

Perceptions of cascading risk and interconnected failures in emergency planning: implications for operational resilience and policy making

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Abstract

Cascading events and the disruption of interconnected critical infrastructure (CI) are a well-known challenge for emergency planning and management. Although new modelling and forecasting tools are increasing the availability of mitigation options, further work is needed to consolidate good policies and practices.

This paper presents a case study on London, United Kingdom (UK). It develops an integrative research process with local stakeholders aimed at applying the theory of cascading disasters in London's response and preparedness strategies. A mixed method approach is adopted to explore the awareness of cascading risk, the perception of possible mitigation measures, and the current levels of training amongst the stakeholders of the London Resilience Partnerships. Specific items investigate the relation of cascades with cross- border crisis management, and climate change.

The results propose new quantitative and qualitative evidence that highlights the divergence between risk awareness and its integration in policies and practices, discussing options for improving multi-agency coordination and organisational resilience. The conclusions define a list of actions that should be strategic priorities for policies and decision makers, such as the improvement of inter-modal coordination and the release of open access guidelines, proposing new open questions for scholars in the field.

1. Introduction

The complexity of networked society and the uncertainties inherent in emerging threats, such as geomagnetic storms, are challenging our approach to crisis management. It has been suggested that extreme scenarios could be more common than was previously supposed, requiring a new understanding of their drivers (Sornette 2009). However, those challenges involve the whole anthropogenic domain and cannot just be associated with specific hazards. It is known from the “normal accidents” theory that interdependent technological systems are prone to multiple and unexpected failures that can trigger cascading disruptions (Perrow 1999). Events such as the failure of telecom satellite Galaxy IV (1998) and the North America Blackout (2003), highlighted the need for improving the protection and resilience of critical infrastructures (CI), intended as those systems or assets that are vital for social functions (Setola et al. 2016). The multiple domains of CI were recognised both in terms of hardware and services, including their interdependencies with all ordinary activities of life (Little 2002; Rinaldi et al. 2001). It became clearer that CI failures could generate widespread breakdowns beyond the conventional organizational and hierarchical borders (Boin and McConnell 2007; Egan 2007; Helbing et al. 2006). However, the cascading dynamics associated with those patterns remained fragmented in literature and practices (May 2007), and scholars often concentrated on models that were limited by the absence of testing in real-life scenarios (Peters et al. 2008).

The state of the art evolved after some high -impact events in the early 2010s, such as the eruption of the Eyjafjallajökull volcano, and the challenges associated with climate change scenarios. It was more visible that the increased complexity of global networks challenged governance, jurisdictions, organisational and societal resilience (Alexander 2013; Ansell et al. 2010; Galaz et al. 2011; Labaka et al. 2016; Parker 2015; Setola et al. 2016). Thus, it was suggested that a paradigm shift in safety and risk analysis strategies was urgently needed to improve the adaptive capacity to complex challenges (Helbing 2013; 2015; Linkov et al. 2014). Further steps in understanding cascading and interconnected dynamics has been supported by the EU 7th Framework Programme and Horizon 2020, evolving forecasting tools and decision support systems (Galbusera et al. 2016; Jonkeren et al. 2015; Setola et al., 2016). Other complementary approaches evolved from CI modelling, including cross-cutting contingency planning and scenario building. It was considered that cascading disasters could be associated with complex and evolving secondary emergencies, which tended to become the centre of the crisis (Pescaroli and Alexander 2015). That process is multi-dimensional. It includes: A) the losses of vital services due to the shifting states of operations in the CI, from routinely to stressed (Nieuwenhuijs et al. 2008); B) The impact of external triggers on hazardous facilities (Argenti et al. 2016; Krausmann and Baranzini 2012); C) The cross-scale challenges involving socio-ecological systems (Galaz et al. 2011). It has been suggested that these cascades require a shift in scenario building and training, focusing on the escalation of secondary events to increase the flexibility in situations of operational uncertainty (Pescaroli and Alexander 2016). First, it has been recognised that CI disruptions can orient international relief by causing a shortfall of goods and expertise associated with the loss of services, NATECH emergencies, and damages to cultural heritage (Pescaroli and Kelman 2017). Secondly, it had been shown that risk maps have to be integrated with critical infrastructure rankings, promoting the development of cross-scale assessments of socio-ecological vulnerabilities (Nones and Pescaroli 2016). Thirdly, vulnerability scenarios could be used in new tools to enhance the capacity of local communities to be resilient to complex events such as blackouts (Münzberg et al. 2017). In conclusion, it is essential to introduce best practices in emergency planning that could frame together the different components of risk,

referring to the possibility of unexpected paths (Alexander 2016). It has been shown that the vulnerabilities in the technological component of CI could be coincident between natural and human-made risks, being also common to other triggers that are unknown, or at least highly uncertain, with the potential of compromising or challenging emergency management (Pescaroli et al. 2018).

A gap that has not been investigated is how cascades, interdependencies and escalations are perceived by CI stakeholders and emergency managers and which could be the implications for preparedness. Specific procedures, such as wider impact trees, have been adopted by some governmental bodies in charge of standards for organisational resilience (Macfarlane 2015), but are these lessons really incorporated in practices? The literature suggests there could be still a lack of understanding of CI dependencies amongst emergency planners and responders, increasing the impact of emergencies (Luijckx and Klaver 2009; 2013). Indeed, the complexity of cascading effects can challenge the existing knowledge of emergency personnel, as well as their familiarity with the possible evolutions of the events, increasing the disturbances and the uncertainties in decisions (Amon et al. 2016).

This paper aims to investigate this area of risk perception (Slovic and Weber 2002), supporting with new quantitative and qualitative data the development of a consistent framework for cascading risk in policy making. We apply an integrative research process with the local institutions to link knowledge into action, considering how to improve decision making under high uncertainties (Cornell et al. 2013; Wardekker et al. 2008). The goal is to verify if cascading risk and interconnected failures are sufficiently addressed in the multi-agency planning assumptions of Greater London. This case study is relevant for the state of art because London's infrastructure and society are highly integrated in the global networks, concentrating some of the financial and transportation hubs in the region. In the next sections the applied nature of the research is explained, including the synergies with the authorities, the research precursors, and the key questions investigated. In the second instance, the methodology adopted for the assessment is described, and the results are illustrated highlighting the implications for the current multi-agency response capacity. In conclusion, possible mitigation actions and guidelines for policy makers are suggested.

2. Integrative research process

This work is a result of a collaboration between the Research Group on Cascading Disasters at the UCL Institute for Risk and Disaster Reduction (CASCADES@IRDR), and London Resilience (LR). LR acts on behalf of the Mayor of London, Greater London Authority, Local Authorities and London Fire Brigade. It aims to coordinate institutions and communities to “prevent, handle, recover and learn from disruption, and adapt to change” (www.londonprepared.gov.uk). The London Resilience Partnership (LRP) includes more than 170 organisations involved in emergency response and preparedness in London, United Kingdom (UK). In 2012, LR developed ANYTOWN, a generic and replicable model used to “raise awareness of the consequences of infrastructure disruption with all emergency response organisations in London” (Hogan 2013). It is structured to be applied easily in most cities using workshops that produce evidence on the typical impacts of disruptions regardless of their initial trigger. The effects of hypothetical failures are reported in an onion-skin diagram including both short- and longer-term effects, communicating the message in a way accessible for non-academic audience. The complementarities of the work of

CASCADES@IRDR suggested promoting a data collection at the ANYTOWN workshop in March 2017. The event was organised by LR, in collaboration with the London Climate Change Partnership (LCCP), the UCL Institute for Risk and Disaster Reduction, and with support from Transport for London (TfL). It was held at the London City Hall to “consider the broader consequences resulting from a disruption to transport networks”, and it was closed -doors. The invitations were sent to the members of the Partnership, such as emergency response organisations, public utilities, businesses, and academia. ANYTOWN was organised in two half day sessions, in the morning and the afternoon, with a cap on the number of participants to assure an active discussion. In each session, an introduction to the workshop explained the ANYTOWN model, the concept of cascading effects and disasters as reported by Pescaroli and Alexander (2015), and London’s strategy for adapting to climate change. A short overview of the scenario was followed by roundtables. The trigger hazard was a hypothetical heat wave, whose features were derived from the existing literature (Birkmann et al. 2014). However, facilitators of LR were present at each table and encouraged the participants to focus on the possible interdependencies, cascading effects, and escalations. A complementary methodology was used to assess the multi-agency response and preparedness capacity and it will be explained in the next section.

