THE 20TH INTERNATIONAL OPERATIONS & MAINTENANCE CONFERENCE IN THE ARAB COUNTRIES

Maintenance and asset management improvement based on resilience and sustainability classification systems

Álvaro Vale e Azevedo; P. Couto; M.J. Falcão Silva; F. Salvado; R. Lima
(ava@lnec.pt)

LNEC – National Laboratory for Civil Engineering
Lisbon, Portugal

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Contents

1. Introduction

- **Building operation and maintenance** covers several activities to provide functional elements to maintain their quality.
- **Construction Information Classification Systems (CICS)** emerged in the XXth century facilitating storage, retrieval and exchange of information that is relevant.
- **Resilience classification** of built assets is increasingly becoming a topic of the greatest importance and relevance for asset managers and building users.
- The Strategy for the Sustainability of the Built Environment establishes several principles of circularity throughout the entire life cycle of buildings, highlighting the use of the **LEVEL(S) sustainable classification approach.**

2. Conceptual framework

- **ISO 15686-1** defines the **maintenance concept** as a combination of technical and administrative actions that allow the building and its constituent elements to perform the functions for which they were designed during their useful life.
- According to **BS 3811**, **maintenance** is the combination of all actions taken to maintain the building or to restore it to a reasonable state.
- **ISO 55000** series, **state that Asset Management (AM)** comprises a coordinated set of activities from an organization to obtain value through its assets, being formulated comprehensively to adapt specific asset needs, changing contexts and differences throughout the organizations.

2. Conceptual framework

- The **Construction Information Classification Systems (CICS)** for the AECO sector emerged in the XXth century to meet some needs of the sector in organizing itself rationally. With a CICS, the objects are grouped into classes, relating them according to their properties.
- **Urban resilience of built assets** can be seen as the ability to withstand severe damage within acceptable degradation parameters and to recover in reasonable time intervals. In Portugal, there are some attempts to develop a resilience classification system, in line with European Standards and Community Policies.
- The **LEVEL(S) sustainable approach** allows for simplified reporting assessment and a defined effect of comparable data, which helps in management activities performance.

3. Resilience classification system

- The proposed Resilience Classification model (for built assets) seeks to be based on **ISO/TR 22845** standard with a focus on natural disasters, whose national exposure is high or medium, adapted from: earthquakes, floods (urban, rivers, seas), fires, and tsunamis.
- The model has a **hierarchical structure** with 3 layers: **Dimensions, Indicators, Parameters.**
- The **classification model**, which is semi-quantitative, is based on existing resilience classification systems and sustainability classification systems that are reasonably mature.
- The scale adopted meets the recommendations of **ISO 11863**, as it considers 5 different levels on a scale of 1, 3, 5, 7 and 9, (1 is the worst performance and 9 the best). For a better interpretation of the final score, the numerical score can be transposed into **resilience classes** from **F to A++**, allowing the differentiation of resilience levels to be understood and intuitive .

3. Resilience classification system

- The **definition of indicators and parameters** aims to assess resilience and facilitate communication and consultation procedures.
- The **parameters subdivide the indicators**, and, in turn, each set of indicators expresses in more detail each of the dimensions.
- The **process of reviewing and calibrating** indicators, parameters, and evaluation criteria, for improvement, is expected to be iterative.
- The **resilience rating system proposed** (Garcia, 2022) was developed to better suit the intended objective for assets maintenance and management and comprises 5 dimensions, 18 indicators and 95 parameters.

3. Resilience classification system

D1 - ENVIRONMENTAL
I1 - Earthquake
P1 - Seismic zoning - type 1 EC8
P2 - Seismic zoning - type 2 EC8
P3 - Seismic vulnerability of PDM soils
P4 - Terrain slope
P5 - EC8 soil type (1)
P6 - Distance to cliffs
P7 - Distance to geological faults
P8 - Population density
I2 - Tsunami and tidal effect
P9 - Land altitude
P10 - Distance to the coast
P11 - Distance to the river
P12 - Natural barriers in the surroundings
P13 - Man-made barriers in the surroundings
P14 - Moving objects
P15 - Rows built between the coast and the building
P16 - Susceptibility to the direct tidal effect PDM
P17 - Relative location
I3 - Flood
P18 - Distance to the river
P19 - Natural barriers in the surroundings
P20 - Man-made barriers in the surroundings
P21 - Vulnerability to PDM Floods
P22 - Distance to vegetation
I4 - Fire
P23 - Density of vegetation
P24 - Vegetation maintenance status
P25 - Type of vegetation
P26 - Adjacent buildings
P27 - Proximity to the industrial zone
I5 - Landslides
P28 - Terrain slope
P29 - Precipitation
P30 - Groundwater level position

D4 - SOCIAL
I10 - Emergency infrastructure parameter
P50 - Access to police stations
P51 - Access to fire stations
P52 - Access to shelters
P53 - Access to hospitals and health centers
I11 - Social responsibility
P54 - Occupants
P55 - Disclosure
P56 - Social vulnerability
P57 - Existence of mutual help programs with neighbors
P58 - No. of social defense organizations
D5 - TECHNICAL
I12 - Conservation
P59 - Year of construction
P60 - Structural system
P61 - State of conservation
P62 - Maintenance, faults, and updates history
I13 Accessibility
P63 - Building density (1)
P64 - Alternate routes (*)
P65 - Street characteristics
I14 - Seismic safety of the building
P66 - Plant irregularity
P67 - Irregularity in height
P68 - Interaction with adjacent buildings
P69 - Slabs unevenness
P70 - Expansion joint
I15 - Building fire safety
P71 - State of conservation of electrical installations (2)
P72 - Gas installations
P73 - Distance between overlapping spans
P74 - Existence of fire compartmentalization (*2)
P75 - Fire detection and alarm (*)
P76 - Existence of emergency signs and lighting (2)
P77 - Existence of security team (2)

