The economic impact of seismic retrofit on heritage buildings with historic reinforced concrete skeleton structure of the interwar time

M. Bostenaru Dan
"Ion Mincu" University of Architecture and Urbanism, Bucharest

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SUMMARY:
Actors (conservators, engineers, inhabitants, investors) put different priorities in interventions on heritage buildings. In seismically vulnerable buildings interventions can be done at different performance levels and the costs of the retrofit and post-earthquake repair differ depending on this target. Not only earthquakes impact a heritage building, but also retrofit measures. Solutions must be found on how much change we accept for retrofit and how much repairable damage we take into account. Numerical simulation was run for interwar buildings, considering also the case when retrofit is done between two earthquakes. A developed system counted building elements according to their degree of damage. Device computations for the retrofit and for the repair measures were done considering the material prices and the labour hour prices, a flexible mean. The total costs vary as addition between the preventive retrofit and the post-earthquake repair, compared to the costs of rebuilding.

Keywords: reinforced concrete, costs, heritage, decision.

1. INTRODUCTION

Strengthening of historic buildings is a way to assure the built substance in areas threatened by earthquakes. Since resources are limited, economic efficiency is important and is evaluated opposite the functional, aesthetic and constructive criteria. Economic efficiency is seen in this paper in terms of the moment in time when a retrofit method is applied. The paper does not aim to generate a continuous curve as a function of costs of the measures but setting levels of costs. The subject of this paper are interwar residential buildings in Bucharest. In urban studies in Romania cultural value is differentiated into monumental buildings, building with architectural value and buildings with environmental value. The first are not the subject of this paper. In interventions on buildings with architectural value style characteristics are considered. In this context interwar buildings in Bucharest have been studied extensively, as they define the urban image of the city. In a likely future earthquake they are most vulnerable. In central Bucharest buildings with different structure, age, condition and sizes are one next to the other. In recent decades there has been a new trend in research on seismic strengthening of historical buildings, not only in countries affected by huge losses from earthquakes. Approaches come from general urban scale methods to detailed interventions on the buildings. Wounds in public awareness in Bucharest and unclear ownership reports make difficult or even preclude interventions on buildings there. The most important international document on restoration of historic buildings is the Venice Charter (1964). In 1986 there was a recommendation of the European community, considered in the research work of the European Association for Earthquake Engineering. Its results are seen in Romanian seismic code P100-92. In 1994 it was passed in the European seismic code Eurocode 8. ICOMOS noted seismic risk that threatens historic buildings in Romania (Nistor, 2002). A design method for the restoration of monuments in Romania is in it. Seismic performance of buildings can target various levels that goal: operational, limit of the damage, safety of life.

Economic design requires a proper structuring of the building as an object, design of deadlines, documentation of results and an analysis of alternatives for optimization. Cost calculation methods are more influenced by availability of data for comparison than the desired accuracy. The existence of data varies from place to place. In the U.S. data were collected for 10 years. In Germany there are data from Baukosteninformationssystem in Stuttgart. The latter are not related to seismic risk. For new construction there are two German indices, one for estimating and another for calculating costs. Costing is based on function spaces. This was used in this paper to estimate the rebuilding cost of interwar buildings. Costing only take place in later stages of design and is based on a subdivision in building elements. Costing methods have been developed for existing buildings only since the 1990s.A seminal work in this respect is that of Rolf Neddermann (2000). He described existing construction elements, which contain all the necessary work to renovate a building element. Under this approach a building can be divided into elements consisting of their buildable parts. Area based methods are unsuitable for buildings in seismic areas, since earthquakes don't affect the whole building but load-bearing elements. So far there are few studies on the economic efficiency of retrofit measures. In FEMA-274 (1997) a three-dimensional interdependence between the level of performance, the severity of the earthquake and the costs is shown. Studies of ATC-40 (1996) did not lead to a cost curve, as aimed in this paper. Economic studies of INCERC are based on devices. Kappos et al. (1998, 2007) has scaled engineering-wise the model of economic costs and the statistics from retrofit after the 1999 Athens earthquake in a similar way computer simulation is validated with experimental results. Smith et al (2004) went to a probabilistic assessment of measures in Turkey.

