Pioneering Seismic Risk Assessments in Bucharest

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Josh DeBare | Nick Miragliotta | Kevin Schultz | Matt Zoner

gr-seismic-risk-d22@wpi.edu

Professor Althea Danielski | Professor Robert Kinicki

Pioneering Seismic Risk Assessments in Bucharest

An Interactive Qualifying Project Proposal submitted to the faculty of

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By

Josh DeBare (Computer Science)

Nick Miragliotta (Mechanical Engineering)

Kevin Schultz (Aerospace Engineering)

Matt Zoner (Electrical and Computer Engineering)

Date:

3 May 2022

Report Submitted to:

Professor Althea Danielski

Professor Robert Kinicki

Worcester Polytechnic Institute

Abstract

Bucharest, Romania, experiences a major earthquake on average every 80 years, yet most citizens live in seismically vulnerable buildings. By conducting interviews with seismic experts, locating seismically vulnerable buildings in Bucharest, and structuring a newspaper article, the project team aimed to assist the Romanian NGO Re:Rise to conduct seismic risk assessments and inform the public on the seismic risk of historical buildings. The team generated recommendations for conducting seismic risk assessments, used GIS to identify 480 buildings as a historically vulnerable building type, and outlined the structure for an article about the severity of the issue. The team hopes that the project inspires change by helping to prepare the citizens of Bucharest for the next major earthquake.

Executive Summary

Introduction and Background

Each year earthquakes directly impact 3.5 million people, killing 60,000 and causing billions of US dollars of damage (Kenny, 2009). Additionally, earthquakes cause significant trauma, including post-traumatic stress disorder (PTSD) and other mental disorders (Ishwari Adhikari & Bhagawati, 2019). Romania is especially vulnerable to earthquakes, as it sits near the Vrancea seismic zone. Despite experts predicting a major earthquake in the next 40 years (Pavel & Vacareanu, 2017), Romania remains underprepared for the next significant seismic event (M. Sumbasacu, personal communication, April 5, 2022).

During the 20th century, as cities grew, seismic risk also grew. Before 1940, although Bucharest had survived many earthquakes, due to the lack of urbanization and tall structures, the city only suffered minor damages. This changed in 1940 when a magnitude 7.7 earthquake killed 1,000 people and injured 11,000 more (see Figure E.1). A second earthquake struck in 1977, killing over 1,500 people and inflicting over 2 billion US dollars in infrastructure damages (Armaş et al., 2017).

Figure E.1: Carlton Block before collapse (left) and immediately after collapse (Georgescu & Pomonis, 2012).

The Romanian government has neglected earthquake vulnerability. For example, under Nicolae Ceausescu's Communist Regime, builders completely ignored earthquake safety when constructing housing, as Ceausescu prioritized rapidly urbanizing Romania over ensuring the safety of the buildings (Mungiu-Pippidi, 2010). After many buildings collapsed or sustained damage in the 1977 earthquake, workers cosmetically fixed structures instead of structurally fixing them (see Figure E.1) (Simpson et al., 2020). Additionally, tens of thousands of communist era buildings only have to meet the codes of their era, rather than modern day codes (Pavel et al., 2021). Furthermore, the Romanian government is plagued with single bidding and political connections where construction companies have pocketed €200 million from corrupt contracts awarded by Romanian officials (Doroftei, 2016).

Additional systemic issues prevent widespread retrofitting and assessing. Current building assessment techniques require certified structural engineers and take two weeks to complete, which are expensive and time-consuming (M. Sumbasacu, personal communication, April 5, 2022). Additionally, if the results from an assessment categorize the building at the highest vulnerability class, authorities mark the structure with a red dot, which reduces property value (see Figure E.2) (Suditu et al., 2020).

Figure E.2: Building marked with a red dot (Simpson et al. 2020).

This discourages building owners from allowing inspectors inside in the first place. Furthermore, even if an assessor inspects a building, each individual apartment owner needs to approve a retrofit and find alternative housing while construction workers fix the building (M. Sumbasacu, personal communication, April 5, 2022). These factors have led to only 23 retrofits out of 335 red dot buildings (Ivanov, 2021) with inspectors failing to assess tens of thousands of buildings (M. Sumbasacu, personal communication, April 5, 2022).

Romanian NGOs are taking action to reduce seismic vulnerability in Bucharest, Romania. One of these NGOs, Re:Rise, aims to "act as a bridge between people at risk of seismic risk and … the technological, financial, administrative and human resources available" (Sumbasacu, 2022). Re:Rise's projects include a registry of construction vehicles and aerial photography methods to assist emergency services immediately following an earthquake. Additionally, Re:Rise maintains a publicly available seismic risk map containing seismic information for individual buildings in Bucharest (see Figure E.3).

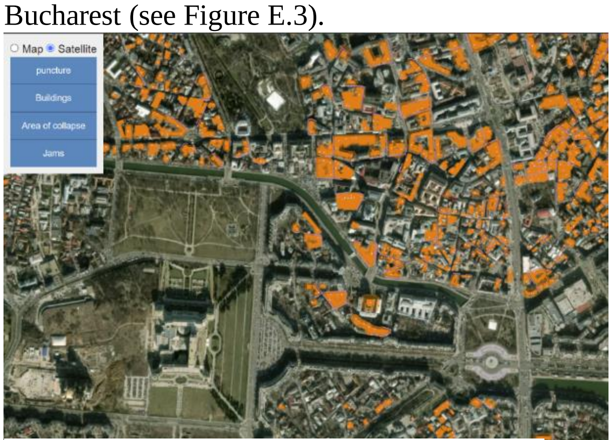

Figure E.3: Re:Rise Map of Risk, accessible at dupacutremur.ro

The goal of this project is to assist Re:Rise in preparing to conduct seismic risk assessments and inform the public on the seismic risk of historically vulnerable buildings in Bucharest, Romania.

We address this goal through three main objectives:

1. Evaluate seismic risk assessment methods
2. Identify similar buildings across Bucharest
3. Educate the public on the prevalence of historically vulnerable buildings in Bucharest

This report analyzes three different seismic risk assessment methods, with varying amounts of depth, cost, and access to structures, and concludes that rapid visual seismic risk Assessments (RVSRAs) have the greatest impact on assessing structures in Bucharest. RVSRAs are a type of building assessment where the assessor views the building from the exterior and notes any seismic cracking or abnormalities that indicates that the building is seismically vulnerable. Assessors can conduct this method quickly and without entering a structure's interior.

To further assist Re:Rise with preparing to conduct RVSRAs, the team studied geo-mapping and its potential impacts and applications as it relates to seismic risk. In short, the team used Q-GIS, a satellite mapping system that connects data to a map by assigning descriptive information to a specific building. Researchers in Grenada, Spain have previously used geo-mapping to identify and categorize structures. This highlighted the areas of the city with the highest population density, which experts used to reduce seismic risk (van Westen & Frigerico, 2011). Seismic applications of geo-mapping have remained unexplored in Bucharest.

Methodology

To accomplish the goals and objectives, the team used three methods: interviews with seismic experts from Romania, Greece, and the United States, locating seismically vulnerable buildings throughout Bucharest, and drafting a newspaper article.

To achieve the first objective, the team evaluated seismic risk assessment (SRA) methods by conducting five interviews with SRA experts, such as engineers, academics and inspectors. The team designed the interviews to gain insight into how experts viewed SRA compared to RVSRA methods.

The team geo-mapped structures throughout Bucharest to achieve the second objective. Buildings with similar architecture and attributes will likely have similar outcomes after an earthquake. Re:Rise founder Sumbasacu showed the team how to identify historically vulnerable double orientation (OD) buildings using GIS software. The team analyzed satellite images of Bucharest to try and mark all OD buildings.

Lastly, to achieve the final objective, the team wrote a draft of a newspaper article to educate the Romanian public about seismic risk, as there is a need to increase awareness about seismic vulnerability.

Results

Expert Opinion of RVSRAs

Experts opined on the advantages and disadvantages of RVSRAs, the applications of RVSRAs, and how to conduct RVSRAs. They largely agreed on the advantages and disadvantages of RVSRAs. All interviewees agreed that RVSRAs are less expensive and faster than traditional SRAs but are less accurate.

Experts gave three major applications of RVSRAs. The first application regarded reducing the building stock to evaluate. Since traditional assessments can take two weeks, an RVSRA can prioritize the buildings most in need of retrofitting where the most people are in danger. Next, an RVSRA can be utilized in conjunction with a seismic model to predict the loss of life and economic loss of the next major earthquake. Lastly, an inspector recommended conducting RVSRAs post-earthquake to determine which structures residents can safely return to without fear of a delayed collapse.

Furthermore, engineers gave professional advice on the best way to conduct RVSRAs. One expert recommended grouping similarly constructed residential areas together, as damage within each zone will likely be similar. Experts expressed the importance of checking the data gathered in RVSRAs; seismic expert Mike Mahoney states “your findings are only as good as the information you have” (M. Mahoney, personal communication, March 23, 2022).

Experts disagreed on the requisite knowledge required for RVSRA inspectors. Some experts expressed the necessity for experienced and accredited inspectors, while others had successfully conducted RVSRAs with undergraduate students. Other experts thought graduate students were the right choice.

Geo-mapping

The team geo-mapped double orientation (OD) buildings throughout Romania using GIS software. In total, the team marked 480 OD buildings (see Figure E.4 and E.5), which could potentially house around 30,000 residents. A high portion of OD buildings have either collapsed or exhibited severe damages in prior earthquakes, meaning their residents are in direct danger for the next earthquake. OD buildings are just one of the many building types found in Bucharest that are seismically unsafe.

Figure E.4: Sector 6 of Bucharest with marked buildings (RED) in QGIS software

Figure E.5: Double orientation buildings marked with red outlines and dots on the team's geo-map

Newspaper Article Draft

Lastly, the team drafted an article explaining the team's experience and findings. For example, the team was alarmed to learn that 30,720 residents living in OD buildings may be uninformed about the structures' risk. The article utilizes these powerful statistics to attempt to sway Romanian citizens and the Romanian government to prioritize earthquake preparedness. Lastly, the team sent the article to the collaborator for further edits and eventual publication.

Recommendations

Use Geo-Mapping to Quicken RVSRA Program

Considering the similarities between different building types, the team believes that conducting RVSRAs on a sample from each building type can accurately indicate the structural integrity of the rest of the building stock.

Create a Seismic Model

Re:Rise should investigate seismic computer models as a tool to estimate the potential damages of the next major earthquake.

Use Graduate Students to Conduct RVSRAs

The team believes that graduate students are good candidates for Re:Rise's RVSRA program, as they have adequate experience and are not as expensive as using professional engineers.

Use Quality Control for RVSRA Results

The team recommends having a quality control measure to ensure the data collected is accurate, as inaccurate data has the potential to make the whole RVSRA operation ineffective.

Establish Credibility for RVSRA Assessors

As residents may be suspicious of individuals collecting information about their homes, it is important that local governments provide credibility and approval to assessors. Additionally, inspectors can wear identifying clothing to signify their official status.

Conclusions

Bucharest is incredibly vulnerable to earthquakes. Thousands of structures remain uninspected and most likely unsafe. The team concluded that RVSRAs are a useful tool to assess structures more quickly than current practices. The team also successfully geo-mapped 480 double orientation buildings and produced a draft of an article to present to the public, which is important because the next major earthquake is due sometime in the next 30 years. The team hopes that this project will inspire change and action to prepare Romania for the next earthquake and save thousands of lives.

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I. Authorship

Section	Writer	Primary Editors
Abstract	Matt	Nick
Executive Summary	Josh/Kevin	Josh/Matt
1.0	Nick/Matt	Kevin/Josh
2.0	Nick	Kevin
2.1	Kevin	Nick/Matt
2.2 (and all subsections)	Nick	Kevin/Josh
2.3 (and all subsections)	Matt	Josh/Nick
2.4 (and all subsections)	Josh	Matt/Kevin
2.5	Matt	Kevin
2.6	All	Matt/Kevin
3.0	Nick	Matt
3.1	Kevin	Josh
3.2	Josh	Nick
3.3	Matt	Kevin
4.0	Matt	Josh
4.1 (and all subsections)	Nick/Josh	Kevin/Nick
4.2	Kevin	Matt
4.3	Nick	Josh
5 (and all subsections)	Josh	Kevin
6 (and all subsections)	Nick	Josh

II. Table of Contents

III. List of Figures

IV. List of Tables

1 Introduction

Earthquakes impact 3.5 million people every year on average, including 60,000 deaths (Kenny, 2009). Additionally, earthquakes leave hundreds of thousands homeless and can cause significant trauma and post-traumatic stress disorder (Ishwari Adhikari & Bhagawati, 2019). Furthermore, earthquakes weaken or destroy billions of dollars in infrastructure, such as buildings, bridges, and roads. Earthquakes cause these damages because vast amounts of infrastructure are prone to failure in earthquakes.

Although much of the world is developing earthquake resistant infrastructures (Dolce et al., 2021), a number of countries lag behind in earthquake preparedness and assessments. The Balkans is one of the most earthquake-vulnerable regions in the world. In 1977, an earthquake in the Balkan region collapsed or heavily damaged 32,900 buildings, left 35,000 homeless families (Georgescu & Pomonis, 2008), and caused two billion USD in damages (Craifaleanu et al., 2016). A shortage of experts and financial backing in the Balkan region does not allow for sufficient building assessment, causing an inability to repair buildings after earthquakes (Santoro et al., 2020). Out of the several countries that the 1977 earthquake affected, it devastated one country in particular: Romania.

Since 1471, a 7.0 magnitude earthquake has shaken Romania nearly every 80 years (Radulescu, 2008), including a magnitude 7.7 earthquake in 1940 and a 7.4 earthquake in 1977. With almost 50 years since the last 7.0 magnitude earthquake in Romania, experts predict that the next major earthquake will occur within the next half-century (Pavel & Vacareanu, 2017). Despite the seismic threat, the Romanian government has failed to retrofit Romanian buildings leaving them vulnerable to collapse (Armaş, 2006; Pavel et al., 2017).

Prior to the 1940 earthquake, the Romanian government had not created building codes to prevent buildings from collapsing. During the Communist Regime, Romania adopted building codes from Russia, unintentionally endangering thousands of lives. The government inadvertently encouraged unsafe structures, as engineers did not design these codes for Romania's earthquakes, which occur much deeper in the ground (Benevedes et al., 2021). After the 1977 earthquake, the Communist Regime resorted to cosmetic fixes rather than investing the time and money needed to fix structural deficiencies. The Romanian government created new building codes after the 1977 earthquake and again in 1990 to reduce earthquake vulnerability. However, these codes only apply to new construction projects which leaves thousands of older buildings vulnerable to collapse. As of 2017, 40,000 of 132,000 (30%) of Bucharest's residential buildings that endured the 1940 earthquake still house people today, meaning those people are at high risk. The Romanian government and building owners allow thousands of people to live in buildings without sufficiently addressing structural deficiencies following damages from the earthquakes (Armaş et al., 2017).

Although post-earthquake damages plague buildings in Romania, assessors have yet to properly inspect most structures. Since these assessments can lead to a decrease in property value and temporary homelessness for residents, both building owners and residents are reluctant to assess their buildings (Gillet, 2014; Suditu et al., 2020). Current assessment methods call for detailed inspections of the interior of a building, as well as soil sample tests, which are expensive and time consuming, as they require trained expertise (Suditu et al., 2020). Experts are developing rapid visual seismic risk assessments (RVSRAs) that enable minimally trained assessors to inspect from outside the building, allowing for inspectors to complete assessments much faster (Applied Technology Council, 2016). However, assessors have not yet used RVSRAs in Romania.

Since a major earthquake hasn't occurred in Romania since 1990, the government and most local organizations have not taken significant action to improve seismic risk in Bucharest. Consequently, the city remains underprepared for earthquakes. However, a few nongovernmental organizations (NGOs) are helping Bucharest prepare. Re:Rise is an NGO that focuses on reducing seismic risk in Romania and is currently developing methods for RVSRAs. In addition, geo-mapping techniques can highlight similar building types across Bucharest and complement the RVSRA process by identifying areas of the city where the assessors should focus their assessments.

The goal of this project is to assist Re:Rise in preparing to conduct seismic risk assessments and inform the public on the seismic risk of historically vulnerable buildings in Bucharest, Romania.

We address this goal through three main objectives:

1. Evaluate seismic risk assessment methods
2. Identify similar buildings across Bucharest
3. Educate the public on the prevalence of historically vulnerable buildings in Bucharest

The team used expert interviews to gain insight on how to adapt RVSRAs to Romania. Members of Geospatial, another Romanian NGO, and Re:Rise trained the team in conducting geo-mapping. After the training, the team utilized geographic information systems (GIS) to create a geo-map of historically vulnerable building types across Bucharest. After creating the map, the team performed both quantitative and qualitative analysis to gather results. The team input the results into Re:Rise’s map of seismic vulnerabilities and delivered a set of recommendations to improve the RVSRA training and assessment processes. Finally, the team drafted a newspaper article aiming to raise awareness regarding seismic risk issues in Bucharest and motivate residents to prepare for the next major earthquake. The group hopes that our efforts inspire action that reduces the seismic vulnerability of Bucharest, Romania.

2 Background

This chapter begins with an overview of the impacts and history of earthquakes in Romania. The next section examines the impact the Romanian government has had on the seismic vulnerability of buildings. This chapter closes by discussing seismic risk assessment (SRA) methods and the advantages of geo-mapping. Appendix A includes a table of abbreviations that appear frequently throughout this report.

2.1 Seismic History of Romania

Numerous historical accounts record the long history of earthquakes in Romania, such as the 1802 earthquake known as "The Big Earthquake of God's Friday," which reached a magnitude of 7.7 and devastated buildings, like the Tower of Colţea (see Figure 2.1a and 2.1b) (Radulescu, 2008).

With smaller population centers and the only tall structures being churches, historical earthquakes took few Romanian lives. This changed in the twentieth century, when two major earthquakes devastated the newly industrialized and densely packed city. The first occurred on November 10th, 1940, producing a 7.7 magnitude earthquake, which caused an estimated 1,000 deaths and an additional 11,000 injuries (Lungu et al., 2008; Pavel & Vacareanu, 2017). A second earthquake of 7.4 in magnitude struck on March 4th, 1977, killing 1,578 people and injuring 11,221 people, most of whom resided in Bucharest (Georgescu & Pomonis, 2012). Additionally, the World Bank valued the economic damage at $2.05 billion USD (Lungu et al., 2008). The earthquake's devastation sparked a new era of academic research and public effort towards earthquake preparedness (Mândrescu et al., 2007).

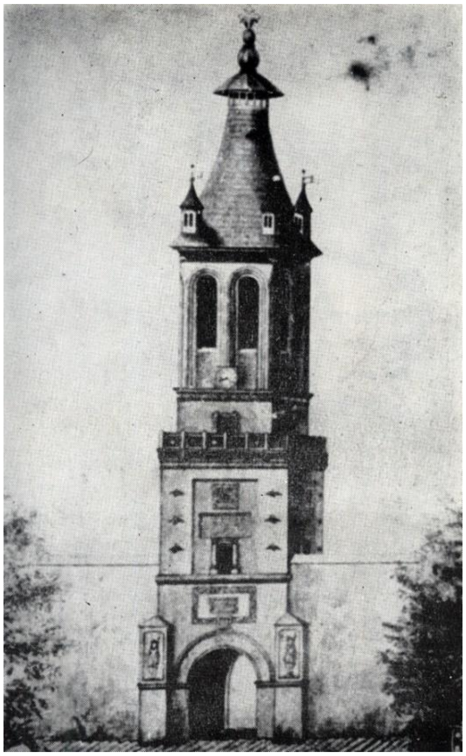

Figure 2.1a: – Ready To Be Toppled –
The Coltea Tower prior to the Vrancea Earthquake of 1802.

Figure 2.1b: – The Mighty Have Fallen –
Tower of Colţea after 1802 earthquake.

Over 90% of Romania's earthquakes occur in the Vrancea region (Lungu et al., 2008; Poiata & Miyake, 2017). Located 135 km northeast of Bucharest, the region produces earthquakes ranging from 5.0 to 8.0 in magnitude (Radulescu, 2008). Unlike seismic zones forming from tectonic plates, causes of Vrancea's seismic activity are still unknown. Current seismology measurements place the average epicenter within the Vrancea region at 60 – 200 km below the surface (Poiata & Miyake, 2017). The intermediate-depth of the seismic source enables the earthquakes to travel large distances and damage taller buildings (Mândrescu et al., 2007). Earthquakes of different depths will impact the Earth's surface differently. To determine the level of vulnerability within Romania, seismologists developed predictive models to illustrate seismic activity in Bucharest and updated seismic codes. One such study produced a map of Bucharest depicting the expected damage of an earthquake equivalent to that experienced in

1977 (see Figure 2.2). The Medvedev–Sponheuer–Karnik Scale (MSK) gives the scale of the damage (Mândrescu et al., 2007). The darker the color and the higher the Roman numeral, the more severe the damage. VII corresponds to older buildings collapsing and VIII corresponds to large cracks and fissures opening on the surface. Appendix B: Figure B.1: Medvedev–Sponheue provides a description of the MSK scale.

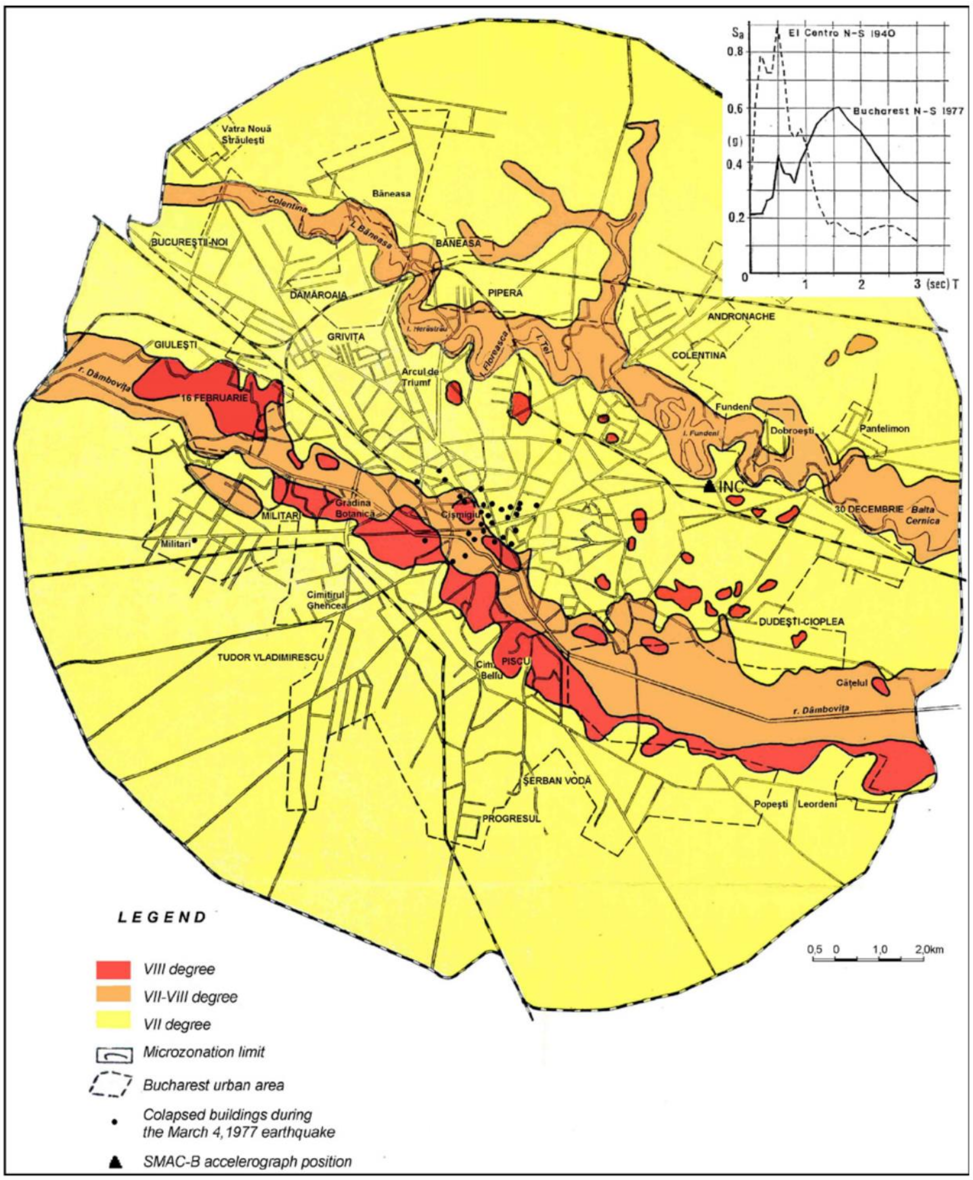

Figure 2.2: Seismic microzonation map of Bucharest (STAS 8879/6-73).

Furthermore, computer simulations have predicted inadequacies in current seismic assessment codes. In simulations, many of the buildings that pass current building codes collapse. If the simulations are accurate, the seismic codes mislead hundreds of thousands of Romanians to believe they are safe from the next major earthquake when they are not (Pavel & Vacareanu, 2017). With almost 50 years since the last magnitude 7.0 earthquake in Romania, experts expect the next major earthquake to occur within the next 50 years (Pavel & Vacareanu, 2017).

2.2 Romanian Government's Impact on Earthquake Vulnerability

In addition to the dangers the Vrancea seismic zone poses to the Romanian public, the government has hindered Romania's earthquake preparedness. During the communist regime, insufficient building codes, poor urban planning, and a lack of repairs to damaged buildings left Bucharest highly vulnerable to earthquakes (Armaş, 2006; Benevedes et al., 2021; Mungiu-Pippidi, 2010). Although building codes improved afterwards, builders seldom followed them and corruption plagued the construction industry (Georgescu & Pomonis, 2012).

2.2.1 History of Communism in Romania

In 1948, a communist government took over Romania. The government implemented Stalinist principles of rigid central planning and an emphasis on heavy industry (Communist Romania, n.d.). This led to an increase in large state-owned buildings, such as factories, apartment complexes and government buildings. In 1965, when Nicolae Ceausescu rose to power as elected president of Romania, he intensified the Communist Party's power, running the country as a dictator with a cult-like following (Communist Romania, n.d.).

