Nat. Hazards Earth Syst. Sci. Discuss., 3, 3287–3321, 2015
www.nat-hazards-earth-syst-sci-discuss.net/3/3287/2015/
doi:10.5194/nhessd-3-3287-2015

Natural Hazards and Earth System Sciences Discussions
Open Access

Hazard impact on settlements: the role of urban and structural morphology

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Received: 19 March 2015 – Accepted: 21 April 2015 – Published: 19 May 2015

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Published by Copernicus Publications on behalf of the European Geosciences Union.

Abstract

We aim to create an alternative to GIS representation of the impact of hazards on urban areas. To accomplish this, we revise the traditional map, so that it can cope with today's innovative ways of planning, namely strategic planning. As in the theory of fractals, we address the building dimension and the urban neighbourhood dimension as different geographic scales between which lessons for decisions can be learned through regression. The interaction between the two scales can be seen when looking for alternatives or the completion of a GIS analysis, or in chosing the landmarks, which, in the case of hazards, become strategic elements in strategic planning. A methodology to innovate mapping as a digital means for analysing and visualising the impact of hazards has been developed. This new method relies on concepts from various geography, urban planning, structural engineering and architecture approaches related to disaster management. The method has been tested at the building scale for the central N–S boulevard in Bucharest, Romania, comprising the protected urban zone 04 "Magheru". At the urban scale, an incident database has been created, in which the case study for the building level can be mapped. The paper presented is part of a larger research work, which addresses decision making using the framework shown here. The main value of the paper is in proposing a conceptual framework to deconstruct the map for digital disaster impact analysis and representation. This concept is highly original, because it considers the representation of elements at different scales to be of different importance in the urban tissue, according to the analysis to be performed on them.

1 Introduction

In a dynamic built-up environment which is characterised by increasing disaster events, a better performing visualisation tool is of great importance for risk mitigation purposes.

Resilience planning is the operational dimension in risk management, while the support of urban morphology represents the organisational dimension of risk manage-

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ment. Resilience has been approached in this context by the European project RISK UE (Mouroux and Le Brun, 2006), which identified strategic elements in different disaster phases (normal, preparedness, reconstruction). The normal phase, in considering preventive planning, can be divided into mitigation and resilience; hence, Bostenaru (2005) approached the urban planning types which correspond to the phases of the disaster planning cycle of reconstruction, preparedness, mitigation and resilience by providing examples of how these historically defined coping approaches now build (action components) layers, ranging from the simplest (reconstruction) to the most complex (resilience). All of the previous stages of planning can be found within the more complex ones and can be translated to layers. Finally, in the World Housing Encyclopedia (http://www.world-housing.net/), the resilience elements of construction are identified for each typology considered.

In this paper, we look at the most evolved form of reaction to disasters: resilience. For a detailed view of the interaction between resilience and morphology, we consider two scales: the urban scale (urban morphology) and the building scale (structural morphology). At the building scale, the International Association of Shells and Spatial Structures approach offers us a wide range of views on structural morphology, from that of Bögle (2005), who builds on morphology as historically understood by Goethe, up to the contemporary design approach of the computational morphology of building structure, which is inspired by organic forms from biology. In both, the structure of the building grows organically from the way that forces are led on their way to being transmitted to the foundation. In this approach of organically determining the structure, Christopher Alexander (1977) went further, considering 3 scales: city, building, and element. Alexander's (1977) approach zooms from the city scale towards the building, by describing patterns of favourable design situations, which can be used in the proposed "language" to compose a new situation. The building (structural) or urban morphology is an aggregate of these patterns. In this paper, we envisage Alexander's (1977) dialogue between scales. Finally, Alexander (1977) also employed a complex network in his "Pattern language", moving away from tradition: the relationship between patterns

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is such a network, without having a map as its basis, and it is based on a mathematical view that was, at that time, similar to HTML. A further challenge is how to map such relationships between different scales, such as we have in Alexander (1977), with a start being conducted in Bostenaru (2004c). Alexander's (1977) approach, to which we will refer later, was also rooted in phenomenology and in seeing the city as an organism.

In urban planning, morphology refers, in particular, to the relationship between the built space and the free space, between buildings, parcels, and streets. Organically grown cities differ from the grid in pre-planned cities, in reality or in computer games. If we follow the approach developed by Lynch (1960) for a street network, we identify another kind of landmark. Chirvasie (1995) placed landmarks, as attractors, in the middle of islands in the historic centre of Bucharest, which are organically grown; according to Chirvasie (1994), this is the only shape to which the method applies. The modification of the street network is dictated by the interaction of the network with these attractors, following fractal rules.

In Romania, urban morphology, in dialogue with risk situations, has also been addressed by Florescu (2009). In Florescu's (2009) work, the city can be seen, in a systemic approach, as an organism as well, and its discontinuities put vulnerability and context into connection. Florescu (2009) applied systemic theory to risks. Systemic theory means seeing the urban organism as a system. This system can be analysed using models. They concern the urban theories, structure and image. Later on, we will discuss the image of the city and its implications for our research. According to systemic theory, in a dialogue between contents (led by the urban or structural forces) and container (urban or constructive structure) at the building level, the space is related to structure, and at the urban level, urban life is related to the urban frame/image. In the context of this study, we include systemic theory, because the two dimensions (the procedural and the physical bases) correspond to the resilience (operational) and the morphology (organisational) of a city, as mentioned at the beginning of the article.

In the following, we will perform a review of several approaches, showing the transition between systemic analysis and strategic planning. These concepts have not been

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connected so far; such a connection is part of our contribution. Salewski (2011) elaborated on the relationship between scenarios and paranoia. Salewski's (2011) work thus introduces the notion of strategy in the case of disasters, which works as a basis for strategic planning. It compares the works of Kahn (1962) and Debord (1957). Kahn (1962) introduced and later developed the concept of scenario, analysing possible future scenarios, which would later move from the military into numerous fields as the basis for so-called "strategies". For our work, the introduction in the 1990s of the concept into urban planning, as strategic planning, is the most important factor, and we will explain how we use it in our methodology. If Kahn (1962) thought about the unthinkable, Debord (1957) relied on visualising an invisible reality when developing a new concept of a map. The "Naked city" map (Debord, 1957) is a way of applying the "derivé" concept from Debord (1955) to deconstruct the map. "Derivé" was a situationist way of visualising the invisible, namely a technique describing the "irrational drifting through the city that would help the protagonist to follow the ways of his or her subconsciousness" (Salewski, 2011). Harley (1989) debated about deconstructing the map, from the classical view to representing systemic relationships. For our research, it is important that the deconstructed map of Debord (1957) is a way of reading, as Lynch (1960) explains, and to which we turn a closer view. It is also a way of visualising the "heritage habitat" of Gociman (2006), which we mentioned in relation to Alexander's (1977) phenomenological approach. If we look, in detail, at research about what can be the strategic elements we are discussing, they are landmarks, according to the seminal work of Lynch (1960) on the image of the city. Bostenaru (2004a) detailed a retrofit decision according to the analysis of an urban quarter, following Lynch's principles. Gociman (2006) introduced the notion of a "heritage habitat", where landmarks are defined by architectural history, but also, green security nodes, a new type of strategic element which can be connected to the lost green spaces of the area.