3. Methodology

The methodology was developed with a constant dialogue between CASCADES@IRDR, LR, and the LCCP that allow maintaining a reliable interface between science and policies (Cornell et al. 2013; Wardekker et al. 2008). First, it had to be replicable in future workshops, being complementary to the output of the discussion groups. Secondly, it had to provide quantitative evidence for policy-makers, integrating possible feedbacks of the participants. In conclusion, the data collection had to target a mixed audience with limited time availability. It was chosen to relay on questionnaire as common practice in the assessment of risk perceptions, civil protection programs, and emergency management at large (Abrahamsson et al. 2010; Alexander 2002; 2005; 2015; 2016; Lindell et al. 2007; Perry and Lindell 2003; Quarantelli 1997; Slovic and Weber 2002). The questions followed the standard approach of quantitative research (Bryman 2012; Van Evera 1997), and were analysed with SPSS V.24. However, the participatory nature of the workshop and the complexity of the topic suggested integrating a mixed method approach to record the bottom up perspectives of the LR Partnership (Axinn and Pearce 2006; Palinkas et al. 2011). Each section of the survey included open questions for the respondents: they asked for suggestions about possible mitigation measures, training strategies, general comments on the workshop, and on who should assure the consistency of information. Those answers were investigated with a qualitative content analysis, using together inductive and deductive considerations (Berg 2004). The categories were cross- checked with LR to verify their consistency with the operational and legislative terminology in use. The main hypothesis was that if the current crisis management approach to cascading risk was inadequate, then it was expected that the answers could highlight:

- 1) A strong awareness of cascading risk and interconnected failures, not adequately supported by policies and planning strategies.
- 2) High values attributed to most mitigation measures, and average integration of longer term climate change in planning.

3) Lack of consistent training, with high values attributed to all the possible tools suggested. The next section describes the design of the questionnaire before proceeding to the analysis of data.

3.1 Questionnaire design

Questions and answers were discussed with LR, and the LCCP, as suggested in the integrative research process. The items were formulated together to limit possible sectorial biases and ambiguities. The output was tested with a pilot involving the LR team that verified the consistency of the terminology for the target audience of the workshop. Similarly, the visual layout of the questionnaires was checked with pre-printing to avoid a lack of clarity that could limit the response rate (Boynton and Greenhalgh 2004). It was agreed a five page questionnaire, including the introduction, that required approximately 5-10 minutes to be completed on a self-administered basis. The first page reported a standard disclaimer that specified the goal of the research, the referents, and guaranteed the anonymity and privacy of the respondents. The questionnaires were structured in four sections:

- ✓ *Section 1 - Stakeholders' perception of cascading events and interdependencies.* This section explored the awareness of cascading risk, its relationship with other drivers such as climate change, and the actual prioritisation in policies and practices.
- ✓ *Section 2 - Stakeholders' opinion about mitigation strategies.* This section investigated the perceived utility of existing mitigation measures and the potential of other tools suggested in the literature. At the end of this section the participants were asked to write down suggestions about possible mitigation measures that should be prioritised and were not included in the list.
- ✓ *Section 3 - Stakeholders' opinion about training related to cascading events and interdependencies.* This section assessed the existing levels of training, and which training measures could be more useful. At the end of this section the participants were asked to write down possible training other than the one listed.
- ✓ *Section 4 - Stakeholders' experience and affiliation.* This section asked general questions about experience, affiliation, gender and perceived utility of the workshop. Those values were needed to correlate the results, promoting more focused policies. There was space left for general comments.

The existence of validated and published surveys was considered for the formulation of each item (Boynton et al. 2004). In the preliminary phase of the design, the possible literature of reference was listed in a descriptive table as suggested by Brugess (2011), then it was discussed with the stakeholders. However, this process was limited by the scarcity of studies linking cascading disasters, emergency preparedness, and training: more than replying to specific questions and results, it was possible to derive possible options generically identified in the literature that had to be tested. The reference for "Section 1" was mostly the references reported in the introduction and methodology of this paper, while in "Section 4" were considered standard drivers of risk perceptions that were also needed by LR as generic data on the workshop. "Section 2" and "Section 3" integrated cross-cutting considerations on mitigation and training. The researches on sectorial failures and cascades, both generic and case-specific specific, suggested testing different mitigation options. In particular, it was possible mitigation role of scenario building and contingency planning (Alexander 2016;

Pescaroli and Alexander 2016), integration of hazard risk with rankings of CI (Nones and Pescaroli 2016), datasets to improve fast deployment of emergency response (Gianluca Pescaroli and Kelman 2017), and decision support systems (Setola et al. 2016). The evidence of the 2010 ash cloud highlighted issues in the reliability of thresholds in probabilistic data, communication and information sharing, and intramodality (Alexander 2013; Scaini et al. 2015; Ulfarsson and Unger 2011). Localized and improved energy supply were also suggested as possible priorities for policy makers, together with the need of considering international mitigation strategies and climate change drivers in planning and activities (Ansell et al. 2010; CAA 2014; Galaz et al. 2011; Helbing, 2015; OECD, 2011; Petermann et al. 2011). The possible training options referred to the ones available by the UK Cabinet Office's Emergency Planning College (Macfarlane 2015), and more in general feasible to be implanted by LR. Table 1 reports the final questions used for the questionnaires, including their section and the number of reference. The multiple items are highlighted in grey, while the open items that allowed discretionary answers in yellow. A standard Likert scale, from 1 (not at all) to 5 (extremely) was used for most items, and reported both qualitatively and quantitatively according to conventions in the assessment of civil protection and emergency management s (Alexander 2015, Bryman 2012, Lindell et al. 2007). The synthesis by Brown (Brown, 2010) was used for maintaining the correspondence between the numeric and qualitative values. Moreover, the awareness of specific tools and experience in training (Q18 a, b and Q22) was assessed using polar questions (yes/no). Three answers (Q13, Q21, and Q23) required the development of new categories:

- ✓ Q13 tested which organisations should be in charge of information in line with the protocols of LR, with a multiple answer that wanted to test collective versus individual responsibilities. The categories were derived by the work of Lindell et. al. (2007), Perry and Lindell (2003), but included a UK perspective that referred to the grey area of stranded passengers (CAA 2014). The possibility of an open answer was included, as has been reported in Table 1.
- ✓ Q21 asked for the respondents' experience and seniority level, but a clear and appropriate scale was not found in the literature. It was derived approaching a standard definition used by human resources online (University of Virginia 2016), which were cross-checked with the feedbacks of the LR team and LCCP (Table 1).
- ✓ Q23 asked to define the respondents' affiliations, which had to be focused on the members London Resilience Partnership. To mediate possible cultural divides, it was decided to integrate the categories used by Lindell, Prater, and Perry (2007), with the one described by the UK legislation for emergency management (UK Cabinet 2013).

In conclusion, it must be noted that questionnaires were distributed in each discussion table at the beginning of the event. This was supported by a short explanation by LR and CASCADES@IRDR, where it was highlighted the value, the simplicity, and the limited time commitment needed for the contribution. It was emphasised that the essential findings will be included in the final report of the event (Burgess 2001), and that the research was finalised to improve the coordination of the LRP. The next sections of this research will explore the quantitative and qualitative results of the analysis. The possible limitations of the research will be included in the discussion section to derive open points for future researches to be included in the conclusions.

