Next Generation Rapid Visual Screening for RC Buildings to Assess Earthquake Resilience

Jon Moseley
Civil and structural engineer, jonmoseleymail@yahoo.com
Stephanos Dritsos
Professor, University of Patras, dritsos@upatras.gr

1. Introduction

In the last 20 years, earthquakes and their tsunami sidekick have been responsible for more fatalities than all the other natural disasters put together (CRED, 2015). To date, efforts to offset the loss of life, injuries, destruction and substantial financial losses caused by major earthquakes have concentrated on assessing the existing infrastructure for vulnerability. Therefore, most earthquake prone countries have introduced some form of an evaluation procedure. The rapid visual screening procedure is the first stage of some of these pre-earthquake assessment procedures. During such a procedure, experts initially gather all available documentation and data before going out into the field to quickly collect crucial structural characteristic information and other parameters, normally in the form of yes/no answers. Rapid visual screening procedures are suitable for identifying a set of buildings that are potentially in the highest seismic risk group. These procedures are not suitable for determining if a specific building is, or is not, at seismic risk. They help to screen a building stock and identify the group of buildings that are more likely to be damaged during an earthquake and, therefore, need to be further investigated through checking the seismic capacity more precisely using specific structural analysis analytical tools. The American Federal Emergency Management Agency (FEMA 154, 1988; FEMA 155, 1988) was the pilot for rapid visual screening procedures and a number of countries have followed suit as, for example, the initial Greek Earthquake Planning and Protection Organization's rapid visual screening procedure (OASP, 2000). The basic problem with rapid visual screening procedures is that they assume that the factors that may affect the effectiveness of the structural system act individually on the structural system. As rapid visual screening procedures have been refined by expert examination over a number of years, it is difficult to see how improvements can be made and, therefore, several authors have investigated alternative rapid visual screening procedures. As an example, Dritsos and Moseley (2013) summarise the development of the fuzzy logic rapid visual screening procedure and observe that one advantage of such a procedure over conventional procedures may be that it considers how the identified structural characteristic parameters interact and affect the overall seismic response. A second advantage of the fuzzy logic procedure may be that it considers the degree to which a structural characteristic parameter may exist. That is, inspectors performing a conventional rapid visual screening procedure have the very difficult task of making yes/no decisions when the truth may be much closer to some degree of maybe. It would be more realistic and much easier if the inspectors had the opportunity to allocate a numerical value to the parameter describing the degree of existence or to describe a parameter linguistically (such as poor, medium or good or, more specifically, very tall, short, very irregular).

It is becoming clear that only assessing infrastructure vulnerability is not enough when considering and preparing for the effect of a major earthquake on a particular region. After a destructive event, a whole region is affected and emergency services will be severely stretched as there will be many high priority life threatening situations. It may be several days if not weeks before a normal level of emergency services can be provided. It could take years if not decades before a region recovers from an earthquake. Considering the effects of earthquakes on urban areas is becoming increasingly important as, due to a demographic population shift, the United Nations Office for Disaster Risk Reduction estimates that 70% of the world's population will be living in urban areas by the year 2050 (UNISDR, 2014). It has been noted by several authors that vulnerable groups, such as people with disabilities, by far suffer the most during and after destructive earthquakes (Aroni and Durkin, 1985; Glass et al., 1977; Harada, 2013; Tierney et al., 1988). It has been reported (Jones et al., 1990 for the Loma Prieta earthquake and Bourque et al., 1991 for the Whittier Narrows and Loma Prieta earthquakes) that the majority of fatalities and injuries were mostly affected by how people behaved during or immediately after the earthquake and the fatalities and injuries were caused by people failing down or being hit by non-structural elements and building contents. It has also been reported (Aroni and Durkin, 1985) that 38% of injured people contacted after the 1982 Coalinga California earthquake were disabled. In addition, due to the 2011 Great East Japan earthquake, the mortality rate for registered people with disabilities was double that of the general population (Harada, 2013). Furthermore, the most earthquake vulnerable social groups are not just people with disabilities, as non-registered people with disabilities, children, the elderly, the infirm, people with injuries, parents with small children, pregnant women, ethnic minorities, migrants, refugees, travellers, tourists, etc. must also be considered as vulnerable groups. It can only be assumed that destructive earthquakes cause disproportionally many more fatalities among susceptible groups when compared to the rest of the population. It has been pointed out that if the infrastructure had been designed with vulnerable groups in mind, the whole of society would benefit (Dritsos, 2014c; Dritsos, 2015). This observation gives a key to how the built environment should be assessed. For example, if a disabled person could easily evacuate a building after a disaster, then everybody else could do the same.

Faced with the above facts, it has become increasingly obvious that society needs to be resilient to disaster. Recently, two efforts have been made to link screening procedures to resilience assessment. The United States Department of Homeland Security has developed an integrated rapid visual screening of buildings (BIPS 04, 2011). It is based on FEMA 455 (2009), which deals with terrorism, and, as such, considers all man-made or natural threats and determines initial or relative risk and resilience for buildings based on a visual inspection only. More specifically, the United States Resiliency Council has developed a building rating system for earthquake hazards (USRC, 2015). It is based on ASCE/SEI 31-03 (2003), ASCE/SEI 41-06 (2006) or FEMA P-58 (2012) procedures. This building rating system translates these procedures into a five star rating for the three defined resilience parameters of safety, damage and recovery.

