

Striving to be resilient: What concepts, approaches and practices should be incorporated in resilience management guidelines?

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Highlights:

- 51 concepts were identified for inclusion in resilience management guidelines
- 7/51 concepts were ranked essential, 43 important, one ranked somewhat important
- Diverse content experts form the foundation for generalisable resilience guidelines
- Collaboration, planning and procedures are the main categories of resilience

Abstract:

Resilience management guidelines address disruptions, changes and opportunities, facilitate anticipation, adaptation, flexibility and provide a foundation for an effective crisis response. The objective and novelty of the study were to propose a holistic framework that enables to evaluate and prioritise concepts, approaches and practices that should be incorporated into European guidelines for resilience management. Based on a modified Delphi process, 51 items achieved a consensus of $\geq 80\%$. 84% of the items (n=43) were ranked as important; 13.7% (n=7) as essential; one ranked as somewhat important. The identified items encompass eleven categories as follows: 1) collaboration [11 items]; 2) planning [8 items]; 3) procedures [8 items]; 4) training [6 items]; 5) infrastructure [5 items]; 6) communication [3 items]; 7) governance [3 items]; 8) learning lessons [2 items]; 9) situation understanding (awareness) [1 item]; 10) resources [2 items]; and, 11) evaluation [2 items]. The identified concepts, approaches and practices seem to be applicable to a wide range of domains and critical infrastructures, such as crisis management, air traffic management and healthcare, due to their generic and abstract characteristics. Important in the Delphi process is the engagement of potential end users in the development of resilience management guidelines to align this development to their needs. Therefore, the Delphi process involved policy and decision-makers, as well as practitioners and other personnel representing different critical infrastructures and academia, in prioritising concepts aimed at achieving resilient organisations, entities or communities.

Introduction

Recent years have brought numerous disasters and crises that, in hindsight, clearly demonstrate the potential benefit of a more resilient and robust community (Woods, 2003; Birkland, 2006; de la Torre, et al., 2012; Comfort, et al., 2010; EUROCONTROL, 2013). One such event is the Deepwater Horizon disaster, which resulted in 11 fatalities and environmental damage from almost 5 million barrels of oil leaking out into the ocean. Studies and after-action reports following the disaster highlighted the need to improve organisational and individual awareness, and the need to develop resilient management strategies that can adapt to anticipated and unanticipated changes (Tinmannsvik, et al., 2011; Colten, et al., 2012). Another example is the Eyjafjallajökull eruptions in 2010, which resulted in an approximate loss of 1 billion Euros. Public enquiries and studies following the aftermath of this event particularly emphasised that there is a clear need to improve emergency management at European level, building better tools for forecasting and anticipation, and improving the coordination across different organisations (Conin, 2010; Sultana, 2012). A third example is the Fukushima Daiichi nuclear disaster in 2011, from which a study reported that Resilience Engineering provides a critical proactive approach that is essential for improving safety in nuclear facilities. The study particularly highlights the need for the ability to manage unforeseen events (Kitamura, 2011). Current events causing increasing concern from an impact and resilience perspective are mass migration from areas of political instability and/or war zones and the incidence of cyber-attacks at national and international level.

The above examples are reminders of the urgent need to improve our ability to reveal, assess and manage resilience, both in everyday operations, and during crises (Hollnagel, et al., 2011). By becoming more resilient, communities should be better able to withstand and recover from

disturbances. Furthermore, they should be able to adjust plans and procedures prior to, during, and following new or unexpected disturbances, so that they can maintain their function as needed throughout the disruption (Hollnagel, 2009).

Resilience depends on many external factors, such as the scale of an event, the size of the population, the parties involved, the terrain, available resources, and so on. Hollnagel (2009, 2015) highlights four abilities of resilient systems and related services (Hollnagel, 2009; Hollnagel, 2015): (1) the ability to respond knowing *what to do* in the event of an emergency situation as well as opportunities; (2) the ability to monitor knowing *what to look for* regarding what happens in the environment, outside the boundaries of the systems as well of what happens within the system, its own performance ; (3) the ability to anticipate knowing *what to expect* regarding potential future crises, that is associated with tactics and strategies which consider both opportunities and threats; and (4) the ability to learn from *what has happened*, *i.e.* learning from past experiences; resilience also considers how the effects of past learning are verified.

Recognising the need for more resilient and adaptive approaches for dealing with disasters and crises, there is already a tremendous amount of effort spent on improving resilience management, both in academia, and by practitioners working in fields such as emergency management, healthcare, disaster medicine, civil protection, aviation, and oil and gas.

Resilience management has gained extensive attention in the last decade, as the shift was made from crisis management to building the ability to anticipate and adapt when facing expected and unexpected events including threats, changes and opportunities (Scott, et al., 2013; Fiksel, et al., 2015; Hollnagel, 2015). Resilience management expands the scope of risk management, in addressing complexities that characterise the operation of large integrated systems, considering

known as well as unforeseen threats (Linkov, et al., 2014). It is concerned with the level of disturbance or crisis that a system can withstand without changing its functionality and the ability to survive and/or recover by adapting to the new situation (Standish, et al., 2014; Teoh & Zadeh, 2013).

Resilience management guidelines are required in order to delineate what needs to be implemented in order to enable all entities and/or systems to adapt to the crisis and extend the capacity to work; e.g. graceful extensibility (McAllister, 2013; Jukić, et al., 2015; Woods, 2015).

The guidelines provide advice on how stakeholders can make more informed decisions on choosing, designing and implementing mechanisms that ensure the ability to adapt in a flexible manner to respond when crises occur and continue to function effectively (Walker, et al., 2002).

Resilience management guidelines address risks and opportunities, facilitate planning and decision-making processes, and provide a foundation for systems and communities to build an effective and holistic response to potential crises (McAllister, 2013). Ensuring the appropriateness of guidelines to the specific needs and characteristics of the target populations is an ambitious task that requires the involvement of relevant and representative stakeholders in the development process (Walker, et al., 2002). Extensive efforts are being made to develop resilience management guidelines that can be successfully implemented in different entities and systems (Arbon, 2014; Zhang & Luttermelt, 2011). These efforts have resulted in a wide, scattered and sometimes overlapping diversity of concepts, approaches and practices for resilience management, ranging from abstract theoretical principles that have yet to be implemented, to practical rules of thumb that are used in everyday practices (DARWIN, 2015).

