# Seismic Losses Scenario for Cultural Promenade in Timisoara Capital of Culture 2021, Romania



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**Abstract**. Timisoara is a European city, located in the western part of Romania, in a seismic area, characterized by shallow earthquakes with most probable magnitude 6 Mw and intensity 7. Timisoara was selected to be the European Capital of Culture 2021, transforming the city into a centre of interest for cultural agenda. One of the major intentions of the city that was highlighted during the selection for the 2021 European Capital of Culture was to connect the visitors to the local community lifestyle, through a lot of outdoor events, where the participants will have to change to feel the real life on Timisoara's streets and to interact with its citizens, especially in the historical urban areas, where the specific atmosphere was kept the most. In this context, there are expected many tourists to visit the city and many events are planned to occur in the historical zones. Along those historical zones, there was proposed a cultural promenade that will connect the most important touristic attractions of the city and the best places for outdoor cultural events. Taking into consideration the age of the buildings that will host events or that will be near the outdoor event spaces, appeared the problem of safety. In order to be able to secure the wellbeing of the visitors and Timisoara's citizens and also the city's most important buildings, there is mandatory to evaluate the current state of the buildings along the proposed cultural promenade and to determine the possible losses scenario in case of an earthquake occurrence. This paper presents seismic scenarios for different intensities and evaluates the possible losses in terms of human life, homes and jobs, architectural and historical values and of course economical losses. The knowledge represents the base of every action, so this study represents only the first part of a larger one that will propose interdisciplinary strategy for prevention and intervention in case of an earthquake occurrence.

## 1. Introduction

Timisoara represents the biggest city in Banat area, which is the second most important seismic zone of Romania [1], lying on the tectonic contact area of the south-eastern border of Pannonian Depression and Carpathian orogeny characterized by shallow earthquakes and strong vertical forces [2]. Timisoara was first mentioned as a city in year 1212. During the Ottoman administration, there were built defence massive walls and the city became an important commercial node. After year 1716, along with the Habsburgic administration, the city started to develop outside the defence walls, generating Iosefin and Fabric areas, with palaces in Secession, Neoclassic, Baroque and Eclectic style [3]. At first, the new constructed zones kept a strategical distance of 948 meters from the defence walls, but later they grow until all they merged. Nowadays, the old part of the city, inside the remaining parts of the defence walls

is named Cetate area, while in the eastern part of Timisoara there can be found Fabric neighbourhood and in the south-western part of the city there is located Iosefin historical area (figure 1).

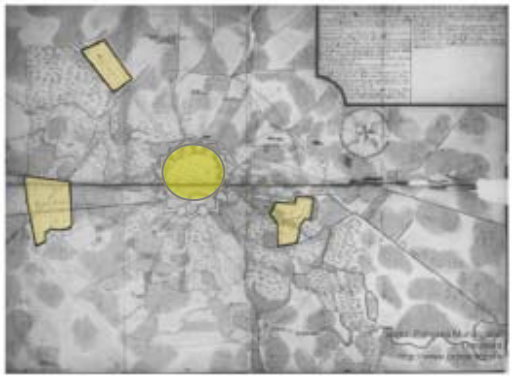
a)  b) 

Figure 1. The historical areas of Timisoara: a) during Hapsburg's administration; b) nowadays [4]

## 2. The context

Timisoara represents one of the biggest poles of urban tourism in Banat area, due to the presence of valuable heritage buildings with diversified architectural styles and the vivid social life and economic growth [5]. Some of the most important touristic attractions are the Palace of Water located in Iosefin historical area (figure 2a), the Baroque Palace located in Cetate historical area (figure 2b) and the Fabric Synagogue located in Fabric historical area (figure 2c). Also, there are two historical bridges that connect the city from long time ago, one of them being Decebal bridge (figure 2d).

a)  b) 

c)  d) 

Figure 2. Some of the main attractions in Timisoara: a) Palace of Water; b) Baroque Palace; c) Fabric Synagogue; d) Decebal bridge [6]

Urban tourism means not only visiting interesting buildings, but also getting to know the architectural and cultural patrimony and participating to various events, such as the International Festival "Musical Timisoara", the Heart's Festival, StudentFest, International Rromani Art Festival, the Spring and Winter Fairs, cultural events that take place every year and are representative for the city [5]. Timisoara city was selected to be Capital of Culture 2021, based on one major axis that provides new cultural-experimental expressions, putting the visitors in relation with the history of the city and the spirit of the place, by organizing several cultural events in public spaces and unconventional indoor spaces [7]. In figure 3 are illustrated the main outdoor spaces that could host small or larger events and also the main architectural, cultural and historical attractions of the city. Overlapping those two maps with the map of the city and its historical zones, there was defined and proposed one cultural promenade for Timisoara, that is considered to be very visited starting with year 2021, as we can see in figure 4. This promenade represents the correlation between the historical-cultural context of the city and the infrastructure that exists, starting from Iosefin are, getting through Cetate zone and arriving to the Fabric historical zone.

In the light of the previous analysis, considering the fact that almost one-third of all buildings from Timisoara are buildings with patrimony value or in protected areas, there is highlighted the fact that the most expected to be visited part of the city is in the same time the most vulnerable in case of an earthquake occurrence, so there is a specific need for a seismic vulnerability assessment.


