ENGAGED COMMUNITY OF PRACTICE

4.1   *Plan to continue collaboration through exploration and exploitation*

The Community of Crisis and Resilience Practitioners, which later changed name to the DARWIN Community of Practitioners (DCoP), was created to ensure transnational and cross sector applicability of the DRMG and also to ensure a long-term relevance of the results of the project. By the end of the project, the DCoP had 173 members from 25 countries in 2018 as illustrated in Figure 14.
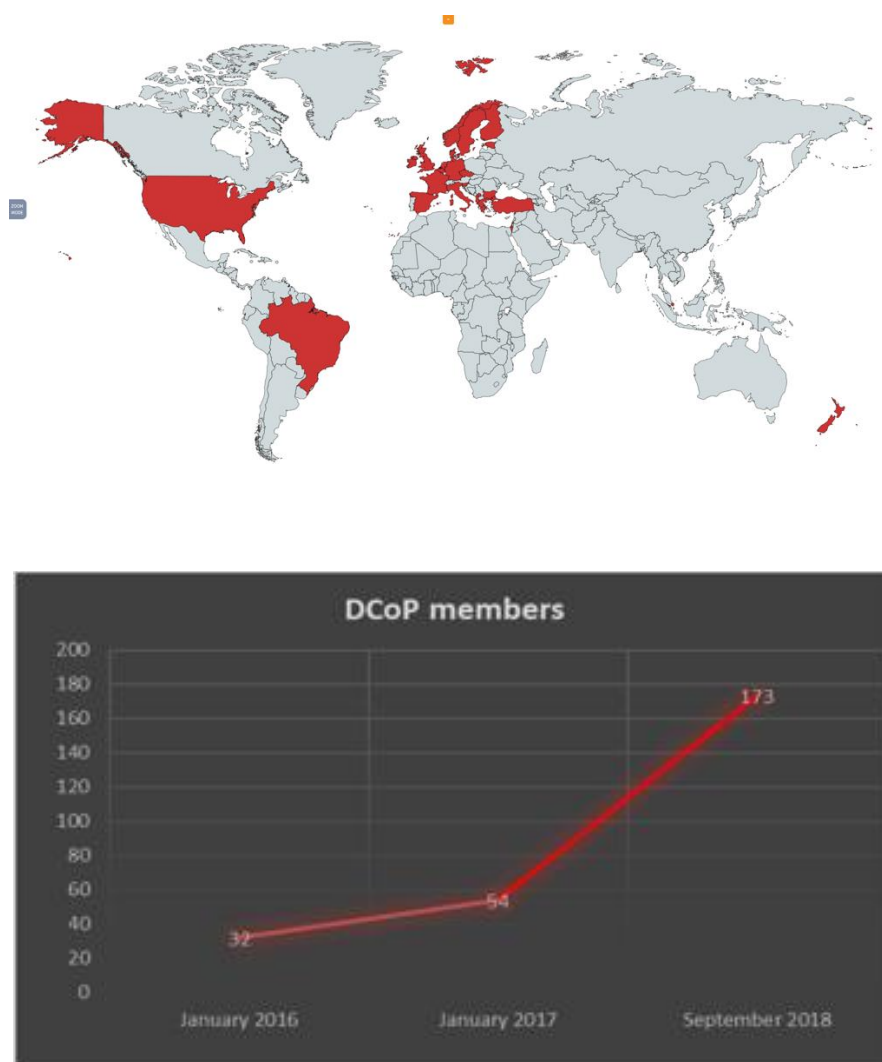
Figure 14. DCoP evolution 2016 - 2018

Membership of the DCoP is free of charge and voluntary. Many participating experts, such as critical infrastructure crisis managers, have already begun implementing the DARWIN guidelines in their respective associations. Please refer to DARWIN Deliverable '[D5.4 DARWIN Community of Practitioners (DCoP) Terms of Reference [Final]](#)' for the terms of reference of the DCoP.

During the project, there was a budget available to cover travel and normal related costs for members to attend the workshops. The consortium members have become DCoP members working to 'keep the momentum' and actively looking for new funding opportunities at both national and EU level. The

members propose activities related to share experiences on the use of the guidelines or relevant developments.

