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A RAPID METHODOLOGY FOR ASSESSING BUILDING STOCKS AND PRIORITIZING MAINTENANCE INTERVENTIONS

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Abstract

The health of buildings is essential for determining their service life. Poor maintenance can accelerate multiple degradation phenomena, significantly shortening the building's lifespan. Inadequate maintenance can accelerate deterioration, leading to a decline in both the functionality and value of a building, and, in severe cases, jeopardising its structural integrity. While the effects of deterioration are well-documented and extensively studied for critical infrastructure, such as bridges, this issue often receives limited attention within the context of buildings. For buildings, deterioration is frequently perceived as an aesthetic problem rather than a technical or safety concern. This underestimation is particularly apparent in the absence of comprehensive methodologies that consider the deterioration of both structural and non-structural components in an integrated approach, especially with regard to ordinary and industrial buildings. As a result, critical safety risks may go unnoticed, leading to delayed maintenance interventions that can exacerbate existing issues. This study presents the development of a rapid methodology for analysing heterogeneous building stocks to establish priority lists for maintenance interventions. The proposed method relies entirely on visual inspections and is structured into two levels of analysis. The first level focuses on assessing individual buildings, providing a scoring system to quantify the degradation state based on visible deterioration signs. The second level expands the evaluation to the scale of the entire building stock, considering the interrelations between stock elements. Finally, the study includes a practical application of the methodology to a real portfolio of industrial buildings, demonstrating its effectiveness and potential for broader implementation. The proposed approach aims to provide a straightforward yet comprehensive tool for stakeholders to prioritize maintenance actions, ensuring a balance between aesthetic concerns and structural safety considerations.

Keywords: Prioritisation, Decision making, Deterioration, Maintenance, Heterogeneous building stocks.

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1 INTRODUCTION

The buildings in which we live and work daily are constantly influenced by a variety of factors, which can be classified as either natural or human induced. These factors vary in type, intensity, and extent, both geographically and temporally. Among them, the passage of time has the most significant impact on existing structures, leading to various alterations and manifestations of degradation that ultimately affect their performance. The safety of buildings is strongly influenced by the condition of their components, both structural and non-structural. Although maintenance activities are crucial for preserving structural integrity, there is no standardised regulation governing how these activities should be carried out, except for specific types of buildings, such as SEVESO industrial sites [1], which are subject to strict regulations.

This concern becomes even more pronounced when considering groups of buildings rather than individual structures. Many organisations and operators, both public and private, manage building stocks that may comprise dozens or even hundreds of structures. These building stocks are often heterogeneous, consisting of buildings constructed with different technologies and built during various periods. As a result, financial resources are frequently insufficient for planning and implementing maintenance activities across the entire stock. Therefore, decision-makers require simplified tools to help prioritize interventions. These tools should strike a balance between ease of use and low implementation costs while ensuring reliable results that accurately reflect the condition of the buildings under analysis. When shifting the focus from degradation assessment to seismic risk analysis, several approaches to prioritisation and territorial vulnerability assessment have been proposed, with methods tailored to different scales of analysis. Mass-appraisal techniques aim at assessing large-scale built heritage or numerous individual assets [2–7]. Another approach relies on the compilation of Rapid Visual Survey (RVS) forms, which are used to identify deficiencies specific to different construction technologies [8,9].

The literature presents various methodologies for evaluating building deterioration. Factorial methods assess the remaining service life of components using correction coefficients, while empirical and analytical methods evaluate degradation based on visible damage. Probabilistic models, including Markov chains, estimate the likelihood of transitions between degradation states for predictive analysis. Advanced engineering approaches use probabilistic modelling for more precise descriptions of degradation, and factorial probabilistic methods enhance traditional techniques by applying probability density functions [10]. The AIJ method [11] was one of the first to assess deterioration, focusing on building facades through visual inspections and assigning a "Deterioration Level" (DL) to each component, although it is limited to external elements. This method was later extended by Rodrigues et al (2013) [12]. The SCARBCC model [13] introduced a simplified deterioration scale for various building types, prioritizing interventions by severity, extent, and location of damage. The SCARBCC model was subsequently applied to a historic building to verify its applicability in historical contexts [14]. Condorelli et al. (2011) [15] developed a factorial model, implementing it in a GIS platform to enable the mapping of the methodology's applications. Gaspar and Brito (2008) [16] propose a methodology for assessing the conservation state of plastered façades. Three main forms of deterioration are considered: stains, cracking, and detachment. A more detailed discussion on the state of the art is available in Fabris et al. (2025) [17].

