CONSIDERATIONS RELATED TO HOUSING AND SEISMIC RISK

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Abstract. The paper aims to present the main problems related to the seismic risk and housing in urban settlements in Romania, with special focus on Bucharest, which is the most exposed city. The paper emphasizes the framework related to evolution of technical regulations and seismic safety of residential buildings, highlighting the main dysfunctions in the National Program for Seismic Retrofitting. At the same time, because the collapse of a single residential building may have major negative effects on the surrounding area (buildings, streets, utilities etc.), the paper is proposing a methodology for evaluation of damages which may appear in such a case. The article is also suggesting several solutions for improving the design and expertise process and also for the seismic retrofitting of vulnerable buildings, especially housing.

Key words: seismic retrofitting, technical expertise, damages

1. Introduction

Romania's exposure to seismic risk is among the highest in Europe (Lungu *et al*, 2000; Armas *et al*, 2008; Sokolov *et al*, 2004; Georgescu *et al*, 2014). Estimates using the lists on the Ministry of Regional Development and Public Administration (MRDPA, 2015) web site suggests that there are approximately 11,000 households occupying more than 600 residential buildings included in Class I (highest) of seismic risk all over the country. Bucharest has the highest seismic risk of all European capital cities and is one of the most vulnerable 10 cities in the world (Bonjer *et al*, 2003). At least 2,300 residential buildings in Bucharest have been already evaluated as vulnerable (classified in risk classes I-III or emergency categories U1-U3) and require seismic retrofitting (Bucharest City Hall, 2015).

The National Programme for seismic retrofitting of buildings was initiated based on Government Ordinance 20/1994, republished with amendments, for the seismic retrofitting of buildings mainly designed for housing, which present a seismic risk, and is implemented by MRDPA. The programme started in 1998 by allocating funds for eight construction sites. By 2000, retrofitting of eight more buildings was financed. The programme provides Homeowners Associations (HA) with public funding in the form of interest-free loans for reconditioning of buildings classified in Class I of seismic risk. Homeowners must repay the loans in monthly instalments over a period of up to 25 years. Nevertheless the current interest-free loan arrangement for residential buildings classified in Class I of seismic risk does not seem to attract the owners. Therefore, the majority of vulnerable buildings have not been retrofitted.

In addition, should any of the buildings with high seismic risk collapse, this may have a major adverse effect on the surrounding area, affecting residential buildings, streets and traffic routes, utility networks, etc., which may trigger significant, not yet quantified public expenses. The present article will propose a methodology which will take into consideration these type of public expenditures.

2. Materials and methods

This article was written using documents, reports and articles published by various authorities with responsibilities in the field and by researchers interested in seismic retrofitting of buildings. There were used statistical data and reports that we analysed, compared and processed in order to outline the conclusions.

Sources of statistical data:

- Bucharest City Hall, Investments Division – Seismic Retrofitting Service
- Ministry of Regional Development and Public Administration
- Institute for Public Policies

The article is intended to answer the following essential questions: what would be the impact on the surrounding area if a residential building collapses? How can we overcome this impact by making all the residential buildings safe?

3. Results and debates

3.1. Progress on technical regulations on seismic safety

Before 1940, design of buildings in Romania ignored the existence of seismic action due to the lack of relevant technical data (magnitude, acceleration, displacement). On November 10, 1940, a strong earthquake, with an estimated moment magnitude (Mw) of 7.7, brought Vrancea seismic centre to the attention of specialists (Lungu *et al*, 2000).

The first technical regulation taking account of seismic action in building design appeared in Romania immediately after this event. In the 75-year period from 1940 to the present day, the concept of seismic design has progressed steadily (Georgescu *et al*, 2014) and, at the same time, the capacity of buildings to withstand exceptional dynamic actions produced by movement of foundation soil caused by earthquakes has increased (Văcăreanu *et al*, 2004).