Despite their heterogeneous nature, these concepts, practices and approaches are important contributions to the field of resilience engineering, and provide crucial input to the future

establishment of European guidelines for resilience management; accordingly, five research projects in complementary ways such as DARWIN (<http://www.h2020darwin.eu/>), IMPROVER (www.improverproject.eu), RESOLUTE (<http://www.resolute-eu.org/>), RESILIENS (www.resilens.eu), and SMR (<http://ciem.uia.no/project/smart-mature-resilience>) address this topic.

Among the diverse topics that have been identified as relevant components of resilience management are: collaboration (O'Sullivan, et al., 2013), planning, regulations and procedures (Desouza & Flanery, 2013), as well as resilience training (Robertson, et al., 2015).

However, work is required to identify and streamline the various concepts, approaches and practices, and to assess their suitability to be incorporated into such guidelines.

The work reported in this paper is part of the European research project DARWIN, which aims to improve responses to expected and unexpected crises affecting critical infrastructures and social structures through the development of resilience management guidelines for both man-made incidents (e.g. cyber-attacks) and natural events (e.g. earthquakes). DARWIN strives to augment the current knowledge by cataloguing and operationalizing resilience concepts, approaches and practices that were identified and delineated in previous studies. This includes the comprehensive work that was initiated and developed under the international frameworks of the "UNISDR, Hyogo Framework for Action 2005-2015" (Innocenti & Albrito, 2011), its successor "The Sendai Framework for Disaster Risk Reduction 2015-2030" (Iitsi-Selmi, et al., 2015), as well as the "City Resilience Framework" (CRF, 2016). These frameworks outlined priorities and guiding principles for achieving disaster resilience, promoted risk reduction actions that may be implemented by all relevant stakeholders, provided means for understanding the complexity of

resilience, as well as a common language for sharing knowledge and experiences. A significant component of these frameworks was a strong encouragement to develop practical guidelines that support implementation of risk reduction measures and engage all relevant stakeholders in actions that promote resilience.

DARWIN aims to build on the results of the former studies in order to transform them into operational resilience management guidelines. The goal is not to develop alternate frameworks, but rather to build on the existing ones and further delineate what needs to be done in the form of guidelines. DARWIN strives to facilitate progress beyond risk assessment and management into operational activities that should be implemented in practical and actionable resilience guidelines, in order to promote and strengthen resilience management. Potential interactions between different operational domains and the related infrastructures, and between them and the public, shall be considered and integrated in the generic guidelines and in their associated operationalisation and implementation. DARWIN's goal is to develop resilience management guidelines that are relevant and/or can easily be adapted to various domains. Specifically, within the scope of the DARWIN project, the guidelines will be adapted to, implemented and validated in two very different domains – healthcare and Air Traffic Management. Within the scope of the project, the applicability of the developed guidelines will be reviewed in varied scenarios, such as function of a local airport as well as distribution of medicines and medical supplies by healthcare services following an earthquake or an epidemic. The guidelines will provide descriptions and examples of methods and guides for their application, as well as tools, training modules and other applicable solutions to support their operationalisation.

The target beneficiaries of DARWIN are infrastructure operators which include service providers and related stakeholders who are responsible for critical infrastructures that might be affected by a crisis as well as the public and media. Examples include: European and national agencies, policy makers, service providers, first responders and industry and enterprises. The first phase of the project was to identify concepts, practices and approaches of resilience management based on a comprehensive systematic review of literature from a wide range of disciplines, and interviews with relevant stakeholders involved in crisis management as well as with members of DARWIN's Community of Crisis and Resilience Practitioners (CoCRP), which were collated in a deliverable – D1.1 (DARWIN, 2015).

The objective of the present study was to evaluate the results of the deliverable in order to determine and prioritise which of the identified items should be incorporated into European guidelines for resilience management.

Method

Concepts, approaches and practices for resilience management were identified in the first phase of the DARWIN project (deliverable D1.1) through a Systematic Literature Review (SLR), which was made between August to November 2015 by three groups of experts, from four countries.

The concepts, practices and approaches were defined as follows: **Concepts** represent a set or conjunction of characteristic features or entities related to a common scope and rationale, with a presumed coherence related to resilience. **Practices** represent a solution that has been incorporated and implemented in a real environment. **Approaches** are methods, ways of working or strategies that that may be integrated and implemented in guidelines and procedures. In order to operationalize the concepts, practices and approaches that were identified in the study and

facilitate their transformation into guidelines, they were all phrased in a uniform mode of actionable items.

The SLR was designed and conducted based on the methodology described by Kitchenham (Kitchenham, 2004) including four basic steps: planning, conducting, data extraction/synthesis and reporting. The keywords used to extract relevant articles were: resilien*AND "safety management" OR "security management" OR "crisis management" OR "crisis response" OR "disaster management" OR "disaster response" OR "disaster relief" OR "emergency management" OR "emergency response" OR "contingency management" OR "contingency response" OR "business continuity" OR "critical infrastructure" OR "community resilience" OR "resilience engineering" OR "contingency planning" OR "incident response" OR "incident command" OR "emergency preparedness". The search query was based on title, abstract and keywords which were integrated in the Scopus search engine. After limiting results to peer-reviewed articles which were cited at least twice (if published before 2014), a total of 1331 articles were identified. The abstracts of these articles were read by three reviewers; among them, 440 articles were identified as relevant for further synthesis and analysis. 21 articles could not be accessed, thus a total of 419 were reviewed. Of these, 122 (29%) were excluded after full article review, leaving the number of articles included in the analysis as 297 (71%) (DARWIN, 2015).

The concepts, approached and practices were converted into elements that can be evaluated by content experts through a five-step process:

- 1) Data gathering – all relevant results from the SLR and the interviews were collected;

- 2) Data analysis – the concepts, approaches and practices were reviewed and, when deemed necessary, rephrased to ensure that each item provides a brief description of only one factor, is standalone, consolidated, generalisable as much as possible and consistent;
- 3) Data cleaning – repetitive items were deleted, similar concepts were consolidated, ambiguous phrasing was corrected, and all terms which seemed to be difficult to understand were discussed within the expert group and resolved, in order to achieve a clear and common understanding of the identified concept, approach or practice;
- 4) Data presentation: a final list of concepts, approaches and practices were streamlined and presented in a neutral and uniform manner, using one sentence per element;
- 5) Categorization: each concept, approach and practice was categorized according to its main focus, as was identified in the first phase of the DARWIN project.

