Natural Disaster Management - An Analysis of the Ferrara Risk Management Network

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Abstract: Risk management, part of the risk analysis process, involves three public policies that are risk identification, risk reduction and disaster management. The management of an extreme event, such as an earthquake, is a complex and dynamic process that inevitably involves different organizations who need to coordinate themselves and work together to pursue the common goal to respond to the emergency in the best possible way. These organizations constitute the management network of the emergency, a complex and inter-organizational social system. The complexity of the management network and the characteristics of an extreme event make the emergency management more difficult. In order to identify the network structures that would facilitate an effective disaster management, we studied the network of stakeholders involved in the management of the earthquake that affected the city of Ferrara in May 2012. In particular, we considered the characteristics of the emergency network, such as numerosity and cohesion, and the positions of the actors based on relational ties, such as centrality, in order to highlight strengths and weaknesses of the network. The risk management network was studied starting from legislative and technical documents, integrated with in-depth interviews with stakeholders who had a key role in the network. The network data collected from the interviews was analyzed using the UCINET 6.0 social network analysis software. The main results have been integrated with parts of the transcribed interviews. Overall, the network of emergency management activated in Ferrara during the earthquake in 2012, has a complex structure characterized by many actors with different functions and roles. The network analysis highlighted that it has a poor level of cohesion and exploits very little of its relational potential. Some pairs of actors are isolated and a hierarchical communication and an asymmetric flow of information seems to prevail between some actors. The functioning of the network also appears to be driven mainly by the establishment of informal relations rather than by formal and pre-existing ones, a flexible operating way probably more suited to the management of an emergency that requires immediacy and rapid response. The population is the most popular actor of this network, however it has a passive role, seen exclusively as the recipient of the process of emergency management.
Several interventions, aimed to improve the functioning of the emergency management network, are proposed in this article.

Keywords*:* emergency management, Ferrara earthquake, natural disaster, network analysis, strenghts and weaknesses

Introduction

Risk management, part of the risk analysis process, is performed to ensure that risk is maintained within an acceptable level to avoid serious adverse effect to the population and the environment by selecting the most suitable alternative, for example in terms of costs and efficacy [1]. Risk management involves three public policies that are risk identification, risk reduction and disaster management [2]. In particular, the management of an extreme event, such as an earthquake, is a complex and dynamic process that inevitably involves different organizations who need to coordinate themselves and work together to pursue the common goal to respond to the emergency in the best way [3], [4]. These organizations constitute the management network of the emergency, a complex and inter-institutional social system, composed by actors each of which with their own characteristics, for example in terms of mission, working methods and management of internal and external relationships.

The management of an emergency is a complex task because of the characteristics both of the management network and of the extreme event. In these situations, indeed, the unexpected is the norm and flexible, rapid actions are required [5], [6].

Early approaches to disaster management were based on a *command and control model* [7], characterized by strong protocols and a hierarchical structure, with a strict definition of tasks, responsibilities and procedures. This model also assumes that people are generally confused and in a state of panic after a disaster and therefore need a strong leadership from a single source [7]. In this approach, the population have a passive role in the emergency management. A *command and control model*, however, has proved to be functional in situations characterized by low levels of uncertainty and predictability, features typical of routine events, such as those that usually can be managed with the resources of a sole governmental agency, using standard procedures and with minimal dislocation [8]. On the contrary, in highly complex and dynamic situations such as those of an extreme event, a hierarchical management does not always guarantee the efficacy of the response. On the other hand, stakeholders' participation may be hampered by the non-transmission or non-circulation of key information or by the inability to reallocate resources quickly in order to meet new demands [9]. The actions carried out in emergency management can only partially be planned [10], having to rely on the integration between information already available (i.e. the characteristics of the territory and population) and new incoming information (i.e. the severity of the disaster or to the type of damage). Furthermore, organizations frequently develop not only formal relationships, but also informal ones, in order to work together to pursued shared goals, address common concerns and attain mutually beneficial ends [11], [12].

