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APPLICATION OF HAZARD RISK METHDOLOGY ON HISTORICAL BUILT ENVIRONMENT IN TIMISOARA

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Abstract

The multi-hazard risk assessment of the built environment, especially in historical urban areas, represents a common topic nowadays, with many challenges in the management process.
Timisoara, which will be the European Capital of Culture in 2023, has several historical areas which present various vulnerabilities to hazards, especially to earthquakes. Heritage buildings in Art Nouveau, Baroque, Secession architectural style present a poor state of conservation, without recent consolidation work and also without a specific knowledge of their expected damage state in case of an earthquake. Considering the fact that Timisoara is located in Banat seismic area, which is characterized by shallow earthquakes of crustal type, the opportunity of investigating the vulnerability of the most important districts of the city is highlighted.
The paper presents a multi-disciplinary empirical vulnerability assessment made on a historical area of Timisoara city, which investigated the structural, architectural-artistic, urbanistic and socio-economic vulnerability of the case-study area, in a simplified and efficient way. The assessment methodology represents a complex, holistic methodology that was proposed by the same authors recently, which aims to consider the cultural value of the heritage buildings in the process of multi-hazard risk management of the built environment.

Keywords: masonry, hazard, vulnerability assessment, heritage buildings, risk management

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1 INTRODUCTION

Historical buildings and historical cities represent one of the most valuable assets of the local communities, as the base of their authenticity. Due to their age and building materials and technology, implemented before the existence of any design codes, historical buildings are more vulnerable to damage or collapse during an earthquake, so their susceptibility to this hazard should be determined, to be able to ensure the preservation and safety.

For historical districts that are located in areas with seismic hazard, vulnerability is a concern for many structures in the city. For increasing their resilience, it is important to be aware of the vulnerability level, possible seismic scenarios and possible losses, to take the necessary measures to minimize the damage and to ensure the safety of the inhabitants.

Seismic vulnerability assessment of heritage buildings is one of the most important tools in the process of ensuring structural stability and preservation in case of an earthquake.

This paper aims to look at a small aggregate in Timisoara city, which has a rich historical heritage, but which is also a seismic area. The aim of the paper is to highlight the importance of conducting vulnerability assessment on those buildings, as a first step in the process of preserving the cultural heritage of the city. The assessment methodology takes into consideration more than just the structural features, so its findings are expected to contribute to the development of strategy for the seismic risk management in Timisoara.

1 CASE STUDY AREA

The paper focuses on one aggregate in one of the most important historical districts of Timisoara city. The name of the district is Iosefin and is located in the western part of the city, on the left bank of the Bega river, as presented in Figure 1 [1]. The district is well-known for its valuable architectural value, with many buildings in Art Nouveau and Eclectic style [2]. The district was built in the 18th and 19th Century and was settled by nobility and wealthy merchants. The most important districts palaces and mansions were built at the beginning of the 20th Century and are well preserved even nowadays. In the context of Timisoara European Capital of Culture 2023, a large number of historical palaces and urban areas in Iosefin district are activated to host several cultural events and festivals [3], [4]

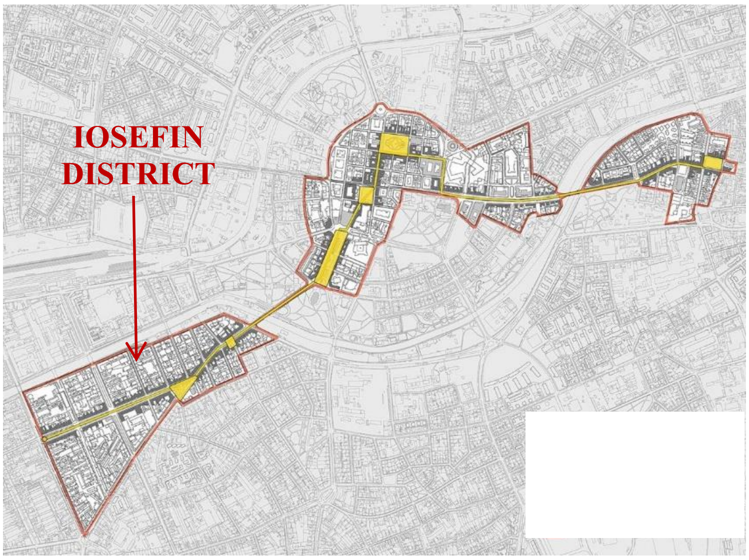


Figure 1: Main historical districts of Timisoara city [1].

