#59 | A rating system for building condition ranking

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Do people know everything about their asset?

CONSTRUCTED ASSET

GLOBAL SERVICE

BOUGHT WITH

MANAGED WITH

LACK OF INFORMATION

UNEFFECTIVE CONTROLS

POOR PERFORMANCES

UNEFFECTIVE MAINTENANCE

EXPENSIVE OPERATIONS

UNSAFE BUILDINGS

UNSATISFACTORY BUILDINGS

LOW YIELD INVESTMENTS

OVERCOSTS

AVOIED BY

BUILDING CONDITION ASSESSMENT

RATING SYSTEM

MAINTENANCE OPERATIONS DATABASE
State of the art

**Building Condition Assessment**

1. quick and rough (e.g. for many buildings in an asset)
2. slow and detailed (e.g. more deteriorated components in a specific building)

- tailored on building function
- planned and not “fault-based”
- associated with a rating
- objective and reliable
- scalable

Before failure detection

Maintenance

After failure detection

Preventive

Corrective

Condition-based

Planned

Continuous

Upon request

Planned

Cyclic

Deferred

Urgent
WBS and diagnostic forms

Functions:
- residential
- office
- school
- hospital
- factory

Building

Technological units

Components

Components:
- Pad foundation
- Strip foundation
- Column
- Beam
- Window
- Component

1 Form data
   name, number, code, ...

2 Component data
   name, WBS link, description, ...

3 Anomalies assessment
   type, presence/absence, extension

4 Service life index
   D_c or D_C, depending on ASL

5 Degradation index
   A_c average of the existing anomalies
BUILDING CONDITION INDEX

TECHNICAL INDEX

SERVICE LIFE INDEX (D⁺, D⁻)

DEGRADATION INDEX (A)

MAINTENANCE OPERATIONS

URGENT

DEFERRED

DOCUMENTS INDEX

DOCUMENTS UPDATE
## Service Life Index

The Service Life Index is the ratio between ASL and RSL ($D^+ \text{ and } D^-$).

## Degradation Index

The Degradation Index is the ratio between anomalies found and possible (A).

### Database with:
- **18** technological units
- **>400** components (organised in a WBS)
- **431** anomalies (low, medium, serious)
- ~**12** anomalies for each component
- **RSL** associated to each component (from literature)
Technical Index

COMPONENTS

Ext. plaster

Flooring

Windows

Heating sys.

Paint

... 

D\(^+\)  D\(^-\)  A

Simple mean

TECHNOLOGICAL UNITS

Elevation structures

Opaque envelope

Transparent envelope

... 

BUILDING

Flooring

Lift

Balconies

... 

D\(_C^+\) = \frac{RSL - ASL}{RSL} \text{ if } ASL \leq RSL \text{ or } D\(_C^-\) = 1 - \frac{ASL - RSL}{ASL} \text{ if } ASl > RSL

A_L = \frac{\sum_{i=1}^{L} P_{L,i} \times E_i}{L}

A_M = \frac{\sum_{j=1}^{M} P_{M,j} \times E_j}{M}

A_S = \frac{\sum_{k=1}^{S} P_{S,k} \times E_k}{S}

A_c = \frac{A_L \times W_L + A_M \times W_M + A_S \times W_S}{(W_L + W_M + W_S)}

D_{Bld}^+ = \frac{\sum_{k=1}^{o} D_{TU,k}^+ \times W_k^{E/C}}{\sum_{k=1}^{o} W_k^{E/C}}

D_{Bld}^- = \frac{\sum_{k=1}^{o} D_{TU,k}^+ \times W_k^{E/C}}{\sum_{k=1}^{o} W_k^{E/C}}

A_{Bld} = \frac{\sum_{k=1}^{o} A_{TU,k} \times W_k^{E/C}}{\sum_{k=1}^{o} W_k^{E/C}}