Figure 3. a) possible outdoor spaces for cultural events [8]; b) the main historical attractions in Timisoara city

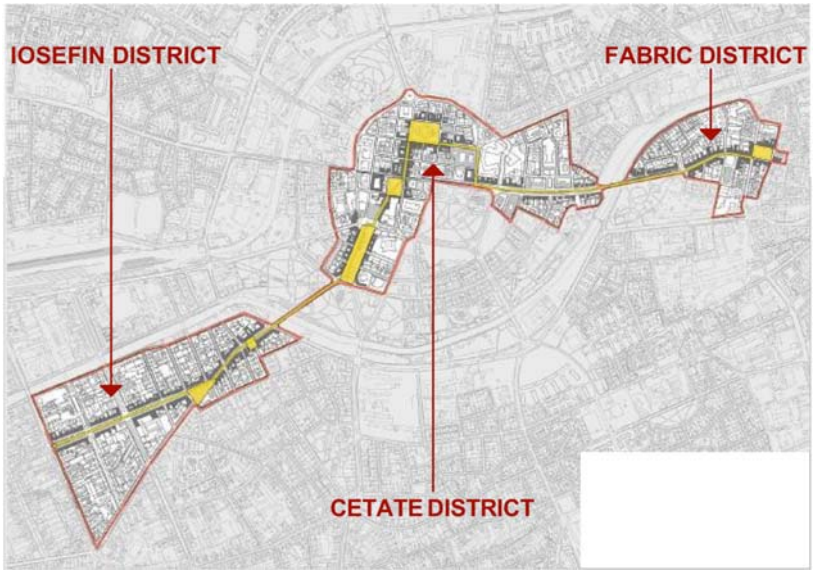



Figure 4. The proposed cultural promenade for Timisoara Capital of Culture 2021 [7]

## 3. Emergency response infrastructure

During the occurrence of an earthquake and shortly after, there are very important some specific zones of a city, such as refuge areas and the ways for people to get there and of course emergency points and the ways from the emergency centres until the possible affected area and the refuges zones. The refuge places could be temporary or permanently, such as parks, squares, sport fields, schools or churches, any place that is safe, big enough and easy to get to. The permanent ones could be locally or regionally, depending on the emergency response strategy of the city and should accommodate a large number of people for more time, with shelters and facilities. The situation of the possible locally refuge places in the historical area of Timisoara and the necessary time to get there by feet is appropriate, as we can see in figure 5a. Regarding the emergency centres (figure 5b), the criteria are quite clear, considering an appropriate distance from any refuge point and their capacity to accommodate the population of the influenced area. In the same time, the width of the main access ways is large enough to assure the access of the emergency vehicles in case of need, as we can see in figure 6. The main access roads should connect the affected area with the main city entrance, with the regional emergency centre and with the airport, while the secondary emergency roads should connect the refuge points to the medical and emergency centres.


a) b)

Figure 5. The emergency response infrastructure: a) possible refuge places in the historical areas of Timisoara; b) the position of the emergency points and other important facilities [8]

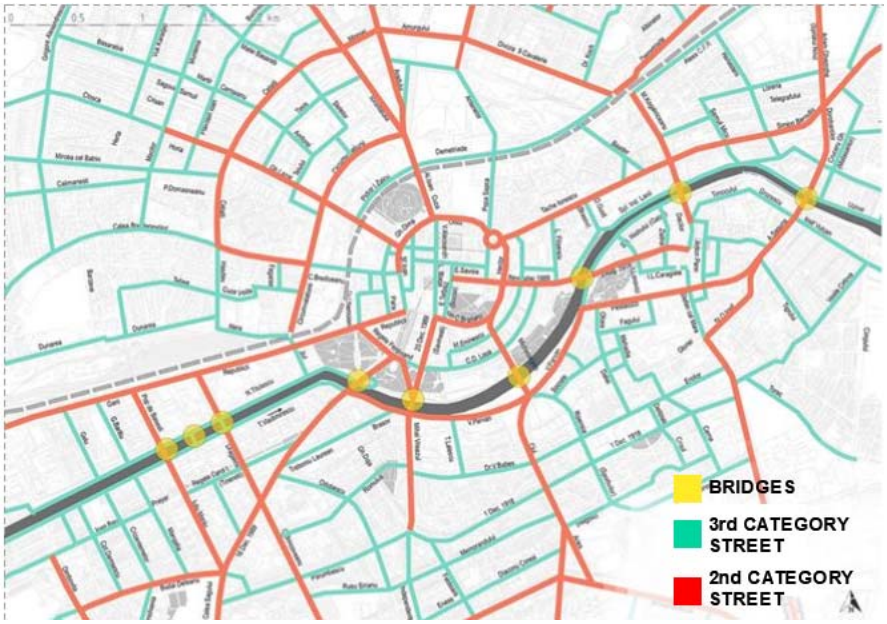



Figure 6. The classification of the roads [8]

## 4. Seismic vulnerability assessment

The main purpose of the study is to highlight the importance of preserving the cultural-historical values of the city and to determine the seismic vulnerability of a possible cultural promenade for Timisoara Capital of Culture 2021, based on Vulnerability Index methodology that can be used at urban scale with quick results.

### 4.1. Seismic vulnerability assessment methodology

Benedetti and Petrini proposed the methodology at first and it considered ten parameters [9]. Later, the same methodology was developed to 15 parameters by the University of Naples [10], considering input data such as geometrical and structural information about the buildings, their regularity in plan and elevation, type of slabs, level of existing damage and the influence of the buildings from the aggregate and obtaining a vulnerability index for each building.

In order to be able to evaluate possible damage level for each building, there should be considered the possible seismic intensities for Timisoara, considering the magnitude-macroseismic intensity correlation law (table 1) [11]. Considering the fact that in Timisoara the maximum magnitude registered was 6 Mw [12], the macroseismic intensity according to EMS-98 [13] could be than considered from 8 to 12, depending on the epicentre distance from the city centre. The paper consider intensity 8 scenario.