4.1.1 Membership, roles and responsibilities

A kick-off meeting of the post-DARWIN DCoP, entitled 'The Constitution of the DARWIN Community of Practitioners – A Post Project Perspective' was held on 25 October 2018 and an initial agreement on roles and responsibilities was reached. The DCoP continues beyond the end of the project as an open network, sharing experiences on implementation of the guidelines and relevant developments in the area of resilience and crisis management. To join the DCoP network please visit the DCoP webpage.

The following roles are agreed:
- Contact point: Euan Morin is coordinating the community with support of the members
- DARWIN Wiki: Matthieu Branlat (SINTEF)
- Contact research-practitioners to adapt and adopt the guidelines and tools: Ivonne Herrera, Carl Oskar-Johnson
- Update of social media platforms: CARR communications.

4.1.2 Activities, meetings, work plan and information sharing

Towards, the end of the project a questionnaire was distributed among the members and over 40% of those who responded highlighted webinars as a preferred channel for collaboration beyond the project's end. Therefore, the following DCoP Webinars are planned:

- January 2019 - Presentation of the H2020-project INPREP;
- February 2019 - 'Let's Not Forget 'The Sharp End When Improving Resilience', presented by Mr Anders Ellerstrand - Air Traffic Controller and Safety and Human Factors Specialist;
- April 2019 - 'Sharing Experiences on Adapting Resilience Concepts Across Diverse Critical Infrastructures', presented by Prof. David D. Woods;
- September 2019 – "Resilience management training - DARWIN Wiki and Serious game - Training for operational for resilience capabilities" facilitator SINTEF; and
- November 2019 – "Sharing experiences on using the DARWIN resilience Management Guidelines" facilitator KMC.

A number of face-to-face meetings are also planned where the opportunity arises. These include:

- February 2019 - A workshop to present DARWIN at the University of California, Berkeley, Center for Catastrophic Risk Management (CCRM);
- June 2019 - A workshop to explore the DARWIN Resilience Management Guidelines is proposed for the 8th Resilience Engineering Symposium 'Embracing Resilience: Scaling up and Speeding up'; and
- February 2020 - KMC are part of the Centre for Advanced Research in Emergency Response (CARER) at the University of Linköping, Sweden. CARER host an annual workshop 'Managing the Incident Site of Tomorrow' (MIST). There is a will to expand this workshop and the board of CARER are interested in the proposal to invite the DCoP to this event. MIST is funded by the Swedish Civil Contingencies Agency (MSB).

Operational crisis management research groups will also be recruited to carry on work performed within the DARWIN project. For example, DARWIN has established collaboration with EU projects (IN-

PREP, eNotice, STOP-IT), national research centres such as CARER. Those established and ongoing projects are encouraged to adapt and adopt the DRMG in their continuing work. For example:

- DARWIN has been invited and will be taking part at the drill held by the EU project eNOTICE on the 22 - 23 May 2019. Selected Capability Cards will be tested in the context of this event.
- DARWIN and the DCoP have been invited to take part in the first annual forum of the EU project DAREnet. The invitation has come through current member of the DCoP and invite has been sent on the 23 January.

DARWIN will continue to survey and identify national initiatives in disaster resilience management to contact and offer introduction to DARWIN outputs and participation in the DCoP network. DARWIN is currentl investigating alternative sources for funding for the DCoP and future activities.

4.1.3 Evolution of the DCoP Community

As of the 23 January 2019, the DCoP consisted of 71 members from 18 countries. Since the final review meeting a member of the nuclear industry has joined the DCoP adding expertise from yet another critical infrastructure to the DCoP. Through synergies with ongoing projects and networks, web presence, webinars, face-to-face workshops and DCoP members participating to events, practitioners are invited to join the community and related activities.
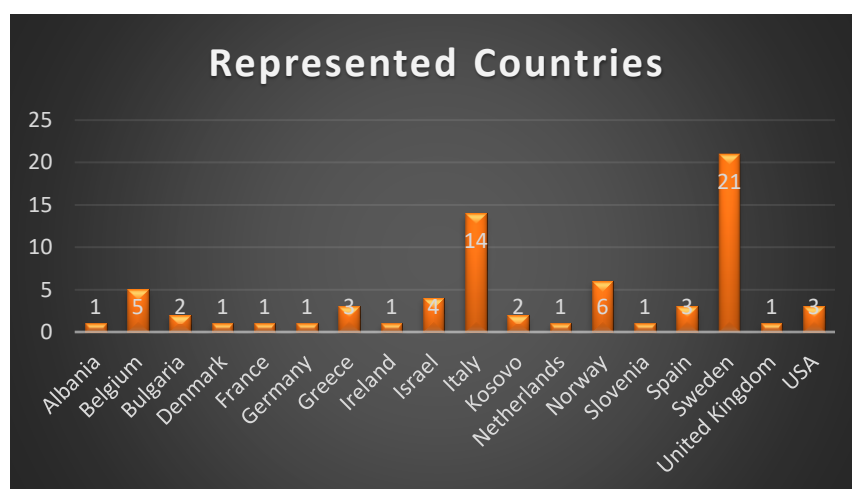
Figure 15. Countries represented in the Community of Practice