D2 - ECONOMIC-FINANCIAL
I6 - Insurance
P31 - Insurance against natural disasters
I7 - Financial and strategic implications
P32 - Financial plan
P33 - Economic assessment of downtime
P34 - Existence of disaster funds
P35 - Access to External/Internal credit
P36 - Access to titles
D3 ORGANIZATIONAL
I8 - Internal organization
P37 - Business continuity plan
P38 - Risk analysis and management
P39 - Post disaster recovery plan
P40 - Routine
P41 - Simulacra
P42 - Learning and updating
P43 - Destructive event data
P44 - Responsible
I9 - External organization
P45 - Compliance with the existing regulatory scenario
P46 - External standards for resilient construction
P47 - Responsible entity
P48 - Relationship between the community and stakeholders
P49 - Monitoring

P78 - Escape paths
P79 - Existence of smoke control and evacuation systems (*2)
P80 - Existence of intrinsic means of combat (*2)
P81 - Existence of fire extinguishers (**2)
P82 - Existence of external hydrants (2)
I16 - Building flood safety
P83 - Existence of barriers (2)
P84 - Existence of pumping systems against flooding (*2)
P85 - Vulnerability and exposure of facades (2)
P86 - Number of floors
P87 - Street characteristics
P88 - Vulnerability of underground floors
P89 - Waterproofing solutions (basements)
P90 - Wastewater drainage systems
I17 - Building safety against tsunamis
P91 - Number of floors
P92 - Guidance
P93 - Ground floor hydrodynamics (*)
I18 - Building safety against landslides
P94 - Degree of Waterproofing (soils)
P95 - Slope stability

3. Resilience classification system – Case Study 1

- To **validate the proposed resilience classification** system **4 public collective use buildings**, located in Lisbon, were used:

- **E1 building** was built during the 50's of the 20th century (RC structure + Exterior and interior walls of simple filling brick masonry);

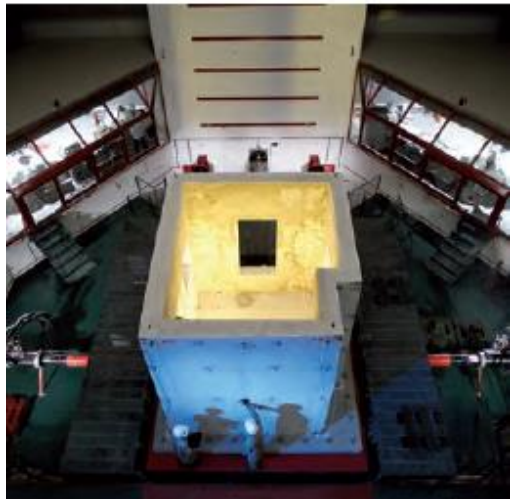
3. Resilience classification system – Case Study 1

- **E2 building** is dated from the 60´s of the 20th century (RC structure + Exterior cladding of the facades in glazed brick);

3. Resilience classification system – Case Study 1

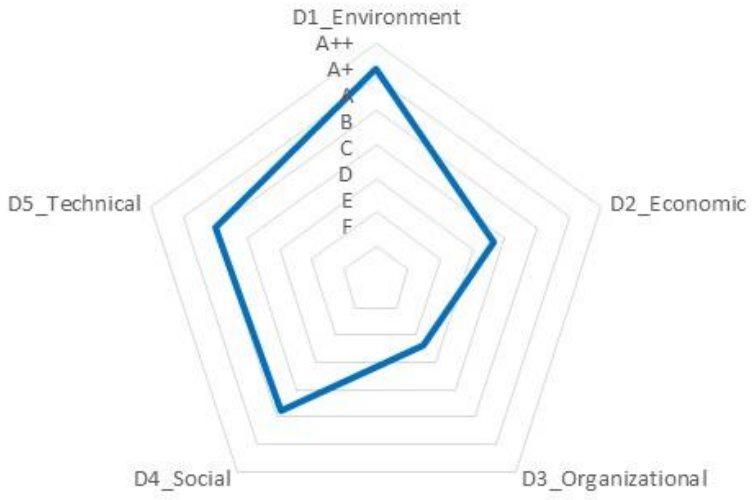
- **E3 building,** opened in 1972 (RC structure + Exterior and interior walls of simple filling of the brick masonry);

3. Resilience classification system – Case Study 1

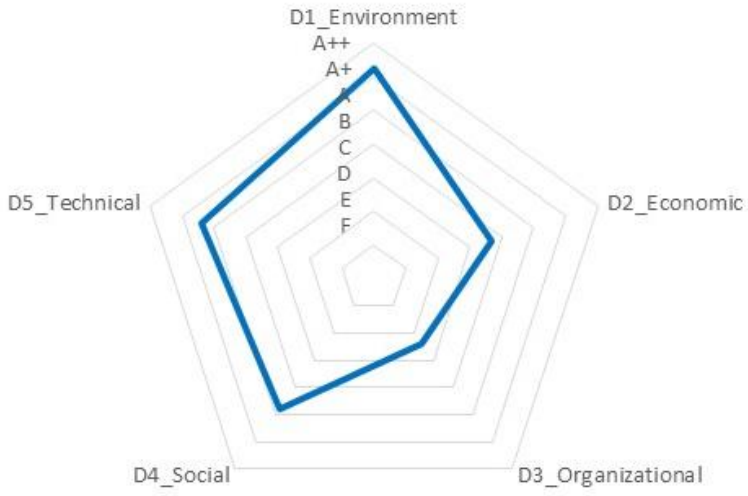


- **E4 building**, already built and inaugurated during the 1990's (RC structure + Exterior cladding of glass / ceramic facades).