Table 1. Progress of seismic design codes in Romania

Year	Name	Remarks
1941	Draft Instructions to prevent damage to buildings caused by earthquakes and to restore damaged buildings	They appear after the earthquake of November 10, 1940. It is the first technical regulation taking into account the seismic action in Romania
1945	Instructions top revent damage to buildings caused by earthquakes	
1958	STAS 2923-58 General design rules in seismic areas	Not approved
1963	Conditional standard on design of civil and industrial buildings in seismic areas P.13-63	
1970	Standard on design of civil and industrial buildings in seismic areas P.13-70	
1978	Standard on anti-seismic design of residential, socio-cultural, agro-zootechnical and industrial buildings P.100-78	It is issued after the earthquake of March 4, 1977
1981	Standard on anti-seismic design of residential, socio-cultural, agro-zootechnical and industrial buildings P.100-81	
1992	Standard on anti-seismic design of residential, socio-cultural, agro-zootechnical and industrial buildings P.100-92	It is issued after the earthqaukes of 1986 and 1990. It is the first regulation containing explicit provisions on how to assess vulnerability of existing buildings
2006	Seismic design code – Part I – Building design provisions, code P100-1/2006	

Table 1. Progress of seismic design codes in Romania

Year	Name	Remarks
2008	Seismic design code – Part III – Provisions on seismic assessment of existing buildings, code P100-3/2008	It is the first seismic assessment standard, intended exclusively for existing buildings.
2013	Seismic design code – Part I – Building design provisions, code P100-1/2013	

3. 2. Securing of existing buildings

3.2.1. Considerations on technical design/expertise

Structural solutions implemented over time depend on the quality of materials, technological solutions, height, foundation solutions, engineering know-how, leading to a virtually infinite diversity of "existing building" situations.

The infinity of built-up situations leads to the necessity to examine each construction on a case-by-case basis.
Code P100/1992 included, for the first time in Romania, several chapters containing provisions on the assessment of the level of protection of existing buildings.
This standard is based on the idea that all buildings are different and, consequently, each building must be assessed individually, by an experienced expert civil engineer, resulting in a technical documentation referred to as technical expertise that contains both an "X-ray of the building" and a substantiation of the intervention solution.

The conclusions of technical expertises conducted over the period 1992-1996 classified examined buildings into three emergency classes: E1 – design and seismic retrofitting within 2 years of expertise date; E2 – design and seismic retrofitting within 3 years of expertise date and E3 - design and seismic retrofitting within 10 years of expertise date.

During this period, according to the records of the Municipality of Bucharest – Investments Division – Seismic Retrofitting Service, a number of 1,594 expertises have been conducted in Bucharest by December 17, 2015, for buildings classified in the three emergency classes, which had to be consolidated until 2006.

Given the clear lack of capacity to implement the recommendations of technical expertises, the buildings have been classified into four classes of seismic risk I-IV since 1996, of which those in classes I and II were considered to require seismic retrofitting.

This approach focuses on outlining the degree of vulnerability of buildings, being clear that the period for seismic retrofitting depends on economic, social and political factors that cannot be quantified by technical regulations.

According to the above mentioned records, a number of 754 expertises conducted in Bucharest classified 664 buildings into classes I and II of risk and approximately 90 in classes III and IV.
Of the total 2,351 expertise buildings (E1, E2, E3, SRI, SRII, SRIII and SRIV) only 65 buildings have been retrofitted by December 17, 2015, namely approximately 1.5% (Fig.1).

Similarly, at national level, there is a number of several hundred expertise buildings, of which only a few have been retrofitted.

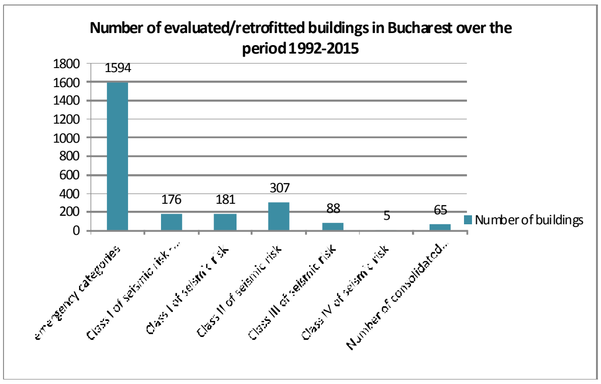

Fig.1. Number of buildings in Bucharest (Source – MDRPA)

In time, legislative changes promoted technical expertise of a building as starting point for recommendations on changes in terms of subsystems of buildings, operating approvals or modernisation works.

a) According to Law 50/1991 related to constructions authorisation, it is prohibited to make changes in the existing buildings without presenting the Technical Expertise based on which the Local Council issues the Building or Demolition Permit.
b) European legislation on energy efficiency imposed thermal reconditioning of buildings. Some of the modernisations to a building system are the thermal insulation of building facades and the restoration of exterior finishes. However, restoration of facades based on an incomplete technical expertise (qualitative expertise), during execution of the thermal system of façade walls, may hide structural damages and give a new aspect to buildings that may present significant deteriorations. A building classified in high seismic risk classes (I or II) must not receive a building permit for execution of modernisation works before seismic retrofitting thereof.

c) Buildings classified in class I of seismic risk can no longer accommodate commercial spaces, according to Law 282/2015 related to measures for reducing the seismic risk of existing buildings.