Table 1 - Sections and questions of the survey		
Section	N.	Question
<i>Section 1 Perceptions of cascading events and interdependencies</i>	Q1	How relevant are cascading events to emergency management?
	Q2	Do you think loss of essential services can cause risks to life and personal safety or security?
	Q3	To what extent are service disruptions catered for in UK emergency planning?
		To what extent do you think cascading events and interconnected failures are:
	Q4a	Prioritised in existing policies? (e.g. multi-agency response frameworks)
	Q4b	Prioritised in practice? (e.g. stakeholder interoperability)
	Q4c	Integrated in agreements for cross-border crisis management? (e.g. activation and deployment of the EU civil protection machinery)
	Q5	Would a common definition of 'tipping points' and definitions of acceptable risk and uncertainty be helpful in coordinating emergency response?
Q6	Do you think cascading events could become more common as a result of climate change?	
<i>Section 2 Opinion about mitigation strategies</i>		How helpful do you think the following tools could be in understanding cascading events?
	Q7a	Scenario building
	Q7b	Contingency planning
	Q8	Do you think information on the resources available to combat service disruptions could be used to improve procurement strategies and the deployment of aid and relief? (e.g. ready-to-eat meals supplied after blackouts)
	Q9	Do you think it could be useful to integrate hazard risk with rankings of the criticality of infrastructure?
	Q10	Do you think improving coordination among different transport modes should be a priority in order to mitigate large-scale disruption?
	Q11	Do you think more localised energy sources could improve the resilience of critical infrastructure?
	Q12	How useful are interactive tools and real-time decision support systems to understand the effects of cascading disruptions?
	Q13	In the case of service disruptions, who do you think should assure the consistency of information given to the public? (One option has open answer)
	Q14	Do you think cascading events and associated service disruptions require the development of international mitigation strategies?
	Q15	Are you considering longer-term climate change in your planning and activities?
	Q16	Is there anything else that has not been mentioned that should be prioritised? (Open answer)
	<i>Section 3 Opinion about training</i>	Q17
		Are you aware of methodologies such as:
Q18a		Wider impact analysis and impact trees
Q18b		Other forward-looking tools
		How useful do you think the following training on cascading events and their interdependencies might be?
19a		An intensive course for public utility services
19b		Roundtable events or table top exercises
19c		Freely available guidelines
19d		Webinars and on-line lessons
19e		National and trans-national exercises
Q20	Is there anything else that has not been mentioned which should be prioritized? (Open answer)	
<i>Section 4 Experience and affiliation</i>	Q21	How would you define your level of experience and proficiency in this sector?
	Q22	Have you ever participated in training sessions or workshops on cascading or interdependent events?
	Q23	What is your affiliation?
	Q24	Are you: <input type="checkbox"/> Male <input type="checkbox"/> Female <input type="checkbox"/> Other <input type="checkbox"/> Prefer not to say
	Q25	Was this workshop useful for you?
	Q26	Do you have any other comments? (Open answer)

Table 1- Items used in the questionnaires, with highlighted multiple questions (grey) and discretionary open answer (yellow).

4. Quantitative analysis

Overall, ANYTOWN was very well attended by local stakeholders. It had 74 participants, 69 without the event coordinators, filling the room available at the London City Hall in both sessions. The workshop had good gender balance, with slightly more female representatives (33 males and 40 females). The full institutional support of LR, LCCP, and TfL, allowed the collection of 57 questionnaires which were equivalent to a response rate of approximately 82% of participants. The forms were considered valid if at least 70% of the mandatory answers were completed, in line with the standard quantitative methodology described earlier, reducing the analysis to 54 questionnaires. This small drop is likely to be associated with the fact that many stakeholders were available for emergency calls or had pre-scheduled meetings, inducing some of them to leave the room before the end of the event. The next sections describe the distribution of the frequencies for each part of the questionnaire, analysing separately their correlations.

4.1 Perceptions of cascading events and interdependencies

The respondents unanimously agreed that cascading events are extremely relevant to emergency management ($M=4.7$, $SD= \pm 0.5$). Despite the common perception that loss of essential services could be very risky to life and personal safety or security ($M=4.57$, $SD= \pm 0.49$), the answers highlighted that disruptions were just somewhat catered for in UK emergency management ($M= 3.31$, $SD=\pm 0.67$). In particular, cascading events and interconnected failures were only marginally prioritized both in existing policies ($M =2.88$ $SD=\pm 0.58$), and practices ($M=2.81$, $SD=\pm 0.68$). Similarly, the respondents perceived a lack of integration in the existing agreements for cross-border crisis management, such as the deployment of the EU civil protection machinery ($M=2.57$, $SD=\pm 0.95$). However, the value of the standard deviation suggests some more fragmentation in the average values, with a consistent per cent of missing responses (13%). The lack of shared agreement on this item could be easily explained by the fact that the operational role of many participants did not necessarily require the knowledge of cross-border drivers. Finally, the questionnaire pointed out that a common definition of 'tipping points' and acceptable risk is needed ($M=3.76$, $SD=\pm 0.77$), while it was agreed that cascading events could become more common because of climate change ($M=4$, $SD=\pm 0.76$). In both cases, slightly more than a half of the answers were concentrated in the highest values of the Likert Scale. Figure 1 provides a graphical overview of the perceptions of cascading risk recorded in this section. It points out the contrast between the relevance and possible impacts, the need for training, the potential of its association with climate change, compared to the integration in policies and practices.

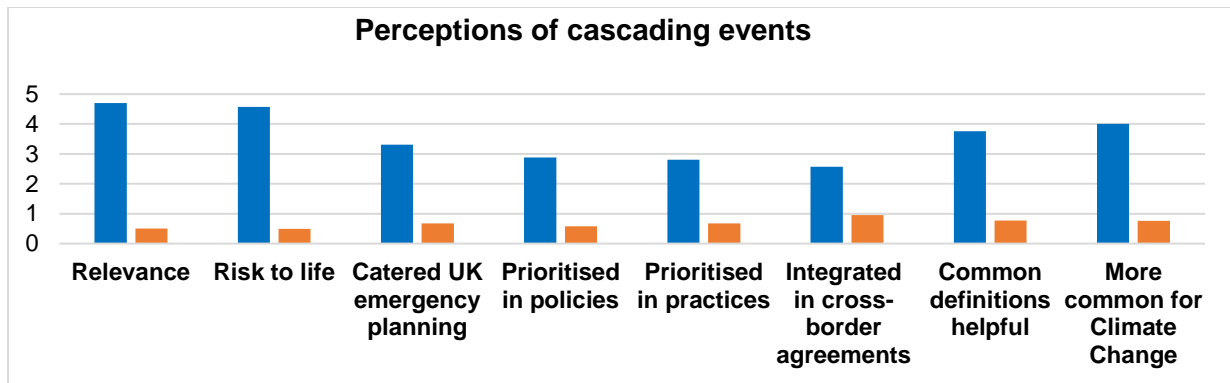


Figure 1 – Perceptions of cascading events and interdependencies (Q1-Q6). The mean is represented in blue and the SD in orange. The values are based on a Likert scale from 1-5, with no answer being 0 and 5 being the most positive value.

4.2 Perceptions of mitigation strategies

Scenario building ($M = 4.09$, $SD = \pm 0.49$), and contingency planning ($M = 4.4$, $SD = \pm 0.57$), were unanimously recognized as essential tools to understand cascading events. The other mitigation measures must be investigated more carefully, as all of them were perceived useful but with different levels of fragmentation. There is agreement that better information about the resources needed for contain escalations could improve procurement and response ($M = 3.77$, $SD = \pm 0.73$). In this case, the valid answers are concentrated in the top tiers but balanced by one third of average answers. In line with the expectations, a very high priority was attributed to the integration hazard risk maps with ranking of CI ($M = 4.02$, $SD = \pm 0.75$) and to improvement of intermodal inter-modal coordination ($M = 4.07$, $SD = \pm 0.72$). In the first case, approximately 77% of valid answers were cumulated in the top values (4 and 5), rising to 85% for intramodality. Interactive tools and decision support systems were perceived as very useful ($M = 4.02$, $SD = \pm 0.82$), but with a fragmentation that can be associated with some of the comments. Similar patterns, but with much more variability, are attributed to energy sources ($M = 3.75$, $SD = \pm 0.95$), which in the frequency table are literally split between some improvement (42% of valid answers), high improvement (approx. 23%), great improvement (approx. 29%). When interrogated about who should assure the consistency of information to the public, the respondents used multiple answers. The government appeared in 82% of cases (39% standard percent), followed by utilities in 52.0% of cases (28.4% standard percent) and business 26% of cases (12.4% standard percent). The category 'other' was used in 22% of cases, while lower values attributed to NGOs and Academia. Surprisingly, individual responsibility or no need for coordination was indicated in just one answer.

