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Comparison of Condition Rating Systems for Bridges in Three European Countries

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Abstract: Europe faces many problems connected to ageing infrastructure which was built in the second half of the 20th century. Bridges are one of the crucial elements of these infrastructures. In recent years, European countries have witnessed many failures of bridges across the continent. For example, the collapse of Viadotto Polcevera in Genoa caught the attention of society regarding its tragic consequences. Therefore, engineers must deal with the assessment of existing bridges which is essential for proper decision-making. Condition rating systems for bridges vary from country to country. Consequently, these differences in the methodology can lead to different conclusions related to the future service of assessed structures. For these reasons, this paper briefly describes condition rating systems for road bridges in Italy, Slovakia, and Portugal and defines the differences in the methodology. Subsequently, the obtained conclusions are compared and discussed. The aim of the paper is to encourage standardization in the assessment of bridge health conditions within European countries, highlighting the differences in the current systems adopted by various countries.

Keywords: bridges; European condition rating system; bridge assessment; standardization; infrastructures

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1. Introduction

Bridges are key parts of transportation systems worldwide [1,2]. In most cases, inadequate control and preservation over time have led to the constant deterioration of their structural conditions, also compromising their safe usage, despite their importance for the social and economic well-being of the communities [3]. The collapses that have occurred over time around the world demonstrated how extremely vulnerable bridges are to both human and natural causes, including overloading, incorrect design, inadequate inspection, and lack of maintenance. In just the last decade, more than 60 bridge failures occurred worldwide, followed by an equally large number of fatalities [4]. In the recent past, the European public was shocked by the disastrous failure of Viadotto Polcevera also known as Ponte Morandi in Genoa, Italy (2018). This collapse resulted in 43 fatalities. However, this is not the only collapse of a bridge in the recent past in the European continent.

The ageing infrastructure which was largely built in the post-war period is reaching its limit of service life and needs to be assessed. Therefore, European administrators and researchers have focused on the development of proper condition rating systems for bridges which should calm the public's concerns and ensure safe bridge infrastructure across the continent. Currently, European engineers use common standards for the design of structures which are called Eurocodes. Consequently, the approach in design procedure differs only in very specific situations which are listed and described in the national annexes of individual states. Current Eurocodes provide specific rules for newly designed bridges, while EC8-3 [5] is specifically devoted to the assessment and retrofitting of existing structures, even if it deals mainly with buildings, although the revision in progress in 2021 also includes bridge structures. Hence, the condition rating system varies from country to country and can lead to different conclusions in the decision-making process. Therefore, the need for a common condition rating system has arisen. A standard rating system may have many advantages, including providing an objective comparison of the health state of infrastructures on the European continent and thus supporting the process of allocating economic funds aimed at rehabilitation and modernization of the infrastructural assets.

The presented paper aims to describe currently used bridge condition rating systems in Italy, Slovakia, and Portugal, with the aim of highlighting differences among these European countries and supporting the process of creating standardization within the European Union. This paper originates from an international collaboration between three European universities (Università Politecnica delle Marche in Italy, University of Žilina in Slovakia, and University of Minho in Portugal) who share a common interest in the health assessment of bridges and who decided to provide this work as a starting point to propel the standardization process in Europe. For each of these countries, the current code prescriptions about existing bridges are introduced and described in depth, discussing the methodologies and parameters that lead to achieve the outcomes regarding the state of the existing bridges. Moreover, the bridge classification procedures currently adopted in each country are proposed to obtain a sort of attention or risk class about a bridge. In Italy, the new guidelines for existing bridge assessment and maintenance propose a class of attention differentiated into five levels of increasing risk. In Slovakia, the classification procedure is based on a load-carrying capacity coefficient and a bridge can fall into one of the seven possible classes. In Portugal, the assessment of bridges is made through an indicator, named condition state, with six possible classes, where, based on inspection, damages are evaluated by severity, extension, damage development and consequences.

2. Italy

In Italy, the national technical code for construction in general [6,7] does not comprehensively address the safety evaluation and management of existing bridges. For this reason, the Italian government recently issued (in 2020) new "Guidelines for risk classification and management, safety assessment and monitoring of existing bridges" [8]. Moreover, these guidelines were further adjourned in 2022 [9], but without making any substantial changes. Nowadays, these guidelines are mandatory as Italian technical codes. The guidelines face the problem of existing bridges through a multilevel approach, which starts from risk evaluation and bridge classification at a regional scale and then moves into safety assessment and monitoring procedures. More importantly, it is an approach that accounts for various types of risk deriving from structural vulnerabilities and from the surrounding environment. Specifically, the structural and foundational risks, the seismic risk, the landslide risk, and the hydraulic risk are considered and evaluated together.

2.1. *The New Italian Guidelines for Existing Bridge Assessment*

The new Italian guidelines have been developed with two main objectives in mind: (1) to define common and standard criteria to be used throughout Italy for the risk classification, the structural safety assessment, and the monitoring of existing bridges, including considerations about the transit of exceptional vehicles; and (2) to obtain a unique rating tool to prioritize maintenance works. The guidelines can be used for both roadway and railway bridges, although details are provided mainly for the former.

The guidelines approach is based on six consequent levels of analysis (from 0 to 5, as reported in Table 1), even if the latter (Level 5) is recommended only for strategic bridges (namely, important in terms of the socio-economic consequences of their collapse and for maintaining communications in emergency situations). The first three levels should be applied to all bridges in the country (with a span length longer than 6 m) and they allow for a bridge classification that accounts for the four risk typologies previously mentioned.

At the end of these procedures, it is possible to obtain the so-called *Class of Attention* (*CoA*) for each investigated bridge. Five *CoA* are defined for five levels of increasing risk: low, medium-low, medium, medium-high, and high.

Table 1. Multilevel approach of the new Italian guidelines.