While these methodologies are useful, they predominantly focus on the condition of the building envelope, placing less emphasis on internal degradation and structural safety. Additionally, many are specific to certain building types, limiting their broader applicability. In contrast, when it comes to infrastructures, the literature presents a more extensive body of research on degradation assessment (e.g. [18]).

To address this gap, the present study introduces a methodology based on the previous work of Saler et al. (2023) [19] for bridges. This methodology has been adapted for both ordinary and industrial buildings. It has subsequently been applied to a real stock of industrial buildings to develop prioritisation lists for maintenance interventions [17,20]. The proposed methodology allows for the development of prioritisation lists for interventions on building stocks. The strategic importance of planning maintenance and retrofit interventions is widely recognised by the Civil Protection Department. In this context, the department is currently coordinating several research projects as part of the national risk assessment framework [21]; see, for example, [22, 23].

2 METHODOLOGY

This methodology refines the approach proposed by Saler et al. (2023) [19], originally developed for assessing bridge deterioration, to evaluate building stocks and prioritise maintenance interventions. The methodology consists of two levels. The Project Level initially ranks buildings based on the deterioration state of their structural and non-structural components. The Network Level refines this ranking by applying a reductive coefficient that adjusts priorities using basic registry data and the relative importance of each building within the stock, enabling a more strategic resource allocation.

2.1 The Project Level Assessment

The Project Level Assessment focuses on evaluating the condition of buildings solely from an engineering perspective. The process begins with the breakdown of the building into structural and non-structural components, each pre-assigned a weight (W) based on its relative importance. Table 1 shows the component table for steel and precast reinforced concrete technologies. A visual inspection is then conducted to identify signs of deterioration, with each component receiving a Condition Value (CV) on a scale from 1 to 5, where higher values indicate more severe degradation. If a component cannot be assessed, a CV of 0 is assigned. To ensure consistency and objectivity in the evaluation, standardised abacuses are utilised, and the methodology follows a worst-case approach, where the most deteriorated score within each component determines the final rating. Figure 1 shows the abacuses for the columns and beams components, while the complete set of abacuses is available in Fabris et al. (2025) [17]. The CV is then converted into a Condition Factor (CF) on a scale from 1 to 10 (Table 2).

	Precast Reinforced Concrete		Steel	
	Components	W	Components	W
C1	Foundations	8	Foundations	8
C2	Vertical Elements	10	Columns	10
C3	Beams	10	Other vertical elements	10
C4	Slab	9	Beams	10
C5	Infill walls	8	Nodes/Connections	10
C6	Overhanging elements	9	Wall bracing	8
C7	Heavyweight ceilings	7	Roofing bracing	8
C8	Lightweight ceilings	6	Slab	9
C9	Plastering/Finishes	5	Infill walls	8
C10	Internal partitions	6	Overhanging elements	9
C11	Flooring	7	Heavyweight ceilings	7
C12	Fixtures	5	Lightweight ceilings	6
C13	Systems	6	Plastering/Finishes	5
C14	Stairs	9	Internal partitions	6
C15	Parapet walls	6	Flooring	5
C16	Roofing - Structure	9	Fixtures	5
C17	Roofing - Extrados	6	Systems	6
C18	-		Stairs	9
C19	-		Parapet walls	6
C20	-		Roofing - Structure	9
C21	-		Roofing - Extrados	6

Table 1: Components and corresponding weights for Steel and Precast Reinforced Concrete technologies.

Condition Value (CV)	0	1	2	3	4	5
Condition Factor (CF)	0	10	7	4	2	1

Table 2: Conversion between CV and CF.