To ensure the items were understandable, unambiguous and clear, and to categorize them according to topics, eight consortium members, consisting of varied professions (engineers, medical professionals, human factors specialists and academics) and organizations (end-users, governing authorities and universities), read and validated their clarity and categorisation in five iterations.

In order to evaluate the concepts, approaches and practices and to decide which should be included in the resilience management guidelines, a 2 cycle modified Delphi process (Okoli & Pawlowski, 2004; Turoff, 1970; Turoff & Hiltz, 1996) was conducted designed specifically to reach a consensus across a large panel of experts consisting of practitioners, academics and other experts in the field of resilience management.

The modified Delphi process is a structured communication tool that is used to achieve agreement among selected content experts concerning very broad topics or when new concepts and/or applications are introduced (Okoli & Pawlowski, 2004). It is based on the assumption that group judgments are more valid than individual opinions but simultaneously, it is important that each expert has an equal opportunity to impact the overall decision-making (Okoli & Pawlowski, 2004; Gracht, 2012; Winkler, et al., 2015).

The content experts that were selected for participation in the modified Delphi process belonged to the following three groups: 1) All 39 members of the DARWIN consortium, which consists of researchers and practitioners in the fields of crisis and resilience management; 2) 30 practitioners that were identified as leading experts in crisis and resilience management, and thus invited to become members of DARWIN's Community of Crisis and Resilience Practitioners (DCoP); and, 3) 4 experts from the Smart Mature Resilience project¹ (SMR). All members of the European projects that deal with resilience were invited to participate in the Delphi process. The SMR consortium team was the only one interested in participating, as they were in a similar stage as DARWIN (planning a Delphi process).

By involving these three groups, we aimed to increase the coordination and mutual contribution between European Union's projects that focus on similar topics, take advantage of their respective expertise, and maximize the output of the respective projects. Together, these experts represent a broad range of actors from fields such as academia, aviation, policy and decision-making, civil protection, oil and gas, water, fire and rescue, civil protection, healthcare, disaster medicine, disaster preparedness and management. This relatively wide and heterogeneous set of experts was

¹ See <http://ciem.uia.no/project/smart-mature-resilience>

selected in order to achieve a comprehensive overview of concepts, approaches and practices that should be incorporated into the resilience management guidelines and enables the generalisation of the study's results. It should be noted that while a large portion of the experts (up to 42%) are currently from academia, most of them have practical experience from different domains from policy to practice. The participants to the survey thus represent different countries, e.g. from UK, Israel, Italy, Sweden, Germany, Norway and Spain; from a diversity of levels and responsibilities; and from a broad spectrum of organisations, disciplines and specialities such as health care, transport and energy.

In order to conduct the modified Delphi process, the concepts, practices and approaches that were identified in the SLR and interviews in the first phase of the DARWIN project, were phrased as sentences and incorporated into a computerised survey tool, using Survey Monkey software (www.surveymonkey.com). The respondents were asked to express agreement/disagreement concerning the incorporation of each item (sentence) into the resilience management guidelines; rank its level of importance (1) essential, 2) important, 3) somewhat important, 4) not important, or 5) I don't know/not applicable; and propose (if deemed necessary) additional concepts for inclusion. The level of consensus achieved in the modified Delphi processes ranged from 51 to 95 percent agreement. The level of consensus required for a concept, approach or practice to be included in the resilience management guidelines was set to a minimum of 80% agreement. This is in line with previous studies which recommend that guidelines should be consensually endorsed by 80 percent or more of the participating content experts (Kim, et al., 2013; Falzarano & Zipp, 2013).

The responses to the survey were examined for quality and consistency through cross-tabulation.

Two types of inconsistent answers were eliminated from the results:

- Respondents that agreed to include an item in the resilience guidelines, but ranked the parameter as "not important". Although there is a slight possibility that this is not a discrepancy, but rather that the respondent thought that relative to other items, the described issue is minor and thus ranked it as "not important". It was assumed that such ranking signifies that it can be excluded from the resilience guidelines. It should be stressed, however, that there were only a few such cases and that the cleaning of the data did not result in any item being excluded from the guidelines.
- Respondents that disagreed to include an item in the resilience guidelines, but ranked its importance as essential, important or somewhat important.

All items that received less than 80% agreement for inclusion in the guidelines in the first modified Delphi cycle were re-distributed for a second cycle among the respondents of the first cycle. The decision to limit the participation in the second cycle to those experts who participated in the first cycle was made in order to adhere to the logic of the modified Delphi process, according to which experts tend to revise their earlier opinions in light of the replies and views of other participants (Slade, et al., 2014). The participants were provided with the percentage of agreement that was achieved in the first cycle concerning the concept, approach or practice (presented in text) as well as the overall accumulated ranking of importance (presented graphically). An example of the data presented in the second modified Delphi cycle is presented in Figure 1.

13. Use a roster-based system for resource management during emergencies, disasters and crises.

In the first cycle 51% of respondents agree that this concept should be incorporated in the guidelines. Results from the rating of importance are given in the below figure.

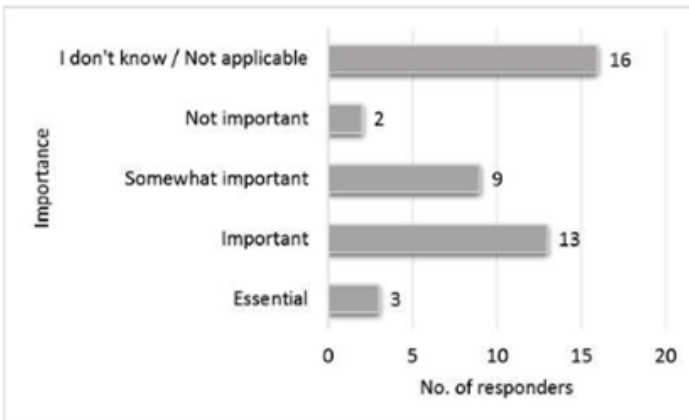


Figure 1: Example of data presented in the second modified Delphi cycle

Following the second modified Delphi cycle, the final level of importance was calculated for each item (concept, practice or approach) that achieved the consensus of 80% or more of the respondents. The goal of defining the importance is to enable the prioritisation of each item in its incorporation in the resilience management guidelines. The importance was defined by calculating the median distribution of ranking into one of the following levels: essential, important, somewhat important, and not important. The option of ‘I do not know/not applicable’ was excluded from the final calculations.