Malczewski (1999) gave in his book "GIS and multicriteria decision analysis" an overview of the stat of the art in multi-criteria decision systems for spatial problems. Three steps, which are intelligence, design and selection were broadly recommended. Detailed steps are: putting the problem, evaluation criteria, weighting the criteria, decision rules, sensitivity analysis and recommendations. Richter (course notes University of Karlsruhe) made a role model for the designer in the decision space between goals, resources, benefits and costs. Fingerhuth and Koch (1996) published a contribution to clarifying the role of the architect in project planning. This model shows that the decision belongs not only to the involved experts but the passive public and active affected people are involved. The task of multi-criteria decision task is to sort the existing number of options with a number of criteria. Strassert (1995) describes recommended steps in this direction. The report entitled "Evaluation and strengthening of concrete seismic" (ATC-40, 1996) is considering a wide range of target groups: building owner, agency representatives, architects and building authorities and structure designers and analysts. Each chapter is addressed in greater or lesser amount to these groups. In Chapter 6 more is done. To reach a retrofit decision retrofit strategies, retrofit systems and building design restrictions have to be taken into account. Retrofit strategies can be technical or management strategies. For the strategy choice there is a questionnaire and a matrix. The housing complex "Living Tomorrow" by Ottokar Uhl in Hollabrunn, a town near Vienna was a success in a competition in 1972. It is characterized by high degree of participation. Planning meant setting decisions and premises for future decisions. The process has two dimensions: time (design decisions) and social (design instances). The renovation of the Weissenhof was in the field of tension between the protection of monuments, construction technique, construction costs and interests. One of the tasks and goals of the renovation was balancing competing interests to a solution. Nägele (1992) has documented these competing goals, and examples of conflicts of interest. The decision process to renovate the Weissenhof Siedlung was viewed in a decision table. It contains examples of building elements preserved, restored and full/renewed. For each measure design is described, followed by a position statement on protection of monuments, the user, the construction techniques and costs, and finally a decision.

2. BUCHAREST CASE STUDY: PROBLEMS AND POTENTIAL

In designing measures to improve the seismic resistance of buildings numerous actors are involved. They are interested in different aspects of the building but must communicate through the same framework. The existing building is to be taken as the basis of all subsequent investigations. Documentation of the geometric characteristics and of building materials takes place during the survey. It is the basis for modelling of structures for the calculation of indicators to estimate project costs and retrofit strategies. A cost estimate requires a special structuring of the building.

2.1. Scale of the study

For setting priorities at urban scale two approaches can be followed. The selection by area involves the application of a scenario on a heterogeneous area built by closed heterogeneous blocks. The selection following goal elements, in this case classes of buildings, is based on the scenario of punctual application on buildings unevenly distributed throughout the area considered. Two ways and appropriate methodologies for surveying were investigated:

- EQSIM (Sonderforschungsbereich 461, Markus et al, 2004). A 1:500 scale urban plan was digitized and data was linked to buildings. These data included fragility curves. Buildings covered the entire surface of the study area (which was a urbanistically protected area in Bucharest, including individual buildings and groups of buildings as monuments, but this was not considered). An earthquake scenario can predict in this case and how many buildings collapse and debris which is blocking the escape routes on streets.
- World Housing Encyclopedia (Earthquake Engineering Research Institute, we are participant since 2001 and member of the editorial board 2003-2006, Brzev and Greene, 2004). A database of different types of buildings described in detail, including assessment of expected seismic performance.

Both models are useful for disaster management but cover different models.

2.2. Collection of data on urban area

Urban plans of Bucharest are available at two scales: 1:2000 and 1:500. These constitute a non-electronic database containing data that can be read directly or mediated. The type of the structural system type cannot be deduced from these plans, while building material is contained. Both concrete and masonry can be found in both types: vulnerable and resilient. In order to asses seismic vulnerability detailed information on the geometric characteristics of the building is necessary. In urban plans the height of floors is not given. This is defining for both building and building aggregates. Also there are no data on the presence of windows in the walls. This influences the extent to which methods such as fiber-reinforced polymer retrofit can be applied to. So a screening at street level was necessary.