For this reason, we build on historic maps/plans, such as those in Lynch (1960), Sitte (1889) and Nolli (1748, http://nolli.uoregon.edu/), which identify landmarks/strategic elements.

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As mentioned in the initial aims, in our study, we intend to do a zoom between scales. At different scales, maps contain different information. At the building level, this information is detailed, and it goes into three dimensions. To be able to visualise and analyse this kind of information, we have to do a morphogenesis of the building. Our study will be based, apart from the concept of morphogenesis at this scale, on the concept of macroelements (Lagomarsino, 1998), which we will detail in relation to morphology. If morphology is the study of the form, morphogenesis is the way in which this form is generated.

As the aforementioned relation with biology, in which the city is viewed as an organism is also based, and the approach of the "contents" (urban activities) as the basis for urban life, morphogenesis has been defined, for example, within the computational morphology approach (Ohmori et al., 2005). In this case, morphogenesis comprises the elimination of the parts from a geometrical solid which does not serve the load of forces, and thereby, the shape is defined. A shape results that is related to what Alexander (1997) proposed at the building level. At the urban level, this is defined by the shaping of the public space of the streets in organic cities that are not pre-planned in a fractal way (see Chirvasie, 1994). If this is a structural way of looking at morphogenesis to define the structural morphology, there is also a building morphology, which refers to the architectural characteristics. A macroelement is a complex of building elements which present a unitary behaviour in the case of an earthquake. The failure modes of macroelements can be seen separately, and they describe the performance level of the building. Lagomarsino's (1998) macroelements are, however, not based on the organic shape, but on the geometric shape that we can see through the morphogenesis proposed by Ioan (2012). The building is divided into complexes of structural parts (such as the roof, the tower, etc.) which can collapse during an event. For the landmarks, according to Kevin Lynch, or the nodes of the complex network, we will use the latter in our digital map. They have also been employed in the aforementioned RISK UE project, for monumental buildings such as churches. Bostenaru and Panagopoulos (2014) elaborated on the morphogenesis of landmarks for the digital representation of the impact of the 1755 Lisbon earthquake. Instead of extending the plan, Bostenaru and Panagopoulos' (2014) method looks at extending the silhouette 2-D model into a 3-D model for the elements at a detailed scale in such a model. The drawing language to be employed for the representation went from an expression through a surface to an expression through a 3-D line.

In the current study, which extends this previous research, we aim to develop complex networks of strategic elements, instead of the urban route of Bostenaru and Dill (2014), without fully abandoning the landscape design configuration of alternative pedestrian routes in the region of the boulevard located in the capital city of Romania. The strategic elements of the city/urban zones, which are defined according to the RISK UE project approach for different stages of planning, are to be modelled in a more detailed way, through morphogenesis. In morphogenetic modelling, the 3-D representation of the shape of the building considers the whole cycle of structural resistance and structural collapse as a macroelement. Bostenaru and Panagopoulos (2014) set forth an approach on 3-D representation according to morphogenesis. This study newly introduces the connection of the morphogenesis, which is seen as architectural language development, to the representation of earthquake resilient or earthquake vulnerable building parts in the macroelements.

Depending on the scale and the analysis goals, the morphogenesis is determined either by urban forces or by physical forces (gravity, earthquake) acting on the structure. In our mapping, we can represent such forces in a graph. Innovatively presented in Debord (1957), today, the graph is present as a vector in the representation of complex networks. In our study, we map the photographs of disasters and analyse them as a complex network. In our research, we also map the street network as a graph to visualise the urban routes which are their correspondents in physical space. Eisenman (1999) worked with a simplified version of a graph which did not include vectors, but only the geometrical dimensions of these flows. Thus, Eisenman (1999) approaches the space looking at how space is connected to structure. The rules for defining this space can be derived by creating a dialogue between 2-D elements, which play the role of partitions. An approach that is similar to the application of Eisenman's (1999) principles to a building designed by the Italian architect Terragni has been conducted by Augustin Ioan (2012) for the Romanian architect Marcel Iancu, which defined new elements of the language which can be composed, as well as by Bostenaru and Dill (2014) for an urban route along the Modernist boulevard in Bucharest, which is one of the sites considered in this research. Bostenaru and Dill (2014) looked for different methods of highlighting selected elements and their connections in an urban area, from visualising georeferenced photos and models to the configuration of the pedestrian routes among them according to landscape design. In the framework of this study, we also worked on transposing this digital approach into the physical space in an exercise of determining visions and scenarios for new pedestrian streets along the Magheru Boulevard. Summing up all of these approaches, the geometric approach of the diagram by Eisenman (1999) can be the basis for the geometrical modelling of language elements, such as those identified by Ioan (2012). At the urban scale, complex networks can be superposed to maps, thus having the mathematical vector dimension over the cartographical representation.

We aim at a multidisciplinary approach. We add an economic view to the way we map urban and structural/architectural building elements. In doing this, we reviewed loss models as an alternative to the statistical ones based on GIS analysis, namely, the structural mechanics models by Glaister and Pinho (2003) and Borzi et al. (2008); their models require the building scale to communicate with the urban scale based on the typologies in a method called DBELA, in which the probability of failure is based on the resonance between vibrations, which depends on building height and structural element characteristics. From these studies, probabilistic analysis can extend the method up to urban loss estimation. These typologies can build the landmarks/strategic elements in our study. This can be the basis for modelling modifiers, or macroelements, taking into account the aforementioned morphogenesis. The macroelements can thus approach the current or future changes in the structure of the building.

The concepts presented have been developed independently of each other by their authors. Our innovation includes linking them into the general methodological framework presented in this paper.