The changes in the votes of the experts between the first and the second cycles were calculated concerning their agreement to incorporate the concept, approach or practice in the resilience

management guidelines. The data was analysed using SPSS software version 21 and by Excel software.

Results

Identification of resilience concepts, approaches and practices

Based on the comprehensive SLR and the interviews that were conducted in the first phase of the DARWIN project, 8 concepts, 8 theories, 9 models, 11 practices and 23 approaches concerning resilience management were identified (DARWIN, D1.1). The SLR performed prior to the selection of resilience concepts, identified 128 methods to evaluate resilience. The methods were reviewed to identify resilience concepts emerging across the literature. These resilience concepts were used as relevant for the evaluation of concepts to be included in the guidelines (SLR documented in DARWIN, D1.1). Following five iterations of data cleaning, consolidation, synchronisation and formulation of the different items, a final list of 56 concepts, approaches and practices was compiled, all phrased in a uniform mode. These items were classified into 11 content-based categories: collaboration, planning, procedures, training, infrastructure, communication, governance, lessons learned, situation understanding (awareness), resources and evaluation of emergency preparedness. The list of items, classified according to the different categories is presented in Table 1.

Table 1: List of concepts, approaches and practices classified according to categories (numbered by their ID)

Concept, Practice, Approach		
Category: Collaboration (11 items)		
1. Link resilience management to other efforts aimed at ensuring continuity	2. Establish coordinated networks of actors to ensure close cooperation between stakeholders.	4. Attain resilience management through implementation of national collaboration.
3. Attain resilience management through implementation of international collaboration.	5. Ensure that the actors involved in resilience management have a clear understanding of their	6. Ensure that the actors involved in resilience management have a clear understanding of the

Concept, Practice, Approach		
	responsibilities.	responsibilities of other involved actors.
7. Ensure that actors that need to collaborate have a mutual understanding of each other's goals.	8. Address potential interdependencies between the different actors and systems.	21. Consider the impact of interdependencies and interaction between actors on resilience management.
52. Coordinate and synchronize systems to ensure efficient collaboration.	56. Provide a comprehensive response to increase trust between responders and populations.	
Category: Planning (8 items)		
31. Plan resilience management based on routine practices.	32. Maintain national operational contingency plans that describe the responsibilities of the involved actors.	35. Define common recovery points in resilience management.
36. Define time requirements in resilience management.	48. Consider unique characteristics of the community in resilience management.	49. Consider people's key needs, especially vulnerable groups, to achieve resilience management.
50. Consider trust for leaders and authorities in resilience management.	54. Develop plans for immediate response as part of resilience management.	
Category: Procedures (10 items)		
23. Consider compliance with rules and regulations in resilience management.	24. Develop procedures that are easily adaptable to both expected and unexpected events (all-hazard approach).	26. Evaluate and revise procedures and checklists continuously.
27. Design procedures that address various sizes and complexities of events.	28. Adjust procedures during crises to the changing reality.	29. Consider flexibility in resilience management beyond adherence to procedures.
30. Develop procedures and guidelines that are clear and non-judgmental.	33. Apply standards in order to ensure business continuity.	34. Apply standards in order to ensure business recovery.
37. Develop checklists that define how work should be performed during a degraded mode of operation.		
Category: Training (6 items)		
25. Define training and exercises in a manner that enables personnel to improvise during the handling of situations when required.	38. Design scenario-based exercises to prepare for worst-case scenarios.	39. Train for resilience management routinely.
40. Develop education programs that focus on resilience management.	43. Address different magnitudes of emergencies, disasters and crises in training programs.	53. Conduct joint training exercises to ensure efficient collaboration.
Category: Infrastructure (5 items)		
16. Consider critical infrastructural needs in resilience management.	17. Incorporate advanced technologies into resilience management.	19. Develop and maintain alternative working methods in case of system failures.

Concept, Practice, Approach		
18. Develop and maintain alternative technological back-up systems in case of system failures.	20. Apply standards to ensure secure and reliable information systems.	
Category: Communication (3 items)		
9. Use supplementary communication tools and methods as part of resilience management.	10. Develop proactive procedures through transparency (open dialogue) and risk communication.	11. Inform the public of emergency procedures so that citizens can react appropriately.
Category: Governance (3 items)		
13. Balance resilience management between local and centralised governance.	14. Centralise and manage assistance in order to provide services to an as large as possible portion of the population.	15. Ensure that resilience management systems are flexible enough to handle different types of situations.
Category: Lessons learned (2 items)		
41. Use joint debriefing sessions to facilitate a shared understanding, reflection and discussion.	42. Build resilience by applying organisational learning techniques (e.g. log-books, debriefings, after-action reviews).	
Category: Situation understanding (awareness) (1 item)		
51. Develop overall situation understanding (awareness) to ensure efficient collaboration.		
Category: Resources (6 items)		
22. Plan for reinforcement of resources in resilience management.	44. Use available manpower optimally.	45. Maintain central (rather than local) control of resources.
46. Establish a hierarchical structure of on-site resource management.	47. Use a roster-based system for resource management during emergencies, disasters and crises.	55. Discourage non-essential travel to and from an affected area.
Category: Evaluation (1 item)		
12. Conduct resilience assessments prior to, during and after emergencies, disasters and crises.		

Evaluation of concepts, approaches and practices – 2 cycles modified Delphi process

The items were distributed through a computerised survey to 73 content experts from the DARWIN consortium, the CoCRP members and the SMR project, in order to attain their agreement/disagreement on the incorporation of each item into the resilience management

guidelines and their ranking of importance. The first cycle of the modified Delphi process was conducted during December 8th to 20th, 2015. 67% (49 out of the 73 experts) responded to the survey. Figure 2 illustrates the distribution of participants in the first cycle in relation to the domain in which they work.

