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STREET NETWORK ISSUES FOR DISASTER MANAGEMENT

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In the frame of the Collaborative Research Centre SFB461 "Strong Earthquakes" a study on a part of the centre of Bucharest was done. This part comprises a section of the N-S Boulevard which is most characteristic for the development of the Modern Movement in Romania: most of the blocks of flats along the street were built in 1920-1940. The study included a survey of the building stock, but also of the street structure. In case a strong earthquake would strike Bucharest, and an emergency would occur, it is necessary to plan the evacuation of the zone. Emergency routes can be included in urban planning. They should lead to a so-called security centre, where emergency housing can be built. The challenge in planning such routes is that the streets might become blocked by rubble. For this reason the surveyed data included the width of the street reported to its fronts. The data were introduced in a GIS database, and attempts to convert the data in 3D were done. The urban frame of a street is defined by its floor, background and fronts. Analytically, the analysis of this frame begins with that of its profiles and parcours. A further step is the historic study. An essential element of the Master Plan of Bucharest 1935 was the circulation network. Circulation control was expressed in the shape of street fronts, for which concepts of style were included. For the centre, the cornice height limit was fixed, except at corners, leading to set-back upper floors. Apart of rubble, also short term earthquake countermeasures such as propping may affect the functionality of the road network. Such issues should be considered in the further model, additionally to the immediate emergency management. The paper thus reviews the approaches so far and give recommendations for the usability of a 3D model considering street network functionality issues in case that an earthquake strikes.

Keywords: disaster, evacuation, street prospect, machinery, rubble

Introduction

Sandu [1] affirms that "out of all urban spaces, the street is available as the most adequate location for the affirmation of the urban character." The spatial manifestation of the street results from a combination of factors: functionality, climate and terrain conditions, historic existence, conceptual design and last but not least "life-way" (Sandu [2]).

Recently playing a computer game on building of a city, the buildings have to be connected to the streets, otherwise the game does not work. Although surveys on built substance usually comprise the buildings, streets are also important. This does not happen in 3D models such as Google Earth.

Thus the characteristics of the street are definitely in urban planning and can thus contribute, on one hand to the vulnerability of the urban area, and on the other hand to urbanism measures of mitigation.

The previous work which is reviewed in this paper includes methods of survey of the street network for assessing vulnerability, at the cross points of urban and seismic microzonation, as well as approaches to the role of the street network in emergency and post-disaster interventions. The aim of the work is to assess to which amount a 3D view of the street, this is, taking into account all its elements, the parcours but also the front of buildings, can contribute to these assessments and intervention proposals.

Review

We review several case studies, directed on two levels of disaster management: the vulnerability assessment and the emergency response. We have come in direct touch with these methods and aiming to learn lessons to implement in 3D city simulations.

Assessment of Vulnerability

The Charter of Athens 1933 (CIAM [3]) stipulated the subdivision of the city into functional zones, circulation being one of them. The street remained a formal expression of functionality. One year after the Charter was proclaimed the Master Plan of Bucharest, Romania, was released. An essential element of the Master Plan of Bucharest was the circulation network. Circulation control is expressed in the shape of street fronts, for which concepts of style are included (Machedon and Scoffham [4]). For the centre, the cornice height limit is fixed, except at corners, leading to set-back upper floors. Inversing of the positive and negative space as promoted by Modernist architecture à la Le Corbusier, placing constructed volumes “in-the-green“ was not undertaken.

An area designed according to the principles of this Master Plan was investigated, situated in the northern-central area of Bucharest.

SFB Approach

In the years 2000-2001 we were involved in the Collaborative Research Centre (SFB) 461 at the University of Karlsruhe (TH), Germany. The work involved the survey of the above mentioned area of Bucharest, which is situated along the north-south boulevard where most buildings were raised after the release of the 1934 Master Plan and before the 1940 Vrancea earthquake which affected Bucharest. This area includes most of the buildings which are today classified in risk class I.