Innovation has been practiced for centuries on paper maps, but today, in the digital age, the key concepts in mapping have to be translated with an application to urban planning. This paper presents a methodology to obtain the components of a multiscale visualisation approach with an application to a spatial analysis of the impact of hazards. In order to achieve our goal of an innovative multiscale visualisation of a hazard impact, we first consider a systemic analysis of the interaction between resilience and urban/structural morphology, respectively.

2 Conceptual framework and methodology

The working principle applied in this paper is the examination of representations that are more adequate for strategic planning. In urban planning, strategic planning means that the urban areas are not subjected to uniform treatment when urban regulations and the studies underlying them are made, as has been the practice, but rather, a hierarchy is established. Within strategic planning, the master plan is a vision which encompasses different planning levels and involved actors. The strategy does not become a regulation. The means to reach the planning goals are applied through measures packages at different planning levels and time horizons. At these levels (which correspond to different scales in GIS), action plans, which can be model plans, demonstrations and pilot plans, are performed. These plans can assume different forms: a partial urban plan, a regulation for a limited area, an architecture project, a spatial structural concept, and/or a development scenario. The way they are performed can also vary (alternate projects, competitions, workshops), as can the means of participation (project team, leading group, PPP, round table, citizen and specialist forums) (Fassbinder, 1993). However, most important for our concept is that, instead of giving the same importance to all zones of the city – and editing them correspondingly – the plan-

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ning strategy connects the intervention levels, one with another, and displays those intensive zones for which detailed solutions are determined, while other zones are described globally. In the CA'REDEVIVUS project, we developed a strategic plan for the preservation of reinforced concrete structures (Bostenaru, 2004b), employing these means in the form of project management.

Lynch's (1960) method identifies landmarks, paths, zones, boundaries, and nodes, as perceived by pedestrians who regularly walk in a specific city, i.e. according to the heritage habitat. In our approach, mainly for the first objective, we will attempt to digitally model landmarks and paths in order to represent and analyse earthquake risks. Zones and nodes will also be considered.

The RISK UE project (Mouroux and Le Brun, 2006) also identified strategic elements according to the disaster cycle phase. Such strategic elements support the decision system between actors at different levels. We superpose a grid upon a map, as is done in planned cities or in computer games. This makes it easier to choose a typology which is common among other studied areas. As is the case with this study, these typological examples highlight landmarks in homogeneous urban/rural areas. The landmarks are detailed as we specified, using the macroelements and the morphogenesis method, and for this reason, we introduce the notion of fractals, the communication between the whole and the part. The employment of fractals is similar to graphs and complex networks.

For example, Romano (2014) has defined modifiers from a simplified structure for buildings in Italy that are contemporary with those on our boulevard in Bucharest. In fact, Giovinazzi and Lagomarsino's (2004) method was derived from monumental structures (Lagomarsino, 1998), which can also build landmarks, and it has been employed in the RISK UE project.

At the building scale, structural morphology methods follow the rules of how forces are employed and tracked. Architects like Santiago Calatrava and Antoni Gaudi design their buildings to include a minimum of materials, following this (structural) morphological rule, while common buildings having rectangular shapes hide the morphological

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shape. Ohmori et al. (2005) translated this approach to making retrofits by eliminating parts of structural walls until the edifice assumes an organic shape.

That which plays a load bearing role at the building scale, corresponds to a strategic role at the urban scale. Strategic building, at the urban scale, can be that which is necessary for emergency intervention and reconstruction, and hence, requires a higher level of performance. Switching the load bearing – non-load bearing role corresponds to switching the function of a certain building. The paths connecting the buildings describe urban forces: the paths to be followed by agents in emergency interventions (Fiedrich, 2004) and also by citizens who are changing their residential or work locations according to the perceived disaster risk (Grinberger et al., 2014). An agent-based following of this movement is just a further development of the association of this movement, which was intuitively well visualised by Debord (1957) in graphs: the representation of urban spaces either as fractals or as complex networks.

Between the two levels (building and urban), which are the pillars of our multiscale approach, lessons are learned through regression. By regression, in this context, we mean what is presented in Bostenaru (2004a). For data sets obtained from case studies, the hypothesis for the decision tree is then induced. From these individual hypotheses, a single hypothesis is obtained, to be integrated into the mission/recommendation. The hypotheses for the individual elements are then derived, and finally, statements about them are deduced. These statements are used as feedback to compare with the induced hypothesis in order to regressively reformulate the latter. The flow of forces at the urban level becomes the flow of agents in an intervention at different stages in disaster mitigation (ex. crisis or reconstruction). While such agents can also be simulated in GIS or in computer games, at this stage of the research, we propose to use a software like Adobe Director for visualisation, which is also the basis for representation software that include zooms, such as Prezi. The software allows the movement of images, and the inclusion of real time 3-D, as well as the creation of the superposition of elements from different time spans.

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In the following, we will show the general workflow of the methodology by detailing the first two tasks, which are directly derived from the Lynch (1960) approach (Fig. 1). Task 3 is a consequence of taking the concept of the grid in planning on a computer further, while Task 4 builds on 3 and 2 and will be the subject of further articles. The digital humanities component (digital methods for cultural heritage) is especially strong in these first two tasks.

3 Applications

3.1 The zoom level of the building

At the building level, the study area is a central protected zone in Bucharest, located north of the historic centre, namely a boulevard which was built in the 1930s: Magheru Boulevard. Typologically, it has the highest frequency of buildings which are classified, according to earthquake engineering expertise, in risk category I, but at the same time, constitute a unique cityscape in Europe. The uniqueness consists in having such a high number of buildings from the 1930s as the building fronts, instead of just having empty plots throughout the city, as in other locations. The 1977 earthquake damaged numerous buildings, some of which collapsed, and were altered or replaced; hence, the original unity is no longer present. Figure 2 presents the position of Magheru Boulevard in the city.

A first step in the workflow was to create a database to be used in further investigation. At the building level, we examined archival images of plans to establish a typical floor plan which can be considered as characteristic of the zone, and at the same time, has the unique characteristics of the landmarks that will be used in morphogenesis. The source of the archival data in this study is the records in the Bucharest Town Hall. The N–S boulevard/Magheru protected zone was built around the 3rd decade of the 20th century, and thus, the building plans have been conserved. The building plans, however, rarely contain details regarding structure. Archival images (Fig. 3) can be placed in dialogue with building surveys, as alternatives to gather the existent structure – the different methods lead to different classifications. For example, building survey photographs can provide details regarding the uncovered structural elements.