First information relevant in the qualitative survey was gathered. In surveying the quality photographic and textual information were saved. A critical point is the decision which data has to be surveyed. If the style of the building remains undefined, it can be helpful to recognize the type of structure to look at places the building structure is cut: courtyard facade, staircases, balconies/loggias, windows, fire walls. Conclusions can be drawn from the same type of building in sites or places where the structure remains discovered (fallen plaster, etc.). Other sources are the literature on specific damage, surveys and building projects. Buildings dating is important to determine the type of structure and construction techniques commonly used at that time, the earthquakes that hit the building and seismic code at that time. Earthquake effects are cumulative. The method described was used for surveying the Romanian built substance in Bucharest. Places to be seen in search of the relevant building elements do not differ in other European cities, so that generalization is possible. Buildings served as an example in Italy, France and Germany.

The first step in quantitative surveys is the vectorisation of the façade. An example of using photographic data in a CAD system was thesis of Bourlotos (2001) including a LISP script used to gain vector data from an imported raster image. There is a numerical relationship between the size of windows and wall that helps diagnose the structure. For calculations on seismic vulnerability not only relationships in the facade are relevant but also relations between the facade and the plan. Petrovici (course material, 1996) gave a matrix of such scores.

2.3. Typological data collection

In this section the paper deals with the problems and potentials in relationship to earthquakes of Romanian residential buildings in the capital. It proved successful to use the questionnaire on which reports from the World Housing Encyclopedia are written. Earthquake Engineering Research Institute and International Association for Earthquake Engineering have an ongoing project which is called World Housing Encyclopedia using the modern technology using the Internet and database experts to make available data on housing construction in the world. Each type of housing is described using a standard report format. Such a report covers relevant aspects of housing such as: socio-economic problems, architectural features, structural system, seismic gaps and earthquake-resistant features, performance in past earthquakes, available retrofit techniques, construction materials used and organizational aspects of the site, insurance. The core of a report and at the same time the encyclopedia is the information on the structural system. In addition to the information in text and numbers there are photos, drawings, sketches such as: photo of a typical building, typical plan of a building, perspective drawing showing major load-bearing elements, critical features, seismic deficiencies and resilient elements, typical earthquake damage, retrofit measures.

The typological survey in Bucharest revealed the following types. Few buildings were kept before 1850. In addition to church buildings there are some with balconies clad in wood with balconies on many levels to the courtyard. More buildings are from the period 1850-1880, so-called eclecticism. Typical single-family homes for this period are type wagon. For the period between 1880 and 1920 New-Romanian style was chosen as representative. Two buildings were typical: a building with ground floor and first floor walls out of masonry and wood slabs and a multi-storey building with masonry walls. Between 1920 and 1940 it was built in interwar style. Typically these buildings were reinforced concrete skeleton for gravitational loads only and brick infill. These proved most vulnerable. For the period 1940-1947 an exceptional type of building was chosen: building of the same type as those of the interwar, but with larger openings and windows, concrete skeleton with concrete diagonals. After the war housing had to be available quickly and was build in neighborhoods in satellite towns as Le Corbusier's theory (international style). Investigated were two types of buildings:

- OD (double direction). A type of building block that collapsed in the 1977 earthquake.
- Y. A type of building with the same structure as the OD, i.e. structural wall cast in situ concrete, but performed well because of three longitudinal load-bearing walls not one as OD.

After the 1977 Vrancea earthquake (http://www.eeri.org/1977/03/vrancea/) which affected Bucharest, new architecture directives of socialist architecture came under dictatorship. Buildings should be grouped in blocks and define the street fronts with neo-classicist decorations, etc. Buildings structure was typically concrete frame of precast structural walls. For this period a typical building with precast concrete diaphragms, but self-supporting facade (with bulbs) was selected. After the fall of the Ceauşescu regime in 1989 the style changed again. Often sites have continued unfinished pre-1989.

3. DIAGNOSIS: BUILDING ELEMENT METHOD

3.1. Retrofit elements in the building survey

Structural material can be concrete, wood or steel. Some detail features or in compliance with building elements can lead to the recognition of the structural type, accompanied by references which are found in Bucharest.