According to the *complex adaptive systems theory* [13], [14], the network of emergency management is a system whose actors are able to adapt their actions to changes in their environments, acting self-organizing behaviors [11], [15]. In this approach the inter-organizational collaboration [16], that is an effective collaborative relationships between the network of organizations, but also their ability to act in a coordinated manner [12], becomes increasingly important. Timely acquisition of information, quick access to them and secure information sharing are important requirements for emergency management [17].

The emergency management, especially related to natural disasters, has become an important issue in our country. Italy is a country exposed to a number of major natural hazards, including earthquakes. Since 1900, in Italy there were 30 earthquakes with a 5.8 or major magnitude, some of which were catastrophic [18]. These include the earthquake that affected the Emilia Romagna Region, characterized by two significant shocks on 20 and 29 May 2012, which caused seven victims. Ferrara was one of the city mainly involved in this earthquake and, on May 22, the Council of Ministers had approved the state of emergency, favoring the activation of the risk management network [19].

How the earthquake emergency in Ferrara was handled? Was the network activated functional to the emergency management? In what way and between who took place the flow of information? Who were the organizations that played a central role? What are the strengths and weaknesses of the network?
In order to answer these questions, we studied the network involved in the management of the earthquake that affected the city of Ferrara in May 2012. In particular, we considered the characteristics of the emergency network, such as the number of its nodes and their cohesion, and the positions of the actors based on relational ties, such as centrality.

Materials and Methods

This research was part of the largest research project CLARA "CLoud plAtform and smart underground imaging for natural Risk Assessment", funded by Italian Ministry of Education, Universities, and Research (MIUR), whose main object was to mitigate the effects of landslides and earthquakes, affecting some Italian towns, by acquiring knowledge related to the environment. The risk management network was studied starting from legislative and technical documents (i.e. the Municipal Emergency Plan for Civil Protection), integrated with in-depth interviews with stakeholders who had a key role in the network.

The interviews were aimed at acquiring information on the structure and functioning of the risk management network, as well as to study its characteristics and the relations activated between different nodes. The network data collected from the interviews was analysed using the UCINET 6.0 social network analysis software [20]. The main results are shown below. In particular, the description of the characteristics and of the structure of the network will be integrated with parts of the transcribed interviews, reported in italics, quotation marks.

Results and discussion

Main actors and functions. During the emergency of 2012 in Ferrara 20 actors with different roles and functions have been activated (see Fig. 1).