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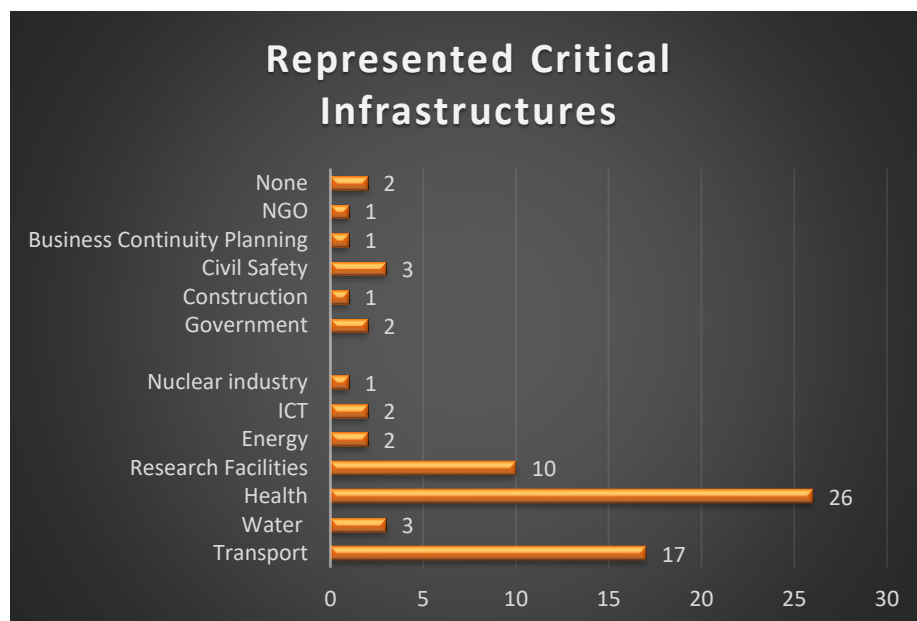
Figure 16 Critical infrastructures and relevant organizations represented

Figure 17 Roles represented

5.   ROADMAP: INDUSTRY ENGAGEMENT, STANDARDS AND POLICY

5.1   Resilience management in healthcare

At a national level, Istituto Superiore di Sanità (ISS) is investigating whether the Italian National Medical Scientific Societies are interested in organizing a Consensus Conference to transform the DRMG into a national best practice and adopt the DRMG and progressively convert them into reference guidelines included in the SNLG (Italian National System of Guidelines).

At an international level, by means of European and international cooperation projects, ISS is willing to invest in projects increasing the standards in the emergency management in cross-border regions, using the DRMG and presenting them at workshops dealing with standard operation procedures for cross-border collaboration of Communities during disasters and emergencies.

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5.2   Resilience management in air traffic management

The aviation domain and air traffic management in particular, have a great track record of safe operations in challenging conditions, even if disruptions or occasional crises may happen routinely. While they can certainly be improved, the domains have already implemented a number of practices and methods, especially related to being able to handle such disruptions or to learn from them. The level of standardization is very high; the number of standards and regulations guarantee that ATM has a great track record of safe operations. Regulatory bodies and concerned actors are well defined together with roles and responsibilities.

Air traffic services providers shall have in place a Safety Management System (SMS), which may be an integral part of their Management Systems which are defined as a 'set of interrelated or interacting elements to establish policy and objectives and to achieve those objectives' [ISO 9000:2005]. Traditionally, separate management systems are developed to address issues such as safety, quality, environment, health and safety, finance, human resources, information technology and data protection. However, it is foreseen that more and more the service providers will establish integrated management systems. Taking DARWIN outcomes as a valuable reference, Resilience could be undertaken following the set of requirements, including the necessary organisational structures, accountabilities, policies, and procedures, that are set in applicable Regulation (EU) 2017/373 and ICAO Annex 19 for the definition of Management Systems and Safety Management Systems respectively.