Level 0	Census/Geolocalization	Territory Scale (All Bridges)
Level 1	Visual Inspections	
Level 2	Attention Classes	
Level 3	Preliminary Evaluations	In-Depth Evaluations (Limited Number of Bridges)
Level 4	Accurate Evaluations	
Level 5	Network Resilience	

Then, for bridges with concerning *CoA* (mainly medium-high and high), in-depth evaluations must be performed; in detail, for bridges belonging to the high class, Level 4 is mandatory, while for those of medium-high and medium classes, the safety verifications could be performed only if the roadway administrator deemed them necessary. The period for which the satisfaction of safety verifications is required should be taken according to the purpose for which the analysis is intended. In this regard, the concept of "reference time" (T_{ref}, the time frame of which the verification is conventionally referred) is introduced. At the end of this time frame, it is generally assumed that the analyses have to be repeated and necessary measures need to be taken to ensure the due level of safety usage (e.g., repair works or load reductions). The safety verifications are conducted following the limit states approach and adopting partial safety factors, and three outcomes can be achieved:

- Adequate bridge: the bridge performance is compliant with the actual Italian technical code prescriptions. The use of the infrastructure can continue without interruptions and traffic limitations;
- Operative bridge: the safety verifications are fulfilled following the code prescriptions but adopting reduced safety factors on loads and material strengths (considering lower return periods—T_{ref} = 30 years). The bridge can be used during the period considered for the assessment (30 years), then the analyses must be repeated;
- Transitable bridge: the safety verifications are satisfied following the code prescriptions but in a very short time period (5 years). The bridge can be used adopting loads/traffic limitations and for only 5 years, then it must be restored/upgraded/rebuilt.

For what concerns the monitoring, obviously, all bridges belonging to all classes are subjected to periodic visual inspection over time, also to adjourn their *CoA*. However, for those with high and medium-high *CoA*, instrumental monitoring is recommended, and the installation of a permanent Structural Health Monitoring (SHM) system is recommended for cable-stayed and suspended bridges with high span length longer than 200 m, for pre-stressed RC bridges older than 40 years and with high span lengths longer than 50 m, for pre-stressed RC bridges or steel bridges difficult to visually inspect, for historical and cultural heritage bridges, and for bridges with very high traffic flows and loads.

2.2. Risk Classification and Bridge Class of Attention

The first three levels (from Level 0 to 2) are those which guide the bridge classification and the definition of the *CoA*. Specifically, Level 0 is devoted to gather the available data of the investigated bridge, namely general information about the structural typology, construction materials, year of construction, geometric dimensions for both the whole bridge and the structural components, etc. This information can be obtained by consulting the original documents and design drawings, as well as all the available technical documents; during this phase, details about the traffic data (type and number of vehicles) must be collected as well.

Level 1 foresees specific site inspections for verifying the current state of degradation and the possible presence of structural and non-structural components affected by significant defects. The on-site survey must include a photo collection of the bridge and of the damaged elements, a geometrical verification (and sometimes collection) of the main geometric features of the bridge and of its structural members, and a visual inspection for the damage individuation. The latter is a very important phase for the whole classification process and requires the whole bridge in its all parts to be controlled. To support and standardize these operations, specific inspection sheets must be filled. The latter are different for each structural typology and must be compiled for each structural member. For bridges with a particular structural typology, in which the failure of structural components may result in a catastrophic scenario including the bridge collapse (e.g., post-tensioned RC decks, RC bridges with half-joint connections, etc.), the guidelines also recommend performing special inspections, namely instrumental destructive and non-destructive tests. Common destructive tests that can be performed are endoscopic tests and core samples, whilst non-destructive tests include using a covemeter, pull-out, georadar, tomography, ultrasonic, X-ray, and dynamic tests.

At Level 2, exploiting the information collected through Levels 0 and 1, each bridge is subjected to a procedure for the *CoA* determination and taking into account the four possible risks: (i) foundational-structural, (ii) seismic, (iii) landslides and (iv) hydraulic (flooding, scouring) risks. Hence, at the beginning, four partial *CoA* are determined considering each risk one at a time; then, a comprehensive class (overall *CoA*) is determined, combining the four partial ones. For each of the *CoA* determination procedures, a qualitative risk evaluation is carried out accounting for three parameters: hazard, vulnerability, and exposure.

Focusing the attention on the structural and foundational risk, hazards depend on traffic loads in terms of a number of vehicles passing over the bridge and load limitations. Vulnerability depends on the damage level, its rapidity of evolution, the design code age, and a combination of the structural typology, construction materials, and span length. The damage level is classified into five sub-classes:

- High: dangerous damage to critical components, such as half-joints, supports, post-tensioned cables, and foundation scour;
- Medium-high: damage to structural components whose crisis may compromise the integrity of the entire structure;
- Medium: damage to structural components whose crisis may not compromise the integrity of the entire structure;
- Medium-low: medium-high levels of dangerous damage or medium to medium-low but in a large number of elements;
- Low: medium and low dangerous damage and in a limited number of elements.

The rapidity of degradation evolution is evaluated considering the bridge's construction period; indeed, heavy degradation affecting a young bridge testifies to a high rate of degradation. The design code age provides information on the design loads that are influencing the structural capacity of the bridge. The class relevant to the vulnerability is determined following a logical path that starts from the damage level (achieved thanks to on-site inspections) and that combines, in order, the rapidity of the damage evolution, the design code age, and the combination of structural typology, construction materials and span length (see Figure 1).