Materials commonly used for load-bearing walls are reinforced concrete and masonry. Buildings with reinforced concrete load-bearing walls were built in large numbers in Romania after the war. In Romania, it was built in two systems: honeycomb and cellular. To differentiate between the cellular system and the dual, the major load-bearing element are in the first the walls and in the second the frames. It can be build with cast in situ or precast concrete. The honeycomb system was possible only because the precast panels were of the size of prefabricated rooms. The joints between the tiles are visible on the facade and precast blocks have different system scales. Since the number of plates is limited these buildings are very repetitive. It is a challenge to distinguish between load-bering and unfaced masonry. Reinforced masonry can be recognised on the basis of both possibilities and features: larger enclosures, thinner walls and more numerous and larger windows.

Horizontal load-bearing elements are floors with their beams. Flat floors are out of concrete or system floor. The girders in system floors can be of metal with brick infill, flat or vaulted, or with timber boards. The resulting complex with metal girders can be recognised at the closures of balconies, while the timber ones end with a simple metal bracket. Apart from the balconies the system can be recognized in the passages. Concrete slabs are the most simple and thin and always accompany vertical concrete structures. They can be cast in situ or precast. Some old buildings have vaulted ground floor or basement. Historical development can result in structural units with different floor system types at various levels or vaulted covering at some levels.

Non-load bearing elements relevant for identifying the structure are infill walls, building facades, and the roof. Frames with masonry infill and reinforced masonry walls have to be differentiated.

3.2. Retrofit elements in project management

Research on the interactions between the characteristics of use, aesthetics and structure determine the technical and operational strategies for possible retrofit measures. Modeling processes, measures and activities for the execution of retrofit measures encompass the design period, resource allocation and the design and cost control. Under these network plans were developed for the retrofit project with fiber glass fabric and carbon fiber reinforced polymers laminates on brick infill walls. A structural plan means in this particular case the project management division to retrofit the building elements. Management strategies were developed for technical strategies for existing buildings. Technical strategies are guided by selective strengthening (Elnashai and Pinho, 1998) so depending on the earthquake considered to achieve high rigidity/change stiffness (immediate use), resistance/change strength (to limit damage) or high ductility (protection of collapse).

3.3. Retrofit elements in costs calculation

The starting point was to assess building performance depending on both the seismic force and the deformation suffered - so-called performance levels. There is a relationship between stress and strain when building elements describe a concrete structure. Strain values may correspond to a certain level of performance depending on the common, occasional, rare or very rare recurrence period.

Project management involves a complex task that is subdivided into smaller tasks that can be treated. The costing method proposed is based on project management. In order to correlate the cost of building measures an additional dimension was introduced, that of time. Time can be expressed in earthquake size, the same size as earthquakes occur periodically.

Cost parameters are the recurrence time of the earthquake, the chosen retrofit method and the level of performance to be achieved. It is based on a room with a recess in the window front. This set back includes a second window that serves to bring more light in depth in order to achieve the minimum natural lighting. Similarly a retrofit measure can be employed to achieve a minimum of performance at a building. The distance between the front and set back leads to increased lighting level more or less in depth depending on the need (for location of the windows at different levels of a building neighboring another). Symbolically this can mean time, i.e. the earthquake affecting the building (Fig. 1). In seismic retrofit maybe only some aspects of the renovation of aging buildings are used, as the latter evenly distributed in the building while the need for seismic retrofit concerns only certain elements.

3.4. Retrofit elements in the investigation of structures

Two building elements were modeled:

- A frame of 4.5 m span and 3 m height with brick infill with windows and windowless, with a structural wall infill, with steel diagonals, carbon FRP laminates on the infill;
- A 3 m high column with metal and RC jacketing, RC side walls.

Modeling parameters for the finite element program were defined. For all these measures there is a description and a building costing.