As a result of these developments, a unitary approach on quantification of buildings and assessment of vulnerability thereof is required at national level.

Seismic design code, Part I – Design provisions for building, P100-1-2013, divides the territory of Romania, in terms of seismic hazard, into several areas, according to the probable peak horizontal ground acceleration, with values ranging from 0.10g to 0.40g. In practice, areas where acceleration exceeds 0.2g are considered zones with significant seismic intensity.

A vulnerability analysis should be conducted at least in towns located in areas with significant seismic intensity to estimate the current number of buildings requiring expertise.

In terms of the significant volume of existing technical expertises, a unitary approach is again required. Expertises completed by 1996, classifying buildings into emergency classes, must be examined and the buildings must be classified in classes of seismic risk.

3.2.2. Failure of the current seismic retrofitting programme

The process of securing the existing buildings has evolved differently according to the type of property:

a. Buildings owned by the state (educational and public health establishments, institutions of central or local interest) received funding from the budget and external co-funding from the International Bank for Reconstruction and Development (IBRD) and the Development Bank of the European Council (DBEC). Seismic retrofitting of these buildings is a slow process, without a record of the total number of vulnerable buildings or of those whose seismic retrofitting process has been completed.
b. Privately owned buildings intended mainly for housing require own funding, most often as homeowners associations. The small number of retrofitted buildings limits the process to the stage of experimental or pilot project.

The failure of securing buildings intended mainly for housing through the National Programme for seismic retrofitting of buildings has many causes:

- Frequency of major earthquakes is not seen as unavoidable, although it is accepted – risk or hazard is seen as relatively low for these buildings, given that the last major earthquake took place approximately 40 years ago (Georgescu *et al*, 2012);
- National history in terms of removing owners from buildings has negative connotations in the collective mind due to past expropriations, nationalisation, evictions, which induces an attitude of rejection from elderly owners;
- Retrofitting works mainly focus on the demand for strength and stability of the building without a visible and concrete effect (comfort, aesthetics, etc.);
- Works costs are considerable, their amount ranging from 200-400 Euro/sq.m.;

- Works execution can take from 18 to 24 months, during which the building is "a construction site";
- Lack of trust in the reliability of construction companies in terms of costs, deadlines and quality of finish;
- Lack of trust in state authorities in terms of credible guarantees to support the citizen – lack of "necessity housing" or other instruments to facilitate temporary relocation of owners/ tenants during the seismic retrofitting works.

3. 3. Impact of building collapse on the surrounding area

In order to understand the actual extend of damages that may be caused in case of collapse of structurally unstable buildings, this is an attempt to draft a methodology for quantifying the impact on the surroundings of a collapsing multi-storey building located in a residential area (Eads *et al*, 2013).

I_0 = *impact on casualties* (persons inside the residential buildings, considering that the earthquake takes place at a time when most people are at home) directly affected by the collapse of the building.
Population numbers can also be taken into account (Derer 1985; Luca, 2003):

- in the public buildings in the area (schools, kindergartens, stores, etc.) for a maximum occupancy;
- casualties on the street or in public transportation means at the time of the earthquake (Stepanova *et al*, 2015).

I_1 = *impact on housing*, namely on the number of equivalent apartments directly affected located in the area:
V_1 = no. of ap_e x S_{equiv} x cost of ap_e (Euro/sq.m.) where:

- V_{ape} = value of damages caused to the apartments in the area of influence;
- no. of ap_e = number of equivalent apartments (considered to have 55 sq.m.);
- cost of ap_e = cost of equivalent apartment (considered to be 50.000 Euro).

A multiplier can be added, corresponding to the value of movables in the apartments, including the value of the vehicle owned by the family, namely 20% of the apartment cost.