Recognising that merely considering vulnerability is not enough, this article introduces a new resilience assessment procedure that will apply to reinforced concrete buildings. Its background is based on the rapid visual screening procedures of the Earthquake Planning and Protection Organisation for structural and non-structural vulnerability (OASP, 2011; OASP, 2012), the American Federal Emergency Management Agency rapid visual screening procedure (FEMA P-154, 2015), experience gained through developing the fuzzy logic rapid visual screening procedure (Dritsos and Moseley, 2013) and concepts developed while contributing to the European and Mediterranean Major Hazards Agreement (EUR-OPA) for the Council of Europe (Gountromixou et al., 2013; Dritsos, 2014a; Dritsos, 2014b; Dritsos, 2014c; Dritsos, 2015), which is a a platform for co-operation in the field of major natural and technological disasters. As this new procedure is in its infancy, this paper is intended to provoke discussion and debate. It is also intended to introduce concepts beyond rapid visual screening procedures that have to be taken into consideration in order to encourage a society to be resilient to earthquake disaster.

2. Resilience

Resilience can be defined as the ability to cope with and adapt to change. Urban resilience involves preparing for, responding to and recovering from disaster. A resilient society would be little affected by and would recover quickly from a catastrophe. Resilience is dependent on the loss of functionality and time taken to return to functionality. It must be noted that a return to functionality is not the same as full recovery after an event. A return to functionality means returning to a state of "business as usual" where a society can operate near its previous equilibrium level even though some difficulties and problems still need to be resolved. Figure 1 schematically presents resilience with regard to community recovery after an earthquake.

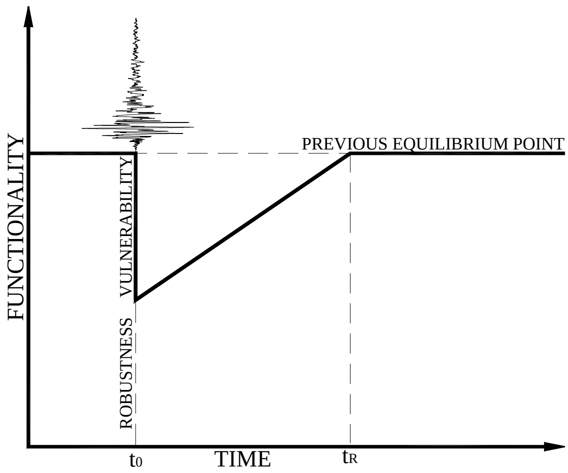

Fig. 1 Recovery after an earthquake

In figure 1, t_0 is the time of the disaster and t_R is the time taken for the affected society to recover functionality after the event. It can be seen from figure 1 that the loss of society functionality is initially dependent on the robustness or vulnerability of the infrastructure and society. A further controlling factor to resilience is the time taken to recover. The area of the triangle in figure 1 is a measure of resilience, as the smaller the triangle the higher the resilience. Looking at resilience in more depth, figures 2 and 3 present the loss of functionality as the variable with a constant recovery rate and constant loss of functionality with the recovery time as the variable.
From figure 2, one possible measure of resilience would be how the functionality of a community is affected. For the same event and a constant recovery rate, a more resilient community recovers the quickest to the equilibrium point before the disaster. The time taken to return to the equilibrium point before the disaster is a second possible measure of resilience, as shown in figure 3. Here, a quick and efficient recovery is desirable and would indicate a resilient community. It must be noted that the

linear recovery lines of figures 2 and 3 are only indicative as it is possible that they could be exponential (slow initial recovery that speeds up), logarithmic (fast initial recovery that slows down) or some other mathematical function such as sine or arcsine. The real situation after any disaster would be some combination of the lines of figures 2 and 3. In both cases, a community may not every time recover to the previous equilibrium point as a new equilibrium state after a disaster is possible, as indicated by the thick dashed lines of figures 2 and 3. Obviously, preparedness before the event is an important parameter as the more a community is prepared the less affected the community will be. Overall, recovery to a decreased functionality is fairly rare as most regions affected by serious earthquakes, in time, recover to an increased functionality.