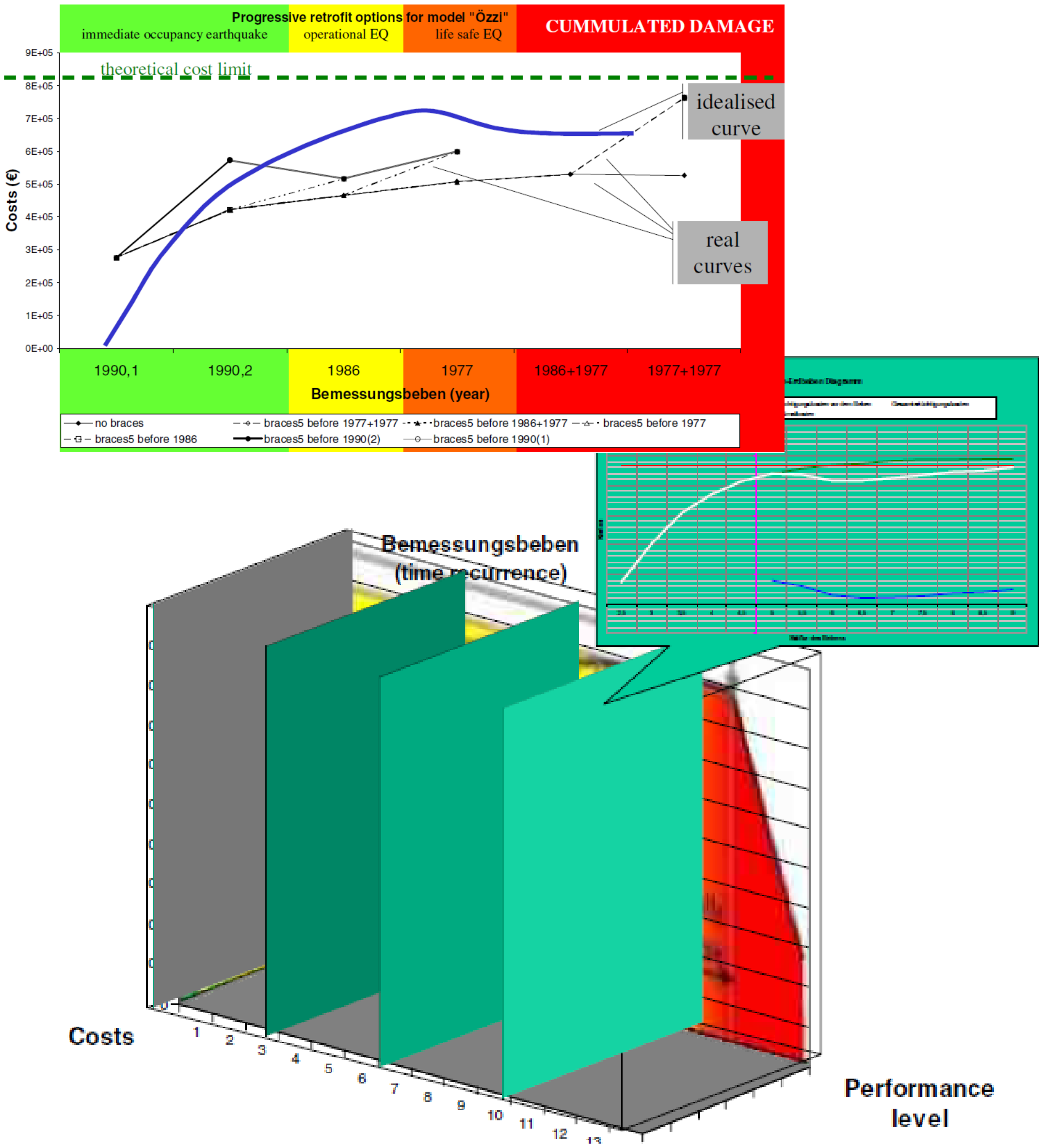

Figure 1. Transfer of the light levels concept to costs concept in relationship with performance levels

Investigating images of real damage, the description of pathology is based on that made by Penelis and Kappos (1997). Damage have been described and illustrated in: columns under cyclic bending, cyclic shear in columns, beams damaged due to the vertical component of the seismic motion, shear beams, beams under bending, column-beam nodes, RC structural walls, floors, infill walls. The spread of these types of damage after the 1977 Vrancea earthquake was investigated as well as the post-earthquake aging damage.

