Good Practices for Critical Infrastructure Resilience: a classification and assessment framework

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The fast-growing occurrence of unexpected events affecting Critical Infrastructure (CI) systems in recent years fostered a shift from a protection-focused approach to CI Resilience (CIR). In this context, the increasing number of interdependencies, which generate domino effects and cascading failures, led to the call for establishing collaborative approaches and partnerships at the regional, national or international level. To support and implement CIR strategies, governments and CI operators often rely on Good Practices (GPs), generally defined as methods or techniques that are applied to solve existing problems producing effective results and bringing benefits to the users. Despite the high number of GPs, they are often insufficient to cover the wide spectrum of capabilities required for effective Emergency Management (EM). In this study, the systematic analysis and review of scientific literature and European projects in the CIR domain, led to the identification of 53 GPs that have proven to be effective in managing CIR. To enable comparison among the GPs the study proceeds with the development of a framework for classifying and assessing GPs according to their application context, the activities and functionalities covered, and the EM capabilities they are able to support. From a research perspective, the framework offers a robust background for future assessment and benchmarking of CIR related GPs; it is also useful for practitioners to assess and select the most suitable GPs under different institutional and operational contexts.

Keywords: Critical Infrastructure, Resilience, Good Practice, Emergency Management capability, Collaborative approaches, Interdependence.

1. Introduction

The concept of CI is related to assets or systems that are vital for the health, safety, security, economy and well-being of a society (European Commission, 2008). In particular, infrastructure systems include networks that produce and distribute essential goods and services. Among them, the ones "whose incapacity or destruction would have a debilitating impact on the defense and economic security" are regarded as critical (President's Commission on Critical Infrastructure Protection, 1997). Therefore, CI systems include energy supply, communications, IT networks, financial networks, food and water supply, health protection, transport, public administration operations and pipelines of dangerous substances (Wróbel, 2019).

Due to their multiple vulnerabilities and (inter)dependencies, CI systems are more and more susceptible to the occurrence of unexpected disruptions and accident events, highlighting the need of enhancing organizational awareness and improving the ability to effectively respond to unforeseen events (Adini et al., 2017). Moreover, under the influence of (inter)dependencies an event affecting a specific CI can produce cascading failures, spreading ripple or domino effects throughout regional or national interconnected CI systems (Wróbel, 2019).

The level of complexity in interconnected CI systems justifies the need of adopting collaborative efforts among different organizations and calls for a progressive shift from a purely protection-driven approach to one that places resilience at the core. This new approach based on CIR is focused on guaranteeing functional continuity of the services when a disruption occurs, limiting the extent of related impacts and ensuring a faster recovery of normal service conditions even when CI is severely damaged (Trucco & Petrenj, 2015b). Effective CIR strategies require approaches and practices grounded on a trustful collaboration between several stakeholders, at different institutional and operational levels, that exchange information by means of a variety of channels.

In this regard, governments and business organizations rely on Good Practices (GPs), generally defined as methods or techniques that are applied to solve existing problems producing effective results and bringing benefits to the users. Among them, Best Practices (BPs) are the ones showing results superior to those achieved with other means (Trucco & Petrenj, 2015b). In spite of the presence of a large number of documented GPs in the context of CIR, they have often proved to be insufficient to cover the wide spectrum of EM and resilience capabilities needed to cope with real events (Jonathan Clarke et al., 2015). Moreover, the importance of implementing coherent and aligned practices within and between different organizations is a prerequisite for effective management of (inter)dependencies and emphasizes the need for a

Proceedings of the 31th European Safety and Reliability Conference
Edited by Bruno Castanier, Marko Cepin, David Bigaud and Christophe Berenguer

ISBN: 981-973-0000-00-0 :: doi: 10.3850/981-973-0000-00-0 esrel2021-paper

structured and robust framework for effective EM of interconnected CI systems.

In light of the previous considerations, the aim of this study is to develop a comprehensive framework for classification and assessment of CIR oriented GPs as a novel contribution towards the achievement of a more harmonized and collaborative EM model for coping with accidents and disruptions affecting interconnected CI systems.

