

Assessing the costs of hazards mitigation in the urban structure

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ABSTRACT

In this paper we look at an issue rarely approached: the economic efficiency of earthquake risk mitigation. The urban scale at which a natural hazard can impact leads to the importance of urban planning strategy in risk management. However, usually natural, engineering, and social sciences deal with it, and the role of architecture and urban planning is neglected. We look at the way ICT can contribute to organize the information from the building survey to economic computations in direct modelling or through games. Also we take into consideration at a rare element, which is the role of landscape planning, through the inclusion of green elements in reconstruction.

Keywords: Green space; Economic efficiency; Games; Information modeling.

INTRODUCTION

A natural disaster is the most rapid, instantaneous and long-range conflict of the natural environment with the socio-economic system and human society (Mercer, 2009). A natural disaster shapes the human and natural environment and disrupts and affects the operation of the regional an economic and social level depending, of course, on the degree and extent of the disaster (Beckeretal. 2013). The linkage between development and disasters is well known. Unfortunately, despite the modern evolution of technology, natural disasters affect the daily lives of people, disturb the smooth operation of society and constitute a permanent threat (Wisner et al., 2004).

The extreme events can even be devastating for developing countries which have less capacity to adapt (Winkler, 2005), but the effects generally relate to both the developed and the developing regions. There is a global concern that natural disasters are becoming more frequent, deadly and costly; they are also more complex, and the impacts to society and the economy are increasingly more intertwined (Khan, 2012). For that reason, mitigation of disaster management in city planning has become top priority for the local authorities in many countries all over the world (Haimes, 2012; Ye et al., 2012; Alexander, 2013). There are many studies on the possible impact of hazards on cultural heritage (Tarraguel et al., 2012; Daungthima and Kazunori, 2013; Ortiz et al., 2013). One of the major aspects of disaster risk reduction is the economic efficiency of natural hazard risk mitigation through pragmatic disaster risk management planning (Yung and Chan, 2012). Meanwhile, no studies have yet been conducted about the economics of natural hazards mitigation and more specifically of earthquake risk mitigation.

The aim of this paper is to explore an aspect of disaster management to which little research exists, namely on the economic aspects of it. The roles of game theory, agent based modelling and networks and urban public policies in designing decision systems for risk management from earthquakes and climate change are discussed. Climate change can lead to risks related to increased floods, desertification, and sea level rise among others. Reducing the sealed surfaces in cities through green spaces in the crowded centres can mitigate them, and can be foreseen in reconstruction plans in presence or absence of disasters. For this purpose we reviewed the role of green spaces and community centres, such as churches, in games, which consist of the core of reconstruction efforts, as also field and archive studies show.

ECONOMIC STUDIES TOOLS FOR DISASTER RECONSTRUCTION

The economic value of building restoration, particularly the rehabilitation of historic city centres were studied in this paper, by getting evidence from existing studies mentioned from Provins et al. (2008). As earthquake retrofit concerns historic buildings in city centres designed before seismic provisions, it is important to study the economic value of mitigating the effects of natural hazards as earthquakes in those valuable areas of the cities.

Novel approaches such as game theory, drama theory and conflict based software for multi-criteria decision problems of economic efficiency in the field of climate change and natural disasters were performed. City building games are actually construction management games, based on the same rules as devices. SimCity is included in the 2D version simulations of events such as fire after earthquake in San Francisco. In Turin, Luca Caneparo is developing SimTorino (<http://www.laq-tip.polito.it/SimTorino/>), an adaptation of SimCity to simulate

urban development. In this paper we looked at both computer games and hard copy board games, especially at their rules. Drama theory is an alternative way to game theory to look at decision making as the one developed so far by the first author based on utility-value or the one this is compared to in the analytic hierarchy process/balancing method we will approach at decision. Although we look to actors at building scale, the balancing method has been initially developed by Strassert for regional science. So far drama theory has been applied to dealing with climate change (Jason et al, 2009).

This paper translates the balancing principles for earthquake protection into a realistic management environment. In the frame of the drama theory an agreement is looked for, and this can be supported by a software called “confrontation manager” (<http://www.ideasciences.com/products/confrontationmanager/>), one concurring with other attempts. We had a look at various software applications supporting decision in the context we are looking at. Previously to the involvement in these COST projects, we had accomplished a research grant (PIANO) from which the exploitable foreground results were:

1. The idea of ontology for zoning, which can be used for the development of object oriented software dedicated at project management in construction industry, other than based on spaces or building elements as it is now (Fig. 1). Ontologies are a way of organizing data types for object-oriented programming. Right now the software for facility management is based on project management, so this would be a new approach. Additional work includes the definition of taxonomies and the creation of a database to try out the concept. The two exploitable foregrounds are connected by the sense of ontologies/semantics, but differ in the field of application.
2. Relationship between function and sign (semantics, as seen by Umberto Eco, philosophy) applied to the zonification of this housing, to be connected with the ontology. Umberto Eco used ontology and semantics in its philosophic sense. In order to make it an exploitable foreground, the definitions have to be converted to those used in computer science, especially in semantic web.

Along these lines we looked into how Building Information Modeling (BIM), in our concrete case the ArchiCAD software, can be employed in restoration projects, to which building retrofit is a special case (Fig. 2). Further, the functional relationships identified in zoning in the project PIANO can be further investigated by means of the so-called “space syntax” (Fig. 3), to be investigated with related software (<http://www.casa.ucl.ac.uk/ajax/>). The computation of prices in the utility-value method is based on this function.

A second step was looking at the application of game theory for urban simulation of the economic environment: review of architecture and urbanism games and their potential, and translation of the resources from the economic computations used at building scale to the urban scale of games using similar rules to existing board and online games.

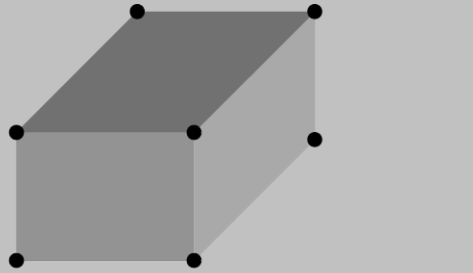
We reviewed, in view to our decision approach, the contribution of the European project SIREN Social games for conflict RESolution based on natural iNteraction (<http://sirenproject.eu/>). Games can also serve the participative dimension of risk communication and disaster prevention awareness. For example, loss models by Glaister and Pinho (2003) and Borzi (2008) will be used to translate the costs for post-earthquake repair or preventive retrofit from building scale to regional scale.