Hypotheses that can be taken into considerations:

- a 2-bedroom apartment in surface of approximately 55 sq. m. has an average market value of 50,000 Euro;
- a collective residence has one parking space for 5 apartments, so we can consider that the number of parked vehicles corresponds to 20% of the number of apartments;
- an average vehicle costs about 5,000 Euro, namely approximately 10% of the apartment value;
- movables in the apartment may worth about 5,000 Euro, namely 10% of apartment value.

Given these hypothesis, we can consider:
V_1 = 1.2 x no. of ape S_{equiv} (sq. m.) x Cost (Euro/sq. m.)

I_2 = *impact of building collapsing on traffic routes (streets and sidewalks) in the affected area*:
V_2= S_{road} x C s_{sw} where:

- $V_{tr\ routes}$ = value of damages caused to traffic routes (streets and sidewalks);
- $\mathbf{S_{road}}$ = area of affected streets (including sidewalks);
- $\mathbf{C_{road}}$ = average execution cost/km of traffic route (streets and sidewalks);

Hypothesis taken into account in assessing impact:

- Value of signalling equipment is considered to be approximately 5% of the total value;

I_3 = impact of building collapsing on utility systems in the affected area

Hypothesis considered in assessing damages/impact by rebuilding affected systems:

- $C_{water\ system}$ = average execution cost/m of water supply system;
- C_{sewage} = average execution cost for sewage, including street manholes;
- $C_{lv\ system}$ = average execution cost for low voltage system;
- $C_{district\ heating}$ = average execution cost for district heating;
- C_{gas} = average execution cost for gas system.

$V_3 = \sum L_r C_r$ where:

L_s = length of system (water supply, natural gas supply, sewage, power supply, district heating);

C_s = average execution cost for system

The value of the tramline directly affected will be added:

$V_{3-1} = L_{tr} \times C_{tr}$ where:

- L_{tr} = length of affected tramline
- C_{tr} = cost to rebuild the affected line

I_4 = impact of building collapsing on transportation means circulating on the streets of the affected area

The following hypothesis will be considered:

- building collapse will damage/affect traffic on the streets in the affected area, impact that can be quantified in damages on the number of vehicles circulating in the area;
- calculation will be based on conventional vehicles, v_c according to the provisions of SR 7348, Romanian Standard related to Equivalence of vehicles to determine traffic capacity (2001);
- average cost for one conventional vehicle, c_{ve} will be 5,000 Euro;
- value of ancillary equipment; assessment of the power supply equipment for trams, trolleybuses, stations can use a fixed cost/km of affected street, namely e_{pw} – power supply equipment consisting of poles, overhead cable, tramway rails. It is estimated that the value of the power supply equipment amounts to approximately 40% of the value of one sq.km of street;
- a conventional vehicle requires approximately 35 sq.m for movement and manoeuvres;
- approximately 140 conventional vehicles can circulate on 1 km of street.

$V_4 = v_c \times c_{ve} \times 1.4$

I_5 = impact on public buildings in the residential area (buildings for education, administration, religion, productive activities, trade, etc.).

- extent of damage/impact is proportional to the total area of the public building and the average value for rebuilding one square meter of construction
- value is increased by a coefficient c_{D5} whose value is the result of the ratio of the value of movables (inventory assets, equipment found in the building) to the (taxable) value of the building; coefficient c_{D5} can reach values above 1 in the case of libraries, museums, art exhibits and others (equipment storage, finished products, historic monuments);

$V_5 = S_d \times$ cost/m^2 of building $\times c_{D5}$

Other indirect impacts can be considered:

I_6 = impact corresponding to complete outage of utilities supplying the beneficiaries in the proximity of the building taken into consideration

Assessment can be made depending on the duration of the outage:

$V_6 = \Sigma\ [(I_u)\ _T{}^k + \beta QE_1\ (T_h{}^k - T^k) + QE_pT_h{}^k]$

where:

