architecture for disaster reduction
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People on the move: Housing, infrastructure and services in times of displacement

Moving the world around

Class "Resilienza e Territorio"

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1. INTRODUCTION

This project is focused on the moving related to the seismic emergency. Earthquakes are one of the most dangerous natural disaster, and they are still causing destruction of entire towns and communities.

The most common reaction of communities to emergencies is moving. The population migrates, and its houses are rebuilt somewhere else. Migration, moving, change: that happens in many seismic places. Not in Italy. Italy is a peculiar country, highly density built, and with communities strongly attached to their land. In case of emergency, Italian communities face very limited moving, modulating their asset in order to keep their position as much is possible. The possibility to find a new asset without facing a real moving requires to count on efficient infrastructures, able to offer a versatile functionality, with change in needs, services, and population distribution even in case of emergency. In other words, the privilege to avoid the moving requires to *"move the world around"*, i.e. to prepare, before the occurring of earthquakes, resilient infrastructures, able to provide the needed services and to be appositely modulated in post-emergency situations. The moving, therefore, is replaced by the infrastructure resilience, i.e. the capacity of the system to maintain a basic functionality, and to provide the minimum required services. In this framework, the Health network becomes the most important element of the entire community, and the possibility for people not to move depends on its efficiency. This project, developed by a class of the University of Florence, is focused on the local (Tuscan) community, and investigates the resilience of the Health system of Tuscany at the occurrence of earthquakes. Tuscany is an Italian region, with three active seismic faults (see Figure 1a), subjected to seismic hazard like the rest of the country. Despite the seismic hazard is lower than in other Italian - and European – areas (see Figure 1b), many severe earthquakes have occurred in the past (see Figure 1c), and even in recent years, causing many damages. The functionality of the Health system depends even on the transport network, which is required to assure the possibility to reach the First Aid Centers. In the project, therefore, the Health system is analyzed together with the transport network, and a global rating is proposed, comprehensive of the most significant information.

a. Main Faults b. National Hazard Classification c. Hazard Classification

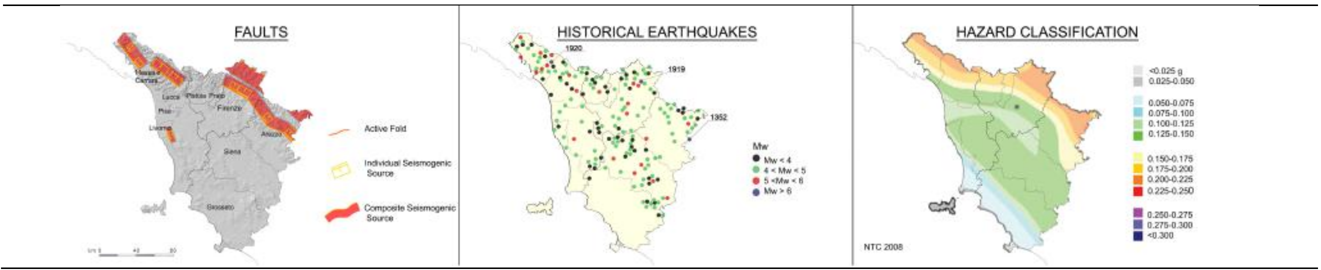


Figure 1. Seismicity of Tuscany

In the work the effective Health system classification has been adopted for the Hospital buildings. Tuscan administration is articulated in 10 provinces. The health system follows such organization, with the addition of three further unities, introduced to better cover the needs of specific areas, for a total number of 12 companies. They are organized in three main districts, which have as much main headquarters, consisting of University Hospital Companies. Each provincial company is made of some Hospital complexes, distributed in the area, having different dimension and number of offered care services. In Table 1 each Hospital complex has been named after Regional (R) and Provincial (P) organization, whilst in Figure 2a the Hospital buildings location is shown.

Table 1. Administrative organization of the Tuscan Health System.