**Table 1.** Magnitude-macroseismic intensity correlation law [11]

| Mw | d [km] | $h_r$ [km] | I [EMS-98] |
|---|---|---|---|
| 4 | 5 | 5 | 9 |
| | 15 | 15 | 6 |
| | 25 | 25 | 5 |
| 5 | 5 | 5 | 11 |
| | 15 | 15 | 8 |
| | 25 | 25 | 7 |
| 6 | 5 | 5 | 12 |
| | 15 | 15 | 9 |
| | 25 | 25 | 8 |

The mean damage for each building was further determined based on the vulnerability index and macroseismic intensity, according to Equation 1 [14].

$$\mu_D = 2.5\ [1 + \tanh\ (\frac{I+6.25V-13.1}{\theta})] \quad (1)$$

where $\Phi$ is considered 2.3 [15] and V is determined based on a normalization formula (Eq. 2) [16].

$$V = 0.46 + 0.0056I_V \quad (2)$$

The 15 parameters that were investigated for the three historical areas of Timisoara are organization of vertical structure, nature of vertical structure, location and type of foundation, distribution in plan of structural elements, in-plane regularity, vertical regularity, type of floor, roofing system, details and non-structural elements that could influence the seismic behaviour, the physical conditions and preservation state, the presence of adjacent buildings with different heights, position of the building in the aggregate, number of staggered floors, structural or typological heterogeneity and type and percentage of openings. The classification was made considering 4 possible situations, from A to D, A being the ideal case and D the worst. The seismic vulnerability assessment results are further presented for each historical area, based on their particularities, considering the correlation between mean damage and damage level (table 2) [17].

**Table 2.** Correlation between mean damage and damage level [16]

| Mean damage range [$\mu_D$] | Damage state [$D_k$] | Damage level [DL] |
|---|---|---|
| 0 ÷ 1.5 | $D_1$ | Slight |
| 1.5 ÷ 2.5 | $D_2$ | Moderate |
| 2.5 ÷ 3.5 | $D_3$ | Substantial to heavy |
| 3.5 ÷ 4.5 | $D_4$ | Very heavy |
| 4.5 ÷ 5 | $D_5$ | Collapse |

4.2. Urban analysis results

For the three investigated historical areas, the constructions are homogenous, from same age, with similar structural characteristics, made with masonry massive walls, masonry vaults and wooden floors. Unreinforced masonry walls usually have brittle failure mechanism, having low drift limits during earthquake shaking [18].

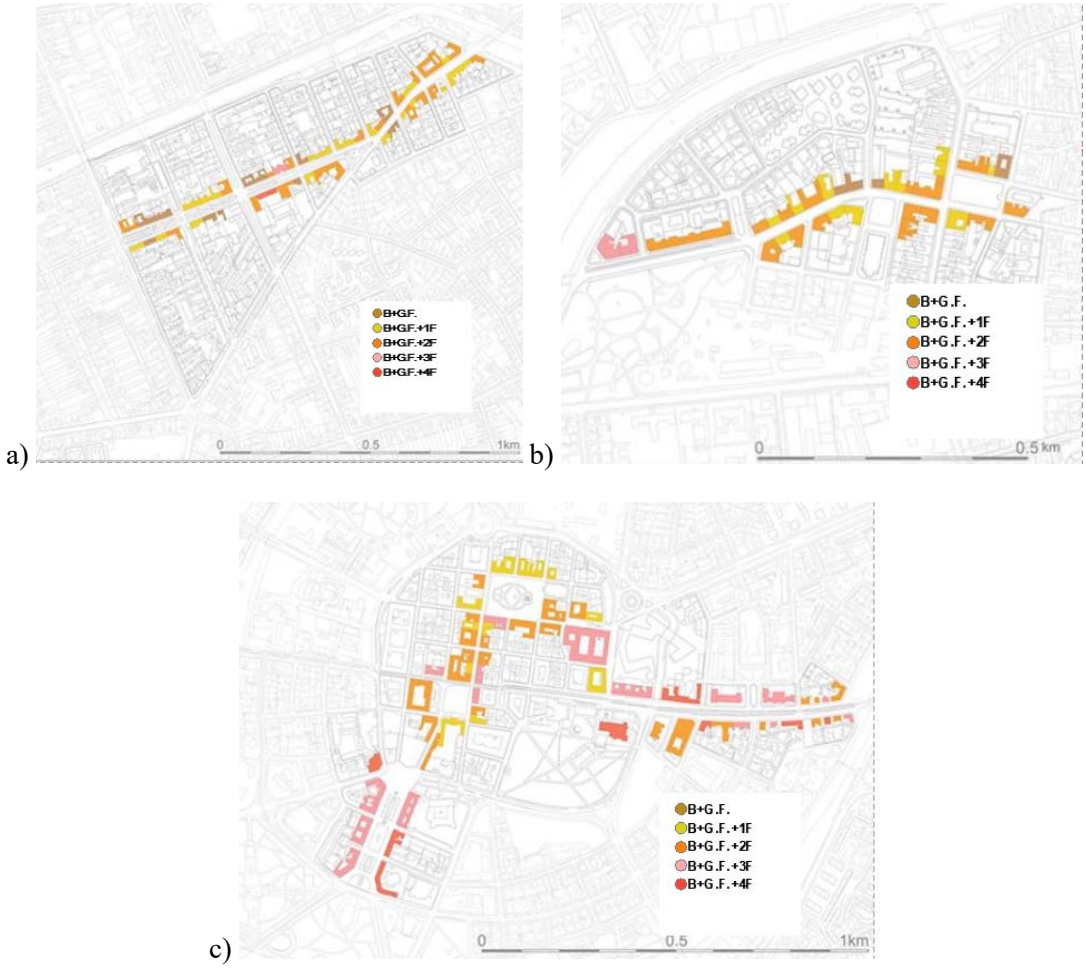



Figure 7. The height regime of the buildings from historical areas of Timisoara: a) Iosefin; b) Fabric; c) Cetate [8]

