

Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

International Journal of Disaster Risk Reduction

journal homepage: www.elsevier.com/locate/ijdr

Revealing resilience features: Analyzing informal solutions adopted in emergency situations

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ARTICLE INFO

Keywords:

Community resilience
 Informal solutions
 Formalization process
 Emergency responders

ABSTRACT

Emergency organizations have pre-established plans and procedures to handle disaster situations, but these formal solutions may not always work due to the unpredictable and complex nature of disasters. In such cases, emergency personnel improvise and adapt to new situations, adopting informal disaster response mechanisms/actions without being certain of their effectiveness. Therefore, beyond plans and procedures (formal solutions) it is crucial to prepare and train emergency responders by strengthening their improvisation and adaptation skills to implement informal solutions when unexpected situations arise.

This paper aims to analyze how knowledge gained from implementing informal solutions can be used to enhance planning and preparedness for future events. To do so, semi-structured interviews with emergency experts from emergency organizations and authorities, Non-Governmental Organizations (NGOs), and the private sector were conducted. As a result, this paper first identifies four critical factors that contribute to the adoption and implementation of informal solutions in emergency response: uncertainty, legal framework, stakeholders, and bureaucratic delay. Secondly, this paper proposes a formalization framework to better leverage the benefits of informal solutions for emergency preparedness. The framework consists of three components: 1) Informality drivers that push toward the emergence of informal solutions, 2) Formalization enablers that facilitate the formalization process, and 3) formalization barriers that impede the transformation of informal into formal solutions.

1. Introduction

The world is witnessing a surge in the frequency and intensity of disasters, such as floods, wildfires, and earthquakes [1]. These events cause significant damage to infrastructure, natural resources, and human lives, often leading to long-term socio-economic impacts. To effectively address such situations, communities need to be resilient. Different fields of study, such as engineering, economics, ecology, and the social sciences, have explored the concept of resilience while tailoring its definitions to align with each of these disciplines' unique perspectives [2,3]. Focusing on specifically community resilience, it could be defined as "the ability of a social system to respond and recover from disasters and includes those inherent conditions that allow the system to absorb impacts and cope with the event, as well as post-event adaptive processes that facilitate the ability of the system to re-organize, change, and learn in response to the event" [4]. This entails not only being well-prepared to prevent the occurrence of disasters, but also planning to respond to, absorb, and recover from them [5,6]. To be able to cope with disasters, emergency organizations rely on predefined plans and pro-

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cedures designed to handle disaster situations, which are applied by formal emergency actors and provide formal solutions for disaster management.

However, as disasters become increasingly large-scale, complex, and uncertain, these formal solutions do not always work [7,8]. Disasters often evolve in unpredictable ways, rendering the existing plans and procedures unsuitable or insufficient for dealing with the disaster [7,8]. In these situations, emergency services and authorities are required to deviate from established protocols when confronted with an unmanageable situation, necessitating their ability to improvise and adapt to new situations [9].

In such cases, informal disaster response mechanisms are put in place to deal with unexpected situations [10,11]. These informal responses include informal procedures that were not previously planned and could be initiated by formal actors from emergency organizations [10], informal actors such as emergent volunteers [12], or both [11]. In this paper, we will focus on the informal actions developed/implemented by formal actors since several studies already cover the informal actions implemented by nonstate actors and emergent volunteers [12–14]. We initially define informal solutions as the informal actions that are created or defined on the fly without being certain of their effectiveness in dealing with the situation.

This paper posits that having the ability to adopt informal solutions is a sign of the resilience of an emergency response team to deal with unpredictable situations in emergency responses. As part of the way resilience is conceptualized, it involves regarding disruptions within socio-ecological systems as opportunities. This perspective associates resilience with the capacity to view disturbances as moments for doing “*new things, for innovation and for development*” [15,16]. This view encompasses the concept that unforeseen events are unavoidable in any system, and resilience emerges from the ability to adapt to uncertainty and coexist with it [16]. Taking this into account, the main research question this paper attempts to answer is: How can we capitalize on informality to enhance community resilience? To answer this question, we have two sub-questions:

SRQ1. What are the characteristics of informal solutions and how do they appear during emergencies?

SRQ2. How do these informal solutions help to improve our capacity to respond to disasters more effectively and efficiently?

In this vein, our hypothesis is that creating and implementing informal solutions can be seen as an indicator of resilience as it contributes to the three main constructs of resilience (preparedness, response, and adaptation). When faced with unexpected situations, informal solutions enable a prompt response to emergencies and facilitate adaptation to new circumstances, as addressed by the first research question. Additionally, the knowledge gained from implementing informal solutions can be used to prepare for future events, as examined by the second research question. Thus, informality can be seen as a reflection of society's capacity to handle disasters, as it is a manifestation of the adaptability, responsiveness, and preparedness constructs of resilience.

Hence, the goal of this paper is two-fold. First, we want to analyze the causes that drive the adoption of informal solutions within overly critical and highly regulated procedural environments such as emergency response settings. With these causes identified and analyzed, we want to use this knowledge to develop better emergency planning and preparedness. Directly connected to preparedness, our second goal is to develop a formalization process that could help capitalize on the benefits of informal solutions to be better prepared for emergencies.

This research was developed in the context of ENGAGE, a European project funded by the Horizon 2020 program. The ENGAGE project builds upon the inherent capacities of society to face crises by enhancing the interaction between emergency organizations and members of society. To achieve the goals of the paper, interviews were conducted with emergency management experts in the context of the ENGAGE European project. The information obtained was complemented with a literature review.

The remaining sections of this paper are structured as follows: Initially, we provide an overview of existing research on improvisation and informality in disaster response. Following that, in Section 3, we explain the methodology utilized for collecting and examining the interview data in detail. In Section 4, we present the outcomes of the interviews and then proceed to discuss our findings. Lastly, in Section 6, we offer our conclusions.

2. Background

Disasters are becoming increasingly complex and uncertain; therefore, improving disaster management is of utmost importance. According to UNDRR, disaster management could be defined as “the organization, planning, and application of measures preparing for, responding to, and recovering from disasters” [17]. Disaster management includes a wide range of stakeholders [18] with different levels of responsibilities and formalities. On the informal side, there are normal citizens and volunteer groups, and on the formal side, there are highly organized non-governmental organizations (NGOs), emergency organizations, and the government [19]. Apart from the stakeholders, there are also different procedures to handle a disaster that differ in their level of formality [19].

On the formal side are formal structures composed of formal disaster response agencies (governmental-level emergency management departments and agencies, first responders, and institutionalized nonprofit organizations) that are coordinated through established formal rules and based on historical collaboration, trust, and intergovernmental political dynamics to manage and respond to disasters [9,20–22]. The formal agencies follow previously established laws, policies, procedures, and mutual aid agreements to respond to disasters, each organization having specific roles and responsibilities and specifying the resources that need to be mobilized and deployed. These formal response activities lead to the creation of a wide range of products and services, such as early warning systems, public information on emergency services, disaster awareness, and preparedness campaigns, mass care services, and search and rescue missions, which are referred to as formal solutions. In this formal environment, the emergency services tend to follow the already established emergency response procedures since deviation from them could lead to bad consequences that may involve legal liability [23].

However, formal disaster response presents several limitations when disasters evolve in unpredictable ways and the pre-established plans and procedures are inadequate or insufficient for effectively managing the disaster. These formal strategies work well for dealing with small-scale or routine emergencies that are well-defined and consistent with the established plans and procedures. However, their effectiveness decreases when dealing with large-scale, catastrophic disasters that involve multiple hazards occurring sequentially in a short time and involve multiple response agents [7,8]. The hierarchical and centralized structures of formal agencies lack the ability to be flexible in taking action, delay the decision-making process, and might not reach the most vulnerable people [19].