The results of the survey have flown into a GIS environment (ArcView with MS Access for the database), the basis for a HLA architecture decision system by Fiedrich [5]. The aim is to design the computer aids for the local decision makers in post-earthquake disaster staff. Fiedrich [5] “proposed the integrative model EQ-RESQUE to support the prioritisation of intervention zones and the efficient allocation of help-and-rescue resources through action proposals. A distributed simulation system connects its two interacting components:

1. Simulation of the dynamic disaster environment and of the work of resources;
2. Decision process modelling using software agents mathematically optimised with expert knowledge concerning the multiple tasks and the communication structures and decision competences within the disaster staff.” (Bostenaru, [6])

On this development built the so-called “Disaster management tool“(Markus et al. [7]), for damage and casualty estimation and detection as well as communication and information support for the disaster management staff. The tool could be employed for both pre-event training and post-event disaster management and has been tested in an exercise by the civil protection.

The “Disaster management tool” integrates a computer aided damage estimation tool: EQSIM which uses the data from the survey. The survey includes not only data on buildings but also data on streets, such as their width or the presence of parked cars, and this has been included in the GIS database. The way the database has been built is described by Schweier [8]. Fig. 1 gives an outline of the area and its street network.

Advantages of the method are that it permits computer aided rapid response and is thus independent of the subjective evaluation of the decision makers in stress conditions.

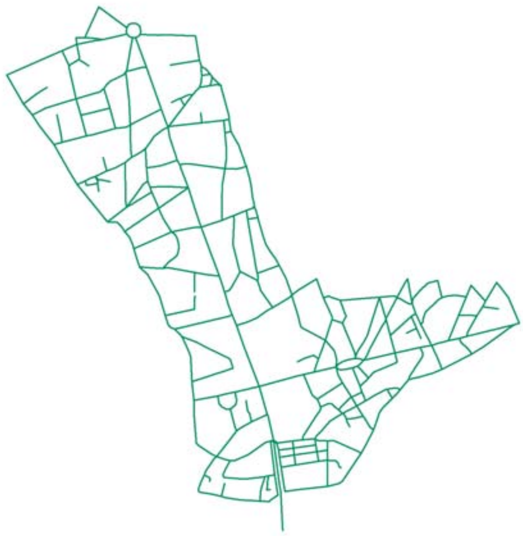

Figure 1. Street network in the northern-central area of Bucharest, as included in the GIS model in the frame of the SFB 461

Disadvantages of the method are:

- In post-disaster response electric current might be scarce to run the necessary simulations;
- The database has to be constantly actualized – for example the number of cars in Bucharest has increased significantly since 2000 when the survey was taken.

There is a lot of expert knowledge which cannot be quantified in an expert system. Thus we proposed an alternative system of decision making in case of disaster response, taking into account actors and their goals, which can be done two-fold:

- Either using a decision tree and weighting,
- Through pair-wise comparison and balancing.

Our Contribution

We have aimed to compare the interdependence between seismic micro zoning and urban zonification. Earthquake engineering and seismology and urban planning interact in what concerns the impact of the earthquakes on the urban areas. However, each discipline has developed its own instruments and when treating them together, as in case of disaster management, multi-disciplinarity rather than inter- or trans-disciplinarity have to be considered. Bostenaru [6] has defined the concepts for these zonations and highlighted the role of the street in urban zonification, which is definitely for urban vulnerability and for taking regulatory measures in preventing this. In this context we may distinguish between the vulnerability given by former Master Plans, such as the one given by the 1934 Bucharest Master Plan, and between the vulnerability reduction which may happen through designing the Master Plans today, such as the Earthquake Master Plan of Istanbul (Balamir [9]). For this purpose the urban morphology elements such as textures, which defines zoning, may be considered when defining one of the risk sectors. The Earthquake Master Plan of Istanbul is an example of mitigation planning.

The urban frame of a street is defined by its floor, background and fronts (Fig. 2-3). Analytically, the analysis of this frame begins with that of its profiles and parcours (Fig. 4). These all are elements which define the regulation in the Master Plan in order to get an urban image, such as a width of the street in the relationship with the height of the buildings, including the existence of recesses so specific for buildings of the interwar time in Romania, the existence of green elements such as trees, the relationship between the height of the buildings in the middle of the front and at corners, or those which are the ends of the perspective of the street. The recesses were dictated by the possibility to achieve an increased height of the building while maintaining the same height at cornice along the street, for reasons of solar insulation, as shown in Fig. 5. These are elements which also render the vulnerability of the buildings: the height, the existence of recesses, the towers at the corners. In the 1977 Vrancea earthquake most collapsed the corner buildings with this position in the street highlighted through a higher tower.