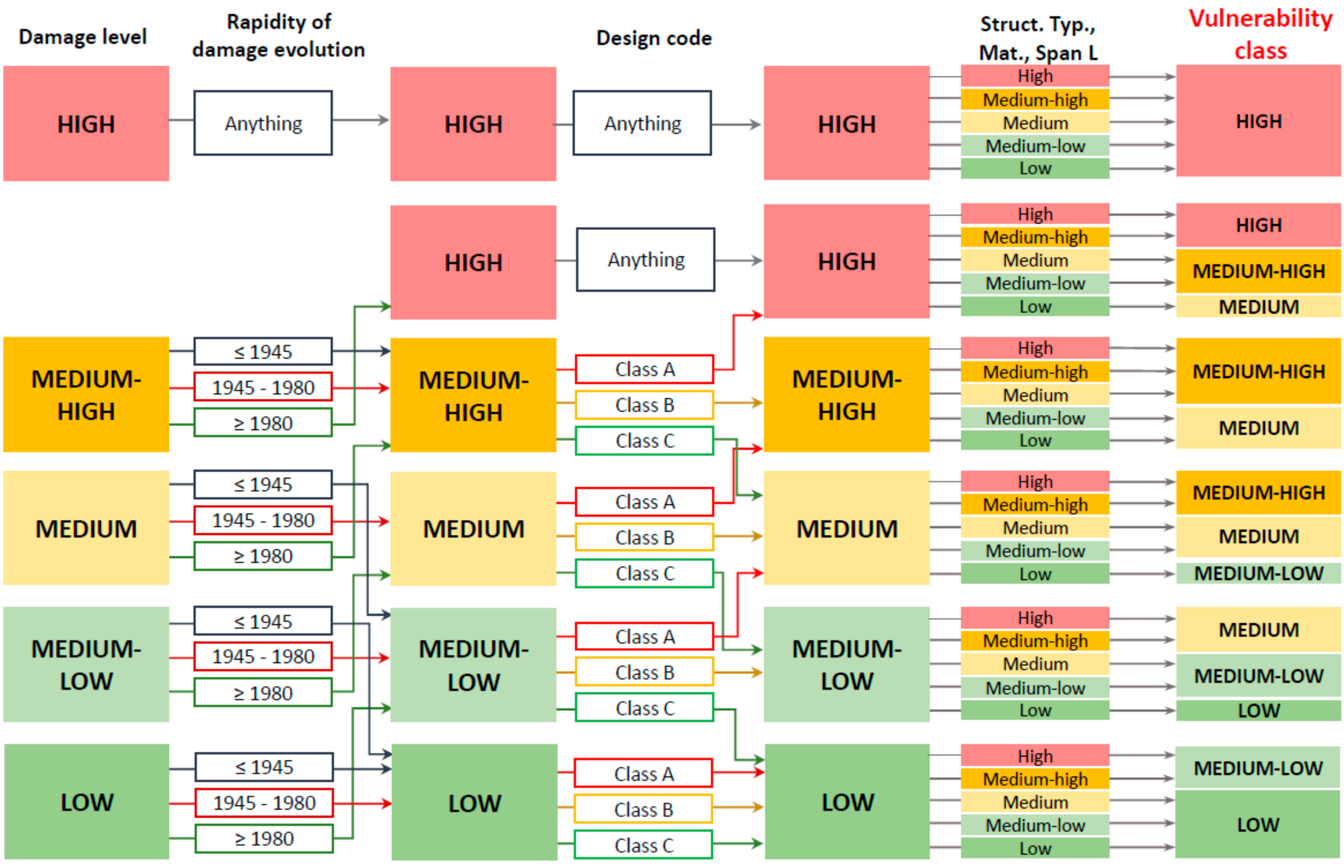


Figure 1. Example of the logical path for the vulnerability determination relevant to the structural and foundational risk.

Exposure is basically evaluated by the number of vehicles passing over a bridge daily (Mean Daily Traffic—MDT), the presence of alternative roadways, and the importance of the by-passed element. Again, thanks to logical paths that start from a combination of the MDT and span length, and consider, in order, the alternative roads and the by-passed elements, the class relevant to the exposure is determined (the logical paths can be found in the guidelines [9]).

By combining hazard, vulnerability and exposure, the partial *CoA* relevant to the structural and foundational risk can be determined. For this purpose, five tables are provided by the guidelines, like the one represented in Table 2. Each of them is built for a specific hazard class (high, medium-high, medium, medium-low, and low); so, choosing the one relevant to the considered hazard class, and entering the table with the vulnerability (on rows) and exposure (on columns), the partial *CoA* is determined.

Table 2. Example of table for the determination of the structural and foundational risk partial *CoA* (case of high hazard).

<table>
<tr><th colspan="7">High Hazard Class</th></tr>
<tr><th colspan="2"></th><th colspan="5">Exposure Class</th></tr>
<tr><th colspan="2"></th><th>High</th><th>Medium-High</th><th>Medium</th><th>Medium-Low</th><th>Low</th></tr>
<tr><td rowspan="5">Vulnerability Class</td><td>High</td><td colspan="5">High</td></tr>
<tr><td>Medium-High</td><td colspan="2">High</td><td colspan="3">Medium-High</td></tr>
<tr><td>Medium</td><td>High</td><td colspan="2">Medium-High</td><td colspan="2">Medium</td></tr>
<tr><td>Medium-Low</td><td>Medium-High</td><td colspan="4">Medium</td></tr>
<tr><td>Low</td><td>Medium-High</td><td colspan="2">Medium</td><td colspan="2">Medium-Low</td></tr>
</table>

Finally, the four partial *CoA* are combined to find the overall *CoA*. Also, in this case, the guidelines provide five tables like the one reported in Table 3: each of them is built considering the five possible partial *CoA* of the structural and foundational risk. Once the table is inherent to the risk class at hand, the overall *CoA* of the bridge is determined by entering the table with the seismic class (on rows) and with a combination of the landslides and hydraulic class (on columns), the latter taking into account the hydro-geological aspects of the bridge territory.

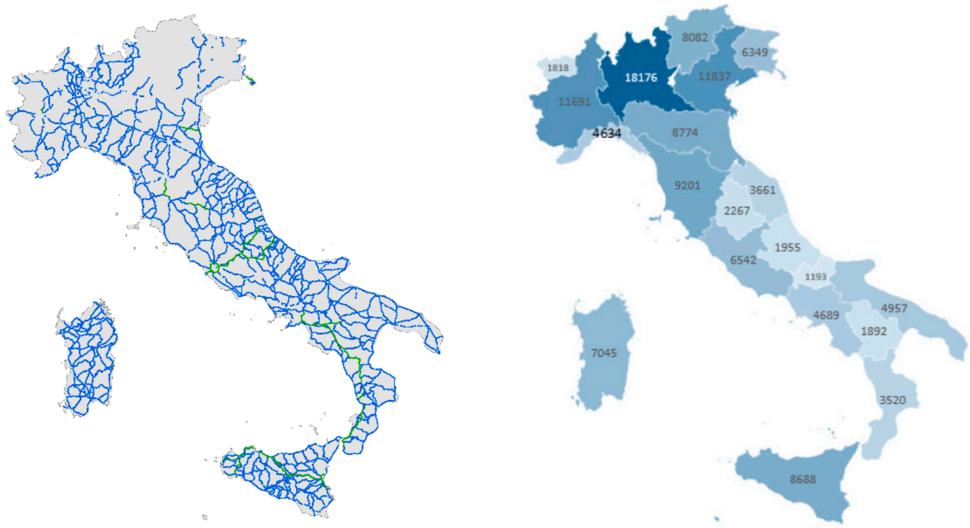
Table 3. Example of table for the determination of overall bridge *CoA* (case of high structural and foundational risk).