Regional Companies	Provincial Companies	Hospital Complexes
	R1_P1	H1.1.1, H1.1.2, H1.1.3, H1.1.4, H1.1.5, H1.1.6,
	R1_P2	H1.1.7
R1	R1_P3	H1.2.1, H1.2.2, H1.2.3
	R1_P4	H1.3.1, H1.3.2, H1.3.3
		H1.4.1, H1.4.2, H1.4.3, H1.4.4
	R2_P5	H2.5.1, H2.5.2, H2.5.3, H2.5.4
	R2_P6	H2.6.1, H2.6.2, H2.6.3
R2	R2_P7	H2.7.1, H2.7.2, H2.7.3
	R2_P8	H2.8.1, H2.8.2, H2.8.3
	R2_P9	H2.9.1
	R3_P10	H3.10.1, H3.10.2, H3.10.3, H3.10.4
R3	R3_P11	H3.11.1, H3.11.2, H3.11.3, H3.11.4, H3.11.5
	R3_P12	H3.12.1, H3.12.2, H3.12.3, H3.12.4, H3.12.5

Hospital buildings location | Trasports system

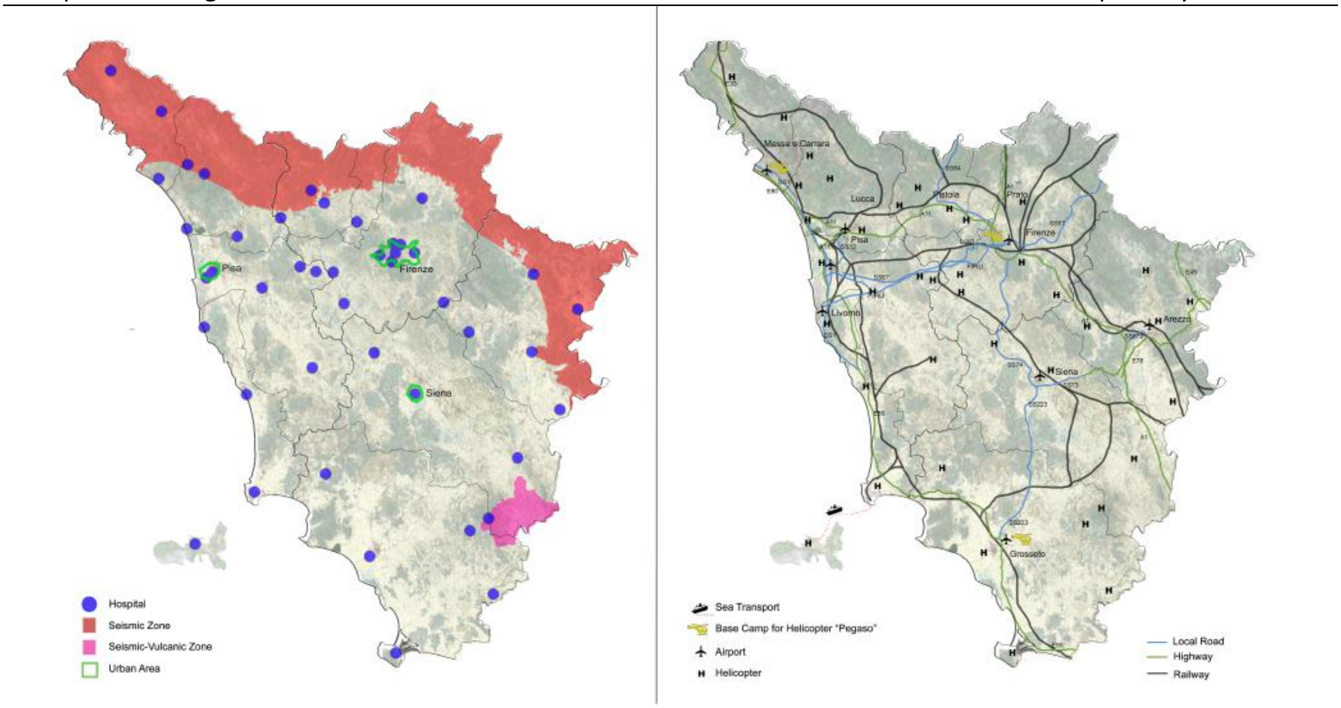


Figure 2. Tuscan Health system.

Figure 2a shows the transport network referred to the Health system, i.e. the mutual connection between each couple of Hospital buildings belonging to the same districts. The transport system comprehends highways, local roads and railways. Furthermore it indicates the location of airports, base camps for helicopters and the see transports involved in the Health system.

2. THE HEALTH SYSTYEM ANALYSIS

In this work both the Hospital buildings and the corresponding connections have been classified according to their functionality in emergency (post-earthquake) conditions. Namely, three different criteria are assumed for the classification of each system.