At the same time the street as an element of urban zoning is rendered by a certain functionality, which was, in the analyzed zone, of commercial function at the lower levels and residential above. Also this fact led to the higher vulnerability, given that the commercial function requested a certain internal partition determining a soft storey.

Other elements of urban vulnerability which are partially influenced by the street network are those determined by the historic evolution of the street, such as an irregular shape of the parcels resulting from the "cutting" of new streets. This fact has determined an irregular shape in the plan of the buildings and thus higher vulnerability through a correspondingly irregular distribution of the load bearing elements. Others, such as a degree to which a parcel is occupied, are not influenced by the street network.

This method of design which has highly influenced the vulnerability of buildings is coming from the times when design was not done with a computer aid. Today simulations, as foreseen by the OECD report on the ecological city (1996) allow having the directed prediction. The disadvantage of the method used, reflected in the vulnerability of the buildings, is, however, not the lack of a computer support, but the lack of communication between the aesthetics and the structural characteristics of the material, which have not been researched enough. Today, although it is possible to run the vulnerability simulations for historic city areas, these are based on the vulnerability scores of behavior of the buildings in such earthquakes, and not on prediction for such structures. Mathematical methods to assess the simplified structures at the urban scale without taking into account the statistics values, on which the vulnerability scores are described, are based on development (Glaister and Pinho [10], Borzi et al [11]) but the irregularity of buildings is not taken into account.

Emergency Response

One way to include the planning of the street in disaster management has already been mentioned with the Earthquake Master Plan of Istanbul. Another one also includes urban planning, which rarely happens, it has been developed at the "Ion Mincu" University of Architecture and Urbanism. And finally there is reviewed one which is not directed to planning, but to the functionality of the street network, long and short term after the disaster strikes.

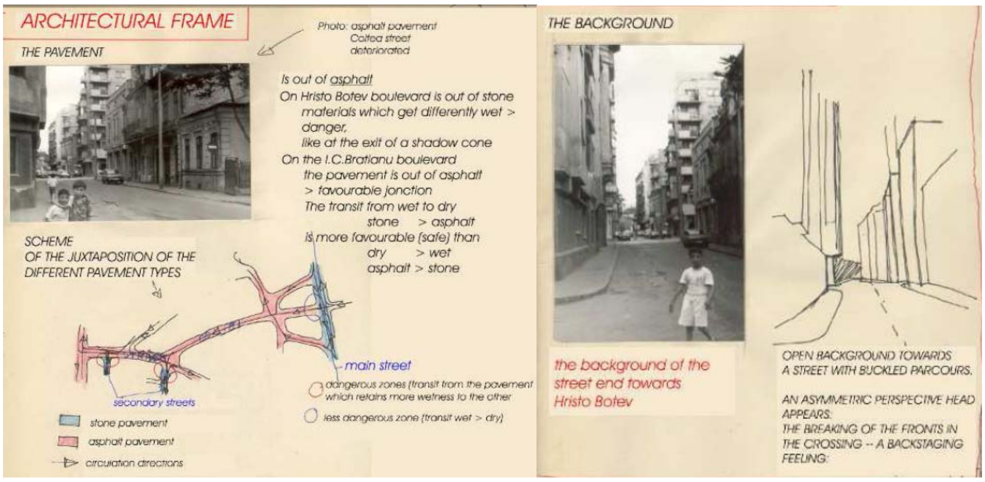

Figure 2. Floor and background of the street (from Bostenaru [6])