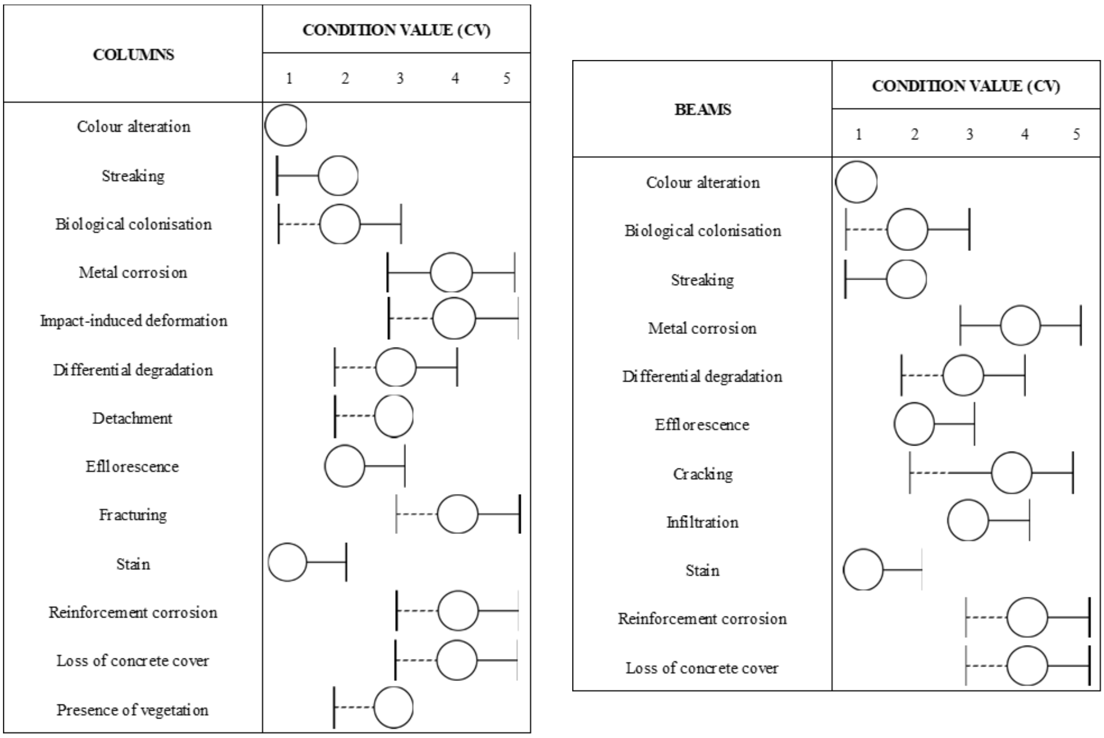

Figure 1: Example of degradation abacuses for columns and beams.

The overall condition of the building is quantified through the Total Sufficiency Rating (TSR_{real}), calculated as a weighted average of the CF values for all assessed components (Equation 1). To account for non-inspected components, TSR_{min} and the Confidence Factor (CoF) are introduced. TSR_{min} represents the worst-case condition, where all non-inspected components are assigned a CF = 1, except for foundations, which are assigned a CF = 4, as they are almost always non-inspectable (Equation 2). The CoF, on the other hand, represents the confidence factor and thus reflects the quality of the inspection (Equation 3). The final Project Level rating (TSR_{PL}, Equation 4) is derived as a weighted mean between TSR_{real} and TSR_{min}, balanced by the CoF. This rating provides a numerical score from 0 to 100, which can be used to prioritise maintenance interventions. Lower ratings indicate severe deterioration, while higher values reflect a good state of conservation. Buildings can also be grouped into intervention priority classes to facilitate large-scale maintenance planning, as shown in Table 3.

$$TSR_{real} = 10 \cdot \left(\frac{\sum_{i=1}^{t} (CF_i \cdot W_i)}{\sum_{i=1}^{t} W_i} \right) \tag{1}$$

$$TSR_{min} = 10 \cdot \left(\frac{\sum_{i=1}^{n} (CF_i \cdot W_i)}{\sum_{i=1}^{n} W_i} \right) \tag{2}$$

$$CoF = 100 \cdot \left(\frac{\sum_{i=1}^{t} W_i}{\sum_{i=1}^{n} W_i} \right) \tag{3}$$

$$TSR_{PL} = \left(\frac{100 \cdot TSR_{real} + TSR_{min} \cdot CoF}{100 + CoF} \right) \tag{4}$$

Rating Classes	
Class A_D	81 - 100
Class B_D	61 - 80
Class C_D	31 - 60
Class D_D	0 - 30

Table 3: Prioritisation classes and corresponding ranges.

2.2 The Network Level Assessment

At the Network Level, the significance of each building within the entire stock is evaluated by adjusting the Project Level rating (TSR_{PL}) with a Penalty Factor (PF). The PF incorporates several risk and importance elements through four coefficients:

- *FUN (Function):* Reflects the building's designated purpose. Public or industrial buildings, which involve higher risks, receive a greater penalty.
- *OCC (Occupancy):* Accounts for the number of occupants, applying higher penalties to more crowded buildings.
- *AF (Age Factor):* Compares the building's age with its expected service life (set at 50 years for standard buildings). Buildings beyond their service life or relatively new buildings with advanced deterioration incur higher penalties.