The step following the consultation of the relevant archival images for the buildings is the determination of the respective risk class (Fig. 4) or the ones displaying high architectural value. According to a study of the URBASRISK project (http://www.uauim.ro/cercetare/urbasrisk/en/), in prioritising decisions in interventions to mitigate seismic hazard, two contradictory factors are seismic vulnerability and cultural value. The extent of an intervention is greater for the first and less for the second of these factors. The architectural value was not mapped in the GIS database to which we had access, so we consulted the plans for the protected zones of Bucharest and the monument records. In this zone, we identified several levels for the protection of buildings: individual monuments, collective monuments, protected assemblies, and protected zones. More details about their digital depiction can be found in Bostenaru et al. (2013). Urban routes between such elements can be identified, as shown in Bostenaru and Dill (2014).

These geometric elements can form a catalogue for digital modelling (GDL), for a library of elements in CAD, and thus, for a more rapid modelling of prototypes for 3-D modelling of urban areas. In our research, we will attempt to identify these kinds of modifiers between the structural dimension and the architectural dimension of morphology. This way, the relationship between space and structure is highlighted. The structural dimension of morphology determines the structure as a load bearing scaffold on which the architectural space, both as an atmosphere and as a container for a function, is shaped. The way it is shaped is defined by the architectural dimension of morphology. For computational morphogenesis, a grid is considered as a basis on which both morphologies are pinned. This will also be helpful in the latter loss computations, for which building elements (like those composing the macroelements) are considered from the level of a survey on which the architectural morphology is based.

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Once we had obtained the plans of the characteristic buildings from the archive, we performed a typological study in order to establish the model for computational mechanics (Borzi et al., 2008; Glaister and Pinho, 2003) based studies of vulnerability. We simulated the possible structure of the buildings as reinforced concrete skeleton buildings (Fig. 5).

A model resulting from these studies can be more detailed in terms of complexity, as was the one that was included in the World Housing Encyclopedia description (Fig. 6). Such a model can be used for finite element model simulations, as is necessary for the macroelement method of Giovinazzi and Lagomarsino (2004). Pursuant to this method, which is fully coherent with our approach, landmarks are chosen for detailed modelling, in order to draw conclusions regarding urban zones. The model in Fig. 6 is detailed enough to allow the identification of modifiers, as in the macroelements method, i.e. the removal of some details through simplification, resulting in a simple model, such as that shown in Fig. 5.

At the urban scale, the typology leads to simplified models, as we considered in our economic and decisional approach (Bostenaru, 2004a). This way, a prioritisation of different interventions for buildings of the same typology, and not a prioritisation among heterogeneous buildings in the same urban area, could be done. For a prioritisation of buildings, Glaister and Pinho's (2003) method can be employed. At its basis, the simplified methods from the typology are necessary, because the method computes building failure based on the characteristics of columns, spans between successive columns, heights, and the expected earthquake. We did this computation: the building class over 4 stories proves to be the most vulnerable in Vrancea earthquakes. This modelling is suitable for the zone, but not for the landmark. Bostenaru and Armas (under review) analyse different modes of computer-supported priority setting for the prioritisation of buildings to be retrofitted in the Magheru area.

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3.2 The zoom level of the urban zone

At the urban level, the archival image is that of 19th–20th century photography, in dialogue with various urban 3-D representation methods (GIS, Google Earth, SELENA, fractals, our proposed urban routes game, SimCity, Second Life). The latter are investigated based on a questionnaire developed in TU0801 COST Action, as depicted by Bostenaru and Panagopoulos (2014).

Our approach, in this study of the Magheru Boulevard, which encompasses the design of the pedestrian routes, builds on a Lynch (1960) analysis of this new study zone. On the other hand, Popa (2014) performed an analysis of landscape photography in accordance with Lynch's (1960) principles. Tension lines or other characteristics of the landscape are identified by Lynch (1960) as some of the elements in the definition of perception: node, landmark, zone, boundary, and path. In this research, we consider images of disasters (such as those in Kozak, 2010, and Wieczorek et al., 2014) to which we can apply this methodology. The Lynch analysis gives the correspondence between the two scales. The 19th century photography of Bucharest was obtained from the archives of the library of the Academy in Bucharest, while 19th century photography of disasters worldwide is available in the 2010 research of the first author at the Canadian Centre for Architecture in Montreal.

The images are investigated according to the Popa (2014) method, which is based on Kevin Lynch, and it is placed in the context of complex networks with the images of other disasters. The software ORA allows for typological, but not spatial, connections (Fig. 7).

The software we propose to employ and the method of Eisenman (1999) allow superposition on the map and zooming from the cartographic elements to the photographic elements. In the classical GIS environment, the link between geographic location and image has been established for Magheru Boulevard within the framework of the SFB 461 project at the University of Karlsruhe.

The connection between the building level and the urban level identified landmarks is specifically provided by the definition of macroelements. As Lagomarsino (1998) shows, macroelements define the level of damage according to how much they suffer in earthquakes. This means that a certain damage pattern is typical for a modifier that is identified in the model. Such damage patterns can be taken from descriptive archival records, as in the history (of art), but also from reconnaissance photographs. Certain types of damage have a certain 3-D display as well, as discussed by Schweier et al. (2004). In a continuation of that previous work, Schweier and Markus (2006) produced 3-D models of typical buildings in order to help assess the damages at the urban scale. The CAD models are those of the landmark and of the typological model at the building scale, which can be identified in the urban scale images. For landmarks, the comparison between the aerial image and the eye level view is important. An example of a modifier, according to Lagomarsino's (1998) macroelement model, for buildings from mid-20th century and on the Magheru Boulevard, is the pancake collapse of the Wilson block tower (Fig. 8). A pancake collapse, and how it can be recognised in photographic images, is included in the Schweier et al. (2004) catalogue. The towers of mid-20th century buildings have been discussed by Romano (2014).

The analyses of satellite images and artistic images from the aforementioned archives are complementary.

We work with the images from multiple points of view. Our completed research includes the philosophical understanding of photography and representation quality (Bostenaru, 2011a, b), including memories, as represented by ruins (de Meyer, 2011).

In this research, the quantitative aspects are essential. As such, we worked out an ontology to organise the consulted database, in dialogue with other databases. As such, we defined parameters connected to photography which can be used to organise the information and can lead to a computerised catalogue of new elements. The concept of the database has been published in Bostenaru (2011c). The diagram in Fig. 7 shows the results as presented at the Future of Historical Network Research conference (http://historicalnetworkresearch.org/hnr-events/

the-future-of-hnr-conference-13/ 13–15 September 2013, Hamburg, Germany). The data connected to each photograph, as included in the ontology for the database, are transformed in metadata and lead to a network in which similar features are connected through the ORA software. This software is not as connected to sequential connections as other softward, but instead, it groups the types of criteria which connect the different images.