2.1 Hospital buildings classification

As regards the Hospital buildings, the assumed features are: the strategic role of each Hospital (SC), its seismic vulnerability (VC) and hazard (HC) (see Table 2). The strategic classification has been made after the criteria provided by the Regional Legislation, which rules the Hospitals role depending on the amount of served population, the number of beds and the number of provided first Aids. The SC is very important in the evaluation of the possible role of the Hospital in the post-emergency organization, since they have a medical equipment less adequate than the others, and are subjected to higher restrictions regarding the personnel and economical sources. The seismic vulnerability classification has been made on the basis of a huge investigation made in the past years as a consequence of a joint agreement between the Tuscan Universities and the Regional Government. The research was developed through the 2nd Level GNDT forms, which provide an evaluation of the buildings vulnerability in the basis of qualitative judgements made on 11 parameters. The parameters concern: type and organization of the seismic resistant system, quality of the resistant system, conventional resistance, building location and type of foundation, storey, configuration in plan, configuration in elevation, maximum distance between the masonry walls (connections and critical elements for RC buildings), coverage (elements with low ductility for RC buildings), non-structural elements, state of maintenance. The result of such survey was a classification expressed in terms of Vulnerability Index (VI), which can range between 0 and 100. In this study a simplified classification, consisting of three classes only, is adopted, with three Vulnerability classes defined after the VI values according to the criterion shown in Table 2.Finally the hazard classification is made on the basis of the information provided by the Italian Technical Code in terms of Peak Ground Acceleration (PGA) of the area. Even this classification consists of three different classes, appositely introduced on the basis of the hazard amount of the Region. Table 2 resumes the criteria adopted for the three classification.

Table 2. Adopted criteria for the Hospital buildings classification.

Strategic Classification				Vulnerability Classification			Hazard Classification		
SC	Relevance	beds	Inhabitants (thousand)	VC	Vulnerability	VI range (1/100)	HC	Hazard	PGA range
A	University	>100	>150	A	Low	0-30	A	Low	<0.15g
B	District	>100	70-150	B	Moderate	30-60	B	Moderate	0-15g-0.25g
C	Local	<100	<70	C	High	60-100	C	High	>0.25g

2.2 Transport system classification

As regards the transport network, the assumed features are: the distance between the two considered Hospital buildings, the flow dimension and the redundancy, i.e. the presence of alternative ways.

The distance classification consists of three classes, based on the length of the connection, as quantified by https://www.google.it/maps. Even in this case the three classes have been defined basing on the range of distances found for the entire Region.

The flow classification takes into account the route typology. The higher rating refers to highways, while the lowest one refers to local routes only. The medium rating, instead, refers to a combination of the other two.

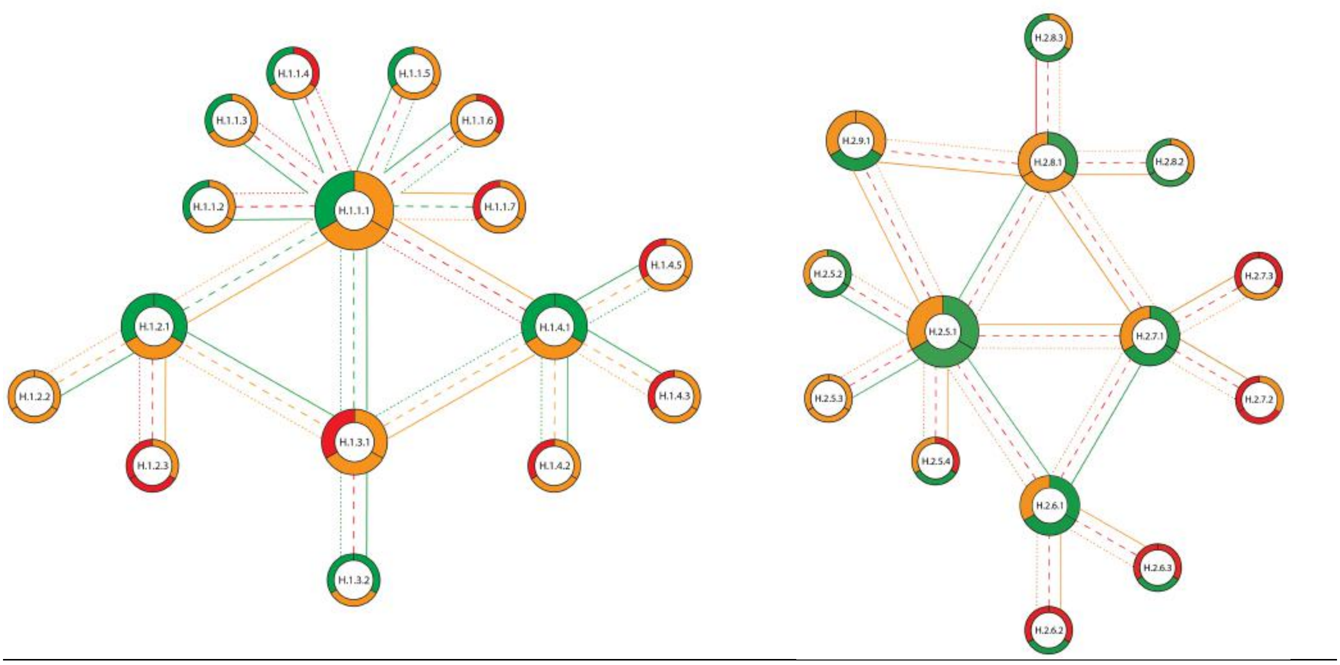
The redundancy classification refers to the presence of alternative routes to connect the two considered Hospital Buildings. The redundancy is very important in seismic scenarios, since the routes can easily face serious damages due to the earthquakes, with the consequence to isolate the First Aid Departments.