3. Resilience classification system – Case Study 1



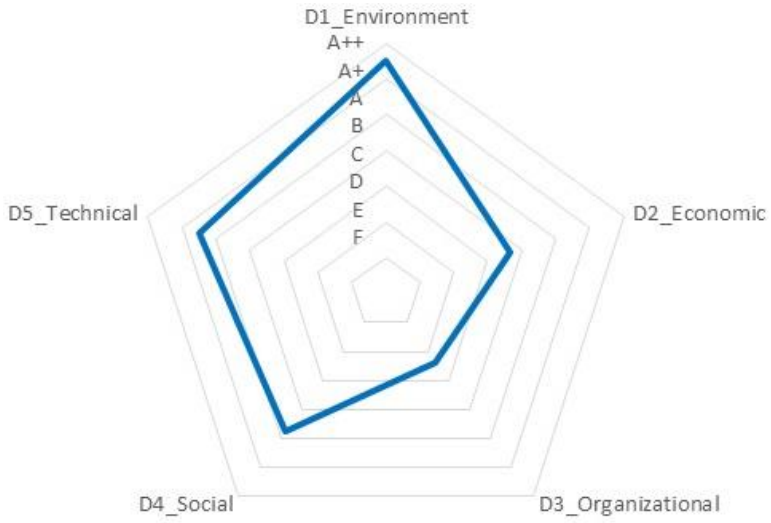
E1 dimensions scoring



E2 dimensions scoring

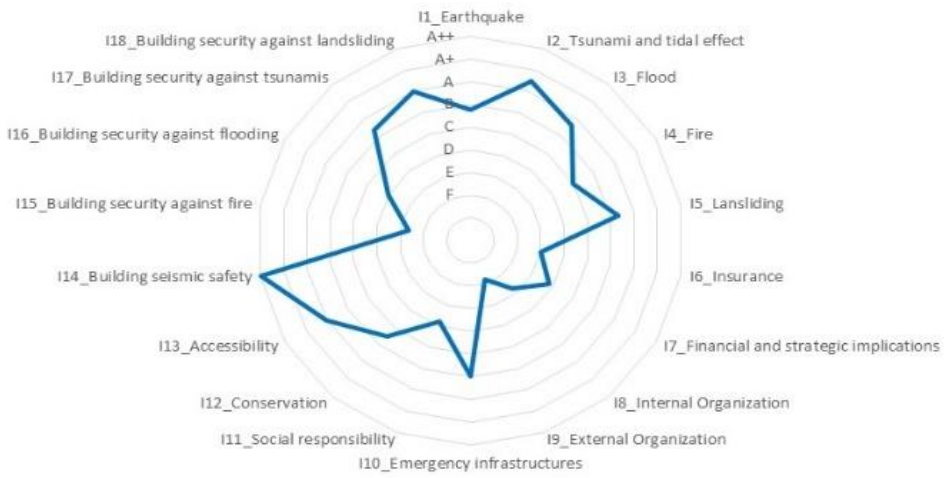
3. Resilience classification system – Case Study 1