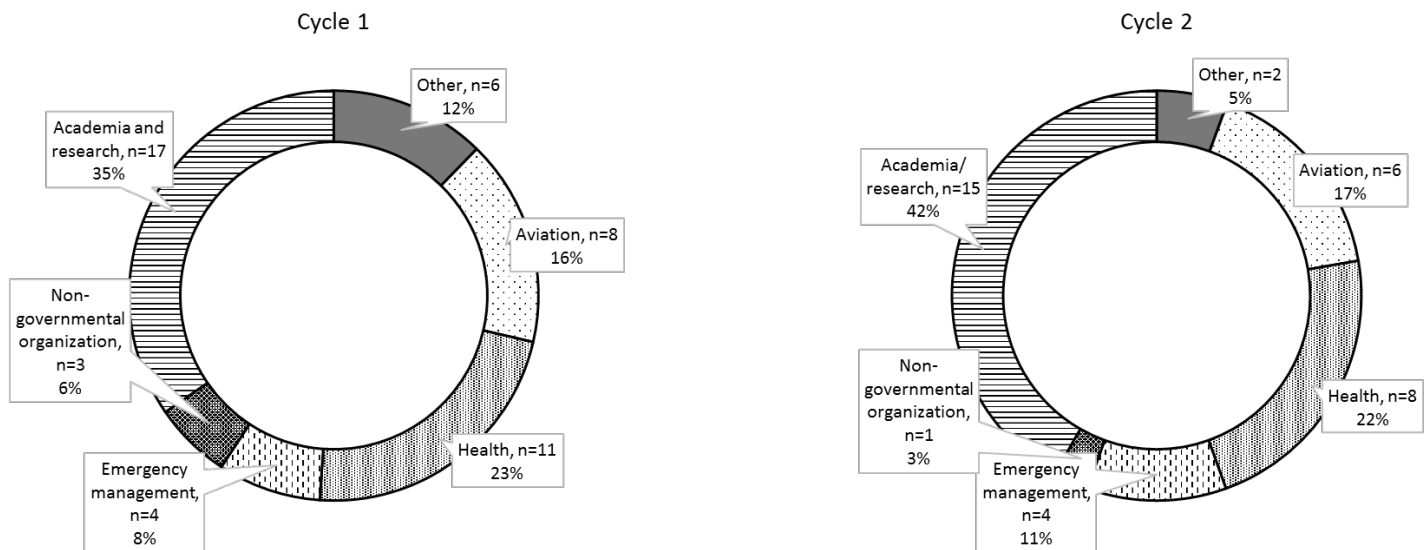


Figure 2: Distribution of participants across work domains in the two cycles of the modified Delphi process

75% (N=42) of the 56 items achieved 80% or higher consensus from participants that they should be incorporated into the resilience management guidelines. The remaining 14 items that achieved agreement from less than 80% of the respondents were integrated in the second modified Delphi cycle. Three additional (new) items were proposed by the respondents for inclusion in the guidelines. These included the following:

- N1- Establish a common terminology concerning resilience management across institutions and authorities.
- N2- Design tools and methods to monitor readiness to cope with crises
- N3- Use resilience management support systems as a part of everyday practices.

The levels of agreement among the respondents concerning the incorporation of the items into resilience management guidelines in the first cycle are detailed in Appendix 1.

The second cycle of the modified Delphi process was conducted during January 13 to 25, 2016.

The online survey that included the 17 concepts, approaches and practices was distributed to only 49 respondents who participated in the first cycle. The response rate for the second cycle was 73% (i.e. 36 respondents from a total of 49). Figure 2, right, illustrates the distribution of participants in the second cycle in terms of the domain in which they work. Similar to the previous cycle, the highest percentage of respondents was in the academia and research domain. Health and aviation domains maintained similar percentages to those viewed in the first cycle.

35% (n=6) of the 14 items that did not achieve 80% agreement to be incorporated into the guidelines in the first modified Delphi cycle, as well as the three new concepts that were introduced in the second cycle, surpassed the required threshold. Eight items did not reach the required 80% agreement, among them four concepts in which the level of consensus decreased from cycle one to cycle two. The difference in the percentage of agreement to incorporate the 17 items between the two modified Delphi cycles, and the relative change, are presented in Table 2.

Table 2: Difference in percentage of agreement to incorporate items between the two cycles

ID	Concept/approach/practice	Agreement to incorporate in guidelines		Difference between cycles	Percentage of change
		Cycle 1 (a)	Cycle 2 (b)	(b-a)	(b-a)/a
1	Link resilience management to other efforts aimed at ensuring continuity.	79.59% (n=39)	90.90% (n=30)	11.31%	14.21%
13	Balance resilience management between local and centralized governance.	79.60% (n=38)	94.30% (n=33)	14.70%	18.47%
3	Attain resilience management through implementation of national collaboration.	79.59% (n=39)	93.90% (n=31)	14.31%	17.98%

31	Plan resilience management based on routine practices.	79.17% (n=38)	91.70% (n=31)	12.53%	15.83%
17	Incorporate advanced technologies into resilience management.	77.08% (n=34)	88.20% (n=30)	11.12%	14.43%
14	Centralize and manage assistance in order to provide services to a large as possible portion of the population.	56.25% (n=25)	82.80% (n=24)	26.55%	47.20%
33	Apply standards in order to ensure business continuity.	75.00% (n=34)	78.10% (n=25)	3.10%	4.13%
55	Discourage non-essential travel to and from an affected area.	68.75% (n=33)	75.00% (n=27)	6.25%	9.09%
35	Define common recovery points in resilience management.	77.08% (n=34)	73.50% (n=25)	-3.58%	-4.64%
34	Apply standards in order to ensure business recovery.	68.75% (n=34)	72.70% (n=24)	3.95%	5.75%
36	Define time requirements in resilience management.	75.00% (n=35)	69.40% (n=25)	-5.60%	-7.47%
46	Establish a hierarchical structure of on-site resource management.	69.39% (n=32)	63.90% (n=23)	-5.49%	-7.91%
45	Maintain central (rather than local) control of resources.	44.90% (n=21)	53.80% (n=15)	8.90%	19.82%
47	Use a roster-based system for resource management during emergencies, disasters and crises.	57.14% (n=25)	41.70% (n=15)	-15.44%	-27.02%
New items proposed by respondents following cycle 1					
N1	Establish a common terminology concerning resilience management across institutions and authorities		94.10% (n=33)		
N2	Design tools and methods to monitor readiness to cope with crises		91.70% (n=32)		
N3	Use resilience management support systems as a part of everyday practices		83.30% (n=30)		

Ranking level of importance of concepts, approaches and practices, according to categories

A total of 51 concepts, approaches and practices (42 in the first modified Delphi cycle and 9 in the second cycle) achieved a consensus of 80% or more among the respondents to be incorporated into the resilience management guidelines.