Tailored on function
### Technical Index

<table>
<thead>
<tr>
<th>TECHNOLOGICAL UNIT</th>
<th>WEIGHTS</th>
<th>WEIGHTED INDEXES</th>
<th>ANOMALIES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td># CODE</td>
<td>D^+</td>
<td>D^-</td>
</tr>
<tr>
<td>01 S.F Foundations</td>
<td>01</td>
<td>20.41%</td>
<td>2.72%</td>
</tr>
<tr>
<td>02 S.C Retains structures</td>
<td>02</td>
<td>12.12%</td>
<td>1.26%</td>
</tr>
<tr>
<td>03 S.E Elevation structures</td>
<td>03</td>
<td>3.83%</td>
<td>0.00%</td>
</tr>
<tr>
<td>04 C.V.O Opaque envelope</td>
<td>04</td>
<td>22.49%</td>
<td>0.00%</td>
</tr>
<tr>
<td>05 C.T Transparent envelope</td>
<td>05</td>
<td>16.89%</td>
<td>0.00%</td>
</tr>
<tr>
<td>06 C.O.I Slab on ground</td>
<td>06</td>
<td>2.18%</td>
<td>0.00%</td>
</tr>
<tr>
<td>07 C.O.A Slab on open spaces</td>
<td>07</td>
<td>4.77%</td>
<td>0.00%</td>
</tr>
<tr>
<td>08 C. Roof</td>
<td>08</td>
<td>13.58%</td>
<td>10.41%</td>
</tr>
<tr>
<td>09 C.L Inernal vertical partition</td>
<td>09</td>
<td>3.73%</td>
<td>0.00%</td>
</tr>
<tr>
<td>10 C.O Electric plant</td>
<td>10</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>11 C.O External horizontal partition</td>
<td>11</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>12 C.O External horizontal partition</td>
<td>12</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>13 I.F.S.C HVAC</td>
<td>13</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>14 I.F.S.DS Water and sanitary plant</td>
<td>14</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>15 I.F.S.E Electric plant</td>
<td>15</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>16 I.F.S.I Sewer plant</td>
<td>16</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>17 I.F.S.R Lift plant</td>
<td>17</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>18 I.F.S.M Fire plant</td>
<td>18</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>32</td>
<td>100.00%</td>
<td>14.39%</td>
</tr>
</tbody>
</table>

- **blue line**: current building condition.
- **green dashed line**: optimal building condition.

D^+ is equal in both cases because the building physiologically gets older, but this is not a failure.

- **133** on 407 possible **anomalies** detected
- **24** components with **ASL ≥ RSL**
- **8** components with **ASL < RSL**

\[ I_{Tech} = \frac{\text{Area}_{Building}}{\text{Area}_{Optimal}} \] [\%]
It is the weighted ratio between available and required documents.

- it relies on a list of documents required by Italian laws
- documents are grouped in 9 families (A to I) using a Documents Breakdown Structure
- each family has an importance weight (calculated with AHP technique)

It allows identification of documents:
- missing
- out of date
- non-compliant

### DOCUMENTS INDEX

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Construction</td>
</tr>
<tr>
<td>B</td>
<td>Fire safety</td>
</tr>
<tr>
<td>C</td>
<td>Structures</td>
</tr>
<tr>
<td>D</td>
<td>Plants</td>
</tr>
<tr>
<td>E</td>
<td>Safety and O&amp;M</td>
</tr>
<tr>
<td>F</td>
<td>Urban planning</td>
</tr>
<tr>
<td>G</td>
<td>Land register</td>
</tr>
<tr>
<td>H</td>
<td>As built</td>
</tr>
<tr>
<td>I</td>
<td>Origin and rights</td>
</tr>
</tbody>
</table>
Ratio between present and required documents for each family

Weighted sum of required documents families indexes

\[
I_{family} = S_{family} \times W_{family} \% \\
I_{Doc} = \sum_{i=1}^{N} I_{family,i} \% 
\]
• **blue line**: current documents available.

• **red dashed line**: level 1 documents – required by laws.

• an high rating does not mean a sufficient documents situation: each single family must be above sufficiency.

• some family may not be present because not relevant for the specific building.

• weights automatically calibrated on analysed docs families

• green/red check for mandatory documents
Building Condition Index

BUILDING CONDITION INDEX

Building index 71%
- average of previous indexes, if both present.

Technical index 63.17%
- There are 38 serious anomalies on 32 diagnostic forms

Documents index 78.74%
- Mandatory documents are all present

- red: average of the below limits
- yellow: average of the below limits
- red: “bad” condition
- yellow: “normal” condition
- red: mandatory documents
- yellow: zero
for different stakeholders and purposes
• incremental system
• to be used both for quick and detailed surveys
• good starting point for maintenance management and energy refurbishment