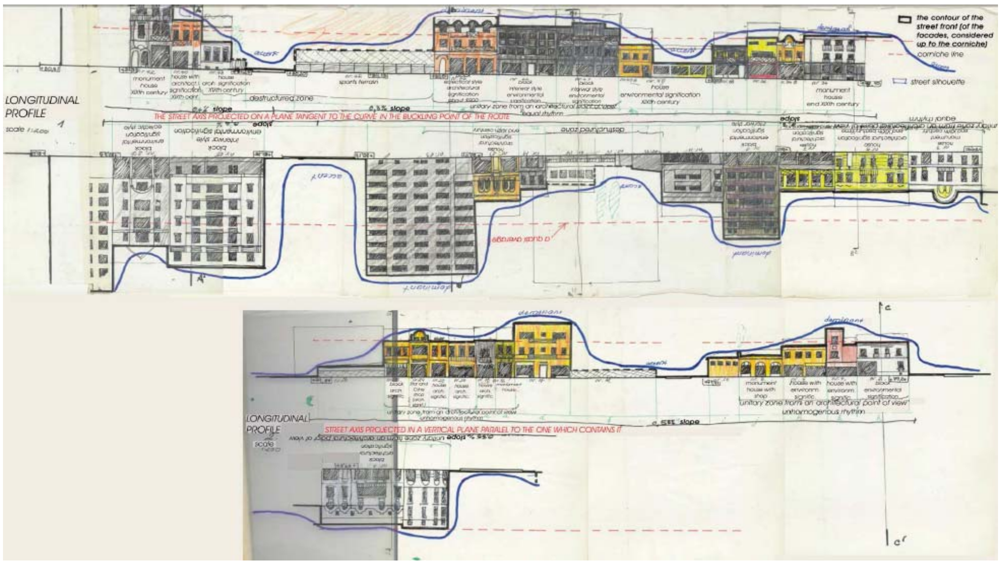

Figure 3. Fronts of the street (from Bostenaru [6])

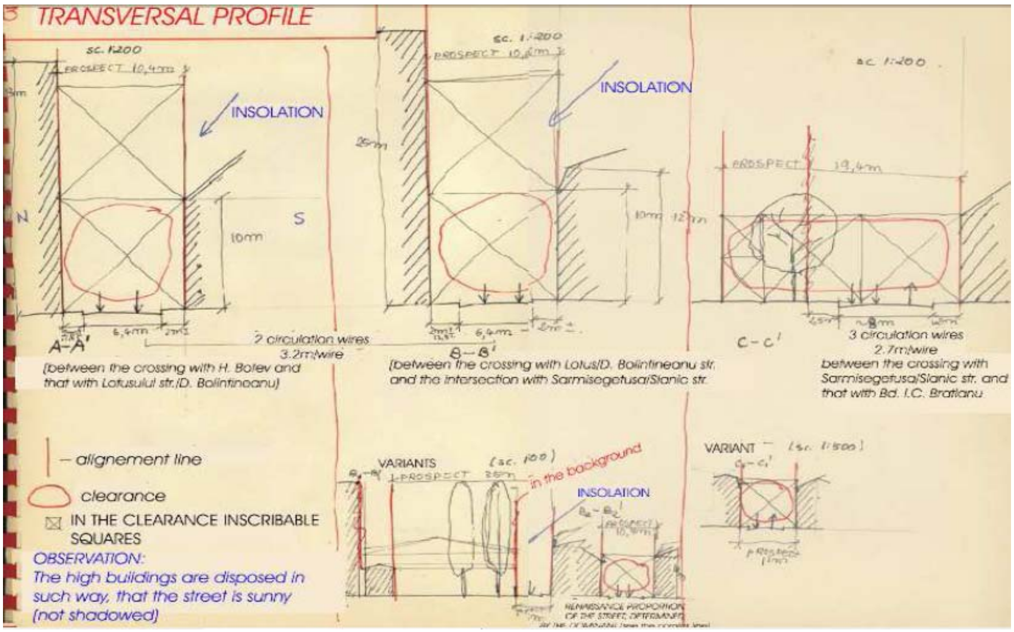

Figure 4. Profiles of the street (from Bostenaru [6])

Cristina Gociman Approach

The approach promoted by Cristina Gociman [12] at the "Ion Mincu" University of Architecture and Urbanism is centered on the idea of planning security zones. It approaches the phase of the emergency management, immediately after the earthquake, as it has been described by Fiedrich [5]. Having in mind that the earthquake might strike, security centers have to be planned. These are twofold: existing buildings may be the security centre immediately after the earthquake and free spaces have to be available to build emergency housing for the next short-term period. In both cases the planning in a new or existing zone has to include the evacuation ways to reach this security centre, as it is shown in Fig. 6. Planning the place for emergency housing also includes the circulation network, as these free places may be green places but also large scale parking.

Another idea of earthquake secure planning by Gociman [12] includes safe planning of the streets, with a sufficient width through the inclusion of green to come up for falling storeys and rubble, or even for earthquake propping, in a so-called "strategical band". Thus she has introduced along with the already mentioned urban zoning and microseismic zoning a new zoning type, using the means of architecture and urbanism, for disaster management: security zoning. Buildings and strategical bands have to be grouped and subordinated to a security centre as it is defined in the previous paragraph and the whole city area has to be covered by such groups.