In conclusion, the respondents are only moderately trying to integrate longer term climate change in planning ($M = 3.56$, $SD = \pm 0.86$), with in some cases additional comments in the open questions. The perceived need for developing international mitigation strategies for cascading events and service disruptions had the lowest values in the section, and it was distinguished also by highest standard deviation ($M = 3.07$, $SD = \pm 1.02$). The values showed the existence of a wide disagreement amongst the respondents that are nearly equally divided between the high-low peaks. Figure 2 reports the visual output of this last question.

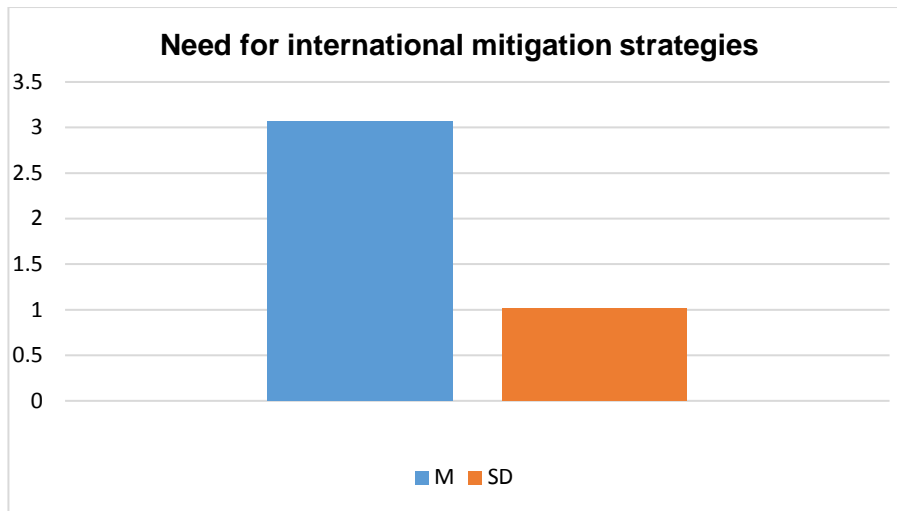


Figure 2 – Overview of two key aspects of mitigation strategies. The mean is represented in blue and the SD in orange. The values are based on a Likert scale from 1-5, with no answer being 0 and 5 being the most positive value.

4.3 Perceptions of training

The perceived levels of training among the respondents were just somewhat sufficient, with high fragmentation in the answers that suggests better analysis of target groups ($M=2.9$, $SD=\pm 1.01$). The frequency table points out a slight concentration in the lower tiers, with 10% of missing answers that in some cases were explained in the comments. However, it is positive to note that most participants were aware of wider impact analysis and impact trees (73.6% valid percent), and other forward-looking tools (60.8%). The most useful options for improving future training were freely available guidelines ($M=3.92$, $SD=\pm 0.8$) and tabletop exercises ($M=3.87$, $SD=\pm 0.68$). They were followed by intensive courses for public utility services ($M=3.77$, $SD=\pm 0.85$) and national and transnational exercises ($M=3.70$, $SD=\pm 0.79$). In the first case, approximately 73% of valid answers were concentrated between very and extremely high values, while the concentration was anyway unequivocal even in the case of the exercises (approx. 62%). Instead, webinars and online lessons were not perceived so useful and were distinguished by high variation in the answers, discouraging *de facto* any investment in that option without any understanding of possible target groups ($M= 3.36$, $SD=\pm 1.02$). The general high values of the possible training tools suggested clearly the need to undertake actions for improving the situation (Figure 3).

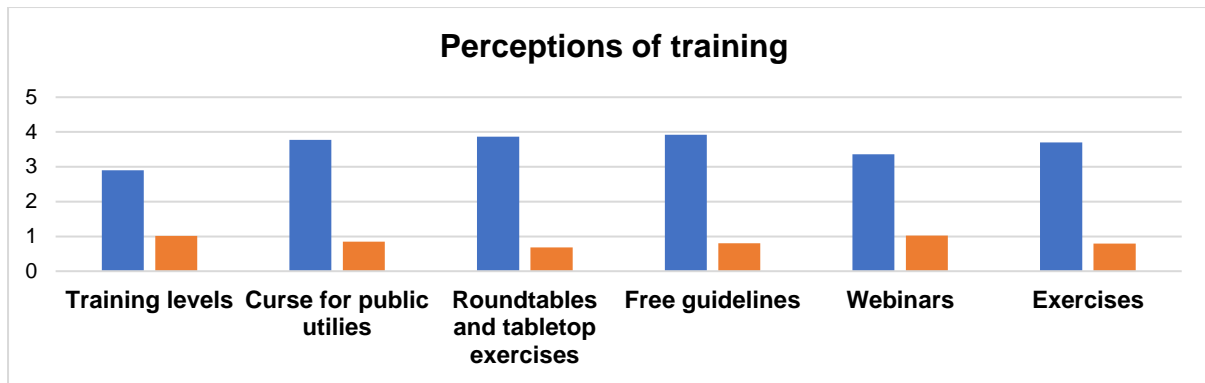


Figure 3 – Perceptions of training(Q17-Q19e). The mean is represented in blue and the SD in orange. The values are based on a Likert scale from 1-5, with no answer being 0 and 5 being the most positive value.

4.4 Experience, affiliation, and gender

The respondents were very well distributed amongst all the levels of experience (Figure 4). There was a perfect balance between novices and stakeholders advanced experience (25% each), a consistent intermediate level between 3 and 5 years (30.8%), and a valid representation of experts with more than ten years in the sector (15.4%). Just a couple of people had basic awareness of the topic, in line with what was expected by the organisers. Most of them (56.6%) already participated in training workshops on cascading or interdependencies. Most participants were Category 1 responders (40.7%), intended as core emergency services and local authorities, and Category 2 responders (11.1%), intended as private sectors bodies such as utilities. These were followed by academia (16.7%), business not included in Category 2. (14.8%), other categories (approx. 11.1%), and with lower participation of NGOs and charities (3.7%). The gender balance of the registered participants of the workshop was reflected in the responses, that had 52.8% female respondents and 47.2% of males. Finally, the ANYTOWN workshop was considered useful by most of participants (M=3.77, SD=0.77).