It is noteworthy that across the ATM industry, Air Navigation Service Providers are at different level of SMS development and implementation. Some service providers have very mature systems, which are fully integrated into the operations; others are still in the early stages of SMS implementation. This diversity can be attributed to the existing differences in national regulatory frameworks, (un)availability of resources at local level and considerable variation in style and content of the used implementation guidance material. Resilience is an innovative concept that, according to DARWIN experience and results, deserves to be undertaken by critical infrastructures organizations and ATM stakeholders. Thus, the intended ATM readership for DARWIN material is policy and standards makers, crisis managers, critical infrastructures managers, resilience engineering managers, trainers, methodologists, community of practice in ATM.

In particular ENAV aims to:

- Include the most relevant Capability Cards into its existing training courses with the purpose of supplementing current training course content (i.e. Safety and Risk Assessment training courses). ENAV also plans to incorporate the most relevant and applicable elements of the DARWIN training courses into its own training courses for current and new clients;
- Use the triggering questions developed as part of the Capability Cards to assess issues and facilitate and encourage discussion related to safety, security and resilience;
- Exploit the DCOP by:
    - participating in the DCOP as an end-user participating member of the DCOP and thereby contribute to its network beyond the lifetime of the DARWIN project;
    - maintaining the relationship with the DCOP for potential future research and consultancy collaborations;
    - connecting with the DCOP members, both potential clients and potential partners; for sharing information about exploitation opportunities; and for sharing expertise that could support future research. In fact, the DCOP is an important source of knowledge-sharing, information and exploitation opportunities at an international level and across multiple sectors and domains. ENAV has long been involved in research and innovation in the Air Traffic

Management domain. It participates in many projects aimed at defining, developing and validating new operational concepts, technologies, systems and functions. ENAV strategy and cooperation activities aim at developing synergies with the major ATM stakeholders to continuously improve the safety and quality of services provided and to explore the opportunities offered by the technology innovation for the benefit of all customers and finally the wider aviation community;

- Exploit the 'adaptation methodology' to adapt the CCs to other organisations and ENAV departments. ENAV has worked with the other DARWIN partners to adapt the DRMG to the Air Traffic Management domain. It thereby already has the knowledge of how to adapt and test the guidelines and make them applicable and relevant with a significant benefit for organisations operating in the ATM domain [32].

5.3   Resilience management across critical infrastructures

The DARWIN project is part of five Horizon 2020 DRS-07-2014 projects, the five projects together produced a white paper bringing together lessons learned from these projects to policy makers [17]. Considering DARWIN results, this section summarizes key points from the white paper with respect to policy and standardization:

> *"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), most European and neighboring countries have prepared National Risk Assessments (NRAs), generally following guidelines provided by the European Commission. These guidelines follow closely the ISO 31000 family of standards."*

Recently, a CEN technical specification on crisis management was published covering principles and practices for crisis management response [33]. This technical specification includes some knowledge from the DARWIN project for example learning from both 'what goes well' positive experiences and "what goes wrong", training that includes possibility for flexibility and improvisation addressing limitation on plans and procedures. Other initiatives on standardization have started including a series of standards addressing city resilience development. Work in standardization and resilience management is still in an early stage and more developments are foreseen. There is a need to include in a systematic manner knowledge and advances gained in the Resilience area in the recent years.

In relation to policy, the concept of resilience is reflected in diverse policies such Digital Single Market, the European Security Agenda [17]. The OECD identified 45 frameworks on resilience highlighted the importance of local authorities, cooperation and sharing among all levels. Resilience is also addressed on specific critical infrastructures such as aviation, the strategic research agenda includes the need for solutions for disruption management and as a cross-cutting issues together with system intelligence, automation and autonomy. The Horizon 2020 programme addresses the need to strength resilience in various areas such as climate adaptation, security, mobility and energy.

Resilience has gained interest both at Standardization and Policy level across many critical infrastructures. It addresses a variety of needs related to societal changes, increased complexity, uncertainty and interdependencies across critical infrastructures. Significant progress has been achieved in the DARWIN project, where practical resilience guidelines have been evaluated and improvements in terms of maturity have and added value with respect to risk management been achieved. Further work is expected in terms of implementation and evolutions across critical infrastructures. Lessons from these advances will need to be consider when updating policies complementing the risk management approaches with resilience management. In this way, addressing the ability to respond to expected and unexpected events.