Most of the buildings in Iosefin (37.31%) are buildings with ground floor and one more level, in Cetate (37 %) are buildings with ground floor and two more level and in Fabric (51.35 %) are buildings with ground floor and two more level, as we can see in figure 7. Most of the buildings have the same site occupancy typology, forming continues street line with common walls to the adjacent buildings and interior courtyards (figure 8). In this area, there can be also observed the presence of the commercial spaces at the ground floor of the buildings to almost 85% of them in Iosefin, to almost 65 % in Cetate and to almost 50 % in Fabric (figure 9). The conservation state of the buildings is medium for more than half of the total number, without recent rehabilitation, as we can see in figure 10.

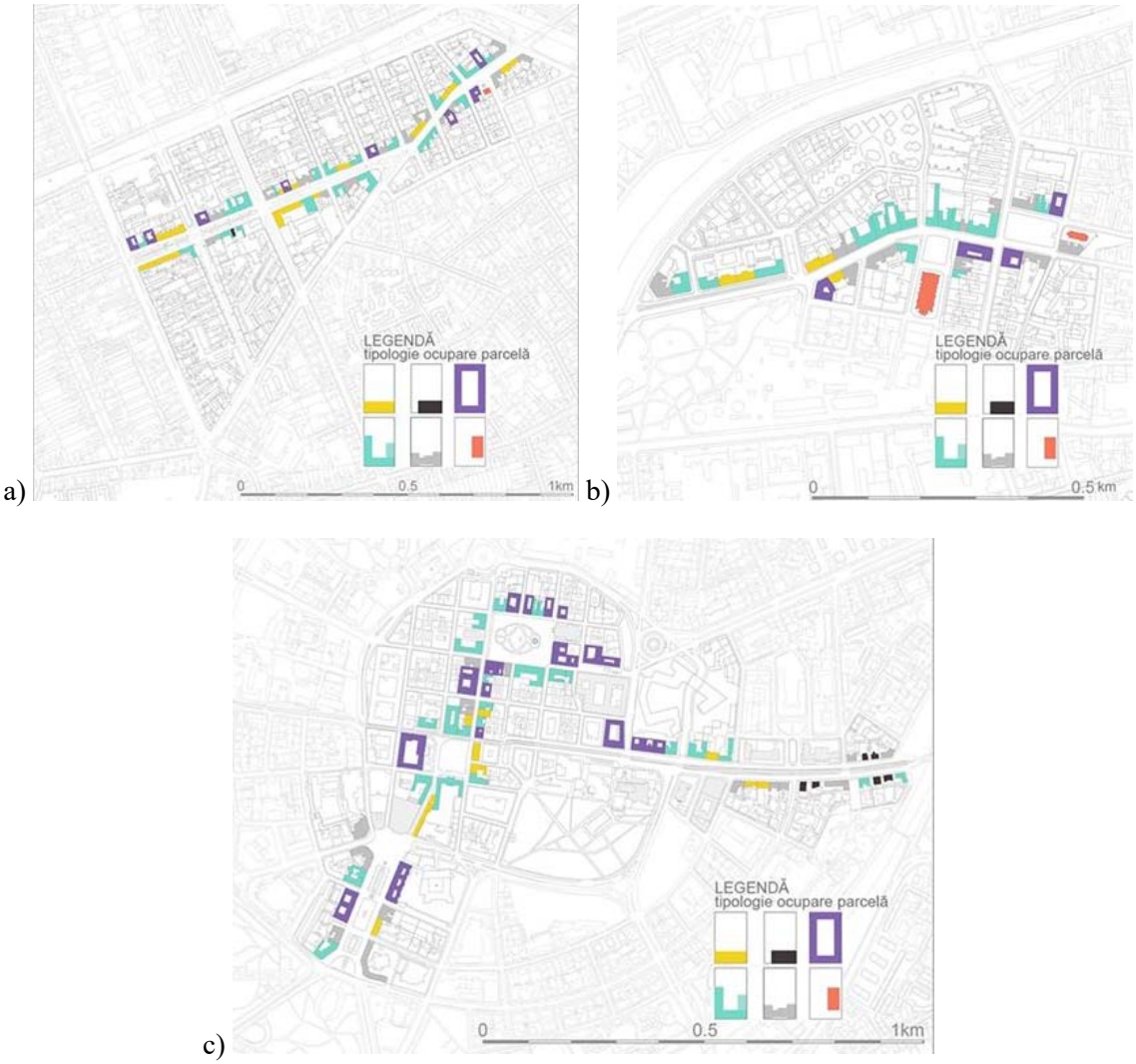



Figure 8. The site occupancy typology in historical areas of Timisoara: a) Iosefin; b) Fabric; c) Cetate [8]