- *NBI (Network Building Importance):* Evaluates the building's relative importance in the stock based on its proximity to decentralised areas.

The Penalty Factor (PF) is calculated using Equation 5, with the required coefficients displayed in Figure 4. The final Network Level rating (TSR_{NL}) is determined by multiplying the PF by the TSR_{PL}, as shown in Equation 6.

$$PF = FUN \cdot OCC \cdot AF \cdot NBI \tag{5}$$

$$TSR_{NL} = PF \cdot TSR_{PL} \tag{6}$$

Function (FUN)	
1,00	Storage - Abandoned Buildings
0,95	Residential - Low-risk Industrial
0,90	Office - Public Services - Medium-risk Industrial
0,80	High-risk Industrial
Occupancy (OCC)	
1,00	Less than 50 occupants
0,95	Between 50 and 100 occupants
0,90	More than 100 occupants
Age Factor (AF)	
0,90	Total Life > Service Life
1,00	Total Life < Service Life
0,80	Life < 20 years and significant degradation
Network Building Importance (NBI)	
1,00	Possible relocation within a radius of < 10 km
0,95	Possible relocation within a range of 10 km to 20 km
0,90	Possible relocation beyond 20 km

Table 4: Coefficients used for PF calculation and corresponding evaluations.

In Figure 2, a summary flowchart of the methodology described above is provided. Given its versatility, the proposed approach lends itself to combination with other types of analysis. For instance, it can be integrated with seismic analyses to achieve a combined prioritisation, as demonstrated in the works of Saler et al. (2023) [19] and Fabris et al. (2025) [17].

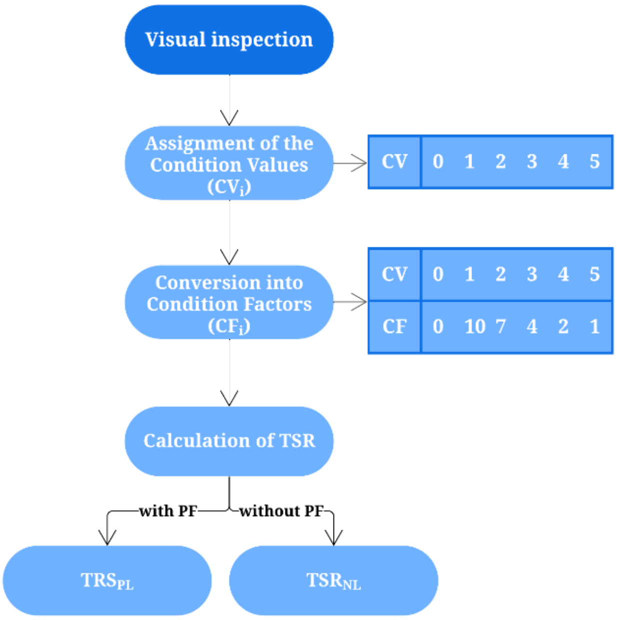

Figure 2: Summary flowchart of the presented methodology.

3 CHARACTERISATION OF THE BUILDING STOCK

This section provides an overview of the building stock inventory (Figure 3), which includes 80 structural units (SUs). Most of the buildings feature reinforced concrete structures, which are further divided into three subgroups: ordinary reinforced concrete buildings (12 SUs), large-span reinforced concrete buildings (13 SUs), and precast concrete buildings (26 SUs). The inventory also contains 18 masonry buildings and 11 steel buildings.

A breakdown of construction periods reveals that 95% of the structural units were built before 2001. Among them, 39% (31 SUs) were constructed between 1987 and 2001. Buildings built before 1971 were designed solely for gravitational loads, as seismic regulations had not yet been established. From 1975 onward, standards evolved to incorporate horizontal forces. Construction techniques shifted significantly over time, with 58% of structural units before 1971 being made of load-bearing masonry. After 1971, precast reinforced concrete became more prevalent, becoming the dominant construction method after 2002. Between 1972 and 2001, 82% of the structural units were made from reinforced concrete, divided into ordinary, large-span, and precast reinforced concrete categories. In terms of function, the majority of the buildings are used for production purposes (38 SUs), followed by office buildings (18 SUs), storage facilities (15 SUs), public service buildings (5 SUs), and residential buildings (4 SUs). Further details on the building stock characterisation can be found in Gaspari et al. (2025) [20].