E3 dimensions scoring

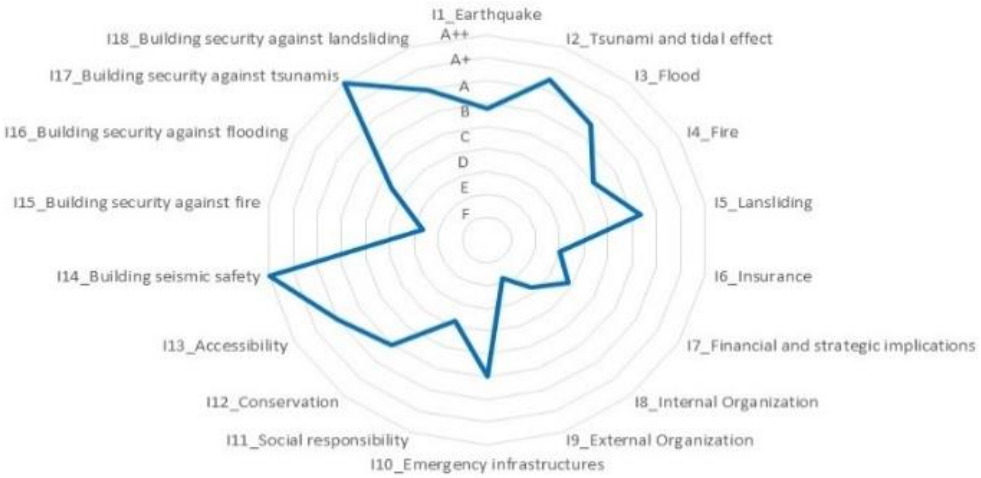


E4 dimensions scoring

3. Resilience classification system – Case Study 1

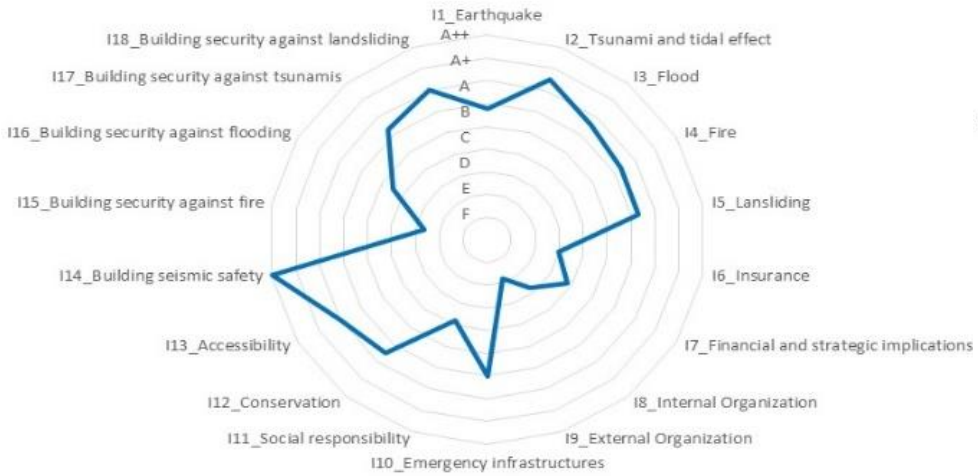


E1 indicators scoring

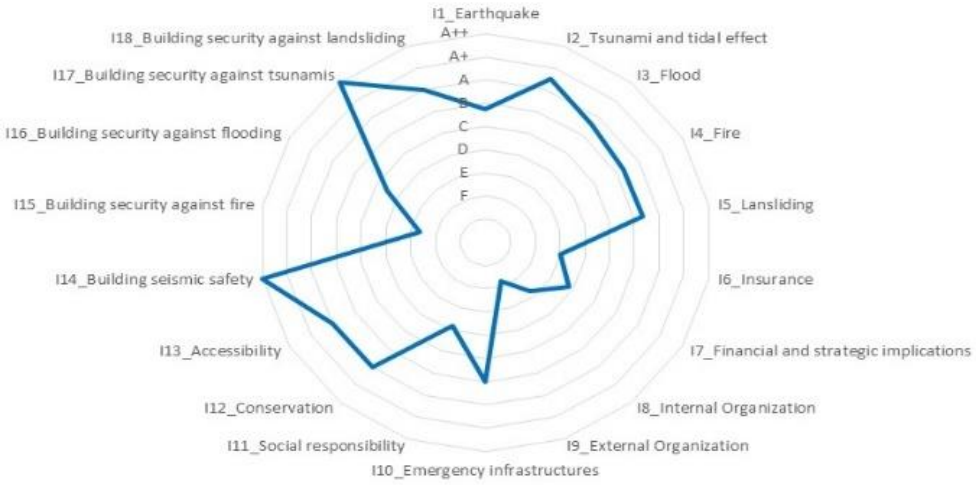


E2 indicators scoring

3. Resilience classification system – Case Study 1



E3 indicators scoring



E4 indicators scoring

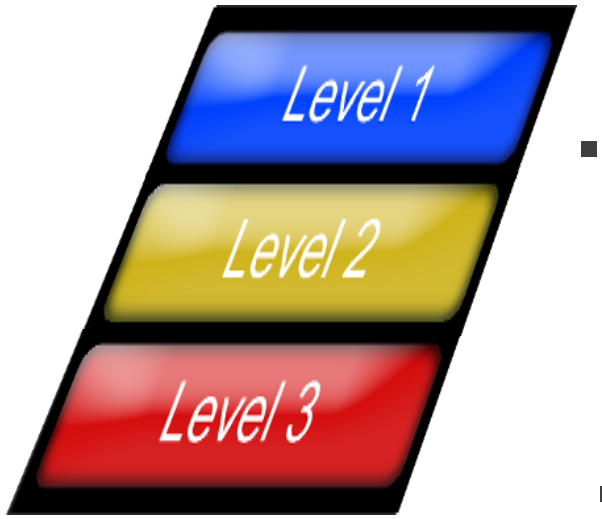
3. Resilience classification system – Case Study 1

- For the different Dimensions, it was obtained **good rating** for all studied buildings, considering **D1** (environmental) and **D5** (technical).
- For **D2** (economic-financial) and **D4** (social), the results achieved correspond to **low to medium rating**, respectively.
- For **D3** (organizational) (all buildings belonging to the same asset manager) **very low rating** was obtained.
- The **better Indicator** (for all buildings) is **I14** (seismic safety) and **the worst** corresponds to **I15** (fire safety).
- All buildings present **similar behavior for I10** (emergency infrastructure).
- Most of the **similarities appear since all buildings belong to the same organization**, having the same type of maintenance and asset management.

4. Sustainability classification system – LEVEL(S)

- **LEVEL(S) uses a set of sustainability indicators** to measure carbon, materials, water, health, comfort, life cycle costs and climate change impacts, evaluated from the design phase to the use phase of the buildings.
- Their common structure is **organized into 3 levels** that represent the increasing complexity of the construction project phases / stages.
- **Each LEVEL has associated indicative stages**, and it may be useful to understand how and when different activities, in each of these stages, contribute to the application of the LEVEL(S) to the project.

4. Sustainability classification system – LEVEL(S)



- **LEVEL 1** (Concept for the construction project) represents **the simplest level**, as it involves a qualitative assessment in the initial phase.
- **LEVEL 2** (Detailed design and construction performance) represents an **intermediate level**, as it involves quantitative assessment of the performance of what is designed and the construction monitoring, according to standardized units and methods.
- **LEVEL 3** (Reality after completion and including delivery to customer) represents **the most advanced level**, as it involves monitoring activity at the construction site and the building and first occupants.