The former method is adequate for reinforced concrete buildings. The way city management



Photographic measurement results

- Back to building shell
 - providing reference points
 - defining building elements between these
 - defining spaces between these



16-18.09.2001 CENAT PhD Meeting 2001
Zürich, Switzerland

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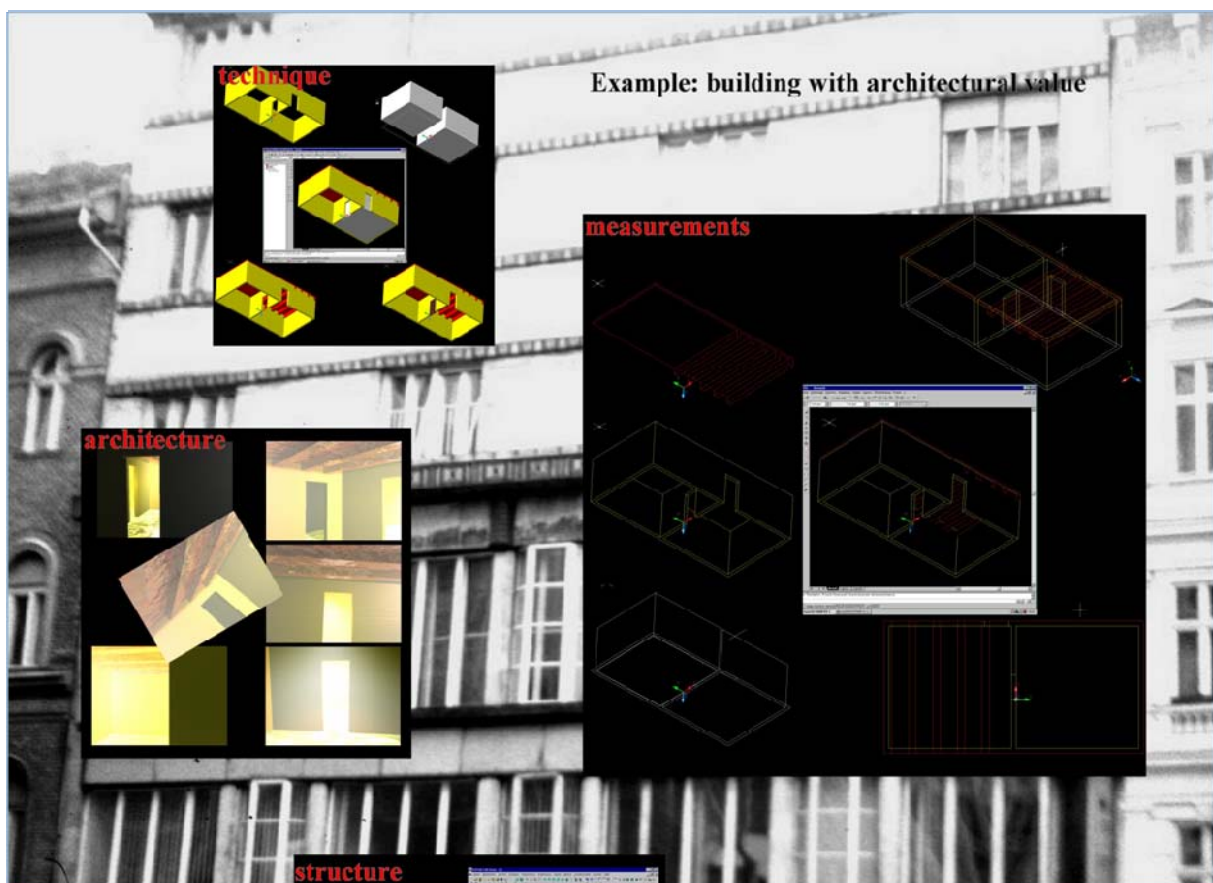


Fig. 1 Building survey system representing the building structure – our approach for a spatial ontology. From building survey to costs – a GIS at building level and an early stage BIM (Building Information Modeling). From a presentation of M. Bostenaru, 2001.