Pushing for urbanization, Ceausescu devised a plan to reconstruct Romania, which included demolishing and replacing 13,000 Romanian villages with large apartment complexes

(Mungiu-Pippidi, 2010) to spread the benefits of urbanism and create uniformity across Romania (Danta, 1993). Out of the 13,000 villages, the government demolished 10,000 of them immediately and planned to destroy the other 3,000 in the coming years, replacing them with apartments on the outskirts of Bucharest in 1975 (see Figure 2.3) (Mungiu-Pippidi, 2010).

Figure 2.3: Apartment buildings in systemized villages (Danta, 1993).

The government rushed apartment construction to house the newly homeless villagers. The increased housing demand led to Ceausescu constructing twice as many apartments as the government originally planned (Mungiu-Pippidi, 2010). To accommodate this change, construction moved at a “mad pace” causing infrastructure flaws (Mungiu-Pippidi, 2010). Ceausescu planned to heat the apartments using firewood stoves, which required apartments to be densely packed to conserve heat (Mungiu-Pippidi, 2010). The government could not afford central heating or modern sewage systems, which resulted in residents using the same water and sewage systems from villages in much more populous apartments (Mungiu-Pippidi, 2010). With such cheaply built mass housing, experts conclude that Ceausescu did not construct the apartments while considering seismic risk (Green, 2005). This increased the country's earthquake vulnerability, since high-density buildings may damage each other upon collapse (Armaş, 2006), which occurred in the 1977 earthquake (Barnaure, 2021).

Even though buildings remained damaged or destroyed from the 1940 earthquake, Ceausescu had no plan to improve or reconstruct Bucharest's historical center (Armaş, 2006). The historical structures remain as a symbol of Ceausescu's failure to rebuild the city.

2.2.2 Corruption in Post-Communist Romania

After several years of changes and instability, Romania started preparing to join Europe, eventually joining the European Union (EU) in 2007. Following its entrance into the EU, Romania rolled back their anticorruption commitments that allowed EU entry in the first place, such as exempting the president, senators, and lawyers from corruption crimes like abuse of office and bribery (Toma, 2015). Additionally, the government reduced the power of prosecutors like the National Anticorruption Directorate – an independent agency dedicated to prevent, investigate and prosecute corruption related offenses – even threatening to shut it down (Toma, 2015).

Since these laws protected politicians from corruption crimes, authorities wielded their power to corrupt government construction projects. Government leaders employed a non-competitive procedure known as "single bidding" where only one company bids for a contract. Researchers found that 32% of the government-awarded construction contracts between 2007 – 2013 involved single-bidding or the existence of political connections, with the construction industry pocketing €200 million (Doroftei, 2016). Additionally, the analysis notes the National

Anticorruption Directorate charged 54% of Romanian county council presidents with corruption from 2007 – 2013, including the mayor of Bucharest, Sorin Oprescu, who went to prison for taking bribes in exchange for public work contracts (Benevedes et al., 2021). Corruption within the construction industry often leads to defective or dangerous infrastructure (Sohail & Cavill, 2019). For instance, a government member may allow contractors to illegally build extra stories or violate building codes in exchange for a payoff (Green, 2005). Between 2007 and 2013, the government awarded 1,086 contracts to companies with political ties (Doroftei, 2016), meaning it is possible the construction companies did not abide by the building codes during construction, increasing the seismic vulnerability of these structures (Benevedes et al., 2021).

2.2.3 Romanian Government Building Code Failures

The Romanian government uses building codes to regulate building quality and earthquake vulnerability. Over the past 100 years, the government has made building codes more rigorous. Experts classify the codes into four distinct periods: pre-code, low-code, moderate-code, and high-code (see Table 2.1).

Table 2.1: Classification of codes for earthquake resistant design of buildings in Romania, (Vacareanu et al., 2004).

Period		Code for earthquake resistance of structures
Pre-code, before 1963	Prior to the 1940 earthquake and Prior to the 1963 code	P.I. - 1941 I - 1945
Low-code, 1963-1977	Inspired by the Russian seismic practice	P 13 - 63 P 13 - 70
Moderate-code, 1977–1990	After the great 1977 earthquake	P 100 - 78 P 100 - 81
Moderate-code to High-code, after 1990	After the 1986 and the 1990 earthquakes	P 100 - 90 P 100 - 92

During the pre-code period, authorities rarely enforced the very few policies that regulated structural quality, leading to the construction of vulnerable buildings (Armaş et al., 2017; Vacareanu et al., 2004). Figure 2.4 shows that Romanians constructed thousands of buildings in Bucharest before 1945 that still stand today.

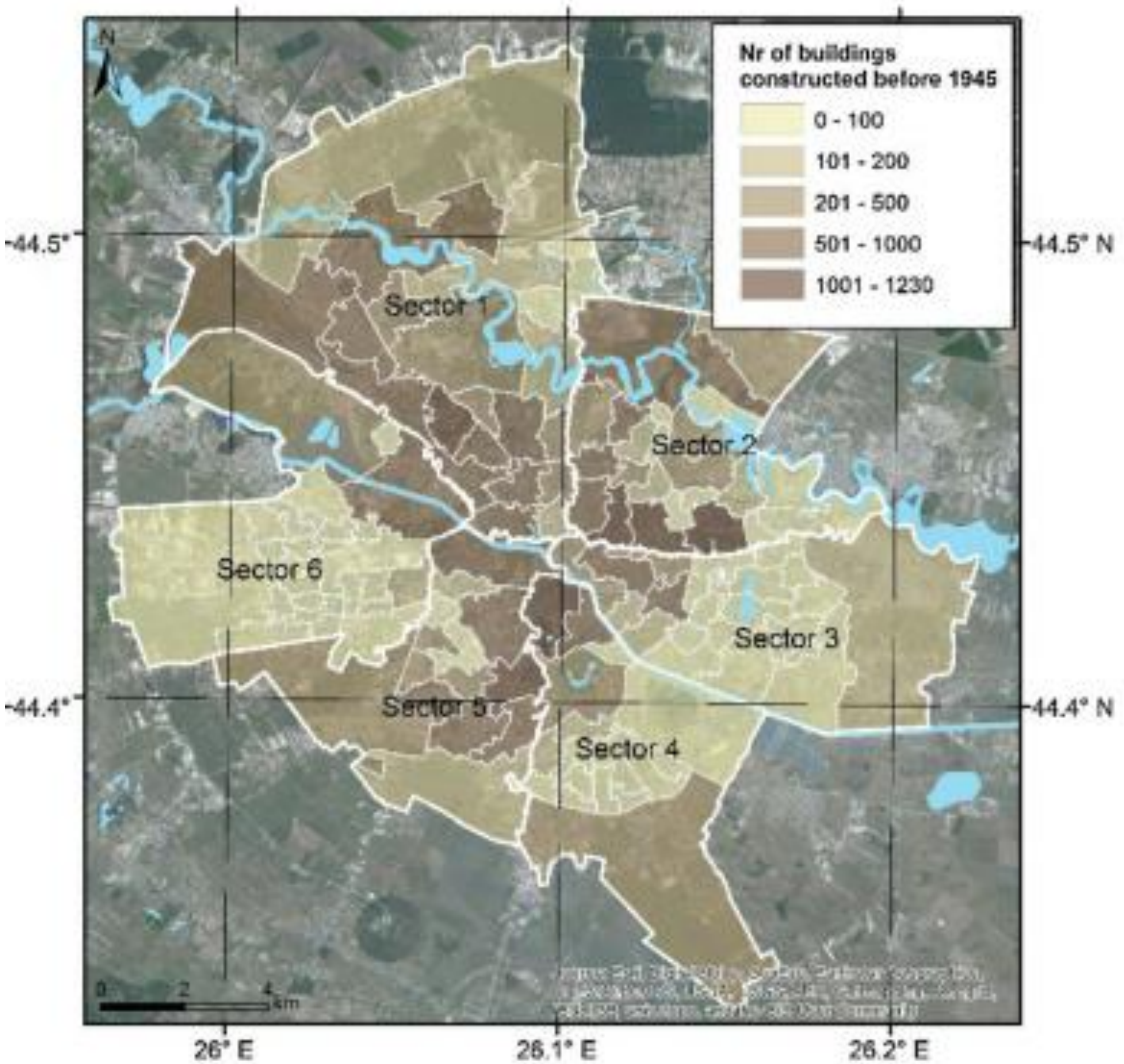

Figure 2.4: The number of buildings in Bucharest erected before 1945 (Armaş et al., 2017).

These buildings remain highly vulnerable to collapse, since they exhibit none of the design regulations that reduce seismic risk today. This proved dangerous in the 1940 earthquake, where a twelve-story structure called the Carlton Building collapsed (see Figure 2.5), killing 140 of 226 occupants and injuring 86 (Georgescu & Pomonis, 2012). Furthermore, in the 1977 earthquake, 19 high-rise apartment buildings from the pre-code era collapsed, contributing to a major portion of the casualties in Bucharest (Georgescu & Pomonis, 2012). This made it clear to the Romanian government that they needed to implement better codes to reduce seismic damage.

Figure 2.5: Carlton Block before collapse (left) and immediately after collapse (Georgescu & Pomonis, 2012).

The Romanian government first implemented low-code regulations, modeled after Russia’s 1960s building code system. Low-code introduced regulations for concrete and steel quality, as well as standards for structural beam sizes (Vacareanu et al., 2004). Additionally, the Romanian government adopted Russia’s strategy of mass urbanization. This style of urban planning did not consider the uniqueness of Romania’s earthquakes, which occur much deeper below the earth's surface than Russian earthquakes (Benevedes et al., 2021). This causes qualitatively different outcomes. For instance, Romanian earthquakes tend to damage taller buildings more, while Russian earthquakes tend to damage smaller buildings (Armaş, 2006). This explains why high-rise buildings like the Carlton building are prone to collapse. Therefore, using a system modeled after Russia proved inadequate in regulating the structural stability of tall buildings in Romania.

After the damage from the 1977 earthquake revealed the inadequacies of low-code, the Romanian government tightened their regulations to moderate-code, which required reinforcement tests in structural columns. Following two smaller earthquakes in 1986 and 1990, the government further tightened the standard of these tests with the establishment of high-code in 1990. Both moderate-code and high-code demanded builders to use better quality and stronger concrete and steel. Although these newer codes have proven to significantly reduce the probability of a building's collapse, the Romanian government does not require owners to strengthen existing buildings from the pre-code and low-code period (Georgescu & Pomonis, 2012). In short, the Romanian government allows the 40,000 pre-code buildings, or 30 percent of all residential structures, to bypass current regulations, putting their inhabitants at risk (Armaş et al., 2017).

2.2.4 Post-earthquake Structural Vulnerabilities

Although the government strengthened building codes after the earthquake in 1977, the disaster left critical structural damage. During the weeks following the earthquake, national engineers began assessing buildings with the most severe damage and recommended a more thorough assessment of all affected buildings. However, President Ceausescu ignored these recommendations and ordered for immediate repair of 14,000 damaged buildings in seven weeks

(Simpson et al., 2020). Shortly after, seeing little progress and dwindling funds, Ceausescu ordered the stop of all repairs (Georgescu & Pomonis, 2011; Simpson et al., 2020), resulting in uncertainty of building vulnerability statuses. In their rush, builders strengthened some buildings, patched others cosmetically and did nothing to most (Barnaure, 2021; Simpson et al., 2020). Experts have described the attempted repairs and the uncertainty surrounding them as a "big mistake" and predict that half of Bucharest hospitals will collapse in the next earthquake as a result (Armaş, 2006; Lungu et al., 2000).

In a seismic vulnerability case study, Technical University of Civil Engineering Faculty member Mircea Barnaure analyzed an 11-story building built in 1962 (Barnaure, 2021). The building in question suffered major damages from the 1977 earthquake and smaller earthquakes in 1986 and 1990. An investigation report from 1993 mentioned cracks in the building's walls, beams, and lintels. Although another investigation report from 2020 mentioned none of these damages, the reported lack of damages resulted from local repairs like the plastering of the shear walls with epoxy resin and fiberglass fabric, hiding the structural damages of the building (Barnaure, 2021). However, a seismic vulnerability analysis concluded that this building has only 20% of the required earthquake capacity loads, needing major strengthening to meet the 65% building code standard. Such findings are representative of similar buildings from the same time period. One source argues that 85% of the buildings with more than five stories in Bucharest still require strengthening from damage caused by the earthquake (Pavel et al., 2021). This amounts to 2,500 highly vulnerable buildings residential buildings that the government or building owners have not repaired (Pavel et al., 2021).

2.2.5 Romanian Socialist Housing

From 1950 until the fall of communism in 1989, the Romanian government built primarily large multi-family apartment complexes. The government ordered the fabrication of these cheap socialist apartments near local factories to bring industry and residential centers close together. Engineers fabricated blocks of identically designed buildings to minimize their cost and complexity. Experts estimate socialist housing utilizes only 10 – 15 distinct fundamental building designs (M. Sumbasacu, personal communication, February 17, 2022). Builders erected uniformly designed buildings so identically that they share structural characteristics and vulnerabilities. Combined with their cheap construction, the government urbanized Bucharest with the construction of a significant number of socialist apartments before the 1977 earthquake during the low-code period (Pavel & Vacareanu, 2020). The immense number of building collapses in the 1977 earthquake demonstrated how seismic design in socialist housing inadequately coped with Romania's earthquakes. The socialist building type "OD" refers to 161 buildings across Bucharest, shown in Figure 2.6 and Figure 2.7. OD buildings – standing for "double orientation" in Romanian – retain sunlight during both the morning and the afternoon.

Figure 2.6: Typical OD Building, (Bostenaru & Sandu, 2002).

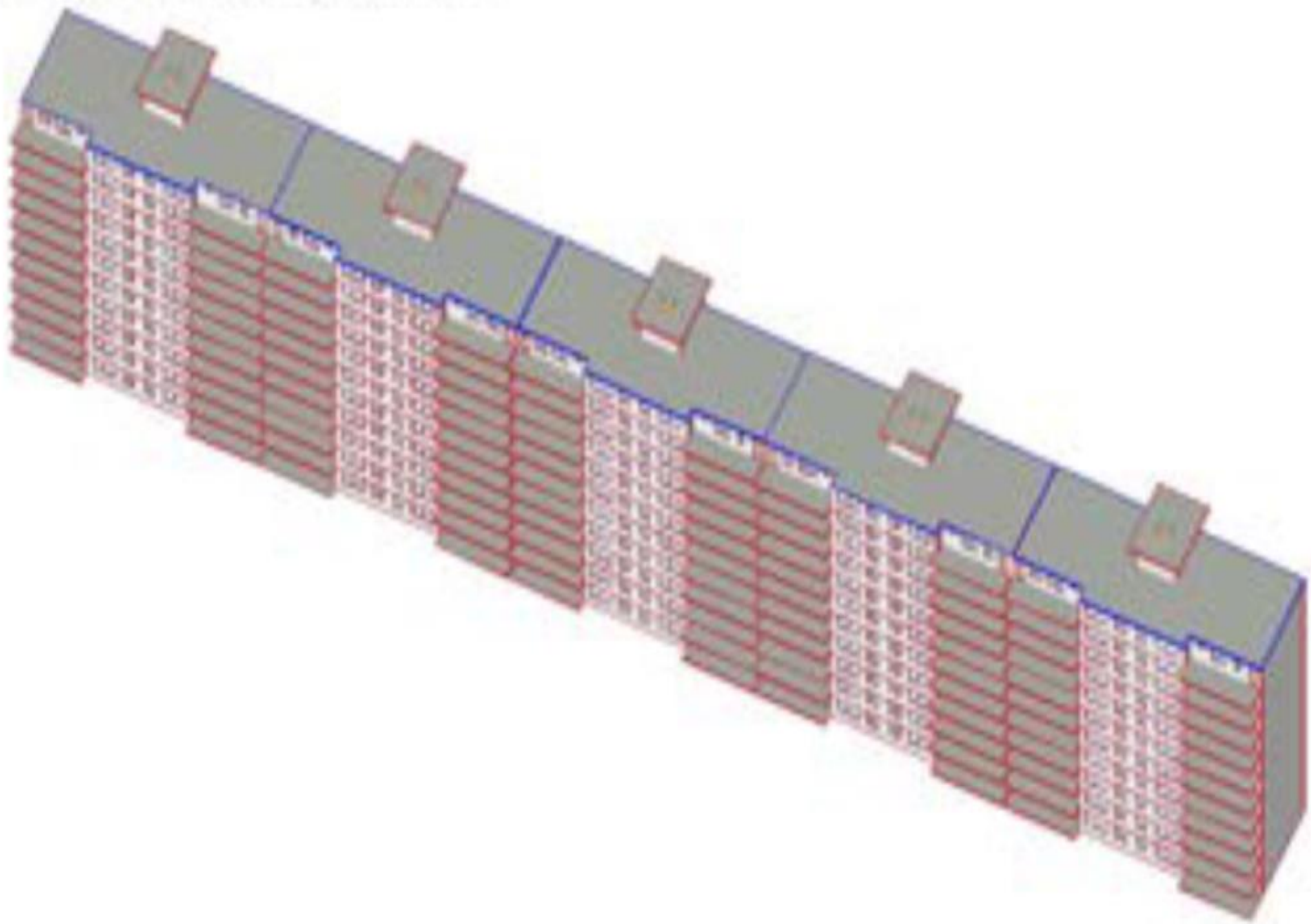

Figure 2.7: Typical Row of OD Buildings, (Bostenaru & Sandu, 2002).

The OD building type, commonly built between 1960 to 1970, proved to be severely vulnerable to earthquakes when the 1977 earthquake extensively damaged or destroyed 27 of them (see Figure 2.8) (Pavel & Vacareanu, 2020).

Figure 2.8: Collapse of building OD16 during the 1977 earthquake, (Bostenaru & Sandu, 2002).

After the 1977 earthquake, out of the 161 OD buildings in Bucharest, assessors only found seven lightly damaged and none with no damages. Although engineers repaired many of the damaged OD buildings, they failed to reinforce the structures, leaving the buildings vulnerable for future earthquakes (Bostenaru & Sandu, 2002). Consequently, hundreds of thousands of Bucharest residents continue to live in thousands of vulnerable socialist housing structures, such as OD buildings.

2.3 Romanian Earthquake Prevention and Preparation

The Romanian government developed the Romanian Code for Seismic Risk Assessment of Existing Buildings P100-3/2008 to determine the likelihood of a building to collapse during the next earthquake (Suditu et al., 2020). The Ministry of Public Works, Development and Administration (MPWDA) is responsible for building regulation and disaster risk management in

Bucharest, including the enforcement of P100-3/2008. MPWDA-certified experts have identified about 2,400 buildings at risk of collapse (Suditu et al., 2020), which the Municipal Administration for the Consolidation of Buildings with Seismic Risk then classified into four sub-groups shown in Table 2.2. Like most Romanian buildings, many of these buildings have a mixed ownership regime, consisting of private and state owners (Ivanov, 2021).

Table 2.2: Classification of buildings in Bucharest on their risk to collapse due to a seismic event (Ivanov, 2021).

Municipal Administration for the Consolidation of Buildings with Seismic Risk Classifications	
Class	Definition of Class
RsI	High risk to collapse
RsII	Likely to have major structural damage
RsIII	Likely to have major structural damage but do not impact structural safety
RsIV	Meet modern seismic risk standards

The Romanian government has marked buildings of classification RsI; buildings with the highest risk of collapse, with a red dot on the side of the building. As of 2021, 358 buildings in Bucharest have red dots (Ivanov, 2021), including 175 in a special category known as “public hazard”, which have four or more stories and commercial spaces on the ground floor (Ilie, 2017). From 2016-2020, owners and the Romanian government began the seismic reinforcement process of 12 of the 358 buildings. As of March, 2021, owners and the Romanian government made plans for reinforcements of 11 more buildings (Ivanov, 2021). These 23 buildings are still not complete and leave 335 assessed buildings that owners or the Romanian government need to reinforce, plus an additional 2,200 vulnerable buildings that experts have not yet assessed

(Sumbasacu, 2022). At this rate engineers will not be able to repair all buildings before the next earthquake, leaving tens of thousands of lives in danger (*Re:Rise, Overview*, 2022).

The MPWDA created a twenty-year plan in 1996 to help track and reduce buildings' seismic risk for the future. Building owners, administrators, individuals, and owners' associations were responsible for hiring experts to inspect their buildings and update a technical charter, which included tracking the mechanical strength and stability of existing structures with insufficient levels of protection against earthquakes and classifying them in the proper seismic risk class. In 2018, two years after the twenty-year deadline, most private and public actors in this plan failed to document and complete these actions, increasing Bucharest's vulnerability (Suditu et al., 2020).

2.3.1 Obstacles to Current Building Assessment

The Romanian government refrains from doing assessments as they can be costly, intrusive, and lengthy. SRAs often involve inspectors to have unrestricted access to a structure over multiple days and high-tech equipment to process laboratory samples. Even with thousands of vulnerable buildings, building owners only requested seven assessments between 2000 and 2014 (Gillet, 2014). One reason for this is the potential that the assessment will yield a red dot, which decreases a building's property value. Most apartments in Bucharest are privately owned, meaning the owners do not wish for their individual apartment prices to drop (Ana, 2018). The current assessment, P100-3/2008, takes two weeks (M. Sumbasacu, personal communication, February 17, 2022) and needs trained professionals to enter the building to record a detailed description of the design of the building (Suditu et al., 2020).

Additionally, Edmond Niculușcă, the current city director, said "the lack of transparency, coherence, and predictability, has led to many of the repair projects being blocked" by the local government (Ivanov, 2021). The Romanian government supplies interest-free loans to residents wishing to conduct building repairs, but only if every resident within the building agrees to conduct repairs (Gillet, 2014). Public distrust of the government following the rise and fall of communism reduces the chance that residents cooperate with government programs. Determining the owner of a building is also difficult “as numerous properties were confiscated by the communist regime and the process of returning these properties to their previous owners is, a quarter of a century after the fall of communism, not yet complete” (Armaş et al., 2017). Additionally, many residents remain resistant to assessments and major repairs as finding alternate living can be costly and scarce, and the Romanian government does not have the available housing to help (Ivanov, 2021).

2.4 Analysis of Various Rapid Building Assessment Methods.

Systemic issues have caused barriers in conducting SRAs under the current method, as they require unreasonable amounts of resources, such as time, money, and trained professionals. As a result, researchers and institutions have created alternative methods to combat these setbacks (Lupășteanu et al., 2021; Pardalopoulos et al., 2012). Each method has advantages and drawbacks, trading comprehensiveness for accessibility and timeliness.

2.4.1 Evaluating Time for Various Assessment Methods

With a rapid assessment method, engineers can speed up the SRA process. Assessors are looking to assess as many buildings as possible before the next earthquake and need a new tool to expedite assessments. In an article published by the Journal of Building Engineering (JBE), engineers used a more streamlined method to document and inspected 90 buildings in 63 days, averaging 1.4 buildings a day (Lupășteanu et al., 2021). JBE’s method reduced average time from two weeks to 1.4 days by eliminating much of the process, such as sending soil to a lab

(Lupășteanu et al., 2021; M. Sumbasacu, personal communication, February 17, 2022). In the Bulletin of Earthquake Engineering (BEE), three Greek engineers published a different method, simplifying the inspection method, by focusing on pillars and walls, while ignoring additional major subsystems like roofing and plumbing (Lupășteanu et al., 2021; Pardalopoulos et al., 2012). Alternatively, the United States' Federal Emergency Management Administration (FEMA) proposes a different method, called a rapid visual seismic risk assessment (RVSRA), that simplifies SRAs even further. FEMA's RVSRA takes between 15 and 75 minutes per building with assessors exclusively using visual methods and focusing only on structural deficiencies visible from a sidewalk (Applied Technology Council, 2016).

2.4.2 Additional Advantages of Rapid Visual Seismic Risk Assessments

RVSRAs further simplify the assessment process to allow quicker assessments. Although rapid SRAs, such as the JBE and BEE methods, reduce the time required for assessors to analyze structures (Lupășteanu et al., 2021; Pardalopoulos et al., 2012), RVSRAs have the potential to tackle many of the underlying systemic issues plaguing seismic assessments in Bucharest (M. Sumbasacu, personal communication, February 17, 2022). For example, residents may block assessors from using the JBE and BEE methods, as they require assessors to access the interior of structures, while RVSRAs methods bypass this problem completely. Additionally, the Romanian government or building owner must pay civil engineers for traditional SRAs (Lupășteanu et al., 2021; Pardalopoulos et al., 2012), while volunteers with no experience can conduct RVSRAs (Applied Technology Council, 2016). Assessors conduct RVSRAs to focus engineers on conducting further, more comprehensive, SRA methods only on high-risk buildings. RVSRAs provide time and cost advantages, identifying vulnerable building types and locating those buildings enable assessors to investigate buildings even more efficiently.

2.5 Geo-mapping and Geographic Information Systems

Geo-mapping allows engineers to transform raw data into a comprehensive building footprint map, by identifying similar building types with high-resolution satellite imagery. Although organizations such as QuickBird, IKONOS, WorldView, and GeoEye supply these images, they are expensive, ranging from $10-17 per kilometer squared of imagery (Hazarika et al., n.d.). Using the $10 price, the cost of receiving imagery for Bucharest would be $1500. However, software such as Google Maps, Microsoft's Bing Maps, and Open Street Map provide free high-resolution publicly available images. In addition to photographic data, Google Earth supplies high resolution topography data, light detecting technology and ranging (LIDAR) data linked with a visual overlay, enabling depth perception images. Analysis of high-resolution topography can extract building characteristics such as height, exterior shape, and other key attributes.

Geographic Information System (GIS) is a form of geo-mapping that connects data to a map by assigning descriptive information to a specific location. Users can utilize GIS to understand geographic content and make interactive and easily interpreted maps. QGIS, an example of a GIS, is a free, open-source software that enables users to assign attributes to buildings using free, high-resolution images (*QGIS*, 2022).

Researchers from the Natural Disaster Risk Reduction Program conducted a building attribute characterization for Grenada, Spain to obtain building footprint maps and assess the city for seismic vulnerability and risk analysis. The building attribute characterization uses two attributes, 'use type' and 'occupancy type' of buildings, which experts used to construct a map (Hazarika et al., n.d.). The attributes are further shown in Table 2.3.