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6.   CONCLUSIONS AND WAY FORWARD

The project has achieved its main objective and core result being the development of European DARWIN Resilience Management Guidelines. It makes resilience concepts, methods, tools and practices more mature by their integration and inclusion of practical interventions. The evaluation provides evidence on usefulness of the DRMG, associated CCs and achieving a big step forward in bringing resilience concepts closer to their practical application. To avoid the guidelines to become 'dust collectors', enable the DRMG adoption and evolution, the guidelines are delivered and supported by diverse prototypes. It includes a set of innovative results such as the DARWIN Wiki and complemented with training tutorials, simulation and serious gaming including virtual reality. All results are highly documented combining academic and practical experience so they can be used as building blocks for future developments of resilience management in critical infrastructures. The DRMG include adaptations to healthcare and air traffic management as a source of inspiration to facilitate the use of the guidelines in other domains and motivate cross-sectorial learning.

Therefore, future work builds on these results and can follow-up diverse lines of inquiry include:
-    Development and exchange of experiences and knowledge on the DRMG;
-    Further development of the prototypes produced within the project;
-    Contribute to consultant activities addressing resilience management;
-    Produce targeted training material;
-    Produce academic journal and popular science targeting impactful publications;
-    Explore adaptation of results to other critical infrastructures;
-    Collaborate with other national and international activities to explore and exploit project results;
-    Continue co-creation and adaptation of the guidelines with the DCoP community.

There is a highly motivated an engaged community of practice that collaborate, co-create and innovate together. There are secured stories, videos with testimonies from project members and practitioners outside the project containing statements on the benefits and achievements the project has provided them. There are early adopters of DARWIN results external to the consortium e.g. member from Swedish red cross as well as within the consortium e.g. KMC, SINTEF. The future brings further exploration and exploitation of the DARWIN results in terms of adaptation and adoptions in diverse critical infrastructures. The consortium actively seeks evolution of the guidelines and its practical use through interactions with the community of practice and consultant organisations, national and international EC funding. The guidelines are proposed in a way that new capabilities and other critical infrastructures can be included to enhance the current content. Another area of further work addresses the systematic use of knowledge gained for standards and policy development.