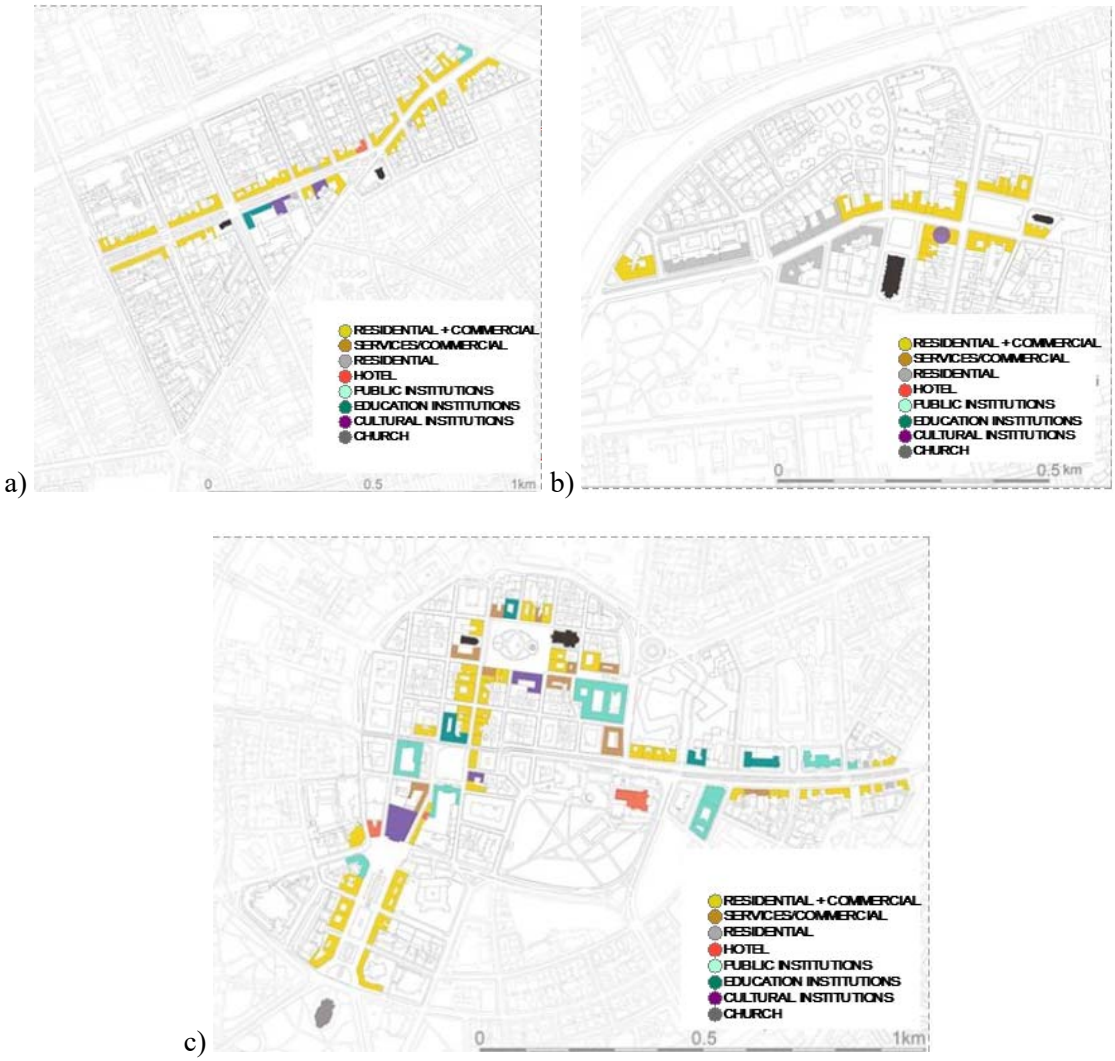



Figure 9. The existence of commercial space: a) Iosefin; b) Fabric; c) Cetate [8]

4.3. Iosefin historical area results

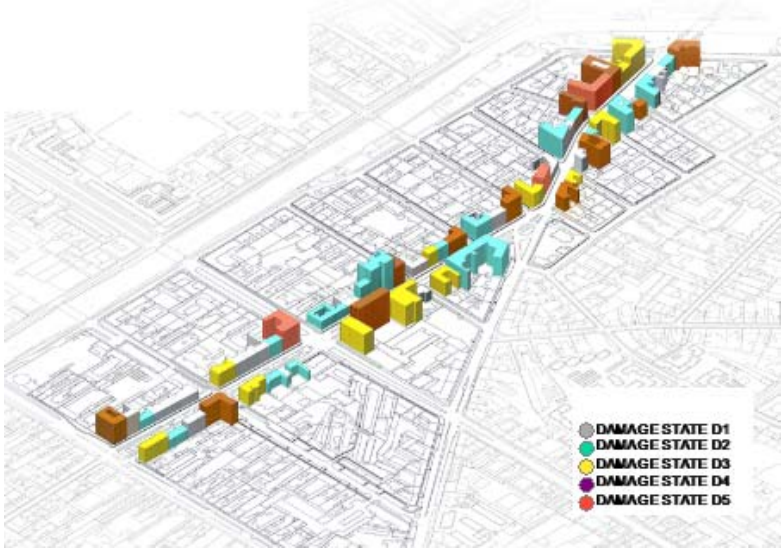
Based on the previously presented methodology, there was made the overall vulnerability for all 67 investigated buildings from Iosefin historical area for macroseismic intensity 8, showing the fact that almost 30% of the buildings could suffer damage state $D_3$ and a bit over 30% damage state $D_4$. Only 14.92% of the total number of buildings will be in danger of collapse ($D_5$), while a bit over 20% are in no danger of structural damage ($D_1$+$D_2$), as we can see in figure 11a. The general vulnerability curve is shown in figure 11b, highlighting an overall medium vulnerability of the area.