Table 2.3: Key for the characterization of building footprints in Grenada, Spain

Use type	Occupancy type	Use type	Occupancy type
Resort	Hotel, beach resort, cottage, holiday apartments, villa	Religious	Church, Mosque
Commercial	Supermarket, market, shop, restaurant, mixed commercial area, commercial, car rental, fuel station, Fish market, Mechanic, material lab	Airport	Airport
Combined commercial and residential	Combined commercial and residential	Recreational	Sports, cricket Stadium, movie palace, Yacht club
Educational	School, college, university	Port	Port, marina, port authority
Health	Hospital, elderly nursing home, medical center, ambulance service	Residential	Dwelling
Institutional	Government offices, Post office, mix office space, fire stations, police station	Cultural Heritage	Fort
Community center	Community center	Graveyard	Graveyard
Industrial	Industrial, spice estate, power station, Agro industries,	Transport	Bus terminal

The researchers mapped Grenada manually by using Google Earth and high-resolution satellite imagery of the entire island to locate buildings. Since the researchers struggled to distinguish between residential and non-residential buildings, they first isolated larger buildings as they are most likely hotels, industries, schools, offices, business centers, supermarkets, and other large buildings (Bhadauria et al., 2013). Researchers then classified other obvious buildings like castles and churches and identified all remaining buildings as residential. Once researchers created the building footprint map, they then assigned attributes, like use type and occupancy type, to each building. The building footprint map can help predict where the most populous places are, which can assist first responders in creating a better disaster response (van Westen & Frigerico, 2011). The researchers then compiled an interactive map from the building footprint map and attribute data, as seen in Figure 2.9. The map shows buildings in red and when clicked on the building displays its attribute information such as type, occupancy, and size. Recently, experts are utilizing geo-mapping to reduce seismic risk.

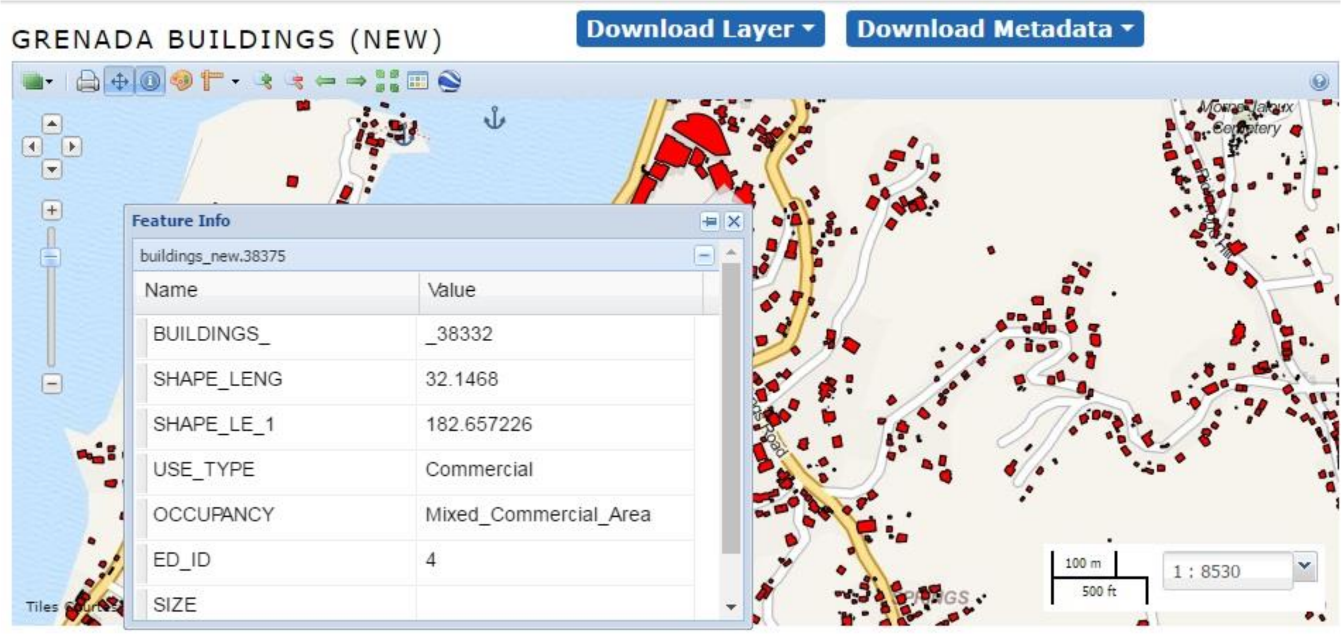

Figure 2.9: Building footprint layer for Grenada with added attributes.

2.6 The Association for Seismic Risk Reduction (Re:Rise)

Romanian NGOs are taking action to reduce seismic risk in Romania. One of these NGOs, Re:Rise, aims to "act as a bridge between people at risk of seismic risk and … the technological, financial, administrative and human resources available" (Sumbasacu, 2022). Re:Rise's projects include a registry of construction vehicles and aerial photography methods to assist emergency services immediately following an earthquake. Additionally, Re:Rise maintains a publicly available seismic risk map containing seismic information for individual buildings in Bucharest (see Figure 2.10).

Figure 2.10: Re:Rise Map of Risk, accessible at dupacutremur.ro

Although Re:Rise utilizes a seismic risk map, much of the necessary data is missing (M. Sumbasacu, personal communication, February 17, 2022). Orange highlights and red dots represent surveyed buildings. Purple lines indicate predicted road blockages. Matei Sumbasacu, founder of Re:Rise, notes that the map intends to help both engineers and first responders. Engineers can use the map to determine which buildings should receive further inspection, prioritizing the most damaged structures. First responders can use the map to predict where rubble will block roads in the event of building collapses from an earthquake (M. Sumbasacu, personal communication, February 17, 2022). This will save lives as first responders will not only know from the map which places have the highest rates of building damage, but the map can also predict where debris will block roads which informs which routes are best to avoid.

Romania has faced a myriad of historical and social challenges that have inhibited its process to identify building vulnerabilities and begin repairing the damaged buildings.

Ceausescu’s regime constructed mass quantities of vulnerable buildings, implemented poor building codes, and failed to repair buildings after the earthquakes. Since current assessment techniques cause a large financial burden and building ownership remains unclear in post-communist Romania, building owners refuse to have their buildings assessed. A large earthquake in Romania has not occurred since 1990, meaning that many Romanians have not experienced an earthquake in their lifetime. However, when the next big one strikes, everyone in Romania will experience the effects of an earthquake. Considering the severity of damage the next earthquake can cause, it is disapointing that neither residents nor the Romanian Governmnent are willing to take immediate actions to prepare Romania for the next big one. These actions include geo-mapping, which can locate the vulnerable buildings and would assist Re:Rise in conducting a RVSRA program efficiently. RVSRAs aid Re:Rise in populating a seismic risk map, which will start to reduce risk in Romania when the next earthquake occurs. In the next chapter, the team outlines the project methodology in pursuing their goal.

3 Methodology

The goal of this project is to assist Re:Rise in preparing to conduct seismic risk assessments and inform the public on the seismic risk of historically vulnerable buildings in Bucharest, Romania. The team pursued this goal through three objectives:

- Evaluate seismic risk assessment methods.
- Identify similarities between buildings across Bucharest.
- Educate the public on the prevalence of historically vulnerable buildings in Romania.

The team completed these objectives from March 14th to May 3rd, 2022. Figure 3.1 outlines the objectives and matches the project's methods to their corresponding objectives. This chapter explains the methods the team used to address each objective.

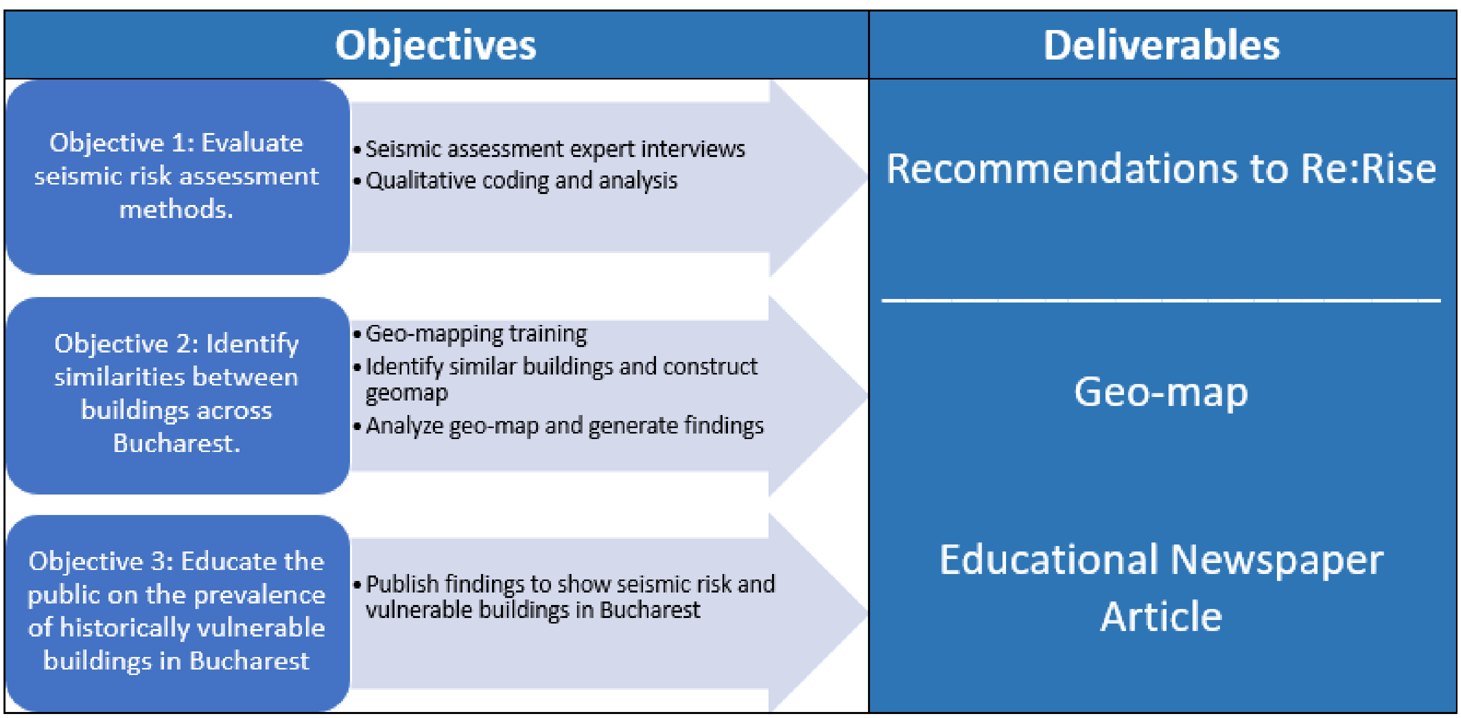

Figure 3.1: Methodology Overview for Project

3.1 Evaluate Seismic Risk Assessment Methods

This project anticipated potential strengths and weaknesses in conducting seismic risk assessments (SRAs), focusing on rapid visual seismic risk assessments (RVSRAs). Expert interviews gave insight into overcoming expected challenges in executing RVSRAs in Romania. The team anticipated using this insight to generate recommendations for Re:Rise, in assisting them in executing their RVSRA pilot program. Since assessors have only applied RVSRAs outside Romania, Romanian seismic experts have not discovered or overcome challenges specific to the current state of the country's buildings. For instance, FEMA's RVSRA method focuses on single unit housing structures, while Bucharest contains many large apartment complexes. In short, Re:Rise does not have to reinvent the RVSRA wheel; the team hopes Re:Rise can better conduct RVSRAs in Bucharest by learning from seismic experts who have conducted RVSRAs in other countries.

The team conducted interviews with five leading experts on SRAs, including civil engineers and seismology researchers (see Table 3.1). To identify potential respondents, the team utilized Re:Rise industry connections within Romania, FEMA's contacts website and globally recognized seismic researchers. Additionally, the team used authorship information from peer-reviewed articles and emails from FEMA's earthquake preparedness page to identify additional interview subjects.

Table 3.1: Respondent information interviews

Respondent	Affiliation	Area of Expertise
Radu Lupasteanu	State Inspectorate of Construction (Romania)	Chief County Inspector
Vlad Lupasteanu	Technical University of Iasi	Department of Concrete Structures, Building Materials, Technology and Management
Forrest Lanning	FEMA	Structural Engineering and Earthquake Disaster Recovery
Stavroula Pantazopoulou	York University	Structural Mechanics and Earthquake Engineering
Mike Mahoney	FEMA	Seismic Problem-Focused Studies

This team conducted interviews on Zoom from March 14th to March 28th, 2022. Each interview had a primary and secondary interviewer. The primary interviewer asked most of the questions and directed the conversation, while the secondary interviewer chimed in if the primary interviewer ran out of questions or forgot something. Interviewers started by ensuring the respondent read and agreed to the Interview Confidentiality Statement (see Appendix C) and requested permission to use audio and video recordings for future reference. Then, the interviews followed a semi-structured format, which gave the interviewer freedom to explore additional stories or points of information not included in the prepared questions from the interview guide (see Appendix D). The interview guide outlines three categories of questions. The first category contains demographic and introductory questions aiming to understand more about the respondent and their experience in the seismic risk field. The next category encompasses seismic risk assessment methods and intends to determine the respondent's experience with conducting SRAs. Finally, the third category incorporates tips and tricks to successfully conduct RVSRAs. The interviewers also asked follow-up questions to gain further insight in certain areas. For example, Radu Lupasteanu worked with the Albanian government to conduct RVSRAs after an earthquake in Albania in 2019. Hence, the team focused on asking questions related to Lupasteanu’s experience and the key components that led to an effective RVSRA process in Albania.

The team used qualitative coding to interpret, organize, and identify main themes and insights from the interviews. The qualitative coding included both deductive and inductive coding. This enabled the team to anticipate the main themes that emerged from the interviews while maintaining room for exploratory research, as experts spoke about themes the team did not anticipate. Figure 3.2 shows the strategy the team used to code the interviews.

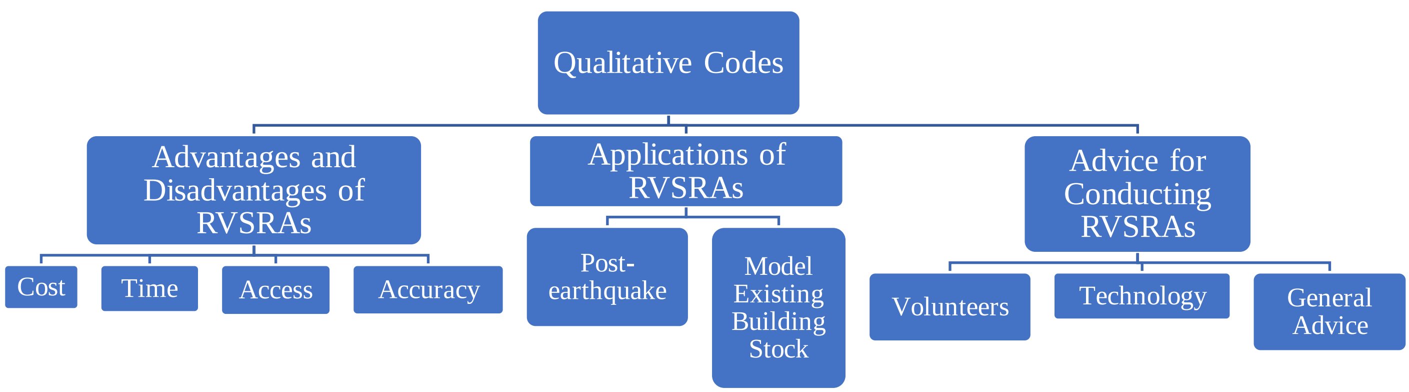

Figure 3.2: Qualitative Coding Strategy.

The team focused on three main themes: advantages and disadvantages of RVSRAs, applications of RVSRAs, and advice for conducting RVSRAs. The team chose these themes to lead to a better comprehension of the purpose and challenges of RVSRAs, as well as how Re:Rise can utilize RVSRAs in their pilot program. These themes include subcategories (defined in Appendix E) helped illuminate important aspects to effective RVSRA methods both generally and in Bucharest.

3.2 Identify Similarly Constructed Buildings

To better realize the seismic risk of Romanian buildings, the team analyzed satellite imagery to identify and categorize communist era structures in Bucharest. The team started with identifying double orientation (OD) buildings because they are easily identifiable and repetitive throughout the city (M. Sumbasacu, personal communication, April 5, 2022). Buildings with similar architecture and attributes will likely have similar outcomes after an earthquake; if one building exhibits high seismic risk, an identical type of building is also likely to exhibit high risk. As assessors have examined few communist buildings in Bucharest, no one knows how many communist buildings exist in the city.

The team created a geo-map that categorizes and identifies each building, giving information regarding the locations, densities, and total number of structures of a particular building type. Matei Sumbasacu, assigned the team a small neighborhood called Colentina in Sector 2 of the city. He chose this area because he already knew the location and number of OD buildings in the area. The team sent the completed geo-map of Colentina, via a QGIS.gpkg project file, to Sumbasacu who verified that the team's work was accurate. Sumbasacu then assigned the team seven red circled areas of Bucharest to continue mapping for OD buildings (see Figure 3.3). The red circled areas indicate neighborhoods where large amounts of communist structures still exist, and the purple highlights show the major roadways that could possibly be adjacent to the unsafe buildings.

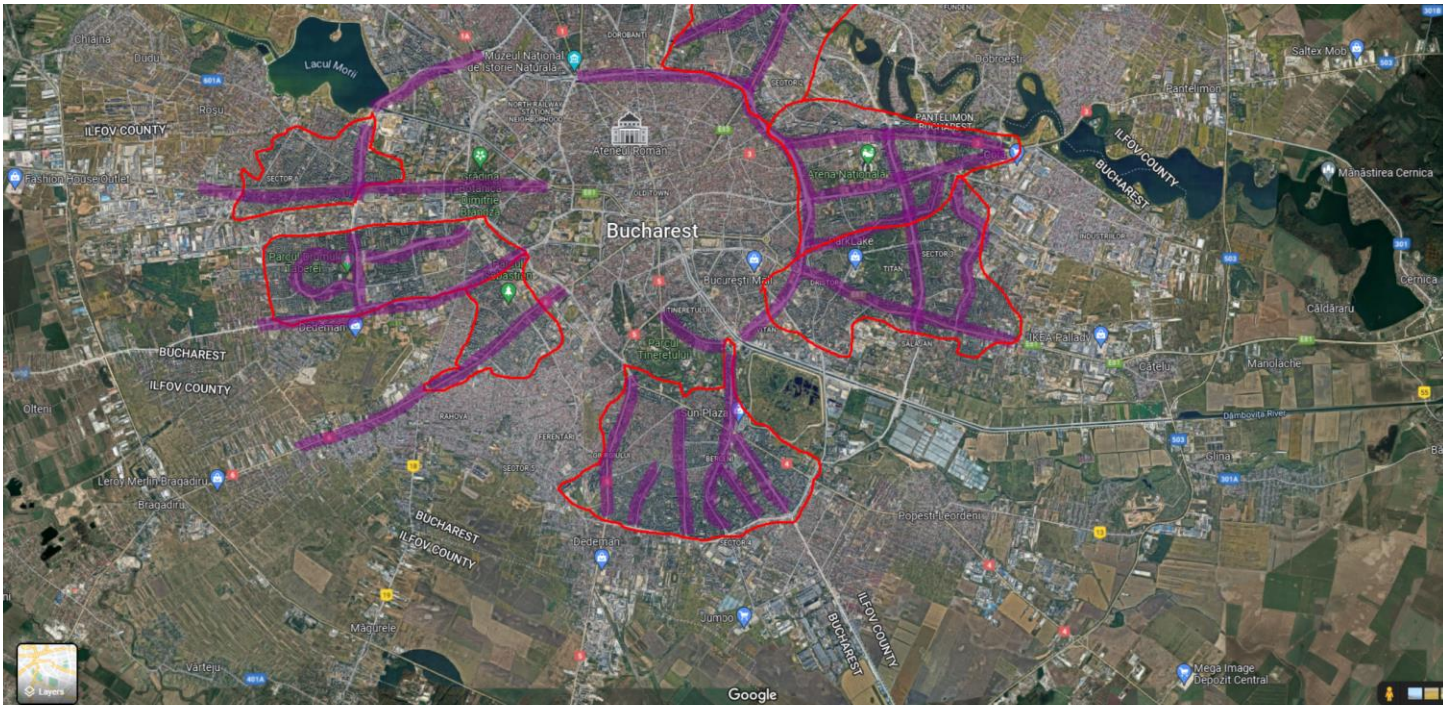

Figure 3.3: Re:Rise Provided Map of Bucharest

He chose the highlighted areas based upon the large distribution of OD buildings in the area. The team then sent the larger geo-map files to Sumbasacu so he could combine them to make one map of all the OD buildings the team had identified. Using the geo-map and existing knowledge of seismic risk related to building type (as explained in the background chapter), the team sought to spotlight the buildings most at risk in the next large earthquake in Bucharest.

To accurately geo-map buildings, the team received training from Sumbasacu and Marius Budileanu, a geology professor working with the Romanian NGO Geospatial. Budileanu introduced the team to QGIS, an open-source software that can use Google and Bing satellite imagery to identify and categorize buildings. After the team downloaded the software, Budileanu conducted a QGIS virtual training meeting over Webex, where he trained the team on the interface and demonstrated the process of building tagging. He explained how to select each building and assign it to a database (see Figure 3.4). Afterwards, Sumbasacu demonstrated how to identify OD buildings from the satellite images, primarily by noting the unique elevator shaft and sewage pipes on the roofs of the buildings (see Figure 3.5). After the training session, Budileanu and Sumbasacu provided guides on satellite information data and additional resources on how to properly classify buildings. The team then used the map provided by Sumbasacu, the QGIS software, and the additional resources to locate and mark OD buildings.

Figure 3.4: Double orientation buildings marked with red outlines and dots on the team's geo-map

Figure 3.5: Double orientation building, the red square indicates elevator shaft, the red circles indicate the sewer pipes

3.3 Educate the Public on the Prevalence of Historically Vulnerable Buildings in Romania

Substantial progress in reducing seismic risk in Romania requires action from the public and the government. For example, seismic retrofitting requires cooperation from individual building owners, as they permit engineers to assess their buildings. Furthermore, residents can reduce seismic risk by creating emergency plans and acquiring provisions for the days following an earthquake. Unfortunately, many Romanian residents remain skeptical that Bucharest will experience a major earthquake in the near future, as they have not yet experienced one for themselves. By educating the public on the pervasiveness of historically vulnerable buildings in Bucharest, the team hopes to clarify common myths surrounding seismically safe structures, raise awareness regarding seismic risk issues in the community, and motivate residents to prepare for the next major earthquake. The team hopes to achieve this education through a newspaper article, which may serve as a platform to invoke social change and put pressure on the Romanian government to prioritize building strengthening efforts and other earthquake safety measures.

To spread information to the public, the team needed a credible platform that could attract their attention. Sumbasacu connected the team with the local publication *Libertatea*, one of the major Romanian newspapers. In 2021, 60 percent of Romanians reported trusting *Libertatea* and 19 percent read the paper weekly (Newman et al., 2021). Furthermore, *Libertatea's* website has accumulated 15 million views in February 2022, making it the fifth most visited news website and the 24th visited website in Romania (*Ranking of Libertatea.Ro*, n.d.). Additionally, the team utilized Sumbasacu's knowledge to translate the article into Romanian and with the goal of publishing the article in both Romanian and English to reach and inform the most people.

To write the article, the team first created an outline that showed the topics it would cover. Then, the team used information from the background chapter and findings from geo-mapping to guide the article. After revising the outline and gaining approval from Re:Rise, the team wrote a first draft of the article.

Although Re:Rise plans on conducting RVSRAs, within the organization only Sumbasacu has experience with SRAs. Therefore, the methods discussed in this chapter aim to assist Re:Rise in their RVSRA pilot program. Experts can potentially provide advice to help Re:Rise avoid pitfalls. Furthermore, it is possible for geo-mapping to cut down the need for an extensive RVSRA program by identifying similarly constructed buildings. Additionally, the article may inform the public on unsafe buildings and relay any findings from the other two methods.

4 Results

This chapter analyzes the results from this project, which aims to help prepare Re:Rise to conduct rapid visual seismic risk assessments, (RVSRAs), and inform the public on the seismic risk present in Bucharest. The team gathered and analyzed insightful information from seismic experts around the world to educate Re:Rise in optimizing future RVSRAs in Bucharest. Additionally, the team created an interactive and scalable geo-map of a building type within Bucharest and analyzed images of these buildings to estimate how many residents from these structures an earthquake will affect. Finally, the team utilized background research and geo-mapping findings to write a newspaper article that informs the public on the current seismic risk in Bucharest.

4.1 Expert Interview Findings

The team conducted five interviews of seismic risk assessment experts as detailed in the Methodology chapter. The following sub-sections detail the findings from the interviews.

4.1.1 Advantages and Disadvantages of RVSRAs

The team ascertained the opinions of experts on the advantages and disadvantages of using RVSRAs, as shown in Table 4.1.

Table 4.1: Coded Interview Totals

Respondents	Aspects of RVSRAs							
	Cost		Time		Access		Accuracy	
	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
Forrest Lanning	0	0	0	1	3	0	0	1
Radu Lupasteanu	2	0	2	0	1	0	0	0
Vlad Lupasteanu	0	2	1	0	1	0	0	2
Mike Mahoney	2	0	2	0	1	0	0	3
Stavroula Pantazopoulou	0	0	0	0	0	0	0	0
Total	**4**	**2**	**5**	**1**	**6**	**0**	**0**	**6**

The "Total" row highlights interview trends by showing the total amount of times a code occurred across all the interviews respective to its column in the table. The "Cost" columns indicate the number of times an expert mentioned the financial expenses related to RVSRAs. Although experts did not mention cost frequently, those that did expressed mixed opinions. For example, experts who thought RVSRAs required more expertise believed them to be more expensive (explained later in section 4.1.3.) The "Time" column indicates if an expert mentioned the approximate time it takes to conduct RVSRAs. Three of the five experts mentioned how the short time required to conduct RVSRAs is advantageous compared to other seismic risk assessment (SRA) methods. Radu Lupasteanu of the Romanian State Inspectorate of Construction noted that in post-earthquake Albania, his team conducted RVSRAs on 300 buildings in four days and Vlad Lupasteanu, a professor at the University of Iași in Romania, suggests that RVSRAs could take as little as 15 minutes per building, both of which are far faster than traditional SRAs. The "Access" column indicates the impact that building access has on completing an assessment. RVSRAs can circumvent any requirement to access a building's interior. Four of the five experts mentioned ease of accessibility.