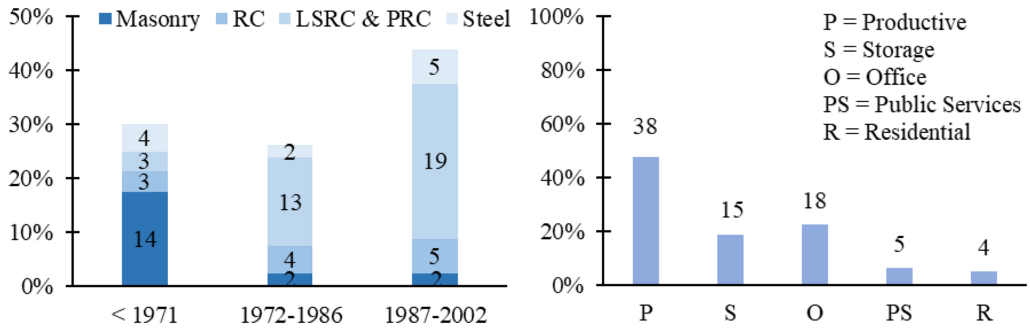

Figure 3: Distribution of construction technology and building use within the stock.

4 APPLICATION OF THE PROPOSED METHODOLOGY TO A BUILDING STOCK

The proposed degradation assessment methodology was implemented on an existing building stock, as outlined in the previous chapters. To streamline field inspections and ensure a systematic evaluation, multiple survey forms were developed, each tailored to a specific structural typology, as described in Fabris et al. (2025) [17]. Figure 4 shows the completed form. The building stock to which the forms were applied is that of Gaspari et al. (2025) [20]. This approach enhances the efficiency of data collection, enabling a structured and scalable application of the methodology across large-scale building inventories. The collected data provides a robust basis for informed decision-making in maintenance and preservation strategies.

At the Project Level (PL) (refer to Figure 5), the majority of structural units are categorized within Class A (41%, equating to 33 structural units) and Class B (51%, corresponding to 41 structural units), while a mere 8% (6 structural units) are classified as Class C. This distribution suggests that the overall condition of the stock is satisfactory, with only a minor proportion of structures exhibiting significant degradation. When evaluated based on construction technology, reinforced concrete buildings are found to be in a more favorable condition than other construction types, which display a higher incidence of critical degradation levels. At the Network Level (NL), the incorporation of the Penalty Factor (PF) results in a general decline in the Total Sufficiency Rating (TSR_{NL}) and a reallocation of units among the evaluation classes (see Figure 6). Following the application of the PF, Class B remains the most represented category, comprising 60% (48 structural units), whereas Class A decreases from 41% (33 structural units) to 14% (11 structural units) and Class C increases from 8% (6 structural units) to 23% (18 structural units). A notable reduction in the final TSR_{NL} is observed in precast concrete and masonry structures, while steel structures remain largely unaffected. This phenomenon is primarily attributable to the functional role of steel structures, which are predominantly utilized for storage or warehouse functions, exhibit low occupancy levels, and are readily relocatable. These characteristics yield Penalty Factor values approaching 1, thereby mitigating their impact on the overall classification. In conclusion, the absence of structural units within the lowest Class D across both assessment levels substantiates the good state of conservation of the analysed stock, with no buildings demonstrating critical levels of degradation.