- V_6 = value of total impact corresponding to the duration T_h of the outage affecting the users in the proximity of the residential area in question whose supply equipment has been shut down/damaged (power substations, thermal substation, gas, power, water systems, sewage, telecommunications);
- p = index of affected product or user p=1, 2…n);
- I_u = impact due to equipment or raw material damage during manufacturing processes due to outage of utilities at critical, product-specific times, T_{cr} (e.g. boiler explosions caused by failures of safety equipment);
- β= coefficient of hourly production or activity capacity usage assimilated during outage of utilities;
- Q = hourly average production capacity of the economic unit in the non-affected area with utility powered equipment whose continuity has been disrupted;
- E_1 = additional use of utilities without production (Euro/piece);
- E_p = E_3+E_4+E_5 components of the value of equipment whose supply has been disrupted (overheads E_3, direct salaries E_4, profit E_5);
- $T_h{}^k$ = duration of technological outage corresponding to k time;
- T_h = duration of complete outage of utilities corresponding to k time;

In case there are utility beneficiaries in the residential area or in the vicinity whose systems cross the affected area and the products/services are highly important in the economy of the administrative entity, the study on the method for determining the damages can be further detailed in consideration of specific elements, outage times and use of independent utility sources (for instance, water reserves, electric generators, gas tanks) which may influence the extent of damages.

I_7 = impact due to interruption of administrative, commercial, financial activity in the proximity of the residential area as a result of blocked traffic (longer access routes and communication connections)

Specific coefficients can be used: administrative expenses/occupant, day; produced/sold values/occupant, day; until resumption of normal activity. The time until resumption of normal activity consists of two components T_{rer} = traffic route repair time and T_{supply} = product supply time.

I_8 = impact of expenses for removal of materials/demolition of damaged buildings, restoration of land to zero level, in consideration of:

- density of materials (kg or tonnes/m^3);
- $V_{damaged\ mat}$ = volume of damaged materials (walls, floors, etc.) which can be determined in consideration of the following elements:
- t_w = thickness of fallen walls;
- n_{level} = number of storeys;
- A_{built} = built-up area on the ground;
- A_{total} = total area of the building;
- d_{tr} = transport distance to the storage place;
- specific transportation cost (Euro/tonne);

I_9 = impact of expenses for isolation of the residential area by:

- changing routes, which generates additional costs; the following elements can be used:
  - L_{bpr} = length of bypassing routes (km);
  - L_{in} = initial length of damaged traffic route
  - C_{spec} = specific consumption of fuel (litres/100 km)
  - p_f = fuel price
  - v_e = number of conventional/equivalent vehicles
  - T_{rer} = traffic route repair time

Value of damages $I_9 = (L_{bpr} - L_{in}) \times T_{rer} \times c_{spec} \times v_e \times$ fuel price/litre

Value of total damages = $\sum_{i=1}^{9} I_i$

4. Conclusions and proposals

4. 1. Proposals for improvement of design and expertise process

It is necessary to prepare a plan to reduce seismic risk of residential buildings. This plan could outline a number of interventions to be used in various scenarios – e.g. historic/non-historic buildings, severity of risk, etc., along with involvement of occupying communities (to increase awareness and facilitate the relocation process). The plan should quantify necessary interventions in terms of budget requirements, phasing, prioritisation and sequence.

During preparation of the future seismic assessment guidelines for existing buildings, efforts should be made to correlate already existing surveys, conducted at the current level of information, to future ones, so as to have a unitary approach in time and to avoid wasting already made technical, scientific and financial efforts; within the new Programme and using subordinated technical experts, MRDPA should propose a re-assessment of technical expertises completed without classifying buildings in one of the seismic risk classes, in order to have a unitary approach.

A national census of the built-up stock higher than GF+1S+M, according to the year of construction, should be conducted. It could be handed over to the State Inspectorate in Constructions (SIC) and regularly updated, using the reception reports checked by SIC upon completion of works.

Works must be based on feasibility studies, including a cost-benefit analysis (where applicable, for buildings that are not included in the national heritage), in order to assess whether demolition and reconstruction could be more effective in terms of costs (Wei *et al*, 2014).

Essential components of such programme are public communication and awareness (Karanikola *et al*, 2015). Many occupants, including private operators (for instance shop owners) are not aware of the risk they are exposed to while working or living in unsafe buildings. Vulnerable groups, such as the elderly, disabled or people with low income are the most reserved in being included in such programmes, considering the inconvenient of temporary relocation (Masuda *et al*, 1988; Georgescu *et al*, 2004). Therefore, it is highly important to highlight the fact that these buildings present a risk for their occupants, as well as the general public.

The more the conclusions of the survey influence the value/benefits of the building, the higher the pressure for satisfactory quotation to the detriment of reality, which is why it is necessary to eliminate dependence on funding of the private beneficiary to ensure objectivity of the technical expert.