FEMA structural engineer Forrest Lanning summarized the obstacles of building access saying, "a lot of buildings are privately owned, so you don't really have permission to actually go inside the building to assess it" (Lanning, see Appendix F for full interview). Senior FEMA Geo-physicist Mike Mahoney furthers the argument noting that larger buildings with tenants pose a difficult challenge when conducting SRAs, as large residential spaces have many more structural components which complicates the SRA process. Although both experts are from the United States, Romania faces similar issues with the prevalence of large, private apartment buildings. RVSRAs bypass these issues, but this yields a tradeoff in accuracy. Just as most of the experts felt RVSRAs increase accessibility, they also noted how RVSRAs yield decreased accuracy. V. Lupasteanu was adamant about this saying, "there may be some problems, some very important damages which are at the interior structure elements which cannot be seen otherwise" (Vlad Lupasteanu, see Appendix H for full interview). Later in his interview he emphasized that the assessor can observe only 30% - 40% of the building by only assessing from the outside. In summary, Table 4.1 shows that experts generally have a positive outlook on RVSRAs, with 15 positive associations and only eight negative associations related to aspects of RVSRAs.

4.1.2 Applications of RVSRAs

Although the experts provided contexts and scenarios for when to conduct RVSRAs, these experts provided a variety of scenarios when RVSRAs are most impactful. For example, Mahoney recommended RVSRAs as a first step to determine which structures assessors should prioritize, as conducting in-depth assessments on all buildings in a city is not feasible. For instance, Mahoney expressed "that rapid visual screening really kind of cuts the inventory of what you're looking at down to buildings that really [need] your attention" (Mahoney, see Appendix I for full interview). Because RVSRAs are quick and inexpensive, assessors can apply them to a large area of buildings. If a structure exhibits severe seismic vulnerability in the RVSRA, then an assessor can conduct a more complex and demanding SRA later. York University Professor Pantazopoulou reinforced this claim stating, "in layer one… you do a visual evaluation of the building population or of an individual building" (Pantazopoulou, see Appendix J for full interview). Professor Pantazopoulou continues by indicating "tier two", or more in-depth assessments, should follow a rapid visual screening.

R. Lupasteanu, suggests the use of RVSRAs immediately following an earthquake, explaining that residents need to know if their home is safe to enter immediately after an earthquake. Without determining the safety of a home, residents could experience an unexpected collapse in the following days. R. Lupasteanu states "the first … hour after the earthquake the local authorities are mobilized in order to firstly to evacuate people … and after that to see if the structures still can be used or if there are various degrees of doubts about it" (R. Lupasteanu, see Appendix G for full interview). RVSRAs allow engineers to assess large numbers of buildings on foot in a short amount of time, so residents can return home if the RVSRA concludes that their structure is safe.

Forrest Lanning has utilized RVSRAs for a third purpose. When conducting RVSRAs in Costa Rica and Columbia, he employed a modelling program to estimate the impacts of an earthquake given a particular day and time. This simulation provides an estimation of the earthquake damages, meaning the regional and national governments have a greater ability to prepare for the cost of the aftermath. Lanning comments, "[RVSRAs] will tell you your potential casualties, injuries, and things like that, based upon what time of day the earthquake happens"

(Lanning, see Appendix F for full interview). Briefly, governments can use RVSRAs to identify the post-earthquake rebuilding and temporary housing plans from models that use RVSRAs. Additionally, first responders will know which areas have the highest density of people living in seismically unsafe structures, as this area will most likely have the most people in need of rescue. As Lanning opines, “this now gave them at least the starting point … [of] what neighborhoods will have higher concentration of collapsed buildings, and therefore trapped people” (Lanning, see Appendix F for full interview). He added, “you can pull out more people in those first 48 hours and save more lives.” (Lanning, see Appendix F for full interview). Concentrating first responders’ efforts to the places that are most in need could mean saving more trapped people.

4.1.3 How to Conduct an RVSRA

The experts disagreed on adequate training for conducting RVSRAs. Forrest Lanning, who utilized RVSRAs in South America, believes undergraduate students can conduct RVSRAs. Conversely, Professor Pantazopoulou and R. Lupasteanu emphasized the requirement that assessors should have more experience and knowledge to increase the effectiveness of RVSRAs.

When Lanning administered RVSRAs, he provided the undergraduate student volunteers a tablet to assist them in their data collection. The tablets contained a helpful and intuitive interface that included drop down menus and a listing of all the necessary criteria. The tablet interface creates a straightforward data collection process for assessors. Furthermore, the students identified their building from a satellite map and took pictures of the structure, allowing Lanning and other experienced engineers to perform double check a random sample of the student volunteers’ work. During this review process, Lanning reported finding mostly accurate results from undergraduates, remarking “we randomly checked the information that was inputted through the tablets by the students, and then we would look at the GPS coordinates to look at a footprint … and then look at the photos they took and then see if we agreed with that" (Lanning, see Appendix F for full interview). Lanning observed that the students did an excellent job collecting accurate data.

Mahoney and Professor Pantazopoulou both recommended employing graduate students. Due to the uncertain nature of RVSRAs and the nuances associated with an exterior building inspection, they thought graduate students were more experienced than undergraduates but less expensive than professionals. Mahoney explained, "a lot of cases when we do these rapid visual screenings it's not engineers doing that because they're too expensive. So, it's like people who know construction but aren't engineers, and in fact grad students quite often" (Mahoney, see Appendix I for full interview). Graduate students in architecture or civil engineering serve as a middle ground between undergraduates and professional, as they may be willing to work for less money, but also demonstrate better foundational engineering knowledge than undergraduates. Professor Pantazopoulou added "I would suggest that in all cases tier one would have to be done by civil engineers and placed actual engineers, but the level of expertise could vary. So, tier one can be done even by a let's say graduating 4th [or] 5th year [student]" (Pantazopoulou, see Appendix F for full interview).

V. Lupasteanu and R. Lupasteanu disagreed with the other expert opinions, expressing that RVSRAs require professional engineers. V. Lupasteanu stressed the importance of expertise noting, "the seismic performance of an existing building has to be assessed … by the so-called technical experts that we have in Romania" (V. Lupasteanu, see Appendix H for full interview). V. Lupasteanu remarks that in Romania, certified civil engineers are the only people allowed to conduct SRAs. This implies students may not be adequate, as only professionals take a standardized exam to receive a license and have a foundational certified knowledge base.

Additionally, four of the experts provided valuable advice on how to effectively conduct RVSRAs. Even though assessors can conduct RVSRAs quickly, Forrest Lanning stressed how assessing the sheer number of buildings in a major city remains impractical. To combat this challenge, Lanning utilizes satellite imagery to create what he called homogonous zones. He explained it as “taking the whole city and you're kind of sub dividing the city into what we call homogeneous zones. Now those homogeneous zones don’t necessarily mean it has the same type of houses or buildings, but it has the same collection of houses and buildings” (Lanning, see Appendix F for full interview). Experts, such as Lanning, create these homogenous zones from factors such as districts, architectural styles and age of buildings. For example, an expert would separate a downtown area built in the 1970s with retail from a newly retrofitted residential area with mostly single-family homes. Once Lanning divides a city into zones, he randomly selects a certain number of houses from each homogenous zone to survey. Finally, a mathematician plugs the results into a mathematical simulation that can predict earthquake impacts.

Mahoney and Lanning both described the importance of mathematical modeling. They utilized this technology in conjunction with RVSRAs to create predictions of the aftermath of an earthquake. Mahoney described the program explaining, “it essentially takes the inventory [of] data and it has some inventory [of] data imbedded in it, but you can make that more accurate by adding more data, but then it costs money to do that. That program basically gives an estimate of what the damage would be for a given area” (Mahoney, see Appendix I for full interview). Mahoney’s simulation utilizes United States census data, but an engineer can adjust input parameters with additional data and toggle earthquake intensity and time of day. Lanning used a slightly different model than Mahoney, as he conducted RVSRAs primarily in Costa Rica and Columbia, but the purpose and main attributes were the same. Although both Lanning and

Mahoney stressed the importance of simulations, they provided few details, as neither of them are simulation experts. Although all the experts conduct RVSRAs a bit differently, they all made clear that the proper training of the assessors is essential to accurate assessments, while utilizing homogeneous zones and earthquake modeling can further improve the results.

4.2 Geo-mapping Vulnerable Buildings

The team geo-mapped various neighborhoods and sectors in Bucharest, identifying OD buildings and marking their location for future reference. Figure 4.1 displays a map of marked buildings.

Figure 4.1: Sectors 5 and 6 of Bucharest with tagged buildings (RED) in QGIS software.

The team identified and tagged double orientation (OD) type buildings, noting the total number of OD buildings that the team tagged in each of Bucharest's six sectors. The QGIS geo-mapping software automatically summed the totals of tagged OD buildings, as highlighted in Table 4.2.

Table 4.2: Table of Geo-Mapped Buildings

		Sector Number					
Building Type		**1**	**2**	**3**	**4**	**5**	**6**
	OD	N/A	119	120	41	3	197

Locational marking of OD buildings highlights the areas seismic risk assessors should prioritize. During our geo-mapping process, the team observed that many OD buildings exist in long narrow rows near major expressways as in Figure 4.2.

Figure 4.2: Geo-mapped OD buildings (RED) near major roadway.

During the next earthquake, these highly vulnerable OD buildings may collapse, causing blockages of major roadways. Damage to local transportation infrastructure has the possibility to block evacuation and emergency response vehicles from accessing disaster areas. The team identified 480 OD buildings which often reside near major roadways.

4.3 Newspaper Article

The team drafted an informational newspaper article in collaboration with Matei Sumbasacu, shown in Appendix K. The article strives to establish the current severity of seismic risk in Bucharest and begins with the team's experience studying Romania's seismic risk remotely. Through researching the seismic problem and speaking with numerous people, both the reaction of Romania as a whole and the Romanian government shocked the team, as their collective pattern of inaction has led to the current circumstances. The article addresses the Romanian public's knowledge gaps of potential earthquake impacts by discussing earthquake vulnerability in Bucharest. This section includes interesting facts related to specific seismic risks in Bucharest, such as the flaws in communist structures, that may catch the Romanian public's attention and further the awareness to urgently assess and strengthen buildings across the city. Next, the article discusses this project and its findings from the geo-mapping. The geo-mapping findings further decrease the knowledge gap surrounding earthquake vulnerability in Bucharest by identifying the vulnerable building types and sectors. Although this information establishes the prevalence of seismic risk throughout Bucharest, which may come across as surprising or eye-opening to many residents, the team hopes to motivate readers to spark change. Additionally, the geo-mapping findings expose currently available actions to the Romanian government and NGOs like Re:Rise in hopes they will act quickly. The article then closes with a plea to urge the readers to educate friends and family, pressure local authorities to begin assessing and strengthening buildings, and to take action in any way they can.

5 Recommendations

The team's interviews reveal the potential for RVSRAs and highlight their ability to quickly survey many buildings. However, if executed poorly, an RVSRA could waste resources by giving inaccurate findings. Below, the team lists recommendations for Re:Rise on how to conduct their future RVSRA program.

5.1 Recommendation 1: Use Geo-Mapping to Quicken RVSRA Program

Bucharest has around 100,000 buildings (Vacareanu et al., 2004). Even with RVSRAs, assessing this many buildings remains impractical due to the sheer number. Considering assessments take between 15 and 75 minutes, assessing every building would take between 25,000 and 125,000 hours. To combat this labor-intensive task, our group recommends geo-mapping the main building types in Bucharest's socialist housing districts. First, participants in the RVSRA program can use Geographic Information Systems (GIS) software to identify all buildings of a specific major building type in Bucharest. Since engineers constructed each building type almost identically, they are easily identifiable and will likely exhibit similar earthquake risk. For example, engineers know OD buildings contain structurally similar elements, such as a centrally offset elevator location, similar buildings materials and similar structural weaknesses. Therefore, if assessors only inspect a portion of OD buildings, they can extrapolate generic results to the entire OD building stock. RVSRA results from the same building type may demonstrate commonalities which provide general insights about the seismic vulnerability of that building type. After assessing more than one building type, the assessors can use the generic RVSRA results to determine which building types generally have the highest seismic vulnerability. In turn, this could help prioritize which buildings should undergo a more in-depth seismic risk assessment.

5.2 Recommendation 2: Create a Seismic Model

Experts with RVSRA experience used computer models to guide their assessments. A model predicts both financial and human costs, which can be valuable. Although surveyors may get a general sense of cost, it may be speculative as many seismically unsafe buildings end up surviving large earthquakes. A model is good at reducing uncertainty by accurately creating predictions. Additionally, a user can change the day of the week and time of day in the model, which gives a better sense of the wide range of impacts from an earthquake. Not assessing enough buildings can lead to inaccurate results as the model requires a sizable amount of data. Assessing too many buildings wastes time, as adding too much extra data has a marginal effect on model results. A model can predict how many buildings will require additional assessments or structural improvements in the city.

5.3 Recommendation 3: Use Graduate Students to Conduct RVSRAs

As the team's experts disagreed on the necessary level of training to conduct RVSRAs, the team decided to compromise the two main theories. Some experts thought assessors needed to be certified professional engineers, while others believed undergraduate students in civil engineering can conduct RVSRAs. The team recommends splitting the difference and choosing graduate students in civil engineering, architecture, or a related field. Firstly, graduate students have more experience than undergraduate students, meaning they are less likely to make mistakes and can pick up the training faster. Additionally, graduate students are less expensive than trained professionals. The team recommends Re:Rise start recruitment by contacting seismic professors at the Technical University of Bucharest.

One issue with graduate students in Romania is that often they are full-time professionals as well as students, so they may not be able to spend time conducting RVSRAs. If Re:Rise is unable to recruit enough graduate students, the team believes that undergraduate students – who may have more time – in civil engineering, architecture, or a related field could suffice. However, the RVSRA training of the undergraduate students will be more critical for them, since they have less experience than graduate students and may be more likely to make mistakes when conducting the assessments.

5.4 Recommendation 4: Use Quality Control for RVSRA Results

Lanning mentioned the importance of double-checking volunteer's work, as graduate student assessors are most likely to be conducting RVSRAs for the first time. Although Lanning used tablets, volunteers can alternatively send pictures to a trained Re:Rise engineering professional to be double-checked. The team recommends taking a random sample from each volunteer and determining if any volunteer's assessments are inaccurate.

5.5 Recommendation 5: Establish Credibility for RVSRA Assessors

Residents may be suspicious of people with clipboards taking notes and staring at their home. To mitigate this, Re:Rise must take measures to establish credibility. For example, Lanning emphasized the importance of receiving a note from the local government giving approval for the assessments. Additionally, inspectors can carry Re:Rise business cards and wear high-visability construction vests. Residents are understandably nervous about the process, as red dots marking high risk buildings decrease property value. Re:Rise should provide a written or prepared statement in Romanian to the assessors, so when a flustered citizen approaches, the assessors can deescalate the situation.

6 Conclusions

The project focuses on two main aspects: preparing Re:Rise to conducting seismic risk assessments (SRAs) and educating the Romanian public on the seismic risk of historically vulnerable buildings in Bucharest. This chapter delves into conclusions derived from both aspects.

To assist Re:Rise in conducting SRAs, the team interviewed experts to understand the advantages, disadvantages, and applications regarding rapid visual seismic risk assessments (RVSRAs). The findings and recommendations emerging from the interviews show that Re:Rise's RVSRA program has the potential to greatly improve Romanian earthquake risk mitigation. Since RVSRAs require little prerequisite expertise, the volunteer-based NGO can train assessors and conduct assessments without hiring certified engineers, which saves money. RVSRAs are fast and can effectively cut down Bucharest's unassessed building inventory by thousands of buildings. With many vulnerable large apartment complexes, as supported by the geo-mapping, RVSRA inspectors can assess buildings from sidewalks, bypassing apartment unit owners denying inspectors' access. With 10-15 similar building types making up much of Bucharest, assessors can extrapolate assessment findings to unassessed buildings, helping them understand the extent of seismic vulnerability without having to assess every single building. These attributes demonstrate that RVSRAs can be an effective technique for assessing seismic risk in Romania at the cost of assessment accuracy.

To increase awareness about seismic risk in Romania, the team incorporated background research and geo-mapping findings to draft a newspaper article informing the public of the severity of seismic vulnerability in Bucharest. The draft aims to show citizens the 480 double orientation (OD) buildings found during geo-mapping, which remain inherently susceptible to collapse as demonstrated by their tendency to collapse in past earthquakes. Although this information targets residents living in these buildings, it may prove invaluable for first responders to understand where buildings are likely to collapse and block roads. Furthermore, publicly presenting this information can help Romanians understand the enormity of the potential damages that surround the next earthquake, increasing awareness to urgently assess and strengthen Bucharest’s’ buildings. An existing draft of the article (shown in Appendix K) serves as an example of an educational resource that can close the seismic risk knowledge gap among the Romanian public. Additionally, this draft can serve as a framework in assisting Re:Rise for future newspaper article drafts.

6.1 Future Work

Since seismic vulnerability remains a multi-faceted and deeply-rooted issue in Romania, the team picked a narrow scope focusing on SRAs as a means to begin reducing seismic vulnerability. While the team initially expected to spend the project term in Bucharest, the Worcester Polytechnic Institute administration restricted international travel due to the COVID-19 pandemic and the Russian invasion of Ukraine. This forced the team to pivot midway through the project term and to adjust the scope even further. Much more work remains necessary to reduce seismic vulnerability in Romania. Re:Rise and future WPI IQP project teams would be good candidates to conduct this work.

One step might be to finish geo-mapping historically vulnerable buildings. Although the team geo-mapped OD buildings in Bucharest, future teams should map the other main building types. The results from geo-mapping show that identifying vulnerable buildings is a manageable preliminary step before conducting RVSRAs, as they give inspectors additional information when analyzing structures.

Although the team created a draft news article seeking to educate Romanians on seismic vulnerability, this is only a first step in tackling a lack of awareness regarding seismic risk in Bucharest. WPI students can support Re:Rise in writing future articles and produce more educational resources, like websites, advertisements, and brochures to raise further awareness, pressuring other Romanian organizations to act.

A 2021 IQP titled, *Investigating the Impacts of Earthquakes on Ethnic and Religious Groups: Bucharest, Romania*, suggests two main hurdles in seismically preparing Bucharest: addressing the lack of building evaluation and convincing Bucharest residents to take action (Benevedes et al., 2021). This project has started to tackle both of those issues, with preparing Re:Rise to conduct a large building assessment program and providing a template to publicize educational resources. This project team urges future IQPs to follow suit, as this line of work will most likely persist until the next major earthquake and has the potential to save thousands of lives.

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Appendices

Appendix A: Table of Commonly Used Terms and Abbreviations

Table A.1: Commonly Used terms and Abbreviations

Term	Abbreviation
Geographic Information System	GIS
Medvedev–Sponheuer–Karnik Scale	MSK
Non-Governmental Organization	NGO
Rapid Visual Seismic Risk Assessment	RVSRA
Seismic Risk Assessment	SRA

Appendix B: Figure B.1: Medvedev–Sponheuer–Karnik Scale, (*European Macroseismic Scale 1992*, 1992)

I. Not perceptible	Not felt, registered only by seismographs. No effect on objects. No damage to buildings.
II. Hardly perceptible	Felt only by individuals at rest. No effect on objects. No damage to buildings.
III. Weak	Felt indoors by a few. Hanging objects swing slightly. No damage to buildings.
IV. Largely observed	Felt indoors by many and felt outdoors only by very few. A few people are awakened. Moderate vibration. Observers feel a slight trembling or swaying of the building, room, bed, chair, etc. China, glasses, windows, and doors rattle. Hanging objects swing. Light furniture shakes visibly in a few cases. No damage to buildings.
V. Fairly strong	Felt indoors by most, outdoors by few. A few people are frightened and run outdoors. Many sleeping people awake. Observers feel a strong shaking or rocking of the whole building, room, or furniture. Hanging objects swing considerably. China and glasses clatter together. Doors and windows swing open or shut. In a few cases, window panes break. Liquids oscillate and may spill from fully filled containers. Animals indoors may become uneasy. Slight damage to a few poorly constructed buildings.
VI. Strong	Felt by most indoors and by many outdoors. A few persons lose their balance. Many people are frightened and run outdoors. Small objects may fall and furniture may be shifted. Dishes and glassware may break. Farm animals may be frightened. Visible damage to masonry structures, cracks in plaster. Isolated cracks on the ground.
VII. Very strong	Most people are frightened and try to run outdoors. Furniture is shifted and may be overturned. Objects fall from shelves. Water splashes from containers. Serious damage to older buildings, masonry chimneys collapse. Small landslides.
VIII. Damaging	Many people find it difficult to stand, even outdoors. Furniture may be overturned. Waves may be seen on very soft ground. Older structures partially collapse or sustain considerable damage. Large cracks and fissures open up rockfalls.
IX. Destructive	General panic. People may be forcibly thrown to the ground. Waves are seen on soft ground. Substandard structures collapse. Substantial damage to well-constructed structures. Underground pipelines ruptured. Ground fracturing, widespread landslides.
X. Devastating	Masonry buildings destroyed, infrastructure crippled. Massive landslides. Water bodies may be overtopped, causing flooding of the surrounding areas and formation of new water bodies.
XI. Catastrophic	Most buildings and structures collapse. Widespread ground disturbances, tsunamis.
XII. Very catastrophic	All surface and underground structures completely destroyed. Landscape generally changed, rivers change paths, tsunamis.

Appendix C: Interview Confidentiality Statement

Introduction

You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

Purpose of the study: To gain expert insight on seismic risk assessments methods and opinions on rapid visual seismic risk assessment methods. This insight will be used to influence a pilot program to rapid visual seismic risk assessments in Bucharest, Romania.

Procedures to be followed: The interviewer will begin by gaining consent from the respondent to be recorded throughout the interview, explain participant confidentiality, and review the purpose of the study. The team will ask a series of questions to the respondent. The duration of the interview is expected to be 30-45 minutes.

Risks to study participants: None

Benefits to research participants and others: None

Record keeping and confidentiality: The team will ask all respondents if the team can record the interview. If a respondent declines, the team will take notes instead. The interview will gather information on current seismic risk assessment methods and rapid visual seismic risk assessment methods. Only the investigators will have access to the recordings, and the team will transcribe and code them for common themes to complement our research. The team will ask the respondents if they can use their name and affiliation (if any).

Compensation or treatment in the event of injury: There is no expected risk of injury or harm. You do not give up any of your legal rights by signing this statement.

For more information about this research, contact: Project Team Group, Josh DeBare, Nick Miragliotta, and Matt Zoner at gr-seismic-risk-d22@wpi.edu

For more information about the rights of research participants, contact: IRB manager, Ruth McKeogh at 508 831- 6699 or irb@wpi.edu

For information in the case of research-related injury, contact: Human Protection Administrator, Gabriel Johnson at 508-831-4989 or gjohnson@wpi.edu

Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without penalty or loss of other benefits.

The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit.

If using Zoom:

Team will ask: Can we have your oral consent to interview you?

Study Participant Name:

Name of Person who explained this study

If in person, the team will print the following agreement form and request the respondent to fill out:

By signing below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

____________________________ Date: ____________________

Study Participant Signature

____

Study Participant Name (Please print)

_____________________________________ Date: ____________________

Signature of Person who explained this study

Appendix D: Seismic Expert Interview Questions

Before any questions are asked in any interview, the team will read aloud the Interview Confidentiality Statement (see Appendix C) to the respondent and obtain permission (oral for Zoom interview or written for in person interview).

Note: Before conducting an interview with an expert, the team will research the respondent to understand their expertise and thus help prepare with potential follow up questions in C2 and C3.

C1 Questions Regarding Demographics and Introductory Questions

C1.1 What is your name and pronouns?

C1.2 What is your job title and what company/organization do you work for?

C1.2.1 Can we use your name, title and affiliation in any reports or presentations that are the outcome of this interview?

C1.3 How would you describe your job to someone who knows nothing about civil engineering or earthquakes?

C1.4 How does your line of work impact seismic safety and preparedness in your local area or around the world?

C2 Seismic Assessment Methods and General Preparedness

C2.1 Could you describe your previous work on seismic risk assessments?

C2.2 How does your work relate to or influence current seismic risk assessment methods?

C2.3 What are the purposes of seismic risk assessments? In what ways to they help improve earthquake preparedness?

C2.4 What are the socio-economic challenges you have encountered when conducting seismic risk assessments?

C2.5 What are the political challenges you have encountered when conducting seismic risk assessments?

C2.6 Have you experienced working with a governmental organization regarding seismic risk assessments? If so, what was it like?

C2.7 What laws are there surrounding seismic risk assessments in your local area? How have they impacted your ability to do seismic risk assessments?

C2.8 What other elements of seismic risk assessments are important that you have not touched on yet?

C3 RVSRAs

C3.1 What is your experience with rapid visual seismic risk assessments?

C3.2 In what circumstances would a RVSRA be more useful than a traditional SRA and vice versa?

C3.3 How does conducting an RVSRA change for the type of building? For example, would assessing a government building be different from an apartment complex be different than a single unit house?

C3.3.1 How does the accuracy of an RVSRA change depending on the type of building?

C3.4 Are there a different set of regulations that exist regarding rapid visual seismic risk assessments compared to typical seismic risk assessments?

C3.5 What challenges have you experienced with conducting rapid visual seismic risk assessments?

C3.5.1 How did you overcome these challenges?

C3.5.2 What could you have done differently to avoid these challenges in the first place?