<table>
<tr><th colspan="7">High Structural and Foundational Class</th></tr>
<tr><th colspan="2"></th><th colspan="5">Landslides and Hydraulic Class</th></tr>
<tr><th colspan="2"></th><th>High</th><th>Medium-High</th><th>Medium</th><th>Medium-Low</th><th>Low</th></tr>
<tr><td rowspan="5">Seismic Class</td><td>High</td><td rowspan="5" colspan="5">High</td></tr>
<tr><td>Medium-High</td></tr>
<tr><td>Medium</td></tr>
<tr><td>Medium-Low</td></tr>
<tr><td>Low</td></tr>
</table>

2.3. The Current State of Italian Road Bridges

The Italian road network consists of many bridges and tunnels, with an incidence of infrastructures per kilometer among the highest in the world. Furthermore, the Italian territory is characterized by a marked vulnerability, both from a hydrogeological and seismic point of view. There are many road management bodies all over the country. The most important ones are ANAS (National Autonomous Highway Company) and AISCAT (Italian Association of Highway and Tunnel Concession Companies). ANAS manages a road network more than 32,000 km long (Figure 2a—data for the year 2022 [10]). Most of this network is made up of highways (about 1200 km) and national motorways (more than 25,000 km). The AISCAT-associated companies manage about 4500 km of highways [11]. Other road management bodies include the 107 Italian territorial provinces and more than 8000 municipalities which are responsible for many local roads. The ANSFISA agency (National Agency for Safety of Railways and Motorway and Highway Infrastructures) declares that there are more than 2000 tunnels and more than 21,000 bridges along national highways and motorways [12]. Santarsiero et al. [13] stated that the number of Italian bridges is approximately 120,000, but it is not confirmed due to the many stakeholders involved in the management of bridges. They also provided an Italian map representing the number of bridges for each region (Figure 2b), which are mostly located in the northern part of the country. However, nowadays there is not a comprehensive document collecting information about all the Italian bridges, since they are managed by many different and local regional entities. For this reason, the Italian government unveiled a digital platform in 2019, called AINOP (National Digital Archive of Public Infrastructures [14]), which aims to collect all the information relevant to all infrastructures over the national territory—including bridges—into a unique database. Up to now, almost 33,000 bridges have been collected within this digital platform and, in the future, information regarding the health condition of these infrastructures will be added, including the *CoA* evaluated following the new guidelines.

Many of the existing Italian bridges and viaducts date from the post-World War II period and the phase of the Italian economic "boom" (around the 1960s), when a noticeable increase in vehicular traffic was detected. It should be noted that these bridges, frequently made of RC or pre-stressed RC, were built in a historical period when the concept of material durability was not given due consideration. For these reasons, the majority of the bridges in Italy are quite old, and very often present defects due to environmental and operating issues. Recently, the FABRE consortium for the research, assessment and monitoring of bridges and viaducts [15] has started an activity for supporting the public roadway management entities in the adoption of the new guidelines all over the national territory. The use of the risk assessment procedure proposed by the new guidelines will support the increase in knowledge about the health condition of all bridges and the development of efficient maintenance activities.



(**a**) (**b**)

Figure 2. Distribution of Italian roadways and infrastructures: (**a**) ANAS highways and roadways [10]; (**b**) bridge locations for each region [13].

3. Slovakia

In general, the rating of Slovak bridges is divided into two groups. Road bridges are classified according to guidelines issued by the Slovak Road Administration ("Slovenská správa ciest", abbr. SSC). On the other hand, the administrator of railways—Slovak Railways ("Železnice Slovenskej republiky", abbr. ŽSR) —has its own approach regarding how to classify bridges. Therefore, this paper will describe only the methodology used for road bridges.

Inspections of Slovak road bridges according to SSC are classified as follows:

- Ordinary: once a year, usually in spring;
- Main: usually every four years;
- Exceptional: after passing of heavy traffic, suspicion of the failures, change in bridge geometry, dangerous effects of vehicle passing, etc.
- Control: part of the supervision or for internal needs.

3.1. Slovak Condition Rating System for Road Brides

The Slovak condition rating system issued in 2013 is based on the classification of the bridge in question into one of the seven possible condition classes (from I. to VII.). The description of the condition classes is listed in Table 4. The purpose of the Slovak methodology is to guide the management of bridges and to introduce a unified system of records, supervision, preparation of maintenance, repairs and reconstruction of bridges and their implementation [16]. In general, condition classes I. to III. describe the structural state which is good and without significant risk in the near future. Condition class IV. represents the state of bridges with possible risks concerning their structural condition in the near future, but which are currently usable structures. However, condition classes from V. to VIII. define a state with the required repair or even immediate closure of the bridge for traffic. Due to the scope of the paper, only the basic principles of bridge evaluations according to the Slovak guidelines are listed.

Table 4. Slovak condition rating system for road bridges based on the extent of the failures [16].

Class	State	Description	LCC Factor
I.	Flawless	Without any hidden or obvious defects.	1.00
II.	Very good	The occurrence of only appearance defects that do not affect the load-carrying capacity of the bridge.	1.00
III.	Good	The occurrence of larger faults that do not affect the load-carrying capacity of the bridge.	1.00
IV.	Satisfactory	The occurrence of faults that do not have an immediate effect on the load-carrying capacity of the bridge, but may affect it in the future.	0.80
V.	Bad	The occurrence of faults that have an adverse effect on the load-carrying capacity of the bridge, but can be removed without replacing the faulty parts.	0.60
VI.	Very bad	The occurrence of faults that affect the load-carrying capacity and cannot be removed without replacing faulty parts or adding missing parts.	0.40
VII.	Emergency	The occurrence of faults that affect the load-carrying capacity of the bridge to such an extent that require immediate remedial action to avert impending disaster.	0.20

The bridge management system is supposed to provide, based on processed and evaluated information, data related to the condition of bridges and documents for planning repairs and reconstructions.

In general, the following three aspects are decisive for decision-making [16,17]:

- The structural state which reflects the difference between the real technical parameters of the structure and designed parameters;
- An operational capability which represents the difference in operational parameters of the bridge (such as load-carrying capacity, traffic intensity, passing speed, passing profile, etc.) compared to the parameters required for the road on the bridge and load-carrying class of the bridge;
- Impact on the environment.

Condition rating systems [16] in Slovakia can be divided into two groups:

- Condition rating systems based on index values, which are determined using mathematical-statistical operations with ratings of structural elements and classification of their failures;
- Condition rating systems based on probabilistic calculations of structural reliability with regard to their load-carrying capacity and service life.

3.2. The Load-Carrying Capacity of Road Bridges (LCC)

Load-carrying capacity (*LCC*) is one of the most important parameters of bridge reliability. The load-carrying capacity of the bridge on highways and roads of categories I., II. and III. and local roads are defined by the heaviest possible weight of one vehicle that can be allowed to pass the bridge under the conditions specified in the [18]. The *LCC* is determined as the lowest value of the *LCC* for the crucial element of the superstructure and substructure of the bridge. It should be provided exclusively by a detailed structural analysis. But for concrete and composite bridges (steel, concrete) it is possible to use an alternative combined structural analysis. It is indicated in the *LCC* analysis according to the applied method as follows:

- V—load-carrying capacity determined by detailed structural analysis;
- K—load-carrying capacity determined by a combined procedure, i.e., by a detailed structural analysis based on the standard rules provided by the original standards (codes from the date of design).