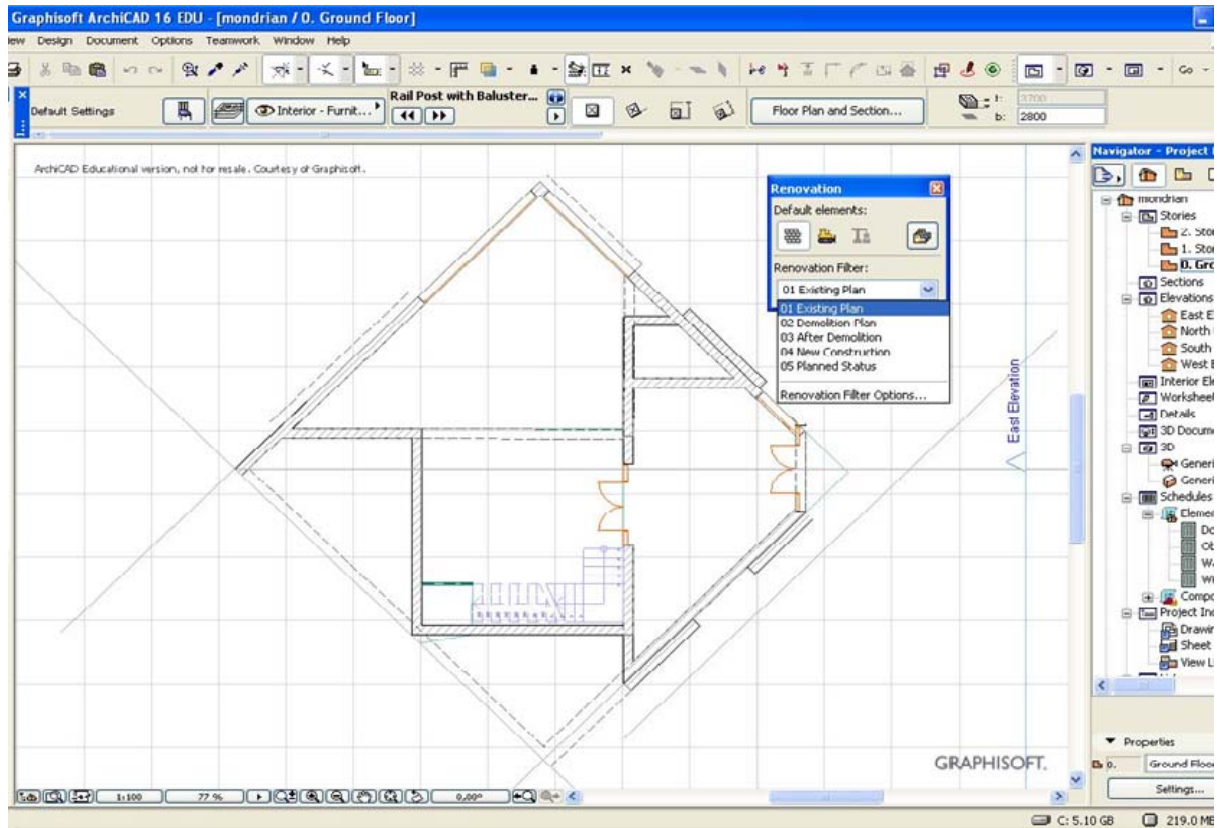


Fig. 2 Today's BIM (Building Information Modeling) – House Mondrian, a house with green walls, designed by M. Bostenaru, 1993, digital modelling 2013. Economic computation in Bursa Constructiilor will follow. http://www.constructiibursa.ro/casa-mondrian-19129&s=proiecte&articol=19129&editie_precedenta=2013-06-28.html

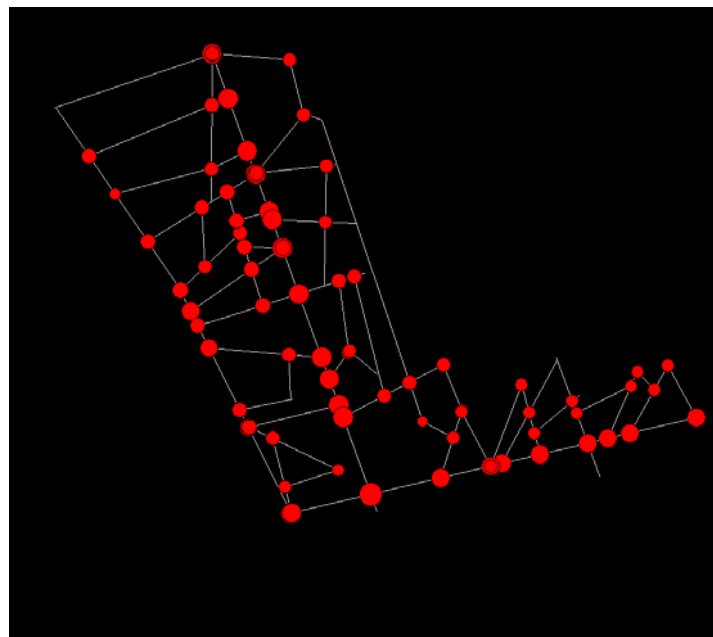


Fig. 3 Space Syntax analysis for the Modernist Boulevard in Bucharest.

games deal with building is strongly related to our computation of preventive retrofit and post-earthquake reparation costs, since it takes into account the resources: materials and people, needed for a certain building element. At the same time it is different from the functional surfaces based computation explained previously. We looked at two kinds of games: cooperative and conflict based games.

The conflict based games put face to face restoration and demolition, an example is the Romanian game “Habitat” (<http://www.odaiacreativa.ro/en/habitat-joc-de-tip-board-game-pentru-patrimoniu-si-urbanism-in-bucuresti/>), which touches the central area, including that in Figure 3 and presented in Bostenaru et al (2013). Economic aspects play a key role, since demolition and rebuild open the way for speculation and faster wins than in the public participation supported restoration. Cooperative games include such as the ones inspired by the novels of Ken Follett, a different medium to the book and the film we also looked at, and there all players contribute to building the landmarks. The comparison between the digital and non-digital implementation of the game was subject of previous research.

We compare hard paper representation to the digital one in the investigation of the game “Pillars of the Earth”. The game is dedicated to the architectural endeavour of the construction of a cathedral using resources such as people and materials, like in construction management. The advantage of the digital method is the better implementation of the rules of the game. Although useful for our general research on project management, it was useful to introduce us to the comparison between “material” and “digital”, leading to conclusion on the material model and the 3D model which later led to the developed concept. Also, in games we have to do with the symbolic dimension, and with no issues of scale. We analyzed the way the economics of construction are reflected in the novel, the game and the film derived from it. Below there are images of the digital and the material version (Fig. 4). The church which has to be built in “Pillars of the Earth” follows two different approaches: in the “material” version it is made out of simple volumes which are put one next to the other, like in building a model at an urban scale for architects or in building a model in Google’s Building modeler, about which we will talk at results. We will return to what a church means in reconstruction, not just in construction efforts, for the settlement, at the end of the paper.

Jeffrey Head, support grant recipient at the Canadian Centre for Architecture, observed how digital tools such as SketchUp are the toys of today in educating the imagination of architects. In the “digital” version the church is built like with a 3D printer. The game taught us how to deal with construction and in a similar way as in civil engineering. A building consists out of devices for its elements. But, when doing project management in architecture, the spaces are considered at the overall scale and the building elements coming in question at detail scale (the m³ of built space or the m² of floor space for a different function determine the costs and not the resources). In architecture the space is represented, considering the walls monolithic, and this is how they are in archive plans (Fig. 7) or in Nolli’s plans (<http://nolli.uoregon.edu/>). The structural elements appear very rarely.

The way building is performed was explained previously. Intervention in case of a disaster involves multiple actors, and this could be the basis of a new game. The aim is to design which components of the real situation can be brought in the abstract (IT) model of a game to support decision making between the actors involved in decision about preventive retrofit compared to post-earthquake repair, the so-called planned conservation. The difference between the mathematical model in collaborative game theory and the architectural/urban approach of designing participative processes through games was investigated. These aspects

relate to urban public policies. The study of Markov populations for example can be related to public policies to relate to disasters (Canbolat, 2013), more suitable however for man-made ones. At the same time, the involvement of these multiple actors in the decision system links to agent based modelling.