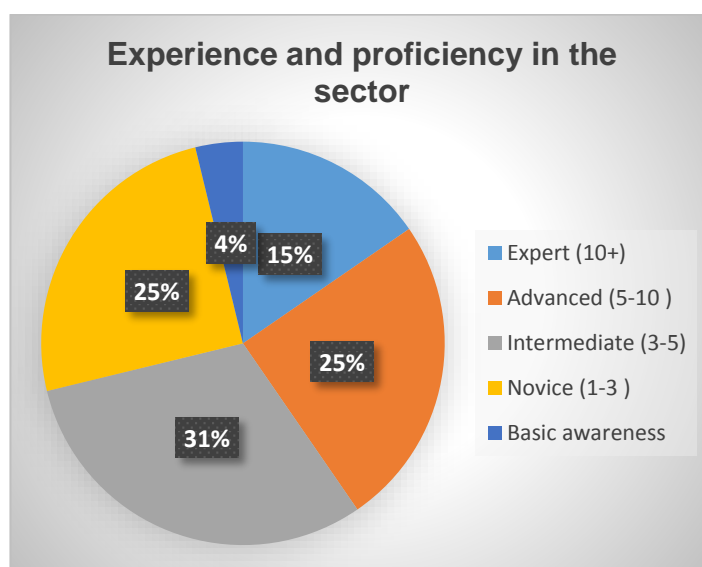


Figure 4- Experience levels among the respondents

4.5 Correlations between answers

The particular nature of the dataset suggested testing the existence of possible correlations among the answers, in order to have a better overview of which items could be associated together (Cohen, 1988; Evans, 1996). However, it must be considered that the final goal of this work is supporting policy making, and not deriving any psychological models for which in-depth methodologies, such as regressions, may be needed. Our analysis used Pearson's coefficient to verify the possible consistency between the continuous variables reported in section 1, section 2, and section 3, according to the research goals. The responses were considered significant at the 0.01 level (two tailed), and the effect size was in line with the values used by Evans (1996). Secondly, cross-tabs were used to assess the correspondence between other continuous variables and the ordinal ones such as experience and affiliation. They were preferred to other tests, such as multinomial logistics or Cramer's v , for two key reasons: 1) To maintain a higher accessibility of the content for end-users; 2) To assess the existence of sub groups, that could determine differences in the development of training strategies and targeted work.

4.5.1 Correlations within sections

A primary analysis explored if there were any of correlations within the answers of section 1 (Perception of cascading events), 2 (Opinion about mitigation strategies), and 3 (Opinion about training). This was done to verify the existence of possible drivers that could be useful for policy makers, and a synthesis of the output is reported in Table 2. In section 1, the results show the existence of a moderate positive relationship between the prioritization of cascading events and interconnected failures in existing policies and practices ($r=0.444$, $n=51$, $p=.001$). Similarly, a moderate positive relationship was found between the prioritization in policies and the integration in agreements for cross-border management ($r=0.508$, $n=46$, $p=.000$). It can be noted that those results suggest that there was a tendency to have a common view between high prioritization in policies and practices, while the responders that perceived some higher values in policies, believed also that there was more integration at the international level. In section 2, higher values perceived for the integration of hazard risk maps and rankings of CI were weakly associated with higher values attributed to the use of localized energy sources for improving resilience ($r=0.366$, $n=50$, $p=.009$). Instead, a moderate correlation was found between the usefulness of improving intermodal transportation and the localized energy sources ($r=0.478$, $n=52$, $p=.000$). These correlations, together with the values of those registered in the previous sections, may suggest that higher value in energy were perceived as part of the interconnected challenges more than a self-standing mitigation. In conclusion, the analysis of section 3 revealed some unexpected trends. A moderate correlation was found between the training received and the perceived utility of roundtable and table top exercises ($r=0.396$, $n=47$, $p=.006$). Intensive courses for public utility services were weakly correlated with training on national and transnational exercises ($r=0.380$, $n=53$, $p=.005$), while those had a similar relation with webinars ($r=0.382$, $n=53$, $p=.005$), and moderate correlations with table top exercises ($r=0.491$, $n=53$, $p=.000$). Instead, a strong

correlation was found between how useful were perceived freely available guidelines and webinars ($r=0.607$, $n=53$, $p=.000$).

Questions and answers correlated within each section	Value (r)	Strength
Q4a (policies) and Q4b (practices)	0.444	Moderate
Q4a(policies) and Q4c (cross-border management)	0.508	Moderate
Q9 (hazard risk and CI ranking) with Q11 (localized energy)	0.366	Weak
Q10 (intermodal transportation) and Q11 (localized energy)	0.478	Moderate
Q17 (training received) and Q19b (roundtables and exercises)	0.396	Moderate
Q19a (course for public utility) and Q19e (transnational exercises)	0.380	Weak
Q19e (transnational exercises) and Q19b (exercise)	0.491	Moderate
Q19e (transnational exercises) and Q19d (webinars)	0.382	Weak
Q19c (guidelines) and Q19d (webinars)	0.607	Strong

Table 2- Correlations within each section of the questionnaire. QN refers to number the full questions reported in Table 1.

4.5.2 Correlations across sections

A different analysis was run to understand the correlation across the sections (1 to 3), with care to understand if training levels were associated to any variations in the opinions about mitigation strategies and risk perceptions. A synthesis table is reported in Table 3, where there can be noted some weak and moderate correlation. The first evidence that emerges is that despite it being expected that the existing training to orient most of the results, there was nothing diffused. Indeed, the general levels of received training were moderately correlated just with the perceived integration of cascading in agreements for cross-border management ($r=0.496$, $n=45$, $p=0.001$). This last item was also moderately correlated with roundtables and table top exercises ($r=0.481$, $n=46$, $p=0.001$), and with the training level on national and transnational exercises ($r=0.422$, $n=46$, $p=0.003$). Surprisingly, the availability of guidelines was weakly correlated with tipping points and acceptable risk ($r=0.372$, $n=53$, $p=0.006$), giving the idea that in case of uncertainties the availability of open source material can make the difference. Instead, there are limited relations between the values attributed to mitigation measures and policies. Contingency planning was weakly associated with the perception that the loss of essential services can cause risk to life and personal safety ($r=0.385$, $n=54$, $p=0.004$). The values attributed to the perception that service disruption require the development of international mitigation strategies were weakly correlated to the perceived prioritisation of cascading risk in policies ($r=0.385$, $n=51$, $p=0.005$). Finally, as may have been expected, the responders that perceived more cascading events more common as a result of climate change had the tendency to include long term climate change in planning ($r=0.381$, $n=50$, $p=0.006$).

Questions and answers correlated across sections	Value (r)	Strength
Q17 (training received) and Q4c (cross-border management)	0.496	Moderate
Q19(roundtables and tabletop exercises) and Q4c (cross-border management)	0.481	Moderate
Q19e(transnational exercises) and Q4c (cross-border management)	0.422	Moderate
Q19c(guidelines) and Q5 (tipping points)	0.372	Weak
Q7b(contingency planning) and Q2 (service disruption and life losses)	0.385	Weak
Q14(international mitigation strategies) and Q4a (policies)	0.385	Weak

Q15(long term climate change in planning) and Q6(cascading more common as result of climate change)	0.381	Weak
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Table 3- Correlations across the sections of the questionnaire. QN refers to number the full questions reported in Table 1.

4.5.3 Are experience and affiliation orienting the perception of training and mitigation measures?

Cross- tabs were used to verify if the values attributed to the training options were associated with any level of experience and proficiency in the sector. In other words, chi-square analysis was used to test any correlation between the levels of experience, risk perceptions, mitigation measures, and training options. This was done to understand the existence of possible target groups, but the test showed low levels of confidence due to a general fragmentation of answers. A similar analysis was applied to test the existence of correlations between the affiliation and the training options. The results showed different levels of statistical confidence, but it was possible some target groups for two forms of training:

- 1) *Courses for utility services* presented fragmented answers ($\chi^2= 0.087$), but they were considered tendentially very useful mostly by Cat 1 responders, Cat 2 responders, and academia.
- 2) *Roundtables and table top exercises* had less fragmented answers ($\chi^2=0.058$). It is unequivocal that nearly the total of Category 1 responders perceived this training very useful, and this is true also for Academia, NGOs and others. Category 2 responders were instead quite undecided, and business had the tendency to perceive this training less useful.

However, it must be noted that this result may have been affected by the limited number of representatives of categories such as Nongovernmental, not-for-profit, and religious organization. We recommend further analysis to test each training. Similarly, we decided not to run correlations with Q18a,b (wider impact analysis and other forward looking) because the vast majority of the participants knew the tools, and the limitations in the dataset could have influenced the result. In conclusion, Gender did not influence the general perceptions of risk, but we decided not to test this possible influence on mitigation and training. This element could have been interesting in a psychological study, while it could not drive suggestions for decisionmakers for whom now these are mandatory non-discriminatory policies.