The *V* method is dominantly preferred for all types of structures. However, in the case of insufficient data from the inspection or diagnostic survey, the *K* method can be applied. In Slovakia, three categories of the *LCC* are used depending on the load types as follows:

- Normal *LCC*—V_n;
- Exclusive *LCC*—V_r;
- Exceptional *LCC*—V_e.

Exceptional *LCC* has been defined only for the selected highways and roads of higher categories. Each of the *LCC* categories is the function of F_z, which is the load factor, that can be determined as follows:

$$F_z = \left(R_d - \sum_{i=1}^{n-1} E_{rs,Ed,i} \right) \Big/ E_{n,(r),(e),Ed} \text{ [dimensionless]} \tag{1}$$

where: *Rd* is the design resistance of the element; $E_{n,(r),(e),Ed}$ is the design value of the live load vertical effects, represented by the appropriate load category for V_n, V_r and V_e; $\sum_{i=1}^{n-1} E_{rs,Ed,i}$ are the design, combination, or group values of the other permanent load effects, which are simultaneously acting with the vertical live load effect.

For the Normal *LCC*, the load model LM1 according to the *STN EN 1991-2* [19] is applied as a value of $E_{n,Ed}$. In the case of the Exclusive *LCC*, the special load model of the heavy vehicle (900/150 kN) multiplied by the dynamic factor (φ = 1.40 − L/500; $\varphi \geq 1.0$; L is affected length in [m]) according to the *STN EN 1991-2* (see Figure 3) is used as a value of $E_{r,Ed}$, whereas for the Exceptional *LCC*, the load model LM3 (3000/240 kN) in compliance with *STN EN 1991-2* is employed as a value of $E_{e,Ed}$.

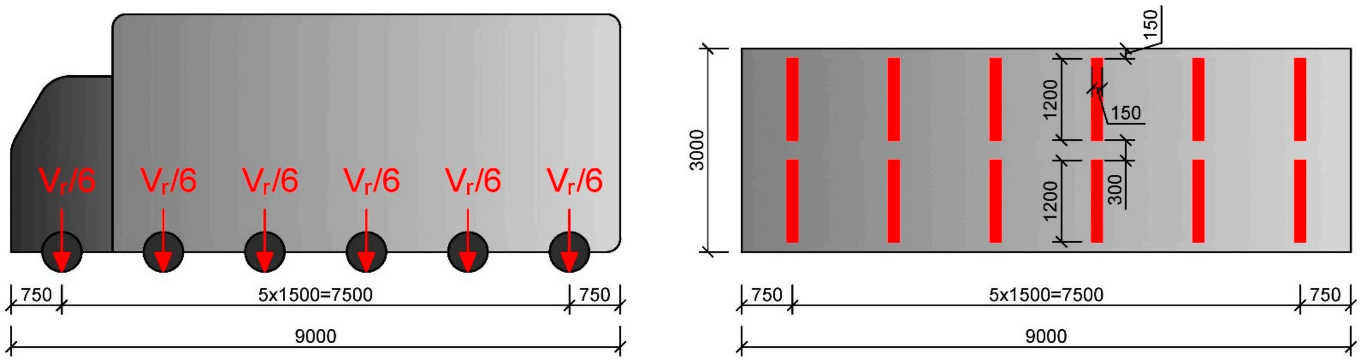


Figure 3. Load model for Exclusive *LCC* − V_r = 900 kN.

The load factor *Fz* corresponds with the *LCC* factor. But *LCC* is expressed in tons and is signalized on appropriate traffic signs, so finally each of the load factors *Fz* is multiplied by the representative value of the vehicle weight, which is 32 t for the Normal *LCC*, 90 t for the Exclusive *LCC*, and 300 t for the Exceptional *LCC*.

Factor of Normal Load-Carrying Capacity *Fz*:

Factor *Fz* describes the bridge's capability to carry the live load represented by LM1 which is used for the global and local analysis of the structure. Consequently, the normal load-carrying capacity expressed in tons is determined based on this factor. Generally, the factor of normal load-carrying is described as the ratio of the "reserve" of the resistance for the decisive live load and the effect of LM1. The reserve of the resistance is represented by the difference between the overall resistance of the bridge and the effect of dead loads. For example, if *Fz* = 0.75, then the normal load-carrying capacity of the bridge is 0.75 × 32 t = 24 t. Finally, the administrator will mark this normal load-carrying capacity on the traffic sign in front of the bridge.

Although the representative vehicle's weight of normal *LCC* is 32 t, the administrator marks the reduction in the *LCC* only if it is lower than 26 t. Similarly, the Exclusive *LCC* is described by the traffic sign placed in front of the bridge only if it is lower than 48 t. However, in the case of the Normal *LCC* higher than 26 t (for example 30 t), but Exclusive *LCC* lower than 48 t (for example 45 t), the administrator will place both traffic signs describing that the Normal *LCC* is 30 t and the Exclusive *LCC* is 45 t.

3.3. Current State of Slovak Road Bridges

Similar to other European countries, the structural state of Slovak road bridges is getting worse. Insufficient inspections and neglected maintenance which should be provided by the administrators negatively contribute to this fact. According to the statistics from the Slovak Road Administration (SSC), overall, 8266 road bridges were in the administration of several subjects which use the same condition rating system [16]. The classification of objects on Slovak roads is listed in Table 5. In Slovakia, highway and motorway bridges are maintained by the National Highway Company (Národná dialničná spoločnosť, abbr. NDS). Bridges on roads of Category I. are administrated by the Slovak road administration ("Slovenská správa ciest", abbr. SSC). Eight Slovak regions (Vyššie územné celky, abbr. VÚC) own bridges on roads of Category II. and III. The distribution of these bridges between regions is very uneven. For instance, the regions of Prešov (Eastern Slovakia) and Banská Bystrica (Central Slovakia) own approximately 1000 bridges each. On the other hand, the region of Bratislava (Western Slovakia) administrates only 130 bridges [20]. Other bridges are owned by municipalities or private subjects. Consequently, NDS owns 11% and *SSC* 23% of road bridges. Eight VÚCs are responsible for approximately 66% of road bridges in Slovakia [21]. The classification of road bridges by road category can be seen in Figure 4. The deteriorating condition of bridges can be observed primarily on roads of Categories II. and III. Importantly, two-thirds of bridges which are owned by the regions (VÚC) are older than 50 years. Moreover, almost one-third of them are older than 70 years [20].