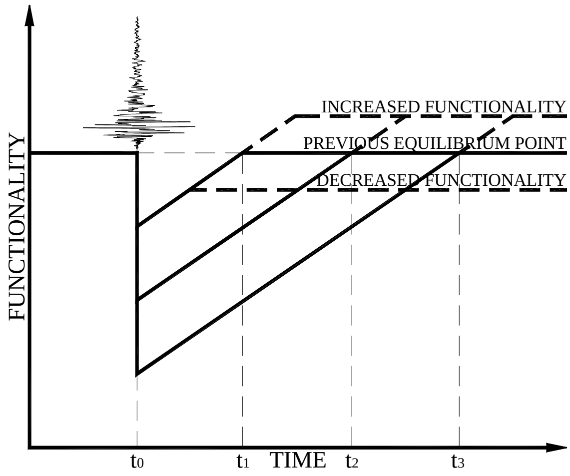

Fig. 2 Recovery after an earthquake, functionality variable with constant recovery rate, t_0 to t_1, t_0 to t_2 and t_0 to t_3 are possible measures of resilience

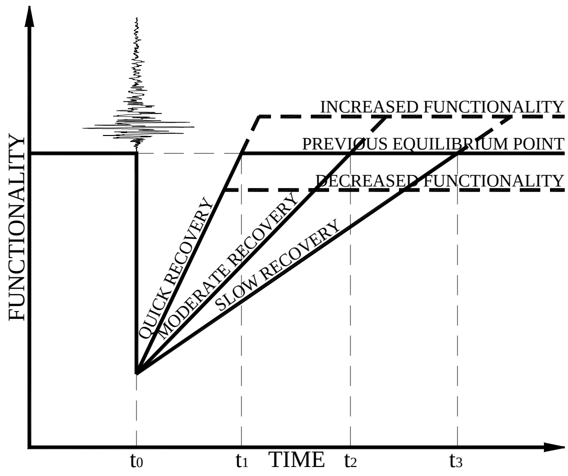

Fig. 3 Recovery after an earthquake, recovery rate variable, t_0 to t_1, t_0 to t_2 and t_0 to t_3 are possible measures of resilience

An example of increased functionality in Greece would be the city of Volos that was devastated by a series of earthquakes in 1955. In the aftermath, the opportunity was taken to completely redesign the city with a new spacious layout and new modern facilities and, today, Volos has grown to be the third largest port in Greece. A further Greek example of increased functionality would be the city of Kalamata, which was severely damaged by the 1986 earthquake. Before the earthquake, Kalamata was suffering from underinvestment and was in decline. The earthquake brought "a wind of change" and now Kalamata is a pleasant vibrant city and a modern provincial capital. An international example of increased functionality would be due to the 2008 Sichuan earthquake, where six and a half million buildings collapsed. The province's industrial base was rebuilt with new factories replacing the old inefficient facilities that had collapsed and now the region is one of the leading manufacturing areas of China (UNESCAP, 2013). It is probable that much of the Chinese merchandise found in shops in Greece and throughout the world originates from this province.

In Greece, an example of earthquake non-resilience leading to a decreased functionality would be the 1953 Ionian earthquake, where most of the buildings on Kefalonia collapsed. Within two months of the disaster, 80% of the island’s population had left to seek a new life, mostly outside of Greece. Descendants of those Kefalonians that left can be found throughout the world. Due to the earthquake, the island’s buildings and economy were destroyed and ruined and abandoned villages can still be found to this day. A population having no other alternative than to leave an affected region can perhaps be considered as the worst case of non-resilience, as there is nobody left behind to start rebuilding and no reason to start rebuilding. On the positive side, it is to be noted that the disaster prompted the introduction of the first reinforced concrete and anti-seismic codes in Greece. Internationally, it took several decades for Lisbon and southern Portugal to recover from the 1755 earthquake and tsunami and Portugal’s position as a colonial power was severely affected. Financially, the event could be considered as one of the greatest natural catastrophes to have affected Western Europe (Chester, 2008) and changed political, theological and philosophical thinking within Portugal (Wikipedia, 2015). Portugal never recovered to its former position of a leading colonial power and, therefore, this must be considered as a case of decreased functionality. On the positive side, this earthquake was responsible for instigating modern seismology and earthquake engineering.

3. Rapid visual screening to assess resilience

High resilience to disaster is a function of the environmental performance during the disaster (for example, the infrastructure’s structural performance), how people behave during and after the disaster and the readiness of plans and resources in order to speed recovery after the disaster. Therefore, a rapid visual screening procedure to assess resilience must take account of these parameters. Figure 4 presents a summary of the proposed procedure.

In the new procedure, it is envisaged that screeners collect relevant information in the same way as for other rapid visual screening procedures. Figure 4 is based on and is an extension of the procedure developed for the fuzzy logic rapid visual screening procedure (Dritsos and Moseley, 2013). In figure 4, w_i represents a weighting factor, as all parameters may not affect resilience to an equal degree. From figure 4, it can be seen that relevant parameters are grouped together in order to obtain eight intermediate parameters. These in turn are used to assess the two parameters of construction vulnerability and people and State (as in government supported services and provided community services) that are considered to affect resilience. Where the new procedure differs from other procedures is that screeners have the opportunity to assess the degree of existence of each parameter by allocating a value between 0 and 1 (0 means very good, while 1 means very bad), as it has been noted that it is difficult to clearly decide yes or no as to whether a parameter exists or not and it has been found that assessing the degree of parameter existence produces more accurate results (Moseley and Dritsos, 2009).