Appendix E: Qualitative Analysis Codebook

- Advantages and Disadvantages of RVSRAs
  - Cost – the financial cost to conduct a RVSRA
  - Time – the time it takes to conduct a RVSRA
  - Access – the building access required to conduct a RVSRA
  - Accuracy – how accurate RVSRAs are
- Applications of RVSRAs
  - Post-earthquake – the use of RVSRAs immediately after an earthquake occurs to understand if a building may collapse
  - Model existing building stock – the use of RVSRAs to understand the seismic vulnerability of a building stock while only assessing a portion of the buildings
- Advice for Conducting RVSRAs
  - Volunteers – whether or not assessors who do not have professional expertise or training can accurately conduct RVSRAs.
  - Technology – the use of technology outside of a clipboard, paper, and writing utensil. Examples include computer simulations and electronic tablets
  - General advice – any advice to successfully conduct RVSRAs

Appendix F: Forrest Lanning Interview Transcript

Zoom Interview, March 18, 2022, at noon EST

DeBare: Can you tell us a little bit about our experience with earthquake assessments, more generally with risk assessments and what is your job and what is it that you do?

Lanning: So my background by trade, I'm a structural engineer. I started off doing seismic retrofits of buildings in the San Francisco Bay area, mainly for hospitals and schools to meet the state requirements for continuing operational for the critical facilities. But then I have I had moved and drive for about 15 years working in different post earthquake disaster areas, more specifically like Bande Ache, Indonesia after the 9 earthquake there and then Christchurch in New Zealand but for about four years and then I also worked in Afghanistan and Colombia and Costa Rica for an urban risk assessment for two different cities down there and during that time the Ecuador earthquake happened and so I just participated in assessing buildings down there for EERI. So my background has a lot of at times has been assessing the vulnerabilities of buildings, both at the micro-level. When I say micro level I specifically mean for that building, doing a thorough investigation of the building, and then also looking at the macro level where when I was working for USAID the Office for Foreign Disaster Assistance, which I know they changed their name to the Bureau of Humanitarian Assistance on urban risk assessments, and that was more looking at the macro level. So you're looking at more of the building stocks and how that is representative, and by taking sampling methods for that. So I kind of worked on both levels of that. More currently, I serve in FEMA as the earthquake response liaison and on some basic level a kind of am an advisor, and a technical advisor on earthquake disasters, on building stock, vulnerabilities on after you know certain aspects in the hours and days and weeks after an earthquake or what to expect and things like that. That's kind of it in a nutshell. On the side I have also consulted for the World Bank and UNICEF on doing some risk assessments and retrofitting, one being in Kurdistan right until the pandemic and then the other one was in Afghanistan again, on doing a risk assessment at schools that were built there too. That's my background in a nutshell.

DeBare: For me it sounds like you are doing a lot of risk assessments. Can you go specifically on how the risk assessments in your line of work like effect earthquake preparedness?

Lanning: Yeah, so I'm going to take the two avenues: the whole individual building risk assessment, which is more thorough and then doing a macro one of the city. So, usually individual building owners like hospitals, schools or even multifamily buildings are going to want to know how resilient their building is and, so usually these rapid visual assessments are a good first step, just determining where they're at. But that only applies to that one specific building. Now when you're looking at a whole city it's not really practical, yet hopefully someday we have a way to do this, but to assess our buildings. And then the problem you're running across to is that you are doing a whole city, like in in Romania, like you're going to be doing in Buda-, Bucha-, Budachr-. I forgot got the name, Budapest, I'm sorry and then on it's not it's that lot of buildings are privately owned so you don't really have permission to actually go inside the building to assess it, and also there could be liability issues for the information you publish if you are talking about a specific building, and that's really the hard challenge of understanding your building stock. So what really the practical means is what we did, I think, in Costa Rica and Colombia, where you do a sidewalk survey. It's a more basic level of assessment, but you're taking … you first start off with taking the whole city and you're kind of sub dividing the city into what we call homogeneous zones. Now those homogeneous zones don’t necessarily mean it has the same type of houses or buildings, but it has the same collection of houses and buildings that repeat itself in that neighborhood. So if you move from a single family homogeneous zone to a commercial zone, then usually those types of buildings repeating in each zone. So once you just subdivide your city into those, then you can go and take a random sampling of the buildings in that area, and the more samples get the better representation you're going to have with that building stock in that particular zone. So we went and [in] San Jose Costa Rica, we took a far fewer samples than we did in Colombia, in Paso, Colombia, which was down by Ecuador, and so we took anywhere from 50 to 200 building samples in each homogenous zone and we can feed that in until our earthquake model, which will show you the percentage of predicted collapsed buildings, and then from that sampling,, you're also even putting the occupancy and lot of these buildings, and that will tell you your potential casualties, injuries, and things like that, based upon what time of day the earthquake happens, and so that is tremendously helpful for the city responders, for the civil defense, or the emergency managers, and also for the city of general to do mitigation programs. So, a lot of cities don't really know what their city would look like after an earthquake. Everybody kind of throws on around the words like it's really bad, it's horrible, but no one really knows what it really, truly would look like and this kind of gives you a little bit of like a crystal ball that can kind of tell you what it is now. Obviously the situation can … It's just a one model of one type of earthquake but it could vary greatly, depending on where the earthquake epicenter is, but more or less it gives you at least a starting point on knowing the magnitude of the problem.

Zoner: Quickly, when you said the 50 to 200 buildings, were those with the sidewalk assessments or (cut off)?

Lanning: Those were with the sidewalk assessments. That’s right.

Zoner: Okay

Lanning: Because when you think of big cities. These are fairly big cities, but they're not like Bogota, Colombia, where there’s 10 million people there. I mean that's just a monumental task to even figure out what that city would look like in an earthquake, and then are also other cities, like Kathmandu and then, maybe in European cities and southern Europe with high size and see what those would even look like. It's really tough to figure that out, but this this at least gives you a ballpark idea so you can actually start knowing how a ballpark idea into how to tackle the problem.

DeBare: Can you go into a bit more detail about the homogenous zones and the data collection. How did they choose the buildings and more detail into that process?

Lanning: So you kind of use satellite imagery and then you're looking at the satellite imagery, and with pretty good confidence. Then you can field check it, but you can kind of tell where the single family homes are. Then you move into a high density retail area or commercial area. You can tell that from that photographs, from the satellite photographs, and so it's really just using judgment from the sky and you can and, if you have any questions you have field staff out there. Then they can verify it really is. Then in Latin America we also have more of the informal construction neighborhoods, where it's just put together by the residents themselves so you can pretty usually tell what area is what zone and now, as I said there could be gray areas, but that's just going to be specifically. This is kind of splitting hairs. But you would have to make a decision on where you think that threshold should be. But so when you actually go into the sampling, we had analysis people training the models and, they will crank out and tell us well this percentage. You're going to be this accurate if you take this many samples and it increases as you increase the samples, but it's almost like <stutters> it's exponentially l more samples you get

- like you double your samples . From the beginning [it] increases a lot, but if you keep doubling it more, it actually only gets you a little bit more accurate. You're never going to be 100%, obviously. It's a model, but you're at a certain point gonna say “well if you're going from 50 to 200 that increase it a good amount, but if you go from 200 to 400 it actually doesn’t increase it that much more,” depending on you know the city and all that. And so you that's where you make a threshold it's gonna depend on what city you're in, but you gotta realize that oh let's just sample 10,000 buildings, and that's a huge tremendous amount of effort, but have little bit payoff becuase it doesn't increase your accuracy that much and you're gonna have to consult with local structure engineers. We were working with the university of Costa Rica, [with] a lot of structural engineering professors who really knew the construction in the region, and the same thing in Colombia, and so that has to happen. You have to have some local expertise on how it's built, how it's designed or how it's not designed, and then also knowing if it is not designed, how likely is it to be built to the designs, and in a lot of developing countries it is still not built how it's designed. So you have to take that into account when you're dealing with your modeling and so local contacts are obviously the best thing to do, and having local personnel out there. We used the local universities. We had the engineering students at all the universities to actually come along and we train them on how to do these sidewalks assessments, and they were all gung ho. They got a lot participation and, they went out and did the sampling. How you pick your buildings in each homogeneous zone <stutters> you're blindly, randomly selecting them. So yeah.

DeBare: So one thing that you mentioned was recruiting university students to do those assessments. Can you talk about that process a little bit and <trails off>?

Lanning: Yes. So what we had is, since we working with the university of Costa Rica for <incoherent> like Costa Rica and then El Niño, which is the they call their provinces' departments in Colombia. So that was the main university in that town, so we kind of do this training, and what happened is we get these checklists basically and we use these little tablets and in <stutters> the tablets we would have certain key questions, and usually our guy - our analysis guy who was running the models and making the model - would come up with a bunch of different questions. Now he's [the] PhD guy. He was running … he was the one that was the expert on what needed to be inputted in it, and so I was doing … I was the director of the program out in the field, and so the questions were things like "how many stories", "what type of construction?", "Was it concrete, steel , [or] timber?", "Was there any irregularities in the horizontal and vertical direction or where there building setbacks?", "Windows, like, how the window placements?" We kind of stayed away from questions that required information from inside the building 'cause that's not going to be happening, because a lot of them are just private homes and there's also <incoherent> sloped because we are inputting the geological information into the model as well. So they had these tablets, they would, use drop down menus and those are the best things. The tablets 'cause you want to be able to… They can just take the GPS coordinate of the house, and then they can also take pictures with it 'cause you also photographic just to double check the information later on down the road, and that was very important, and when you're dealing with hundreds and hundreds of buildings, you just gotta have it organized right up front and have it done in almost in real time and the tablets don't necessarily need to be connected to a cellular connection or anything to be … You can always download it at the end of the day, and that's what we were doing 'cause these only had Wi-Fi and they didn't have cellular, so you don't need to go all that fancy. But having an app built just to input it directly by the students, and we did trial runs. So we took them on a couple… We spent two days going around in neighborhoods and then just entering information and seeing how it goes, and they want to make sure that you're actually taking the GPS coordinates of the house, not where the person is standing. So there was a way to actually … The student would be able to see a satellite image of where they're standing, actively, and then they can just put a pin drop on the actual building that they're assessing.

DeBare: Think how they did not have much experience is there a training program like how to use the tablets and how to answer the questions?

Lanning: No honestly everyone has smartphones, so everyone kind of knows how it how to do that. There were Google tablets so and obviously your Android is the most common phone OS overseas, so everyone really know it, and also you know a lot of them knew English, because the whole app was all in English, so it was it was fairly easy for them to understand how to use that the tablets. <stutters> There wasn't … there wasn't any training that was needed. It was more of a judgment call a lot of times. They're gonna be, like, kind of insecure of if they made the right decision and so it was more building that confidence. What is a vertical irregularity or a horizontal one or a set back? At what point do you consider that sometimes people just think a re-entry corners. Like “oh that window isn't … is recessed a little bit. Is that consider re-entry corner? So you gotta kind of come up with thresholds and let them know at what point you would identify something with a certain attribute. That was kind of the thing that took the longest to get up to speed.

DeBare: so for these students you mentioned that we've got them from the university? Can you go more into the process of how you recruit the students? Did you send an email to someone at the university? Did you talk to them directly?

Lanning: So this, yeah, that's a good question. So in those programs what happened is because this … we were obviously a foreign government diplomacy agency working in another country, we were … the product was gonna end up being used … we wanted the product to be used by the city, the municipal government there or the national government, but usually the municipal government. So we wanted them to trust the information. We wanted to be believed in the information, that it was accurate. We didn't wanna be like “oh Americans coming in here telling them what their problems are” and then and all of that. So we wanted to have the local university as a partner because with this the municipal government … the first people they're gonna look at when you approach them, and they're gonna look at their own technical advisors, which is usually the local university saying “Like are these guys for real? Are they legitimate?” and so we … the first people I contacted when I was setting up the program down there was the professor and luckily, though I wouldn't be able to do this without this help, one of my colleagues in Christchurch New Zealand was from Costa Rican and he went to the school at University of Costa Rica studying instructional engineering, and so he gave me a name of a professor and then I contacted him. But if it wasn't the case then I would have sought … looked for someone in that department. Now also is having a local Rep, and so we hire local program managers in each of those countries, and those program managers were gonna be basically the eyes and ears and the face of the program, and as a foreigner I would step … I would step back and just have them be the point person because they're a local. They know how to communicate with them, and so I hired a program manager in both Costa Rica and Colombia that went to both the schools in that area. So they also knew the professors there and, they were former students themselves and, so that was how the connection, and we just basically approached the professors with what we wanted to do, and they both agreed <Lower “Professor”Voice> “Oh yeah! Our city is high risk,” and they agreed with everything, and they want to do something. So we get input from them, and then we kind of, like, if the program needed to change a little bit then we you have to allow some allowances to change a little bit depending on the local advice, and then once they're on board then we could approach doing this, and then we can actually approach the municipal government on the results and then the results and then, the professors would be more than happy to sit in those meetings with you, and also vouch for it and talk about it and have them feel like they're at an equal partner … part of the program.

Zoner: Did you find any challenges with actually conducting the assessments or analyzing the data afterwards?

Lanning: Not really. A problem analyzing data, but conducting the assessment sometimes can be a problem. It depends on the city and there are there are areas in both cities that are you know questionable safety. They're in the more dangerous parts of the cities, and so those even for the locals there were … they they still went in there and did it. We just told them “If you don't feel comfortable, then don't deal. We'll figure out another way.” But they went still went in, and so there were some places that they had to really limit how much time they spent there they weren't … they would use a car and then jump ,you know, jump out into the assessment, then jump back in and drive somewhere else rather than just [be] completely walking the whole , and things like that. So it just depends on the neighborhoods, you know you can run into problems conducting this assess- So that was the only problem we had conducting the assessments. Now dealing with like … I guess you guys are working with a company and not working with the actual local government. Sometimes getting buy in from the local government is a challenge and sometimes the local government takes a long time to make decisions … to move and that was a problem in

Costa Rica and Colombia. They were everything. Everybody was pretty enthusiastic about it, so it went pretty fast.

DeBare: For this data, since you're having people you mentioned, some of it being some judgment calls on if you consider this at … Can you talk about how you can from the validity and like the accuracy of the data that was collected.

Lanning: How do you confirm accuracy? Well we confirmed … the only thing we can really confirm is the data that we're collecting is accurate. So what we did is, we randomly checked the information that was inputted through the tablets by the students, and then we would look at the GPS coordinates to look at a footprint, you know satellite image and then look at the photos they took and then see if we agreed with that. So it required a looking at that, checking the data. We obviously spot checked, it but how do you how … you can't really, not that I know of … can't really verify the model … the model like in data output. I mean unless an earthquake of that same exact scenario happens, there's really no way to … no way to verify that. I think it really just comes down to having good data and then also having a solid way of running the model. I guess there's percentages you can figure out and how the model runs. I couldn't comment that. That's getting too deep into the analysis part, but yeah. It's really just checking the data. The rest can be figured out mathematically through the analysis.

DeBare: <Audio Missing> would you would you scrap the rest of that person's data and put it and do it again, or would you calibrate it to make it better, or would that process look like?

Lanning: Well <stutters> we didn't come across that I … I was out in the field a lot of times. When I wasn't with them all the time but … but if there was a person that was constantly putting in inaccurate data, then I would have all the all of the data inputted by the person be checked. I don't know necessarily I would throw it all out and this was really horrible, but it definitely if you did see a pattern with certain students taking bad data, then it's a red flag to check more of their … their work so we never really had that problem. There … there might be a few buildings that were kind of gray area of certain things and so they needed a different interpretation of it.

DeBare: Um so … the model is really interesting. It sounds like um that you were more involved in the data collection.

Lanning: So we had a guy back in California that was random model and he's the one. Like I know in principle how it works. I cannot tell you detail how the model happens. What happens, what basically happens at a higher level is we're … we're building fragility curves of the different types of structures [that] are out there and then that is being applied to the types of buildings that were sampled in each of the homogenous zones, and then basically you're putting the soil types in those homogenous zones and then when the earthquake, happens you get a you know … kind of like a estimated shake intensity on each of these areas, and they're … they're … you're running miniature models in each of those homogenous zones and then .. and then making a mosaic of the results.

DeBare: Would you mind giving us the information of the person that does the model so that we can follow up with them and …?

Lanning: yeah uhm, I think he still works there. it's my from there's … I don't obviously work through the same place I did, but I can give you his contact information if you want to follow up with him. Or specifically on that, I'll send it in the email or something. <Pause> So I don't know if that is what you guys are looking at, because there's also rapid visual rapid assessment, dealing more specifically with the building, more in detail and because what I was talking about was a more … is a quick rapid sidewalk assessment, and now I know the actual visual rapid assessment is more in depth of each building. Yeah, that's just didn't seem … that's not practical on a citywide level, [with] that type of method. So we had to come up with something more realistic.

Zoner: Yeah, from what we were told, we would do more of the sidewalk method

Lanning: I mean some of the teams went inside the buildings, they spoke to the owners of the commercial building I don't I don't want … I mean that's fine. They did that and I normally would say like don't even bother. I just don't want to bug the bug people just because, you know, they're gonna start asking questions, or "Why are you looking at my building?" and then people are gonna get a little bit defensive and we don't want any type of conflict or anything like that. So that's the hardest thing, is like, especially when we're dealing with private homes and all and … So we kind of have to do it kind of casually and then if someone does ask like, it's gonna be hard to convince them, but for them to think that we're not specifically noting down there building. [It] is not attached to the owners [or the] people living there. It's just the GPS coordinate with the type of build in there and that's it for the assessment. So you do need some type of, like, this is actually very important. It's like … you do need something that the team is going out [to] have some type of documentation saying what they're doing and if you can get permission from the city authorities, or something to do that … that helps a lot because people are gonna ask questions. Seeing you guys are seeing people out there walking around, you know tablets and all that. So that kind of … we got one from the mayor's office saying, like you know, they're doing this for <incoherent> and blah blah blah, and that usually satisfied most people who were asking questions. So hopefully the local company would be able to have a contact somewhere that's doing that, and it doesn't … best it was from the city government, but it doesn't have to be. If it's some local organization that people may know of, the general public may know of that that would be fine too.

DeBare: Can you going into more detail about you before you mentioned and so the model, like with the results from the model, how does that make the … what do you do with that information to make the city safer?

Lanning: So this program was specifically looking at the response, so the city's ability to respond to an earthquake. It wasn't necessarily, though it could be used for mitigation purposes, but [for] mitigation purposes, there's gonna be limited [impact] because it's not specific buildings. It's gonna look at so … Let's first talk about the response. So this response was, well we have all these <incoherent> urban search and rescue teams in the city. Like, is there enough? Is there even remotely enough? What do we do? you know … How many … how many build instructions do we expect to lose and how many people are in casualties there are? How many trapped people are gonna be in buildings? This is … no one really knew. So this now gave them at least the starting point, a number of like potentially what neighborhoods will have higher concentration of collapsed buildings, and therefore trapped people, and then you can figure out like can we … All cities are gonna have way under not enough search and rescue teams. It's always a problem. Here in California, it's no one is … no one is really trying to do anything 'cause no one knows how to do anything, but there's never not even nearly even respectable amount of to meet the needs, and so I'm .. and then these other countries, developing countries, are going to have huge astronomical problems, and so it basically shed light on like there needs to be more teams. They need to be able to be mobilized more effectively or efficiently, quickly because the people that you know 'cause they have… The first two days is always the most important time to rescue people, so you need to really be efficient on where you send your you search teams 'cause lot of times search teams, they go, they sweep the city back and forth checking all buildings and they start tagging the buildings with the spray paint, saying this building has been searched for occupants. We didn’t find anything, moving on to the next building. So it's really up to the local authorities to figure out if you want to change that system, if you know ahead of time where you're gonna have more trapped people, and so that could … that could dramatically increase your time if you're … you're concentrating effort … efforts in the highly dense areas, where this trapped people. You can pull out more people in those first 48 hours and save more lives. So it really just comes down to that. Also, it gives them an idea about medical facilities, and things and so like, how much medical need is going to be coming into the city? For mitigation, It can give you an approximate idea on how much funding you need, 'cause you would now have a a total number a damaged buildings, what type of buildings they are. Are they' all masonry buildings or concrete or timber or whatever? And so you have an idea of that but that's … that's about where on mitigation side will stop, 'cause mitigation is gonna need a little bit more detailed information. Yeah 'cause at that point, your … your results are gonna just show you how much damage in residential buildings, how much damage or commercial buildings, and how much damage in government or industrial buildings. So it'll just be broken down to those levels, but obviously you can break it down to a more defined … define level. You can bring it down to single family homes, versus multifamily apartment buildings. That might be able to be more little bit more useful in the mitigation side, so the more … the more information you collect on each building, gives you a little bit more detail, um um, on your results, or a better breakdown on your results. <pause>

Zoner: I just want to add that the company we are working for is also mostly looking post-earthquake. So they're developing a website that will let you know which roads will be blocked so that first responders can access the streets more easily, which I think is really

Lanning:Yeah that's that's … that's very … I was gonna say, like, in San Jose, Costa Rica it's .. it's in an interior valley, but it's kind of high. It's about 4000 feet in elevation, and it's a pretty mountainous area, so the rivers are pretty major, like rushing mountain rivers and so [they] carve out deep canyon[s] so that the city is divided into this deep canyons and even from one side, like, even getting from the airport where I was living, you had to drive the long way around just get to the only bridge, that I would cross and then come back down. So [if] those bridges go out, that's a huge problem and that also gave them an idea because we did separate side project of assessing some of these bridges, just for that reason You can't cross those canyons without … without an actual bridge, and so we needed to know if certain neighborhoods are gonna cut off from rescue efforts. There are air support to bring people in and rescuers, and food, and all of that, so that is definitely something hugely important. Obviously that, that would have to be looking at that specific infrastructure, things like bridges and roads would have to be side add onto the projects. You wanna obviously collect that in your own building stock data, so yeah. We also did a side one looking specifically at the hospitals too, and that was a little bit more detailed. We actually went into the hospital and did it. That was using the more detailed visual assessment. <pause>

DeBare: Matt, mind if I tangent to a different topic

Zoner: No, I don't

DeBare: Okay, so one thing that the organization is doing is a bit of a drone program. They are gonna try to automate drones to fly over the city after an earthquake to take pictures

out from high altitude to get a good before and after picture to see where the damage actually is.

Lanning: mhmmm

DeBare: We noticed that on your website there was, like a coming soon project that had a picture of a drone looking at hospitals do you have any…

Lanning: yeah

DeBare: …information?

Lanning: That's something I've been trying to figure out. It's been a pet project of mine for a number of years, is to … is to do damage reconnaissance remotely with using drones and all that and so it's … There's a project that .. that I was working with through FEMA with NASA, as NASA has … this is kind of parallel to what I was going to do with drones, but they are this ISAR, which is a interference, like, synthetic aperture radar. [It] is this huge satellite array system that's this center .. no, it's not an array. It is just a single satellites that has these huge canopy of this huge reflector that unfolds, and then what happens is it shoots down a certain radio frequency off of the city, and then it reflects back on this certain image, and then, post earthquake, theoretically, you'd be able to send down the same image down and reflects back a different image and then they overlaid images and you get an interference pattern of the areas that have changed since the two, but the problem with that is that your tree canopy's could have foliage or no foliage depending on the seasons grass could have been moed, and so there's a lot of different changes that we don't really care about that needs to be filtered out. So you have to use AI and machine learning to try to weed all the other insignificant information out and then once you get down, when you boil it down, then you start to get the actual building changes and theoretically that should show you. I got a heat map showing you where the damaged buildings are. Now using drones to get could also be done too because, this is the thing that I've noticed. This is a need that has been around for many years, ever since, like even back in the mid 2000s during Bande Ache’s earthquake <incoherent and all that, but when you think about Bogota, Colombia - major metropolitan area - even LA, which is under my jurisdiction … my area of responsibility is like you know like, when a major earthquake happens down there, how the hell are we gonna find out where all the damaged buildings are? It is huge problem, and so you can use it … you can use aerial photography. It doesn't have to necessarily be drones. It could be the helicopter and all that, but right now they're gonna be as it stands right now, the method would be someone is going to be in that helicopter flying around, and you're flying around LA metropolitan area, which is like half size of Connecticut. How are you gonna … how the hell are you gonna find where all the buildings are, document that down, send that to the right people, who need that information, in the hours after earthquake? It's just such a huge area to keep track of all this information is gonna be just not realistic. That's why you need something that like, LIDAR that would be able to scan … scan the buildings and assuming you have a have a lidar data set from before the earthquake, you can compare the two. But yeah, so anyways, that was something I was trying to do on the side to try to get some funding and things like that to get going. [redacted]

[redacted]

DeBare: So how would you connect this. How would you get this data that's more accurate than these hazards?

Lanning: Well, I think if you're getting more information on the types of buildings out there. So this is going down to like back to when I was saying where you could sample more, you know you increase the samples, and you keep increasing your samples, doubling the number of samples you take. At a certain point, it starts to taper off your accuracy. It doesn't … it doesn't give you much bang for your buck, but if the machine's doing it automatically, but who cares? That’s what's that's the best thing about machine learning is: to do repetitive processes and they can do you know you can do 100 thousands of judgment things, and so I I'm saying it's like if I can walk down a street in LA and with relatively confident, let’s say with 80% accuracy, I can say that building, it's just knowing the construction types in California really are … It has a crippled wall or it has soft story blah blah blah and then … and then put that in there, just based on looking at it from the street and the satellite image. And that's it. If I can do that, then you can train a machine to do the same thing. You just have to run samples. You may have to, like you know … it's like the … I don't know they guys have it out in Massachusetts, but here we have these self driving cars [redacted] It's like, every day they're just driving, just so many of them. I swear like 10% of them at least and there's a driver in there, and all they're doing is driving around and it's taking note of what the driver is doing, if there's someone crossing the road, and it's getting all the samples that it could use to start interpreting in the future, and that's what you would have to do. Someone would have to go through all these photos and make the call; This is a wood frame building with a cripple wall or whatever and then you start doing that. After several 100 times and there should be some progress on that machine program being able to make those judgment calls in the future.

DeBare: That can they conduct these sidewalk rapid visualization seismic risk assessments automatically?

Lanning: Eventually, but you remember you just have to make sure that whatever country you're in, it needs to be fine-tuned for that country. So you can't just take … all this effort that you did in one city or one country… You can't just say “oh let's do this city.” You're going to have to do this whole machine learning practice again in a new region and the [cuts out] construction type it is different so you need to fine tune to the region. [cuts out]

Zoner: Josh, do you have anything else for him?

DeBare: [cuts out] and we wanted to thank you for your time when your expertise. It's been really helpful and you have had some really great information. I think will help us. Would you like us to send you a copy of the report once you finish it, so you can look over what we actually did and how your insight helped us on our project?