5. Qualitative content analysis: Mitigation, training, and other comments

The qualitative content analysis (Berg, 2001) offers a complementary overview of stakeholder's perceptions, integrating a bottom up perspective. The comments are categorized following to their sections in the questionnaire (Mitigation, Training, Other), to provide a better framework of the answers.

5.1 Suggested mitigation strategies

Approximately a third of the participants (17/54) suggested some mitigation options that were not already included in the questionnaire. Table 4 reports the category of the training suggested, together with the identity of each questionnaire, the affiliation, the participation to previous training (Q22), the experience in the sector, and the transcription of each comment. All the levels of experience and affiliation were represented, although not in the same proportions as the quantitative data. In particular, it must be noted that most of the suggestions (13/17) were made by personnel that already participated in training sessions (Q22), and may have already had a clear idea of what was missing in the current practices and policies. This makes the qualitative analysis of particular relevance, in line with the needs of LR and LCCP, highlighting some common problems reported in the literature (Abrahamsson, Hassel, and Tehler, 2010; Alexander, 2002, 2005, 2016; Alexander, 2015; Lindell, Prater, and Perry, 2007; Perry and Lindell, 2003; Quarantelli, 1997). The coding process, cross-checked with LR to maintain coherence with their operational language, suggests the following areas of improvement:

- ✓ Community resilience. Comments referred to the need for better mitigation strategies aimed to improve local resilience, integrating top down and bottom up approaches, and the specificities of local contexts. The respondents had mixed affiliation and the experience, while 3/5 of them had already participated in training sessions.
- ✓ Coordination. Comments reported one of these coordinations is still a challenge that needs to be solved at all levels. The answers referred to inter-agency protocols, to the central government and the local authorities, but also between protocols of climate change adaptation and emergency preparedness. In this case, 3/4 of the comments were made by Category 1 responders, and all of them participated in training sessions.
- ✓ Knowledge of risk, interdependencies and vulnerabilities. Comments referred to the need to assess better the dynamics associated with the topic of the workshop, and the vulnerability of the system at large. In this case, the answers were just affiliated to academia and Category 2 responders, that for the majority participated in training and had a polarised experience between novice and advanced.
- ✓ Information sharing and financial support. The information sharing was perceived as an essential element to improve and still not timely enough for business. There was suggested more governmental support in terms of information on how to access funding. The affiliation was mixed, all respondents had training and experience.

Mitigation suggested	ID	Affiliation	Training	Exp. (years)	Opinion about mitigation strategies Q16) Is there anything else that should be prioritised?
Community resilience	M01	Cat. 2	No	10+	"Lessons learned to improve processes".
	M16	Academia	No	3-5	"Difference between local/national +urban/rural context".
	M23	Cat.1	Yes	10+	"If we combine fire +police is there a risk of lack of resources/funding in a major emergency? Community resilience".
	M25	Cat.1	Yes	1-3	"More public awareness of longer term consequences of sudden impact events and building community resilience into people mind sets (The public should no longer expect public sector to instantly resolve their issues)".
	A 02	Cat. 2	Yes	3-5	"Culture and behaviour of populations. Training for individuals – perhaps in conjunction with (word not understandable) services".
Coordination	M22	Cat.1	Yes	3-5	"Central government support for when local capacity is exceeded. How we prepare communities for this risk".

	A16	Cat. 1	Yes	10+	"More focus on transferable (word not understandable) warning info inter-agency, cross- warning (or working)
	A22	NGO	Yes	1-3	"Coordination between police, NITS, fire government tv control communication, operations etc."
	A28	Cat. 1	Yes	3-5	"Linking climate change adaptation with emergency preparedness response arrangements".
Knowledge of risk, interdependencies and vulnerabilities	M10	Cat. 2	No	5-10	Do we <u>fully</u> understand all the key risks and (word not clear) the utility to quantify them?".
	M12	Academia	No	0-1	"Key vulnerabilities e.g. food supply routes, mortuary capacity".
	M24	Academia	Yes	5-10	"Simulation of nonlinear interdependencies and feedback loops as help to understand consequences, e.g. system dynamics, system thinking tools etc."
	A01	Academia	Yes	1-3	"There are still unknown (inter)dependencies that can cause/affect cascades. Something like route <i>diversion</i> (?) that can result in railway bridge strikes or water main bursts that can interrupt transportation services and other business. Not much data/information/understanding available".
	A11	Cat. 2	Yes	5-10	"Weather effect on civil failures".
Information sharing and financial support	M19	Business	Yes	5-10	"Communication to business and people are key if must be timely more than 100% accurate (80% often is better than 100% less often)".
	A09	Cat. 2	Yes	3-5	"Financial + funding required for info gathering +production of support systems etc. where is the money going to come from?".
	A31	Cat.1	Yes	10+	"Guidance for finance, human resources, what would the government do to assist".

Table 4- Open answers and categories of "mitigation strategies".

5.2 Suggested training

The comments on training were far fewer, with 10 answers the total of which just 9 were coded. The explanation for the difference in the participation is that the most common options used for training were already included in the questionnaires, as highlighted by one of the respondents (answer not coded). Table 5 reports the training suggested, the identity of the respondents, the affiliation and the comments transcribed from the questionnaire. In this case, the number of participants that had training is well balanced with its overall percentage, while the majority of the comments were made by Cat. 1 responders. The coding was harder due to the limited number of suggestions, but some general outlines can be derived:

- ✓ Training and awareness of the public. The comments suggested improving the training of the public, raising awareness. This approach could be in line with the previous answers suggesting the development of mitigation actions on community resilience.
- ✓ Coordination. This is often a structural issue in disaster prevention and management. Some elements were recurrent with the previous table, such as the support of central government planning to local planning, and the need for a multi-agency approach that includes business continuity. Interestingly, it was suggested to consider better the implications of transportation disruptions on the movement of key personnel.
- ✓ Optimised scenario and exercises. Some answers highlighted the relevance of scenario and exercises, in particular "in person" ones, supporting the evidence defined by the quantitative data. However, one comment refers to the need to understand better the lessons learned from the existing training, which is in line with the need for integrating the qualitative commentary in this research.

Training suggested	ID	Affiliation	Training	Exp. (years)	Opinion about Training Q20) Is there anything else that should be prioritised?
Training and awareness of the public	M09	Cat.1	No	3-5	"Public awareness campaigns. Public in the UK are ill prepared for emergencies unless near COMAH included sites".
	M16	Academia	No	3-5	"Training for the public too".
Coordination	M22	Cat.1	Yes	3-5	"Central government planning and support for local planning".
	A28	Cat.1	No	1-3	"Business continuity→ multi-agency approach e.g. to prioritising critical sources across sectors".
	A02	Cat.2	Yes	3-5	"Considering impacts of movements of key staff outside of expensive city-centre location and therefore more transportation required implications".
Optimised scenario and exercises	M23	Cat.1	No	1-3	"More lessons learned. Lots of public reports etc. etc. not necessarily put into practice".
	M24	Academia	Yes	5-10	"Scenario games".
	A11	Cat. 2	Yes	5-10	"Cat 1+Cat 2 exercises and workshops".
	A18	Cat.1	Yes	5-10	"Real 'in person' sessions are better than 'virtual as networking + talking+ listening to colleagues in other professions gives extended understanding of other priorities/ challenges +needs".
NN	A31	Cat.1	Yes	10+	"None".

Table 5- Open answers and categories of "training" . For "training" is intended if the respondent had ever participated in training session or workshops on cascading or interdependent events (Q 22, Table 1).

5.3 Other comments

Even when the option "other" in answer 13 is considered (Table 6), most of the comments refer to the need for better integrating of the local communities as pro-active agents instead of mere receptacles of information, while all the actors should act more "together". Indeed, the open option to question 13 on who is in charge of assuring the information does not add much evidence to the quantitative findings. Many of the respondents chose multiple answers and decided to write comments near their options as reported in the last table. The coding was harder due to the limited number of answers, but some general outline can be derived:

- ✓ Multiple actors at different levels: The majority of respondents in the table marked multiple choices, and commented using the option "other", or the blank space, to highlight the existence of levels of responsibility and coordination dependent on the situation. One referred directly to the role of Gold Commands as a specification of governmental duties.
- ✓ Local resilience forum and partnership: It is interesting to note that some answers referred to resilience forum, devolved institution and partnerships that have a mixed nature, representing a network more than single institutional actors.