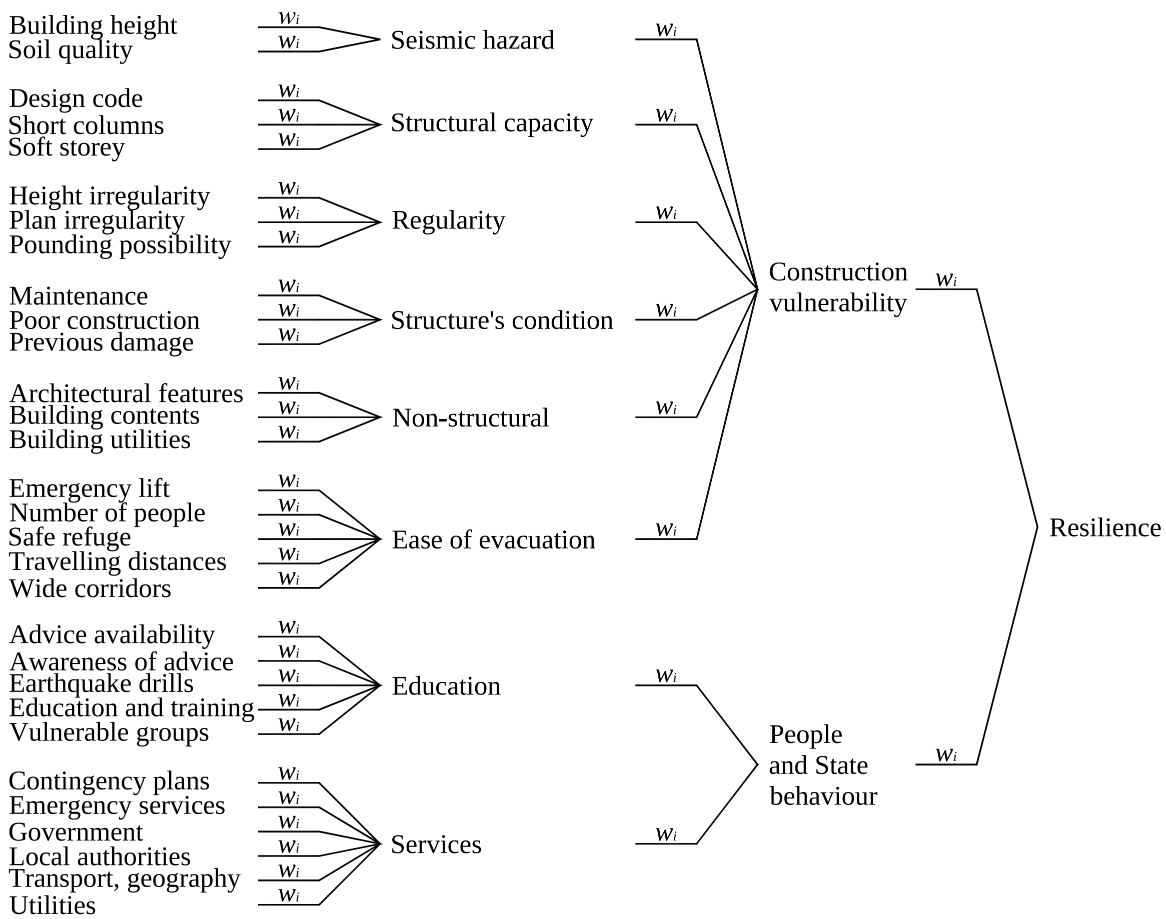

Fig. 4 Resilience assessment system representation

3.1 Intermediate variables

In developing figure 4, in comparison with the fuzzy logic and Earthquake Planning and Protection Organisation procedures (Dritsos and Moseley, 2013; OASP, 2012), some rationalisation and simplification of the individual parameters making up the intermediate variables seismic hazard, structural capacity, regularity and structure’s condition has been performed. For example, ground motion is not considered as a parameter as the earthquake must be severe in order to cause destruction. In addition, infill wall layout and torsion possibility have been removed as these could be taken into account when considering the plan regularity parameter. The further parameter of poor construction has been added as an experienced screener can instantly see if this parameter exists. For these four intermediate variables, guidance for assessing the individual parameters can be found elsewhere (FEMA P-154, 2015; Moseley and Dritsos, 2009; OASP, 2012). In particular, Moseley and Dritsos (2009) and to a lesser extent FEMA P-154 (2015) define the degree to which some parameters exist, which should serve as a model for the other parameters of figure 4.

3.1.1 Non-structural intermediate variable parameters

The non-structural intermediate variable is obtained by considering architectural features, building contents and building utilities. Extensive guidance concerning this variable has been published by the Earthquake Planning and Protection Organisation (OASP, 2011). In brief, architectural features concerns the presence of false ceilings, windows, doors, lights, exterior and interior trim, exterior wood paneling, glass, etc. that could fall or break during the event resulting in the death or injury of residents or impede the evacuation of the residents after the event. Building contents deals with computers, communication devices, cabinets, storage shelves, bookcases, kitchens, laundries, furniture, etc. Again, these should not affect or impede the residents and it is important that rooms are uncluttered so as to have a number of alternative routes through the contents to the exit route. Building utilities concerns hydraulic, electromechanical, gas, elevators, solar energy installations, etc. As above, these should not break or fall and affect the residents. In all cases for architectural features, building contents and building utilities, susceptible non-structural features should be strongly bolted to the ceilings, walls or floors.