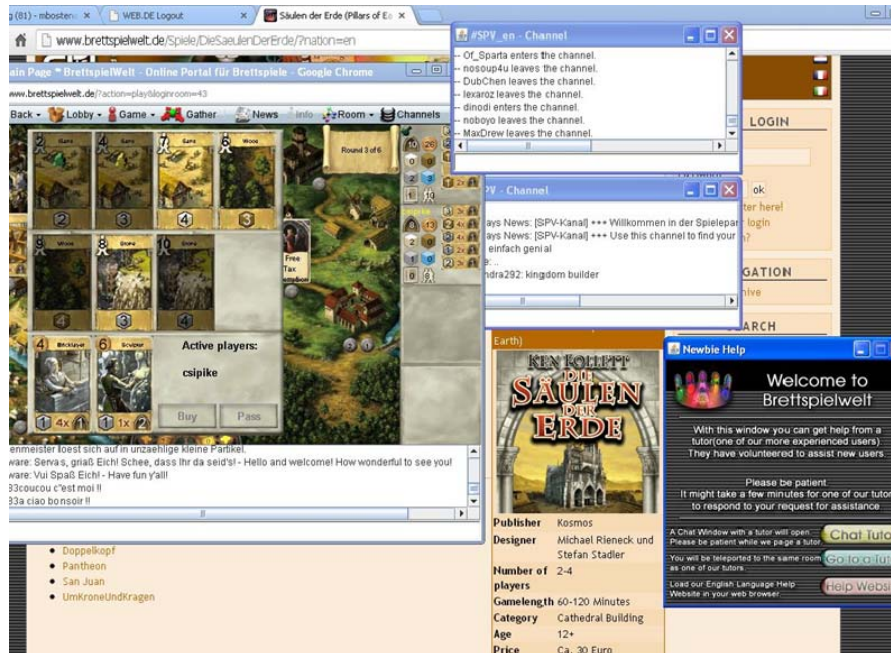


Fig. 4 Dealing with resources in the medieval city in “Pillars of the Earth” – computer game versus hard copy. Photo: M. Bostenaru, 2013.

Going out from a decision tree which we developed between four actors: architect, engineer,

investor and user, with the later going over to participative models, a review of similar (the group around Caterino, 2009) and alternative decision systems for earthquake resilient planning, for example, agent based modelling of allocation of resources in post-earthquake intervention (Fiedrich, 2006), including the functioning of the street network was performed. The actors have been selected to incorporate a variety of criteria used historically for decision making, including project implementations, theoretical models, and databases of various associations. Several novel methods will be used in developing decision models. These include:

- (i) Traditional quantitative decision trees and qualitative balancing methods (Bostenaru, 2004),
- (ii) And newer methods based on adaptive decision trees. The particularities of the newer methods are based on interdependencies between the various criteria (as supporting or aggravating each other), and developing them into a programming environment (as an ontology). For implementing the alternative to utility-value analysis, namely the balancing method of Strassert, confrontation manager can be employed (<http://www.ideasciences.com/products/confrontationmanager/screenshots.php> a software from IdeaSciences which takes into account the "what if" cybernetic approach of Christopher Alexander (<http://www.patternlanguage.com/>)).

SETTING UP COMPARATIVE ANALYSES OF ECONOMIC STUDIES TOOLS

First a comparison between agent-based modelling (fully computer based choice of resources to be employed in earthquake protection for example) and our approach of decision as well as the drama theory related one was performed. Agent based modelling also involves expert opinion, but not in real time. Instead, plans of reaction in case of a disaster are available for choice after communication between the agents.

Our analysis shows that agent based modelling is more suitable for processes of linear action, such as spread of fire and movement along the street network (thus touching a third element relevant for the action), than for modelling the cooperation in pre-disaster retrofit for example, which is directed to specifically chosen buildings or elements of a building, difficult to model also on GIS, for which reason BIM is more adequate. However, we emphasize the role of agent based modelling for the modelling of resource allocation, the process of retrofit and repair being also one of resource allocation (materials and people).

A further development is the application of a Monte Carlo simulation to numerical simulations at building scale used for the computation of costs using the retrofit elements method developed by the first author; comparison with real examples of earthquake retrofit and their costs (planned conservation: preventive retrofit versus post-earthquake repair).

MODELLING RECONSTRUCTION AFTER DISASTERS

The grid of the planned (re)construction, from case studies to computer games was subject of the modelling. The case study was Lisbon and it was used 3D modelling to model the impact of the 1755 earthquake, but without examining the economic aspects yet. In particular it was related to the development of the Baixa quarter and the timber frame typology used there.

From that case study it could be drawn also conclusions for the city of Bucharest, where several national funded projects on related topics are running (Bostenaru-Dan et al., 2013). We analysed the representation of Lisbon reconstruction in Second Life by a group at CHAIA, University of Evora, a game with rather participative than economic dimension, and at our previous outcome of developing urban traces games. We visited several museums in Lisbon which visualize, interactively in multimedia or not this new urban development, having contact with some of the developers of the software to present GIS content on 3D hard copy model and with researchers reflecting on the post-earthquake development today.