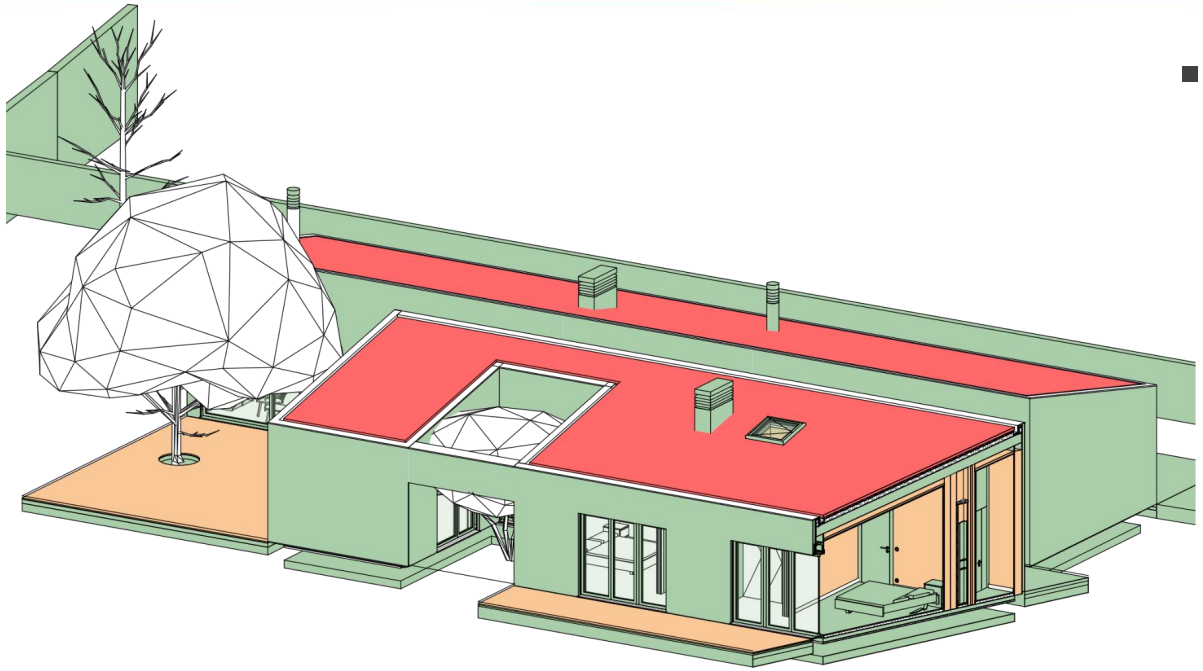
4. Sustainability classification system – LEVEL(S)

- The **LEVEL(S) structure indicators** are **divided into 3 different Areas**: i) Resource use and environmental performance during the life cycle of a building; ii) Health and comfort; and iii) Cost, value, and risk.
- **Each area** is **subdivided into Macro-objectives**, that describe the strategic priorities, for the contribution of buildings, to the European Union's and Member States' policy objectives, in the field of energy, use of materials and waste, water, and indoor air quality. The LEVEL(S) approach suggests **6 Macro-objectives** for buildings.
- **For each macro-objective, performance Indicators are defined**. The LEVEL(S) approach suggests **16 performance indicators** for buildings.

4. Sustainability classification system – LEVEL(S)

AREAS	MACRO-OBJECTIVE	INDICATOR
Use of resources and environmental performance	1. Greenhouse gas and air pollutant emissions along a buildings life cycle	1.1 Use stage energy performance
		1.2 Life cycle Global Warming Potential
	2. Resource efficient and circular material life cycles	2.1 Bill of quantities, materials, and lifespans
		2.2 Construction & demolition waste and materials
		2.3 3 Design for adaptability and renovation
		2.4 Design for deconstruction, reuse, and recycling
	3. Efficient use of water resources	3.1 Use stage water consumption
Health and comfort	4. Healthy and comfortable spaces	4.1 Indoor air quality
		4.2 Time outside of thermal comfort range
		4.3 Lighting and visual comfort
		4.4 Acoustics and protection against noise
Cost, value and risk	5. Adaptation and resilience to climate change	5.1 Protection of occupier health and thermal comfort
		5.2 Increased risk of extreme weather event
		5.3 Increased risk of flood events
	6. Optimised life cycle cost and value	6.1 Life cycle costs
		6.2 Value creation and risk exposure

4. Sustainability classification system – Case study 2



- The **validation of the LEVEL(S) classification system** was carried out by applying it to a single family house located in the North of Portugal.

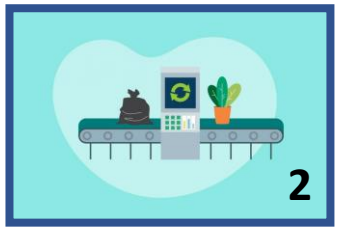
4. Sustainability classification system – Case study 2

- After analyzing LEVEL(S) approach and comparing it with its objectives, an **application of some classifications was made, based on Macro-objective 2** (resource efficient and circular material life cycles) **and Indicator 2.2** (construction & demolition waste and materials).

- The decision was based on the **macro-objective to contain the indicators most related with the reuse and recycling of materials** for the Life Cycle Analysis (LCA) and the adaptability of dismantling buildings.

- The **indicator 2.2 estimates and measures the total amount of waste generated by construction, renovation, and demolition activities** (in kg) which, when broken down into the main types of CDW (Construction and Demolition Waste), according to the entries in the European Waste List, results in mapping for a better destination of CDW.

4. Sustainability classification system – Case study 2



PARAMETERS TO BE CLASSIFIED		PARAMETERS DESCRIPTION
Waste type	Inert Dangerous Not dangerous	Waste classification to be generated according to the type of material that is present
Waste constitution	Concrete Tile Roof tiles Ceramics Wood Glass Plastics Bituminous mixtures Copper / bronze / brass Aluminium Iron Steel Other metals Cables Soil and stones Drainage spoil Track ballast Insulation materials Asbestos-containing materials Gypsum-based materials Door elements Window elements	Waste type classification to be generated based on its composition according to the European Waste List (LER Code), the same classification used in the Excel spreadsheet: Estimation of amounts of waste from Indicator 2.2 of the LEVEL(s) approach.
Waste material destination	Residual material for reuse Residual material for recycle Residual material for recovery Residual material for disposal	Classification indicating the destination of the material that can support the measurement of how much construction or demolition is associated with recycling, reuse, and waste of materials.