Lanning: Ya, that would be a great. I am assuming you guys are all structural or civil engineering students is that why?

Zoner: Nope. I'm an electrical and computer engineer.

DeBare: I’m a computer science major

Lanning: So how do you to get into earthquakes assessments?

DeBare: So we have, at our school … there's an interdisciplinary project that will take a bunch of people from different majors, and it's supposed to teach you social science to engineers. So we do things like … we do interviews, we do observation studies to solve a larger problem

Lanning: OK

DeBare: So ideally you're not supposed to have any technical knowledge, although for some things it kind of bites people that they don't have any knowledge. For instance we would need someone to actually make the assessments, like the criteria. We would need to get someone else to do that because we don't have any expertise in that. That's where the research and the interviewing and all that comes in.

Lanning: Oh I see but you're looking at putting this into practice in Romania, though right?

DeBare and Zoner: Yes

DeBare: That would be with our collaborators. The person who runs the organization we are working with is a civil engineer and is one of the leading seismic experts in Romania. He has been on on NPR. He has been published in the New York Times multiple times.

Lanning: Yeah

DeBare: And so he basically provides all the expertise to us and we do a lot of the … seeing who else has done this and giving advice to program. We're going to be doing probably some kind of geotagging. We're going to be looking at these buildings virtually and seeing what the homogonous zones would be In Bucharest.

Zoner: Yeah we're also looking at the recruitment side. So he doesn't really know how he's going to recruit. He wants to recruit people from the university Bucharest civil engineering students, like you did. So he doesn't really know how he wants to do that, so we're going to help him on that thing too.

Lanning: Cool

DeBare: It's really interesting because they are so many of the buildings are old and they have never been looked at and with mistrust, no one lets inspectors into their building because of based on the communist government, there's been so much mistrust in the government that if someone goes into a building and says "This is unsafe. This is going to fall in an earthquake," then what happens is they get a giant red dot on the building and property value goes down and it could result in them being homeless as they need to fix it then.

Lanning: That is … that is a big that is a big concern, even here is that the real estate industry will be very angry if … I honestly tell you truth. What I would love is to have an map out and to see the risk assessments city wide, and if you're buying a home then you can look at that risk map of the property you are potentially buying. But I know the real estate agent pissed but there's already soil maps out there. People know where the [incoherent] zones are and there's nothing they can do about that. So dealing with the building itself is a little bit more … it's more personal because it's dealing with the actual building rather than land sitting. But there's gonna be law suits challenging it. Like this is that public information available because people are going to lose value of their homes. They're not going be able to sell them if you find out your building is dangerous and on bad soil. [incoherent]. But I think that knowledge needs to be out there 'cause that's the only way to actually get people to stop building in bad areas or building poorly [incoherent] is to start identifying these dangerous buildings publicly. But that's just me personally saying, not my position but that's what I would love to do is to publish … have some GIS maps online where people just go there and find out.

Zoner: Yeah. I completely agree with you that the safety of every civilian is more important the financial gain from building crappy buildings

Lanning: [incoherent] they're buying in a flood area somewhere and people buy you know get flooded and they get insurance money and they and they still live there. So it's just repeating the process and… I'm glad I don’t work with the floods but I mean that's just that's just must be a depressing area to keep living … just seeing over and over. People say, don't quote me these numbers, but they say over half of them claims for floods are all repeat. Half the claims for floods [incoherent] they're just repeat over and over and over and somehow that cycle is got to stop and this is you know.

DeBare: Yeah so one thing our collaborator is doing in Romania is they are making a map and they're putting all the dots on the buildings that are really unsafe and they don't have enough people to actually do that with resources. So that's why they're doing to look at the sidewalk assessments, and then another thing that they're doing is there's a law that the government is allowed to acquisition any construction vehicles after an earthquake to help clean debris up. So they are getting a database of where these vehicles would be and what the government could actually use so the government can actually coordinate this after an earthquake.

Lanning: That is a law there. Oh really. I guess it could work there. It won’t in all countries doing that.

DeBare: But yeah yeah thank you.

Lanning: My pleasure.

DeBare: we will send you an email asking for a follow up about the person

Lanning: Alright sounds good.

Zoner: Thank you very much for your time.

Appendix G: Radu Lupasteanu Interview Transcript

Zoom Interview March 16, 2022, 11 am EST

Schultz: We are now doing the dictate mode and we have started recording. Just want to verify with you one last time you had a chance to read it to review confidentiality statement and you agreed to this recording being used for our project and being reported at all for this interview correct?

R. Lupasteanu: Yep

Schultz: Perfect, thank you keep on going!

R. Lupasteanu: So we had the when we had there in Albania we had the opportunity so to put into practice what we already theoretically knew according to our Romanian technical regulation it's a methodology concerning the technical assessments of buildings after earthquake and we saw that theory is very good but when you are put into position to operate very quickly in such difficult situations things would be improve and based on our we sent to our ministry and development of public works a proposal but until now the things are in terms are in terms of normities of regulations. We've also had this years on local area yash we had some joint actions together with our colleagues from the state inspector for emergency situations. Something like less perfect like like that, but only as the simulations we had 30 people from Romania had this opportunity to put in to inspect and to practice and to see what's happening and how the procedure of the traditional assessment could be easier perform. And from this point of view, I think the the methodology proposed by Vlad firstly in his paper could be easily adapted as a solid instrument for the second phase of evaluation of assessment of the buildings after the earthquake this would be the place where the proposed methodology of the paper could be easily adapted.

Miragliotta: Great! Yes! I guess we could jump right into things so you touched on a little bit but on in your own words could you describe the purpose of seismic risk assessments and what ways do they help improve earthquake preparedness?

R. Lupasteanu: The first purpose in the first stage of inspection after technical inspection after the earthquake is to identify buildings that are certainly sure and buildings with some that are collapsed the second theory and the third and more difficult part of the buildings are those buildings with various degrees of deficiencies after the earthquake. But our normaty are technical regulation are concerned mostly from an engineering point of view to the technical assessment of the structural performance of the building. In real life after the earthquake the first concern comes from the aptitude of the building to be used to be habitable or not so those technical parameters those technical performances of the buildings, depending on the derogations, should be translate in the mind of the assessor also in the best in this characteristic this is the first the first in one hour after the earthquake the local authorities are mobilized in order to firstly to evacuate people to do the rescue or activities and so on and after that to see if the structures still can be used or if there are various degrees of doubts about it. And people should be remote relocating where appropriate. After that after one day, two days, three days necessary for people to be accommodated in other locations where is needed, the second sort the second kind of technical assessment is to be preformed and to see for those buildings that were without at the first evaluation to see the degree of damages structural damnages, non structural elements that are affected and could produce risks accidents and could be as sources of risk for habitants. This second evaluation is a more deeper one, and also the final the final target the final scope of this evaluation is to recommend whether the building can be used even with some local restrictions or people should be removed find another location. And also to advise the owners about some rapid relatively simply technical meaning meanings devices to to make supports to debate short. For example, in Albania, in we assessed about 300 buildings in four days so there is also a time indication in this activity it's very difficult to approach to turn inspections per day but also but also there are some also some human aspects that have to be based near the assessor maybe there should spend some time to count the population of people to make them confident in their life in the future from those almost 300 buildings, somewhere above two hundreds were not very severe damaged but from the point of view only 150 could be used future days almost 50 not because of structural damages but nonstructural elements finishing works and are the roses were advised to be removed until the immediate measurements to make things safer had been performed. Also I'm speaking now on the basis of our normative regulations, that the time being limited, too many paperwork is not appropriate for example our normative refers to some placard's to some plastic boards that should be attached on the building where relevant information should be filled in. You you don't have time for this and from the first day in Albania, we left this methodology and we we took three sprays colored sprays one green, one red and, and one brown the marked with green a safe building with red non safe building and with brown, a building really that should be expertized or should be further assessed. And that was the main conclusion after our experience there.

Miragliotta: Great so you mentioned some of the time challenges with paper work, what are some of the greatest challenges related to seismic risk assessments that you've seen or experienced?

R. Lupasteanu: Well firstly the people who who conduct this assessment should not be alone. The crew should be opposed of 2 persons and that are structural engineers and are possess solid experience and trained before in this view. There, in Albania, we were also were conducted together us or with people from the City Hall that one or two people that showed us the way, he showed us the buildings before we came there they already have preformed the first evaluation and they already knew the first evaluation where they recommended that the building should be left or sure to be used. And we mostly went to those buildings where they had some doubts after the first evaluation. So people from City Hall should conduct the the specialist there they have to be two because anyway one formula should be filled in when you go there and we didn't encounter any risky situation but you never know. Being too nice and you have the possibility to consult your partner to find the most appropriate result of what you are seeing there. Also I recommend that the crew, in Albania we were teams from Romania, from Italy, from Poland I think, from United States, form Israel as I remember. Now and very useful is a lantern and a small hammer to remove the plaster the when you have cracks and to see that the effects on the concrete or masonry structure of evidence in order to make the clear image in what you are seeing there.

Miragliotta: great so just to kind of probe the challenges a little bit more any like socio economic or political challenges particular that may be encountered with seismic risk assessments?

R. Lupasteanu: I don't understand your question

Miragliotta: Uh like any socioeconomic so like highly trained professionals can be really expensive sometimes, you mentioned structural engineers, do you see that as being an issue ever with conducting seismic risk assessments?

R. Lupasteanu: Ya we had some training sessions in the state inspectorate in construction in Iași, in Iașicounty, as you probably know, in Romania there are some uh in the field of construction building engineers there are some that test is some certified professions that acts in in the field site supervisor on the site on behalf of the client chief foreman an engineer which acts as the with as a quality supervisor for that seat from behalf of the contractor we also have specialists attested specialists, specialists they are dealing with the verification of quality of the design works we also have specialists the higher rank that are technical experts. Unfortunately the core of experts is quite reduced and the average age is somewhere over 65 but the others are younger, or more agile, and they are obliged by our regulation to take part in this assessment action after the earthquake. We invited I think three years or four years ago many of them especially those are acting as sites supervisors superintendents and then they came to our institution and they were given a short training, they were familiarized with the forms that have to be filled that they were familiar with the instruction procedures about the steps and uh things like this. But not very often these actions are happening.

Miragliotta: So something you mentioned was the regulations and the normatives that govern seismic risk assessments. Can you talk a little bit more about that?

R. Lupasteanu: Yeah I I told you about the one of the piece of this regulation methodology for technical condition assessment of construction after earthquake I show you here that time period you see if you don’t see I will send you one maybe if you are interested. This is the basic regulation after that sending that concerning nobody that tested people there are procedures according to what they are certified by authority institutions. The authority institution is the state inspector in construction for site superintendents and the the ministry of development and public works for word design verifiers and technical experts. Another another sensitive issue yeah I remember when you go there in the field as a specialist requested to take part in his actions, I believe the government would have to make a life insurance for those that are participating. But my institution offered us such health and life insurance there. Another another sensitive issue, even now in 2022, although ask from speculate had numerous other conversations with the local authorities, municipality, in order to provide those plastic boards to be attached from on the the structures and that's why they didn’t banish to remove this thing and that's why I would propose to the change things and to just use just spray colors to mark the degree of risk of the building

Miragliotta: yeah so you mentioned some of these changes, a lot of this surrounds rapid visual seismic risk assessments as opposed to kind of more traditional high device, high experience ….

R. Lupasteanu: no no no! high device that's stage you don't need high devices even though people people expectation is quite is quite weak they were inspected they were hoping for us to have for example thermometers and we explained them that it's not our purpose now to make the conduct a deeper investigation in order to find the the the precise for performances structural performances of the buildings our meaning now our purpose now being defined the habitability measure if the building in this stage after these two stages the third one normally inspected and technical expertise even some design work to propose the proper consolidation system works and and so on. The single crew they they possessed such sort that devices square meters were the guys from Israel.

Miragliotta: Yes I believe we have we've read the group from Israel's articles as well which is great so now something that in a lot of rapid assessments is important that type of building, I know in your article with Vlad, you mentioned that it doesn't matter what type of building at the assessment still works. Can you talk a little bit more about that?

R. Lupasteanu: Yeah, our normative regulations, as well as Vlad's paper, conduct the methodology of investigations taking into consideration some uh a few a few types of buildings reinforced concreate so buildings having the skeleton of things so bearing another type cell bearing masonry works so it is very useful to have some some previous checklists each of them appropriate to our each type of structure and to make a a library of possible damages that can be seen there and to make life easier for those who conduct the assessment there. So things should be prepared before a earthquake is produced and the assessors do their homeworks, they could they could be more more efficient. Based on such sorts of checklist sheet sheets. And the methodology for example in our in our regulation, we don't have a sound methodology for the second sort of technical evaluation and that's why I already mentioned here methodology proposed by Vlad even a little bit made more concise or more appropriate for this type of investigations should could be fitted into this place.

Miragliotta: So something we're working on is that second stage assessment isn't the regularly scheduled, I think it mentions yearly in the P130 norm, how do you think the rapid assessment should be adapted to be able to achieve that?

R. Lupasteanu: I think the most sensitive activity refers to the training of the assessors, but this is the most sensitive point of procedure and also because we are speaking about Romania in this case, maybe the legal provisions, technical regulations should be reviewed and should be adapted to the [inaudible] concrete and the effects that some of us already went there.

Miragliotta: So something you've mentioned quite a bit is the training of the inspectors. I know something our collaborating organization is looking into is utilizing volunteers who they give a training course to, to then assess buildings, do you think that's feasible?

R. Lupasteanu: Yeah why not, why not, why not? It's a good idea. I think - maybe - well I'm speaking now having in mind last two weeks [inaudible] Romania because of the war in the Ukraine and we saw that people are willing, very open to help other people when needed.

Miragliotta: That's great I know that using volunteers will kind of reduce the cost will still be able to do the preliminary settlement that stage one and then we can recommend the stage two which could be done by highly trained professionals do you think that this could be applied to a large scale? I know something like that Romania struggles with is having the financial aspects and having the time since the current code takes a lot of expertise.

R. Lupasteanu: So as I mentioned the most difficult step is the second step, the second evaluation and here speaking about costs, well, costs could be reduced thinking the advantages given by the Romanian legislation and regulation that obliged those engineers, attested engineers, to take part on these sort of situations and also as I already the told you, it is provided by law that state inspectorate in construction to take care of this type of activities. State inspectorate for critical situation also municipalities have also obligations in our laws to perform. So those difficult aspect or cost is to put these institutions and persons together. Not very costly, but someone should help the initiative.

Miragliotta: Great! So I'm curious have you and Vlad talked at all about that second stage of assessment? Is that work currently going on already?

R. Lupasteanu: Sorry?

Miragliotta: You mentioned the second stage of assessment is still in development have you or Vlad worked on it already or is it still in development?

R. Lupasteanu: No, no. Vlad and mine concerns are not focused on assessments after earthquake but our main interest domain is to conduct these technical assessments in normal conditions but you gave me a good idea and maybe I will renew my proposals to the state inspectorate of construction and why not to the Ministry of Development [and Public Works] because the state inspectorate of construction is under the command of the Ministry of Development and Public Works and the administration. This government agency is the principle responsible in Romania with management of this type of activities after in terms of earthquake to prevent the effects, the bad effects of the earthquake and to treat the consequences after the earthquake is produced. We mostly worked 90%, 80% of our work, in state inspectorate was concerned in to prevention activities because we checked the quality of projects by something. When I mean project I mean technical documentation, technical design and also we conduct a large number of inspections on sites to check whether the design work is respected or the technical regulations are also applied to the site. So all these controls, all these inspections contribute to as a preventive action in case of [inaudible] to reduce the consequences in case of an earthquake.

Miragliotta: So is the state inspectorate using those rapid assessments already or are they using the more traditional?

R. Lupasteanu: Yes, yes we use periodically I told you one time ago five years, in when we conduct some simulation interventions in case of an earthquake, we conduct such simulations. So we are aware about this regulation and how to apply in case of earthquakes.

Miragliotta: So I remember you mentioned that was in Albania, has it been done in Romania at all or?

R. Lupasteanu: Sorry?

Miragliotta: I know you mentioned you've done the inspections after earthquakes in Albania, has it also been done in Romania?

R. Lupasteanu: We had no earthquake in the last 20 years as I remember. So we didn't need to conduct such investigations in real terms. You know, there was one earthquake in 2019, in the end of November I think and after a week we went there. I proposed to my chief, my boss in state inspectorate, to go there and he approved he contacted the Ministry of Foreign Affairs and very quickly we managed to assemble 10 people, 10 inspectors team and went there to help them in that case.

Miragliotta: Great, that sounds great. I know one concern that we came across in our research is the weaker building codes before the 1940 earthquake and a little bit before the 1977 earthquake, do you think that still affects a lot of the buildings today?

R. Lupasteanu: From most of the buildings that were built before 1944 have collapsed in 1977 as I remember, I was 15 those years. Well, some of them have been consolidated, some of them still need to be consolidated. Some of them are already marked with a red circle, probably you saw, that means that the building is unsecure even for normal use more than that in case in urban earthquake. What is built now after 2000 let’s say, theoretically should have very few problems because the normative regulations, the standards increased the coefficients of safety for the building and also the control regulations have been enforced more than they were used in the 90s, let's say. So, well, it’s difficult for me to make [inaudible] but I should be quite secure that most new buildings will have a normal contact a normal life in case of an earthquake. Still, we have a lot of [inaudible] buildings for example that were built even in the 19th, 18th century and a lot of work should be done there and also to those buildings that you already mentioned built between 1950s to 2000, let's say. We still have some records in state inspectorate and city halls with a block of flats that were built at the beginning, most of them, ‘60s last century which are quite sensitive now to this type of input.

Miragliotta: So you mention the red dot buildings and we’ve read all about that and we've had fun reading about it. I know some experts estimate that some buildings that need to be, that are in that vulnerability class, that are red dot buildings they haven't actually been marked yet or they haven't been assessed yet. Do you agree with that estimate and what are your thoughts about it?

R. Lupasteanu: Could you repeat please?

Miragliotta: Yeah so a lot of experts estimate that some of the buildings that have been red dot buildings that are high vulnerability buildings -

R. Lupasteanu: That are vulnerable buildings? What?

Miragliotta: That are high vulnerability buildings haven't been marked yet, they haven't been assessed yet.

R. Lupasteanu: Yes, yes they are right. People do not know for sure their structural reserves, their structural performance. Because to conduct an expertise, technical expertise, needs quite a lot of money. Things became more complicated in case of the owners’ buildings. So here I appreciate that the government should finance such type of technical expertise because it's very very difficult to make people to speak the same language. Some of them could afford the money necessary for expertise, some of them could not afford, some of them are waiting to, some of them are not waiting to, and things became complicated.

Miragliotta: So I know one thing in our research we found is that the people of Romania, they have a high mistrust of the government due to the treatment of the communist regime from the 40s to 89. And some building owners might not let the government go inside their home or inspect their home, kind of what are your thoughts about applying rapid assessments to avoid those obstacles?

R. Lupasteanu: Well, people is not very anxious to go to the doctor, to the medic and in case of construction there [inaudible] disposition is even lower but we have some regulations. Law number 10, 1995 concerning quality in construction that theoretically, and sometimes even practically, obliged to owner to conduct such assessment one year, each year, one per year in normal conditions as you probably saw in Vlad's paper. The degree of concerning is on three levels. Normal assessment, the special assessment, and some intermediate stage. As we, but I was, in the last 19 years, I think 15 years, I was chief of the county inspectorate in construction and when I came in this institution and I went deeper to the Romanian legislation I saw that this regulation that the regulations concerning condition assessments are like Cinderella, are on the last place in a concerning topic related to structural safety. And step by step, more public buildings, schools, theaters, public buildings, I think I convinced them with good words with showing them the regulations and in Iași at least. Quite a lot of technical assessments I think, somewhere 20%, 30% maximum of the buildings are regularly assessed in terms of condition. But I don't know the rest of the country how things are going [inaudible].

Miragliotta: Great! Well, this has been amazing, thank you so much for your insight. I don't want to hold you up too much more, so that's it for me, Kevin do you have anything or?

Schultz: No, I think that was amazing, so thank you for all your explanations and your insight, it's been really valuable.

R. Lupasteanu: good luck with your work!

Schultz: Thank you so much as next steps go, we can send you our final report if you like. We're obviously struggling a little bit with travel to Romania given the current world situation so we'll see how far this project can go as it stands currently, hopefully we can conduct some assessments in some way or another but we'll see.

R. Lupasteanu: Ok if you come to Iași city, I'd be happy to meet you.

Miragliotta: Thank you so much!

Schultz: But if you like we can send that along and also if you have any questions for us afterwards feel free to shoot them along and if it's okay with you we might do the same.

R. Lupasteanu: Ok.

Schultz: Perfect, awesome, sweet, thank you, awesome. I'm going to end my recording then and thank you so much it’s been massively insightful.

R. Lupasteanu: Bye-bye

Appendix H: Vlad Lupasteanu Interview Transcript

Zoom Interview March 18, 2022, noon EST

Schultz: And then just for the recording and it's sake, you got to read through the interview confidentiality statement and consent to a recording and the interview itself, correct?

V. Lupasteanu: Ok, yeah.

Schultz: Perfect, awesome, sweet we can get started then. So would you mind giving us a brief introduction about yourself, some of the previous work that you've done?

V. Lupasteanu: Yeah, so my name is Vlad Lupasteanu, I'm a lecturer at the faculty of building services and civil engineering in Iași. I'm a civil engineer since 2007, my main academic profile, let's say, focuses on the management of quality in construction and on the technology of carrying out construction works, but besides the academic career, let's say, I'm also part of the industry because I run a company which is focused on assessing building condition assessments on buildings, all sorts of buildings, we also have a certified laboratory for testing construction elements, technical expertise and all sorts of technical documentations which are necessary in our industry.

Schultz: Cool, thank you that's all great, that's awesome. So as part of the help that we're giving to Re:Rise, we're trying to help them gain a better understanding of where risk is in Bucharest. So originally in our email we detailed how we were going to do some rapid visual seismic risk assessments and this would be standing outside the building and visually inspecting it to get a very brief understanding of if the building needs a more in-depth analysis, right. Unfortunately due to the world crisis that's happening right now with

Ukraine, it seems unlikely that we will be able to physically conduct those tests in the near future. So as alternative we're looking into a more virtual means of doing that through satellite imagery, geo-tagging, and more publicly available photos to generalize things. Could you talk a little bit about various buildings that exist in Bucharest and especially in the –

V. Lupasteanu: As a matter of fact I'm not very familiar with the, let's say, built environment in Bucharest because I'm located in Iași which is the second largest city in Romania. But as a short introduction, let's say, regarding the necessity of assessing the technical condition of buildings, obviously this field of our industry is very regulated, yeah? So we have a couple of norms, we have a couple of normatives which are introducing and stating what is the approach that the technical bodies or specialists should have when they are assessing the condition of buildings. So in this particular manner we have a norm which is known as P130 from 199 which is basically the general norm which presents the way in which buildings should be assessed, all their conditions should be assessed. So this norm doesn't focus especially on the condition of buildings after an earthquake hits, yeah, so every building in Romania has to be checked at least once a year. So there are at least two types of assessments, yeah, the first one is a simple or basic condition assessment which is very similar to the classical building condition assessment approaches which are available in the literature around the world, while the second one, yeah, is a more precise one, is a more complex one, very similar to the, for example structural health monitoring approaches, I don't know if you are familiar with them in any way, so there is SHM, they are also known in the literature, so that the special monitoring of the condition is done with specialized tools with devices, yeah, which are monitoring different parameters of the building, like displacement, vibration, accelerations, temperatures, yeah, and so on, the list is extremely long. So we are already assessing the technical condition of buildings, at least in theory, once every year. The problem is that not all the owners of the buildings are doing that, yeah, because this is the main responsibility of the owner of the building, yeah, so just like you have a car and once a year you take it to a shop and you check if the brakes are ok, the finals are ok, and the emissions are ok, and so on. So from my experience, probably less than 5% of the buildings in Romania go through this periodic check, yeah, even if we talk about the basic building condition assessment which is done by visual inspection and we have simple measuring tools. So this is the first part, yeah? Then if we are only focusing on the seismic response of buildings, we have another very very important code in Romania which its name is P100, yeah? So probably you've heard about it. P100 has the first part, so P100 part one from the latest version is from 2013, which is the design code for new buildings with respect to the seismic action, yeah, so this is basically the most important code that we have in Romania which is in a way close to Eurocode #8 which is the code for seismic design of buildings available at European level but obviously we have a lot of particular aspects since Romania is one of the most important countries in Europe with respect to the seismic intensity. But this norm only applies to new buildings, so if I want to have a new building I have to follow the regulations given in this norm. For existing buildings, there is the third part of this norm so P100 part 3 from 2018, which is designed and publicly issued by the Romanian government, for evaluating the seismic safety of existing buildings, yeah, so this norm has to be applied when the performance, the seismic performance of an existing building has to be assessed and this is usually done by the so-called technical experts that we have in Romania, which are some very, let's say, important factors, yeah, civil engineers which are acting in our industry, they have to go through a certain examination, yeah, in order to get the certificate and they are the only ones who are allowed to carry out these technical expertise. The outcome of the technical expertise is to rate the building with respect to its seismic safety. So basically we have buildings which are built, I don't know, starting from the 14th century up to modern ages, and we want to know if these buildings are safe or not, yeah? And there are four classes to classify the buildings with respect to the seismic risks one, two, three, and four. If the building is in a lower class for example the first and the second one are the most dangerous ones, it means that the building if the design earthquake hits it will go through severe damages and it will probably collapse or the life of the persons who are operating the buildings is in great danger. If it's in the 3rd or the 4th grade it means that it will go through certain damages, but they will not be important structural damages, yeah, it will be more at the level of the non-structural elements and the life of the people who are using the building is not in great danger. So this is the big picture let's say, yeah. If you are only focusing on the assessment of the buildings immediately after an earthquake hits, yeah, a certain region of Romania, we also have a norm, it's not actually a norm, but it's more like a methodology which is being applied, which is regulated through another norm, yeah, another code which is ME 003 from 2007, yeah. I don't know if you can find these pieces of legislation in English, yeah, but if you need any, I don't know, translation, any correlation between them maybe I can help you with a few, let's say the main ideas of these norms. So this guide ME 003 is a methodology which focuses on the assessment of the buildings immediately after an earthquake occurs, yeah, and I don't know if we have time now to go into further details, but it basically states the way in which the inspections should be done, who carries them, yeah, what is the approach and so on.