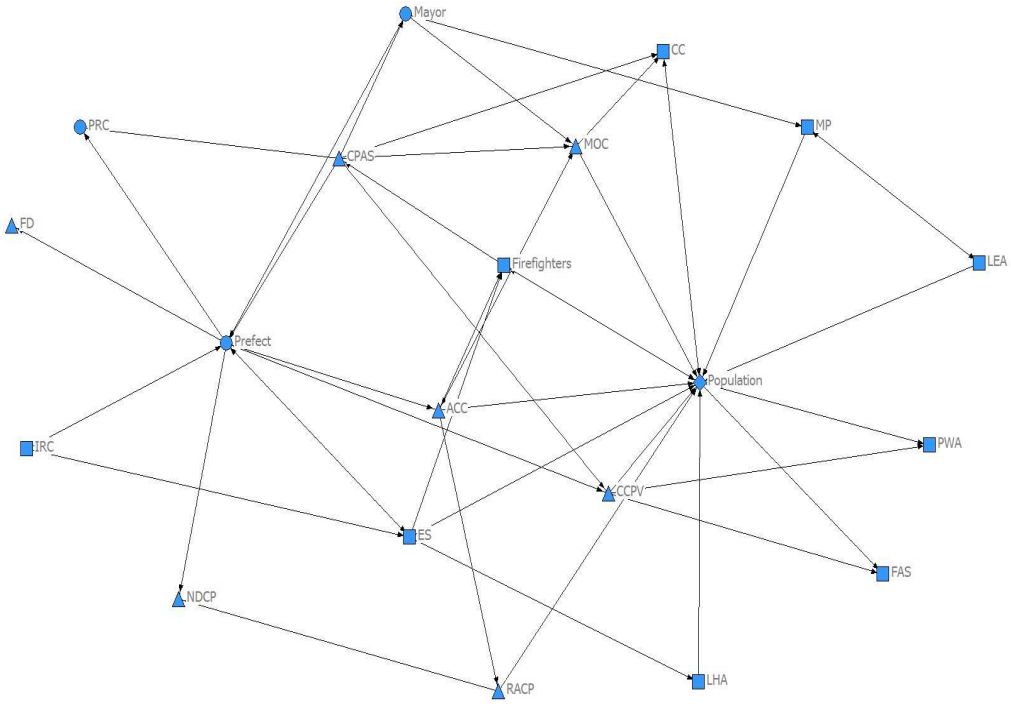

Figure 1: Main actors of the Ferrara emergency management network.

Actors of the network have been grouped according the role performed during the emergency management. The identified categories are placed along a continuum that starts from a decision-making role and arrives to an operational role, going through a coordination role. In particular, with regard to decision-making component, the players involved were the Mayor, the Prefect and the President of the Regional Council (PRC). They had different territorial competences and, according to the Augustus directive [21], they are activated depending on the severity of the event. In particular, in the case of a-type event, each municipality intervenes with his own resources. In the case of b-type events, the level of intervention is extended to provincial and regional level, and the Mayor will request the intervention of the Prefect, of the President of the Province and of the Emilia Romagna Region. In the case of the c-type events, the level of intervention become national, and the Prefect and the Region will ask for the intervention of the National Department of Civil Protection.

Among the actors with a coordinating role, we find the Municipal Operations Centre (MOC), the Civil Protection Associate Service (CPAS), the Aid Coordination Centre (ACC), the Regional Agency of Civil Protection (RACP) and the National Department of Civil Protection (NDCP), the Fire Department (FD) and the Coordination of Civil Protection Volunteers (CCPV). In particular, the Civil Protection Associate Service has had an essential role in the emergency management of 2012, because it was the trigger point of the emergency management network. It is, in fact, a service that does not need to be activated by other actors in the emergency phase and that maintains a direct communication with the Mayor, to which article 15 of Law n. 225/92 [22] allocates the role of Municipal Civil Protection Authority.

> *"The Civil Protection Associate Service is a service that is not activated by others. Immediately after the Ferrara earthquake we met ourselves in the office of the Civil Protection Associate Service. I called my colleague, we called our manager who in the meantime was calling us...Two minutes after the shock my manager called the Mayor, telling him that we would have a meeting with other technicians and the Councillor and, after the meeting, we would have informed him".*

It represented a focal point between different levels of intervention (municipal, provincial, regional and national), maintaining contacts with the different actors with decision-making functions. Furthermore, its relationship with the Municipal Operations Centre of which ensures the functionality, was essential. Also the Municipal Operations Centre has had an important role in the emergency phase, representing the operating structure of the municipality in which they are organized the civil protection activities. It performed mainly the functions of coordination and it was arranged by representatives of municipal services with a specific role in emergency management or public utility activities, such as roads, schools and health. It was also important his relationship with the Aid Coordination Centre, the highest organ of coordination of civil protection in the emergency at the provincial level. This relationship is essential in order to ensure integrated management of interventions and dissemination of information to the population. Another actor who has had an important role in helping the population was represented by the Coordination of Civil Protection Volunteers that is an Association of second level, which groups the 30 voluntary associations operating in the field of Civil Protection of Ferrara.