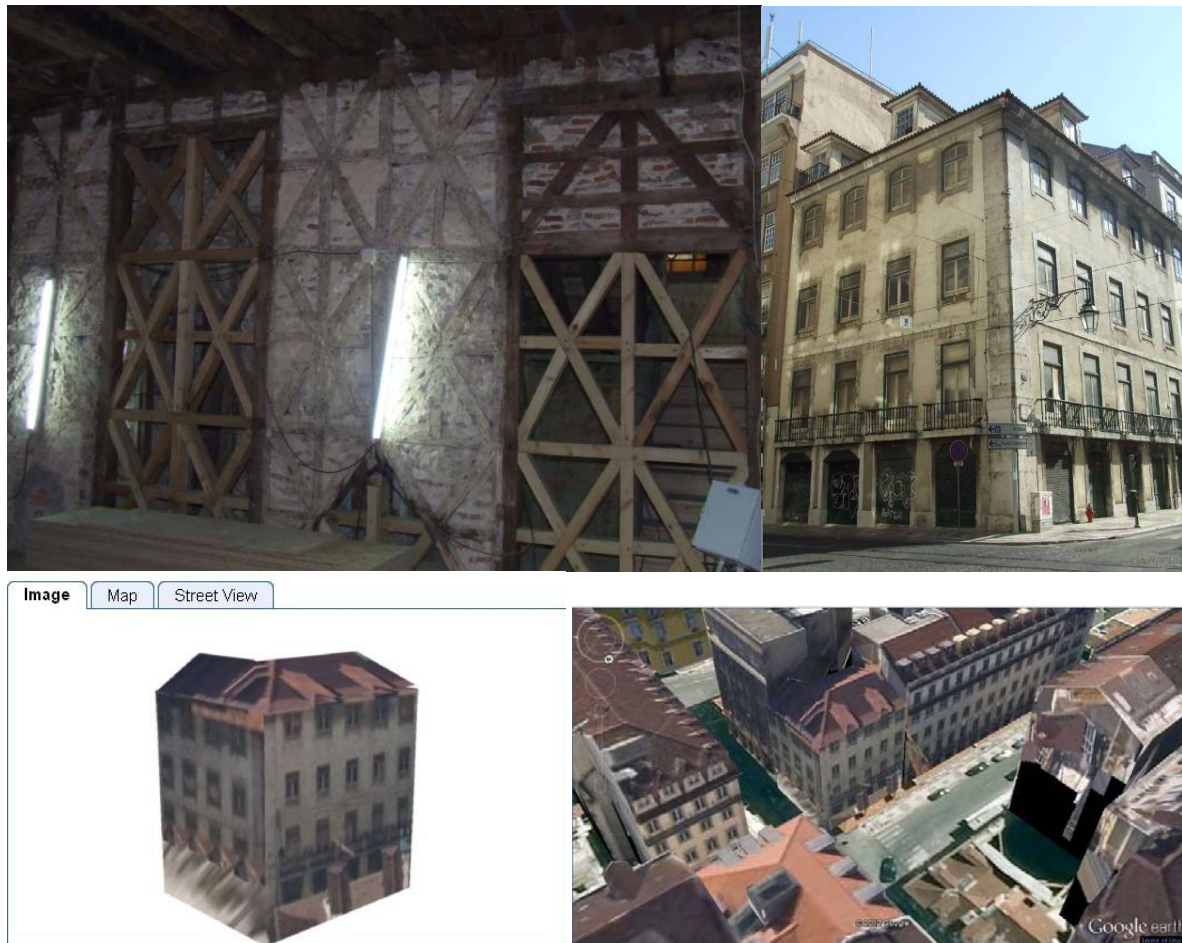


Fig. 5 Modelling on different levels of detail for Baixa, Lisbon: reality and Google Earth model contribution by us with Building Maker. The SketchUp model as alternative can include interior details. Photos: M. Bostenaru, 2008, model M. Bostenaru, 2012.

In continuation of the previous research we identified some of the landmarks presented in the Azulejos depiction of pre-1755 earthquake Lisbon in the city, with the aim of a 3D city model, from eye level and from above, using Lisbon's numerous "miradouros" (points of looking from a hill). Urban traces between landmarks such as those of the Lisbon 1755 earthquake can build the basis of creating a parcours of Pocket Parks in the city (see Bostenaru and Dill, 2014, where we considered the centre of Bucharest as depicted in Fig. 3). Landscape will be the road between the landmarks which are the nodes of the urban trace/route. The

Baixa quarter has a grid structure typical for the geometric development of Baroque cities when reconstruction was done, and is therefore suitable for this research. In Figure 5 can be seen an application of modelling on different levels of detail for Baixa, Lisbon. Here we took into account the concept of monolithic versus modelling of the structure about which we talked at the game analysis and in the early stage BIM design. The SketchUp model can contain the structural modelling in BIM, while the Building Modeler model contains only the textured monolithic common buildings according to Nolli's plan. See Bostenaru and Dill (2014) for more details.

The 3D city model would assure going over from the building size to the city size, thus modelling the region. A special attention was given to Lisbon's green walls, a feature supported by the particular climate (warm and wet), and to the way green spaces contribute to economic development, such a feature being of potential use in earthquake reconstruction, if happening today (Fig. 6).