The median ranking of importance was calculated for each of these items. 84% of the items (n=43) were ranked by 50% or more of the content experts as important; 13.7% (n=7) were ranked as essential; and only one item was ranked as somewhat important (ID 14 – centralise and manage assistance in order to provide services to an as large as possible portion of the population). **Figure 3** presents the median ranking of importance of all 51 items classified according to their categories. In the figure, the circles (dots) signify the median, while the boxes

represent the interquartile range. The 51 items are presented below, according to the various categories.

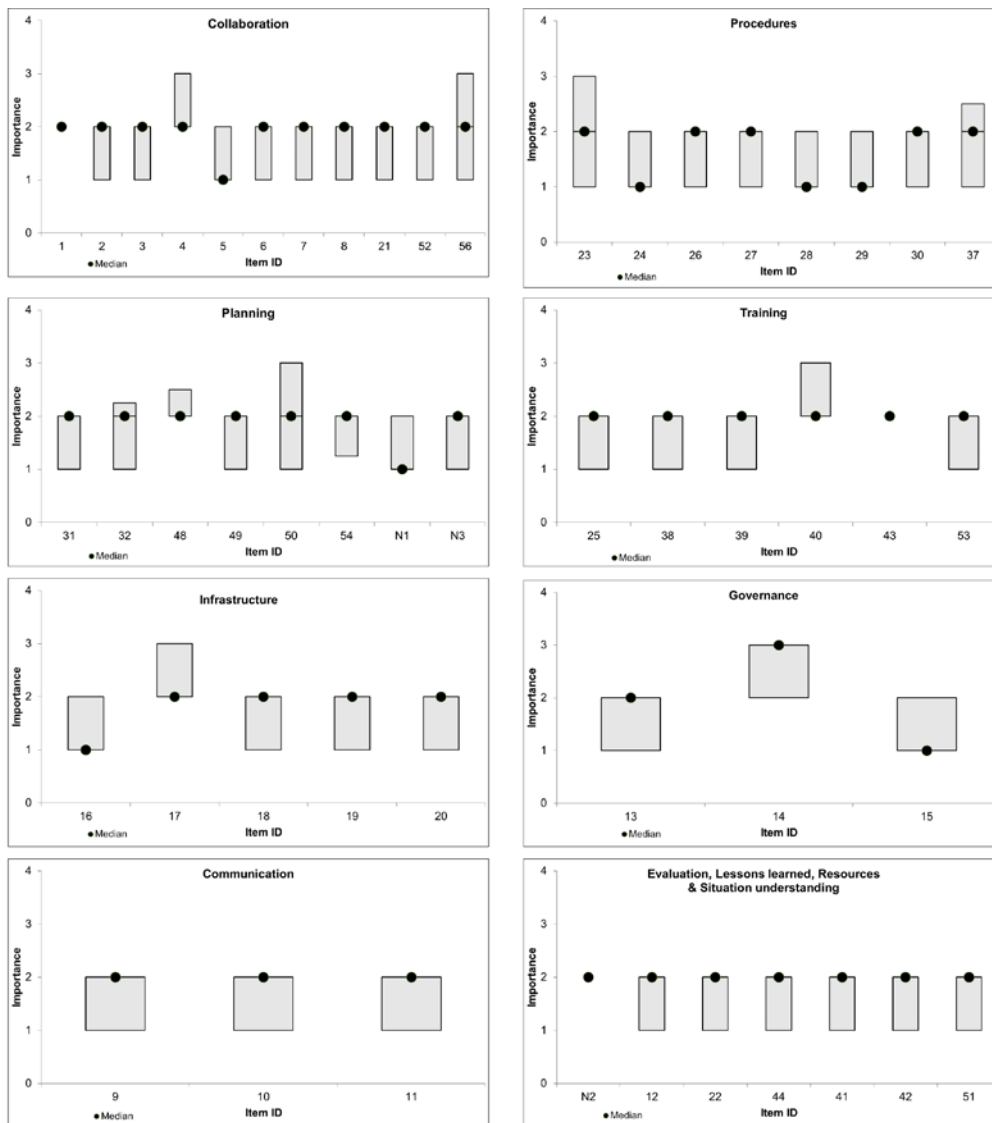


Figure 3: Ranking importance of items according to the resilience management categories

Discussion

The main contribution of the present study is the evaluation of concepts, approaches and practices that should be integrated in the resilience management guidelines which were formed in a structured methodological manner. Although some of these concepts were recognised before this

evaluation, the review of such a broad scope of items that were assessed by researchers and/or practitioners facilitated the identification of concepts, approaches and practices that form the foundation for generalisable resilience management guidelines (DARWIN, 2015). Thus, DARWIN Resilience Management Guidelines (DRMGs) consist of a set of principles, methods, practices and strategies to aid organizations in the creation, assessment or improvement of their guidelines. Based on resilience management concepts identified in the study presented in this article, the DRMG help each organization in developing a critical view on its own crisis management activities. The DRMGs are intended to complement existing guidelines, procedures and practices already present in an organization. The guidelines are addressed to policy makers, decision makers and managers at different levels in an organization responsible for designing and implementing crisis management plans and strategies. The DRMG should be applied on regular basis when an organization needs to design or improve crisis management capabilities (DARWIN D2.1, 2017, under preparation - DARWIN Deliverable D2.1 Generic Resilience Management Guidelines. DARWIN Consortium to be published Feb 2017: [http://www.h2020darwin.eu/project-deliverables.](http://www.h2020darwin.eu/project-deliverables))

The novelty of the present study is the ability to present a holistic framework of the various components that should be incorporated in resilience management guidelines, as well as their prioritisation. Eleven categories of concepts, approaches and practices were found to be relevant and important for inclusion in the guidelines. The four major categories that included the highest number of items were *collaboration*, *planning*, *procedures* and *training*. These results reinforce findings from previous studies, each focusing on a different component of resilience management (O’Sullivan, et al., 2013; Desouza & Flanery, 2013; Robertson, et al., 2015). Collaboration was previously identified as an important component in providing an adaptive response to crises and

strengthening the ability to withstand disturbances (O'Sullivan, et al., 2013). Planning processes are initiated in order to ensure the ability to utilise resources optimally and to implement measures before a disaster strikes; this reduces vulnerability and increase resilience. Significant outputs of the planning are regulations and procedures designed to formulate linkages between relevant actors and to build robust structures, so as to achieve and maintain ongoing resiliency (Desouza & Flanery, 2013). Resilience training has been shown to improve personal well-being, psychosocial functioning as well as performance outcomes (Robertson, et al., 2015).