Regarding the operational component, it is possible to distinguish actors whose intervention regards security and public order, that is the Municipal Police (MP), the Law Enforcement Agency (LEA) and the Firefighters; actors whose intervention is related to health sector, that is the Emergency Services (ES), the Local Health Authority (LHA) and the Italian Red Cross (IRC); actors with the main task of giving information, that is the Call Center (CC); structures with the function of welcome and assistence the population, that is Population Waiting Areas (PWA) and First Assistance Structures (FAS). Among these, an important role is played by Firefighters, the first to take action immediately after the earthquake, activated spontaneously or by the calls of the citizens.

> "*Firefighters have an essential function immediately after the earthquake, they are the first to be involved and they are always active. They intervene when there are problems, dangers, when houses need to be evacuated, where there are some collapses...In the morning of the earthquake,, when the employees of Civil Protection arrived, the firemen were already around in the city , they had been activated by the numerous calls of citizens"*.

Particularly important is the relationship between the Firefighters and the Civil Protection Associate Service, because it ensures the bottom-up flow of information related to interventions made during the emergency management. This flow of information is crucial to foster an efficient coordination by the Civil Protection Associate Service. This last is also an intermediary node between the operational components and the decision-making ones.

> *"The Firefighters constantly communicate with the Civil Protection Associate Service, but not immediately after the quake. At the beginning they work independently, for example by doing inspections. Then they ask to the Civil Protection Associate Service, for example, to evacuate people, and the Civil Protection Associate Service emanate ordinances to the Mayor based on the information they receive from the Firefighters. In the case of Ferrara, given to the high amount of calls, the first interventions were made by Firefighters without verbalize anything. Later, they took note of the interventions made, and only in the following days these notes became a real detailed verbal of the intervention. Then the Civil Protection Associate Service took on the responsibility of these interventions, and sorted them to the Municipal Operations Centre on the basis of the kind of intervention required. For example, if it was a problem related to electricity, the intervention has been transmitted to Enel, if the problem was related to roads, it was reported to the competent service"*.

Finally there is the Population, who is the primary beneficiary of the interventions of the emergency management process.

Ego network size. In order to investigate the network size of each actor and to analyze the relationships between ego and alters, it was calculated the *ego network size*. Considering the mutual relations, it is possible to note that the ego network size is higher for the population (12 ties), followed by the Prefect and the Civil Protection Associate Service. If we consider the actors grouped according to their main functions, we can see that among the actors with a decision-making role, the Prefect has a more numerous network (9 ties). Among the actors who have a coordinating role, the Service Associate of Civil Protection has a more numerous network (7 ties), followed by the Coordination of Civil Protection Volunteers, by the Municipal Operations Centre and by the Aid Coordination Centre (5 ties each). Among the actors who have an operational role, instead, the Emergency Services and the Firefighters have the largest network, respectively with 5 and 4 ties (see Tab. 1).

Table 1: Ego network size

Nodes	Size
Mayor	4.00
Prefect	9.00
PRC	2.00
RACP	3.00
MOC	5.00
ACC	5.00
NDCP	2.00
FD	1.00
CC	3.00
CPAS	7.00
MP	3.00
LEA	2.00
CCPV	5.00
Population	12.00
Firefighters	4.00
ES	5.00
LHA	2.00
IRC	2.00
PWA	2.00
FAS	2.00

As a whole, ego network size confirm the relevance of the role played from the different actors in the emergency management in Ferrara. The fact that the more involved decision-making level is the provincial one, could be explained considering that improbable the emergency can be managed with resources available to the municipality.

> *"Actually, the earthquake can never be managed at the municipal level, unless there is an earthquake in the city center of Rome. The structures which have to intervene, don't exist in the Municipality, both in terms of skills and services, for example hospitals. Everything has to be managed at a wider level than the municipal one, even if is the case of a small earthquake"*.