2. Research method

In order to identify the means and solutions that practitioners and experts can rely on for the management of CI-related disruption events, the work started from the analysis of the GPs currently used in this domain. To collect and review relevant sources we implemented a systematic procedure consisting of the following four-steps:

- Data gathering: the most important projects in the context of CIR were analyzed (Trucco and Petrenj 2015a; The Rockefeller Foundation 2015; Horizon 2020; DARWIN Project 2015; Resilens Project 2016; SMR Project 2015; Resolute Project 2015), with the aim of collecting information about the most effective practices currently used in this domain. Other practices were identified by consulting scientific literature and institutional websites on Google, by using keywords as "Critical Infrastructure*", "Resilience" and "Practice*".
- Data analysis and data cleaning: the information on each single practice was analyzed to select the practices that were already implemented in practice, or at least piloted, and that are reasonably transferrable to other similar contexts using the information made available by the authors. At the end of this step, 53 GPs were selected.
- Data presentation: each GP was documented in a standardized way, using a common template, to clearly report the main objectives and features.
- Categorization: each GP was classified against a unified classification taxonomy. Analyzing previously collected information, emerged the need of using three classification dimensions to properly characterize the different GPs and enable an effective comparison. The dimensions taken into consideration were: GP main characteristics, GP activities and functionalities, EM capabilities directly supported.

Experts' judgements were additionally collected to complement the literature by means of a specific online questionnaire. The aim was to link the classified activities and functionalities of GPs to the taxonomy of EM capabilities. In particular, experts were asked to express an informed judgement on the importance (i.e. positive contribution) that each single activity or functionality of the selected GPs may have in building or improving a specific EM capability. The questionnaire was administered to about 150 international experts, through direct contacts or professional associations, and 23 usable responses were finally collected.

The questionnaire results enabled to assess to what extent the EM capabilities are covered by the GPs. An ABC analysis was then performed to identify the range of EM capabilities fully covered by each GP, i.e. its degree of comprehensiveness. The final ranking led to the identification of the BPs. Fig. 1 provides a graphical representation of the implemented research method.

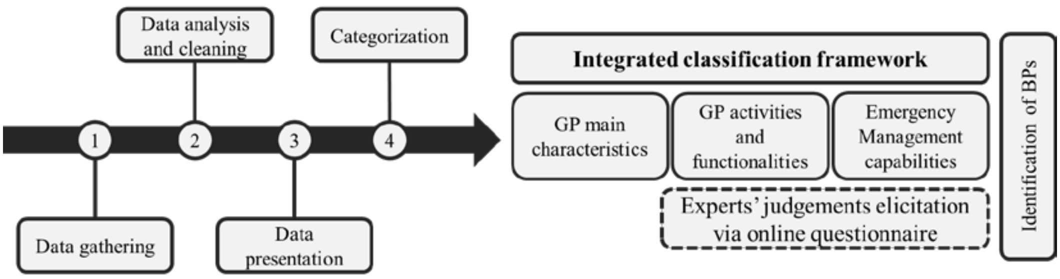

Fig. 1. Research method

3. Review of the selected GPs

The 53 selected GPs have the common aim of supporting different organizations in the management of emergencies when CI systems are involved. However, they achieve this goal by adopting different methods, tools, technical solutions, e.g. specific IT systems, or organizational arrangements. To this end, GPs were clustered into six groups according to the main purpose and the most relevant functionalities. The list of GPs taken into consideration in the present study and their grouping into six clusters is given in Table 1.

The *Information sharing* cluster is composed of GPs which have the main purpose of facilitating the sharing of situational information or knowledge at different levels (e.g. intra-organizational, national, multinational). They are mainly web-based information sharing platforms that facilitate collaboration and coordination between organizations, providing greater visibility of impacts and strengthening the resilience of communities. The constant collaboration among institutions leads to the development of integrated strategies for the management of CI emergencies which take into consideration the presence of system interdependencies.

The *Geographical visualization and information sharing* cluster is composed by GPs that have the main purpose of both monitoring the areas of interest through geographical visualization and sharing useful information within those areas. Most of these practices are tools that allow for a georeferenced visualization of events, strategic places, resources and possible dangerous situations; they also provide information for emergency response in relation to different types of events (e.g. quickest way to reach the affected area).