The specific aggregate that represents the case study of this paper is one of the most important ones in Iosefin district, as it represents the first buildings that are seen coming from the city center, the visual connection between Iosefin and Cetate districts. The aggregate is located in the eastern extremity of the district, as shown in Figure 2a. An aerial view of the buildings within this aggregate is presented in Figure 2b.

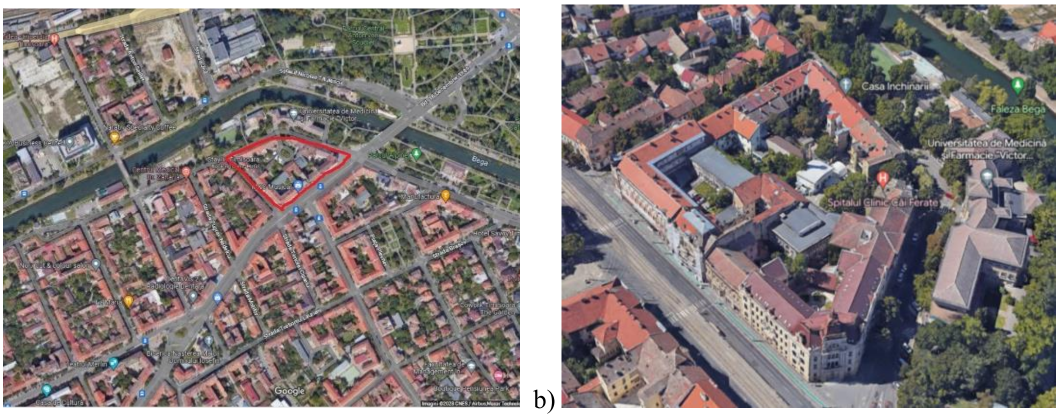
a)  b)

Figure 2: Case study aggregate: a) position within the Iosefin district; b) aerial view.

The buildings in the investigated aggregate are all with historical and cultural value, built in the years of 1900, in Art Nouveau principal architectural style and Eclectic secondary architectural style, with decorated facades and several architectural-artistic assets, as illustrated in Figure 3. The buildings are all made in burnt clay brick masonry with lime, with thick perimetral masonry walls and thin transversal masonry walls, with masonry vaults above basement and wooden floors [5] (in some cases concrete slabs as a retrofitting modern intervention), with rigid wooden frameworks in German style [6].

Figure 3: The historical buildings within the case study aggregate.

2 SEISMICITY OF THE AREA

Timisoara is located in Banat seismic area, which represents the second most important seismic region of Romania. The seismicity of Banat area is a moderate one, with earthquakes of crustal type [7]. The magnitudes in the area are between $M_W = 0.2 \div 5.6$ [8], as presented in Table 1 [9], and according to the Romanian Design Code, the peak ground acceleration for Timisoara is PGA = 0.20g [10]. Following the considered PGA, there was determined the most probable macroseismic intensity, based on Equation 1 [5], which is IX EMS-98, as presented in Figure 4 [11].

Seismic intensity	V	VI	VII	VII-VIII
Year	1889	1973	1859	1879
	1896		1879	1915
	1902		1900	1991
	1907		1941	
	1950		1959	

Table 1: The most important seismic events in Banat area (MSK intensity scale) [9].

$$\ln(PGA) = 0.24 \times I_{EMS\text{-}98} - 3.9 \quad (1)$$

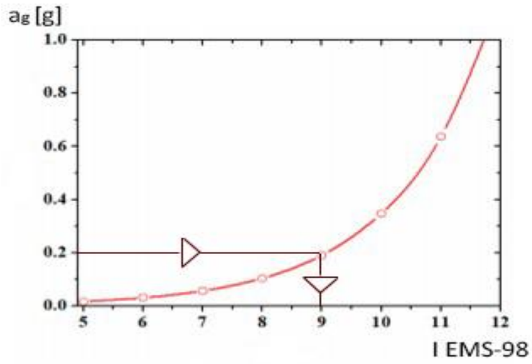


Figure 4: Correlation between the PGA and the expected macroseismic intensity EMS-98 [11].