So far, we have considered the historic events from the Canadian Centre for Architecture archive, which are mainly historic events that occurred in the 19th century. This way, an incidents database can be built and mapped in a different way. More traditional ways of mapping, which are less connected as a database, but which have a stronger spatial dimension, were employed by the DESURBS project (DSSP, CIMNE database, http://www2.cimne.com/websmaps/desurbs/mapa.aspx or in the tool http://desurbs.it-innovation.soton.ac.uk/). In contrast, these were used to map contemporary (past 20 years) events. If they are mapped in a unitary way, both databases can represent different slices of time. Apart from these two databases, we are aware of a number of other incident data which could be mapped this way. These include major historic incidents, many of which preceded the era of photography. The book by Kozák and Cermák (2010) on the illustrated history of natural disasters is one source of data, while Wiczorek et al. (2014), which provides a catalogue emerging from a project and exhibition on “Images of disasters”, is another. Finally, within the coursework supervised by the first author and Gociman, further data on historic, but more recent, incidents were collected, and this could be used to update the DESURBS database. Unlike the DESURBS approach, which looked for weak points which could be avoided using the developed tools should the disaster happen again, our focus is on the visual representation of the impact, i.e., on the image.

Applying the same method from these lessons learned for macroelements, we also consult special ontologies for buildings (English heritage, architectural elements ontology from the University of Geneva, Getty Institute of Conservation ontology).

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At the city level, as a next task, we also look at the relationship between the urban morphology and the constructive structure. Depending on whether the city was shaped by organic growth or planned, between tradition and innovation, the shape can be organic or superposed to a grid. Although our approach is to underpin a grid to all of the developments to obtain better visualisation, sometimes this can be seen in the development of the street network – along which the paths are constructed and along which the agents move. We looked in particular at the street network.

We chose Space Syntax as a complex networks and graph investigation means. The accessibility of landmarks has been investigated (Fig. 9). Figure 9 displays the nodes from a Lynch analysis.

Morphologic decomposition is followed by the classification of the elements, which is based on the documentation in the previous task. In this Space Syntax analysis, the graph of the network is cartographically superposed. A combination of the two methods can lead to the mapping of the images of disasters. Either artistic or technical images can be mapped in a place which is adequate as a landmark or node. The aim is the optimisation through element reordering, following the strategic role of elements. A disaster smooths the urban surface, while (re)construction striates it, if we follow the concepts of Deleuze (1980). Also, the historic centre was reshaped following the 1847 fire, with a new street grid, which is superposed on some of the old buildings (ancient hotels). The foundation of it has been recovered in recent restructuration efforts. Recovering the images of lost buildings and public spaces of the city on maps would be another level of the application of the Bostenaru and Panagopoulos (2014) method. The role of green has to be considered, as well as the memory of the ruins, for example, the lost gardens. The method described here is another level of the fractal connection between the part and the whole, as the loss models and the urban routes. Urban routes serve to transpose the digital routes into physical space, as their implementation requires scenarios and strategic planning.

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4 Discussion and conclusions

We investigated the relationship between the information from the archives, which we collected for this study, as well as the information from the building survey in the field (physical dimension) for the decision making process. The information from the the archives includes the drawings of plans, which can be used to generate ontologies, making it possible to define macroelements and taking the interior of the building, in its entire 3-D dimension, into consideration. The differences between the two approaches are found in their attempts to adapt methods for new buildings in the approach to historical buildings. For several decades, different methods have been concerned with this goal, but there has been no unanimously accepted solution. Macroelements do not have to be defined as the changes in the simplified structure, as seen in Romano (2014); they also consider the earthquake damages, depending on what stopped working and what can be identified as patterns in the urban images of destruction (see the catalogue in Schweier and Markus, 2006). Such macroelements can be elements in the 3-D library (for ex. how does archiCAD complete the library with elements, as we saw such an element for green walls) and can be used again at other sites, as well as for structural software (ex. SeismoSoft). ArchiCAD also has the advantage, for our concept, of being able to make a plan part of another plan, for example, part of the urban plan. These plans are defined through Geometric Modelling Language. For this reason, we also consulted the references of the diagram (Eisenman, 1999) to see how the geometry is reflected. Ionescu (2011) saw the diagram as being the expression of a catastrophe as a pictorial representation. However, we can also look, as we will see, at the diagram as an expression of temporality, as related to photographic rendering. Geometry can also be combined with augmented reality, as Markus and Schweier's (2006) study showed. This way, another link between the physical dimension and the digital dimension is created, in addition to the field data collection and the scenario development for pedestrian routes. Furthermore, the search direction of the relationship between the geographic scales, for which we provide details with the macroelements,

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is confirmed. The zoom generated by the detailed treatment of some strategic zones makes the applications more economically feasible. The zoom can also be adequate for different associated cultural values (protected zones, assemblies with ambient value, historical buildings, etc.), because the zone considered for our detailed study (Magheru Boulevard) is a protected one.

The ontology for photography that we developed can also be applied to 3-D models to search for models that have already been constructed for import into our application. The macroelements method is also useful for the 3-D modelling of buildings as cultural heritage: modules like the modifiers can be marked and identified for 3-D searches, or they can be defined as templates for future 3-D reconstructions, through geometric modelling language. With this goal, we approached Europeana to see the metadata, and we will contribute our models of Romanian buildings as a start. Figure 6 is just one of the models covering the whole span of Romanian historical buildings which we modelled in 3-D and can contribute to Europeana. The addition of metadata will enhance the possibility that these buildings can be mapped at other geographical scales and in different complex networks. The parametrical study for these models does not have to consider a mesh for their modelling, but rather, macroelements, based either on structure or on the architectural style. We will be able to compare these metadata with these study parameters. This is an example of the lessons learned regarding the two scales that are addressed in this paper.

Oosterom and Stoter (2010) developed the concept of 5-D modelling, which means 3-D + time + scale. The underlying idea is the same, namely to save resources from the detailed modelling in 3-D of whole areas, so that certain areas are presented in more detail (the scale dimension). In our approach, however, which depicts the urban studies dimension, instead of the computer science dimension, with an emphasis on the humanities, it is also innovative that the specific ingredients for modelling natural hazards have been considered, with detailed areas being defined as strategic elements for risk mitigation.