4. Sustainability classification system – Case study 2

- The **classifications proposed** are necessary for better information management and standardization of CDW properties and characteristics.
- With these codes, the **language used by the different agents of the project is standardized,** thus avoiding divergences in the communication among them.
- Once the information is classified, it can be introduced in the **LEVELS(S) calculator** (https://ec.europa.eu/buildings-performance-calculator/screen/home).
- The information may also be introduced in the **Excel format template** (https://susproc.jrc.ec.europa.eu/product-bureau/product-groups/ 412/documents).

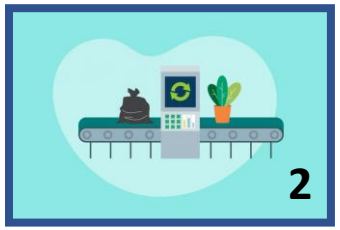
4. Sustainability classification system – Case study 2

- The **validation of the LEVEL(S) classification system** was carried out by applying it to the case study of a single family house.

- It was **made for 2 examples of the parameters of the classification system** and **all life-cycle phases,** although **not completely representative of a diversified sample**, either in terms of quantity or in terms of distinguishing CDW characteristics.

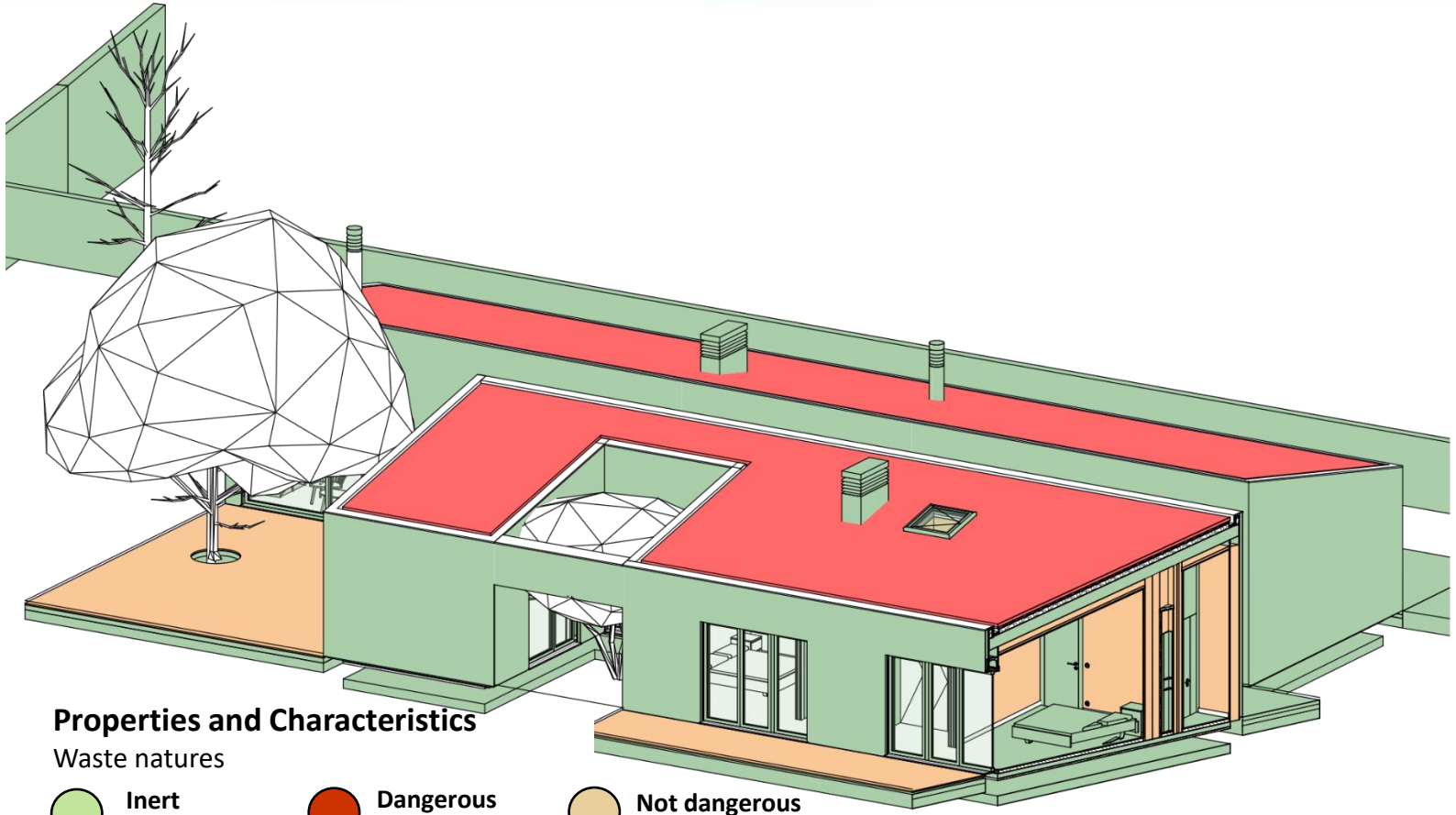
- This will allow the **classification system expeditious validation.**