The *Planning* cluster includes GPs that provide guidelines to better prepare CI operators and other stakeholders to cope with CI disruptions. They give ad-hoc instructions, guidance notes, templates or structured steps to support risk and resilience assessment, decision-making and information sharing. In particular, they provide instructions on how to collect relevant data and information, identify relevant stakeholders and (inter)dependencies between systems, set priorities and needs for interventions, and finally, develop and implement a strategic plan.

The *Training, exercising and simulations* cluster includes GPs whose objective is to provide adequate preparedness for CI operators, institutions and experts to deal with all the EM phases. These GPs can be either in the form of tools (e.g. simulation platforms) or processes (e.g. workshops, exercising programs). Simulations create a virtual environment to test specific tasks or policies adopted during rescue operations, disruptions to resource availability and the consequent effects on CI operations. Users can try different policy options (different scenarios), identifying the implications of each of them in the resilience improvement process. Exercise programs, instead, allow dealing with response, recovery and mitigation activities, trying to guarantee better visibility of available resources and needs in affected areas, and to find ways to guarantee first aid. Finally, workshops engage stakeholders, experts and sometimes citizens to communicate existing problems, try to effectively understand their root causes and learn about new ways to solve them.

The *Risk and Resilience assessment* cluster is composed of practices that have the main purpose of supporting the analysis of interdependencies and assessing risk and resilience at different system levels. Tools based on flexible cartography approaches are used for the analysis of the interdependences and the simulation of the domino effects. Thanks to constant monitoring of the territory, they are able to assign a risk level to different areas that could be impacted by an emergency event. Other tools are based on templates that guide users throughout the whole process of risk or resilience assessment. They support an assessment of how shocks and stresses in the local area interact to impact specific assets, specific locations, different business sectors, residents and users. Based on the risk level assigned to the key hotspots, some GPs provide access to policies recommendations that can support the identification of measures to mitigate risks within the area. A similar approach is followed to evaluate the resilience levels of a region.

Table 1. List of selected GPs

Cluster	Good Practices (GPs)
Information sharing	V-BEOC Virtual Business Emergency Operations Center (National Business Emergency Operations Center, 2020), NWWARN Northwest Warning, Alert and Response Network (CRDR, 2020), DARWIN Wiki (DARWIN Project, 2015), Focus on Flows (Resilient Regions Association, 2020), MATRICS Multi Actor Threat Recognition, Information and Collaboration System (Astir, 2020), SATool Situational Awareness Tool (Trucco & Petrenj, 2015a), Resilience Building Policies (SMR Project, 2015), Multi-State Fleet Response Initiative (Trucco & Petrenj, 2015a), Big Business – Small Business (NIMSAT, 2012), Louisiana Disaster Recovery Alliance (LDRA Consortium, 2020)
Geographical visualization and information sharing	EM Dashboard (Cruscotto Emergenze in Italian; Regione Lombardia, 2020), Copernicus Emergency Management Service (European Commission, 2020), GIS Mapping for CI Assets (Trucco & Petrenj, 2015a), Resilience Information and Communication Portal (SMR Project, 2015), Traffic Scotland Information Service (Transport Scotland, 2020), ESSMA Emergency Support Smart Mobile App (Resolute Project, 2015), CRAMSS Collaborative Resilience Assessment and Management Support System (Resolute Project, 2015)
Planning	PRISM Performance and Risk-based Integrated Security Methodology (Harnser Group, 2012), COLAB (The Rockefeller Foundation, 2015), TTF Thematic Task Forces (Alberto Ceriani, 2011), Partnership Alignment for Enhanced Security (Trucco & Petrenj, 2015a), European Resilience Management Guideline (SMR Project, 2015), Public Safety Canada (Public Safety Canada, 2020)
Training, exercising and simulations	Blue Cascades Exercise Series (Newman, 2018), MICC Major Incident Control Committee (MICC Partners, 2020), CATEX Catastrophic Exercise (All Hazards Consortium, 2017), City Resilience Dynamics (SMR Project, 2015), SimEnv (DARWIN Project, 2015), Serious Games based on Virtual Reality (DARWIN Project, 2015), GINOM Global Infrastructure Network Optimization Model (EIS Council, 2020), Opportunity Assessment Tool (The Rockefeller Foundation, 2015), Problem Framing (The Rockefeller Foundation, 2015), Project Scan Tool (The Rockefeller Foundation, 2015), Resilience Accelerator (The Rockefeller Foundation, 2015), Resilience Garage (The Rockefeller Foundation, 2015), Resilience Value Realization (The Rockefeller Foundation, 2015), 100 RC Systems Studio (The Rockefeller Foundation, 2015), Tactical Urban Resilience (The Rockefeller Foundation, 2015)
Risk/Resilience assessment	DOMINO Tool (Trucco & Petrenj, 2015a), GRRASP Geospatial Risk and Resilience Assessment Platform (GRRASP, 2020), Assets and Risk Tool (The Rockefeller Foundation, 2015), Local Area Risk Assessment (The Rockefeller Foundation, 2015), Risk Systemicity Questionnaire (SMR Project, 2015), THREVI2 (r2macs, 2020), CI System Definition Tool (Resilens Project, 2016), Resilience Management Matrix Tool (Resilens Project, 2016), GIS based Resilience Mapping Tool (Resilens Project, 2016), Resilience Management Audit Tool (Resilens Project, 2016), City Resilience Index (The Rockefeller Foundation, 2015), Smart Resilience Indicators (Jovanovic Eu-Vri, 2016), Resilience Maturity Model (SMR Project, 2015), Resilience Actions Inventory and Stakeholder Perceptions Review (The Rockefeller Foundation, 2015)
Business Continuity Management	BCM for enterprises (Okabe, 2009), Area BCM (Baba et al., 2014)