Therefore, according to Ref. [9], emergency response organizations should be prepared to improvise during emergency response activities and adapt to unexpected situations that may arise and impact their planned activities.

Improvisation and adaptation have become inherent features of disasters today. As Tierney argues, if improvisation is not needed in response to an event, then it is unlikely to be a disaster [24]. Improvisation is “the spontaneous and creative process of attempting to achieve an objective in a new way” [25]. Improvisation holds a crucial place in emergency management, as it relies on the resources and capacities of training, practical experiences, and a deep understanding of both the emergency services and community to deal with unpredictable and ever-changing conditions of a disaster, where not all possibilities have been foreseen or prepared for [23]. Adaptation, in turn, is defined as the process of changing from previously established routines and finding ways to allocate roles and resources to assist in resolving emergency requirements [26–28]. In the face of uncertainty, improvising from scratch may imply a huge risk, and therefore, ways to mitigate these risks and remove uncertainty from untried actions are necessary. In this regard, adaptation provides a means for meeting an uncertain situation, drawing on previously tested and successful activities applied in other comparable situations, reducing the risks and allowing for a level of confidence [28].

Improvisation can manifest at different levels, encompassing the individual and organizational levels [29]. Individual improvisation involves employees adapting their tasks in real-time based on emerging information or devising innovative solutions to challenges. Organizational-level improvisation encompasses both the organization’s overall capacity for improvisation and the institutionalization of structures or practices that facilitate improvisation within the organization. Essentially, it signifies improvisation by either the organization itself or its individual members [29,30]. Organizational-level improvisation can either result from the aggregation of individual improvisations or represent an inherently collective and seamless process. Ultimately, it falls upon the organization to foster an appropriate culture and environment to promote improvisation and innovation [31]. In this sense, this paper emphasizes this interchangeable relationship between individual and organizational-level improvisation.

Although both adaptation and improvisation converge in many aspects, they diverge in others. In order to adapt, there should be an external triggering event that forces the response teams to change their way of dealing with disasters. On the other hand, improvisation can occur without any external triggering event. Another divergent aspect is time, which takes on an ontological nature in the concept of improvisation. Improvisation implies that actions are planned and executed at the same time, whereas adaptation allows for the planning and execution of actions at different times [32]. The act of improvising disaster response actions can span from minor adjustments to a complete overhaul or modification [33]. In other words, improvisation can encompass anything from the basic substitution of initially intended personnel and equipment to more substantial alterations, including the creation of entirely new protocols [34]. These kinds of improvisation and adaptation are expressed through informal actions.

In practice, response operations work along a continuum from formal response management to informal response management based on the magnitude and nature of the disaster. Emergency responders must be ready to improvise while concurrently adhering to well-structured planning to minimize the necessity for improvisation [35]. As a result, we propose the following matrix (see Fig. 1) to

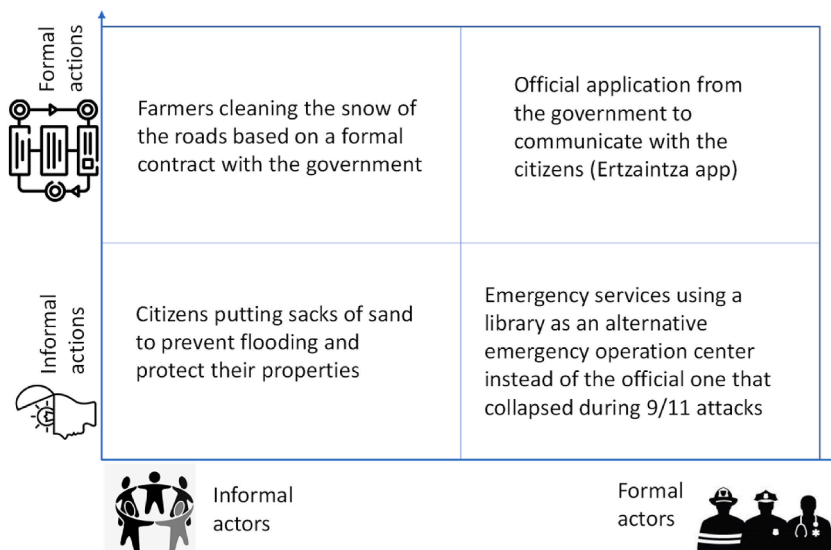


Fig. 1. Two-dimensional matrix to differentiate between formal and informal disaster response.

explain the formal and informal disaster responses based on two dimensions: the formality level of the stakeholders involved in disaster management, and the formality level of the actions and tools used to deal with the events.

The bottom-left quadrant represents the case of informal actors conducting an action that is not formally established to deal with floods. This is a totally informal response situation involving informal actors undertaking an informal action. The top-left quadrant represents the case of informal actors conducting a formal action: clearing the roads of snow through a previously established contract. This response situation is neither a totally formal nor totally informal solution but rather falls in the continuum between the two. The bottom-right quadrant represents a similar situation but in the opposite direction. The actors involved are formal but are putting into practice an improvised action to substitute the collapsed emergency operation center. In this case, a local public resource (a library) was accommodated to become an alternative emergency operation center to help maintain the formal coordination of the response operations. Lastly, the top-right quadrant represents a totally formal response situation, in which the actors are formal and are using an official tool to communicate with the public.

This paper focuses on the bottom-right quadrant, namely, formal actors implementing informal or improvised actions not established beforehand to adapt to unexpected situations. Thus, this paper aims to explore the potential of informality to improve the capacity to respond to disasters and build resilience. We will first define the specific characteristics of informal solutions and how they arise when improvising and adapting to new emergencies. Subsequently, we will explore how these informal solutions contribute to gaining knowledge, enabling better preparedness for future emergency events.

3. Methodology

The primary source of data for this study is semi-structured interviews. Semi-structured interviews allow for a thorough understanding of the topic under investigation and the exploration of topics that diverge from the pre-defined set of questions. The results obtained from the semi-structured interviews were complemented and triangularized with the literature.

3.1. Data collection

We conducted interviews with emergency experts who work in formal emergency organizations. These experts were members of the Knowledge and Innovation Community of Practice (KI-CoP) of the ENGAGE project. KI-CoP is a community of practice that involves organizations related to disaster management and provides support and guidance to the ENGAGE project activities and results. These organizations cover emergency organizations and authorities, non-governmental organizations (NGOs), and the private sector which have a direct relationship with emergencies, for example, developing technological solutions for disaster management. In total, we conducted nine interviews. Table 4 in the Appendix shows the distribution of the experts among the different job profiles and countries. In the case of semi-structured interviews, the minimum number of participants required for ensuring the validity of the results may vary and it depends on the expertise level of the participants as well as on the theme under study [36]. In general, in collaborative research methodologies such as the Delphi panel considering a heterogeneous population, 5 to 16 participants is enough [37–39]. In this research, after these nine interviews, a point of saturation was reached where the data collection no longer was generating new inputs to the questions [40,41]. The participants were selected in order to represent the diversity of emergency organizations: two of them were conducted with first responders, another two with authorities, three with experts from private companies providing consultancy to emergency services, and the last two with members of NGOs involved in emergency management. The interviews were conducted by members of the ENGAGE project. Before the interview, we sent emails to the potential interviewees asking them to participate. In the email, we attached the information sheet explaining the aim of the interview and the whole process. Additionally, we attached a consent form for them to sign if they agreed to participate. Participants had the right to withdraw from the interview at any time. The interviews were conducted in September 2022, and the duration of each interview was between 60 and 90 min. To guarantee the reliability of the collected information, the interviews were conducted by two researchers; they were audio-recorded and later transcribed into a specific template to facilitate the analysis process. All the interviews were done in English.