Table 5. Classification of objects on Slovak roads, adjourned to 01.01.2022 [21].

Type of Object	Number	Length of Pavement [m]	Type of Object [m^2]
Bridges	8266	305,191	3090,582
Underpasses	1209	236,65	228,557
Sluice	28,836	332,638	-
Railway crossings	591	6803	42,082

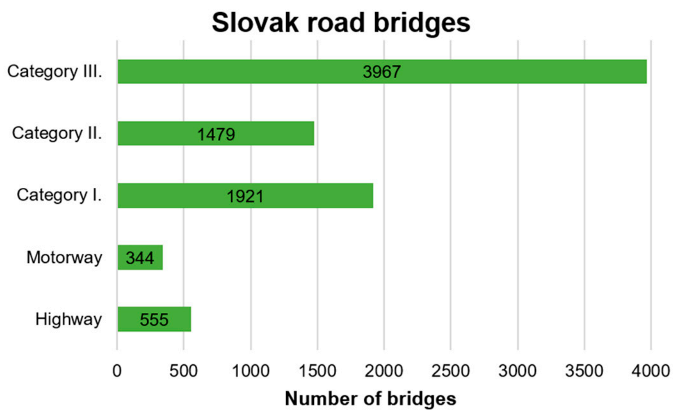


Figure 4. Classification of road bridges by road type, adjourned to 1 January 2022.

Figure 5a illustrates the evolution of the classification of Slovak road bridges from the year 2000 to 2021. Figure 5b shows the number of bridges in condition classes from V. to VII. significantly increased since the year 2010 [21]. For example, in the year 2021, more than 26% of road bridges belonged to these classes. This fact is alarming and demands immediate attention. In such cases, the safety of the structure is threatened, and demountable temporary bridges must be mounted. As a result, this inevitably leads to additional costs for the administrators [22].

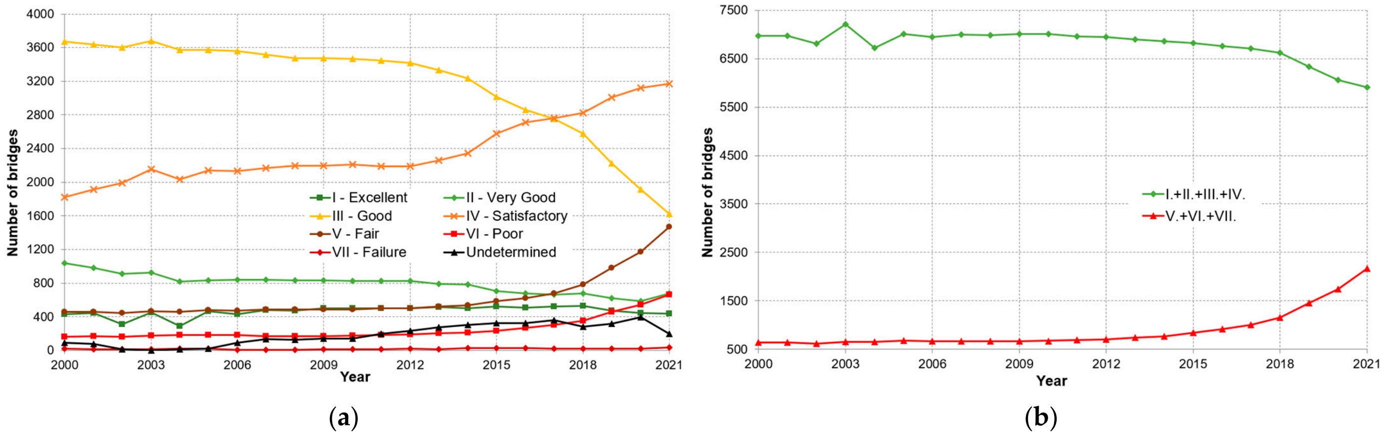


Figure 5. (**a**) Slovak road bridges according to their condition class (2000–2021); (**b**) illustration of the deteriorating condition of Slovak road bridges [21].

The current situation in Slovakia, especially with precast girder bridges, shows the need for new diagnostic methods. Bridges in Podbiel, Nižná, and Trstená are among the most recognized cases illustrating this alarming situation. Moreover, in the summer of 2020, a footbridge in Spišská Nová Ves collapsed. Similarly, a road prestressed concrete bridge near the village of Veľká Lodina failed too. Early detection of serious problems can prevent an emergency situation that could endanger people's lives and cause economic damage [23]. The collapses of some prestressed concrete bridges are shown in Figure 6.

Figure 6. Collapses of Slovak road bridges since 2015.

4. Portugal

In Portugal, the inspection of roadway and railway bridges follows the specifications of the Portuguese rail and road infrastructure manager, Infraestruturas de Portugal, S.A (IP) [24]. Different asset management systems exist in Portugal. Also, several proposals for the inspection and management of bridges appeared over time. In the following, the management methodology followed in Portugal according to IP for the inspection and decision-making process of roadway bridges, viaducts and similar structures is presented.

4.1. Inspection and Decision-Making Process in Portugal

IP takes use of an intern asset management system, which consists of the (I) inventory and preparation of the inspection with the aim of gathering the existing historical data and preparing for the next phase, (II) inspection with the aim of accessing the condition of the structure and establish the necessary actions and alerts (see Figure 7).