The *Business Continuity Management* (BCM) cluster includes programs for embedding business continuity into organizations (BCM of an enterprise) and regions (Area BCM) to help them cope with CI disruptions. While traditional BCM system is designed to prevent the company's core business from being interrupted in emergency circumstances, Area BCM aims to secure the critical resources, which include external goods and services essential in supporting the business operation within and around an industrial area. The resulting Area BC Plan should address various issues, including CI protection, coordinated disaster preparedness and response, quick recovery from damages, supply chain cooperation and monitoring of BCM activities.

4. Framework for CIR GPs assessment

The aim of this study is to develop a comprehensive framework for the classification and assessment of GPs for CIR. The proposed framework is made of three pillars directly related to the classification levels:

- Specification of GP's main characteristics;
- Specification of GP's Activities and Functionalities;
- Specification of EM capabilities supported by the GP.

The structure of the integrated classification framework, highlighting its components and relationships is shown in Fig. 2.

4.1. *GP's main characteristics*

This classification dimension includes several dimensions that highlight the relevant characteristics of each GP, considering the type of support they are able to provide, the stakeholders involved in its implementation, and the original context of application.

Firstly, GP Type specifies the GPs according to their nature (Trucco & Petrenj, 2015a): Tools and Technologies include GPs that achieve their specific goals through a set of means, technologies, methods and techniques; on the other hand, Processes include GPs that achieve their specific goals through actions, tasks, organizational arrangements and procedures.

The EM Phase identifies the phases of the EM cycle supported by each GP (Trucco & Petrenj, 2015a). Following the classification and the definitions provided by FEMA (2020), EM encompasses four phases: Preparedness, Mitigation, Response and Recovery. Partnership Type concerns the type of organizations involved in the partnership (i.e. public organizations, private ones, or both). To further detail the Partnership Type, the *Key Partners* dimension is used to specify the different stakeholders involved, (i.e. public institutions, CI operators, universities, local communities, public and private companies, CI and resilience experts). *Inter-Organizational Scope* has been introduced to understand if the GP can be autonomously implemented by a single organization or requires collaboration between different organizations (i.e. intra- or inter-organizational GPs). The *Data Type* indicates if the GP is able to provide real-time support during an emergency, by showing real-time situational information. The *Extension* is concerned with the largest geographical area of documented applications of the GP (i.e. city, region, country, or more countries). Finally, the *Transferability* indicates if a GP can be applied only within a specific context or it can be flexibly and broadly applied in different cases (i.e. specific or broad).