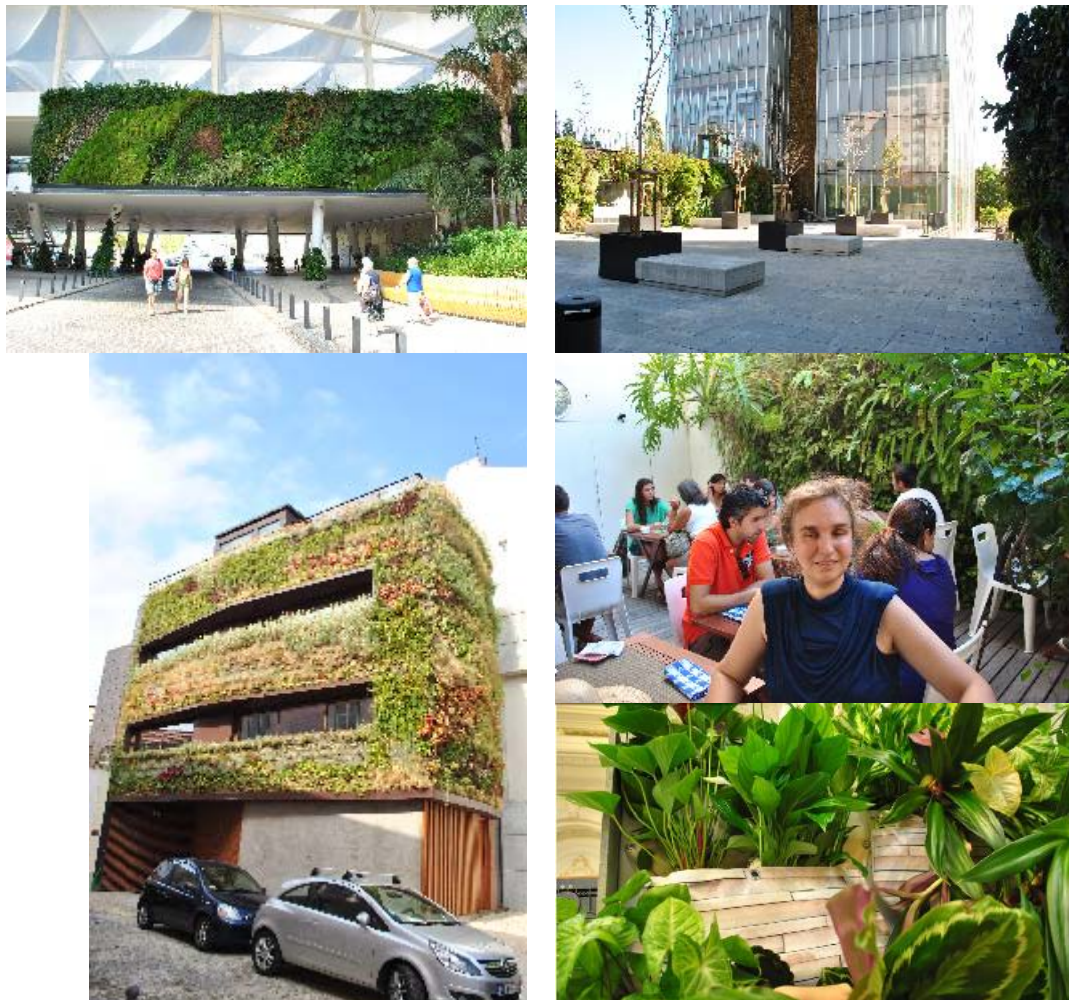


Fig. 6 Green walls in Lisbon, a possible inspiration for supporting green elements on the timber structure from Baixa in a similar design as that proposed in the Mondrian house, displayed and modeled in BIM through a potted system. Photos: M. Bostenaru, 2012 and portrait.

In city centres with crowded construction as here green spaces can appear only in form of

pocket parks, or, if even more crowded, on the facades. And they contribute to the improvement of the local climate, against heat islands, and mitigating the raising of temperatures due to climate change. Such a reconstruction is supported by the structural typology of the buildings in central Lisbon as timber supports such a structure (the relationship between timber as support for green walls in reconstruction efforts has been shown in Bostenaru and Mendes, 2013).

The modeling of the costs at the level of resources as from device based computation of costs at the single building included the definition of the interface between structural engineering results and construction economics computation, based on either element costs computation - applicable for the rough structure - or on functional space surface computation - including architectural finishing. In a fore work to ontology we completed several forms on structural taxonomy of buildings, following World Housing Encyclopedia reports (<http://www.world-housing.net/related-projects/share-your-knowledge-of-buildings/building-taxonomy-summary-reports>), for which we also analyzed to criteria according to the decision tree. It includes employment of the developed ontology for elements and ontology for spaces and how this can react to common architectural design and building management software such as, for example, archiCAD and its new – 2011 – building rehabilitation module.

The resources can be translated in the symbols related to materials or building elements in a game and therefore they build a basis for collaborative decision in bargaining in an earthquake risk management environment. We envisage in developing this with a similar case study in Hungary, which aims to do research in economic bargain games and in landscape planning, connected to our findings resulting the role of green spaces in reconstruction. In Figure 7 the church can be seen as community centre in the middle of a green space in case of reconstruction designed by the architect Richard Bordenache after mountain floods in the 1940s (war time in Romania) and after a chemical disaster in Ajka for Devecser designed by the architect Imre Makovecz. In the first case urban planning played a role in the reconstruction by relocating the settlement to a higher position in the mountains. Such savings of space to provide green spaces can lead to higher rental prices in the neighborhood. Both approaches follow traditional building with timber, as we saw also for Lisbon. For Antonești-Corbeni we did a research on the economics of the houses which were sold under a price. Figure 8 presents part of the computation of the costs devices for the house of Antonești-Corbeni shown in Figure 7. In designing a game for such issues we can consider the model of construction from Pillars of Earth, focused on the church, and the spread of different items related to it in a later intervention such as in World without End, inspired also from Ken Follett novel, thus having the new construction on the disaster flattened space of the reconstruction in existing tissue to compare. Also, we have the different scales: for the unique object of the church the building scale is considered, while for the urban scale we may consider common buildings such as in World without End. For World without End no electronic form of the game was available.

The ontology of decision (the IT component of the modelling) must adapt again from another more frequent approach to our topic. The IT component of the modelling is that of energy modelling (O'Donnell et al, 2013), also present in the archiCAD module, of structural earthquake retrofit. The results of the modelling will be integrated into a decision system based on regression between the two scales: building object and urban scale of the quarter. An example from this decision support integrated into city planning games (SimCity and CityVille) can be seen in Figure 9, where the vicinity of green spaces increases rental prices