3 VULNERABILITY ASSESSMENT

The vulnerability assessment of the investigated aggregate in Iosefin district was performed following a methodology that was previously developed by the authors [12], that considers also the importance and the impact of the cultural value in the process of vulnerability assessment [13]. The aim of this procedure is to be able to calibrate the seismic vulnerability based on the level of cultural importance of the building. This aspect could allow the local authorities to prioritize the rehabilitation works not only based on the highest structural vulnerability, but also based on the highest cultural value of the buildings. The preservation of the most important architectural heritage of the city, is in accordance with the European guidelines for the preservation of the cultural heritage assets [14] and also with the UNESCO program for the cultural landscape [15].

3.1 Methodology

The methodology is an empirical ones, based on the visual inspection of the investigated aggregate, appropriate for investigations of large urban areas, quick and simplified. It considers four categories of parameters, such as structural, architectural-artistic, urbanistic and socio-economic ones. Each category influences the vulnerability score in a smaller or higher percentage, from 70% for the structural features to 5% for the social economic ones. The investigation form contains a total number of 42 parameters, from which the first 15 parameters refers to the structural category.

This first category, the structural one, represents actually a well-known vulnerability assessment methodology that was first proposed by profs. Bendetti and Petrini [16] for the first 10 parameters and developed by profs. Mazzolani and Formisano for the other 5 parameters that considers the interaction within the aggregate [17].

The other three categories were proposed by the authors of this paper, following several research and Romanian codes [12], [18], [19]. Those parameters are based on a personal appreciation of the architectural-artistic, urbanistic and socio-economic value of each aspect, following recommendations and guidelines from Romanian code for monument consideration and several research contracts in the field. The weights of each parameter were calibrated following the application of the form on more than 100 historical buildings.

The vulnerability index is obtained by fulfilling the final investigation form, which is presented in Table 2, as the sum of each individual score of each parameter multiplied by a corresponding weight, as in Equation 2 [20].

%	Criteria	No.	Element	Class				Weight
				A	B	C	D	
70 %	STRUCTURAL	1	Vertical structure organization	0	5	20	45	1.00
		2	Vertical structure nature	0	5	25	45	0.25
		3	Type of foundation and location/soil	0	5	25	45	0.75
		4	Distribution of structural elements in plan	0	5	25	45	1.50
		5	Regularity in plan	0	5	25	45	0.50
		6	Regularity in elevation	0	5	25	45	1.00
		7	Floor type	0	5	15	45	0.75
		8	Roofing	0	15	25	45	0.75
		9	Other details	0	0	25	45	0.25
		10	Conservation state	0	5	25	45	1.00
		11	Presence of adjacent buildings with different height	-20	0	15	45	1
		12	Position of the building in the aggregate	-45	-25	-15	0	1.5
		13	Presence and number of staggered floors	0	15	25	45	0.5
		14	Effect of either structural or typological heterogeneity among adjacent structural unit	-15	-10	0	45	1.2
		15	Percentage difference of opening area among adjacent façade	-20	0	25	45	1
15 %	ARCHITECTURAL ARTISTIC	16	Representative architectural style for the area	0	10	15	25	1.50
		17	Age, importance of the build époque	0	10	15	25	1.20
		18	Original woodwork/joinery	0	10	15	25	1.00
		19	Original stucco, brick, floors or ceilings	0	10	15	25	1.00
		20	Original statues or bass-reliefs	0	10	15	25	1.00
		21	Original gable/fronton	0	10	15	25	1.00
		22	Original balconies and railings	0	10	15	25	1.00
		23	Original mosaics or stonework	0	10	15	25	1.00
		24	Original paintings or frescoes	0	10	15	25	1.00
		25	Degradation state of artistic assets	-5	10	15	25	1.00
		26	Authenticity/ originality (global, elements)	0	10	15	25	1.00
		27	Official monument (national, regional, local, protected area) status	0	10	15	25	1.50
		28	Particular construction techniques/materials	0	10	15	25	0.50
		29	Conservation state of original materials	-5	10	15	25	0.50
		30	Representative historical events	0	10	15	25	0.50
		31	Archaeological site	0	10	15	25	1.50
		32	Representative/ original wooden framework	0	10	15	25	1.00
		33	Past restoration work	-5	10	15	25	1.00
10 %	URBANISTIC	34	Importance in contouring the street profile	-5	10	15	25	1.50
		35	Importance in contouring the urban silhouette	-5	10	15	25	1.50
		36	Annexes, relation with the urban pattern	0	10	15	25	1.00
		37	Location (central area, touristic area)	0	10	15	25	1.50
		38	Representative/particular shape of the roof	0	10	15	25	1.00
	SOCIAL	39	Public/social functions	0	10	15	25	1.50