This classification dimension allows exhaustive profiling of the 53 GPs; it characterizes the nature of the GPs and the context of their use, thus highlighting their specificities or similarities as well as limitations in scope and level of transferability.

4.2. *Activities and functionalities of GPs*

GPs were divided into two main groups: i) Processes; and ii) Tools & Technologies.

Processes can be described as procedures or sets of actions and tasks performed by a single organization or a group of them to achieve a specific aim; the GP can be described as a coherent set of activities. On the other hand, Tools and Technologies can be described through a piece of equipment or software whose features are adequate to achieve a specific aim; hence, the GP can be described as a set of functionalities (Cambridge Dictionary, 2020).

The definitions of the classification dimensions adopted to specify the main features of both groups of GPs are provided in Table 2. Each feature is defined as functionality (F), activity (A), or both (A&F). This classification is also used to assess the level of support granted by the 53 GPs to different types of activities and functionalities. A score from zero (activity/functionality not supported) to five (activity/functionality fully supported) was assigned by the authors to each GP for all the identified activities and functionalities.

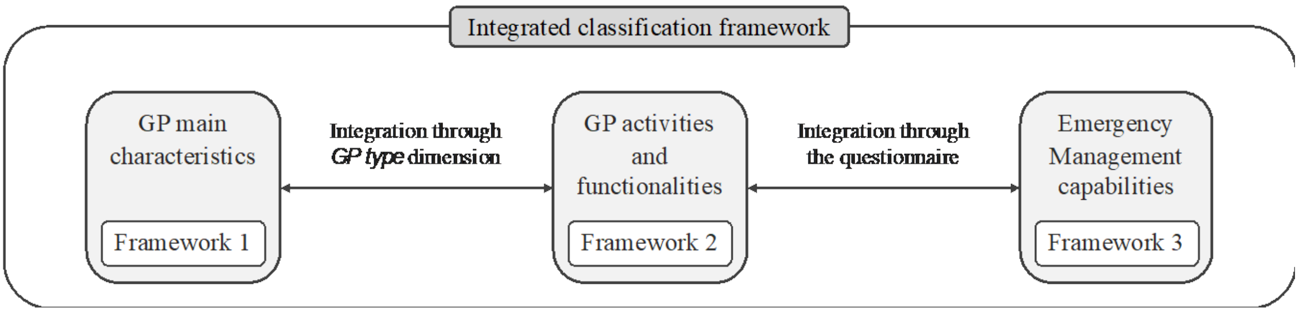

Fig. 2. Integrated classification framework

4.3. *EM capabilities*

The EM Capabilities classification identifies the set of relevant capabilities required to effectively manage an emergency where interdependent CI systems are involved. The term capability of an entity (e.g. organization, system, person) can be generally defined as a feature, faculty or process that promotes the achievement of its objectives. Similarly, resilience capabilities can be understood as resources, activities and functions that enable resilience goals (Kozin et al., 2018), so they refer to the ability of an organization, or of a group of organizations, to prepare for, mitigate, respond to and recover from disruptive events.

The areas covered by EM capabilities include resource management for the allocation and deployment of resources (ISO 22325, 2016), risk management to direct and control an organization with regard to risk (ISO 73, 2009), communication and coordination to favor the information exchange outside the boundaries of the organization (ISO 22325, 2016), EM planning for establishing measures and assessing needs (CDC, 2018), and surge management to provide support to humans and the environment (CDC, 2018).

Starting from the classification of capabilities provided by FEMA (2020) and CDC (2018), the capabilities considered for the study are: Access control and identity verification, Logistics and transportation services, Community resilience building, Interdiction and disruption, Threat and hazards identification, Risk assessment, Supply chain integrity and security, Information sharing, Operational coordination, Public information and warning, Planning, Environment protection services, Human protection services, and Cybersecurity.