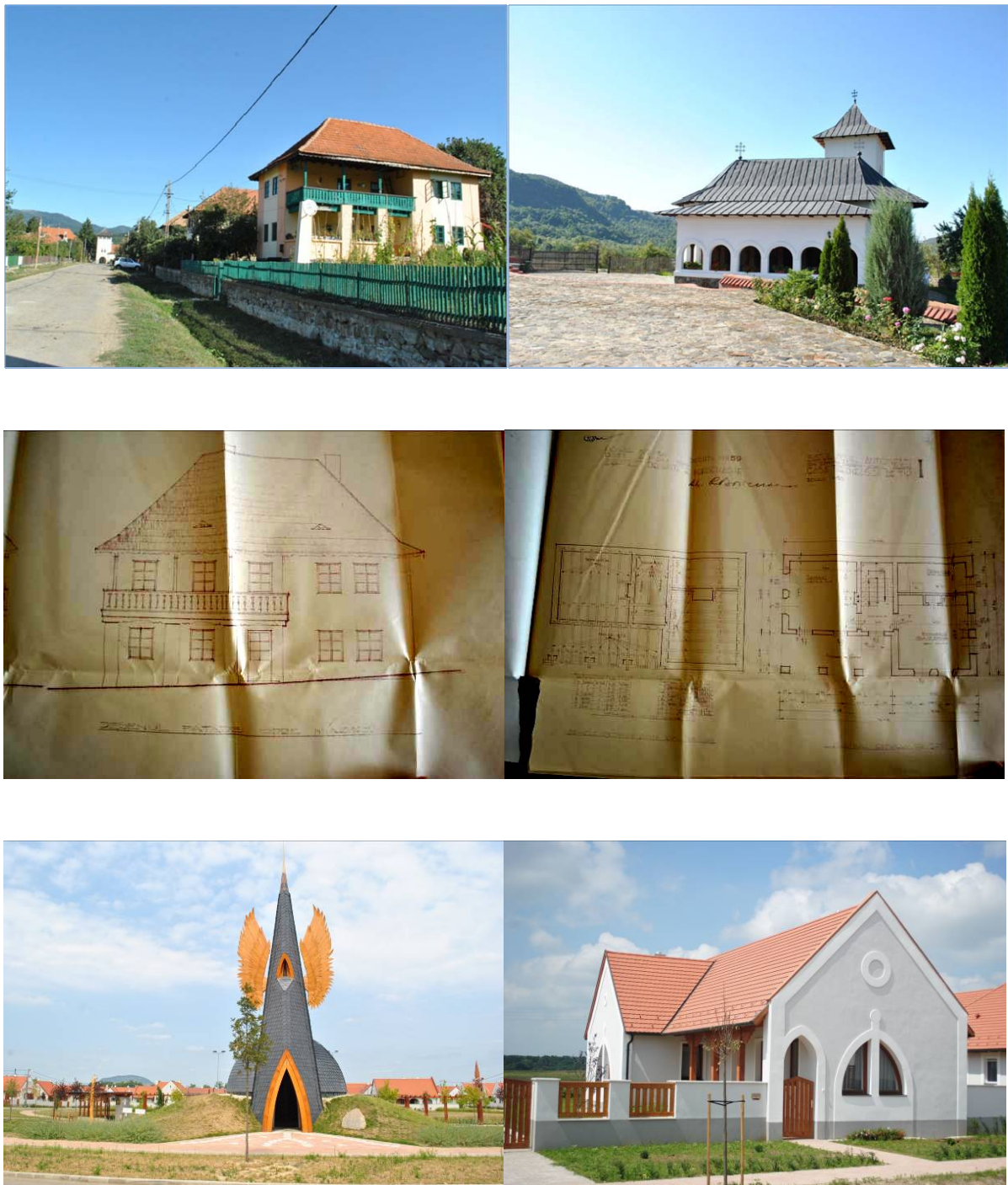


Fig. 7 The church as community centre in the middle of a green space. Reconstruction after floods/mud-floods respectively; the case of traditional housing in Antonești-Corbeni Romania(upper two rows) and of Devecser in Hungary (row at the bottom). Photos: M. Bostenaru 2012/13.

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Prefectura Jud. Argeş
Antierul satului model „Antonesti” - Goleeni

Serviz estimativ

APROBAT DIN PUNCT DE VEDERE TEHNIC
 Inspector de Drumuri

Pentru lucrările casei tip F
 Parcela nr. 35

Nr. de ordine	Natura lucrărilor	Partea anului	Dimensiuni				Cantități sau suprafețe		Prețuri unitare	Costul	
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1	Trasarea planului										
2	Idem							26.100	155		4046,5
3	Trasarea planului							89.100	190		16929
4	Trasarea planului							6.750	83		560,25
5	Trasarea planului							28.100	1460		38906
6	Trasarea planului							24.000	3210		77040
7	Trasarea planului							7.100	3370		23957
8	Trasarea planului							26.000	40		1040
9	Trasarea planului							74.200	2800		214760
10	Trasarea planului							12.200	9200		121440
11	Trasarea planului							1100	85		9050
12	Trasarea planului							980	600		58800
13	Trasarea planului							1200	300		45900
14	Trasarea planului							39.000	300		13650
15	Trasarea planului							6	700		4200
16	Trasarea planului							18.500	530		10175
17	Trasarea planului							20.000	880		17600
18	Trasarea planului							6.600	170		11220
19	Trasarea planului							7.500	270		2025
20	Trasarea planului							31.000	290		16690
21	Trasarea planului							24.200	280		6776
22	Trasarea planului							1	400		400
23	Trasarea planului							1	300		300

VERIFICAT în conformitate cu prevederile art. 22 din Legea pentru asigurarea patrimoniului public

Seful Serviciului
 Inspector de Drumuri

Fig. 8 Computation of the costs devices for the house shown in Fig. 7 – archive image from the Romanian national archives, Argeş branch, Piteşti.