Schultz: Yeah, so we've been doing some research on the barriers to assessments and it seems like from our research that people are apprehensive or that many residents wouldn't

want their buildings inspected because they could result in like a decreased property value or invasion of privacy and other barriers you know could –

V. Lupasteanu: So basically you're talking about the inspections which are carried out outside the occurrence of an earthquake, yeah, like maybe once every five years or something like that.

Schultz: Yeah so, 'cause you said you worked in the industry of doing these inspections, correct? Have you faced any of any barriers with being able to conduct –

V. Lupasteanu: Well it depends because usually we are working as a private company, yeah, so basically we have some building owners who are hiring us in order to inspect their buildings, yeah, so usually people are very responsive to this check that we do because they are hiring us, yeah, so there were maybe some cases when, I don't know the people in the high levels of the company were the ones who were hiring us but then we had to deal to interact with people working in those facilities or maybe administrators, yeah, and guys who are responsible for the maintenance program and so on, and yes they were in a way probably I don't know, not happy to see us there or maybe they were thinking that we are trying to prove that they didn't do their job correctly, yeah, especially for those who are directly responsible for the regular maintenance programs, yeah, and simple repairing works and so on, yeah. So yeah there were maybe some local cases and some few cases when we have like a sort of negative reaction from them but usually since they are the ones who are hiring us to check if their building is behaving accordingly there we didn't have problem with that yeah, but remember the fact that we were especially in probably 90% of the cases working with private entities with private properties, we didn't inspect or survey public buildings, yeah, or buildings who are not directly operated by a certain company or something like that yeah that makes sense that makes sense we've been looking at a lot more of some public buildings or community owned buildings as we focus in on

Bucharest have you had the opportunity to do any of the large like residential buildings as part of your assessment processes the privately owned as a you know a large we had a couple of large extremely large projects that we well done probably since in the last five years most of them were private property just like I told you but also some of them were belonging to the public authorities or bodies or agencies one thing that we have seen is that if a building is owned by private person or a private company the interest of the uh owner is much higher in having a safe building yeah so the buildings which belong to the public to the public property let's say after the to the agencies or any other type of public institutions uhm usually their interest is much lower because there is a higher here arkie which has to be followed the bureaucracy is extremely is is far more complex than in case of public ownership in case of private ownership and things are usually moving at a very very lower rate compared to the brackettville properties yes but during the last ten years that let's say we've done a lot of building condition assessments some of them have simple inspections the other ones being more close to the structural health monitoring basically we focused on measuring the displacement of the buildings the eventual settlements different variations in terms of environmental temperatures conditions yeah uh yeah the the sound proofing of the building scan and the list is much larger so I don't know if I if I I've answered your question yeah I I know that you could as a good answer I just want to understand your experience with the you know large residential complexes and if I'm focusing more on the private let's say building residential building complexes which one which probably are the ones that we have dealt most with yes some of them are really interested in in in uh checking the condition of buildings every year in order to see if there are any damages which may prove that the structural system might be in a certain level of uncertainty they are interested in also programming the maintenance works in order to ensure that the stephi in use conditions are satisfied Are you sure in order to check if there are any problems with the building surfaces because this is also very important component of any building turn networks yeah yes natural gas electricity and and and so on so some people especially those who are willing to pay for this kind of service they are really interested in in in playing on the stage side yeah so they want to feel safe in their property and they're willing to pay for that and one way of feeling safe is carrying out this let's say yearly building condition assessments the problem is that I told you the beginning there is along in Romania I have the the the first norm that I've presented to you be 130 which is like a law technical law says that all buildings have to be assessed at least at least once a year and if we are talking about private properties but the ones who are in contact with the population let's say like malls shopping malls like office buildings in order to so respect to to follow the regulation they are contracting specialized companies just like Howard is who every year comes and for a couple of days uh runs Lucy this technical inspection of the building and after that we are issuing we are preparing a report in these these reports we are presenting the entire list of damages that we have identified we are presenting their possible risks you know where is the risks that may arise from these damages and unconformities and also we are proposing some methods of repairing the damage yeah also run different maintenance programs or even strengthening or rehabilitation yeah it depends from one case to the other but in in this purpose this methodology of running the building condition assessment is not very precise in Romania in fact the norm doesn't state a very clear methodology of running this this this assessment and This is why on a national level it is very frequent to see that different building surveyors are having different approaches yeah and this is for example one way or one reason why who proposed that molding yeah in that paper that you told me that you have saw in journal building engineering I think yeah we tried to to design a building condition model which can be applied to a very large number of buildings yeah with different functionalities with different purposes with different structural systems in such a way that the outcomes of these building condition assessment processes is the same one yeah or is similar at the national level but unfortunately there is there's not much help from the let's say government authorities or agencies in order to to change the norm this be 130 norm is actually very old it comes from 23 years ago and um uh it should be improved in terms of increasing its applicability in terms of making it more more easy to to to be applied for different let's say branches of our industry in order to make it more clear for people to understand how this building condition assessment is done with the general purpose or with the central purpose or aim to increase the safety level of buildings because this is the the the most important thing that guy is our activity so in regards to that your assessment you proposed sessanta pest assessment what makes that kind of different and makes standardizes the the process to make it easier for people to inspect buildings well first of all there is no standard method give them in the Romanian norm yeah so the Romanian norm only says that the condition of the building up of the buildings can be done by simple measurement tools or by visual inspections yeah it is the simple ECA or the complex one yeah close to the structural health monitoring but it doesn't tell you exactly how to relate to a building how to how to approach its components how to divide the building in in in subsystems how to identify the possible damages which may have uh any building how to assess their intensity how to assess their possible impact how to assess the risks which are generated did the people who are using the building yeah either direct or indirect users so they're actually there is no methodology Romania the norm only says that everybody has to do it yeah it gives some very general principles or guiding lines about this condition assessment but it doesn't tell you exactly how to do it yeah

V. Lupasteanu: so if for example, in other a lot of other countries there are standard methods of running the building condition assessments and a couple of them are also cited in our work because we have tried to see what other countries do in this purpose. In Romania there is no methodology and this is why we felt the need to propose it, because actually this methodology comes from the way in which we are already doing these building condition assessment processes in our company, yeah? So starting from the norm we have followed the general principles, the general guiding lines of the norm, and we have designed our own methodology, yeah? And this one, the best methodology, is very close to the one that we are already using, meaning that if we have a building, first of all we are analyzing the records of the building, yeah we want to see if they have the technical project, we want to see if they have any other technical documents that prove that the building went through certain changes throughout its lifespan, we want to see if any maintenance strengthening rehabilitation works have been done, and after that we do like a first inspection of the building when we are trying to see what are the components of the building yeah. Once we see the components we are trying to divide the building because if you want to assess a building it's very difficult to just look at it and decide if it's good or not. So if you want to make it more easy for you as a building surveyor, obviously you have to look on different slices of this building and this is what we are doing in the first part of our assessment. We are dividing the building in a certain number of slices, also depending on the degree of investigation that the owner proposes because sometimes owners are only willing to pay a limited amount of money and they say “ok I have only this amount of money I want to make a small or a short assessment of the building.” In those cases we are of course trying to fit the amount of money that they have and we are trying to make it as better as possible but usually we are dividing the building in subsystems and for each subsystem we are having like a register, like a collection of possible damages and unconformities that we have either seen before or collected from the literature, yeah? So at the beginning when we have started this activity we have read a lot, we have followed a lot of other BCA approaches which are available in other countries, and we have extracted like typical damages for each type of construction system. Once these checklists are compiled and put together, it's very easy for us to just pick the ones that we need for every building, yeah, because buildings are more or less composed of the same elements, yeah? So if you have like I don't know 200 pieces, 200 checklists that can select 50 or 75 for a building and just apply them. Obviously there are cases when minor, let's say adjustments, have to be done to each checklist but since we have this checklist it’s very easy for us to just look precisely on a certain building element and to see if there are any problems, any damages with that. Next, obviously all these damages which are seen, let's say, when you are investigating the buildings they have to be assessed and this is basically the most important thing, yeah, you know because you have to decide where is the possible impact hope those damages, yeah. Outside the seismic action, yeah, we are just talking about the normal condition assessment of buildings which is done every year, yeah, without focusing only on the seismic events. So you have to assess the possible damages or the possible effects of the damages and to decide upon the class in which you place the building, yeah, and this is the main part of the past methodology, is to analyze the building first of all we are dividing and we are analyzing separately the structural system and the non-structural components because in Romania since we are in a very important seismic region it is very useful to focus separately on the structural system because it is extremely important to be on the safe side with respect to the structural system. So each of these two main components of the building, yeah, the first of the structure of the system the second one being the non-structural components, are placed in a certain let's say degradation class, yeah, and depending on this degradation class we have tried to make like some standard recommendations or things to be done, yeah, either the operation of the building is stopped because the building is not safe for being operated, yeah, and this can happen also due to structural damages or to non-structural damages, yeah, and there may be some problems even if they are not coming from the structural members but because of them people who are inside the building are not safe, yeah, and we are recommending to stop the operation until the problem is solved. So yeah, this is the main, let's say idea, of the method that we have proposed to separately, first of all, separately assess the structural and non-structural components and then to try to place the building insert and degradation classes in such a way that building owners who are not civil engineers who are almost never familiar with the special terms or the special things that we are talking about in this industry. They just want to know what is the thing that they have to do next, yeah, is it safe to use the building, if it's not whether they have to do, and another thing which is missing in our methodology but we didn't try to expand it very more, very wide, is the economical impact because this is the next thing that comes in their mind: "ok my building is not safe to be used, how much does it cost to make it safe" yeah, but we are proposing, we are thinking about a way of adding another, let's say tool or like a add-on, to this methodology in order to include the economical impact of the damages, the economical impact of the level of uncertainty and {inaudible}.

Schultz: That's really great. So I have a question, you mentioned how visually from the outside of the building you know, you need a little bit more detail. One of the things that are you know, that our collaborator Re:Rise is working on is trying to do just visually from the outside from the exterior appearance. Do you see that as a method that would be unpractical or impractical to gain enough information to determine if a building will

collapse or not, or do you really need to go inside or divide the building up in order to understand if the building will collapse or not?

V. Lupasteanu: Now we are coming back to the seismic evaluation of buildings, right?

Schultz: Yeah

V. Lupasteanu: No it's not enough to just look at the building from the outside. No, it's just like, well, so the structure of the building is not only on the outside. There may be some problems, some very important damages which are at the interior structure elements which cannot be seen otherwise, yeah, so by looking only on the outside yeah maybe only I don't know 30 or 40%, yeah, close to the real thing, yeah, so there is a very important, let's say issue regarding the way which the inspections are done. It is advisable to check also the interior spaces as long as there are no important or let's say severe doubts about the stability of the building, because if we are talking about the stability of the building immediately after an earthquake hits there might be a risk for the surveyor to be, I don't know, injured, yeah, by the possible failure of the building once he goes inside, but usually if a building is very close to its collapse state you can see it from the outside, yeah. So there are probably 3 to 4% of the buildings of the cases where from the outside everything looks alright and once you go inside everything collapses on your head, yeah, so I don't know if it's advisable only judging respect to the small percent to limit your inspection only from the outside because you probably maybe in the case of not being able to access correctly the bill, yeah. So I think that it should be inspected as more in detail as possible.

Schultz: Interesting that you say that, that's really insightful. Part of the goal with exterior visual assessments that can be done very quickly, can you talk more about like the length of time it takes to seismically assess a building?

V. Lupasteanu: Yeah this is a very good question. Well, there is no right answer to that, the right answer is that it depends. First of all, it depends on the size of the building, then it depends on the extent of the damages, yeah. If we are only talking about this very quick seismic inspection which is done after an earthquake, probably it should take, I don't know, 15 to 20 minutes, yeah, for each building, close to that, in order to get a very let's say general picture of the building, yeah, to make an idea about it's possible damages.

Schultz: Ok and what would it take –

V. Lupasteanu: If you go inside, yeah, if you go inside then you want to look very closely to the structural elements, to the nodes of the structure if it's a framed one, to the link between the slabs and the wall so if you want to look to all the key points of a structure let's say, it will probably take you more in order to decide if there are important or damages or not.

Miragliotta: Yeah, so one thing you mentioned earlier was that less than 5% of the buildings actually do the once a year inspections. Do you think, kind of what are the obstacles with that and could this rapid {inaudible} assessment help {inaudible} percentage of building assessed, although it's not ideal with the detail of it.

V. Lupasteanu: I didn't understand exactly what you have asked, but probably you've asked me if it's ok to make a compromise, right?

Miragliotta: Yeah exactly

V. Lupasteanu: To accept more, let's say, a less detailed inspection in order to cover a larger percentage of the buildings. Yeah, this is a very good proposal, but in the same time I don't know if it reaches it's purpose, its purpose. The first part of your question was why do I think that only such a small percentage of buildings are inspected every year. Well the main problems are two of them. One is the lack of, let’s say, control from the governmental agencies, they should control the owners of the buildings, yeah, and they should tell them, “well you know maybe you didn't know but every year you should check your technical assessment, you should assess your building from the technical point of view.” But just a moment because my battery from the laptop is almost zero and I have to charge it, yeah excuse me {inaudible}.

Schultz: No worries.

V. Lupasteanu: I have to plug it.

{20-second pause}

V. Lupasteanu: Now it’s better. So the first reason is the one that the public agencies, yeah, the public, the governmental agencies who are responsible with the control of the buildings which is the case of the state inspectorate of constructions, they should go at least once a year to, maybe not all of the owners of the buildings, but maybe to a part of them, and to tell them that you know there's this norm which says that you should check your building, maybe you didn't know about that, yeah, maybe you didn't think that it was compulsory for your building, yeah, and the second reason is that a lot of building owners are not willing to pay for them, yeah, because this is a service, a technical service which obviously costs, yeah, and they are not willing to pay they don't see the purpose in that, yeah, why should I pay, I don't know a certain amount of money for someone to come and look at my building and tell me if it's safe or not, yeah. I look at it, it looks fine, I'm fine with that, I feel safe, yeah, please go away, and this only happens because the state doesn't put them to do that, yeah, just like you pay your taxes, if you don't pay your taxes, yeah, once a year for your property you will get a fine and in the end you'll have to pay a lot of money. You won't be able to sell it, you won't be able to rent it, and so on. Similar tools should be applied also for this component, for this assessment, yeah, building owners should be in a way, let's say, forced to do it because it is in their own interest, yeah, and in the general interest because we all want to have a safer environment and safer kind of buildings in our communities. So this is why only such a small percent of – but the trend in the last let's say 5 to 10 years is one that gives us hope, yeah, because every year more and more building owners are trying to find a way in which they can include these components, these inspections, in their annual, in their yearly budget, let's say, in order to make sure that everything is at least visually ok, yeah. So yeah, this is the answer to the first part of your question and for the second one I don't think that we should decrease the level of the investigation, the deepness of the investigation because if we go below a certain level the results may be too uncertain, yeah, they didn't reach their purpose, we do this activity without having a strong or important outcome out of it.

Schultz: Awesome, sweet, thank you. This has all been so insightful and has really, you know, it's really going to help influence the further research we do and the work we do, so thank you so much for your time, I don’t want to take too much of it, so do you have any other further questions for us?

V. Lupasteanu: Well, I don't think so. I'm really happy that there is an important interest from you about the safety of the building in Romania and especially about these approaches that we have, these methodologies, of assessing their condition and I really hope that things will change, yeah, at least in the following five to ten years, in order to make us feel safer in our buildings and in order to, maybe this building condition assessment can be a very important tool in selling and buying the properties just like it is in other countries, yeah, in so many other countries you cannot sell or buy property without knowing exactly where its technical state, let's say, yeah, unfortunately in Romania we don't have this thing which must be applied when properties are sold or acquired. I really hope that things will change in a couple of let's say, five to ten years in order to make it more safer for us.

{casual conversation continues for 2 minutes}

V. Lupasteanu: How long does this project that you have is it only for this year or do you plan to extend it more?

Schultz: So we've been working on it since the start of this year end we were physically as students at WPI are going to be working and helping Re:Rise for about the next 7 ish weeks and then Re:Rise is gonna be continuing obviously as an organization and WPI WPI partner with them every year so our students will will we work with them for a very small chunk of time but their projects roll over so.

V. Lupasteanu: And the final outcome of their project?

Schultz: Of ours or Re:Rises?

V. Lupasteanu: Yours will you write your thesis based?

Schultz: So we're gonna write so right now we're probably gonna right we're gonna be helping Re:Rise get the proof right like provide data to rewrite through some of the stuff that we are going to collect through some additional means and see if it's useful it's not useful data like you were talking about where we can't accurately predict buildings and that's when the results that we're giving able to give them and tell them that they're going to need more or if we could show that you know some visuals inspections can be used to generalize buildings just to produce a general map of risk.

V. Lupasteanu: So you're only focusing on Romania right?

Schultz: Only with the risk hoping to also produce like an article to help raise awareness of the need for an assessment and earthquakes book in earthquake documents in Romania and we're planning to make that in both English and Romanian so it could be shared.

V. Lupasteanu: If you need any help with the paper that'll help you yeah.

Schultz: Thank you!

V. Lupasteanu: Check on it add somethings yeah.

Schultz: Yeah if when we get it done we will send it out so don’t worry.

V. Lupasteanu: It was nice to chat with you it was nice good luck!

Schultz: Thank you so much have a good day bye bye

Appendix I: Mike Mahoney Interview Transcript

Zoom Interview on March 23, 2022, at 2:30 PM EST

DeBare: We wanted to interview because you were the senior geophysicist at FEMA. Can you describe that entails? and what you do as a senior geophysicist?

Mahoney: So FEMA is one of four agencies under the national earthquake hazard reduction program. NEHRP or we call it, “neherp”, refer … that acronym. Coming from the four agencies, which are the US Geological Survey who does the earth science mapping that sort of thing, the National Science Foundation which funds basic research, both building and engineering related, as well as science related the National Institute of Standards and Technology, who funds basic currency to be applied research on issues that… that work their way into, you know, a building standards and building codes, and then FEMA is the Federal Emergency Management Agency, right, where the big implementation arm of that program … We take research results from both NSO and NIST, and develop design guidance. We have probably over 100 different publications on design related issues and uh and then we also work with the nations building codes and try and get those guidance information into the model building codes that are then adopted by all 50 States um and regulate construction from that, and then we also actually have a grant program that we fund earthquake loss reflection or risk reduction activities at the state level and there's about uh. I want to say about 23 states that our high considered high , and we fund, we provide funding to those states for their state level activities. We also found some other organizations : for example, the Earthquake Engineering Research Institute, which is one of the world's largest membership organizations of earthquake issues. We provide them some funding for specific products as well so FEMA is really the implementation started program trying to get improve, you know, the nation's ability to respond … to recover from what stands to prepare for an earthquake and we fund a lot of different organizations and some people to help us do that. Specifically, I'm the team lead for the technical team in the earthquake and wind programs branch. We bring earthquake and wind programs together some sort of a lot of similarities and I lead a group of three other engineers, technical folks. So four of us basically have different activities we do within, you know, the earthquake world. We have one person who works with new building codes. The new building codes primary reference ASC-7. American Society of Civil Engineers, they have a standard called ASC-7 which provides the technical basis for the building codes. We have another one, a person who does the exact same thing on existing building side and I primarily work with probably more specialized projects. For example, we were tasked by Congress a couple of years ago to look at the issue of what we call functional recovery. Right now, the building code really is a life safety building code. It's meant to have a building survive and earthquakes such that people would be able to get out of the building. So, building doesn't collapse building. [The building] isn’t so badly damaged. That’s what the building code does now, but that really doesn't help us with resilience so the building still can meet the building code but still be badly damaged enough this thing usable for months, years or ever in some cases. So, we're trying to improve or come up with ways of possibly improving the building code to increase the resilience and have the building remain functional after a earthquake or within a certain time. So long way of answering your question, but I work on projects like that to help, you know, improve the nation's resilience.

DeBare: So one thing you mentioned was an existing building codes, and from what I understand it can be difficult to get existing buildings [or] buildings that were built before the new building codes to apply current standards. How can you .. how do you get people to want to spend money into their building?

Mahoney: Great question. We are actually approach existing buildings in kind of a tiered arrangement. The first product we have is called rapid visual screening, and it's a way of quickly assessing a building basically from the street, although it helps if you're able to get inside to basically just determine it's just building bad or good. You know and it comes up with a really simplistic score of if you're over a certain level, the building either has collapse potential or is going to experience a lot of damage and needs further attention. If you're below that score [mumbles] then even though it is an existing building built to an earlier code, it is still in pretty good shape and is expected to be and is still get damaged obviously, but it's not expected to collapse or get so badly damaged that people are injured. So that rapid visual screening really kind of cuts the inventory of what you're looking at down to buildings that really needs your attention. When I say it's usually this is done at the community level, [the] community has a group of older buildings. They want to know if some of these buildings are really bad actors that we need to focus our attention on and that allows them to do that. It's based on the type of construction, when it was built, because the codes didn't have it proved over the years and it allows you to at least focus on the bad actors. The next level is assessing those bad buildings, those bad actor buildings, and for that there's a couple different ways of doing that, a couple different products. The highest level and the one used on a national basis is another, different ASC standard American Society Civil Engineers Structural Engineering Institute and this is Standard Number 41 and it's called Seismic Assessment and Retrofitting of Existing Buildings and within that standard, that's actually also adopted by reference into the international existing building code, which was then adopted by the different states, where that's an issue that the standard has different tiers of types of assessments you can do on a building, to determine more accurately that this is still a bad building and needs to be assessed in more detail, or [after] a better look it's okay actually and we don't need to pursue that. So this ASC 41 allows you to even more narrowly focused down on the bad buildings, with a greater degree of confidence that there's an issue here and then 41 also includes retrofitting criteria as well. So how would you retrofit that building to address the seismic hazard or risk involved with that building so that the standard is one size fits all, [and] covers all types of buildings and it's what you would normally point to? To do those activities, and I am still getting to your question. I'm just going the around way, taking the scenic [mumbles]. FEMA also has other guidance products on specific types of buildings that provides maybe a different way of assessing and retrofitting those buildings then what's in ASC 41 and I'll give you 2 examples of that. One is what we call the soft story or weak story buildings. If you remember SF a little more and the Loma Prieta Earthquake, the Marina district which are these older residential multifamily four or five story wood frame buildings built fifty, 60, 80 years ago, and the first stories were either retail or parking, but in either way they remove walls to allow access for those activities. Well, by removing those walls and making that first story a week story, a soft story and that's what collapsed. [Mumbles] and buildings that didn't fully collapse with that first floor collapsed, so we actually put out a design guide, FEMA P 807, on how to just retrofit that week story, instead of having to retrofit the entire building, which is just cost prohibitive in a lot of cases. If we just strengthen that first story, not necessarily putting walls back, but maybe putting in additional frame in there or something, but strengthen that story to the point where it then can act with those upper stories as a single unit and this is the earthquake [munbles]. So that's one FEMA guideline that we've done on that. Another one, more recent, spent a couple of years on FEMA P1100 and it's addressing vulnerabilities of residential structures. Houses generally, if you have just a normal box type residential single family house, they tend to do very well in earthquake: wood frame the flexible, so we get some movement but they're pretty strong and they don't collapse, but there are what we called vulnerabilities in those types of buildings, and there's four examples we use. One is hillside where one side of the house is, basically right on the ground or on a concrete slab in the ground, that is connected there. But the other side, the downhill side, has an open frame holding up the house. So that open frame is much more flexible where as the uphill side is very strong because it's anchored right to the ground and that differential just beats the house up in an earthquake, and you wind up getting collapse of that weak, open frame on downhill side. So that's one vulnerability that we provide guidance on. Another vulnerability is where you have a garage and then you have part of the house above the garage. Like the garage is essentially a week story - that garage door opening. So we have a way of retrofitting that by adding a frame inside that garage to strengthen that wall, so that is enough to support the house above. A third one is masonry chimneys, which always collapse in earthquakes, and they're kind of what we really recommend. If your masonry chimney is damaged in an earthquake, instead of replacing it with another brick chimney using lightweight metal flue chimney, will do much better in earthquakes. And then the last one is what we call cripple wall structures, don't know if you're familiar with those, but it's essentially a foundation like a crawl space, but instead of a masonry wall it's a wood frame wall, and those can be very weak, and those collapse in earthquakes, so there were recommending putting up a layer of plywood on the inside of that wall to strengthen it. So again, a FEMA design guy giving you that information. Our ultimate goal, to answer your question, is we're trying to come up with ways of retrofitting those buildings or identifying them, assessing them, and retrofitting them, that is as affordable as possible, and it's still not cheap in a lot of cases, especially for a building owner, but we're trying to find ways of just improving how we can make those buildings survive earthquakes at a more reasonable cost.

Zoner: I want to step back and go back to the visual assessments you're talking about earlier.

Mahoney: Yes! The rapid visual training

Zoner: Yeah, yes. Have you seen any strengths or weaknesses of doing that first before you do the more extensive assessments?

Mahoney: Well, we normally recommend doing that first actually, because what you're trying to do is reduce down the number of buildings that you have to do a more detailed assessment on, again to reduce the cost of having to do this. So the screening is really meant to be a first layer tool, to identify the bad actors and allow you to kind of [go] “okay we can ignore these guys because we know they'll do okay in an earthquake.” You ask about strengths and weaknesses. I mean the strength is that it allows you to do a very quick survey of a large number of buildings, and it's a really good first step for doing that. That has an associated weakness, which is it tends to be because you're really not doing an assessment of the building, but just kind of a windshield visual survey of the building. It tends to be very conservative because we don't know how strong that wall is, or what the interior sheeting was made of. So we kind of assumed the worst, than go and go from there, and it's as good as the people who do it, and a lot of cases when we do these rapid visual screenings it's not engineers doing that because they're too expensive. So it's like people who know construction but aren't engineers, and in fact grad students quite often, [we] use engineering students do those, but again it's a first step and for that purpose it is a good first step.

DeBare: So, when doing these assessments and it sounds like you've done it before, what are some of the most common issues that you went into, well, connecting these?