The contribution that different types of Activities & Functionalities give to each EM capability was assessed (on scale from zero to five) through the administration of the CIR Questionnaire to international experts. The aim was to understand to what extent each Activity & Functionality is relevant in building a specific EM capability. The results are summarized in Table 3.

Table 2. Definitions of types of activities (A) and/or functionalities (F) supported by the GPs and included in the framework

Term	Definition	Class.
Alerting/warning	It represents a signal that makes you understand if there is a possible danger or problem, especially one in the future (Cambridge Dictionary, 2020).	F
Brainstorming / Problem solving / Lessons learned	It includes activities aimed at suggesting new ideas to find solutions to problems and at sharing knowledge or understanding gained by experience (TRP, 2020).	A
Communication	It allows exchanging information among entities (organizations, people and technologies).	A&F
Coordination	It is the process of allocating and managing all the resources during the response phase of EM.	A&F
Decision support	It is based on an information system that supports business, organizations or authorities in decision-making activities.	F&A
Expert involvement	It includes the involvement of experts to share lessons learned, guidelines and BPs for continuous improvement.	A
Geographical visualization	It refers to a set of tools and techniques supporting the analysis of geospatial data through the use of interactive visualization.	F
Knowledge management	It includes the sharing of lessons learned, guidelines and BPs for continuous improvement.	F
Monitoring	It is based on the collection of routine data that are used to track changes in the situation over time and to provide regular feedbacks and early indications of possible disruptions (ERM Insights, 2020).	A
Planning	It is a fundamental management function, which includes deciding beforehand, what is to be done, when is it to be done, how it is to be done and who is going to do it (Business Jargon, 2020).	A&F
Risk assessment	It refers to the overall process or method of hazard identification, risk analysis, risk evaluation and risk control (CCOHS, 2020).	A&F
Surge management	It includes all the activities that are performed during the response phase of EM as a first response to a crisis or disruption.	A
Training/exercising	It includes exercises, training and simulations to improve all hazard incident management, as well as integration and interoperability (TRP, 2020).	A&F

5. Findings and discussion

The GP mapping against the 14 EM capabilities was performed by combining the values of Table 3 with the A&F classification framework: for each GP, the scores attributed to each activity and functionality were multiplied by the scores assigned by experts, thus obtaining the level of coverage granted by each GP to the EM capabilities.

The obtained results enabled us to assess the degree of comprehensiveness of each GP (i.e. range of capabilities fully covered) and consequently to identify the BPs of each cluster as the GPs that cover the widest spectrum of EM capabilities (Table 4). To this end, we performed an ABC analysis on the overall scores, where class A is represented by those capabilities that are better covered by a GP. The degree of comprehensiveness of each GP was then

Proceedings of the 31th European Safety and Reliability Conference
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ISBN: 981-973-0000-00-0 :: doi: 10.3850/981-973-0000-00-0 esrel2021-paper

calculated as the number of class A values. The most interesting findings resulting from these analyses are summarized in the following.

GPs belonging to the *Information sharing* cluster contribute to community resilience-building by introducing platforms accessible by citizens, thus involving them in the sharing of information with operators. The BPs of the Information sharing cluster are V-BEOC and Multi-State Fleet Response Initiative. V-BEOC is a web-based platform with a unique source of information enabling real-time communication among public and private institutions. On the other hand, Multi-State Fleet Response Initiative is a Working Group where partners share sensitive information to improve resources and fleet movements across the border, with the support of the SISE platform (Sensitive Information Sharing Environment), In both cases, information sharing is guaranteed before, during and after an emergency, in order to collect inputs to support decision-making in all the phases of the EM cycle. Meetings and conferences organized by partners allow to develop a common and integrated strategic planning, while the constant operating status updates provide a complete situational awareness. V-BEOC and SISE platforms are endowed with components useful to manage resource deployment during emergencies and are publicly accessible to warn and inform the community.

Table 3. Evaluation of GPs' Activities and Functionalities against EM capabilities according to experts (average values; scale: 0-5).