3.2. Interview script

The interview was divided into four main parts. First, a reflection on the experience of the participants: their relationship with emergencies, the different positions they held, and the different communities they worked in. The second part is related to the definition of informal solutions, and the differentiation between formal and informal. To study this difference, we conducted a short survey with five examples, asking the participants to rate the solution from 1 to 5, where 1 means extremely informal, and 5 extremely formal. The list of the examples serve as a starting point for engaging the interviewees in discussions about informality. The examples were carefully selected based on specific aspects to ensure they reflect the diversity of informal solutions encountered in emergency settings. These aspects include the main actors involved in the solution, the adherence to officially documented protocols, and the planning of the solution usage. How the selected examples relates to these aspects is presented in Table 5 in the appendix. The examples used for the analysis can be found in Table 1.

The third part of the interview is related to the participant's experience with informal solutions; if they applied them before, why, when, how, and what were the limitations? The fourth part covers the process of formalizing the informal solutions as part of decreasing their disadvantages or limitations. The interview questions are included in the Appendix.

3.3. Analysis

We conducted a thematic analysis [42,43] to process the data from the interviews. The utilization of thematic analysis as a qualitative research methodology is growing in popularity in the academic community [44]. This increasing popularity can be attributed to

Table 1
Examples used for exploring the definition of formal and informal solutions.

#	Title	Description
Ex1	Shortage of surgical masks	During COVID-19 peak times, healthcare workers used homemade cloth masks and reused the surgical masks after treating them with different techniques such as UV rays.
Ex2	COVID-19 bed availability	When COVID-19 hit, it was a tough situation in the emergency units in hospitals, there were no available beds for patients. So, a doctor in an Italian hospital decided to visit his patients at their houses and give them the needed treatment. Then, other hospital staff joined this doctor in his work and visited more patients. The hospital and donors provided the needed resources for the doctors' work to continue. In general, this is a standard procedure for compromised patients, however, in the case of COVID 19 the problem was not related to the patients themselves but the hospital's over-saturation.
Ex3	Firefighters' follow-up calls	During a crisis, the fire department officials alert the regional operative cluster by calling the halls of operation instead of using email which was the main channel of communication in the established protocol. They also send an official email to track the action. After 15 min they call the regional operative cluster again to know if they received the email properly.
Ex4	Church bell	Using the church bell to alert the population during a crisis. In small towns, the city hall or the mayor contacts the priest to inform him that there is an emergency, and the priest rings the church bell to alert the population.
Ex5	The Basque police app	The main objective of the application is to create a communication channel between citizens and the Basque police. The application facilitates new means of communication with the police through any mobile device and through various channels such as SMS, email, telephone, or WhatsApp.

its systematic and flexible approach for processing qualitative data [45]; transcending the mere quantification of words and phrases, offering a comprehensive description of the phenomena under investigation [46]. Furthermore, its ease of application and theoretical adaptability make it suitable for a wide range of research domains [43]. While the process of thematic analysis is often depicted as a linear procedure, it is, in reality, an iterative one involving a back-and-forth movement between various stages until convergence is achieved [43]. When executed correctly within this iterative framework, thematic analysis yields results that are trustworthy (according to established criteria in Refs. [43,47]). To conduct the thematic analysis we applied the following steps:

1. Data familiarization: Scan all the interview templates to gain an understanding of the participants' opinions.
2. Initial coding: Reread the templates and assign initial codes to the data snippets.
3. Code merging: Combine all the similar codes.
4. Theme identification: Group the related codes into themes.
5. Theme revision: Determine if the identified themes are a good representation of the associated codes, as well as do any necessary merging, deletion, and creation.
6. Theme naming: Assign coherent and presentable names to each of the identified themes.

It is important to highlight that our analysis is guided by the main parts of the interview and the questions covered in each. Therefore, the general themes are the same as the questions, although we came up with sub-themes under each of the questions. For example, if we are asking about the formalization process (the main theme), "the barriers" of the process is a sub-theme, "the enablers" of the process is another, and so on; the codes are going to be the barriers themselves of the enablers themselves; for example, availability of resources is an enabler of the formalization process.

4. Results

In this section, we will cover the two main aspects covered in the interviews. First, the criteria of informality/formality: What factors are used to differentiate between a formal solution and an informal solution, what are the characteristics of informal solutions and how do they appear during emergencies? We will be reflecting on the results from the scaling exercise in the interviews (the second part of the interviews). Second, the formalization framework is presented as a way to improve our capacity to respond to disasters more effectively (the fourth part of the interviews).

4.1. Criteria for informality

During the second part of the interviews, we asked the participants to rate five solutions on a scale of extremely informal to extremely formal. Figs. 2–6 show the distribution of answers across the different solutions. In each of the figures, the text above the columns highlights the main comments of the responders. Concerning example one (Fig. 2), all the responses tend to define the solution as informal, except for one interviewee (I7) who defined the solution as extremely formal, as it was approved by the World Health Organization (WHO). The responder justified his point of view as follows "I consider this solution is extremely formal as it was announced by the WHO, it was an official recommendation by an international body which has the maximum accountability in the health sector" While conducting the interviews, the participants emphasized the significance of the time frame associated with the solution. They highlighted that considering the short-term perspective categorizes it as an informal solution. However, as the time frame extends to the long-term, the solution transitions towards formality, becoming part of a formal procedure and obtaining approval from governing entities. One responder commented "Things are on a scale. Things that are informal at some point can become formal etc. It is fluid."

While there is a strong agreement that the first example tends to be informal, this is not the case for the second one (Fig. 3). According to participant I4, this solution is informal, "as it is pragmatic innovative, and not part of the emergency planning system". Other participants justified the informality because the solution is not legally backed, for example, interviewee I1 said "It's without legal packing. It's the medical sector themselves – they are the owner of the solution"; participant I5 mentioned a reason closely tied to the patients themselves, expressing that they will see this as an informal procedure as they do not go to the hospital, where they are sup-

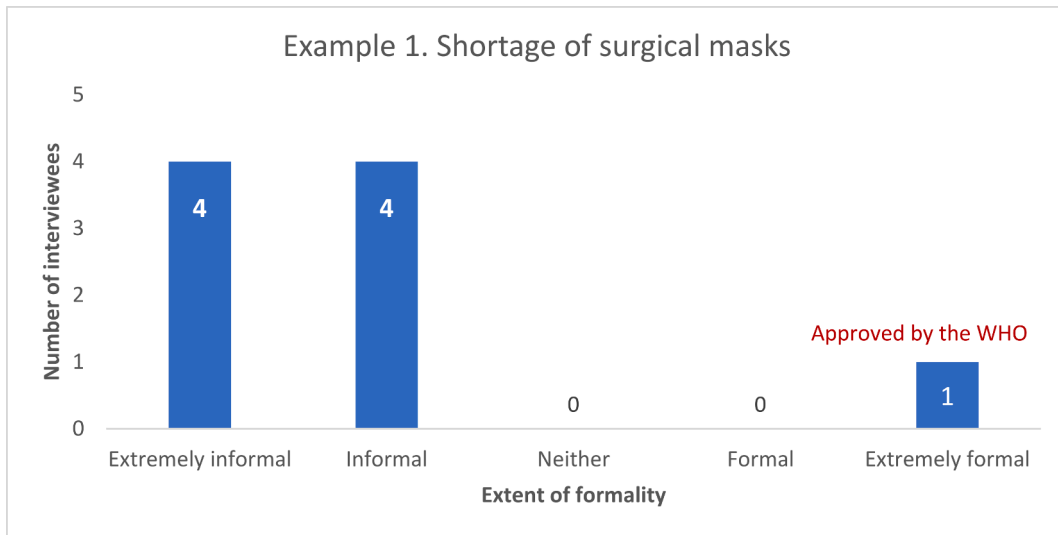


Fig. 2. Distribution of responses among the interviewees rating the first example on a scale from extremely informal to extremely formal.