3.1.2 Ease of evacuation intermediate variable parameters

After a destructive earthquake event, the general advice is to leave the building in a quick and orderly fashion without using the lifts. This can be facilitated through the proper design of exit routes from the building. The ease of evacuation intermediate variable can be determined by considering if there are short travelling distances through wide uncluttered corridors to an area of safe refuge that contains the stairs and an emergency lift. The maximum number of people that inhabit the building at any one time would also be a parameter. In more detail, ideally, buildings should be designed with one or more strong central cores. These central cores should be structurally overdesigned in order to resist any earthquake. Central cores should be places of safe refuge and contain exit routes in the form of stairs and emergency lifts. Emergency lifts are stronger than normal lifts and are fire resistant. Such lifts have more than one back-up battery power source, so that they remain operational even if the electricity fails. Lift shafts containing such lifts must be designed to withstand virtually all earthquakes. Quite simply, the only way to evacuate with dignity many classes of people with disabilities, people that are bedridden, etc. is through the use of emergency lifts. Placing central cores in a building ensures short travelling distances to a place of safe refuge. Corridors leading to the central cores should be straight, uncluttered and wide enough to avoid the slowest holding up everybody else and leading to panic. Connecting doors, particularly those leading to exit points should be arranged in the same line so that everybody can travel directly to safety. Proper universally recognised signing of exit routes would be essential.

3.1.3 Education intermediate variable parameters

This intermediate variable concerns the parameters of advice availability, awareness of advice, earthquake drills, education and training, and vulnerable groups. The object of this intermediate variable is to assess peoples' behaviour. It is essential in an earthquake region that all the population is educated concerning what to do before, during and after an earthquake. Government, relevant organisations and experts must publish education and training material and make such material readily available in the form of textbooks, booklets, leaflets, videos, posters, TV spots, e-learning, e-books, websites, seminars and tutorials. It must be ensured that all the population is made aware of such advice. Community leaders, police, fire brigade, armed forces personnel, teachers and other people or groups of people that would play a leading role after a disaster must undergo education and training. In preparation for a disastrous event, earthquake drills must be performed on a regular basis. Vulnerable groups must not be forgotten and advice, which may not be the same as that for the general public, should be produced in a number of languages to take into account people with learning difficulties, ethnic minorities, migrants, refugees, travellers, tourists, etc.

3.1.3 Services intermediate variable parameters

The services intermediate variable deals with recovery after a destructive earthquake event. Here, the government and the local government would play a leading role. The government must be ready to quickly and continually allocate resources to an affected region in order to alleviate the impact on the community. Contingency plans must be in place and emergency teams and equipment must be ready to travel to an affected region at a moments notice. All concerned parties must be prepared. Emergency shelter, food and water must be readily available. Transport and geography would be an important parameter. Alternative routes to a region must be considered, particularly in mountainous regions. In cities, it is possible that narrow streets could be blocked by falling debris making ready access very difficult. Utility companies must also be on standby to go to a region to quickly restore water and electricity supplies.

4. Worked example

An existing building has been selected and investigated as a means of illustrating the proposed technique. The building in question is on the corner of two streets and just off a city centre. It is rented shops on the ground floor and rented offices above. Figure 5 presents a schematic plan and elevation of the building. It is a reinforced concrete frame structure without shear walls.