		CAPABILITIES													
		Access Control and Identity Verification	Cybersecurity	Logistics and Transportation Services	Community Resilience Building	Interdiction and Disruption	Risk Assessment	Supply Chain Integrity and Security	Information Sharing	Operational Coordination	Public Information and Warning	Planning	Threat and Hazards Identification	Environment Protection Services	Human Protection Services
FUNCTIONALITIES/ACTIVITIES	Communication	5	5	5	5	3	3	4	5	5	5	3	4	5	5
	Geographical Visualization	4	5	4	4	4.5	3.5	4	3	4.5	3	3	4.5	4.5	2.5
	Alerting/Warning	5	3.5	4	5	4.5	3	4	3	4	5	2.5	4	4.5	5
	Training/Exercising	4.5	4	5	4	3.5	3	4	4	5	4	4	4	5	4
	Planning	4	5	5	4.5	4	4	5	4	4.5	3.5	5	4.5	4.5	4
	Coordination	5	5	5	5	4	3.5	5	5	5	4.5	5	5	5	5
	Risk Assessment	4	4	3	4.5	5	5	4.5	3.5	3	3	4	4	4	4
	Knowledge Management	3	3.5	4.5	3.5	4	5	4.5	4.5	4	4	4.5	4	4.5	4
	Decision Support	3	4	3.5	4	3.5	4	4	3.5	4	3.5	4	3.5	4.5	4
	Expert Involvement	4	4	4	5	5	5	4.5	3	4	4	4	5	4.5	5
	Surge Management	3	4	3	4	3	3	3	2.5	3.5	3	3	3	4.5	3
	Monitoring	5	4	3	4.5	4.5	3.5	4	3.5	4	4	3	4	4	5
	Brainstorming	4	4	4	4	4	3.5	4	3	3.5	3	4.5	4	4	4

GPs belonging to the *Geographical visualization and information sharing* cluster include solutions mainly aimed at enabling information sharing among institutions and operators and at detecting interdictions and disruptions. The study showed that these practices could facilitate the coordination of response operations by integrating their current map visualization tools with instruments able to support resource deployment during emergencies. Another extension that may be adopted by these GPs concerns the possibility to represent on the maps the location of potential threats and hazards. A further contribution coming from experts' judgements highlighted the importance of involving the community in the resilience-building process and of warning citizens in case of threats or emergencies to provide guidelines and support. The BPs of this cluster are CRAMSS and ESSMA. They both provide a georeferenced visualization of strategic places, resources and possible dangerous situations. This supports a prompt identification of emergencies, thus giving the possibility to intervene immediately in the affected area. They are applications available also for the public, therefore they are able to warn citizens and to support them in dealing with emergencies. Moreover, they provide instructions and guidelines to the operators that have to intervene in the affected area, showing the routings to reach the location and suggesting evacuation procedures to be followed.

GPs belonging to the *Planning* cluster include instructions aimed mainly at guiding the development of plans and at providing methodologies for prompt identification of threats and hazards. It emerged that these practices should guarantee the integrity and security of the supply chain by fostering collaboration among actors and developing common strategies. The BPs of the Planning cluster are TTF and Colab. Colab provides a set of guidelines to develop strategic plans to improve local resilience: it guides stakeholders through the identification of current challenges and the development of solutions to face them. On the other hand, TTF involve different operators that work jointly on a specific theme to achieve aligned plans and procedures.

GPs belonging to the *Training, exercises and simulations* cluster include platforms and training programs mainly aimed at supporting planning. This cluster can be better discussed by introducing a distinction between workshops and simulation platforms. The former could support community resilience building by involving citizens in the discussions, thus having the opportunity to develop better integrated solutions in line with the expectations and the needs of the whole community. Concerning simulations platforms, instead, the results of the questionnaire highlighted the importance of supporting operational coordination. In this regard, it could be possible to extend the usage of these tools also throughout an emergency event, by performing real-time simulations to support resource deployment during the response phase. The BPs of this cluster are Opportunity Assessment Tool and Problem Framing. Both are workshops where stakeholders discuss existing problems affecting a city and learn about new ways to solve them. In particular, they teach participants to identify barriers that hinder opportunities and to prioritize resilience actions with the aim of achieving that opportunity.