Q13 "Other"	ID	Affiliation	Training	Exp. (years)	Q13) Who do you think should assure the consistency of information
Multiple actors at different levels	M10	Cat.2	No	5-10	Multiple answers, comment: "at different levels".
	M11	Other	Yes	3-5	Multiple answers, is specified "transport companies" that should be business.
	M16	Academic	No	3-5	Multiple answers, it is specified "with a coordinated routine".
	M17	Cat.1	Yes	10+	Multiple answers, it is specified "The lead agency who declares major incident".
	M14	Cat.1/academic	Yes	3-5	Marked just other: "the owner of the risk should /does own the communication. and multi-agency platform uniform the message".
	A 11	Cat.2	Yes	5-10	Multiple answers, comment: "joint".
	A 16	Cat.1	Yes	10+	Multiple answers, comment "It could be all depends on situations. I would want SME's to deliver info- not police talking fire brigade stuff!" All the options are marked together.
	A 18	Cat.1	No	3-5	Multiple answers. Comment "Together. Health authorities in relation with partners".
	A 19	Cat.1	No	1-3	Multiple answers, comment. "All- Joint agreement of messaging required".
	A25	Cat.1	No	1-3	Multiple answers, comment "London Gold Comms. Group".
Local resilience forum and partnership	M23	Cat.1	No	1-3	Government and "Local resilience forums".
	A09	Cat.2	No	1-3	"Local devolved institutions".
	A 12	NGO	No	3-5	"Resilience partnership".

Table 6- Comments reported in the section "other" of Question 13, "who do you think should assure the consistency of information".

Finally, Table 7 reports other comments included in the questionnaire that can support the interpretation of the answers. There was a limited number of adds-ons, and three categories were identified:

- ✓ Climate Change: the comments, made by Cat. 1 responders, mostly referred to the problems of understanding medium term impacts that can be seen in contrast with immediate priorities, in particular in situations of budget cuts.
- ✓ Guidance on training: two comments highlighted preferences in training. A member of business pointed out the usefulness of tabletop exercises, while the cross tabs suggest some slightly more negative perceptions of this training for this category. Instead, a Cat. 1 responder confirmed the usefulness of guidelines and the contrast with webinars in line with the frequency distribution.

In conclusion, it is needed to add the category "other" for two specifications that could be of use: In correspondence of a high value attributed to DSS as mitigation tool it was reported that its limit was "unless GPS collapse", while a member of academia highlighted the availability of statistical methods as forecasting tools.

Q13 "Other"	ID	Affiliation	Training	Exp. (years)	Other comments
Climate Change	M08	Cat.1	No	3-5	Referring to Q15 on integration of climate change in planning "Trying to - does not happen as much as it should. There is still a view that impacts are too far ahead and local authorities look to 4-5 years planning dates".

	A16	Cat.1	Yes	10+	Referring to Q15 on integration of climate change in planning specifies “limited budgets create limited opportunities for such long-term planning”.
	M14	Cat.1/academic (other)	Yes	3-5	“Need a definition on cascading events and secondary impacts emergency response plan and preparedness to all events - climate induced or man-made. Cat 1 and2 responders are well trained and experienced in response and communication. No focus on climate change as priority is immediate life -saving”.
Guidance on training	M19	Business	Yes	5-10	Specifies that roundtables and table top exercises (Q19b) are the “most useful” training.
	A 31	Cat.1	Yes	10+	Specifies that guidelines (Q19c) are “very useful especially for planners”, While webinars (Q19d) “not useful at all” because of “no time”.
Other	M15	Academic	Yes	3-5	It specifies that “thresholds are important and using subjective terms could cause more confusion”, referring to Q5. Moreover, it specifies the role of “Bayesian and Markovian networks mapping the interdependencies” as methodological options together with impact trees and forward-looking tools.
	M16	Academic	No	3-5	The value of Decision support systems I high “Unless GPS collapse!”.

Table 6 – Answers to “other” comments, that correspond to Q26 as reported in Table 1.

6. Discussion

Our evidence confirms the hypothesis that the current crisis management approach to cascading risk is inadequate. London’s stakeholders are concerned and aware of the relevance of cascading events and interdependencies, that are perceived as threats to life without being sufficiently incorporated in the current policies, practices, and emergency management at large. There is more awareness about the need to create a paradigm shift to improve the resilience to cascades and complex events, but this is far from being fully implemented (Helbing 2013; Linkov et al. 2014). However, while many gaps confirmed the first hypothesis, the results suggested also a slight improvement of the situation if compared to the evidence provided by Luijff and Klaver (2013). It is clear that the definitions of operational tipping points and uncertainties are critical challenges that need immediate actions, although they are recurring issues highlighted in the literature on the 2010 ash cloud, environmental change, and cascading effects (Alexander 2013; Amon et al. 2016; Scaini et al. 2015; Wardekker et al. 2008). On the one hand, the definition of tipping points and uncertainties could increase the flexibility of response, in line with the need for specifying priorities and inter-organisational coordination highlighted as critical elements for emergency planning by Perry and Lindell (2003). On the other hand, contingency planning and scenario building were considered the solid bases for providing a better understanding of cascades, and could be used to increase the flexibility to uncertainties and the escalation of secondary crises as argued by different authors (Alexander 2016; Münzberg et al. 2017; Pescaroli and Alexander 2016). Finally, the respondents believed that cascading events could become more common as a result of climate change as is recognised in the literature due to the increased pressure on the built environment, leadership and on society (Galaz et al. 2011; Linkov et al. 2014). Most mitigation measures received high values in the responses, confirming the hypothesis that improvements on the status quo are urgently needed. It is commonly perceived that hazard risk maps and critical infrastructure rankings should be integrated in the broader

legislation (Nones and Pescaroli 2016), as well as improvements in intermodal coordination (Alexander 2013). The value attributed to decision support tools is high, and could be associated with the need to assure communication and exchange of information that could be vital in complex emergencies (Scaini et al. 2015; Setola et al. 2016; Ulfarsson and Unger 2011). This seems to be confirmed by some of the qualitative answers about mitigation measures. The knowledge of interdependencies was a critical point also in the qualitative comments, but mostly within the academic community and Cat. 2 responders more than Cat. 1 responders which may suggest reflecting better on the target groups for which each strategy is settled. Moreover, the responders attribute some priority to the need for improving information for optimising procurement strategies and deployment, as well as for the integration of the local energy supply for increasing CI resilience. This was quite surprising, because we expected much higher values and shared agreement on those two items. The result is not low enough to contradict the literature (Helbing 2015; Pescaroli and Kelman 2017; Petermann et al. 2011), but further investigations should be made to understand if those measures are more context dependent than what believed. Some separate considerations must be made about the perceived need for international mitigation strategies, where the values were very low and completely different from what could have been expected. There is an unequivocal misunderstanding of the cross-border dimension of cascades, aspects of which have been described widely in the literature (Boin and McConnell 2007; Ansell et al. 2010; Galaz et al. 2011). This may be associated with different operational roles that do not necessarily provide a vision of the bigger picture, but also influenced by training levels as verified with the analysis of correlations.

The qualitative answers proposed a complementary point of view about mitigation measures. The respondents consistently pointed out that knowledge of risk, interdependencies and vulnerabilities must be associated with a better work on community resilience, coordination and information sharing. Again, there was highlighted the need for more shared responsibility of emergency management and more dialogue between the local and the national level. These are well known issues for the emergency management community that developed criteria and framework such as the work of Quarantelli (1997), Alexander (2002;2005), Boin and McConnell (2007), and Abrahamsson et. al. (2010). These should be applied also in mitigating cascading risk, using the need for renewal to improve and evolve the existing system. The low level of participation of NGOs and charities suggests that further steps are needed in that direction both in policy, practice and future researches. Some other points highlighted open issues in linking climate change adaptation in emergency planning, both in terms of uncertainties about longer term impacts, and possible coordination issues as commonly agreed in the literature (Wardekker et al. 2008, Linkov et al. 2014).