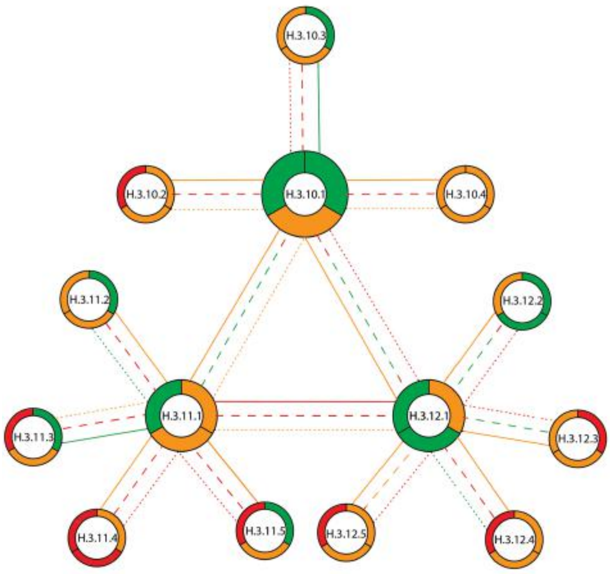
Table 2. Adopted criteria for the Transport system classification.

DISTANCE CLASSIFICATION			FLOW CLASSIFICATION			REDUNDANCY CLASSIFICATION		
DC	Distance	KM	FC	Flow	Routes types	RC	Redundancy	Redundancy conditions
A	close	< 30	A	fast	Highways only	A	redundant	Alternatives for the entire length
B	medium	30-100	B	medium	Combined routes	B	medium	Alternative for a partial length
C	far	>100	C	slow	Local routes only	C	weak	No alternatives

The results of the analysis

All the Hospital buildings constituting the Tuscan Health system have been classified according to the described criteria. Figure 3 shows the results of the classifications made on the Hospital buildings and in the transport system.





Main information on the Hospital Complexes

	H1	H2	H3
University Hospital	1	1	1
District Hospital	3	4	2
Local Hospital	12	9	11
Total Hospital	16	14	14
Total beds	5035	3958	3166
Birth points	8	8	9

Figure 3. Results of the Health system classification.

3 THE PROPOSED PROJECT

The results provided by the performed analysis have been used to propose an intervention to improve the functionality of the Hospital buildings involved in the most probable seismic events. The location of the Hospital buildings has been crossed with the active faults, and the Hospitals possible involved by the seismic emergency have been found. Three different buildings have been selected as possible head quarter of post seismic emergency, in the three faults areas, respectively. The three selected Hospitals evidenced exactly the same rating both for the Hospital buildings (SC=C, VC=B, HC=C) and for the connection to the corresponding district Hospital (DC=B, FC=C, RC=C). As a consequence of the analysis, therefore, an hypothesis of temporary integration to the current Hospital building has been designed, in order to make it more adequate to provide the necessary immediate rescue. Such hypothesis can be considered to be applied to any of the three assumed emergency scenarios, since they have the same properties and needs. Two different projects have been proposed, depending on the assumed ground motion intensity. The first hypothesis, shown in Figure 4, refers to a seismic intensity equal to the one provided by the National Hazard classification. The second hypothesis, instead, is shown in Figure 5; it refers to an higher seismic intensity, according to what happened in the most recent Italian earthquakes.

3.1 Case study 1: Emergency scenario at the occurring of an earthquake having an intensity equal to the National Seismic Hazard

In the first scenario, hospitals are not very damaged (only 20-30% are expected to be affected by damages). In this case, therefore, the designed intervention consists of introducing a temporary camp hospital to support the existing one, in order to improve the provided first rescue service. In this way the standard Emergency Department functionality would be increased, in order to face the increase in the care need. In this hypothesis, indeed, not only the local population needs the Hospital services, but also people coming from the neighbourhoods. The additional devices should be effective not only in the temporary post-emergency time, but even in a longer term, until the standard functionality is fully recovered.