4. Sustainability classification system – Case study 2



NUMBER	DESCRIPTION
Table PC	Properties and Characteristics
PC_10	**Construction and demolition waste and materials**
PC_10_01	Element Properties
PC_10_02	Nature of waste
PC_10_02_01	Inert
PC_10_02_02	Dangerous
PC_10_02_03	Not dangerous
PC_10_03	Waste destination
PC_10_04	Waste constitution
PC_10_04_01	Concrete
PC_10_04_02	Bricks
PC_10_04_03	Roof tiles
PC_10_04_04	Ceramics / tiles
PC_10_04_05	Wood
PC_10_04_06	Glass
PC_10_04_07	Plastic
PC_10_04_08	Bituminous mixtures
PC_10_04_09	Copper / bronze / brass
PC_10_04_10	Aluminum
PC_10_04_11	Iron Steel
PC_10_04_12	Other metals
PC_10_04_13	Cables
PC_10_04_14	Soil and stones
PC_10_04_15	Drainage garbage
PC_10_04_16	Runway ballast
PC_10_04_17	Insulation material
PC_10_04_18	Material containing asbestos
PC_10_04_19	Gypsum based material
PC_10_04_20	Door element
PC_10_04_21	Window element

4. Sustainability classification system – Case study 2



Properties and Characteristics

Waste natures

- **Inert** PC_10_02_01
- **Dangerous** PC_10_02_02
- **Not dangerous** PC_10_02_03

Type Properties

Family: System Family: Basic Roof

Type: MC_CS_RevTelha_PlasmaBrancoPerola66p7_E66p7

Load... | Duplicate... | Rename...

Type Parameters

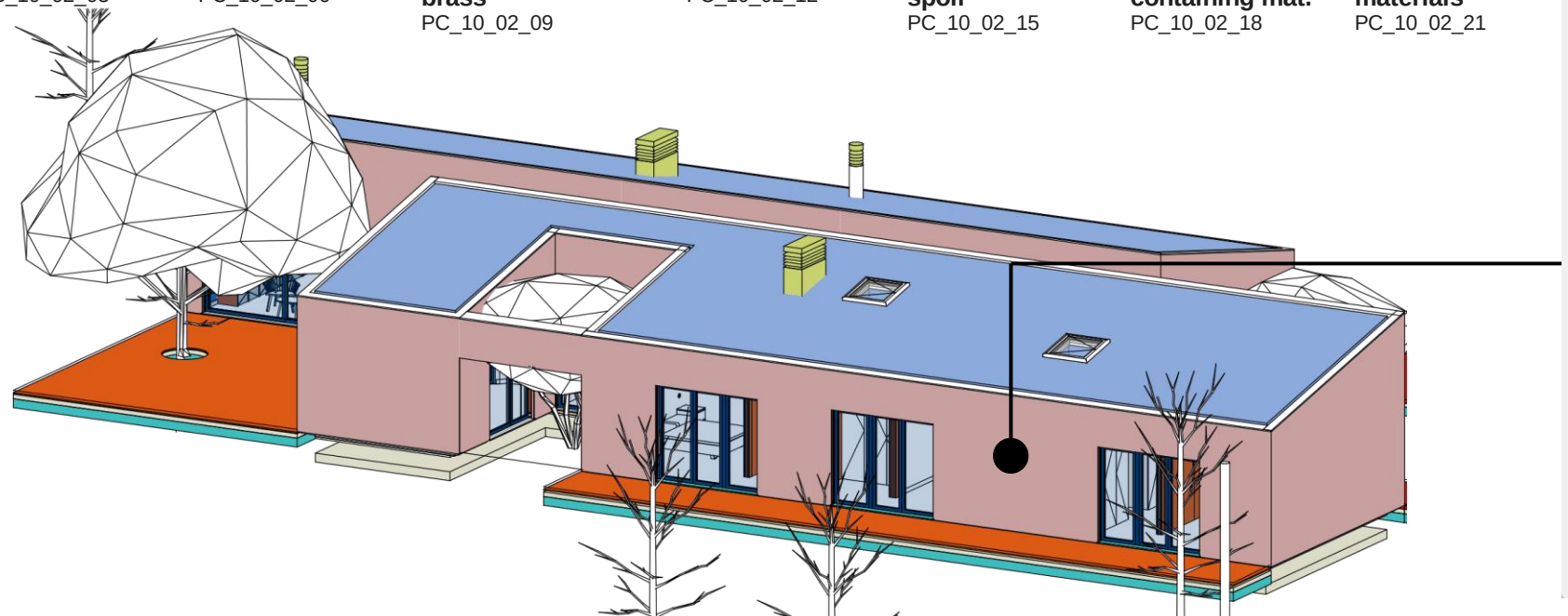
Parameter	Value
Description	Telha plana
Assembly Description	
Assembly Code	
Type Mark	
Cost	
Workset	Roof Types
Edited by	rodrigo.tavaresRPSKF
Green Building Properties	
Natureza do resíduo - Código	PC_10_02_02
Natureza do resíduo - Descrição	Perigoso
Destino do resíduo - Código	PC_10_03_16
Destino do resíduo - Descrição	Destruição térmica por incineração
Constituição do resíduo - Código	PC_10_04_17
Constituição do resíduo - Descrição	Materiais contendo amianto
Data	
ClassificacaoSecclassEFNumero	EF_30_10
ClassificacaoSecclassEFDescricao	Coberturas - Roofs
ClassificacaoSecclassSsNumero	