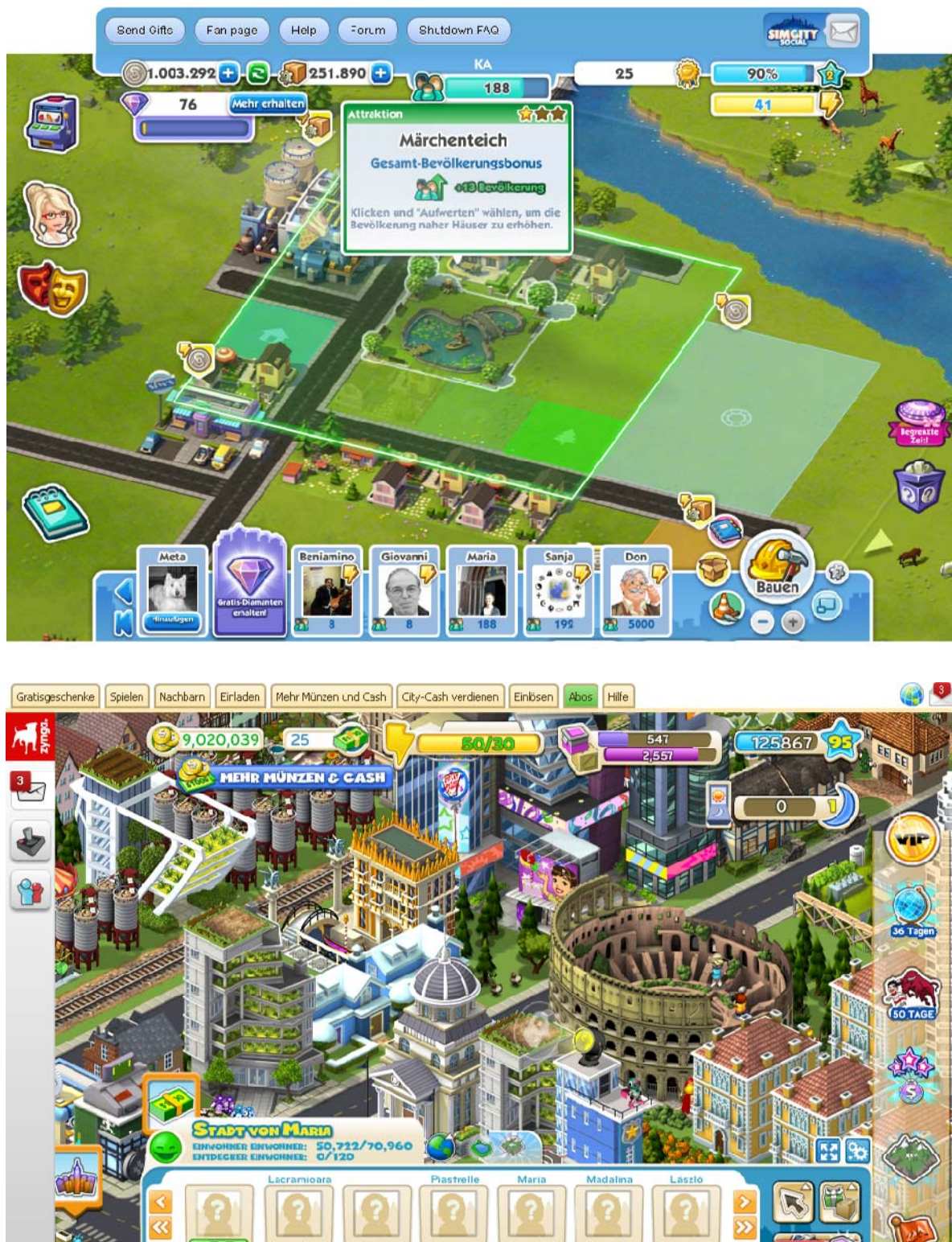


Fig. 9. In SimCity: the vicinity of green spaces increases rental prices (upper image); in CityVille the green houses increased urban agriculture production, as this one is foreseen instead of industry for the economics in this game (lower image). City projects by M. Bostenaru.

through, and green houses increased agricultural production with a limited footprint of the buildings.

For real life situations see papers by Ichichara and Cohen (2011), Conway et al (2010), Mell et al (2013), Saphores and Li (2012), Sander and Height (2012), which evaluate the benefit of green space on land value, while for archive research as ours we recommend Woinaroski (2013). Not only are green spaces contributing to reducing heat islands and thus mitigating climate change effects in city centres, but also are convenient from an economic point of view. Therefore they are to be recommended in reconstruction efforts. The destruction of settlement areas by disasters, such as the chemical catastrophe in Ajka or the floods in Argeş county are an occasion for projects, and for such reconstruction, as earthquakes are. The land is flattened by the disaster and striated by the reconstruction, if we were to follow the philosophy proposed by Gilles Deleuze (1980). Building a new settlement such as these ones requires a community centre, which is foreseen by urban planning rules and included in the rules of city building games (the socio-economic model does not allow adding new residential buildings to raise the number of inhabitants if such buildings are not foreseen). But, as we see, the presence of green spaces also allows certain extensions (Fig. 10), not only rental price increase, since green spaces are a community gathering space as well. We designed ourselves such a new quarter, followed by designing quarters in the computer games. While board games have a pre-designed plan, computer games allow, in frame of a grid (such as the re-building of Lisbon) for urban planning creation. The limited space, as we saw, makes the economic value of green spaces decisive, such as in crowded city centres, as it was the question of re-building in central Lisbon or in central Bucharest.

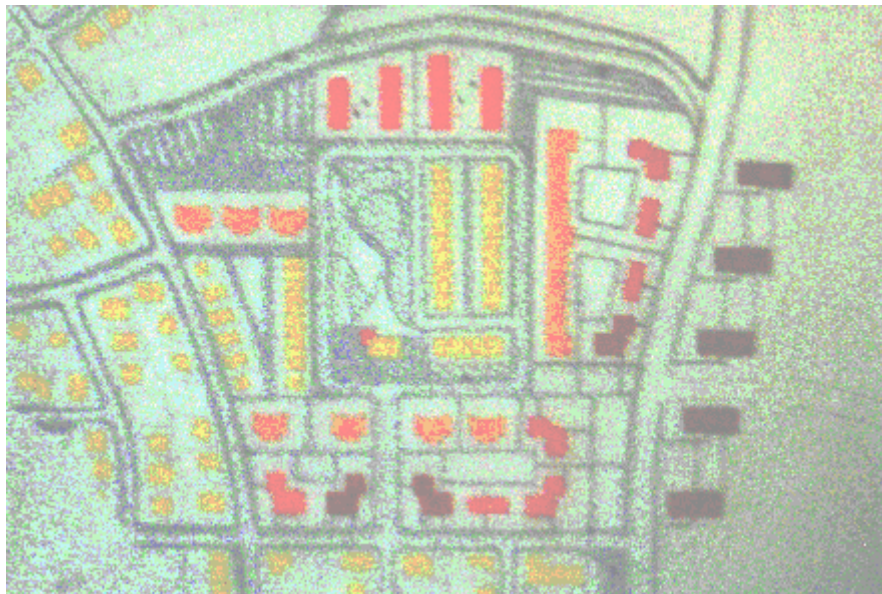


Fig. 10 New quarter in Linkenheim-Hochstetten, Karlsruhe. Note the green space with community centre in the middle. Project by M. Bostenaru, 1997. The surroundings of Karlsruhe feature some more garden city, “Siedlungen”, and a similar approach (with a church) was foreseen also for the Modernist masterpiece Dammerstock.

CONCLUSIONS

The paper has explored the economic aspects of risk mitigation. The roles of game theory, agent based modelling and networks and urban public policies in designing decision systems for risk management were also discussed. The urban scale at which a natural hazard can impact leads to the importance of urban planning strategy in risk management. However, usually environmental engineering and social sciences deal with it, and the role of architecture and urban planning is neglected. ICT can contribute to organize the information from the building survey, for example, through taxonomy and ontology, to economic computations in direct modelling at urban or building scale or through translation of games' rules and thus facilitate decision making. Games rules are at the same time supported by our field and archive studies, as well as research by design. We also take into consideration a rare element, which is the role of landscape planning through the inclusion of green elements in reconstruction after the natural and man-made disasters or in reconstruction efforts to mitigate climate change. Apart from existing old city fabric, also landscape can be endangered by speculation and therefore it is vital to highlight its high economic value, also in this particular case. As ICOMOS highlights for the 2014 congress, heritage and landscape are two sides of the same coin. Landscape may become or can be connected to a community centre, the first being necessary for building a settlement, the second raising its value, or it can build connections between landmarks in urban routes. For this reason, location plays a role not only for mitigating the effects of hazards, but also for increasing the value of land through vicinities. Games are only another way to build a model of the complex system, which is the urban organism in this regard; a model is easier to be analysed than the system while displaying its basic rules. The role of landscape of building roads of memory between landmarks in the reconstruction is yet to be investigated in a future proposed COST action.

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