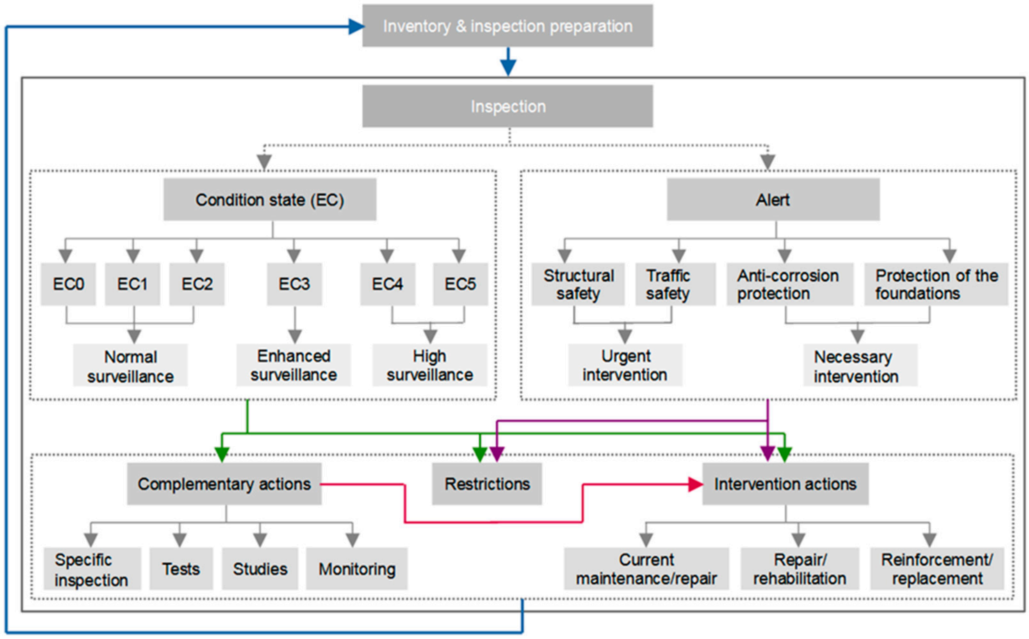


Figure 7. Framework followed by IP.

4.1.1. Inventory and Preparation of the Inspection

This phase consists of the preparation of the inspection. Data concerning identification, location, construction, and existing documents; components, geometry, intersected way, and surroundings; and changes, existing inspections, monitoring, intervention actions and damages, is collected and stored in a private database, not accessible to people outside the institution. The reading of existing inspection reports helps to identify existing damages, interventions, or changes in the structural functioning. This phase also includes the selection of equipment and tools to be used, and the identification of possible restrictions, such as the necessity of traffic restrictions or the use of specific tools, like the use of a platform to access the deck.

4.1.2. Inspection

This phase consists of a visual inspection, where a team—usually composed of an engineer and a technician—register the most relevant damages, by writing on a predefined checklist the description, location and photographic record for each component with damages. Nowadays, the inspection can be complemented using unmanned aircraft systems (UAS) that cover the structure and take photos. Moreover, specific tests or monitoring actions can also be requested.

The condition state of the components is evaluated through five parameters: (i) functionality of the component, (ii, iii and iv) severity, extension and prediction of the development of the damage, and (v) possible consequences of the damage for other components (see Table 6), each one graded between 0 and 1. The sum of the previous parameters gives the condition state of the component, going from 0 (excellent condition) to 5 (bad condition), according to the grading scale presented in Table 7. In addition to these, a NI (not inspected) level exists for those situations in which it was not possible to inspect the component (e.g., a component completely covered by vegetation). Moreover, an IC epithet was added to the 6-level scale for those situations in which it was not possible to inspect the component entirely also exists (e.g., a component partially covered/hidden by vegetation). The global condition state of the structure corresponds to the worst condition state (with a higher value) among the fundamental structural components. Moreover, during this phase the analysis of the damages with the consequent selection of the causes and consequences, taking into account the structural behavior, is performed. Also, the necessary actions are established. These can be (i) complementary actions (specific inspection, studies, monitoring or tests), (ii) restrictions to the operation of the bridge and (iii) intervention actions (current maintenance/repair, repair/rehabilitation and reinforcement/replacement).

Table 6. Classification parameters, according to the IP specifications (adapted from: [25]).

Parameters	Values	
	0	1
Functionality	Fulfils the component function	Do not fulfil the component function
Severity	Low severity	Severe
Extension	<50% of the maximum admissible value	≥50% of the maximum admissible value
Prediction	Small, being expected a small or no evolution	Big or with a fast evolution expected
Consequences	No consequences for the other components	With consequences for the other components

Table 7. IP condition grading scale, composed of eight levels (adapted from: [25]).

EC Level	EC Classification	Definition
NI	Not inspected	Not inspected due to difficult access/hidden.
0	Excellent	Excellent condition state. Negligible anomalies allowed.
1	Good	Normal condition state. The behavior is not yet affected but the durability can be compromised.
2	Regular	Satisfactory condition state. A not significant impact on the behavior occurs and/or a relevant influence in the durability and/or functionality may occur.
3	Irregular	Deficient condition state. The behavior is conditioned and/or a significantly reduction of the durability may occur. The safety, in the future, could be affected by the rapid evolution of the damages.
4	Deficient	Critical condition state. The behavior, resistant capacity and structural safety are predatory affected, and the integrity is influenced. The minimum requirements to perform the function are not met.
5	Bad	Imminent ruin state. The integrity and the structural safety are put into question. The resistant capacity is severely affected.
IC	Conditioned	An IC epithet is added to the 6-level scale when the component cannot be observed on its whole.

Abnormal situations that may impact the operation of the bridge or the integrity of its structural components in the immediate and short term should be identified via established alerts (structural safety, traffic safety, anti-corrosion protection or protection of the foundations). According to the type of alert, different intervention periodicities exist (see Table 8). The intervention actions are proposed to be performed during the next 2 to 5 years after the inspection, with the exception of those structures with a critical to imminent ruin state, global or at the component level (EC ≥ EC4), where it should be between 1 and 2 years. Regular inspections are performed every 6 years. For those cases where a component has a deficient condition state (EC 3) or a critical to imminent ruin state (EC ≥ EC4), an intermediate inspection after 3 years or 1 year, respectively, is necessary (see Table 9). Whenever an EC4 or EC5 is assigned, as well as an alert situation is identified, the owner/manager should be informed.

Table 8. Intervention periodicity according to the alert situation (adapted from: [25]).

Alert Situation	Intervention Periodicity	
Structural safety	Urgent intervention	
Traffic safety	Urgent intervention	
Anti-corrosion protection	Necessary intervention	(2 to 3 years)
Protection of the foundations	Necessary intervention	(1 to 2 years)

Table 9. Inspection frequency and intervention time according to the IP specifications (adapted from: [25]).

Condition State	Intervention Time	Inspection Frequency
EC $\leq$ 2	2 to 5 years	Normal surveillance (every 6 years)
EC = 3	3 to 5 years	Enhanced surveillance (every 6 years + every 3 years for the components with EC = 3)
EC $\geq$ 4	1 to 2 years	High surveillance (every 6 years + every year for the components with EC $\geq$ 4)

4.1.3. Database and Inspection Report

This phase consists of the inclusion of the collected data during the previous phase into a database. It includes the confirmation and complement of the causes and consequences, as well as the actions and alerts. It also includes the selection and editing of the photos with the most relevant damages. In the end, an inspection report is available. After each inspection, the information on the database is updated, as well as the inspection report.