We were involved in teaching this method to master in urban design students (Fig. 5).

The method is theoretical, and it is not supported by the computer based simulations. It is suitable for being included in Master Plans developed with today means, even for restructuring the urban areas. It may make use of existing free spaces and taking care to maintain them as such, or prescribing the creation of such.

The disadvantage lays in the above mentioned lack of computer simulation – for example in what concerns the evacuation ways (such as presented in Fig. 5), where more collaboration with the means of Civil Protection is to be aimed for.

The advantage is bringing knowledge of duty to include the protection from disasters into urban planning, legally compulsory, but a way breaking issue, since the urban planners are seldom being involved.

Italian Civil Protection Approach

In 2005 we edited a special issue for the Bulletin of Earthquake Engineering which included a paper by Goretti and Sarli [14] about the approach to the street network in post-disaster interventions. As it has already been mentioned in the introduction, the paper takes into account the interaction between the buildings and the roads.

The paper distinguishes between the short term and the longer term intervention needs in emergency response after an earthquake strikes. In the short term it is important that the heavy machinery reaches those in need for search and rescue, as it also has been investigated by Fiedrich [5]. Here mostly the rubble may block the roads, as it is shown in Fig. 7. It is important to have a good road network topology, in order that these teams reach the relevant buildings (in two directions: fire services have to reach the damaged buildings, ambulances have to reach hospitals). Such a network topology was considered previously by Gociman [12] for the evacuation measures. In longer term, so Goretti and Sarli [14], the road serviceability is important, and here eventual propping measures may block the road, as shown in Fig. 8 for the city of l'Aquila in Italy long time after the earthquake. Another aspect in this period longer time after the earthquake is the existence of unusable buildings, which is also the case of l'Aquila. The paper thus assesses not only the static characteristics of the road network, which we have done in our study for vulnerability (frame of the street, parcour, fronts, profile, pavement), but also the mobility demands of vehicles and people and the way this is influenced by the interaction of buildings, subject of change due to earthquake damage and post-earthquake measures. The potential change in building shape has not been considered for the road network in the previously reviewed survey for the study by Fiedrich [5] for the intervention of the disaster management teams. However, the change in building shape was reviewed for the building-only study of the search-and-rescue interventions in the disaster management tool.

Goretti and Sarli [14] have developed the formulae to assess the road topology and the road serviceability, in the short and in the longer time intervention in post-earthquake management. They have implemented the concept for the road network of the city of Potenza, in southern Italy, an earthquake prone zone.