5 %	ECONOMIC	40	Importance for the local community memory	-5	10	15	25	1.00
		41	Economic value	0	10	15	25	1.50
		42	Cultural functions	0	10	15	25	1.50
						$I_{V\ CULT}$		

Table 2: The investigation form that considers also the cultural value [9].

$$I_{V\ CULT} = 0.70 \times \sum_{i=1}^{10} s_i \times w_i + 0.15 \times \sum_{i=11}^{28} s_i \times w_i + 0.10 \times \sum_{i=29}^{33} s_i \times w_i + 0.05 \times \sum_{i=34}^{37} s_i \times w_i \quad (2)$$

Following the seismic vulnerability index influenced by the cultural value, there is obtained a normalized vulnerability index V_{CULT}, based on Equation 3 . Later on, the mean damage is obtained following Equation 4, which was previously calibrated for Banat seismic area by the authors and the most probable damage state for each building, for the considered seismic scenario, is obtained [5].

$$V_{CULT} = \frac{I_{VCULT} - I_{VCULT\ MIN}}{I_{VCULT\ MAX} + I_{VCULT\ MIN}} \quad (3)$$

$$\mu_D = 2.5\left[1 + tanh\left(\frac{I + 12.50 \times V_{CULT} - 13.1}{\Phi}\right)\right] \quad (4)$$

, where Φ is considered 2.3 because the residential predominant function of the investigated buildings [21].

3.2 Results

The seismic vulnerability influenced by the cultural value, for each individual investigated building, is illustrated in Figure 5 and shows expected damages states from D2 to D4, which indicates possible damages from only to non-structural elements till consistent damages to structural elements. The individual damage state, correlated with several other parameters, are illustrated in Table 3.

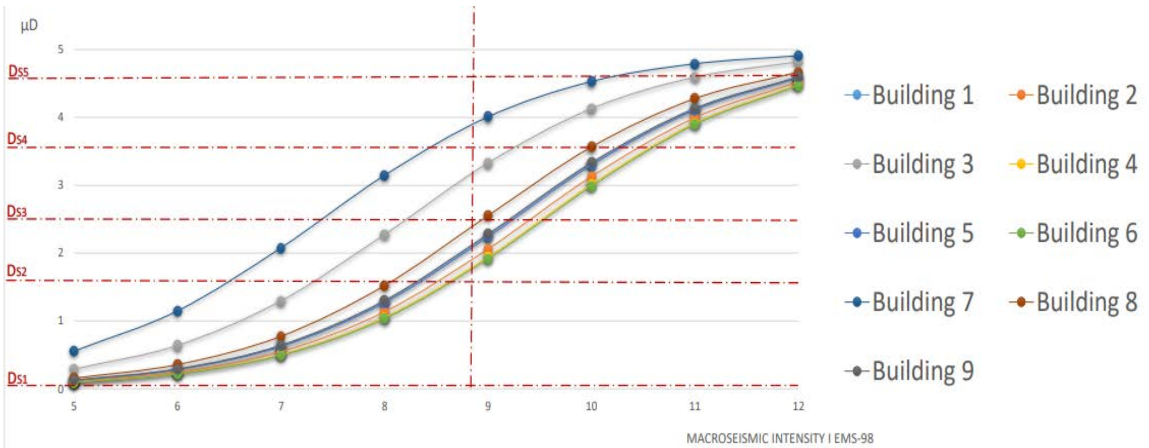


Figure 5: Seismic vulnerability curves influenced by the cultural value for each individual investigated buildings.