<table>
<thead>
<tr>
<th>#</th>
<th>CODE</th>
<th>NAME</th>
<th>WEIGHS</th>
<th>WEIGHTED INDEXES</th>
<th>ANOMALIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>SF</td>
<td>Foundations</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>02</td>
<td>SC</td>
<td>Structure</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>03</td>
<td>SE</td>
<td>Elevation structures</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>04</td>
<td>CV</td>
<td>Casque envelope</td>
<td>5</td>
<td>20.61%</td>
<td>2.72 % 13.37% 19.14% 22 on 50</td>
</tr>
<tr>
<td>05</td>
<td>CVT</td>
<td>Transparent envelope</td>
<td>8</td>
<td>12.12%</td>
<td>1.26% 6.06% 9.34% 44 on 100</td>
</tr>
<tr>
<td>06</td>
<td>CD</td>
<td>Steel on ground</td>
<td>1</td>
<td>8.83%</td>
<td>0.00% 1.92% 3.57% 3 on 11</td>
</tr>
<tr>
<td>07</td>
<td>CWO</td>
<td>Steel on open spaces</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>08</td>
<td>CS</td>
<td>Roof</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>09</td>
<td>FV</td>
<td>Internal vertical partition</td>
<td>5</td>
<td>22.49%</td>
<td>0.00% 13.87% 17.07% 26 on 50</td>
</tr>
<tr>
<td>10</td>
<td>FHO</td>
<td>Internal horizontal partition</td>
<td>4</td>
<td>16.89%</td>
<td>0.00% 11.96% 16.07% 6 on 96</td>
</tr>
<tr>
<td>11</td>
<td>FE</td>
<td>External vertical partition</td>
<td>1</td>
<td>2.19%</td>
<td>0.00% 1.99% 1.77% 1 on 20</td>
</tr>
<tr>
<td>12</td>
<td>FEO</td>
<td>External horizontal partition</td>
<td>2</td>
<td>4.77%</td>
<td>0.00% 2.18% 2.55% 17 on 27</td>
</tr>
<tr>
<td>13</td>
<td>IPS</td>
<td>HVAC</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>IPSL</td>
<td>Water and sanitary plant</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>IPSL</td>
<td>Electric plant</td>
<td>4</td>
<td>13.58%</td>
<td>10.41% 13.58% 13.49% 3 on 22</td>
</tr>
<tr>
<td>16</td>
<td>IPSR</td>
<td>Sanitary plant</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>17</td>
<td>IPSR</td>
<td>Lift plant</td>
<td>2</td>
<td>3.73%</td>
<td>0.00% 2.49% 3.49% 2 on 12</td>
</tr>
<tr>
<td>18</td>
<td>IPS</td>
<td>Fire plant</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>33</td>
<td>100.00%</td>
<td>14.39% 67.32% 87.70% 133 on 407</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Corrective maintenance

<table>
<thead>
<tr>
<th>COMPONENTS ANOMALIES</th>
<th>Ext. plaster</th>
<th>Windows</th>
<th>Heating sys.</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cracks</td>
<td>broken glass</td>
<td>water leakage</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>missing parts</td>
<td>dust</td>
<td></td>
<td>...</td>
</tr>
</tbody>
</table>

### MAINTENANCE OPERATIONS

<table>
<thead>
<tr>
<th>External plaster</th>
<th>cracks</th>
<th>missing parts</th>
<th>Dust</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>restoration</td>
<td></td>
<td>partial replacement</td>
<td>cleaning</td>
<td>...</td>
</tr>
<tr>
<td>partial replacement</td>
<td></td>
<td>complete replacement</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- directly connected with components anomalies
- can be grouped together (opportunity maintenance)
- divided in macro-categories (restoration, cleaning, replacement, …)
- best interventions to be done must be selected by the user
- associated with a schedule (short-medium-long term) and a description
**Urgent maintenance operations**

<table>
<thead>
<tr>
<th>ANOMALY</th>
<th>OPERATION</th>
<th>SCHEDULE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finishing degradation</td>
<td>Restoration</td>
<td>long-term</td>
<td>Repainting and/or replacing hardware parts</td>
</tr>
<tr>
<td>Superficial deposits</td>
<td>Cleaning</td>
<td>long-term</td>
<td>Use of specific instruments and products</td>
</tr>
<tr>
<td>Hardware degradation</td>
<td>Restoration</td>
<td>middle-term</td>
<td>To be fixed, oiled and tuned</td>
</tr>
<tr>
<td>Gasket degradation</td>
<td>Partial replacement</td>
<td>middle-term</td>
<td>Disassembly and replacement</td>
</tr>
<tr>
<td>Biological attack</td>
<td>Restoration</td>
<td>short-term</td>
<td>Biological colony removal</td>
</tr>
<tr>
<td>Missing parts</td>
<td>Partial replacement</td>
<td>short-term</td>
<td>Disassembly and replacement</td>
</tr>
</tbody>
</table>

Extract of maintenance operations for a *wooden window*

Possibility to combine with other operations to be done on the main façade
Further developments

- complete maintenance profile for each component
- Life Cycle Cost for components maintenance profiles

External plaster LCC comparison
- planned maintenance (blue)
- corrective maintenance (red)

- Building Condition Indexes as an instrument to find the asset true market value

Evaluation of:
- asset market value
- maintenance cost to restore market value
The system helps in filling the lack of information for a constructed asset:

• it gives the **current building situation** (documents and degradation)

• It helps in the definition of **maintenance operations** to be done

• it is **incremental**

• it is **objective** and building **function** tailored

• it can be used both during **refurbishment** and **handover**

• its **reliability** has been tested with several case studies (made by different people’s categories)

• it can be connected to a **quantity survey** and to **BIM** technologies