Figure 4. First proposed project, made by assuming a seismic intensity according to the Code classification

3.2 Case study 2: Emergency scenario at the occurring of an earthquake stronger than the expected one, with a seismic intensity two or three times the one provided by the National mapping.

In the second scenario, the majority of the hospitals has been damaged (or collapsed); therefore a more radical intervention is needed, aimed to provide the required devices in long-term operations; our proposals refer to new architectural technologies for construction of sanitary- health structures and temporary accommodations, in the shortest possible time. The proposed approach is aimed at providing the base care to the local population, to lead it not to move. The communities involved in these scenarios are relatively isolated from the more urbanized centres, and they evidence a special adversity in moving. The proposed intervention, therefore, is aimed at moving whatever needs to ensure a basic life to the local population.

Our proposal

If a quick intervention is needed, due to the emergency occurring, the new technologies must be involved to achieve effective health devices to support the existing, and eventually damaged, Hospital buildings.

In this proposal, the technology called "Contour crafting", which uses a composite concrete mixture is adopted. Its main property is the capability to be self-supporting almost instantly after being laying. A Chinese company is now using such technology to build single houses and apartment buildings at the cost of just $5000 per house. According to that company, a single building measuring 10 x 40,2 x 6 meters can be

constructed in less than 24 hours. They reduced waste by 70%, and labour cost by 50-80% per building, compared to the brick and mortar construction.
A significant advantage of being able to print structures using 3-D printers is that they can be designed to include cavities for running conduits, plumbing, electrical works, and so on. Structures can be printed to virtually comply any design with all of the necessary cavities built in. This procedure makes interior finishing much faster, easier, and more efficient. Last year this technology has been used to build ten houses in less than twenty-four hours. This year has been possible to print a five-story apartment block and a 1.100 square meter mansion.
The buildings were created using the same 6.6 by 10 meter tall printer which builds up layers of an "ink" made from a mixture of glass fiber, steel, cement, hardening agents and recycled construction waste.

Other alternatives
Alternative projects with more traditional constructive methods can be realized as quick, even if there are more problems of stock.
"Brikawood" is one of these alternatives. Brikawood is made of wooden bricks which can be built like a Lego, without glue neither nails or screws; the constructive criterion is to produce timber frame walls for any type of architecture. Each component is made of four wood plates, two side plates that provide the vertical sides and two transversal spacers for its structural coherence. The components are designed to allow an easy assembly and to achieve strong walls. The assembly requires a rubber hammer to mount the bricks, a drill to secure the sill plate on the slab; finally the wall cap closes the walls, after blowing and conditioning the insulation (wood chips). Various tests have been carried out with freezing rain simulations from zero to less 20 degrees; the obtained results proved to be satisfactory compared to those referred to houses with stacked beam poles. Brikawood can also withstand earthquakes of 8.5 on the Richter scale. This system can last until 50 years; after that, the building is 100% recyclable.

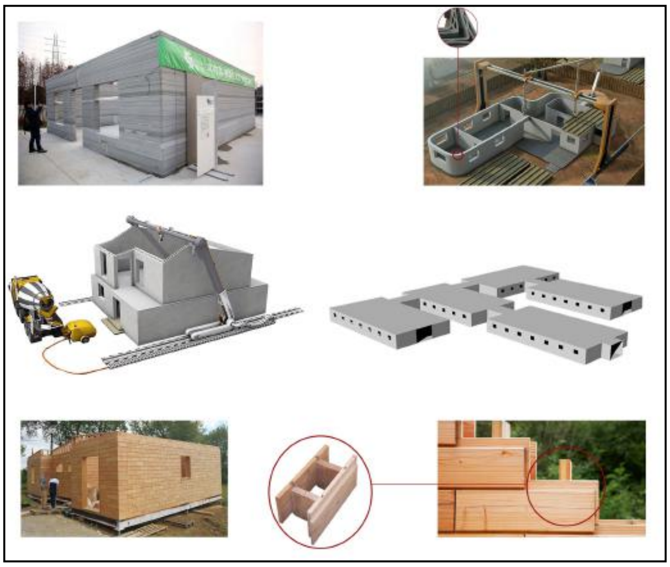


Figure 5. Proposed projects, made by assuming a seismic intensity double than the one provided by the Code classification.