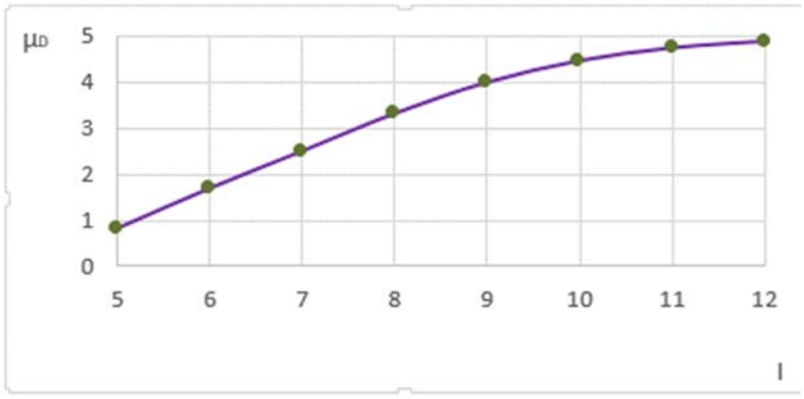
a) 


b) 


c) 


Figure 10. The conservation state of the buildings: a) Iosefin; b) Fabric; c) Cetate [8]

a) 

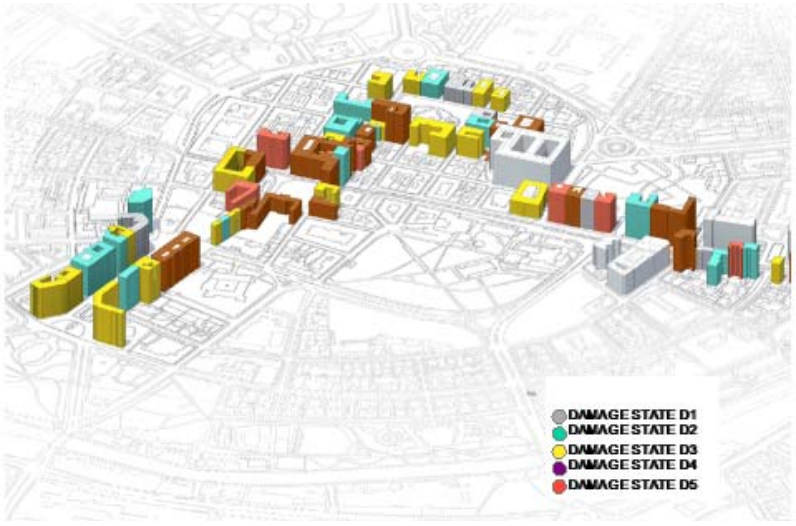



b)

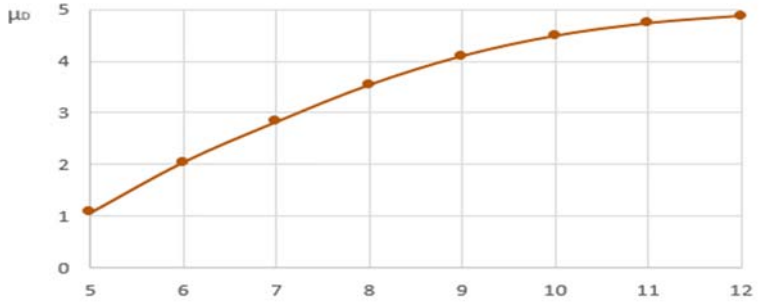
Figure 11. The seismic vulnerability of the historical area Iosefin: a) seismic vulnerability of each building; b) overall vulnerability curve for the entire area

4.4. Cetate historical area results

The overall vulnerability assessment for all 89 investigated buildings from Cetate historical area for macroseismic intensity 8, showed the fact that almost 40% of the buildings could suffer damage state $D_4$ and a bit over 20% damage state $D_5$ and $D_3$. Only 17.97 % of the total number of buildings are in no danger of structural damage ($D_1$+$D_2$), as we can see in figure 12a. The general vulnerability curve is shown in figure 12b, highlighting an overall medium vulnerability of the area.




a)




b)

Figure 12. The seismic vulnerability of the historical area Cetate: a) seismic vulnerability of each building; b) overall vulnerability curve for the entire area

4.5. Fabric historical area results

The overall vulnerability assessment for all 37 investigated buildings from Fabric historical area for macroseismic intensity 8, showed the fact that almost 35% of the buildings could suffer damage state $D_4$ and a bit over 15% damage state $D_5$ and $D_3$. Almost 30 % of the total number of buildings are in no danger of structural damage ($D_1$+$D_2$), as we can see in figure 13a. The general vulnerability curve is shown in figure 13b, highlighting an overall medium vulnerability of the area.