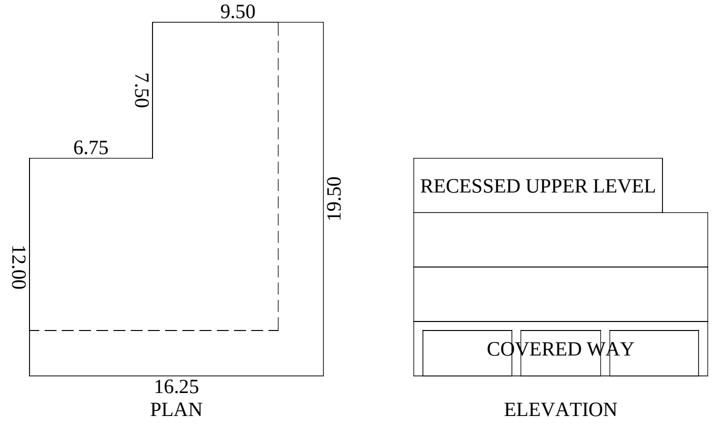

Fig. 5 Schematic plan and elevation

Table 1 presents the determination of the score for the first intermediate parameters, while table 2 combines these scores to determine a resilience value. For the building in question, the following provides a brief explanation of the individual parameter scores in table 1 that could be allocated during a screening procedure: The building is four storeys high with an underground. The soil is more good than bad. The building appears to have been built between 1985 and 1995 but probably nearer 1985. Short columns do not appear to exist. As the ground floor is shops and one side of the building has an open sided covered way for pedestrians where isolated outside columns support the upper levels, a severe soft storey situation exists. The last level of the building is recessed from the rest of the building on both street sides and column dimensions are reduced in upper levels leading to a height irregularity. The building is "L" shaped in plan and walls on the ground floor are only between the shops and enclose the back of the building. Therefore, there is a serious plan irregularity. Considering pounding, buildings on either side have floor levels at different levels to the building in question and there does not appear to be any seismic gap between the buildings. Buildings on either side are lower than the building in question, which would be relatively flexible due to its is column only design and it is a corner building. Whatever maintenance that has been performed only appears to have been carried out when the owners have been forced to do it. Ingress of rainwater appears to be a general problem. The building is in a general dilapidated condition but some tenants appear to have taken matters into their own hands, particularly those that rent the shops. The construction quality appears to be fairly poor as some spalling and corroded reinforcing bars can be seen at the edges of balconies and on parapets indicating a possible lack of concrete cover. In addition, some outside walls of the offices are not constructed within the beams and columns of the concrete frame. A serious consideration would be the presence of drainage pipes inside the columns. Inside, beam on beam connections exist around the stairs. There appears to be a little previous damage as minor cracking can be seen in infill walls and between infill walls and the concrete frame. Architectural features are minimal but all the shops are glass fronted and some have false ceilings. Here, the serious problem would be the presence of a heavy wooden false ceiling in the ground floor entrance leading to the lift and stairs for the offices. This could fall and block the exit. The offices on the upper levels are cluttered with desks, chairs, bookcases, etc. As nothing appears to have been bolted down, the building contents could cause problems. Building utilities appear to be fairly robust. The lift is not an emergency lift. Normally, there are not so many people in the building but, as most of the offices provide a direct service to the public, the maximum number in the building could be quite high as, at times, several families may visit the building at the same time. There is no safe refuge. Travelling distances to leave the shops or to leave the offices are short and fairly direct to exit routes but there are no signs to tell people which direction to travel. The corridors leading to the offices are narrow and the stairs are a little narrow and awkward, particularly when changing direction. Single file only is possible in places on the stairs. It is known that in recent years the Earthquake Planning and Protection Organisation (OASP, 2016) has made tremendous efforts to make available advice concerning what to do before, during and after an earthquake. Much of this material is aimed at vulnerable groups and is in a variety of languages. Unfortunately, most of the occupants of the building in question appear to be unaware of this advice. The education and training parameter is unknown and, therefore, has been allocated the median value. Earthquake drills have never been carried out. It is clear that vulnerable groups have never been considered. Contingency plans, government, local government and utilities are fairly unknown quantities and likely values have been allotted. Both streets at the sides of the building are one way. The building fronts one of the few main routes into the city and double parking throughout the day and evening is common. It could be envisaged that a bus or large truck passing in the one remaining lane at the time of an earthquake could lead to blocking the entire street not only severely restricting access to the building but also causing chaos in the city centre. The side street is narrow with parking on both sides. It would be impossible to drive heavy moving equipment, fire trucks, etc. down this street. Looking at geography, the building is not on the side of a hill and there is no chance of a landslide.

Table 1 Intermediate parameter scores

Parameter	Score	Weight	Intermediate parameter	Calculated score
Building height	0.60	0.60	Seismic hazard	0.52
Soil quality	0.40	0.40		
Design code	0.70	0.30	Structural capacity	0.56
Short columns	0.00	0.35		
Soft storey	1.00	0.35		
Height irregularity	0.80	0.30	Regularity	0.94
Plan irregularity	1.00	0.40		
Pounding possibility	1.00	0.30		
Maintenance	1.00	0.25	Structure's condition	0.58
Poor construction	0.60	0.45		
Previous damage	0.20	0.30		
Architectural features	0.80	0.35	Non-structural	0.68
Building contents	0.80	0.35		
Building utilities	0.40	0.30		
Emergency lift	1.00	0.25	Ease of evacuation	0.85
Number of people	0.60	0.15		
Safe refuge	1.00	0.25		
Travelling distances	0.40	0.15		
Wide corridors	1.00	0.20		
Advice availability	0.00	0.15	Education	0.75
Awareness of advice	0.90	0.25		
Education and training	0.50	0.15		
Earthquake drills	1.00	0.20		
Vulnerable groups	1.00	0.25		
Contingency plans	0.20	0.30	Services	0.48
Government	0.30	0.15		
Local government	0.40	0.15		
Transport, geography	1.00	0.25		
Utilities	0.40	0.15		

Table 2 Determination of resilience

Intermediate parameter	Score	Weight	Intermediate parameter	Score	Weight	Resilience
Seismic hazard	0.52	0.15	Construction vulnerability	0.70	0.50	0.67
Structural capacity	0.56	0.15				
Regularity	0.94	0.15				
Structure's condition	0.58	0.15				
Non-structural	0.68	0.20				
Ease of evacuation	0.85	0.20				
Education	0.75	0.60	People and State	0.64	0.50	
Services	0.48	0.40				