Based on the findings of the DARWIN project, the development of guidelines can now differentiate between items that should receive a higher degree of attention versus elements that may be less emphasised or elaborated. The concepts, approaches and practices that were identified in the study and found to be important, can now be transformed into resilience management guidelines that will be operational for the end-users. For example, the concept that states that there is a need to "balance resilience management between local and centralized governance" (ID 13) will now be transformed into specific guidelines that delineate actions that need to be implemented by local authorities on the one hand (such as disseminating information to the community concerning hazards that threaten the area) and by the national government on the other hand (such as deployment of risk assessment measures to estimate the various hazards and their potential consequences). Currently, the selected concepts are elaborated as a set of guiding principles indicating criteria organizations need to consider in order to increase their resilience. They are presented as interrelated concept cards that may help each organization to assess its own crisis management activities. This work is part of the current DARWIN activities concerning development of the guidelines and is performed in close collaboration and interactions with end-users to ensure usability and alignment to their needs.

Reviewing the items that were evaluated as essential suggests that they comprise of at least one of three common elements that are frequently found in definitions of resilience: 1) They refer to the need to maintain *flexibility*, *adjustability* and *adaptability* i.e. develop procedures that are easily *adapted* to expected and unexpected events (ID 24 in appendix); *adjust* procedures during crisis to the changing reality (ID 28 in appendix); ensure that resilience management systems are *flexible* enough to handle different types of situations (ID 15 in appendix); and, consider *flexibility* in resilience management beyond adherence to procedures (ID 29 in appendix). 2) They require *sharing* and/or *understanding* among the responders i.e. ensure that the actors involved in resilience management have a clear understanding of their responsibilities (ID 5 in appendix); and, establish a common terminology concerning resilience management across institutions and authorities (ID N1 in appendix). 3) They focus on components that are considered vital to the organisations, systems or communities; i.e. considered critical infrastructure needs (ID 16 in appendix).

Similar to the all-hazard approach to crisis management which is based on the assumption that there are common components for responding to different types of emergency situations (Adini, et al., 2012) the present study aimed to build resilience management guidelines which are widely applicable to different domains. For this reason, a diverse group of experts representing different types of domains, proficiencies, experiences and competencies were selected for participation in the modified Delphi process, so that the outputs are applicable and generalisable to a wide variety of fields.

Many studies have shown that the modified Delphi process contributes to decreasing variability of opinions as the exposure to the attitudes or thoughts of other experts converges views of the participants towards consensus (Slade, et al., 2014; Winkler, et al., 2015). In line with this assumption, 64% (9 out of 14) of items that did not achieve the consensus of 80% or more of the experts for inclusion in the resilience management guidelines in the first modified Delphi cycle, exceeded this threshold in the second cycle of voting. More so, the three concepts that were introduced only in the second cycle of voting, representing items suggested by the participants of the modified Delphi process themselves, were all endorsed by more than 80% of the experts, despite the fact that this was the first time they were exposed to them. This phenomenon of mutual influence, regardless of the lack of direct communication or dialogue between the participating experts, well demonstrates the power of the group as a whole (Gracht, 2012).

Nonetheless, contrary to the tendency to be influenced by group opinions, concerning four of the concepts that were reviewed in the present study, the level of agreement to incorporate the items in the resilience management guidelines decreased in the second cycle compared to the initial views expressed in the first cycle. These four elements represent two categories – planning and resources. The concepts that were excluded from the planning category focused on defining 1) common recovery points and 2) time requirements in resilience management. The support of their incorporation in the guidelines dropped slightly from 77% and 75% in the first cycle to 73.5% and 69% respectively in the second cycle. In the resources category, the two items with decreased levels of agreement were focused on 1) establishing a hierarchical structure of on-site resource management, and 2) using a roster-based system for resource management. The level of decrease in support of their incorporation in the guidelines dropped from 69% to 57% in the first cycle to 64% and 42% respectively in the second cycle. A close scrutiny into the essence of these four

items suggests that one common characteristic among these concepts is that they are less likely to be generalisable for all domains. Common recovery points and time requirements for example, are more applicable and common to resilience engineering than social or ecological resilience (Schagaey & Kaegi-Trachsel, 2016). Including a hierarchy or roster-based system in resource management may have been perceived by the experts as being too specific and should be left to the decision of resilience managers, thus enabling them to operate with a higher flexibility in the decision-making process.

The main limitation of this study is that only two cycles of the modified Delphi process were conducted. Following the second cycle, four out of eight items which did not achieve a consensus of 80%, were recommended by over 70% of the respondents for incorporation in the resilience management guidelines; amongst them, one item "apply standards in order to ensure business continuity" was endorsed by 78% of the respondents. As the cut-off point was defined as 80% consensus among the content experts, this concept is not included in the items that are recommended to be included in the resilience guidelines. It is possible that this item, as well as some of the other concepts, may have achieved a higher level of consensus if another cycle of voting was conducted. Nevertheless, it should be mentioned that former studies have found that the most notable changes are reached between the first and second iteration (Winkler, et al., 2015).

Conclusions

The results presented in this paper form important contributions to the field of resilience by identifying and consolidating a wide variety of concepts, approaches and practices for resilience

management; and by evaluating their general applicability to be incorporated into guidelines for resilience management.

Based on a systematic literature review carried out for the DARWIN project, 56 concepts, approaches and practices have been identified and evaluated. The results of the modified Delphi process presented three additional concepts as well as that 51 previously identified concepts are relevant and important to practitioners and experts, and need to be taken into account when developing guidelines for resilience management. Moreover, the identified items seem to be applicable to a wide range of domains, such as crisis management, air traffic management and the health care.

The concepts, approaches and practices encompass eleven categories that were identified by experts belonging to the DARWIN team, each consisting of several items as follows: 1) collaboration [11 items]; 2) planning [8 items]; 3) procedures [8 items]; 4) training [6 items]; 5) infrastructure [5 items]; 6) communication [3 items]; 7) governance [3 items]; 8) learning lessons [2 items]; 9) situation understanding (awareness) [1 item]; 10) resources [2 items]; and, 11) evaluation [2 items].