Network Cohesion. In order to study the cohesion of the network it has been used the *density index*, which represents the degree of contacts that the members of the network have between them. It is expressed as the ratio between the sum of the existing links with respect to all the possible ones. It indicates how much the network is far from its maximum potential and takes values between 0 and 1. In our case the density value is 0.118 (Std Dev 0.323), because there are only 11% of all possible links. This low value indicates that the emergency management network activated in Ferrara during the earthquake of 2012 did not have a good level of cohesion. This aspect is confirmed by the value of standard deviation, which indicates the presence of a little amount of high variability in the ties. Furthermore, looking to the average number of connections for each node (2.25), we may notice that each actor in the network has just over 2 links with other actors (see Tab. 2).

Table 2: Density index

Density	No. Of Ties	Std Dev	Avg Degree
0.118	45	0.323	2.25

We are therefore faced with a network that exploits only a small part of its relational potential. The network that has been active in Ferrara has not well strengthened from the point of view of common working practices, cooperating for the first time in the management of such an important event, the earthquake of 2012. Therefore, the relationships activated were driven more by existing personal knowledge or by spontaneous bottom-up collaborations rather than by stable working practices. At the same time this data may be read as a process of simplification, perhaps more

suitable than a bureaucratic one for the management of natural disaster which, as all complex phenomena, are unpredictable and require a rapidly response leaving no space for a large number of relationships.
This aspect was highlighted from one of the interviewees, who stressed the necessity of an intervention model in which roles and functions of each actor are well defined. At the same time this model should be flexible, allowing actors to "deviate" from the theoretical model in a more functional way to the practical situation.

> *"I think that a model of intervention is useful, the levels of command are needed, so you can understand the roles, the tasks and the limits of the intervention of each actor. But at the end, very often, it is done in another way. I give you an example: the Aid Coordination Centre needs tents and asks to the Municipal Operations Centre. Very often the Civil Protection and the volunteers have directly faced these issues, and I think that the Prefect has never heard about this. In theory, the Civil Protection should ask to the Aid Coordination Centre, the Aid Coordination Centre should ask to the Municipal Operations Centre and the Municipal Operations Centre, in turn, should ask to the Civil Protection to set up the tents. This process should happen in theory, in order to allow to have everything under control, but often the practice is different. Not only phenomena of bottom-up cooperation, but also informal relationships between different actors of the management network develop in the practice".*

In order to study the cohesion of the network, we also used the *distance index*, that refers to the distance between links. The values in the matrix of distance (see Tab. 3) represent the length of the shortest path connecting each pair of actors.

Table 3: Matrix of distance

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		M	P	P	R	M	A	N	D	C	A	M	S	C	P	F	E	L	I	W	S
1	Mayor	0	1	2	3	1	2	2	2	2	4	1	2	2	2	3	2	3		3	3
2	Prefect	4	0	1	2	2	1	1	1	3	3	5	6	1	2	2	1	2		2	2
3	PRC			0																	
4	RACP	4	4	4	0	4	5	1	5	2	3	5	6	4	1	2	5	6		2	2
5	MOC	4	4	4	2	0	1	3	5	1	3	5	6	4	1	2	5	6		2	2
6	ACC	3	3	3	1	1	0	2	4	2	2	4	5	3	1	1	4	5		2	2
7	NDCP							0													
8	FD								0												
9	CC	4	4	4	6	4	5	5	5	0	3	5	6	4	1	2	5	6		2	2
10	CPAS	1	1	1	3	1	2	2	2	1	0	2	3	1	2	3	2	3		2	2
11	MP	4	4	4	6	4	5	5	5	2	3	0	1	4	1	2	5	6		2	2
12	LEA	4	4	4	6	4	5	5	5	2	3	1	0	4	1	2	5	6		2	2
13	CCPV	4	4	4	6	4	5	5	5	2	3	5	6	0	1	2	5	6		1	1
14	Population	3	3	3	5	3	4	4	4	1	2	4	5	3	0	1	4	5		1	1
15	Firefighters	2	2	2	4	2	3	3	3	2	1	3	4	2	1	0	3	4		2	2
16	ES	3	1	2	3	3	2	2	2	2	2	4	5	2	1	1	0	1		2	2
17	LHA	4	4	4	6	4	5	5	5	2	3	5	6	4	1	2	5	0		2	2
18	IRC	4	1	2	3	3	2	2	2	3	3	5	6	2	2	2	1	2	0	3	3
19	PWA																			0	
20	FAS																				0