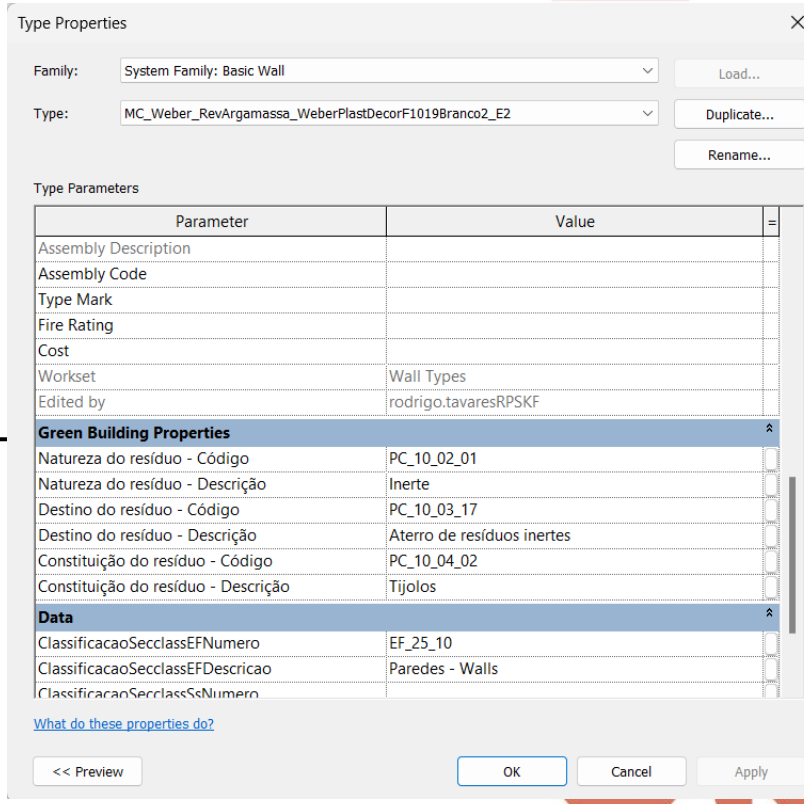
What do these properties do?

<< Preview | OK | Cancel | Apply

4. Sustainability classification system – Case study 2

- **Concrete** PC_10_02_01
- **Ceramic** PC_10_02_04
- **Plastic** PC_10_02_07
- **Aluminium** PC_10_02_10
- **Cables** PC_10_02_13
- **Track ballast** PC_10_02_16
- **Gypsum-based materials** PC_10_02_19
- **Bricks** PC_10_02_02
- **Wood** PC_10_02_05
- **Bituminous mixtures** PC_10_02_08
- **Iron / steel** PC_10_02_11
- **Soil and stones** PC_10_02_14
- **Insulation materials** PC_10_02_17
- **Element-door** PC_10_02_20
- **Tiles** PC_10_02_03
- **Glass** PC_10_02_06
- **Copper /bronze / brass** PC_10_02_09
- **Other metal** PC_10_02_12
- **Dredging spoil** PC_10_02_15
- **Asbestos containing mat.** PC_10_02_18
- **Element-window materials** PC_10_02_21





Type Properties

Family: System Family: Basic Wall — Load...

Type: MC_Weber_RevArgamassa_WeberPlastDecorF1019Branco2_E2 — Duplicate... Rename...

Type Parameters

Parameter	Value
Assembly Description	
Assembly Code	
Type Mark	
Fire Rating	
Cost	
Workset	Wall Types
Edited by	rodrigo.tavaresRPSKF
Green Building Properties	
Natureza do resíduo - Código	PC_10_02_01
Natureza do resíduo - Descrição	Inerte
Destino do resíduo - Código	PC_10_03_17
Destino do resíduo - Descrição	Aterro de resíduos inertes
Constituição do resíduo - Código	PC_10_04_02
Constituição do resíduo - Descrição	Tijolos
Data	
ClassificacaoSecclassEFNumero	EF_25_10
ClassificacaoSecclassEFDescricao	Paredes - Walls
ClassificacaoSecclassSsNumero	

What do these properties do?

<< Preview — OK — Cancel — Apply

4. Sustainability classification system – Case study 2

- Another function of the standardization and codification of these classifications is the **possibility of being used as parameters in the BIM methodology**.

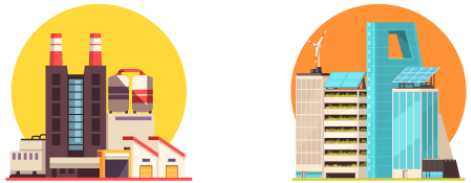
- This makes it **possible to generate graphically informative models**, based on how the elements may be intended with respect to their nature, or even what type of material is being applied in the construction, with the possibility of **extracting the information directly from a BIM model**, through proprietary routines.

5. Conclusions

- The **results of the calibrations of the resilience classification system** proposed, for 4 Collective Use Buildings were presented;
- It's still **necessary to develop complementary work** to implement the proposed assessment, in a representative diversity of the constructed assets types, as well as to extend the scope of the proposed multivariable classification system about other types of risks and the identification of countermeasures and their classification;
- **Different buildings with different functions and uses can, and should be used,** as empirical case studies to show how technical performance and risk engineering can be programmed defensively to improve resilience and reliability in a more sustainable environment for future generations;
- The **expansion of the approaches** presented include an online platform GIS and a roadmap to increase the reach and extended impact of project results, for public and private organizations that manage construction assets (government agencies, banks, insurance companies, design and construction companies;

5. Conclusions

- The **LEVEL(S) approach** proposed by the EU also appears as a **starting point** for the **development of a classification component with a sustainable aspect**, supporting users in “greener” decisions;
- Divided into six macro-objectives, the proposed **classification focused** on the **life cycles of circular and resource-efficient materials;**
- **Suggested 4 indicators**, to describe: materials and their life cycles (2.1); classification of construction and demolition waste (2.2); adaptability of buildings to promote greater life cycle (2.3); criteria that facilitate the disassembly, reuse, and recycling of materials (2.4);
- The **results of classifications for indicator 2.2 have already been defined** and are in the evolution phase for application and dissemination in building projects.



THANK YOU VERY MUCH FOR YOUR ATTENTION

Álvaro Vale e Azevedo; P. Couto; M.J. Falcão Silva; F. Salvado; R. Lima

(ava@lnec.pt)

LNEC – National Laboratory for Civil Engineering
Lisbon, Portugal