To learn more about the DARWIN project, please visit h2020darwin.eu

REFERENCES

1. Comfort, L.K., Boin, A. & Demchak, C.C. (2010). Designing resilience. Preparing for extreme events. University of Pittsburgh Press.
2. Hollnagel, E., Pariès, J., Woods, D. D., & Wreathall, J. (Eds.). (2011). Resilience Engineering in Practice: A Guidebook. Aldershot, UK: Ashgate
3. Bostrom, N. & ƒÜirkoviƒá, M. (2008). Global Catastrophic Risks, Oxford University Press: Oxford.
4. Beck, U. (1992). Risk Society: Towards a new modernity, Sage Publications: London
5. Rasmussen, J. and I. Svedung (2000). Proactive Risk Management in a Dynamic Society (Swedish Rescue Services Agency, Karlstad, Sweden).
6. Boin, A., & McConnell, A. (2007). Preparing for Critical Infrastructure Breakdowns: The Limits of Crisis Management and the Need for Resilience. Journal of Contingencies and Crisis Management, 15(1), 50-59.
7. Topper, B., & Lagadec, P. (2008). Fractal Crises - A New Path for Crisis Theory and Management. Journal of Contingencies and Crisis Management, 21(1), 4-16.
8. Hollnagel, E. (2008). The changing nature of risks. Ergonomics Australia, 22(1-2), 33-46.
9. Beck, G. & Kropp, C. 2011. Infrastructures of risk: A mapping approach towards controversies on risks, Journal of risk research, 14:1.
10. Wackers, G. (2006). Vulnerability and robustness in a complex technological system: Loss of control and recovery in the 2004 Snorre A gas blow-out. Working paper no. 42/2006. Oslo: Center of Technology, Innovation and Culture, University of Oslo.
11. Woods, D. (2006). Creating Foresight: How Resilience Engineering Can Transform NASA's Approach to Risky Decision Making. Testimony on The Future of NASA for Committee on Commerce, Science and Transportation, John McCain, Chair, October 29, 2003.
12. Rosness, R., Grøtan, T.O., Guttormsen, G., Herrera, I.A., Steiro, T., St√∏rseth, F., Tinmannsvik, R., Wærø, I. (2010). Organisational Accidents and Resilient Organisations: Six Perspectives. Revision 2. SINTEF. Trondheim. Norway.
13. Stephens, K. K., & Malone, P. C. (2009). If the organizations won't give us information…: The use of multiple new media for crisis technical translation and dialogue. Journal of Public Relations Research, 21(2), 229–239
14. European Commission (2017). - Non Paper -Towards a Stronger Security Union: Current state of play and future trends in EU Security Research. Security, Research, Innovation and Education Event, Security Research Conference in Tallinn.
15. World Economic Forum (2017). The Global Risks Report 2017 12th Edition, Insight Report, Switzerland. Available at http://wef.ch/risks2017
16. European Commission (EC, 2017). Joint Communication to the European Parliament and Council. A strategic approach to resilience in the EU¬¥s external action. Downloaded July 30, 2018 from: https://eeas.europa.eu/sites/eeas/files/join_2017_21_f1_communication_from_commission_to_inst_en_v7_p1_916039.pdf
17. Herrera, I., Save, L, Lange, D., Theocharidou, M., Hynes, W., Lynch, S., Bellini, E., Ferreira, P., Sarriegi, J.M, Maresch, S. (2018). White Paper on Resilience Management Guidelines for Critical Infrastructures. From theory to practice by engaging end-users: concepts, interventions, tools and methods.
18. DARWIN (2017). Deliverable D3.3. Resilience Management Guidelines Toolkit. Available at: http://www.h2020darwin.eu/project-deliverables.
19. DARWIN (2017). Deliverable D3.4. Resilience Management Concepts and Application Tutorials. Available at: http://www.h2020darwin.eu/project-deliverables.
20. DARWIN (2018). Deliverable D5.5. DARWIN DCoP resilience concepts, users and academia interactive workshops. Available at: http://www.h2020darwin.eu/project-deliverables.

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21. DARWIN (2016). Deliverable D5.2. Community of resilience and crisis practitioners (DCoP) resilience concepts, users and academia interactive workshops (WS1). Available at: http://www.h2020darwin.eu/projectdeliverables
22. DARWIN (2017). Deliverable D5.3. Community of resilience and crisis practitioners (DCoP) resilience concepts, users and academia interactive workshops (WS2). Available at: http://www.h2020darwin.eu/projectdeliverables
23. DARWIN (2018). Deliverable D4.4. Final guidelines evaluation report. Available at: http://www.h2020darwin.eu/project-deliverables
24. DARWIN (2015). Deliverable D1.1. Consolidation of resilience concepts and practices for crisis management. Available at: http://www.h2020darwin.eu/project-deliverables.
25. DARWIN (2016a). Deliverable D1.2. Evaluation and selection of resilience concepts and approaches. Available at: http://www.h2020darwin.eu/project-deliverables.
26. DARWIN (2016b). Deliverable D1.3. Practitioner and academic requirements for resilience management guidelines. Available at: http://www.h2020darwin.eu/project-deliverables.
27. DARWIN (2017). Deliverable D2.1 DARWIN Generic Resilience Management Guidelines. Available at: http://www.h2020darwin.eu/project-deliverables
28. DARWIN (2016). Deliverable D4.1. Evaluation plan. Available at: http://www.h2020darwin.eu/projectdeliverables
29. DARWIN (2016). Deliverable D4.2. Initial evaluation of the guidelines. Available at: http://www.h2020darwin.eu/project-deliverables
30. 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.
31. DARWIN (2017). Deliverable D2.2. Resilience Management Guidelines adapted to healthcare. Available at: http://www.h2020darwin.eu/project-deliverables.
32. DARWIN (2017). Deliverable D2.3. Resilience Management Guidelines adapted to healthcare. Available at: http://www.h2020darwin.eu/project-deliverables.
33. DARWIN (2018). Deliverable D2.4. DARWIN Resilience Management Guidelines. Available here: http://www.h2020darwin.eu/project-deliverables.
34. CEN-TS 17091 (2018) Crisis management – guidance for developing a strategic capability. Available at: https://bsigroup.com/

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