BUILDING CONDITION ASSESSMENT APPLIED TO PUBLIC BUILDINGS

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Introduction

The construction sector is facing continuing difficulties with defects that are avoidable with the design for sustainable maintenance considerations. AECO sector is among the most responsible for negative impacts on the environment, being also a key target for minimizing the climate changes causes. Despite this, almost no maintenance and rehabilitation solutions and processes were subject to Life Cycle Assessment (LCA).So, a BIM-based platform that allows an easy and building monitorization with reliable management actions supported by Key Performance Indicators (KPIs) and Life Cycle Assessment (LCA) is intended to be developed. So far, a set of Key Performance Indicators applied to Building Condition Assessment were analysed, compared and narrowed down for Condition Assessment purposes. Also, a study comparing the LCA software were carried out to assess maintenance and rehabilitation processes and which will be integrated into a BIM platform. This work provides an overview of the work done until now, as well as of the expected future developments.

Key Performance Indicators

Key Performance Indicators aims to provide an evaluation of performance progress along the way [1]. Since the building envelope relates the building aesthetics with its internal environment, has also the responsibility to regulate internal physical conditions [2]. So, this study pretends to evaluate the envelope building condition, with intention of being reproduced to other building elements. For this purpose, a criterion was defined, which took the object under study into account and allows to select the most important indicators. Thus, a set of 58 Key Performance Indicators were analyzed and compared, in the following aspects :

- Category of application
- Objectives
- Scope
- Inspection method
- Attributes assessed
- Disagregation level
- Weighting coefficient
- Assessment criteria
- Calculation formula
- Results
- Implementation tools
- Validation methods
- Potential to support BIM in BCA.

Among 58 KPIs, 15 were considered as the most important being depicted in Figure 1.

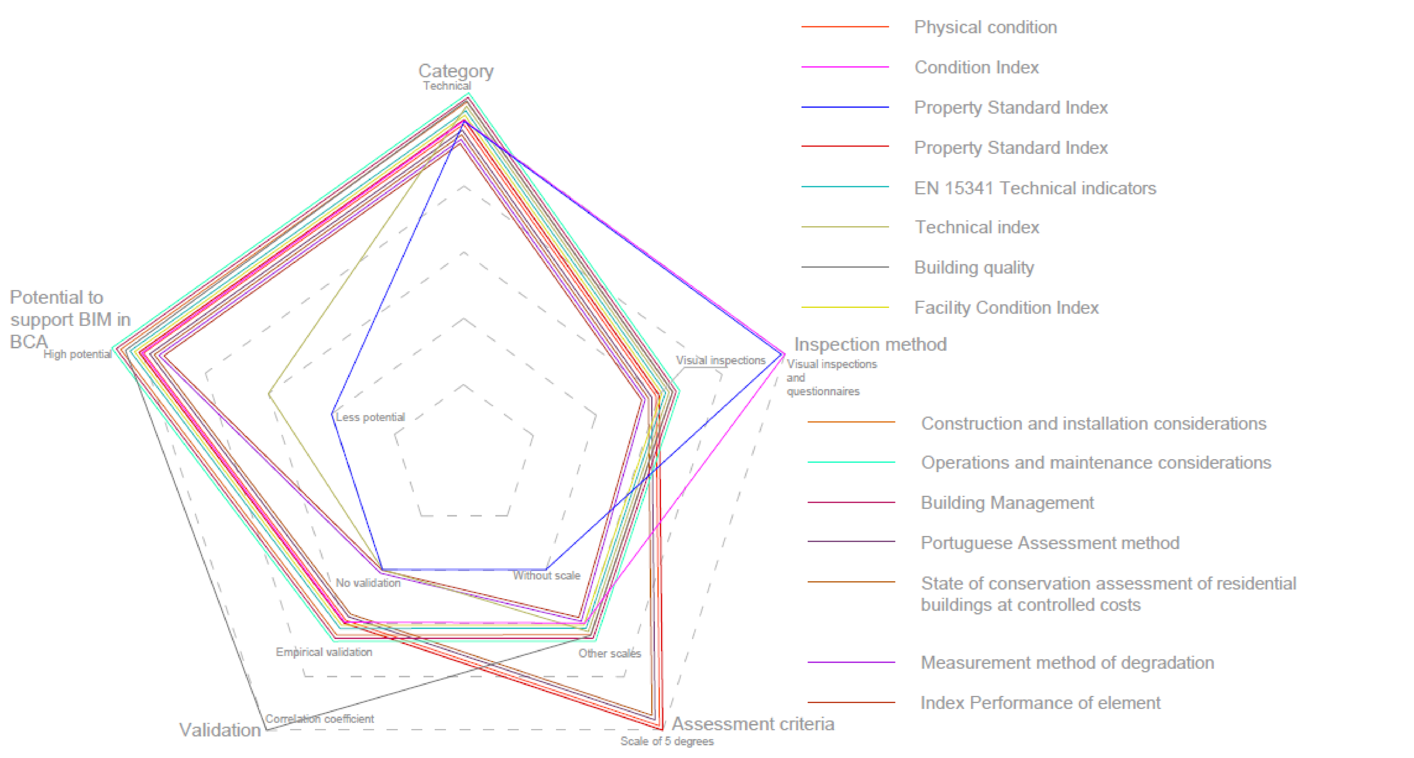
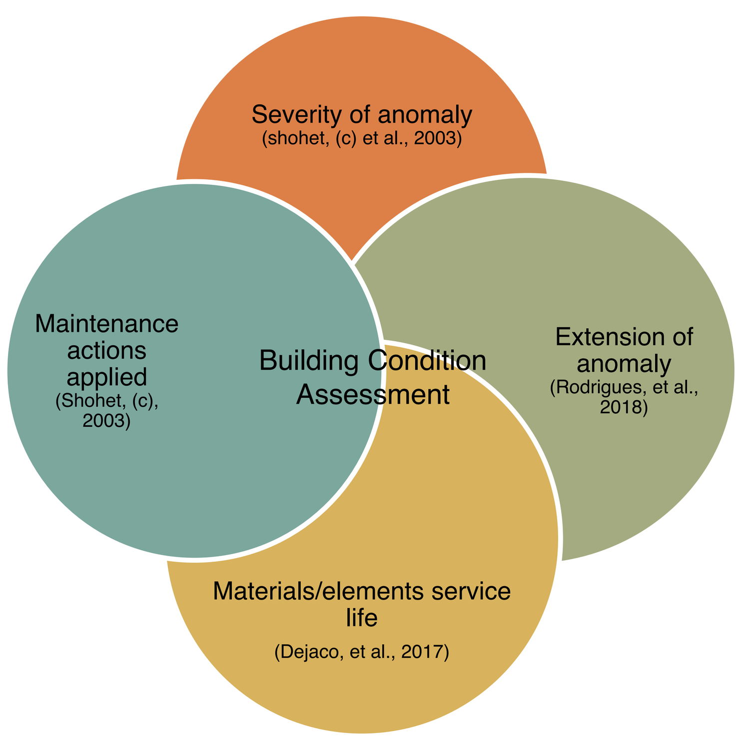