Funding through the European programme for reduction of energy consumption to heat buildings should be granted only to buildings that have a technical expertise certifying the building's class of seismic risk.

4. 2. Socio-economic proposals for improvement of the retrofitting process

Failure of the seismic retrofitting programme is due to psychological, social and economic causes resulting from specificities of the building process, as well as deficiencies of the Romanian society. In this context, the strategy for approaching this field must be rethought to match/eliminate the reasons for the lack of interest in securing privately owned residential buildings.

In a liberal approach, the owners take full risk and responsibility. Collapse of a tall residential building, as described above, is affecting the owners and tenants, as well as the persons and the properties in close vicinity. Based on the reasonable hypothesis that most owners and tenants will die if a multi-storey building is completely collapsing, post-earthquake responsibilities for death/destructions "collateral" to collapse of the building remain uncovered.
In order to prevent this situation, the state should become a reliable partner that ensures the balance and safety of the civil society and of bona fide owners.

In a first stage, the body of experts certified by MRDPA should identify, based on existing expertises, the situations where buildings can be retrofitted without the relocation of owners or with a reduced time for relocation. Buildings with high vulnerability on a small area, such as "blocks of flats with flexible ground floor" could be included in this category (Lozinca *et al,* 2007; Văcăreanu *et al* 2008).

This approach allows for the "unfreezing" of the seismic retrofitting programme with soft solutions that may improve the safety of buildings, is requiring less financial efforts from the beneficiaries, do not require relocation during works and is enabling state institutions to build a necessity housing stock to relocate owners from buildings that need full seismic retrofitting (Che□ca *et al*, 2007).

On the other hand, the retrofitting solutions using innovative seismic isolation systems (Dănilă *et al*, 2014) can be adapted in order to reduce the relocation duration.

Given that buildings classified in class I of risk are mainly located in the centre, are spacious and very comfortable, it is recommended that the process of building necessity housing focus on highly comfortable and ultra-central public/state owned buildings in order to create a feeling of safety/trust in a serious undertaking so that beneficiaries accept relocation, which is a costly process, in terms of both psychological and financial resources.

The next step would be the identification of owners who are willing to start the seismic retrofitting process in the owners associations of buildings classified in class I of risk.

Obviously, 100% acceptance is statistically impossible. A sequential approach can be used, with solutions adapted to each case, as follows:

- Associations where the owners who accept retrofitting represent a minority (0-50%) will be invited to observe the seismic retrofitting of other buildings with focus on the advantages of the completed process.

- Associations where the owners who accept retrofitting represent the majority (51-75%). Given that the right to ownership is intangible and the decision of the minority affects the safety of the majority, a legislative approach could be implemented to cast down passive attitude towards structural safety by doubling the property tax for owners who oppose the majority.
- Associations where the owners who accept retrofitting represent a significant majority (75-90%). The same mechanism as the one described above could impose tripling of the property tax. Such form of financial coercion may reduce the number of persons who are undecided/ impassive or may determine renewal of the owners by sale of the apartments, whose owners are financially strained, on the free market and creation of funds at municipality level to finance the retrofitting design or relocation of owners who are willing to consolidate their buildings.

This approach could make owners associations reach an acceptance level higher than 90% but rarely 100%. In such cases, the state must give owners who oppose retrofitting the choice to sell their property on the free market or to be compensated in a reasonable period of time (before starting the retrofitting works) at the market price, the state becoming thus the owner of the apartment.

Legislation needs to be changed in order to warn occupants living in buildings exposed to risk and to penalise owners who hold back the seismic retrofitting works, since such buildings are also a public hazard to neighbouring people in case of collapse (most likely in the case of structures in class I), and may trigger damages that can be quantified according to the aforementioned.

An intrusive approach of the state could focus on purchasing the apartments in the building classified in class I of risk from the owners by a specialised state agency and retrofitting them with public money. The next step would be selling the apartments, with a pre-emptive right of former owners, at a price equal to the initial amount plus retrofitting costs. Such mechanism would give the owners a choice to buy another apartment or to arbitrarily dispose of the received amount without having to return to the building when the works are completed.

The seismic risk reduction programme for residential buildings can be accompanied by banking instruments providing loan guarantees or interest-free loans to apartment owners.

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