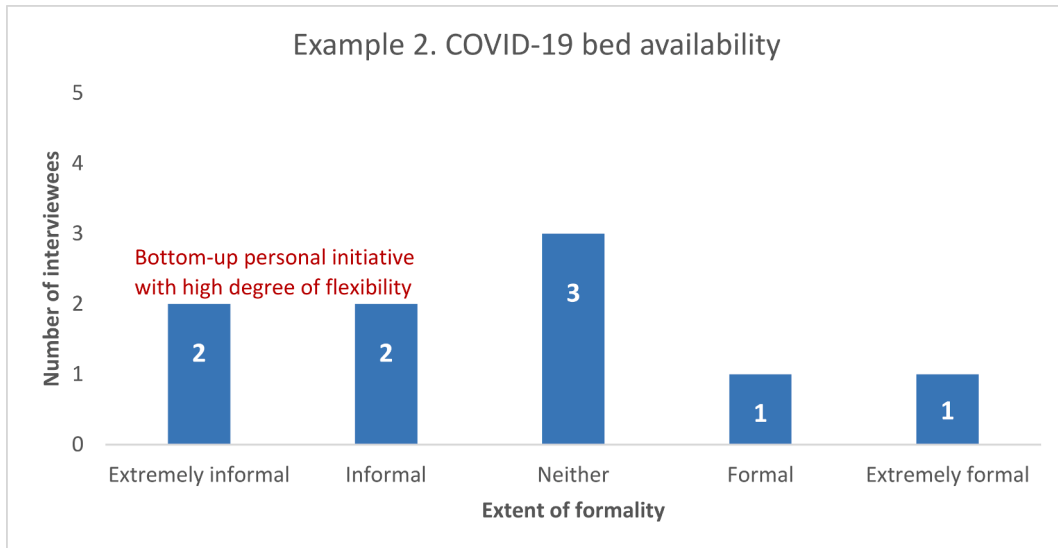


Fig. 3. Distribution of responses among the interviewees rating the second example on a scale from extremely informal to extremely formal.

posed to receive the necessary treatment. The participants who considered the solution as “extremely informal” justified this because the solution was initiated by a single doctor – a bottom-up approach – with a high degree of flexibility. I8 said, “*This initiative is a personal effort by the doctor. If it were a hospital-led initiative, the solution would be considered formal, as there would be established mechanisms for control and monitoring*”. However, some responders highlighted that this could depend on the place or the country. Interviewee (I3) said, “*In some places this is something that is not totally new, in house visits are not uncommon. This solution was already there*”. He believed that in these cases the solution would have been formal.

Regarding example 3 (Fig. 4), the participants were almost equally divided between formal and informal. Those who defined the solution on the informality side said that this is because the solution is not part of the formalized protocol, although it increases the flexibility of the formal procedure. According to I8, this is a solution coming from “*an angry citizen*” who is annoyed by the bureaucracy of the formal procedure. The interviewees who placed the solution on the formal side highlighted that the firefighters already use the formal procedure, sending emails, and they use the calls as an extra step to facilitate the work. I1 said “*it is a replicable, transferable solution that enhances the response process and at the same time, it is easy to track the calls and identify the ownership (responsible person), as ownership is the important aspect in this situation*”. I3 adds that “*the calls make things easier and reduce the number of painful confirmations that take place during these events.*”

Concerning the church bell example (Fig. 5), the responses tend toward the informal side. I7 stated “*The church is very important in rural areas besides the mayor and the school. However, It is informal because it is not legalized, and there is no legal responsibility on the church if it doesn't ring the bell.*” The participants mentioned that it could be considered a formal solution as it follows a well-defined

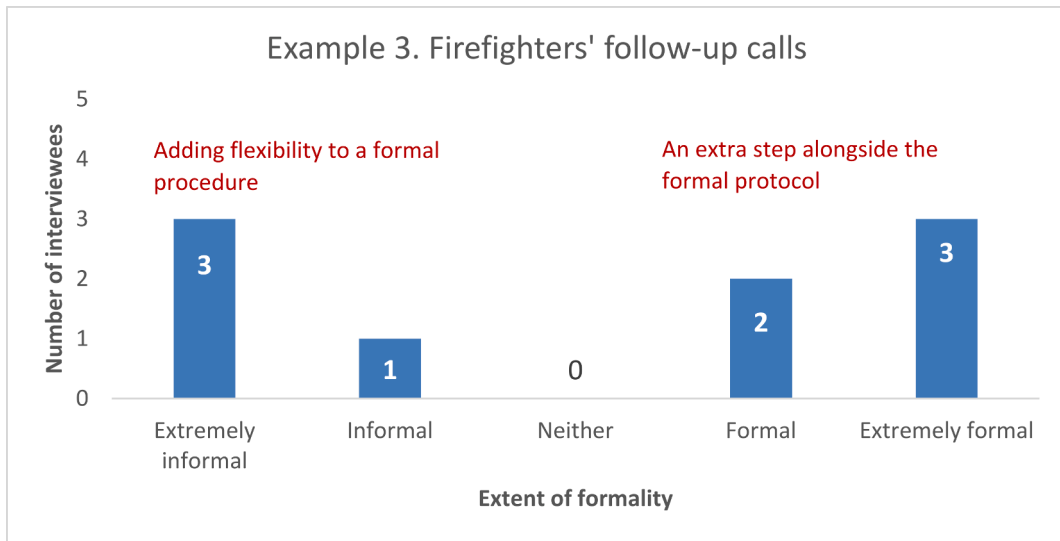


Fig. 4. Distribution of responses among the interviewees rating the third example on a scale from extremely informal to extremely formal.

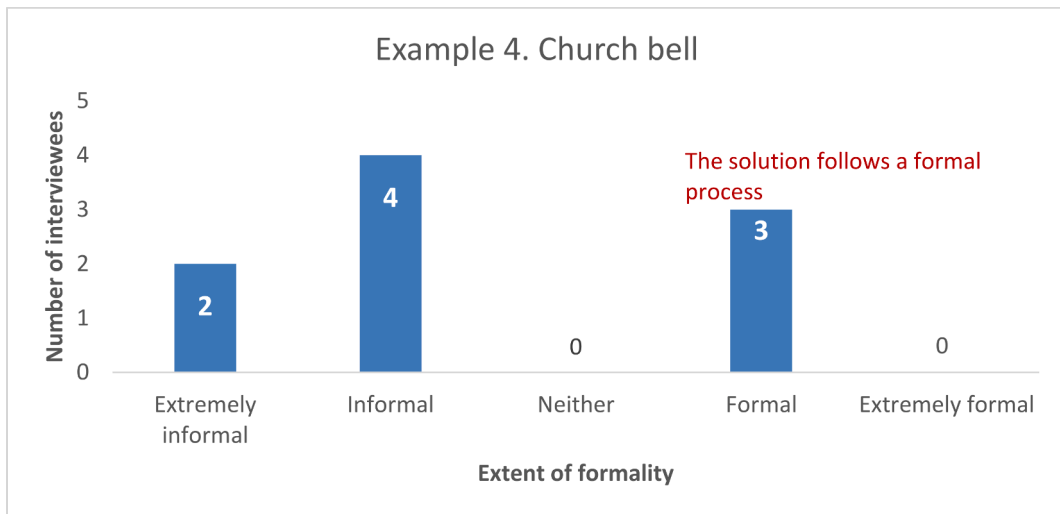


Fig. 5. Distribution of responses among the interviewees rating the fourth example on a scale from extremely informal to extremely formal.

procedure and is replicable and repeatable; it is formalized in other places. Moreover, it is effective in alerting the population when a crisis occurs.