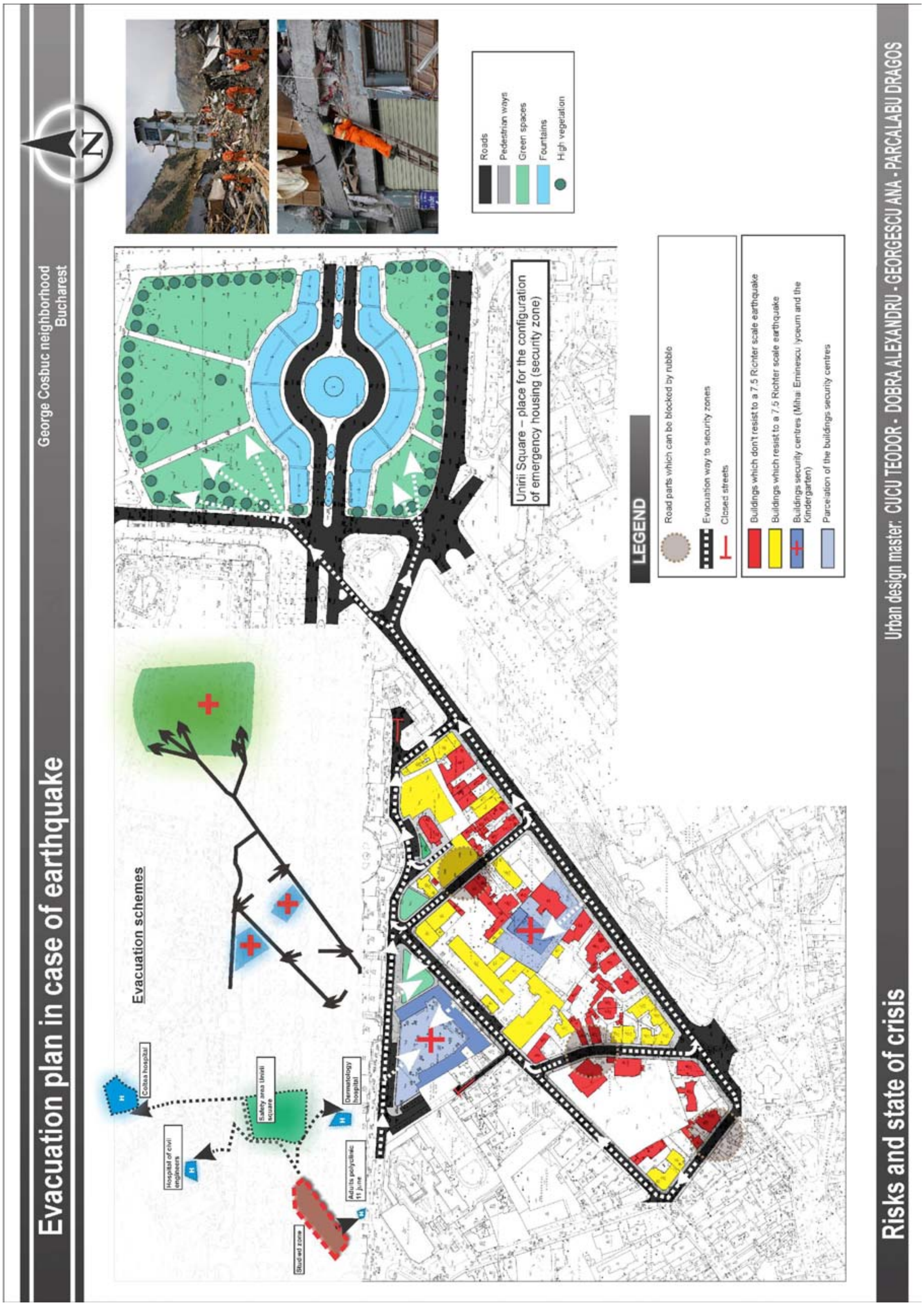

Figure 5. Evacuation plan in case of an earthquake. Study work by the group of: Teodor Cucu, Alexandru Dobra, Ana Georgescu, Dragos Parcalabu, Master "Urban design", advisors: Cristina Gociman, Tiberiu Florescu, Maria Bostenaru (from Gociman et al [13])

Figure 6. Street blocked by rubble. Photo: maris/photocase.com

Street in the Photograpy Archive of Disasters

In June-July 2010 we had a research stay at the Canadian Centre for Architecture to investigate the photography archive dealing with the aftermath of disasters: earthquake, flood, fire, revolution. Some of these photos were 1906 San Francisco earthquake, done by the star photographer Arnold Genthe. They display the way the street has been affected by the disaster (http://commons.wikimedia.org/wiki/File:Quake.jpg?uselang=de). Understanding the photography of disasters was different in the 19th century. The virtual travel done via souvenirs was highly valued and accessible to everyone, unlike today, when the photographies of catastrophes are reserved for the specialists looking for technical failure and to media (Bostenaru, [15]).

Figure 7. Street blocked by propping in the city of l'Aquila, Italy, 1 year after the 2009 earthquake and the displaced people visiting their former city. Photo: M. Bostenaru, 2010.

Today such photography is a document of the approach to disaster management of more than 100 years ago, and it is also useful to document reconstruction. It also displays the interaction of not only streets and buildings but also people's mobility and reaction, and, last but not least, the way of life of people of that time, which may determine the way the streets are developed. It is documentary photography but at the same time an artistic photography, as it is argued by numerous writings analyzing the aspect (Bostenaru, [15]).

It is a virtual conservation, as the shape buildings and rubble and buildings and propping take, the image of the ruin after disaster, is a temporary one, erased with the reconstruction as soon as it was created by the disasters, "ruins of the moment", as Constanze Baum [16] has said.