No.	Street	Picture	Position	Ground floor (square meters)	Floor no. (with basement)	$I_{V\ CULT}$	Expected damage state

1	16th December		Corner	1069.32	4	103.05	DS3
2	Tudor Vladimirescu		End	389.23	3	92.9	DS2
3	Tudor Vladimirescu		Line	356.47	3	133.85	DS3
4	Miron Costin		Corner	770.88	3	87.175	DS2
5	Miron Costin		Line	439.23	3	98.675	DS2
6	Miron Costin		Line	349.55	3	87.925	DS2
7	16th December		Corner	1375	4	163.175	DS4
8	16th December		Line	342.35	4	111.225	DS3
9	16th December		Line	349.79	3	100.025	DS3

Table 3: Correlation of each individual building to the expected damage state.

The mean vulnerability curve of the entire aggregate is presented in Figure 6, highlighting a medium seismic vulnerability influenced by the cultural value, with a general D3 expected damage state.

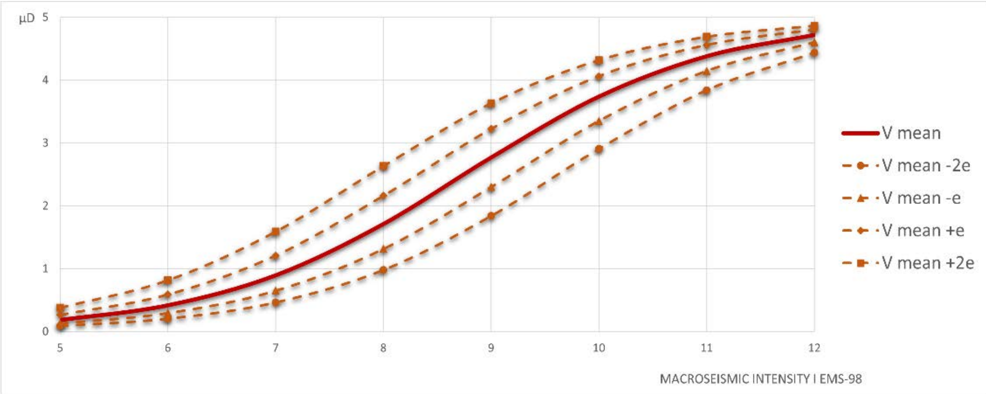


Figure 6: Mean seismic vulnerability curves influenced by the cultural value for the entire aggregate.

Moreover, there was investigated the relations between the vulnerability index for the investigated buildings, with focus on the buildings that are on a corner position (Figure 7) or with the most number of levels (Figure 8). After this correlation, there can be said that in general, with some exceptions, the most vulnerable buildings are the ones that are the tallest and in corner position.

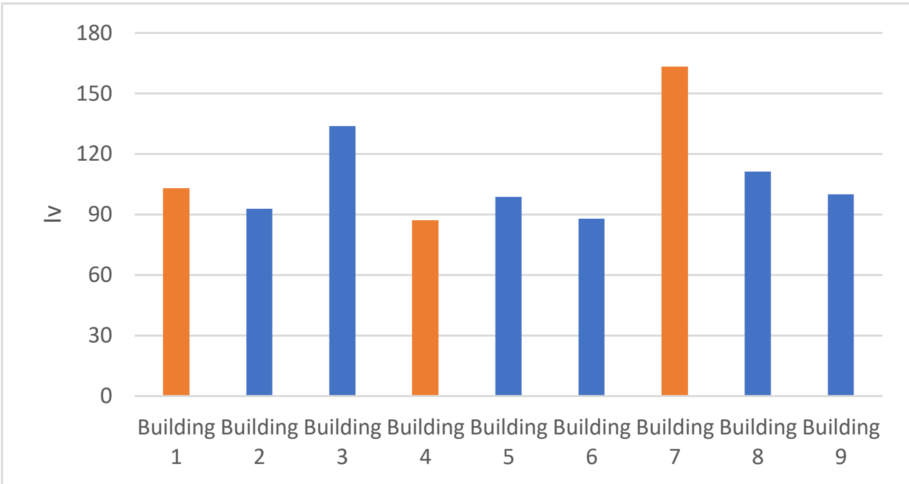


Figure 7: Vulnerability index for all buildings, with highlight on the buildings located in a corner position in the aggregate.