Regarding the last example, the Basque police application (Fig. 6), the solution falls on the formal side. I2 provided the following reasons for classifying the solution as formal “because the regulations/guidelines, the ownership belongs to the authorities, they are using the app and they have a legal responsibility as well for what kind of information the app is gathering and what information to give to the public.” Interviewee I9 rated the solution as formal rather than extremely formal because the public is not legally required to use the application. He justified his opinion as follows “It is also informal. Citizens are under no obligation to use the app. The police have a legal obligation to provide correct information. The feedback from citizens is informal, but the information uploaded by the police is formal.”

During the interviews, while discussing the previously mentioned examples and applying the thematic analysis, it was found that the participants placed particular emphasis on four key criteria when discussing informality in emergency response settings. These criteria include uncertainty, legal framework, stakeholders, and bureaucratic delay. These aspects were identified as critical factors that contribute to the adoption and implementation of informal solutions in emergency response. Concerning uncertainty, the interviewees mentioned that solutions are informal when the situation is vague; hence, there is no plan or formal solution at hand to handle these new situations. I4 affirmed that “The informal solutions are opportunistic, unplanned, not part of emergency planning system (not part of protocol), more innovations and more opportunistic”. Moreover, due to uncertainty, pre-planned solutions are susceptible to failure. Uncertainty usually leads to improvisation and following a person's instinct. I9 explained the risks of adopting informal solutions individually without the endorsement of the whole chain of command “Individual initiatives without a global vision lead to lack of coordination ... autonomous decisions are very dangerous.” Moreover, informality appears in certain situations and special cases that do not

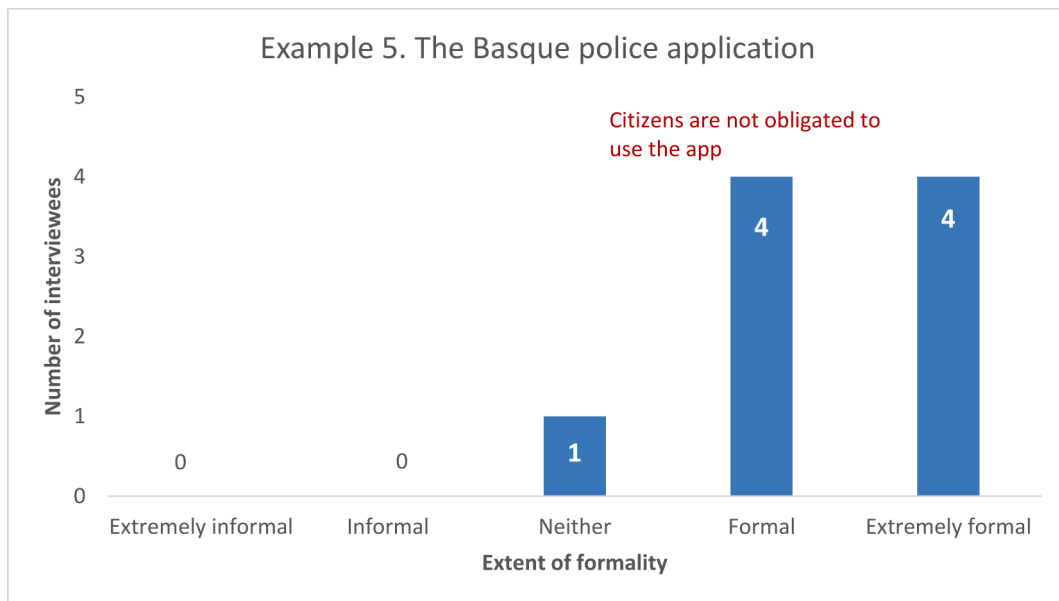


Fig. 6. Distribution of responses among the interviewees rating the fifth example on a scale from extremely informal to extremely formal.

follow a generalized procedure. I8 explained in what situations the informal solutions are originated “because the common/ordinary solutions are not available then we need to develop new solutions.”. As for the legal framework, the participants highlighted that solutions are informal when they are not backed by a legal framework or a governing structure. I9 believed that “Formality requires legal responsibility and enforceability”. In the same vein, I4 stated that “Formal solutions are following a protocol in management”. Informality also appears when the stakeholder who is taking the action has no legal responsibility neither accountability for anything that could happen. Many participants commented on this issue in the example, of the priest in the church bell. I7 stated the following “It is informal because it is not legalized, and there is no legal responsibility on the church if it doesn't ring the bell.” In other words, the less accountability the stakeholder has, the more informal the solution. The interviewees highlighted that the informal solutions are initiated by individuals. “If the solution come from a bottom up then it is considered informal.” was stated by I8. These individuals can be citizens who are not affiliated with any emergency organization or emergency responders who try to improvise to contain the crisis or are motivated by frustration with bureaucracy and the sluggishness of formal solutions. This leads to the aspect of bureaucratic delay; informal solutions are faster and more flexible than formal solutions. I3 stated that “When you increase the flexibility of a formal procedure (because you need to adapt to new situations), you make it more informal.” Table 2 summarizes these results. While the criteria presented in the table do provide a framework for evaluating the formality or informality of solutions, it is important to recognize that they are inherent aspects of the context that shape the formality or informality of the solution. The context determines the level of uncertainty, the stakeholders accountable for the solution, the legal ramifications, the governing structure, and the flexibility and adaptability of the emergency response system.

4.2. Formalization framework

The second idea addressed in this section is the formalization framework (Fig. 7). This framework was created based on the answers gathered from the interviewees in the third part of the questionnaire. In this part, we asked the participants about the situations in which informal solutions are adopted, the factors that favor as well as the barriers that hamper their adoption and implementation. These results were used to nurture the formalization framework. The framework covers three components: informality drivers, for-

Table 2
Summary of criteria of informality identified through the interviews.

Criteria	Related aspects
Uncertainty	<ul style="list-style-type: none"> • No plan or formal solution at hand • New situations • A preplanned solution fails • Special cases that do not follow a generalized procedure • Improvisation
Legalization	<ul style="list-style-type: none"> • No governing structure • No legal responsibility
Stakeholders	<ul style="list-style-type: none"> • Individuals who are less accountable
Bureaucratic delay	<ul style="list-style-type: none"> • Informal solutions are more flexible • Informal solutions are faster

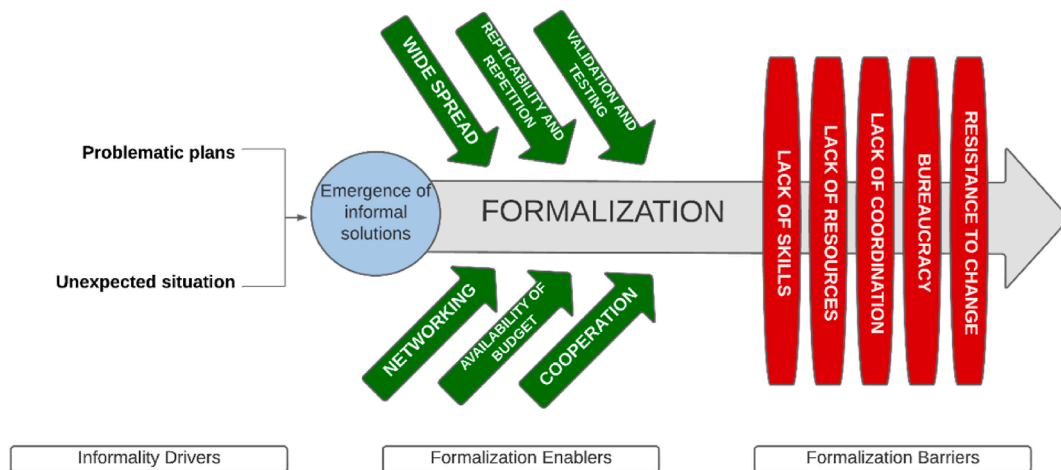


Fig. 7. Formalization framework.

malization enablers, and formalization barriers. Informality drivers are the key factors that propel the emergence of informal solutions. Formalization enablers are the aspects that facilitate the formalization process or transform informal solutions into formal ones included as part of formal response procedure. Lastly, formalization barriers act as the opposing force to the enablers; they are the factors that impede the transformation of informal solutions into formal ones. These three components were identified in the last part of the interviews.