Figure 1 – Comparison of KPIs features, considering the category, inspection method, assessment criteria, validation method and potential to support BIM in BCA.

This chart establishes the comparison of 15 KPIs in terms of category, inspection method, assessment criteria, validation methods and potential to support BIM in BCA, being possible to observe that:
All of the KPIs included in this study are technical and based on visual inspection without any statistical forecast. Thus, the evaluation is always subject to the subjective opinion of the surveyor. As for assessment criteria, a scale of 5 degrees is preferable since it reduces the difficulty in its application and it has higher objectivity. Besides that, the most used validation method in the analysed KPIs is empirical validation and the potential to include the KPI into BIM were also studied. It was concluded that most of the KPIs can be supported by BIM in BCA. From this study, it was also possible to verify that the most common weighting coefficient is the AHP process and DEMATEL method to determine the relative importance of the elements.
Based on these conclusions, and taking the current work proposal into account, criteria were defined: the selected KPI should be technical, should include visual inspections, as well as defects projections and the assessment criteria should be composed by 5 degrees, Based on that, the features to be evaluated will be combined to optimize the Key Performance Indicators to be applied according to Figure 2.



The optimization of KPI should allow to evaluate the current building condition and its progress, to quantify building defect gravity and to prioritize maintenance actions.

Figure 2 – Combination of KPIs features to optimize Building Condition Assessment

Key Performance Indicators into BIM

A brief integration of Key Performance Indicators into BIM has already been done. The methodology developed allows collecting and analyse the diversified information about building systems condition, permits calculating the systems' and the whole building`s performance in an automated way. This calculation is possible through shared parameters attributing the BPI parameters to Revit object families and through interoperability Revit-Dynamo-Excel.

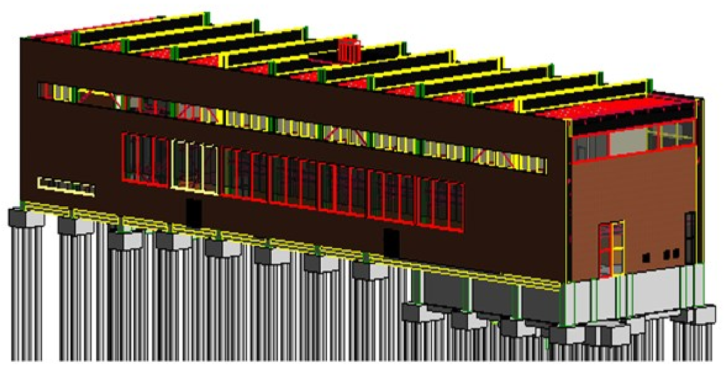


Figure 2 –Visual prioritization of maintenance actions by "color splasher" application to 3D View of the building model.