The distance matrix shows that some values are rather high because some pairs of actors are quite far. In particular, if we consider the diameter of the network, that is the longest geodesic distance, we observe that some actors are distant up to 6 ties from each other. These data confirms the findings of the density index, namely that we are dealing with a network not well connected and not very "compact".

We can also see that some nodes of the network are mostly isolated, not having the possibility to connect themselves with the other nodes of the network. These include some major actors with coordination functions, as well as the Population Waiting Areas and the Structures of First Assistance. This data are confirmed by the *distance-weighted fragmentation index*, variable from 0 to 1 and which indicates the proportion of pairs of nodes that are not reachable from each other. In our case the value of this index is 0.680, confirming the fact that most of the pairs of nodes of our network are mostly isolated.

If we look at the length of the shortest path connecting some pair of actors, we can note, for example, that the Mayor, actor with decision-making powers at the municipal level, is quite far from the Civil Protection Associate Service, actor with important functions of coordination at the municipal level (the shortest path consists of four steps). On the contrary, the second one is connected to the first one by one step. The Prefect, actor with decision-making powers at the provincial level, is 4 steps far from the Mayor. Also in this case, however, the second one is connected to the first one by one step. The Call Center, operative node of the network with primarily informative functions, is far from the operational components of health area, in particular from the Local Health Authority and from the Emergency Services (respectively 6 and 5 Steps). However, these components are distant from the Call Center only two steps.

It would seem that the relationship between some pairs of actors is not immediate in a reciprocal manner, as if the relationships organize itself in a hierarchical way and this influences the direction of the flow of information. The distance between some pairs of actors and the absence of a reciprocal immediate communication, could make more difficult the communication and the exchange of information between nodes of the network that should be immediately and continuously in contact with each other, so they can face the emergencies also in absence of some nodes.

> *"The Prefecture of Ferrara is in an historic building and if an earthquake occurs in the city center of Ferrara, it is the first building to collapse, therefore in the command level should missing the Prefect. Even if some things can be scheduled, the practice could change. It's difficult to plan an event like an earthquake, because certain important levels of the emergency management network could be missed".*

Network Centrality. The network centrality allows us to define the position of an actor in its network in a relational way. In particular, in order to study the centrality of our network, we referred to the *index of degree centrality*. This index takes into account, for each actor, the choices made (that is the degree of propensity towards the other) and the choices received (that is the degree of popularity). On the basis of this index, the centrality of each node depend on the number of choices that the same has received. In the case of our network, the population is the node that has received the most choices (10 choices), therefore appears as the most popular actor, that is the more central of the network of emergency management. The population is the most popular actor because it is the principal beneficiary of the interventions of emergency management.
If we consider the OutDegree measure, the network of the population is reduced to 4 ties, confirming that the population is the principal beneficiary of the interventions and has also a passive role in the network. Furthermore, two of the 4 output ties are addressed to the Population Waiting Areas and to the First Assistance Structures, whose primary function is to welcome and assist.

> *"Population hasn't an active role during an earthquake. For example people never spontaneously reach the Waiting Areas, because they don't never leave their homes or their belongings. This only happens in theory! So they should be trained with practical exercises for abandon their homes without having to be informed by anyone".*

The Civil Protection Associate Service and the Prefect are the actors with the highest value of outdegree, that is, those who have the greatest number of choices, specifically 6 each, and have a higher degree of propensity towards others. The more peripheral actors are those who received the lowest number of choices, which in our case are represented by the Italian Red Cross, with 0 choices received, and another set of actors including, for example, the Local Health Authority and the Fire Department, each with only one choice received (see Tab. 4).

