Figure 12. Mean damage (Vicente).

Figure 13. Mean damage (Polese et al. method).

3.9. Evaluation of Social and Economic Losses

As described in Section 2, damage maps combine vulnerability and seismic hazard. It is feasible to create risk maps that visually illustrate losses and impact indicators by including exposure information and finally define the priority matrix.

To calculate the economic losses, with reference to the procedure previously described, in the case of Lisbon, a reconstruction cost of EUR 5000/sqm was considered. By multiplying this cost by the floor area and the number of stories, the total cost of the considered building can be found. This value is then multiplied by the percentage referring to the level of damage based on Vicente et al. (Table 5) to obtain an estimation of economic losses. The same technique can also be used to determine casualties, multiplying the proportion of fatalities and injuries by the total number of individuals and the impact, which is determined

by multiplying the percentage of useable, unusable, or collapsed structures by the total number of buildings. Table 7 shows the total losses for the entire area considered.

Table 7. Total losses.

Cost of Repair (€)	Fatalities	Injuries	Usable Buildings	Not Usable Buildings (Short Time)	Not Usable Buildings (Long Time)	Collapsed Building
290,619,820	2	6	873.2	23.2	33	1

The results of the calculations carried out using the Qgis software [48] in terms of repair costs are shown below since it is the most relevant result in terms of losses to be reported on the map (Figure 14).
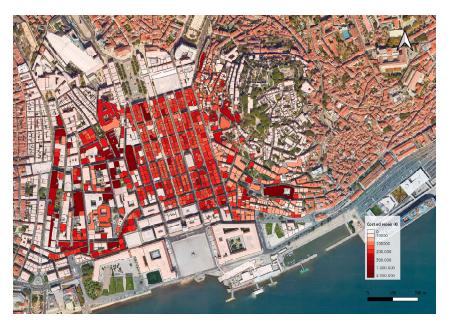

Figure 14. Cost of repair of Lisbon downtown (€).

3.10. Urban Resilience Assessment for Lisbon Downtown

Finally, the final strategy for resilience assessment was applied as theorized in Section 2.

Through a matrix approach, all the data collected and the processing carried out for risk management were combined, until a priority matrix was obtained to optimize the management of the recovery process and preventive planning.

The result of this processing is shown in the map in Figure 15 which indicates the priorities for action on the built heritage in ascending order.

Figure 15. Map outlining the priorities for intervention in the historic center of Lisbon.

4. Discussion

This paper examines the conceptual and procedural aspects of resilience assessment in historic centers.

The methodology used is efficient on an urban scale, allowing for the quick identification of structures at risk and the display of the geometries, favoring the interpretation of the phenomenon's geographical distribution. By creating a geodatabase that is as complete as feasible, engineers and planners may analyze the seismic damage to the building stock, record economic and human losses, and prepare swift responses by using space-based seismic scenarios. Novel elements derive from evaluating resilience for historic areas, focusing on tangible and intangible aspects of cultural heritage. A case study, the historic district of Lisbon, was used to validate the methodology. The results represent the starting point for the proposal of intervention measures.

The two methods used for the assessment of seismic vulnerability are effective in giving a first interpretation of the expected damage, although, for a real result, it would be useful to deepen and calibrate the two methods. The methodology experimented by Vicente [14] would seem more suitable for describing the behavior of Pombalino buildings, while that experimented by Polese [35] appears to be more severe in predicting damage, but being the latter more rapidly applied and considering fewer parameters, it presents a greater degree of uncertainty even if with the same level of knowledge. This method could be improved by using the regional modifier in Equation (1) as it has not been applied in this study because of the uncertainties related to the present dataset.

The limitation of the applied methodology lies in the constructions' scenario to which they can be applied: the considerable number of data brings a great measure of uncertainty due to a lack of information, errors, incorrect classification etc. Data collection on-site will be necessary for a more thorough analysis of the seismic vulnerability of Pombalino buildings because those structures' actual seismic susceptibility today greatly depends on the interventions that have been made to them throughout the course of their existence. These were typically connected to the installation of new systems (for instance water or gas piping), the expansion of spaces by adding additional floors or the interruption or suppression of columns and walls, particularly on the ground floor to open up large spaces for storefronts and indoors to create larger spaces, the introduction of reinforced concrete structural walls for the installation of elevators, and the replacement of the original roof structures with heavier struts. Most of these modifications were made without any consideration for the

buildings' seismic resistance, which was made possible by a legislative loophole and the absence of technical standards that applied to work on older structures. Additionally, most of these structural changes are not formally documented, making it impossible to identify them without thorough reconnaissance and inspection of the structures.

Finally, this case study would contribute to the seismic assessment of these types of masonry buildings and perform research for predicting losses, evaluating intervention priorities and resilience to support the management and reduction of seismic risk.

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