Informality drivers cover two main categories: problematic plans and unexpected situations. Problems with the plans include: 1) Bad planning (usual situations not included in the plan), 2) The plan is not working (lack of resources when needed, unexpected action outcomes, unexpected situation, unpredicted events, etc.), 3) The situation does not match the plan prediction, 4) Lack of training – unable to respond adequately. Unexpected situations cover: 1) Overwhelming emergencies, 2) Unprecedented situations, 3) Lack of resources not as a result of bad planning, but because of an unexpected event; for example, if a road leading to the emergency scene is blocked, it is impossible for the necessary equipment to reach the location.

The formalization enablers cover two sets of factors. The first set is related to the solution itself, which covers aspects such as the extent to which the solution is replicable and repeated; the frequency at which the solution is used; and if the solution is valid and effective. For instance, participant I8, mentions “Using the informal solution repeatedly makes the solution to become formal.” The second set is related to the implementation aspect of the solution, such as budget availability, cooperation, and networking efforts among different stakeholders. For example, interviewee I2, stated “If I said that budget or corporation isn’t important, I would be lying ... it is important. Volunteer organizations are not involved without money or cooperation. It is also important to be in touch with different types of demography from the community. They know what the community needs and what works and what does not. We affect them. We want to make them stay in a place. It is important for us. As a volunteer organization we are in need of funding. We need formalization because in this context we can show and tell and this can affect in this way. We are quite in need for reports and formal solutions that will show us as serious actors for the municipality.”

The last component of the framework includes the barriers to transforming informal solutions into formal ones. These barriers include the lack of skills to implement the solution and the lack of resources, whether financial, human, or equipment, etc. Many interviewees emphasized this barrier, concretely, I2 said: “If I said that budget or corporation isn’t important I would be lying. It’s important. Volunteer organizations are not involved without money or cooperation”. Another significant barrier is bureaucracy, which entails the need to navigate multiple layers of management, paperwork, red tape, inflexibility, and approvals just to change a single procedure; this cumbersome process of change discourages people from trying to pursue it. In relation to this, interviewee 3 mentioned “The government not willing to admit that they need help, bureaucratic struggles.” Resistance to change and lack of coordination are also barriers to the formalization process.

5. Discussion

Based on the findings derived from the interview data and supplemented by existing literature, we have established a conceptual framework for informal solutions, delineating their specific attributes. Additionally, we have differentiated between formal and informal solutions. Finally, how informality fosters resilience is described as well as how the informality can be built through improvisation and adaptation.

5.1. Definition of informal solutions

In this research, we describe the formality level of disaster response based on two dimensions: the actors who implement the solution and the extent to which the activities and tools used to deal with the events were previously established (see Fig. 1). Specifically, in this paper, we discuss informal actions developed or implemented by formal actors. Below, we describe in detail the characteristics of informal solutions addressed in this paper. This definition is based on the findings of the interviews.

5.1.1. Who implements informal solutions?

These solutions are created, managed, and implemented by formal response groups, such as first responders, emergency managers, authorities responsible for disaster management, and organized volunteer organizations. However, for a solution to be considered informal, it should be different from already established and planned solutions. Many times, the difference is not huge; some minor deviations can make a solution become informal if it is not implemented as expected. This normally depends on the magnitude of the disaster. When the situation is completely unexpected and unplanned, then the improvisation comes from a strategic level and disaster managers must implement informal actions. When a disaster is anticipated but operational-level improvisation becomes necessary, it is the first-line responders who adapt to the situation and implement informal actions to deal with the situation.

5.1.2. Why and when are informal solutions applied?

Formal actors adopt informal solutions in the following situations:

- Poor planning and preparedness: although knowledge about the situation exists, there are no formal solutions already developed or incorporated in the response plan, and emergency responders are forced to adopt informal solutions whose effectiveness has not been tested or validated beforehand.
- Failure of formal plans: in certain situations, formal planning may prove ineffective because the planned resources might not be available. The absence of necessary resources for executing the prescribed formal solution may require the creation and improvisation of alternate informal solutions to address the situation.
- Unpredicted situations: despite efforts to encompass all possible disaster contexts, it is impossible to consider every possible scenario. A lack of information can also give rise to unforeseen situations or incomplete and unreliable information about the disasters. In such situations, informal solutions need to be created and implemented, with no guarantee of their success.

5.1.3. How do formal response groups typically approach the implementation of informal solutions?

In the aforementioned circumstances, when already established and planned solutions are insufficient to deal with situations, alternative solutions should be implemented. These solutions are called informal solutions. However, in general, formal response groups are careful when implementing informal solutions, since they are accountable and legally responsible for possible damage. Overall, they try to utilize formal procedures and only in extraordinary situations, when there is no alternative, do they implement informal solutions. Normally, the more extreme the situation, the more informal the solution since the predefined formal solutions may prove inadequate to address the situation, thereby requiring the development of pragmatic solutions. However, formal responders tend not to diverge significantly from the predefined formal solutions due to legal responsibility and accountability issues. For example, during Hurricane Katrina, the US Coast Guard made several alterations to their standard operational procedures and managed to rescue over 22,000 individuals, surpassing the total number of people they had saved in the previous 50 years. They were only focused on helping people in need without adhering to protocols and were collaborating with a group of civilian boat operators [11]. This is a successful example of implementing informal solutions. In contrast, the decision to deviate from the official disaster response protocol in the case of the Costa Concordia cruise ship resulted in failure with the loss of 30 lives [33].

5.1.4. How does the context affect the implementation of informal solutions?

In general, the context and legal framework can favor or hamper the efforts of formal actors to implement informal solutions [11]. If they have some flexibility in their actions and decisions, they may be better prepared and proactive in creating and implementing informal solutions when the situation becomes complex and difficult to cope with. In this regard, the lack of flexibility provided by the organization to implement informal solutions as well as the legal accountability for possible unintended consequences could hamper the proactivity to adopt and implement informal solutions from emergency responders.

5.2. Difference between formal and informal solutions

Based on the criteria outlined in Table 2 and the definition of informality discussed in the previous section, Table 3 will be used to distinguish between formal and informal solutions. These characteristics have also been described by different authors in the literature [48–53]. By utilizing this approach, we can effectively differentiate between the two types of solutions and gain a better understanding of the unique characteristics and implications of each.

5.3. Informality and resilience

Informality provides means for emergency actors to improvise and adapt to unpredicted or unplanned situations and deal with emergencies. Improvisation implies coming up with new solutions and putting them into action without prior planning or preparation. The distinctive aspect of improvisation is the temporal aspect since the conception and execution of the activity converge in time. Normally, improvisation is associated with urgency [28]. Challenges often arise, leading to the need for urgent action, with little or no time to plan or assess the effectiveness of the improvised action. Therefore, the actions are implemented and created simultaneously [28]. Adaptation represents the system's ability to change its way of performing in response to an external trigger. In order to adapt, it is necessary for an external triggering event to occur, provoking changes in external conditions. During this time, the system needs to be flexible and adjust to these changes, adapting to the new conditions [28]. Although they are different, both converge in the face of unforeseen disaster situations, where established formal solutions prove inadequate to handle the situation and new solutions should be implemented without planning. In this scenario, informality presents a potential avenue to deal with the situation, as it allows for the adoption of and implementation of informal solutions to effectively cope with the disaster. Therefore, informality

Table 3
Formal vs Informal Solutions.