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Table 4: Degree centrality measures

	Nodes	OutDegree	InDegree
10	CPAS	6.000	1.000
2	Prefect	6.000	4.000
6	ACC	4.000	2.000
14	Population	4.000	10.000
16	ES	4.000	2.000
13	CCPV	3.000	2.000
1	Mayor	3.000	1.000
5	MOC	3.000	3.000
12	LEA	2.000	1.000
18	IRC	2.000	0.000
4	RACP	2.000	1.000
11	MP	2.000	2.000
15	Firefighters	2.000	3.000
17	LHA	1.000	1.000
9	CC	1.000	3.000
3	PRC	0.000	2.000
7	NDCP	0.000	2.000
8	FD	0.000	1.000
19	PWA	0.000	2.000
20	FAS	0.000	2.000

Considering the network as a whole (see Tab. 5), there is a low level of network centralization relating to the outdegree (20.776%), which means that outdegree indexes of actors are fairly homogeneous and a higher level of network centralization relates to the indegree (42.936%).

Table 5: Network centralization measures

Network Centralization	Percentage (%)
Outdegree	20.776
Indegree	42.936

Conclusions

Overall, the network of emergency management activated in Ferrara during the earthquake in 2012, has a complex structure characterized by many actors with different functions and roles. The network analysis highlighted that it has a poor level of cohesion and exploits very little of its relational potential. Some pairs of actors are isolated, furthermore a hierarchical communication and an asymmetric flow of information seems to prevail between some actors. The functioning of the network also appears to be driven mainly by the establishment of informal relations rather than by formal and pre-existing relationships. This could be more suited to the management of an emergency that requires immediacy and rapid response. The population is the most popular actor of this network, however it has a passive role, seen exclusively as the recipient of the process of emergency management. By this analysis emerges that the existence of a model for seismic risk management is an essential, but not sufficient tool for the emergency management. This model need to be dynamic and flexible, that are key features for dealing with events, like earthquakes, which by their nature are difficult to be predicted [23]. Response to disasters requires good planning but should leave room for improvisation due to unusual challenges created. Some authors [24] argue that disaster management requires a degree of control which rarely exists in these situations, for this reason standard management methods are not suitable for disaster situations [25].

The flexibility, allowing a fast communication between different stakeholders and a better efficiency of the intervention, is one of the strengths of the Ferrara risk management network. However the flexibility is not accompanied by a good connection between the different actors and the presence of a symmetrical communication that ensures the flow of information in a circular manner, aspect that could ensure a good management of

emergencies also in the absence of some nodes of the network. The intervention model should also be integrated by a clear definition and a shared knowledge of tasks, roles and functions of different stakeholders, whose scarcity represented one of the main weaknesses of the seismic management network. Work practices, aimed at the promotion among different stakeholders of shared languages and working methods, should be promoted too. Populations should to be involved in the emergency management. If people are empowered, community members can cope with the adverse effect of natural hazards. Involvement of communities is important in both pre-disaster mitigation and post disaster response and recovery process [26].

This study represents a first analysis of how functioned the network that managed the emergency in Ferrara and do not expect to be exhaustive. One of the limitations of the study it is to have included in the analysis of the network only the main actors, but other stakeholders took part in the management of the emergency. In addition, interviews involved only some of the major actors and the information gathered on the network might be integrated with the point of view of other stakeholders involved.

Regarding future developments of this study, it would be interesting a comparative analysis between the model of emergency management defined in the legislation and the model that is actually triggered, and also see how the network management have changed during different stages of emergency management. Theoretical insights could regard the study of trust between the different actors, as well as the processes and motivations that lead the different actors to violate norms. It would also be interesting to activate working groups between the main actors of the emergency management network, in order to promote knowledge management processes and foster the development of shared working practices. Further interventions may be aimed at the involvement of the population, which could become one of the actors who have an active role in the emergency management.

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