Due to the generic and abstract nature of some of the concepts, approaches and practices that have been selected to be incorporated into resilience management guidelines we suggest that future work should involve additional concretisation of the concepts and practices as input to the further development of resilience management guidelines. Building on these concepts, practices and approaches, the DARWIN resilience management guidelines are now being developed for a

general type of crisis and a variety of actors, so that local adaptations can be made depending on the specific contexts.

The concepts, approaches and practices can also facilitate the development and implementation of guidelines outside the scope of the specific DARWIN project (i.e. beyond the healthcare and ATM domains), as their generic and abstract characteristics make them suitable and applicable to a much wider realm. For example, the concept of "adjusting procedures during crises to the changing reality", the approach of "coordinating and synchronising systems in order to ensure efficient collaboration", or the practice of "developing proactive procedures through transparency and risk communication", can be used outside of this project. These items may prove to be useful to policy and decision-makers, as well as to end users, practitioners and other personnel from industry and academia, in prioritising their efforts aimed at achieving resilient organisations, entities or communities.

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Appendix 1: levels of agreement in modified Delphi cycles concerning the incorporation of concepts, approaches and practices into resilience management guidelines

ID no.	Category	Concept/approach/practice	Agree to incorporate cycle 1	Agree to incorporate cycle 2
1	collaboration	Link resilience management to other efforts aimed at ensuring continuity.	79.59%	90.90%
2	collaboration	Establish coordinated networks of actors to ensure close cooperation between stakeholders	98%	
3	collaboration	Attain resilience management through implementation of national collaboration.	79.59%	93.90%
4	collaboration	Attain resilience management through implementation of international collaboration.	89.60%	
5	collaboration	Ensure that the actors involved in resilience management have a clear understanding of their responsibilities	100%	
6	collaboration	Ensure that the actors involved in resilience management have a clear understanding of their responsibilities	98%	
7	collaboration	Ensure that actors that need to collaborate have a mutual understanding of each other's goals	95.90%	
8	collaboration	Address potential interdependencies between the different actors and systems.	89.60%	
9	communication	Use supplementary communication tools and methods as part of resilience management.	91.30%	
10	communication	Develop proactive procedures through transparency (open dialogue) and risk communication.	95.70%	
11	communication	Inform the public of emergency procedures so that citizens can react appropriately.	95.70%	
12	evaluation	Conduct resilience assessments prior to, during and after emergencies, disasters and crises.	100%	
13	governance	Balance resilience management between local and centralized governance.	79.60%	94.30%
14	governance	Centralize and manage assistance in order to provide services to a large as possible portion of the population.	56.25%	82.80%
15	governance	Ensure that resilience management systems are flexible enough to handle different types of situations.	100	
16	infrastructure	Consider critical infrastructure needs in resilience management.	97.9	
17	infrastructure	Incorporate advanced technologies into resilience management.	77.08%	88.20%
18	infrastructure	Develop and maintain alternative working methods in case of system failures.	97.9	
19	infrastructure	Develop and maintain alternative technological back-up systems in case of system failures.	91.3	
20	infrastructure	Apply standards to ensure secure and reliable information systems.	93.20%	
21	collaboration	Consider the impact of interdependencies and interaction between actors on resilience management.	100%	
22	resources	Plan for reinforcement of resources in resilience management.	95.70%	
23	procedures	Consider compliance with rules and regulations in resilience management.	93.20%	
24	procedures	Develop procedures that are easily adaptable to both expected and unexpected events (all-hazard approach).	95.70%	
25	training	Define training and exercises in a manner that enables personnel to improvise during the handling of situations when required.	93.90%	
26	procedures	Evaluate and revise procedures and checklists continuously.	93.30%	

27	procedures	Design procedures that address various sizes and complexities of events.	90.90%	
28	procedures	Adjust procedures during crises to the changing reality.	95.60%	
29	procedures	Consider flexibility in resilience management beyond adherence to procedures.	93.90%	
30	procedures	Develop procedures and guidelines that are clear and non-judgmental.	85.10%	
31	planning	Plan resilience management based on routine practices.	79.17%	91.70%
32	planning	Maintain national operational contingency plans that describe the responsibilities of the involved actors.	89.40%	
33	procedures	Apply standards in order to ensure business continuity.	75.00%	78.10%
34	procedures	Apply standards in order to ensure business recovery.	68.75%	72.70%
35	planning	Define common recovery points in resilience management.	77.08%	73.50%
36	planning	Define time requirements in resilience management.	75.00%	69.40%
37	procedures	Develop checklists that define how work should be performed during a degraded mode of operation.	93.50%	
38	training	Design scenario-based exercises to prepare for worst-case scenarios.	93.20%	
39	training	Train for resilience management routinely.	95.70%	
40	training	Develop education programs that focus on resilience management.	93.20%	
41	learning lessons	Use joint debriefing sessions to facilitate a shared understanding, reflection and discussion.	93.80%	
42	learning lessons	Build resilience by applying organizational learning techniques (e.g. log-books, debriefings, after-action reviews).	91.10%	
43	training	Address different magnitudes of emergencies, disasters and crises in training programs.	93.60%	
44	resources	Use available manpower optimally.	91.50%	
45	resources	Maintain central (rather than local) control of resources.	44.90%	53.80%
46	resources	Establish a hierarchical structure of on-site resource management.	69.39%	63.90%
47	resources	Use a roster-based system for resource management during emergencies, disasters and crises.	57.14%	41.70%
48	planning	Consider unique characteristics of the community in resilience management.	85.40%	
49	planning	Consider people's key needs, especially vulnerable groups, to achieve resilience management.	91.70%	
50	planning	Consider trust for leaders and authorities in resilience management.	85.40%	
51	situation understanding	Develop overall situation understanding (including awareness) to ensure efficient collaboration.	93.60%	
52	collaboration	Coordinate and synchronize systems to ensure efficient collaboration.	95.70%	
53	training	Conduct joint training exercises to ensure efficient collaboration.	100%	
54	planning	Develop plans for immediate response as part of resilience management.	95.80%	
55	resources	Discourage non-essential travel to and from an affected area.	68.75%	75.00%
56	collaboration	Provide a comprehensive response to increase trust between responders and populations.	91.10%	
N1	collaboration	Establish a common terminology concerning resilience management across institutions and authorities		94.10%
N2	evaluation	Design tools and methods to monitor readiness to cope with crises		91.70%
N3	resources	Use resilience management support systems as a part of everyday practices		83.30%