Criteria	Formal	Informal
Uncertainty	It is impossible to predict all situations. In real-life situations, there is always the chance of encountering unexpected situations or achieving favorable results.	When everything formal fails, a response team should not freeze its actions. Informal solutions play a role in this context. Informal solutions can and must be adopted based on guidelines, improvisation techniques, and expertise-based intuition to produce successful solutions.
Legislation	Legislation provides support for actions that are part of official procedures. When something goes wrong, the approach that responders will take becomes unclear due to legal constraints.	Legislation concerning the responsibility of non-official actions can be dubious, even when actions are common sense. This legal grey area can sometimes prevent responders in an emergency from following or adopting certain actions due to potential legal liability.
Bureaucratic delay	For actions to be formally included in a plan, they should undergo a process aimed at effectively integrating them with the plan's objectives and interconnected actions. Designing and testing the collective outcome requires time, as well as documentation and training.	In general, informal actions have undergone validation through practice, attaining integration through systematic success. However, a successful and proven action/procedure takes time to be formally incorporated into the formal plan. In the meantime, it is considered a "de facto" procedure.
Stakeholders	It is assumed that formal stakeholders, i.e., those who are part of the official team, are usually associated with formal procedures, not only because they are an official resource, but also because they have been trained and participated in simulation exercises; however, as seen in Fig. 1, informal stakeholders could also apply formal solutions.	Informal stakeholders, i.e., those involved in unofficial organizations like volunteer groups, are often more commonly associated with informal actions; however, this is not necessarily true, as formal stakeholders may also engage in informal actions when the situation requires (see Fig. 1).

serves as a means when improvisation and adaptation are required. Fig. 8 presents an overview of the relationship between informality, improvisation, adaptation, and resilience.

The ability of emergency services to create, adopt, and implement informal solutions demonstrates their capacity to deal with and bounce back from disasters, adapt to new circumstances, and capitalize on the new possibilities offered. This results in improving the resilience capacity of emergency services. This aligns with the idea that resilience views disturbances as an opportunity for innovation and doing new things [15,16]. This perspective encapsulates the notion that unanticipated occurrences are an inherent aspect of any system, and resilience arises from the capacity to adjust to unpredictability and coexist with it [16]. Therefore, resilience is defined as the capacity of emergency services to be prepared and planned in order to absorb and bounce back from disasters, while also being able to adapt to emerging situations [54] by going beyond pre-established formal solutions and incorporating informal response solutions.

5.4. Being prepared for the next emergency

Preparedness and improvisation are the foundations of effective emergency management, highlighting the need for a balanced approach to emergency management [23]. Together, these two elements can help organizations be better equipped to respond to disasters and other unexpected events. And as long as disasters exist, informality and the need to improvise and adapt will exist [55]. Hence, we need to prepare and train for informality. This can be achieved in two ways. Firstly, by implementing proper planning and

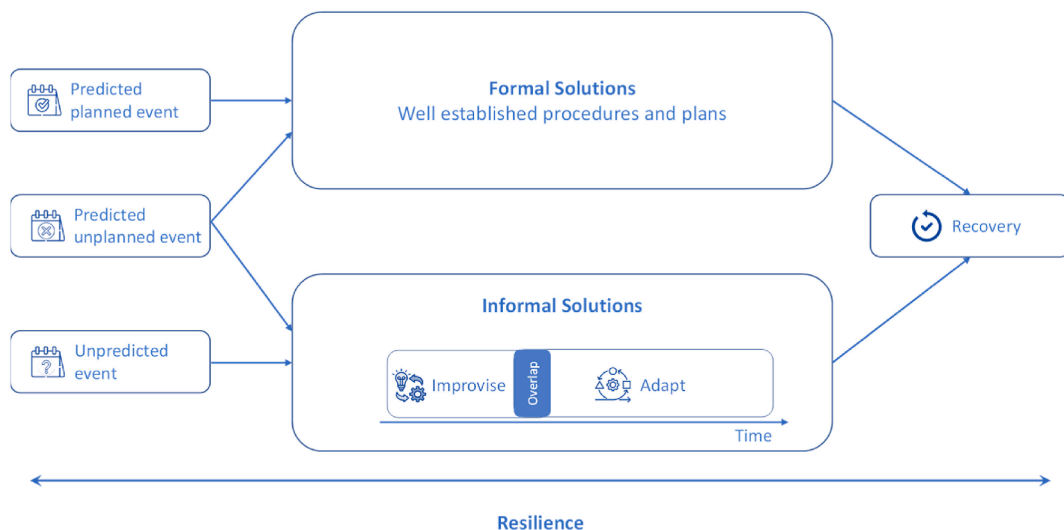


Fig. 8. Relationship between informality, improvisation, adaptation, and resilience.

preparedness for anticipated disasters, or in other words, having formal solutions to minimize the need to improvise. Secondly, by equipping emergency responders with the necessary skills to improvise and adapt when a disaster occurs.

Good planning and preparedness prior to a disaster are critical for effective disaster management. They involve developing plans and procedures, training personnel, and conducting exercises to ensure that response agencies and authorities are ready to respond to disasters quickly and effectively. Good planning helps to decrease the impact of disasters by outlining the appropriate courses of action, assigning the necessary resources, and testing and evaluating the planned procedures/solutions beforehand. Formalizing informal solutions is part of appropriate planning since informal solutions can be fast and effective and they also highlight existing gaps in current formal procedures and plans. Moreover, the need for formalization is driven by the repetition and effectiveness of an informal solution. Effective planning goes beyond simply developing a plan [10]. It should also prioritize shared vision, awareness of strengths and weaknesses, flexibility, and communication, all of which allow for improvisation [10]. In other words, improvisation should be considered as a backup plan that complements detailed planning, with the understanding that some level of improvisation will be necessary for a disaster. As Drabek put it, "We plan in detail so that we do not have to improvise, knowing that we will have to improvise." [35].

Besides being prepared with plans and procedures, emergency responders also need to be trained with the necessary skills to improvise and adapt when unpredicted situations occur. According to Wachtendorf and Kendra [10], a lack of flexibility and creativity can hinder improvisation and the ability to respond to new situations effectively. To avoid these obstacles, emergency responders need to cultivate a culture of curiosity. Approaching problems with a "beginner's mind" and being open and curious is crucial to ensure that no important issues are overlooked. Moreover, emergency responders need to have the authority to make quick and responsive decisions and take action [56]. They also need to create an incentive structure that encourages good performance and accepts honest mistakes, regularly review procedures (even those that have worked well in the past), and be able to abandon old habits that are no longer useful [10]. Keeping this in mind, the expertise gained from past events plays an important role as it provides emergency responders with the knowledge and skills necessary to devise solutions for unforeseen situations [57].

In the same vein, Vert et al. [58] define the following properties that facilitate dealing with unpredicted situations: situation awareness, sensemaking, monitoring, decision-making, coordination, learning, and resources. Being aware of the situation and understanding and making sense of the problem or the situation are essential elements in making informed decisions to effectively address the situation [56]. Monitoring the system's performance allows for the timely detection and recognition of potential threats and acting accordingly [59]. When responding to and managing potential threats, it is essential to effectively manage the interdependencies that may exist between tasks, activities, and required resources and equipment [60]. Therefore, coordination is required to properly distribute the available resources and efficiently perform the required tasks and activities. After improvising and adapting to unpredicted situations, disaster responders learn by acquiring skills and knowledge from successfully implemented tasks and encountered problems [61,62]. Continuous learning is instrumental in enhancing preparedness for future potential risks.

Furthermore, targeted training and exercises can help emergency responders to become more effective improvisers. Such training can focus on enhancing communication, decision-making, problem-solving, and leadership skills. Additionally, exercises that simulate emergencies such as games and simulations can help responders to develop the ability to adapt to changing circumstances, which is a key element of improvisation [57]. By training together, responders can gain a better understanding of each other's strengths and weaknesses, as well as their communication and decision-making styles. This shared knowledge can help to build a sense of team cohesion, which is critical in high-stress emergency situations.