GPs belonging to the *Risk/Resilience assessment* cluster include methods and templates mainly aimed at identifying threat and hazards and assessing risk or resilience. In some cases, the GPs provide instructions to develop strategic planning starting from the risk or resilience scores obtained. The BPs of this cluster are DOMINO and GRRASP. Both are tools based on a cartography approach used to locate system infrastructures and simulate domino effects; by analyzing situational information of CIs, they assign a risk level to the different areas that could be impacted by the emergency event and provide information about the propagation of the disservice.

GPs belonging to the *BCM* cluster include steps and activities mainly aimed at supporting BC planning activities, in order to avoid the interruption of critical systems and processes or recover them as soon as possible. Given the very limited number of GPs in the cluster, no BP was identified.

Table 4. EM capabilities covered by the BPs, with class A capabilities colored in grey.

	CAPABILITIES													
BPs	Access Control and Identity	Cybersecurity	Logistics and Transportation Services	Community Resilience Building	Interdiction and Disruption	Risk Assessment	Supply Chain Integrity and Security	Information Sharing	Operational Coordination	Public Information and Warning	Planning	Threat and Hazards Identification	Environment Protection Services	Human Protection Services
V-BEOC	25	25	25	25	22.5	17.5	25	25	25	25	25	25	25	25
Multi-State Fleet Response Initiative	25	25	25	25	20	17.5	25	25	25	25	25	25	25	25
ESSMA	25	25	25	25	22.5	17.5	25	25	25	25	25	25	25	25
CRAMSS	25	25	25	25	20	17.5	25	25	25	22.5	25	25	25	25
TTF	20	25	25	25	25	25	25	20	22.5	20	25	25	22.5	25
Colab	20	25	25	25	25	25	25	20	22.5	20	25	25	22.5	25
Opportunity Assessment Tool	22.5	25	25	25	25	25	25	20	25	20	25	25	25	25
Problem Framing	22.5	20	25	25	25	25	22.5	20	25	20	22.5	25	25	25
DOMINO	20	25	20	22.5	25	25	22,5	20	22.5	20	20	22.5	22.5	20
GRRASP	20	25	20	22.5	25	25	22.5	20	22.5	20	20	22.5	22.5	20

6. Conclusions

The primary objective of the present study was to contribute to the ongoing scientific and managerial effort in enhancing CIR by developing a comprehensive classification and assessment framework for a robust multidimensional comparison of GPs. In particular, the analysis led to a better understanding of how a specific GP may support the deployment of different EM capabilities and its possible limitations in terms of practical implementation and transferability. It is important to highlight that the use of the comprehensive framework can be extended to the classification and assessment of GPs not included in our analysis – the framework structure is easily applicable on both existing CIR GPs and emerging ones.

Practitioners can use the proposed framework to compare GPs and select the most suitable ones according to the context of application and other applicable requirements. In this regard, the main contribution is given by the EM capabilities framework which allows practitioners to select the BPs, given the range of capabilities covered and the expected level of improvement. From the analyses carried out, it is possible not only to identify the GPs, but also to understand the potential for improvements of each GP already in place. To further develop the study, the identification of the different clusters in order to group the GPs would be effective. Indeed, when searching for the composition of a possible optimal bundle, to cover all the capabilities with the lowest number of GPs, it would be necessary to gather GPs belonging to different clusters.

Finally, the classification dimensions of the GPs adopted in the framework can support practitioners in the understanding of GPs key features, so as to avoid overlaps or conflicting factors and exploit possible synergies.

However, the present study still has some limitations. The most relevant one concerns the robustness of the results obtained from the online questionnaire. Indeed, the number of feedbacks received was limited due to time constraints and involving a higher number of CI experts could have guaranteed a greater consistency of the results. Moreover, an issue that emerged during the design of the CIR questionnaire is that the two taxonomies of the Activities & Functionalities and of the EM capabilities are not fully orthogonal and this may induce some ambiguities if used only by labels.

In the near future the study will be extended by submitting the questionnaire to further CIR experts and try to increase the rate of responses. From a methodological point of view, an algorithm will be developed to identify the optimal bundle of GPs to fully cover the spectrum of EM capabilities in a balanced way, when designing a new CIR program or improving an existing one.

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