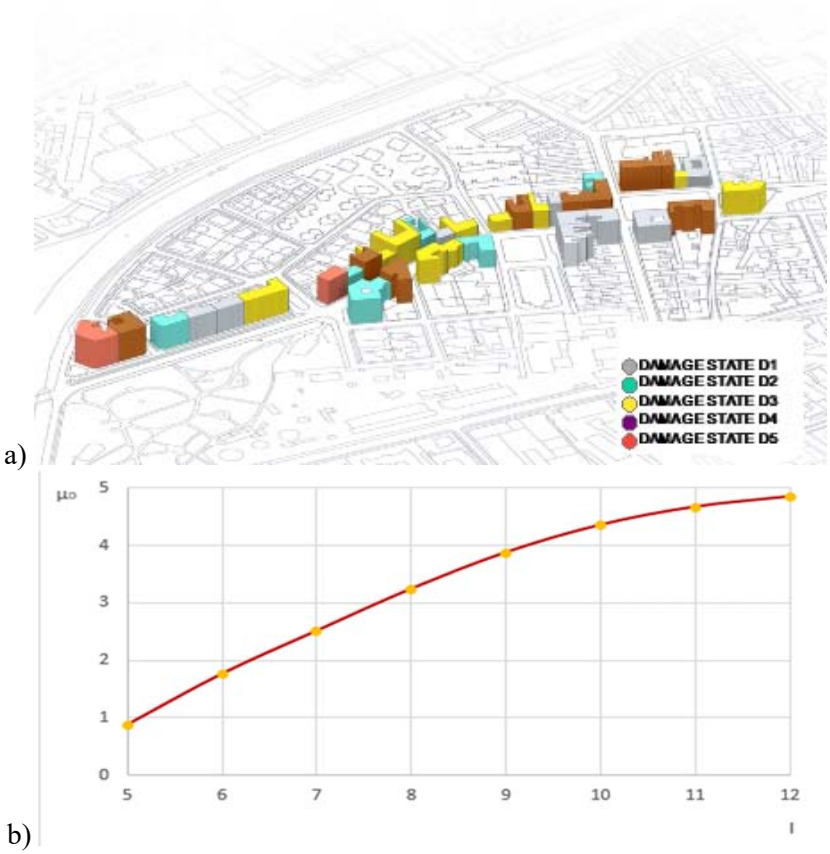



Figure 13. The seismic vulnerability of the historical area Fabric: a) seismic vulnerability of each building; b) overall vulnerability curve for the entire area

## 5. Losses scenario

The scenario was made for macroseismic intensity 8, in order to be able to estimate the number of the buildings that will become for a period of time not usable, number of possible deaths and people left without home or job and possible financial losses.

The evaluation for the number of buildings that will no longer be available for living or working ($UNU_{SD}$) was determined based on Equation 3 [15]. The total number of buildings that could become unusable temporary or permanently from the investigated historical areas are shown in figure 14a.

$$UNU_{SD} = U_{MF} \text{ x } \%MF \quad (3)$$

where %MF= 0.9 x P[$D_3$] + 1.0 x P[$D_4$] + 1.0 x P[$D_5$], P[Dk] representing the possibility (%) for having a specific damage level k and $U_{MF}$ represent the total number of multifamily units.

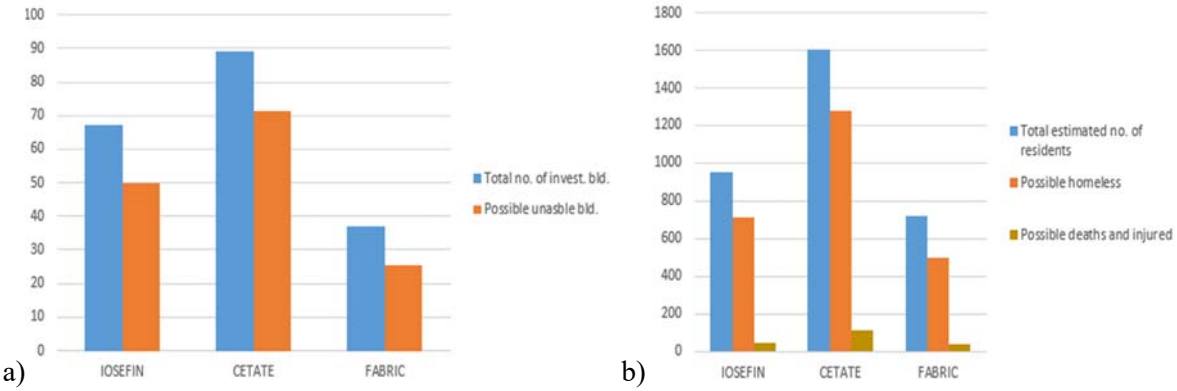
The number of people that could remain without shelter or jobs was determined based on Equation 4 [15]. The estimated number of people that have changed to remain without shelter and the possible number of injured persons or even deaths can be seen in figure 14b.

$$P_{unu} = P_h \text{ x } UNU_{SD} \quad (4)$$

where $P_h$ represents the number of people/family unit.

The number of possible deaths and severely injured (figure 14b) was determined with Equation 5,

$$P_{\text{dead and severely injured}} = 0.3 \times P[D_5] \quad (5)$$




a) b)

Figure 14. Estimation of possible no. of buildings that will become unusable in the investigated parts of the historical areas of Timisoara

The estimated financial losses (figure 14) were evaluated based on Equation 6 [15] and are shown in figure 15.

$$S_{\text{cost}} = \sum_{k=2}^{5} CS(k) \quad (6)$$

, while $S_{\text{cost}}$ represents the total repair cost CS for the most expected damage states k.

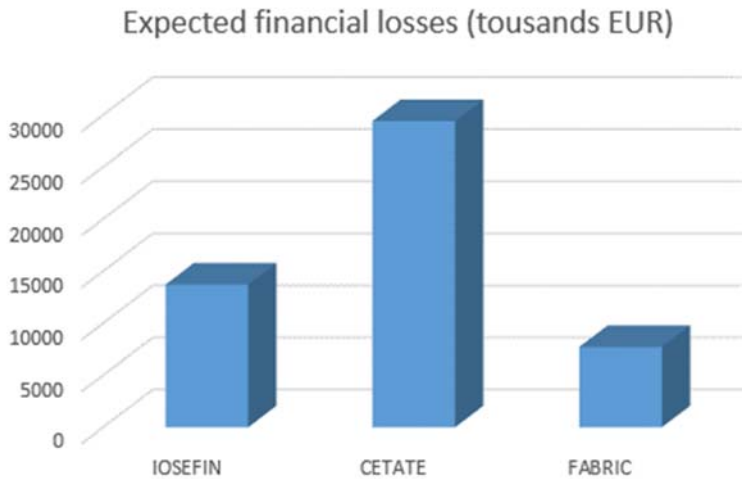



Figure 15. The expected costs for repairing the damages in the investigated parts of the historical areas of Timisoara

In the investigated areas of Timisoara, all buildings are classified as buildings in protected historical sites, and some of them, especially in Cetate historical area, are even classified as historical national monuments (figure 16). Considering the fact that the chances for the buildings to suffer considerable damages to non-structural or structural elements are very high, there should be considered the possibility to be lost a lot of architectural historical decorations and even entire buildings, losses that are irreversible, as we can see in figure 17. Conservation planning represents the key of protecting and sustainable developing a historical city [19].