Weighting factors on tables 1 and 2 have been determined by the authors. It must be stated that this is an illustrative exercise only as a proper detailed screening procedure has not been performed. That is, no attempt have been made to gather all available documentation and data, and relevant authorities have not been contacted and questioned regarding their readiness for a catastrophic earthquake event. Therefore, some of the scores on table 1 are pure conjecture.
Considering the resulting values of table 1, it can be seen that regularity, ease of evacuation and education would cause the most reasons for concern. All values seem rather high and although most services parameters are low, the transport situation around the building may cause rather serious problems. From table 2, it can be seen that the problems noted above lead to a relatively high final value indicating a low resilience situation. It can be seen from both tables 1 and 2 that there could be considerable room for improvement.

5. Discussion

As urban areas are set to grow in the next few decades, the risk of catastrophes caused by natural hazards is also set to increase exponentially (UNISDR, 2014). Efforts to offset the disastrous effects of natural hazards must concentrate on providing resilience. Resilience applies to the built infrastructure, the population and readiness of plans and resources. Earthquakes can have a huge impact on human life and economical resources, as demonstrated by past historical events. It is know that the most vulnerable groups in society suffer the most during and after an earthquake catastrophic event. Past efforts to offset the devastating effects of earthquakes have only concentrated on assessing the built infrastructure's vulnerability. Clearly, this is not enough as the population is not considered. It would be narrow minded to concentrate efforts on making sure that the buildings do not fall down if the population does not know how to prepare for, or react during and after an earthquake. Moreover, the government, local government, emergency services, etc. that would play a pivotal role must be on standby to quickly step in when a catastrophe occurs. Short term and long term resources must be planned for and available to assist an affected region and its population to quickly recover from a disaster.
This paper has attempted to build on rapid visual screening procedures to assess vulnerability to develop a screening procedure to assess resilience. In the worked example above, it can be clearly seen where efforts should be concentrated in order to improve resilience. Remembering that 1 represents very bad and 0 represents very good, figure 6 presents a suggested resilience scale.

Fig. 6 Suggested resilience scale

The final score for the building in question was 0.67, which, from figure 6, indicates borderline moderate to bad and represents a rather worrying resilience result. As noted above, this new procedure is in its infancy and this paper is intended to provoke discussion and debate. With reference to figure 4 above, it may be that there are other parameters that contribute to resilience and it may be found that some of the parameters of figure 4 are not important.

6. Conclusions

This paper has attempted to build on and move on from rapid visual screening procedures to merely assess seismic risk. The concept of resilience has been described. A new rapid visual screening procedure to assess urban resilience has been introduced. Factors that affect urban resilience were found to be environmental performance during the disaster (for example, the infrastructure's structural performance), how people behave during and after the disaster and the readiness of plans and resources in order to speed recovery after the disaster. It has been determined that vulnerable groups in society must be considered, as such groups suffer the most during a disaster and, if the built infrastructure was designed to account for vulnerable groups, everybody would benefit. The intention of this paper was to introduce concepts beyond rapid visual screening procedures that have to be taken into consideration in order to encourage a society to be resilient to earthquake disaster and to stimulate discussion and debate concerning urban resilience.

A worked example on an existing building has been performed to demonstrate the new procedure and, worryingly, the building in question, its inhabitants and its supporting administration were found to be not very resilient. The worked example and, therefore, the new screening procedure highlighted areas where there would be considerable room for improvement.

It is concluded that it is time to move forward from merely assessing vulnerability and concentrate on resilience. It has been demonstrated that performing a rapid visual screening procedure to assess resilience has identified the weakest links in a society's resilience to earthquake disaster and indicated areas for improvement to increase resilience.

References

Aroni S. and Durkin M. E. (1985), "Injuries and occupant behavior in earthquakes", Joint US-Romanian Seminar on Earthquakes and Energy, Bucharest, Romania, Architectural Research Centers Consortium, Washington, DC, Vol. 2, pp. 3–40.

ASCE/SEI 31-03 (2003), "Seismic evaluation of existing buildings", American Society of Civil Engineers (ASCE), Reston, Virginia.

ASCE/SEI 41-06 (2006), "Seismic rehabilitation of existing buildings", American Society of Civil Engineers (ASCE), Reston, Virginia.

BIPS 04 (2011), "Integrated rapid visual screening of buildings", US Department of Homeland Security, Buildings and Infrastructure Protection Series (BIPS), https://www.dhs.gov/xlibrary/assets/st/st-bips-04-irvs.pdf(downloaded May, 2016).

Bourque, L., Aneshensel, C. and Goltz, J. (1991), “Injury and psychological distress following the Whittier Narrows and Loma Prieta earthquakes”, background working paper for the UCLA International Conference on the Impact of Natural Disasters, Los Angeles, 42 p.

Chester, D. K. (2008) “The effects of the 1755 Lisbon earthquake and tsunami on the Algarve Region, Southern Portugal”, http://core.ac.uk/download/pdf/104862.pdf (downloaded May 2015).