4.2. Current State of Portuguese Bridges

The main Portuguese entity responsible for the management of the railway and roadway network is Infraestruturas de Portugal (IP), comprising the main bridges, viaducts, and hydraulic passages. The national railway network is made up of lines and branches (in operation and not operated) with a total length of 3621.6 km. Seventy percent of the network is in operation, which corresponds to an extension of 2527 km. The total length of the roadway network operated by IP is currently 15,056 km, of which 14,042 km is under direct management and 1014 km are sub-concessions. The vast heritage under IP's direct management totals 7800 particular structures, of which 5800 (75%) belong to the road network and 2000 (25%) are part of the national rail network.

Since 2010, around 300 million Euros have been invested in the rehabilitation and maintenance of those structures, and in 2021 contracts worth 17 million Euros were awarded, with an investment of 41 million Euros expected for 2022. IP carried out, in 2021, close to 6200 inspections of the state of conservation of bridges, viaducts, hydraulic passages, and tunnels, among others, which are part of the National Road and Railway networks under its direct management. The results reveal that 90% of those structures in charge of IP have a state of conservation that varies between Good and Reasonable, which means that they have an adequate level of service without the need for investment in the medium term. These values over the years have consistently improved and in 2010 stood at 80%.

In 2017, IP stated that in 1.7% of all road engineering works, the need to carry out an intervention within a maximum period of two years was identified, situations for which the company had already planned and developed projects with a view to carrying out repair interventions. For the structures identified with a lower assessment, plans are already being developed for carrying out the necessary investments, with a view to carrying out, in the short term, the appropriate interventions, be it repair, rehabilitation or full replacement.

5. Discussion

The paper showed that European countries use different methodologies in the decision-making process regarding existing bridge management. For example, the number of levels (or classes) used for the description of the structural state of the bridge varies, but in general, they describe a similar evolution of deterioration. Therefore, this should not significantly influence the final decision. Nevertheless, if the number of levels in condition rating systems is higher, it can be more difficult to describe the differences in the structural states because the border between them is not so significant. All mentioned countries use the multilevel approach in the bridge management system.

The comparison of presented condition rating systems for bridges in three countries is listed in Table 10. Some differences are in the applicability of listed condition rating systems as the Italian methodology can be used in the case of both road and railway bridges. On the other hand, engineers in Slovakia and Portugal use different approaches on roadways and railways.

Table 10. Comparison of condition rating systems.

	Italy	**Slovakia**	**Portugal**
Multilevel approach	✓	✓	✓
Unified rating system for road and railway bridges	✓	✗	✗
Prioritization of bridges in the bridge management system	Based on the *CoA*	Based on the structural state	Based on the structural state
Number of levels/Classes describing structural state	5 (From Low to High)	7 (From I./Flawless to VII./Emergency)	6 * (From EC0/Good to EC5/Bad)
Frequency of inspections	Based on the *CoA* (at least every 2 years)	Ordinary: every year Main: every 4 years	Regular: every 6 years for EC $\leq$ 2
Most important component in the rating system	Vulnerability class	Quantification of LCC factor	Inspections

* Eight levels if we consider NI (Not Inspected) and IC (Conditioned).

Regarding the periodicity of inspections, the differences are much more significant. For example, in Slovakia, the administrator should visit and visually inspect the bridge every spring and more precisely every four years during so-called main inspections. In Portugal, for bridges in EC $\leq$ 2, the inspections are performed every six years. And finally, in Italy, the inspections are decided on the basis of the *CoA* and, in any case, at least every two years.

The final assessment in the decision-making process is based on different factors. In Italy, the conclusion is proposed considering the *CoA*. The Slovaks consider the *LCC* factor as the most important information for the administrator, and the Portuguese propose the next steps according to the outputs of inspections.

6. Conclusions

The aim of the present paper was to briefly illustrate various methodologies in the field of condition rating of bridges in Europe. Rating systems in Italy, Slovakia, and Portugal can be summarized as follows:

- In Italy, the Italian government recently developed new guidelines for the risk classification, management, safety assessment and monitoring of existing bridges. These guidelines have been issued with the twofold aim of standardizing the assessment criteria in all country and prioritizing maintenance works. The contents of these guidelines can be divided into two main parts: the first one (to be applied to all bridges) deals with the determination of a bridge class of attention, while the second one is inherent to the safety assessment following the code verifications. The novelty of these guidelines is that for the determination of the class of attention, many risks are simultaneously considered: the structural and foundational risk, the seismic, the landslide risk, and the hydraulic risk. Hence, visual inspection for damage detection over the structure must be integrated with technical document reviews and the collection of information regarding the hydrogeology of the site, as well as its seismicity.

- In general, the Slovak rating system is based on two main approaches—a rating based on the classification of the state of the structural elements determined during visual inspection; this approach can insufficiently describe the real state of the bridge. The second, more detailed approach is based on the load-carrying capacity which is determined with consideration of current standard loads and deterioration of material properties. This methodology is more accurate, but also more time-consuming and cost-intensive.
- In Portugal, a condition rating for bridges is primarily based on onsite inspections, allowing for a class related to the presence and severity of a given damage to be defined. Based on that condition rating, intervention actions and periodicity of inspections are defined within a decision-making process for management of these assets. This framework is therefore suitable within the perspective of an asset owner/manager, but would benefit from the analysis of evolution of the performance of the asset as to predict future maintenance and intervention actions with a more optimized use of resources.

To sum up, the unification of bridge management systems in Europe will become increasingly important. A common condition rating system should be simple and comprehensive for all engineers across the continent and should reflect the needs and challenges including climate changes. One of the actual main concerns is the fact that each European country has his own rating system and, very often, these codes are written in the local language, so a consultation of them is very difficult by foreign users. The classification of bridges into several levels or classes is a simple approach and is suitable to describe their current structural and healthy state. The number of such levels should not be very high to ensure that the engineers will be able to easily classify bridges without any difficulties. The final decision should be made after collecting all important data such as drawings—geometry, reinforcement layout, and structural state of all elements of superstructure and substructure. The determination of the bridge load-carrying capacity and remaining service life could be described by factors which express the ability of the structure to carry current load models listed in Eurocodes. Subsequently, the performance of existing bridges should be compared with common European standards which are used across the continent. Future European methodologies should include the prioritization of bridge assessment based on the importance and current structural state of the bridge because, in the near future, concerns with existing structures will become more significant. Hence, it will be unrealistic to deal with the issue on all problematic bridges at the same time.

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