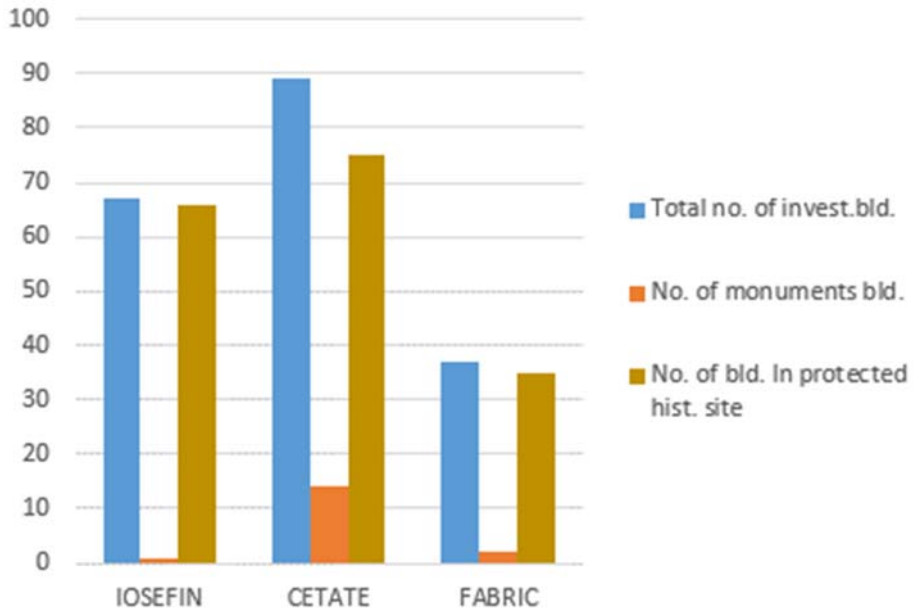



Figure 16. Number of monuments and buildings in protected historical site from the investigated parts of the historical areas of Timisoara

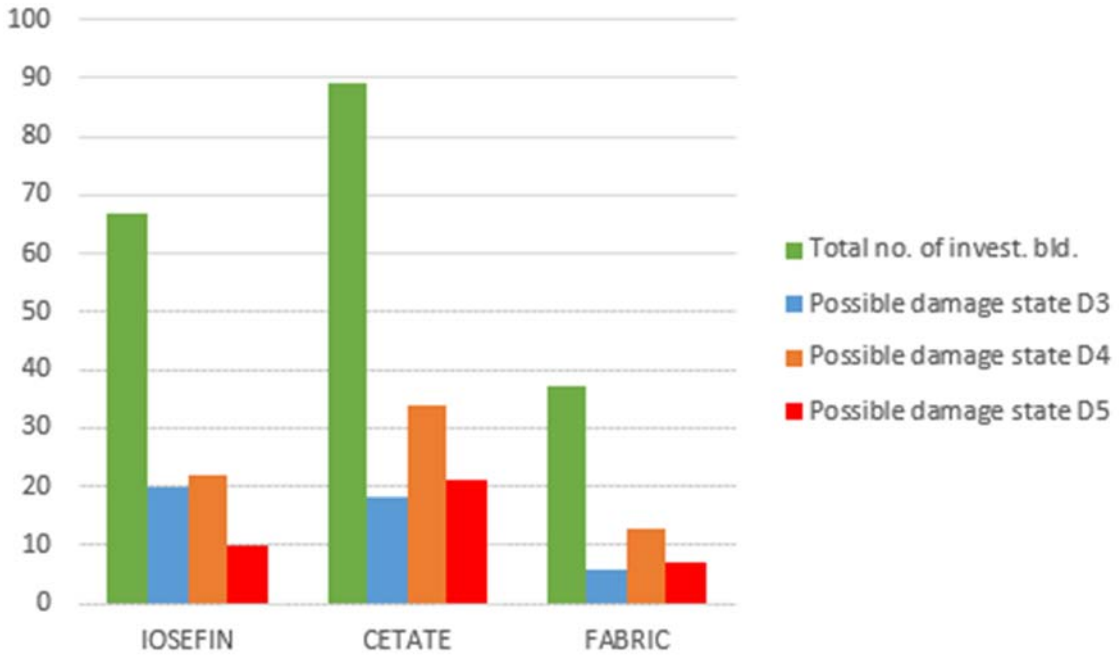



Figure 17. Estimation of most probable damage state for the investigated buildings of the historical areas of Timisoara

## 6. Conclusions

The study has revealed the fact that, in case of an earthquake occurrence, the historical area of Timisoara city could suffer relevant damages, their effects having social, economic and cultural consequences. Considering the large number of buildings that are classified as national monuments or buildings in historical protected sites, the possibility of losing irreplaceable architectural, historical, aesthetical elements based on the previous seismic scenario is significant, highlighting the need of protecting the history and identity of the city and its community. In the context of Timisoara Capital of Culture 2021, the three presented historical areas will become the main attraction points and events host, so preserving

the authenticity of the previously presented buildings is mandatory, for the next generations to be able to feel and live the original spirit of place. This kind of multidisciplinary seismic vulnerability assessment at urban scale study were started together with research teams from University of Padua, Italy [20] and University of Naples, Italy [21] and could offer a quickly support for the local authorities to develop a global strategy for the historical areas in order to assure the safety of the buildings and their residents and visitors.

**Acknowledgments**
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