4. DECISION-MAKING ASPECTS OF BENEFIT-COST ANALYSIS

4.1. Actors and criteria

The key elements of a management process (orientation, size, leadership mode) and a system are described. Joedicke (1976) looked into techniques that are useful in the design of buildings and stressed in this context aspects of the decision. Using some of these techniques is useful for systemic decision. Such one is the regression. Features and criteria are derived based on the analysis of existing projects while general knowledge of objects is derived from science. Databases are derived from case studies and a hypothesis is induced. From these assumptions a single hypothesis is gained which is integrated in a single mission/recommendation. Assumptions for individual elements are derived and finally statements about them. These statements are opposed to the hypothesis and feedback induced to reformulate it regressively. Decision trees were derived by the mean of regression:

a. goals of the architect
    a. induction
        i. database: maintenance, configuration, survey
        ii. hypotheses: minimal intervention in the built substance
    b. deduction
        i. hypothesis: character preservation.
        ii. hypotheses: the appearance of elements
        iii. statements: change the size, appearance, material
c. criteria relating to the retrofit elements
    a. induction
        i. database: reports on building types
        ii. hypotheses: problems and potentials building, retrofit measures, damage types
    b. deduction
        i. hypothesis: retrofit elements
        ii. hypotheses: technical and management strategy
        iii. statements: types of damage

In a detailed study of decision making the following actors were considered: structural engineer, architect, tenant and investor. The seismologist was not taken into account. All these actors belong to a group which may be contained in the interested participants. Interested participants are a group acting on a level with the decision makers. At the same time the architect, the engineer and the seismologist belong to the group of experts, while the tenant belongs to the affected ones. Criteria are attributes which can be measured based on the extent to which goals were achieved. They are given a measure space. The criteria tree was compared with one built on the basis of World Housing Encyclopedia reports. Goals are set and focused in the tree. Criteria were assigned weights. In this case the group decision was simulated by multi-criteria, each actor being considered a criterion. The sum of all criteria remains 1 (100%). In design it is shown to what extent the decision tree can be applied for more alternatives. On the opposite, the pair comparison method does not require assigning weights. Alternatives are ranked instead in order of preference for opposite criteria. Möller (1984) distinguished four methods of benefit-cost analysis in construction, these being two of them. Decision trees belong to cost-effectiveness calculation, according to this classification.

4.2. Modelling the structure

Two regular models were considered. The first has four and respectively three openings in two directions and six storeys. For this model four measures are considered: metal jacketing, sdding side walls to columns, adding a structural wall in the frame, adding steel diagonals. The second building has five and respectively three spans five floors. The spans are unequal. For it diagonal steel addition was considered in different positions and to different amounts. A real block from the interwar time was considered as well. All floors plans were available with dimensions details of structural elements, but without details of reinforcement. There was also a concrete retrofit project available, which, however cannot be subordinated to any of the schemes considered above. It involves adding concrete walls and jacketings. Their effect is to reduce the irregularity in the plan. The building has a ground floor, basement and five floors, and no set backs. Beams often are supported on other beams, not columns. Two other blocks of flats have been designed with features similar to those of inter-war housing, but without some features, such as secondary beams. They have ground floor, basement and five floors, of which the last two set back. Spans are different.

As permanent load 1.4 t/m² was taken as concentrated load at the upper end of the columns. In the first stage static pushover was run. In the second stage of dynamic earthquake accelerograms (1977, 1986 and 1990), obtained from European Strong Motion Database (Ambraseys, 2002), were applied (all three components). For comparison with the situation in other countries, Greece was considered and the earthquake of 1978 in Thessaloniki.

4.3. Results

Results related to the relationship between retrofit size and the impact of future earthquakes were analyzed in interwar buildings.