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Another progressive idea is the so-called “time machine”. We developed a multimedia application for the city of Köln, in which we have a time slide; however, these transformations have to be visible in a graphic way, on the map or in a 3-D model. The macroelement modifiers can precisely mark this change in time. The models obtained through morphogenesis can be printed in 3-D. If we go into the study of iconography, this modification in time can be shown through graphical codes (colour, transparency), as we proposed for the ontology of the function (Bostenaru, 2013). In Schwäbisch Hall (Germany), a project has been done (http://www.schwaebischhall.de/buergerstadt/geschichte/haeuserlexikon.html) in which the archive plans have been considered for a lexicon of houses. The city has to be seen as a network of the stories of houses, which is strongly connected with social stories, as in building archaeology. “Paths” from the “Image of the city” by Kevin Lynch (1960), which we intend to apply, act as hyperlinks between these stories (between the house correspondent of these stories); the city is a network in this sense, which can be represented digitally, as a space syntax, or physically, as we tried to do at our AESOP Urban Public Space workshop (http://becominglocalbucharest.ro/, Bucharest, Romania, June 2014). The “path” becomes a story, and this way, the means of social sciences and humanities (narratives) are imported into this research. The nodes can be a parcours in space and time. The creation of such a path can occur in the virtual space (as for the lost landmarks in Köln, Lisbon or Bucharest) or in real space (as at the aforementioned AESOP workshop). To create such a parcours, new curators are needed. For the investigation of such networks, complex networks can be used (the graphs between images, ex. COMOB, see Amoroso et al., 2013), but also, the ORA grouping which we propose can be used. In the ORA grouping, we consider the metadata, but we also consider the object itself (the analysed image) and the narrative text. How to superpose the complex network to the geographical dimension, the map, remains a further challenge.

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5 Outlook

In the large framework of the methodology that is shown, we aim to integrate our findings in a decision system based on a regression between the two scales. From game theory, a next step can be taken to drama theory (employing conflict manager software) and to analytic hierarchy in decisions, instead of a decision tree. This way, the qualitative aspect precedes the quantitative. However, we need to take into account that, while GIS considers the qualitative aspects, datascapes are built on quantitative aspects. Datascapes are 3-D models of GIS plotted into Google Earth, where the height dimension is replaced by plotting data connected to different characteristics of the building. In an attempt to consider both, the qualitative aspects from GIS are translated for datascapes, based on their agent-based modelling role – the landmarks and strategic elements serve a certain area of a residential zone, for example. From the measurement spaces employed for the criteria at the building level (Bostenaru, 2006), we thus go to the measurement spaces for the urban datascapes through regression. In a first step at the urban level, we have assigned weights to the GIS, but this will be the subject of another article (Bostenaru and Armas, in review). These criteria can be connected through an ontology or through a complex network for translation into an exploitable foreground for a computer system.

Acknowledgements. This work was supported by the strategic grant POSDRU/159/1.5/S/133391, Project "Doctoral and Post-doctoral programs of excellence for highly qualified human resources training for research in the field of Life sciences, Environment and Earth Science" cofinanced by the European Social Found within the "Sectorial Operational Program Human Resources Development 2007–2013".

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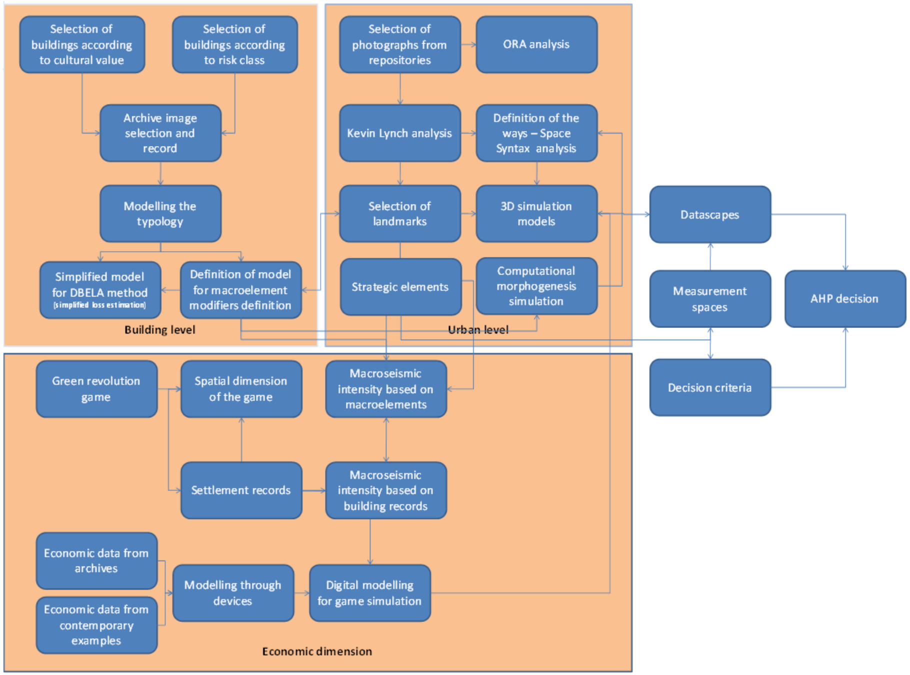

Figure 1. Methodology workflow with zoom on those detailed in this paper.

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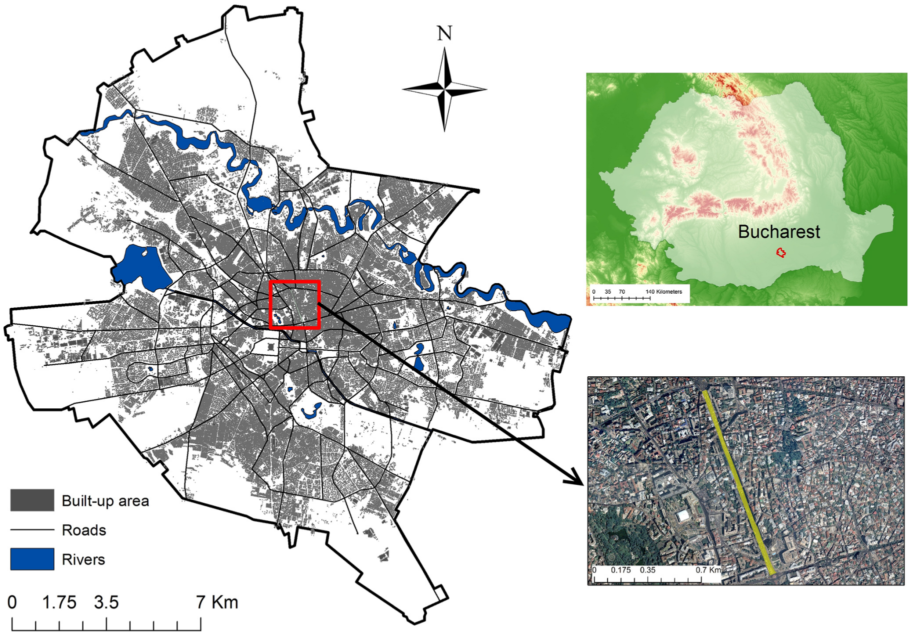

Figure 2. Position of the Magheru Boulevard, which is located in the northern part of the historic centre of Bucharest.