Deterioration Assessment - PRC buildings Survey Form

Form ID	Compiler	Date of completion	Building location	
			latitude	longitude

FUN =	0,95	OCC =	1,00	AF =	1,00	NBI =	1,00	PF - Penalty Factor =	0,95

Components	CV - Condition Value							CF - Condition Factor	W - Weight	CF x W
Foundations	Abs	**0**	1	2	3	4	5	0	8	0
Vertical Elements	Abs	0	1	2	3	**4**	5	2	10	20
Beams	Abs	0	1	2	**3**	4	5	4	10	40
Slab	**Abs**	0	1	2	3	4	5		9	
Infill walls	Abs	0	1	**2**	3	4	5	7	8	56
Overhanging elements	**Abs**	0	1	2	3	4	5		9	
Heavyweight ceilings	**Abs**	0	1	2	3	4	5		7	
Lightweight ceilings	Abs	0	**1**	2	3	4	5	10	6	60
Plastering/Finishes	Abs	0	1	2	**3**	4	5	4	5	20
Internal partitions	Abs	0	1	**2**	3	4	5	7	6	42
Flooring	Abs	0	1	**2**	3	4	5	7	7	49
Fixtures	Abs	0	**1**	2	3	4	5	10	5	50
Systems	Abs	0	1	2	3	**4**	5	2	6	12
Stairs	**Abs**	0	1	2	3	4	5		9	
Parapet walls	**Abs**	0	1	2	3	4	5		6	
Roofing - Structure	Abs	0	1	2	**3**	4	5	4	9	36
Roofing - Extrados	Abs	0	1	2	**3**	4	5	4	6	24
-										
-										
-										
-										

∑Wi of assessed components only	1	∑	78 (1)	409 (2)
∑(CF*Wi) of assessed components only	2			
∑Wi of all the components	3	∑	86 (3)	441 (4)
∑(CF*Wi) of all the components	4			

TSR_{real}	52
CoF	91
TSR_{min}	51

TSR_{PL}	52	class C
TSR_{NL}	49	class C

Figure 4: Assessment form for deterioration in precast reinforced concrete technology, completed for the case study, and supporting photos taken during the on-site inspection.

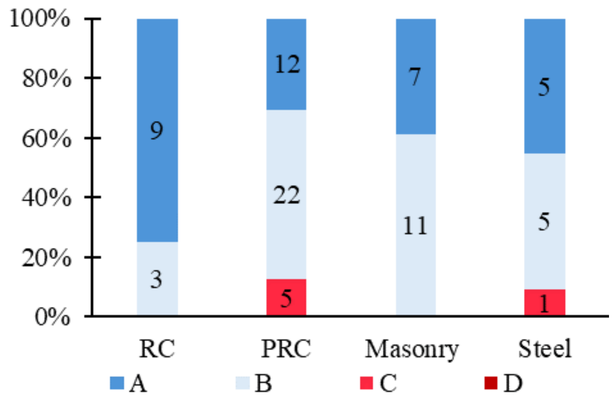

Figure 5: Project Level assessments categorised by construction technology.

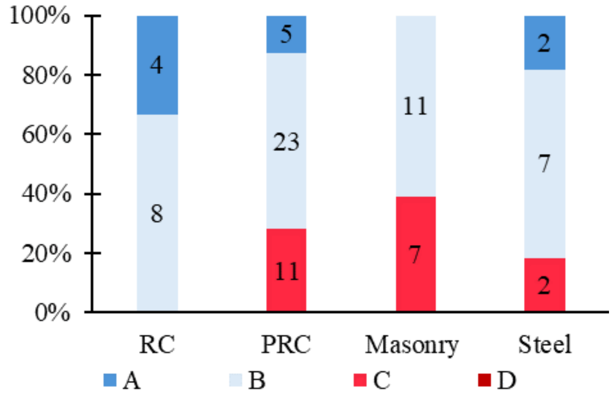

Figure 6: Network Level assessment categorised by construction technology.

5 CONCLUSIONS

This study proposes a rapid assessment methodology tailored to industrial buildings, enabling the classification and prioritization of maintenance actions.

The proposed methodology is structured across two levels. The first, the Project Level, assesses individual buildings through visual inspections, assigning scores to both structural and non-structural components based on predefined deterioration scales. The second, the Network Level, refines these assessments by introducing a Penalty Factor that accounts for functional and contextual elements, ensuring that maintenance priorities align with the broader significance of each structure within the stock. This significance is determined by the building's functional role and operational importance within the industrial network. This approach provides a structured and scalable evaluation process, maintaining a balance between simplicity and accuracy.

When applied to the analysed industrial building stock, the methodology provided a clear categorization of degradation levels and intervention priorities. The results confirmed the generally good condition of the stock, with only a small percentage of buildings exhibiting significant degradation.

The primary advantages of the methodology are its ease of application and cost-effectiveness. By relying solely on visual inspections and standardized abacuses, the approach allows for rapid assessments without the need for extensive resources. However, a key limitation is that the abacus-based evaluation provides degradation ranges based on expert judgment, introducing an inherent degree of subjectivity. Despite this, the methodology remains a valuable tool for decision-makers, facilitating efficient and informed maintenance planning. In addition to this, given its nature, the methodology can be effectively combined with other types of analyses, such as seismic assessments. Future developments will focus on applying the methodology to other building stocks.

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