Geometric and material characteristics described for the building elements were used. Three methods of analysis were applied: pushover, dynamic time-history analysis, stress-strain approach based on the one before. The innovative type of analysis lies in the last one. Such an analysis allows not only the description of the failure model and setting limits eventually reached by the building but also the specific determining of the place and the number of structural elements suffering some damage. This result can be the basis of further interdisciplinary studies. In case of retrofit of pre-damaged building structures it is of interest to study the economics of the need to retrofit/repair damaged elements opposite to preventive retrofit. Types of progressive damage were described (crack only, yield+crack, yield+spall+crack, crush+yield+spall+crack, fracture+crush+yield+spall+crack). The method used in this study involved the use of a software for processing accelerograms, a fibre based finite element software, a spreadsheet software, a database software (MS Access) (Fig. 2). The proposed algorithm method was supported by the possibilities of the software programs. With the method the number of elements which have a damage type could be determined. The spreadsheet environment the transition from a fine grid of finite elements to a coarse grid was performed. The size of the total damage is communicated through a database question. It can be determined which elements suffer what level of damage. To determine the retrofit measures certain scenarios were investigated. One of these is when the building is lightly damaged, in which case retrofit would be more expensive than repair. The other would be when the costs of retrofit and repair are added as the building is heavily damaged. Not all retrofit measures are leading to the same reduction in damage. Jacketing does not prevent cracking and structural walls significantly improve behavior but they are themselves affected.

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Otpt No:  73   Time= 9,3360,  spallig reached.   Elm:   Cb51ba.  Unc Conc Strain =  -0.002173 - G.p.(b)
Otpt No:  73   Time= 9,3360,  spallig reached.   Elm:  Cb2051a.  Unc Conc Strain =  -0.002116 - G.p.(b)
Otpt No:  73   Time= 9,3360,  spallig reached.   Elm:   C2031a.  Unc Conc Strain =  -0.002198 - G.p.(b)
Otpt No:  73   Time= 9,3360,    yield reached.   Elm:    C11bb.     Steel Strain =   0.002502 - G.p.(a)
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Typical log-file output

Otpt No:	Time=	reached	Elm:	Mat 1	Mat 2	Strain =	Gauss point
1	0.1500,	crack_cover	bmz3412.	Unc	Conc	0.000107	G.p.(b)
1	0.1500,	crack_core	bmz2511.	Conf	Conc	0.000101	G.p.(a)
1	0.1500,	crack_cover	bmz2511.	Unc	Conc	0.000113	G.p.(a)
1	0.1500,	crack_core	bmz2512.	Conf	Conc	0.000108	G.p.(b)

Log-file output imported in MS Excell

ID	Otpt No:	Time=	reached	Elm:	Mat 1	Mat 2	Strain =	Gauss point
1	1	0.1500,	crack_cover	bmz3412.	Unc	Conc	0.000107	G.p.(b)
2	1	0.1500,	crack_core	bmz2511.	Conf	Conc	0.000101	G.p.(a)
3	1	0.1500,	crack_cover	bmz2511.	Unc	Conc	0.000113	G.p.(a)
4	1	0.1500,	crack_core	bmz2512.	Conf	Conc	0.000108	G.p.(b)
5	1	0.1500,	crack_cover	bmz2512.	Unc	Conc	0.000122	G.p.(b)

Log-file imported in MS Access

Gesamtsumme von ID	yield	crush	spall	crack_core	crack_cover	element
15	4	1	2	4	4	bmx121
14	4		2	4	4	bmx122
14	4		2	4	4	bmx133
14	4		2	4	4	bmx141
14	4		2	4	4	bmx142
10	2			4	4	bmx152
10	2			4	4	bmx153
10	2			4	4	bmx154
8				4	4	bmx161
8				4	4	bmx162

MS Access query

Figure 2. Algorithm used to compute the number of retrofit elements

The innovation in this contribution is to determine how the results from structural assessment are useful for economic studies. In the investigation structural models were chosen and only the structural cost of calculated. Such devices could be used for retrofit elements. Costs can be ordered to the execution steps which generated them. Assumptions were made in the structural modeling: no modeling of floors, reduced number of nodes in the finite element model, only bending demand, not shear.

There are four types of retrofit elements:

- Old element which are only the existing repaired elements,
- New elements added to existing elements (structural walls, steel diagonals),
- Consolidated elements that are building additions to old elements (elements jacketing,

columns with RC side walls, masonry corners at reinforced door frames, columns of the ground floor with low stiffness),
- Replace elements that are new elements built in place of old damaged elements (repair of severely damaged items).
A taxonomy was built for these.