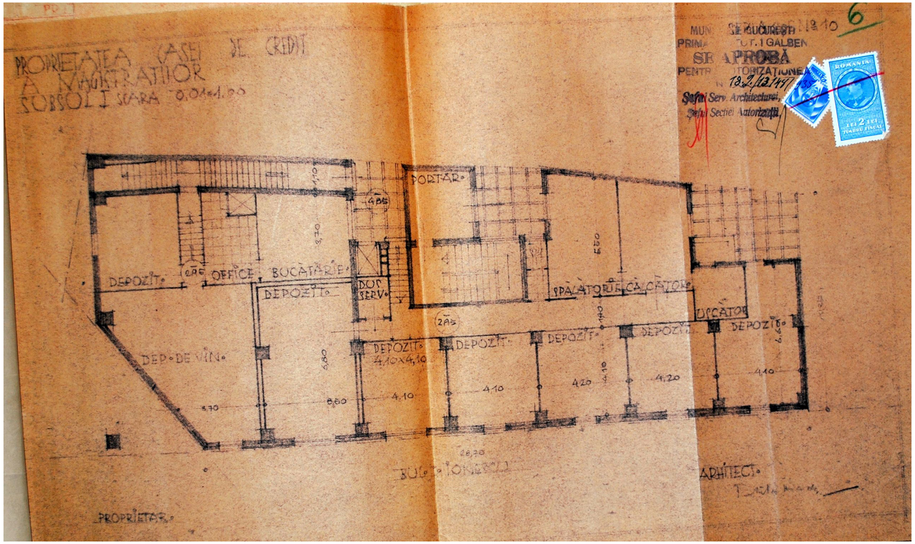

Figure 3. Archival image of a typical building.

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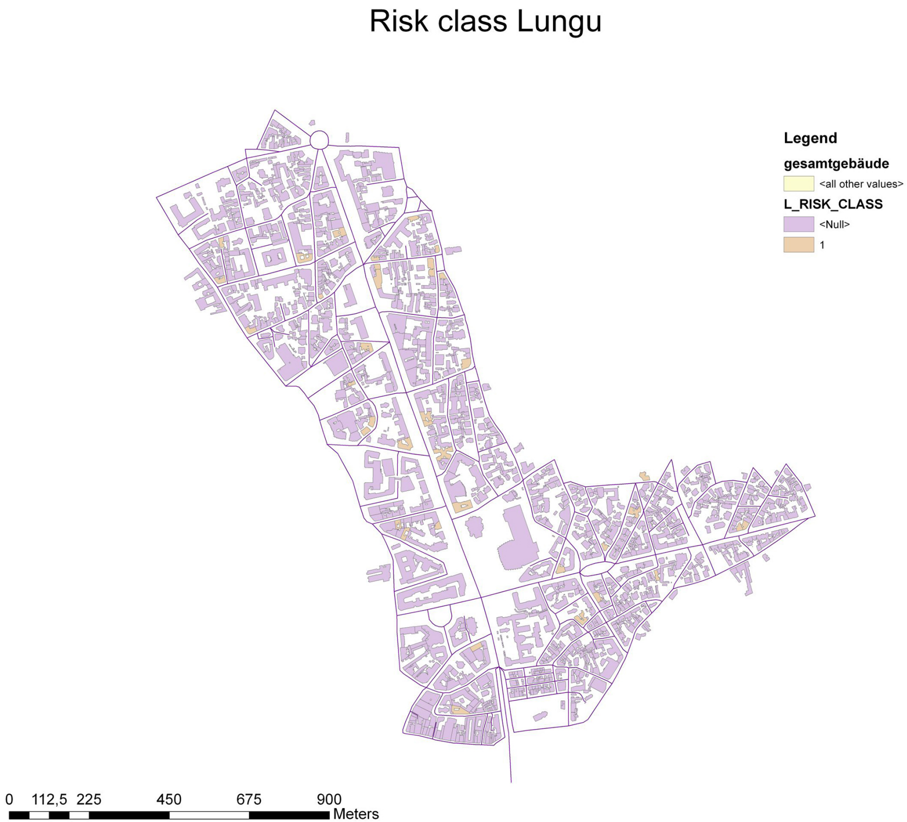

Figure 4. The N–S boulevard area, highlighting the risk class I buildings, database developed in frame of the SFB461 project, Karlsruhe, Germany, used by permission.

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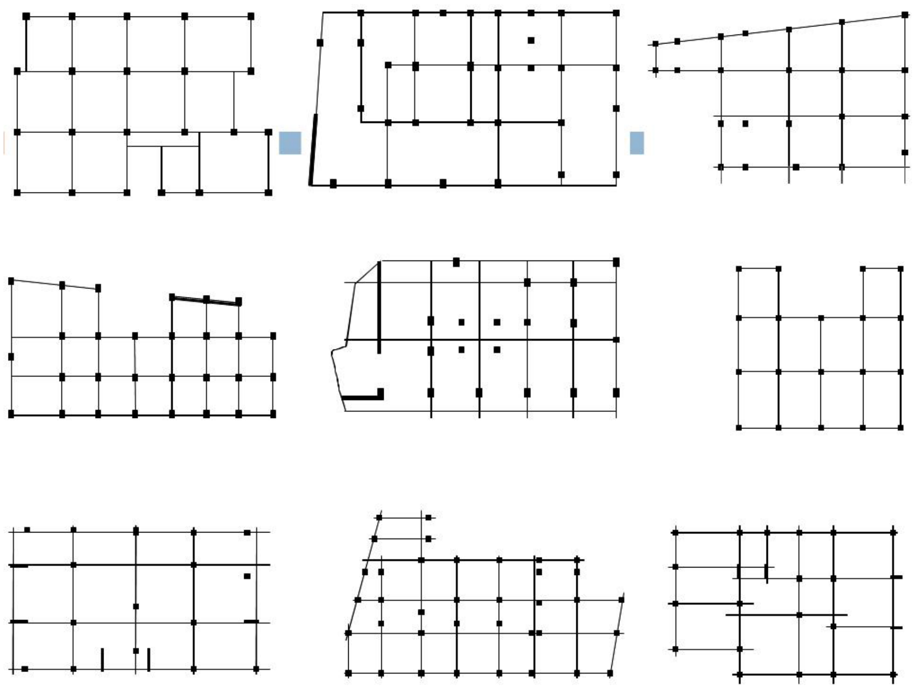

Figure 5. Typological studies.