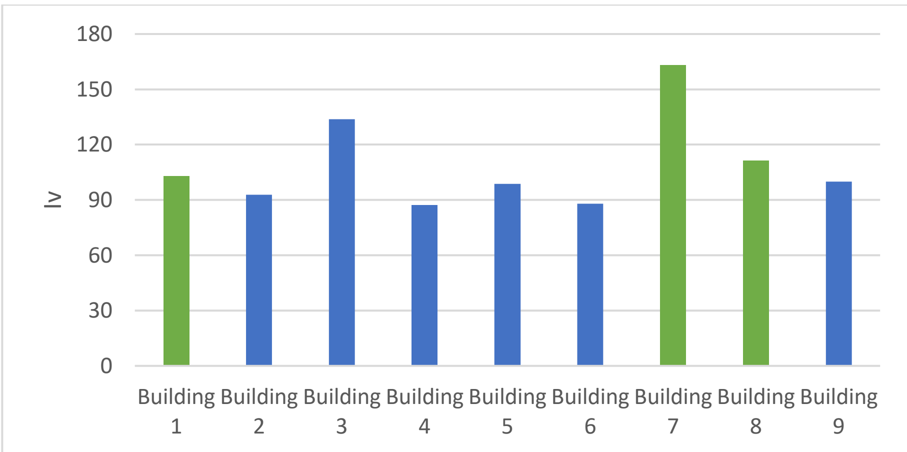


Figure 8: Vulnerability index for all buildings, with highlight on the highest buildings within the aggregate.

In the end, there was investigated the vulnerability index without the consideration of the architectural-artistic, urbanistic and socio-economic parameters, to observe how much the cultural value could influence the mean vulnerability of the case study buildings. The comparison between the vulnerability curves with and without cultural value is presented in Figure 9, showing that the consideration of the parameters that are not related only with the structural system lead to the increase of the mean vulnerability with 6%, without changing the expected mean damage state.

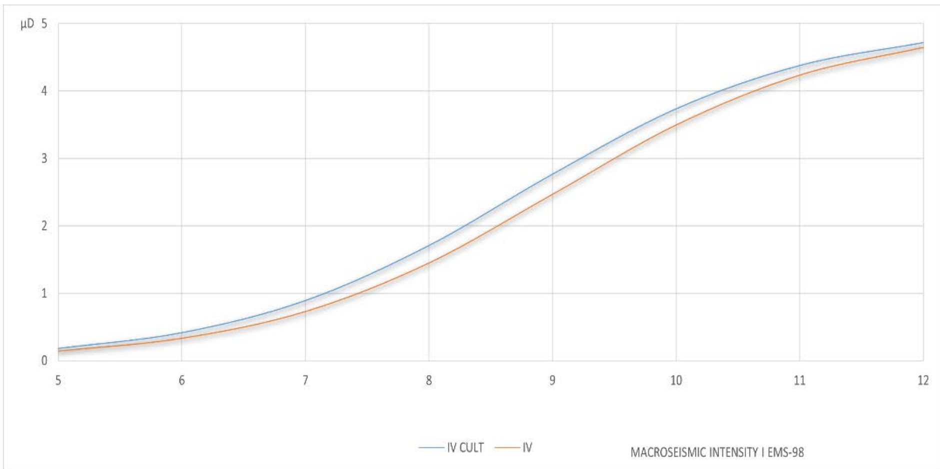


Figure 9: Comparison between mean vulnerability curves with and without the cultural value considered.

4 CONCLUSIONS

The case study building in Timisoara were investigated not only from a structural point of view, but also from a cultural perspective, by considering some supplementary investigations parameters that evaluates the architectural-artistic, urbanistic and socio-economic value of the heritage buildings. The results of the assessment are concluded bellow, as follows:

- The investigated historical masonry buildings in Iosefin district, Timisoara, present a medium cultural value, which influences the seismic vulnerability.
- The investigated buildings present a medium seismic vulnerability for the specific seismic scenario (macroseismic intensity IX EMS-98).
- The less vulnerable building is expected to be in the D2 damage state, meaning only non-structural damages, while the most vulnerable buildings is expected to reach D4 damage state, meaning also extensive damages to structural elements.
- The general expected damage state for the entire aggregate is D3, which means significant damage to non-structural elements and minor damage to the structural ones.
- Despite the D3 damage state for the aggregate, which isn't dangerous for structural safety, a lot of architectural-artistic assets could be damaged in case of an earthquake.
- The most vulnerable buildings are in general the ones that are the tallest and in corner positions, but some exceptions occur due to the different levels of decay between buildings.

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