The low average values attributed to training levels contrasted with the high value reported for all the tools of improvement, and in line with our expectations the responses defined the need for further work. It seems that the priority should be attributed to increase the dialogue and availability of information for improving inter-agency coordination, which is one of the critical points suggested by Perry and Lindell (2003). Open access guidelines could be considered a feasible tool to support this process. Moreover, the good values attributed to training and exercises may be in line with the positive effects registered by Parker (2015), after the 2010 eruption, and more in general with the basic strategies adopted for improving emergency management (Lindell et al. 2007). Even in this case, the open answers supported the idea the need for improving the involvement of the public and the coordination process (Quarantelli 1997; Alexander 2002;2005, and Abrahamsson et. al. 2010). They also stated very

clearly the role of scenario and exercises for understanding better cascades as suggested recently (Pescaroli and Alexander 2016, Alexander 2016, Pescaroli et al. 2018). However, it must be noted that the knowledge of wider impact analysis, impact trees and other forward-looking tools suggested by Mc Farlane (2015) was much better than expected. This may confirm again that a process of change may be in progress at least in our case study, shifting slightly from what was suggested by Luijff and Klaver (2013).

In conclusion, the analysis of correlations does not add consistent evidence for the discussion. The limited strengths that we registered in the tables may be oriented by the size of the dataset, that further analysis should be done in that direction. However, there can be noted a constant influence of the training received by the respondents with the perceptions of cross-border management. In other words, the cross-border element of cascading risk is something more associated with training levels as it does not necessarily enter in the operational routines of stakeholders. This is in line with the evidence that training is a vital support for understanding the bigger picture of emergencies and disaster (Alexander 2002;2005;Lindell et al. 2007), and it could be useful to produce a better understanding of the cross-border component of cascading crisis among the respondents. In conclusion, the stronger correlation recorded was between the values attributed to possible training tools such as free guidelines and webinars, which were the most and the least popular options. This may be associated with the fact that the two things are often complementary, for example in the training provided by the United Nations, but in a situation of limited resources these data may suggest concentrating the budget on the better perceived option as the target may be the similar. Further research should investigate this aspect, while in the next section we draw some general conclusions from this study and recommendations from this study.

7. Conclusions

This research investigated the perceptions of cascading events and interdependencies among London's stakeholders, and provided evidence to support actions for improving policies and operational resilience. Our analysis highlighted that cascades were perceived as a very relevant threat for society and emergency management, but further work is needed for adapting mitigations and training strategies. The diffused perception that the loss of services can cause risk to life has strong implications for multi-agency coordination: disruptions can be seen as directly challenging the core mission of emergency services, like other conventional threats such as floods. *De facto*, our data show that cascades cannot be considered anymore as marginal topics and need to be better catered for in emergency planning, including considerations on their relationship with climate change. It is strongly needed to evolve policies and practices, developing an agenda that should include some key strategic actions:

- ✓ Improving intermodal coordination at the local, national and cross-national levels, which has been a lesson not applied from the 2010 ash cloud;
- ✓ Integrating hazard risk maps and critical infrastructure maps, using existing frameworks such as the European floods directive;
- ✓ Promoting definitions of tipping points and acceptable risk for supporting multi-agency coordination, linking climate change adaptation and preparedness arrangements, and clarifying the attribution of responsibilities in the scenario of high uncertainties;

- ✓ Including community resilience, training of the citizens, and the involvement of pro-active resilience actors in the planning and management of cascading risk;
- ✓ Investing in table-top exercises and guidelines for end users, developing scenario building and contingency planning, and supporting the awareness of interdependencies with the use of Decision Support Systems;
- ✓ Using training to strengthen the cross-border component of cascading risk, including adaptation to climate change drivers as part of emergency preparedness;
- ✓ Improve the discussion on the possible use of localized energy sources and on which datasets on the resources needed to contain extended services disruptions.

Our data set has limitations, but they do not invalidate the results, while suggesting new steps for future researches. We are aware that expert judgment must be used with care, as it can introduce subjectivities and cultural biases into the assessment (Skjong and Wentworth 2001). We mitigated this issue piloting the questionnaire, using together descriptive and numeric Likert scales, explaining the concepts at the beginning of the workshop, and adapting a mixed method approach. However, the limitations of assessing risk perceptions remains. It must be considered that the results could have been influenced by the synergies with ANYTOWN in different ways.

First, it cannot be excluded that organizations with higher awareness of cascading and interdependencies could have been keener to support the participation of their personnel. This factor seems to have a limited impact on our dataset because the distribution of frequencies on previous training and participation to other workshops suggest that the respondents were mixed. Further research should consider a focus on how organisational culture could influence the preparedness to cascades in order to highlight possible gaps and inconsistencies that need guidance from coordination agencies.

Secondly, the initial focus on transportation could have attracted some sort of “sectorial” expertise, influencing the answers on mitigation measures. Even in this case, in our data this component seems to be mediated by the cross-cutting interest registered in the workshop and by the strong involvement of Category 1 responders. We would recommend that further steps should be made to explore the differences between organisations and categories of responders, including a better perspective of small- medium enterprises, charities and NGOs whose participation to the workshop was limited.

Thirdly, using London as a case study presented the advantage of accessing a mixed target group that otherwise could have been very hard to involve in this type of research. The collaboration with LR and LCCP allowed the unique opportunity to develop an integrative research process, accessing stakeholders that otherwise may have not been so collaborative. The unique level of global interdependencies concentrated in London was an essential part of this process, as it determined the existing projects of the authority. However, it may be considered also a limitation. How much does London’s ranking in the global cities influence the risk perception of stakeholders? Are data elsewhere still more in line with the evidence provided by Luijff and Klaver (2013)? It could be desirable to replicate this study in different environments to understand the variations in risk perceptions, testing possible differences between rural and urban areas to promote new coordinated measures for operational resilience.

In conclusion, it must be noted that this research does not pretend to be exhaustive, but it consolidates the basis for further cross-disciplinary analyses. For example, this paper did not

investigate the psychometric dimensions of cascading risk because it was decided with these stakeholders to focus on other and more “basic” aspects. It could be argued that a better analysis of the psychological drivers could be another element to investigate in the future, exploring other correlations and defining specific target groups for training and policies. Future research may benefit also from a wider use of qualitative methodology, such as semi-structured interviews and focus groups, that in this case were not feasible because of time and resource constraints. A final and critical point that should be addressed involves the citizens’ perception of cascades to understand how to increase the preparedness of society and to produce timely responses in case of disruptions. Are citizens’ priorities changing and influencing what they expect from emergency services? It could be argued that cascading events and interdependencies cannot be intended anymore as one of the many aspects of emergency planning and management, but must be seen as a constant background that will orientate future disaster risk reduction from citizens to planners. There is a long way forward to achieve effective policies, mitigation, and training for a complex and fast evolving context.

Acknowledgements

This work had been supported by the UCL Knowledge Exchange Award and by the UCL Institute for Risk and Disaster Reduction. The research was not possible without the essential collaboration and experience of Matt Hogan (London Resilience), Kristen Guida (London Climate Change Partnership), Alex Townsend-Drake (London Resilience), and Prof. David Alexander (UCL). The author gratefully acknowledges Dr. Bayes Ahmed (UCL), Dr. Serena Tagliacozzo (UCL), and Angela Cooper (UCL) for their feedbacks and help. Finally, the comments of Prof. Arjen Boin (Leiden University), Donald Blondin (Donald Blondin), Wout Broekema (Leiden University), and Christian Kalbassi (FDJP) were fundamental for improving the first version of this paper. **References**

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