Mahoney: I mean a couple of things: one is your information is only, or you're finding is only as good as the information you have, right? So, in dealing with an existing building there are usually a lot of unknowns, especially with older existing buildings we don't know, short of you know peeling off the interior wall to see what's behind there, we don't know whether it's plywood sheeting or it's you know lath board or diagonal board, sheeting or no sheeting at all and it's just plaster and lath, which plaster is really strong, but the lath basically, they are there just to hold the plaster in place. So not knowing what is inside that building, how it was built, was it properly connected to its foundation? Unless you break a hole in the wall to see the bottom footing of the wall, to see whether it's bolted down to the foundation, you don't know for sure, so the unknowns are a huge issue and that's why I said before that we tend to be conservative, that we don't know. If we can't find out, then we kind of assume that it probably needs some additional repair work or something or strengthening. Other unknowns is getting access to a building, especially if it's a larger building with tenants, both just to do the assessment as well as the actual retrofit.

Do you have to work around people, or can the people relocate out of the area to another building perhaps while you do the work?

Existing buildings just have a huge unique set of issues that you don't have to worry about with the new building and that's what makes it much tougher to deal with, but you have to deal with them. I mean the vast majority of the building stock in this country, and you know I'm not the same with Romania as well is these older buildings where we don't what we're really dealing with. I do have to ask. I meant to ask this before : why Romania? IS there an issue that you're looking at there, or was there a connection somehow?

DeBare: So we have, through our school there is a program, where we go and study abroad and tackle these large issues, and it happened to be a project center in Romania. This

happens to be a really huge issue in Romania because a lot of these buildings, like with the whole communist regime that came in, and they were not thinking about earthquake safety about these 100-year-old buildings that have no retrofits.

Mahoney: Exactly right, in fact there was, I forget the name of, but there was a huge earthquake back in the 70s, not in Romania but in the Soviet Union back there and these comments area buildings as you mentioned, they're all concrete, but not adequately reinforced concrete, and there were a huge number of collapses in that earthquake back in the 70s, huge loss of life and, I'm sure those buildings exist in all the communist bloc countries, back in the day and huge risk there.

DeBare: One of the issues I'm running into is that trying to convince people that this is an issue because people things like "it survived two big Earthquakes and therefore it has to be safe" and they dount there is going to be another big earthquake in the future. Do you have any experience with something like educating the public on that earthquakes are an issue that you need to take seriously?

Mahoney: Yeah it's a huge issue and my experiences yeah but not good experience. Earthquakes are a really tough hazard because it happens so infrequently, people's memory is - it doesn't last very long. If they've never been through an earthquake and they have a huge percentage of the population everywhere, you know and in the world, that have not been through an earthquake, here in the US as well that they'll feel what we would consider to be a moderate earthquake a big earthquake, but it was very deep so it fools you into thinking it was a big earthquake, but you know the ground motions really weren't that much because the depth of earthquake and they'll think "Oh well that was an earthquake I did find. My house is still standing. I survived it. The earthquakes not a bigger deal right." The perfect example that here in US back in the 90s, the

Nisqually earthquake in Seattle, outside of Seattle WA. It was a magnitude 7, but it was 70 miles deep or whatever, I mean not exact number, but it was a very deep earthquake and that's my whole issue with the magnitude, that the Moment Magnitude Scale, used to be the Richter Scale, they change the name. It is that number you know magnitude X right is a measure of the energy released at the epicenter, you know at depth right and in that case you had a very large magnitude number but it was a very deep earthquake so the ground motions by the time they got to the surface had attenuated to the point where it was more like a magnitude 5 earthquake on the surface, but there was like "oh it was a magnitude seven and we didn't have any damage. We are all fine." Overcoming that mentality is a huge issue and we try and do some things. For example, we helped sponsor an annual earthquake drill called the shakeout. USC actually are the organizers of it but we fund all the high risk states to actually help put that on, and it's an annual message of what to do in an earthquake : drop, cover, hold, which is you're fighting people's instinctive to immediately run out of the building, which is the worst thing you can do, and then we're also adding messaging to that. This is what it would be like in an earthquake. This is what you do now, what to do next? Do you have a go kit? Do you have three days supply or more, hopefully more, of water, food, medicine, whatever - whatever it is you need, so we're trying to add that message every time to help people be prepared. I hope we will be prepared you know, have it go kit, have a plan. You're at work and your kids are at school. How do you know who is going to get the kids. So we have a lot of material we put out on how earthquake safety and planning as part of that as well.

DeBare: So, a lot of these things require buy-in from people to pay and convincing people that the program should funded or that you should take earthquakes more seriously. Have you had any issues convincing the government?

Mahoney: Seriously that's a great question, and we here at have FEMA anyway are fortunate that we get - FEMA gets its annual appropriation, the money that the government gives us to do what it is we do. Usually in appropriation they actually specify how much money to be spent for the earthquake program and it's not much money actually it's pretty pretty low, given all the other government programs, we get we get about 8,000,000 a year, which sounds high but that pays the salaries - all the expenses associated with the program and out of that, what's left, that's what we pay to do these guidelines, fund the states, that sort of thing. So it doesn't go very far, but at least we have that language the Senate provides, so we don't have to fight for that money. We generally aren't able to fight for more money, but at least we have that. It's like everything else, everybody focuses on the last disaster, closing the barn door after the horse so if we had we had a hurricane last year that was bad, caused a lot of lot of damage then usually the focus is on what are we doing about hurricanes, and since we haven't had a really a big damaging earthquake since Northridge in ’94. We had smaller ones, but Northridge was really the last considered to be a major earthquake. People totally forgot about that, so unfortunately it's going to take another earthquake, hopefully not a huge the big one earthquake, but sometimes that's what it takes to get funding to address some of the issues. So now this is people you know how their perceived patterns of what risk is and how to address it.

DeBare: So on top of all the political issues there are all these socioeconomic issues of the people often who need the most help with their building getting it safe for earthquakes don't have the money to do so.

Mahoney: Absolutely. Right. You're absolutely correct and that's something that we're focusing more and more on. In the last couple of years, we tried to put a greater emphasis on that with our states. For example, with our state grant program, where we give money to the states, we're trying … We allow certain activities to be used for that money and one one of them that we've try to put a greater emphasis on is addressing at underserved communities and folks that just don't have the resources to address the risk that they face, and it's not just earthquake. That's every hazard. A great example of that was Katrina and New Orleans, where you have a whole lower 9th ward for example. It was the lowest area of the city and had the poorest population and people did not have ways of evacuating, even though they knew the hurricane was coming and they wound up with people evacuating after the fact to shelter those already overcrowded and just all the bad things that happen from that. We're trying to do a better job, but it's you're kind of fighting you know we can't just give money to people. We try and support their activities, but we have to do it within the context of the program, and congress is what set it up and, so we give money to states but we can't give money directly to individuals, for example. We try and encourage activities we have the grant program to the state that in turn can provide support to communities, especially underserved communities. So trying to do that, but you in a lot of cases those folks don't necessarily own those homes, so and can you convince the landlord to retrofit those buildings. There are a lot of cases, they're just trying to get the income from the rent and we're keeping proposition for him and they don't have funding to improve those buildings, rightly or wrongly, So [there is a] big issue. A lot of work [is] supposed to be done.

DeBare: It's one thing to go in and to have those rapid visuals seismic risk assessments. Can you talk a little bit more about what the results are able to do some sort of modelling? How do you predict the potential impacts of a large earthquake on a metropolitan area:

Mahoney: Sure. Yeah. We actually funded a long time ago, a loss estimation computer program - modeling program. It's called HAZUS, which stands for hazards-US – "HAZUS", and there's actually a FEMA website what will describe that program. But it uses census tract data. It uses available databases on types of buildings in an area, population, the infrastructure - that sort of thing and you can model in a given earthquake or what the USGS says would be the probability of a certain type of earthquake. You determine the probability and it gives you the earthquake. But you use that as the input. It essentially takes the inventory data and it has some inventory data imbedded in it, but you can make that more accurate by adding more data, but then it costs money to do that, That program basically gives an estimate of what the damage would be for a given area, community, whatever area you said set it up to to do. So we developed, made that available, free of charge to states and localities for them to use. They have to run it themselves. they have to put their own data in it, but we provide the software for free, and hopefully the intent was to give the community a better idea of what their risk is. It started off just being earthquakes. We've added wind, tsunami and flood so it allows you to do other hazards as well, but that's really the best tool we have out there for the community to figure out what is there risk.

DeBare: Do you think we can apply this to Romania if you use the same kind of information and plug it into Romania?

Mahoney: That's a great question I don't know. It was meant to be for the US. So there's the embedded data is only for the US. But the model itself, I believe, I'm not an expert on it, but I believe you would be able to put in whatever data you wanted to put into it, whether how available that data is I don't know. Ya, something worth exploring. Now there possible that somebody in that country's already done that. I've not heard of that, but it does get used outside the US quite a bit.

DeBare: So shifting, we were going to do these rapid visual assessments in Romania, but with the war in Ukraine, we didn't feel safe traveling. But now we are doing geo-tagging too

identifies similar buildings, to help with the assessment later on. Do you have experience with this?

Mahoney: Not directly. No. But I know there are organizations, and I can name a couple of them that have done some similar work. In some cases they've just focused on hospitals being a critical facility that you need to know that that hospital is going to be able to function after an earthquake. I know there have been studies where they just looked at hospitals. Same thing with schools. Schools are quite often used as emergency shelters, so they looked at schools as well. There's an organization called geohazards international that does a lot of work in in other countries. They're based in California, but they they've done studies and a lot of different countries. I don't know if Romania is one of those or not. I know for example after the earthquake in Nepal, that they did a lot of work there. After that, that's probably the first one I could think of. I know that there's another organization called the Applied Technology Council, ATC, and they do work when they're contracted to do that and I know they've done some work in Eastern Europe, but I don't remember what countries. But again they were looking at the countries building code and whatever is needed improvement to address retrofitting issues or not so. But you could look on their website and then some stuff there.

DeBare: Talking about the building codes, one problem that Romania is having is that they sometimes have trouble enforcing the building codes.

Mahoney: That it's not just Romanian that's everywhere. Yes. Okay. There are a lot of countries that have a great building code, but enforcement becomes an issue and that's not true in a lot of a lot of the US. It's probably easier with new construction because jurisdiction. You have to have a permit to build the building. To get the permit you have to show that you have designed the buildings to the code and all that. So new construction is a little bit better than existing buildings.

Unless the jurisdiction knows there's work going on, people can make alterations of buildings and nobody would know it, so unfortunately code for existing buildings is much much tougher. it kind of depends on the culture, I guess maybe, that you know if the construction community grew up learning the trade without having to worry about the building code, getting them to start to you know think about the building code is tough. *Mahoney changes to a slightly lower lower voice for the quotations part* “We always did it this way.” So tough issue it is. It usually takes the government really giving the building department tools they need to enforce, not just about, but enforce the code and the messaging that goes out with that that building code is not your enemy. It's helping to keep the building, providing a safe product to your customer. Big issue. You’re right.

DeBare: Matt, do you have anything you would like to ask that you think I missed?

Zoner: There is one more thing. I just want to know when conducting the rapid assessments, do you ever take into account multiple of the same buildings. Maybe there's multiple of the same condo or same apartment building. Do you ever take into account and are able to generalize those, when you look at each of them or do you look at them individually?

Mahoney: You know, generally I don't do these. We provide the guidance for it. We provide the training for it. We go out and help community start to do them but our goal really is to build up a pool of trained people at the community level that can start doing them and can continue to do them. So generally the work is done by others, but excellent question and to a degree yes. If you've got a block of apartment buildings and they're all the same construction era, material, height and all that, I mean you still need to inspect them just to make sure there isn't something different, like they knocked out a wall on the first floor to put in a gym or something, or some kind of special thing, so you need to make sure they are all identical, but knowing that, yeah, you can basically reach the same conclusion that it applies to all of them. So to a degree, yes, you can cut down your work by doing that, but you still need to be careful, but that they are truly identical and nothing's changed.

Zoner: I think that's all I had, Josh.

DeBare: I think that you got all of the questions. Thank you for your time and your thoughtful answers, and we look forward to doing more work and research on this and if you have any questions.

Mahoney: Josh, you got my email. Send me a question I'll be happy to answer it.

DeBare: We might ask for additional contacts, or like you mentioned geohazard international and things like that.

Mahoney: So yeah, look them up on the website, but if you need a contact let me know, but I think you'll find what you need.

DeBare: Thank you

Mahoney: [Something]

Matt; Thank you very much

Mahoney: My pleasure. Good luck guys.

Zoner: Thank you

Mahoney: Bye

DeBare: Bye

Appendix J: Stavroula Pantazopoulou Interview Transcript

Zoom Interview on March 21, 2022, at 3 PM EST

DeBare: I think it might also be useful to talk about how the different layers interact with each other for instance if we're doing layer one and you're doing layer two there's probably some things in layer one that we that happen that would make it easier for layer two to happen as well. (talking about doing RVSRAs before SRAs)

Pantazopoulou: I'm not sure I'm catching this. I don't know.

DeBare: Have you ever had someone do layer one and do not a great job of layer one so that layer two is harder for you to do your job and layer two or is it generally pretty separate of like

Pantazopoulou: It is pretty separate. So in layer one as I said, you do a visual evaluation of the building population or of an individual building, and you, based on your engineering judgment, you may say that there are certain things that are wrong in this building. But that in no way interferes with whether you are going to go. I mean it's up to you to decide that you're going to go to adhere to assessment. However in a systematic way if this were to become a some sort of a policy as I said you mark the buildings. You start with a perfect mark and then you start … subtracting from that perfect mark items that correspond to various flaws that you visually assess and you reduce from the perfect mark to something that is below, and then it's up to the policymaker to draw a sort of line and say any building that falls below that type of line will have to be evaluated with a two kind of [assessment]. So in order for this to be robust it should be the decision made by some authority that any building that falls below a certain limit has to be evaluated in a Tier 2. But there is no interaction between the two methodologies that these that one could prevent you from doing the other it says that the tiers, that there's the methodology for assessment as you go from one to three then the manual effort for the and the expertise required increases exponentially and therefore it's a … critical decision by whoever makes the policy as to the best investment of human resources and monetary resources how much of this will be tier two evaluations and how much of this will be tier three

Zoner: So would you say that tier one can most likely be done by volunteers where Tier 2 needs to be civil engineers or seismic experts?

Pantazopoulou: I would suggest that in all cases tier one would have to be done by civil engineers and placed actual engineers but the level of expertise could vary. So tier one can be done even by a let's say graduating 4th 5th year student. Tier two would need to be done by a more specialized person the one that knows what to look for in buildings and tier 3 definitely would require a graduate degree in order to be done. you can't have your average civil engineer do tier 3. They would require specialized training.

DeBare: Basically what I'm hearing is that you have to decide if for instance the progress there are so many buildings that need to be assessed and fixed that in your being to figure out which ones have the most people in which ones have the biggest risk to focus on those buildings because there's only so many people who can do tier 3

Pantazopoulou: So yeah. That's in … that's the socioeconomic component, which you can choose to add it as an extra weight in the decision, making [it] so after you grade the buildings then you can add this as another parameter and decide in addition to the cut off mark like for instance saying all buildings that are below two out of five will have to be assessed for tier 2. You can then add so you would still end up with a very large population of buildings and there's a very large number because remember that not just in Romania but in throughout the world I'm most of the built environment was constructed by the early 80s if not earlier 50s for instance in North America it was built before the 50s so very old goals. so the large majority of what you see around you built is built in all times and therefore it is not necessarily designed for earthquakes that does not mean that it would collapse during an earthquake but it is not designed for the earthquake. So if you do these visual screening of the buildings and you identify the potential problematic buildings then you can then because it because the amount of effort required to assess of this at the tier two level would still be humongous it can then use other parameters such as socioeconomic parameters to further identify or focus on a smaller population

DeBare: I imagine these parameters, and the people weighing it in different places would weigh things differently as an example the way the measure which buildings go to the next level in Romania might be different from Greece which might be different from Turkey

Pantazopoulou: I don't know about that I would think that not not that different, definitely commercial versus public buildings have different approaches the public buildings usually because the bill is paid for by the state usually are in high priority and also another parameter apart from the socioeconomic component is the building importance which says what is the function of the building and what is the consequence of a potential failure so that's a consequence based assessment. So definitely from the large population of buildings that may come to not meet the five out of five criteria you cannot associate [inaudible] status the private versus public what kind of function the building serves but also what would be the consequence of failure of a building. These are all different parameters that you may add in order to prioritize and also in order to allocate funds for the procedures because the Tier 2 assessment would require some money

Zoner: Have you ever faced any political challenges while trying to assess buildings has anyone stepped in your way?

Pantazopoulou: No not necessarily. I got to say that last buildings that I am doing assessment on in order for it for you to do Tier 2 assessment you need to have access to building drawings or at least access to the building. Let's say to determine some basic parameters of the building and of course in order to get access to the drawings to the the plans, for instance, of the building we need to be given that access by some local authority would have to be participating in addition if you're talking about private buildings not public usage buildings but private buildings because your decision … would affect the commercial value of this. You run a very high risk of being sued eventually, because the result of your assessment and your study could deprecate the real estate value of their building. It could also create as a 7 degree of insecurity to the occupancy. So there are implications coming out of this and these are all political implications. So access to information access to the building to obtain the important characteristics that would enter your calculations but also resolving issues such as what happens with the finding. Keep it private or have to publicize it or it depends on the ethical framework of the professional organization that governs the territory with this going on. So in Canada for instance, you as an engineer you are obliged you have a duty of care disclose information regarding let's say things that you found dangerous but you run the risk of being sued at the same time so it's a very serious thing and I I even worried about that myself over the years although because I'm an academic and not a professional in the industry I would never go and cross the line to do things that could get me into that kind of trouble. However I do remember when I was in Greece teaching, had that population buildings around the university which were built in the 70s where at the time it was very common to use soft first story construction for parking to accommodate parking and in apartment buildings, the apartments or from second tier onwards. Same thing is happening also in Florida for instance use of the Florida building collapse right in the summer so the first floor is for parking and the basement and then the apartments are higher up so you do have very typical … soft [story] formations and when you have soft store formations you know the damage is going to happen there. All the seismic demands are going to be taken by the [inaudible] and if they are not designed for to provide the deformation capacity that is needed you know that these are caps they are going to collapse and they are going to kill people. So what do you do with this information. You walk by this state and if you had any experience earthquake and here you can tell what are the problematic buildings what do you do with this information. It's a very serious ethical problem that I have not been able to resolve that

Zoner: Yeah we found just in our background research in Romania that engineers started putting red dots on buildings to signify that they were unsafe but that lead to buildings being lowered in value and that people stopped requesting assessments because they didn't want their buildings which left a whole heap of buildings that aren't seismically safe and that aren't assessed

Pantazopoulou: Yeah that's … actually a very bad idea to do though you don't [do it] publicly it's like you know the the scarlet letter you remember the story you don't do that particularly if you are not certain if this is private property you don't do that sort of thing of course you may be referring to a different thing. After the earthquake happens … in the major urban areas, there is lots of damage. It's usually the professional engineers of the … who go and inspect the buildings to identify those that are potential collapses … from those that need repair and those that are safe and they usually use the color code like yellow or orange sorry red orange and green in that order. That is used in order to support a political decision, state decisions not political, state decisions regarding who we get funding to replace their building or who will get funding and what extent of funding in order to do retrofitting OK so this is a post disaster measure you don't do that in a peace state you don't do that even in a non post disaster because then that is like targeting buildings to deprecate their real estate for you in order I mean you can you can have that speculators moving in and just buying complete property. Keep in mind that with every standing whatever building is standing because not collapsed. It could potentially be retrofitted and therefore recovered. So if I can deprecate the value of your building the building you live in and buy it for nothing then put a little bit of money to retrofit then they have a very good property that's not fair. And that could bring in lawsuits and serious serious legal implications

Zoner: Yeah I do believe the red dots were post a major quake in 1977 so I believe they were supposed that if you're talking about that

Pantazopoulou: Yes yes yeah but, they still just didn't they have an obligation to fund either retrofitting or second tier assessment to determine whether actually demolition or retrofitting is called for and then to give low interest loans to the occupants to retrofit or to replace to to build altogether a new building. So they these are usually the things that are done after the post disaster event following this tagging of buildings

Zoner: I wanna go back a little to the soft story buildings were describing. Would you normally categorize certain types of buildings in order to see which ones need to be assessed or would you.

Pantazopoulou: Yeah that's the that's part of the marking system that I told you in the visual screening the presence of a soft story is a whistle it's it brings in negative marks with five and you how do you go down to four if you have eccentricities you go down to three and so on. So there is, as I told you there is a list of things that can take away marks from a building start evaluation.

DeBare: So one thing is that a lot of times is so especially information there's a mistrust of the government and people coming in to inspect buildings. Do you know a way to like … how would you rebuild that sort of like 'cause a lot of people don't want a civil engineer or some expert to go into their building

Pantazopoulou: Especially given us any incentive appreciation of their property. So there's got to be an incentive because otherwise all you're doing is just damaging my property by putting a tag on it and making it look really bad so here this represents all the savings of my life. I want to be able to sell this for my retirement. I am expecting it to close or it will bring me I don't know €100,000 and you can put the tag on it and it takes me 10,000 euros you destroyed, OK. So I cannot trust you therefore so in class we are not living in a in an innocent society it's not as if they you know people just mistrust they mistrust because of experience past experiences and one of experience that we do know nothing Romania have nothing to tell about Romania North America there's a lot of speculation of real estate so if I can come and tell you that your building is crap and therefore I can deprecate it and then my friends who I have access to and I give them private information comes and buys it for nothing and then we do a retrofitting deal on it and then resell it and 10 times the the price then I have gained, you know legally in a way so it's not the mistrust there is always a reason behind the mistrust OK. And so you have to find incentives to fight to to convince people that it's for their safety., [and] safety of their loved ones. Class there is a correlation and that's an interesting correlation that you may want to do and between the marking of the building and the income level of the people who live in that so earthquakes are very very how can I say class dominated so rich people buildings rarely have damages. It's the poorest people which is the vast majority that lives in substandard and earthquake vulnerable buildings. So it's got to be an effort statewide to convince the people that yes you need to improve the security the safety of your family who lives in that building the same way you wouldn't send your kid to cross a heavy traffic street in any other place other than the traffic lights it's the same thing you put your kid in in the harm's way by just keeping them in a very dangerous vulnerable building so this but these arguments I'm sure the sociologists could articulate. So that’s the correlation that I would look into. What's the value of the building and then come with the family

Zoner: Yeah I definitely agree that that correlation will probably drive more people to wanting assessments being done.

DeBare: If a lot of people if they're living in poor neighborhoods where they can't afford to even if it is an unsafe building they can't afford to fix it at all they would need to be extra incentives in order to make their home safer

Pantazopoulou: Well the state also has their own here I mean the state has to provide some sort of a safety to its people so the state Romania would probably be getting a lot of funding from the EU to do that sort of thing so they could decide that's a political decision to funnel a certain amount of money. Even low income low interest loans with long term repayment for people to fix their buildings that's it's been done in Greece for sure. Of course in order for this to be adapted for the rich European states they have they're trying to combine insulation, terminal insulation for energy for reduction of energy consumption because the largest consumer of energy in urban areas is the heating. They are trying to combine this with retrofitting. That has been a ticket that has been very attractive for people to take. So the rich states are selling the poorer states all this material for retrofitting [inaudible] all the insulation stuff. And this is combined with the retrofitting, the seismic retrofitting method in order to reach an objective a goal. This is happening in Greece Im sure something similar is happening in Romania or could happen in Romania.

Zoner: So something we found to be a challenge in Romania is that while a building is being repaired there is not enough government housing supplied to citizens, is this a thing in Greece?

Pantazopoulou: No, there is no such or if it is there is very little. It is not the situation in Greece. I can imagine that they would have to relocate people yeah. I would imagine that they would have to relocate people and I imagine long term they would have to develop facilities that people could families could rotate. This is all political decision making that the money is not it is not in our hands.

Zoner: Josh I don't have anything, do you?

DeBare: No I do not, so

Zoner: I just want to thank you professor for your time

Pantazopoulou: Not a problem not a problem, just let me know if I can help you in any other way

Appendix K: Newspaper Article Draft

Since 1471, a 7.0 magnitude earthquake has shaken Romania nearly every 80 years, including the 1940 and 1977 earthquakes. Experts predict next earthquake to be near, and many of the buildings in Bucharest remain seismically vulnerable. Prior to 1977, over 100,000 buildings were constructed when Romania's building codes were weak and ineffective. Several case studies show that high-rise apartment buildings from the 1960s and 1970s are likely to collapse in the next earthquake, as they are unrepaired from the 1977 earthquake. Although the Romanian Government has identified about 350 buildings in the highest vulnerability class, less than 20 have been adequately retrofitted and experts estimate over 2,000 vulnerable unassessed buildings.

We are engineering students at Worcester Polytechnic Institute (WPI) from the United States, and we recently completed a project about reducing seismic vulnerability in Bucharest. As we began this project five months ago, we started by researching the alarming prevalence of seismic risk in the city, but eventually began asking questions about how this problem is still prevalent. After more research and many discussions with Re:Rise, a local organization dedicated to reducing seismic risk, we were shocked to learn about the failure and inaction of the government since the 1977 earthquake. We'd like to share some of our findings to demonstrate the urgency to act, as Bucharest is almost due for a major earthquake.

In our project, we marked 480 double orientation (OD) buildings on a map. OD buildings are high-rise apartment buildings constructed across Bucharest under former president Nicolae Ceausescu. These buildings proved to be vulnerable in the 1977 earthquake, as each OD building sustained damage, with 27 being heavily damaged or collapsed. When the next major earthquake occurs, all of these buildings are vulnerable to collapse, especially the ones damaged in the 1977 earthquake. We estimate that these buildings could house over 30,000 people, putting them in grave danger for the next earthquake. We also found that many of the OD buildings are located near roadways, meaning they could kill pedestrians upon collapse and block evacuation and emergency response routes after an earthquake.

Although dismal, there is opportunity in Bucharest to retrofit the seismically unsafe buildings. With a standard building type like OD, it is possible that a standard retrofit solution could be used widely on all OD buildings. A standard solution could make thousands of people safer and could have little design costs. This process could easily be repeated for the other common building types constructed under Ceausescu's urbanization. We urge the citizens, local organizations, Romanian Government, and any other building owner to begin assessing and retrofitting vulnerable buildings as soon as possible, since the next earthquake may happen as soon as tomorrow.