The street photography of the N-S Boulevard in Bucharest by the photographer Nicolae Ionescu, investigated in the SFB 461 research, are very fashionable today, and it may help us see the unity of the boulevard before the earthquake strike and identify the buildings which collapsed, and see their features from technical and aesthetic point of view, as well as the vehicles for which the street was planned at that time.

For the city of l'Aquila a 3D model was built in Google Earth (http://www.comefacciamo.com/aq3d/aq3d.php). Although Google presents a feature of maps with highlighting of streets, the interaction between Google Maps and Google Earth is minimal. The potential of such applications has to be further investigated. However, Google Earth makes use of an issue we approached, the virtual testimony photography gives, in using photographs of the damaged buildings for the reconstruction. It is a further step after the 3D imagery we gained through the pictures of Soule of the Fire in Portland (Maine) in the 19th century through stereo. Apart from the stereo photographs, which are taken from the related view angles, the historic photography does not allow a 3D reconstruction such as in Google building model, or another photo modelsoftware. In order to allow this, photography has to be taken on this purpose and numerous photographs are necessary. However, such photographs, and also other photographs of the building may be organised in a computer database in order to allow for example the vulnerability studies. A first step was taken by defining the ontology of photography of disasters in Bostenaru [17].

In any case, the evaluation of the road serviceability shall be also included in that following the use of satellite imagery, along with assessing the degree of damage of buildings.

Future Study of 3D Modelling

None of the reviewed studies does use 3D city models. But it has been shown that the study of the street involves not only the horizontal dimension represented in plans, it also refers to its fronts and its profile (the section). This is valid for both studies of the vulnerability (the existence of recesses, the existence of towers) as of emergency intervention (the probable area to be covered by rubble and/or propping). Such aspects may be better seen in a 3D presentation than in two 2D images. At the same time, each case study allows further development in involving computer aid, a further step being a 3D model. Except of the case of rebuilding from the photographs, the most suitable is a 3D GIS model. Some programming applications allow building it today (Armas et al [18]), but without including the semantics talked about.

Coming back to the introduction, another feature to be investigated is the modeling of the role of the street networks in computer games. 22.10.1997 – 31.05.1998 the CCA hosted the exhibition "Toy Town". Toys may appeal to the imagination of architects when doing their planning. Apart from the architecture toys, a field, where the principles of the city building are applied, are architecture games. City building games are a subgenre of the construction and management games, the best one, known by everybody, is SimCity. In its initial version of 1989 SimCity included disaster scenarios including 1906 San Francisco earthquake, but also flood, fire etc. During the further development only the fire remained, implemented as in the initial scenarios. It was a way to look at the role of disasters in urban planning, not only as a way for a new beginning, but also as mitigation and earthquake management. Today such city building games evolved to 3D applications, the semantic enrichment of which involves the economic model. It will be interesting to compare the digital 3D model with the "hard copy" 3D model which architecture toys represent. The connection to another games genre, such as video games, the board games, will be investigated, since there are games on construction and reconstruction of a cathedral and its tower and a bridge based on two novels of Ken Follett, "Pillars of the Earth" and "World Without End" approaching the topic. This would allow something aimed for in both vulnerability and emergency management exercises: training in pre-disaster phase.

Conclusions

This paper has investigated several approaches in dealing with planning the road network to reduce the vulnerability and to intervene efficiently in case of disasters, particularly the earthquake disasters. A few characteristic approaches have been considered, to the development of which there is a link with the research of the author.

Although in most cases the vulnerability of buildings is being assessed in studies related to the earthquake disaster management, the vulnerability of the road network and its response in the emergency situation is equally important. The assessment of the road network cannot be fully independent of that of the buildings along the streets, as they belong to the definition of the street. Particularly in disaster management, when the shape of the buildings also changes during the event, this interaction is important. But not less important is that urban planning issues influence the shape of the street and of the buildings along it by the definition of the street. All these aspects related to the volume of buildings along the street influence the mobility of vehicles involved in emergency response, as the street image considerations influence the shape of the buildings.

Since there are issues of volume shape, and not just facade issues, that are, involving the profile of a street, they are adequate for representation in 3D. Such approaches are not yet known to the author, but they are highly desired. A possible approach is being seen in the first test of the viability at the level of computer games, where the importance of the link between the building and the street is recognized, unlike in 3D modeling of Google Earth, which does not yet make use of Google Maps. A further step will be running such simulations and assessing the role of the road network.

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