For each type of failure predicted by the simulation images of the damage were built (drawing and devices table). Such damage not only describes the way of failure but builds also the basis for the design of repair measures. After reviewing all types of failure in the section of concrete and steel of the structural elements three basic types for columns and three for beams were defined. Measures to repair them were defined. The repair costs for the damage types were calculated according to building material costs and hourly rates in Germany. Calculation algorithms can be adapted though for other countries with minimal effort, the calculation formula being based on a linear project management. Using the results from the structural analysis the repair costs were calculated for each time the entire model. Finite element simulation provides data on the number of damaged elements. By multiplying and adding costs set for building elements the total costs for retrofit/repair of a building model can be calculated. Very important but difficult to quantify is the interdependence between benefit and cost. The costs of building measures may be the same, but should be compared to benefit on the basis of the size of improving the seismic performance. To determine the economic efficiency costs before and after an earthquake should be considered. The following retrofit scenarios were considered:
- New building is designed earthquake resistant, reinforced building is undamaged,
- Predamaged building is retrofitted,
- Collapsed buildings is demolished and replaced with a new earthquake safe building.

Earthquakes were also applied cumulatively. These studies are served by several indicators such as the reports: retrofit cost / new construction cost, repair cost / retrofit cost, economy in repair cost / retrofit cost (with threshold of 30%). One of the most important results of this work is to create levels of curves with the values obtained. The images for two families: alternative retrofit measures types (one model), alternative retrofit measure with steel diagonals positioning and amount (the second model). The latter presents herewith the cost effect of retrofit phases. These were applied according to the expected earthquake. The idealized curve derived from our economic studies concept described before was compared to the numerical results, but improvements in the model are necessary, including statistical refinement through a Monte Carlo simulation to improve the number of simulation runs from the five models considered. It should be noted that these curves have been scaled to achieve a certain level of performance, yet are an illustration of the algorithm used.

5. CONCLUSIONS

Disaster prevention includes reducing seismic risk as through the retrofit of existing buildings seismic safety requirements are met. This paper shows where are the differences between the estimated costs in renovation and seismic strengthening. It develops a method for estimating the costs of inter-war buildings in Bucharest, Romania. Interwar buildings in Bucharest are characteristic historical buildings of reinforced concrete skeleton designed for gravitational loads only. Economic efficiency is related to issues of benefit-cost analysis. While cost estimates for retrofit measures is a new theme, benefit communication is even more difficult. The first issue to resolve was whether to considered an urban area, discretized in buildings, or a building, discretized into elements. The choice was whether to be chosen buildings typologically or from an area. Inter-war buildings describe urban protected zone (an instrument of conservation in Romanian legislation) in the centre of Bucharest. Thus the choice was for typological analysis for the most vulnerable type. Strategic planning has been placed on the interfaces between levels of detail. The decision is interactive and avoids excessive involvement of computer support. Models of the structure of existing buildings were designed. It focused on identifying elements of the building space that can be the basis for linking data to them, in a semantic enrichment. The choice of such items takes into account the different information needs of actors. The actors are in different fields such as architecture, engineering, economics. New features are in the research on visual recognition of the structural elements of buildings. Other results were achieved in the cost estimates. In Bucharest there are no statistical data on seismic strengthening. The method developed in this paper can be applied in such areas. In retrofit projects the structural studies take a long time and there are tools for calculation of costs, leading to further loss of time. By this method data collection surveys and costing take place simultaneously. To get closer to transferability real inter-war buildings were modelled. Contacts were established with researchers from Greece and Italy to ensure portability. The method presented in this paper has an appropriate depth to develop a catalogue of retrofit elements appropriate for the respective building style. Further research on the applicability will include modularity, supporting communication and cooperation is among the participants in the design process (experts, public, affected) and computer support. Further studies must be in sight of other typical construction groups. The World Housing Encyclopedia includes a description of the retrofit only, no costs (devices) to them. Costs can be estimated only if there are certain statistical databases in the region; not the case for Romania. One advantage of this method is that simultaneously generated a database of estimates can be generated. Once the method is used for several projects, the values can be saved in a standardized format to be helpful for future ones.

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