CRED, (2015), "The human cost of natural disasters", Centre for Research on the Epidemiology of Disasters (CRED), http://reliefweb.int/report/world/human-cost-natural-disasters-2015-global-perspective (downloaded March 2016).

Dritsos, S. E. (2014a), “Design for earthquake preparedness”, Conference on Including People with Disabilities in Disaster Preparedness and Response, EUR-OPA, Council of Europe, Strasbourg.

Dritsos, S. E. (2014b) “Development of information documents in emergency management in the field of earthquakes”, Workshop on civil protection in diverse societies: Migrants, asylum seekers and refugees in the context of major risks prevention and management, EUR-OPA, Council of Europe, Strasbourg.

Dritsos, S. E. (2014c), “Design for all: Earthquake preparedness including people with disabilities”, Conference on Including People with Disabilities in Disaster Preparedness and Response, EUR-OPA, Council of Europe, Brussels.

Dritsos, S. E. (2015), “DRR Preparedness: Implementing a training and education strategy in case of earthquakes”, Workshop: Toolkit on Disability and Disaster Preparedness, EUR-OPA, Council of Europe, Brussels.

Dritsos, S. and Moseley, J. (2013), "A fuzzy logic rapid visual screening procedure to identify buildings at seismic risk", *Werkstoffe und Konstuctionen; Innovative Ansätze*, Ernst and Sohn Special, pp. 136-154.

FEMA 154 (1988), "Rapid visual screening of buildings for potential seismic hazards: A handbook", American Society of Civil Engineers (ASCE), Reston, Virginia.

FEMA 155 (1988), "Rapid visual screening of buildings for potential seismic hazards: Supporting documentation", American Society of Civil Engineers (ASCE), Reston, Virginia.

FEMA P-154 (2015), “Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook”, Federal Emergency Management Agency (FEMA), Washington DC.

FEMA P-58 (2012), “Seismic performance assessment of buildings”, Federal Emergency Management Agency (FEMA), Washington, DC.

FEMA 455 (2009), “Handbook for rapid visual screening of buildings to evaluate terrorism risk”, Federal Emergency Management Agency (FEMA), Washington, DC.

Glass, R. I., Urrutia, J. J., Sibony, S., Smith, H., Garcia, B. and Rizzo, L. (1977) “Earthquake injuries related to housing in a Guatemalan village”, *Science*, Vol. 197, Issue 4304, pp. 638-643.

Gountromixou, C., Pelli, L., Lekkas E. and Dritsos S. (2013), “Earthquake protection policy for people with disabilities” Workshop: Including People with Disabilities in Disaster Preparedness and Response, EUR-OPA, Council of Europe, Paris.

Harada, K. (2013), "Persons with disabilities in the Great East Japan Earthquake", Global Platform for disaster risk reduction, Geneva, Switzerland, May, 2013, http://www.preventionweb.net/globalplatform/2013/programme/ignitestage/view/399 (downloaded November, 2014).

Jones, N. P., Noji, E. K., Smith, G. S. and Krimgold, F., 1990, "Preliminary earthquake injury epidemiology report", in Bolin, R., editor, The Loma Prieta earthquake: Studies of short-term impacts, A Natural Hazards Center monograph, University of Colorado, Boulder, pp.33-43.

Moseley, J. and Dritsos, S. (2009) “Rapid visual screening to assess the seismic vulnerability of RC buildings using a fuzzy logic database”, CD Proceedings of the 16th Greek Concrete Confere*nce*, Pafos, Cyprus, paper no. 271102.

OASP (2000), "Provisions for pre-earthquake vulnerability assessment of public buildings (part A)", Earthquake Planning and Protection Organization (OASP), Athens (In Greek).

OASP (2011), “Assessment of non-structural vulnerability”, Earthquake Planning and Protection Organisation (OASP), Athens (In Greek).

OASP (2012), “Assessment of structural vulnerability”, Earthquake Planning and Protection Organisation (OASP), Athens (In Greek).

OASP (2016), "Earthquake Planning and Protection Organisation website", http://www.oasp.gr/.

Tierney, K. J., Petak, W. J., and Hahn, H. (1988), "Disabled persons and earthquake hazards", Institute of Behavioral Science, Boulder, Colorado.

UNESCSP (2013), “Building resilience to natural disasters and major economic crises”, United Nations Economic and Social Commission for Asia and the Pacific (UNESCSP), http://www.unescap.org/sites/default/files/ThemeStudy2013-full2.pdf, (downloaded January 2015),

UNISDR (2014), “Urban risk reduction and resilience”, United Nations Office for Disaster Risk Reduction (UNISDR), http://www.unisdr.org/files/37966_finalwp3.pdf (downloaded May 2015).

USRC (2015) " Implementation manual: USRC building rating system for earthquake hazards", United States Resiliency Council (USRC), Atherton, California.

Wikipedia (2015), “1755 Lisbon earthquake,” http://en.wikipedia.org/wiki/1755_Lisbon_earthquake (downloaded May 2015).