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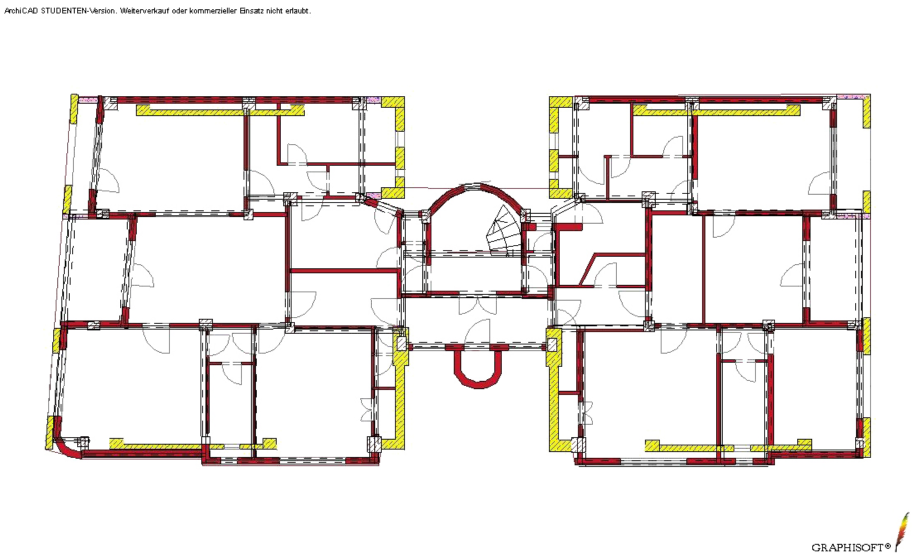

Figure 6. Model of Romanian interwar building in the World Housing Encyclopedia.

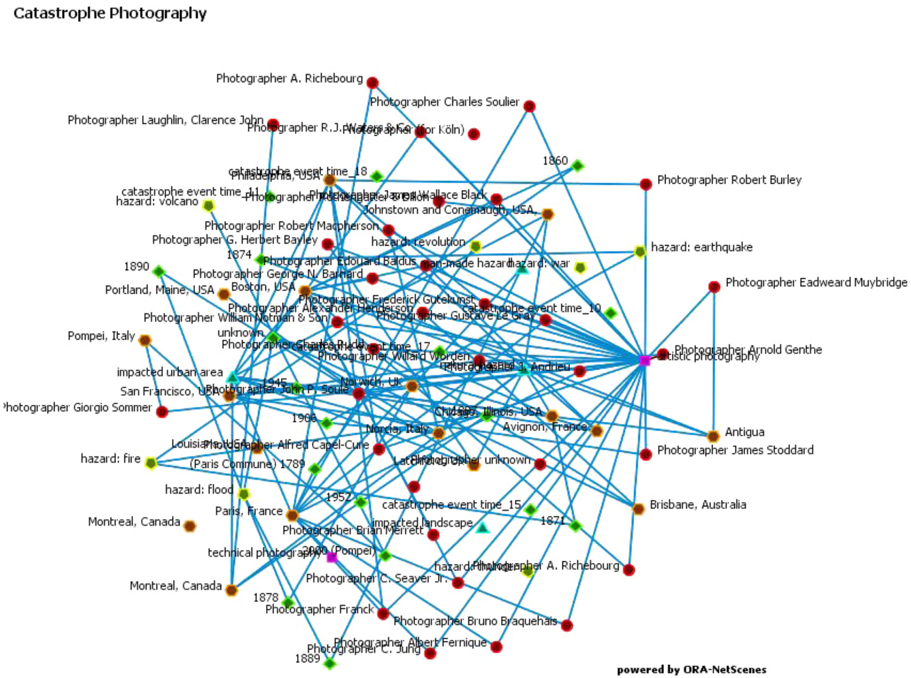

Figure 7. Historical network research of catastrophe photography.

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Figure 8. Wilson block of flats after earthquake (1977). Source: courtesy of Rezistenţă urbană.

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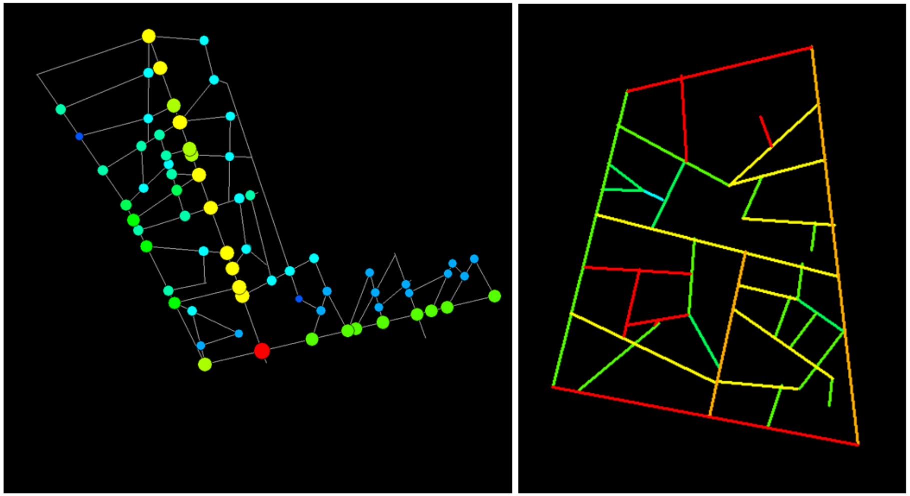

Figure 9. Space Syntax analysis of the street network in an organic (historic centre) and a pre-planned (N–S boulevard) area in the centre of Bucharest, following two modes of expression.

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