6. Conclusion

The increasing complexity and unpredictability of emergencies pose challenges to the effective implementation of pre-existing formal protocols and procedures. In these situations, emergency personnel often rely on improvisation and adaptation developing and employing informal disaster response methods without certainty about their effectiveness. Implementing informal solutions demonstrates emergency response teams' resilience in handling unpredictable circumstances. This capacity complemented by already defined formal procedures and planning form the fundamental aspects of resilience. Therefore, it is crucial to prepare and train emergency responders to improve their ability to design and implement informal solutions through improvisation and adaptation alongside formal solutions. Furthermore, the knowledge gained from implementing informal solutions can be valuable in preparing for future events and enhancing community resilience.

Distinguishing between formal and informal solutions (SRQ1) is essential for understanding their unique characteristics and implications. Uncertainty of the situation, legal accountability of the solution, bureaucratic delay to get the approval of a solution, and the stakeholders implementing the solutions are the most important criteria to differentiate between a formal and informal solution. Informality empowers emergency actors to improvise and adapt, enabling them to effectively respond to emergencies in case the already established formal solutions are not suitable to handle them. The need for these solutions appears when there are: unpredicted situations, poor planning and preparedness for the situation, and failure of the formal plans due to the absence of necessary resources. This paper has examined the causes and characteristics of informality within highly regulated emergency response. In that case, due to some legal liability, emergency responders tend not to deviate much from already approved procedures to avoid any accountability and legal responsibility for possible damage. When the situation is totally unpredictable and unplanned, improvisation is applied at a strategic level, and informal solutions are designed and proposed top-down ensuring a coordinated and integrated response. When these informal solutions prove to be successful and highly used, they might be included in the formal response procedures leading to a real opportunity for improving the response towards emergencies. This paper illustrates the process of formalizing informal solutions

at the organizational level through a framework composed of drivers that enable the formalization of the solutions and barriers that hamper or limit this process.

Regarding the SRQ2, the findings of this study highlight the importance of embracing a holistic strategy that integrates preparedness, improvisation, and adaptation to enhance the effectiveness of emergency management. Emergency responders should be equipped with the necessary skills to create, adopt, and implement informal solutions that would help them to improvise and adapt during crises. This will help enhancing the resilience capacity of emergency services. Therefore, emergency services should be prepared and trained to adopt and implement informal solutions that would help them to improvise and adapt in the face of unpredicted situations. In this regard, the flexibility provided by the environmental context as well as the legal framework is vital to facilitate the implementation of informal solutions. Furthermore, we believe that formalizing successful informal solutions is part of appropriate planning for disaster management. It enables the recognition of the potential effectiveness and agility of informal solutions in bridging gaps within existing formal procedures and plans. Improvisation should be seen as a supplementary contingency plan that complements detailed preparation and planning since some level of improvisation will always be necessary for disaster scenarios.

In addition to plans and procedures, emergency responders must undergo targeted training and exercises to enhance their flexibility, creativity, communication, decision-making, problem-solving, and leadership skills. By training for informality, emergency personnel can effectively respond to disasters and other unexpected events, ensuring the best possible outcomes for affected communities.

CRediT authorship contribution statement

Sahar Elkady: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Josune Hernantes:** Writing – review & editing, Supervision, Investigation, Funding acquisition. **Eulalia Gómez:** Writing – original draft, Methodology, Formal analysis, Data curation. **Leire Labaka:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used ChatGPT in order to paraphrase some of the text to improve its readability. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Leire Labaka reports financial support was provided by European Commission, through the European Union's Horizon 2020 research and innovation program, grant number 882850.

Data availability

Data will be made available on request.

Acknowledgment

This work was supported by the European project ENGAGE, funded by the European Union's Horizon 2020 research and innovation program [grant number 882850].

Appendix

Interviewees profiles

Table 4 shows a summary of the interviewees' profiles.

Table 4
Interviewees' codes and jobs

Code	Jobs	Country
I1	Security advisor in a municipality	Belgium
I2	Director in a humanitarian organization	Norway
I3	Manager in a volunteer organization	Portugal
I4	Disaster advisor in a private consultancy	Australia
I5	Manager in a private emergency company	Israel
I6	Senior advisor in a municipality	Norway

(continued on next page)

Table 4 (continued)

Code	Jobs	Country
I7	Manager in emergency services	Romania
I8	Manager in a private company that provides solutions for volunteers' management	Sweden
I9	Manager in emergency services	Spain

Selection of examples in the interviews

Table 5 presents how the selected examples relate to the different informality aspects.

Table 5

Selection of the examples presented in the interviews

Example	Actor/solution implementer	Official documented protocol	Planned beforehand or not
Shortage of masks	Formal actor (health sector)	No, health workers should use surgical masks	It was not planned but it was generalized till the surgical masks were restocked.
COVID-19 bed availability	Formal actor (health sector)	Adaptation of an existing practice.	It was planned for compromised patients, not for everyone.
Firefighters' calls	Formal actors (emergency sector)	No, the official protocol defined another way of communication.	Yes, it was a common practice to enhance the workflow.
Church bell	Not a formal actor since a priest is not part of an emergency organization	No, it was not documented.	Yes, it was a common practice.
The police app	Formal actor (police)	Yes, it is an official app developed by the Basque police.	Yes, it is an official way of communicating with the police.

Interview questions

Part 1: Background Information.

- Please tell us more about your professional experience. What is your current job and how long have you been working in this job?
- What is your relationship with emergencies?

Part 2: Definition of informal solutions.

- Please use the following link (<https://www.surveymonkey.com/r/5YTPDY6>) to rate the level of informality of the solution. Table 6 describes the different examples of solutions that were presented to the interviewees to be rated from 1 to 5, where 1 is extremely informal and 5 is extremely formal.

Table 6

Description of the examples mentioned in the interviews to rate the informality

#	Title	Description
Ex1	Shortage of surgical masks	During COVID-19 peak times, healthcare workers used homemade cloth masks and reused the surgical masks after treating them with different techniques such as UV rays.
Ex2	COVID-19 bed availability	When COVID-19 hit, it was a tough situation in the emergency units in hospitals, there were no available beds for patients. So, a doctor in an Italian hospital decided to visit his patients at their houses and give them the needed treatment. Then, other hospital staff joined this doctor in his work and visited more patients. The hospital and donors provided the needed resources for the doctors' work to continue. In general, this is a standard procedure for compromised patients, however, in the case of COVID 19 the problem was not related to the patients themselves but the hospital's over saturation.
Ex3	Firefighters' follow-up calls	During a crisis, the fire department officials alert the regional operative cluster by calling the halls of operation instead of using email which was the main channel of communication in the established protocol. They also send an official email to track the action. After 15 min they call the regional operative cluster again to know if they received the email properly.
Ex4	Church bell	Using the church bell to alert the population during a crisis. In small towns, the city hall or the mayor contacts the priest to inform him that there is an emergency, and the priest rings the church bell to alert the population.
Ex5	The Basque police app	The main objective of the application is to create a communication channel between citizens and the Basque police. The application facilitates new means of communication with the police through any mobile device and through various channels such as SMS, email, telephone, or WhatsApp.

Part 3: Experience with informal solutions.

- Considering the examples we discussed before, have you ever applied/created something like that before? How did you apply/create it?
- Why did you apply such a solution? And did it work?
- In which situations do you think that informal solutions may be adopted?
- What are the barriers that prevent you from adopting informal solutions?

Part 4: Formalizing the informal solutions.

- Are you aware of any informal solutions that become formal? How and why?
- Are there some contextual factors that favor the formalization of the solutions?

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