The maintenance priorities also were included in the 3D model, to visualize the condition of the systems graphically (Figure 3).
The integration of this indicator to Revit Software contribute to study how LCA can become integrated into FM practice.

Life Cycle Assessment

Life Cycle Assessment is a methodology, which allows the evaluation of the environmental impacts from a product system throughout its life cycle [3]. The products and the maintenance and refurbishment processes shall be subject to an environmental impacts evaluation by LCA software.
By this, it is possible to evaluate the sustainability of products and processes applied to the building maintenance and refurbishment actions and at the same time, to optimize and promote the more efficient use of natural resources and materials to create cost savings. To achieve this goal, an analysis of the most studied life cycle stages are presented (Figure 4), and also a comparison between the different LCA software's was carried out (Figure 5).
This work has a high impact since it promotes the proper working of the facilities, decreases the environmental impacts and allows fast building adaptation to trouble times, as pandemic times, using affordable, reusable and sustainable materials to respond to other services demands.

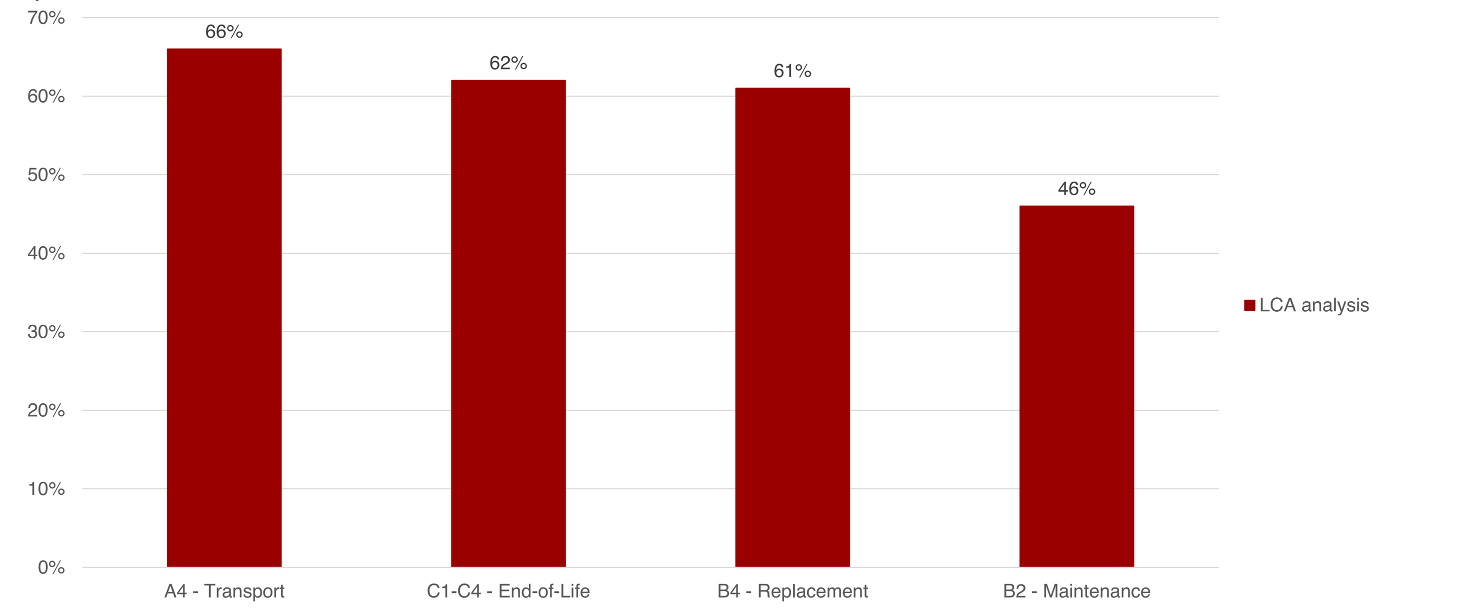


Figure 4 – Analysis of LCA studies per Building Life Cycle phases.

Figure 4 shows that most of the LCA analysis has been focused on the transport phase, being the maintenance stage the less analysed. LCA scenarios to illustrate the environmental impacts of Operation and Maintenance tasks shall be taken into account, because, without these, a sustainable built environment cannot be achieved. Thus, there is a need to evaluate the environmental impacts of the production and refurbishment process. For this purpose, a software system will be used to evaluate the sustainability of products and processes applied to the building maintenance and refurbishment, to produce more sustainable processes in Portugal. For this purpose, LCA software was compared concerning the required user knowledge, data source, entry format, optimization, default settings, Life cycle phases, Revit add-in, classification and version and purpose.

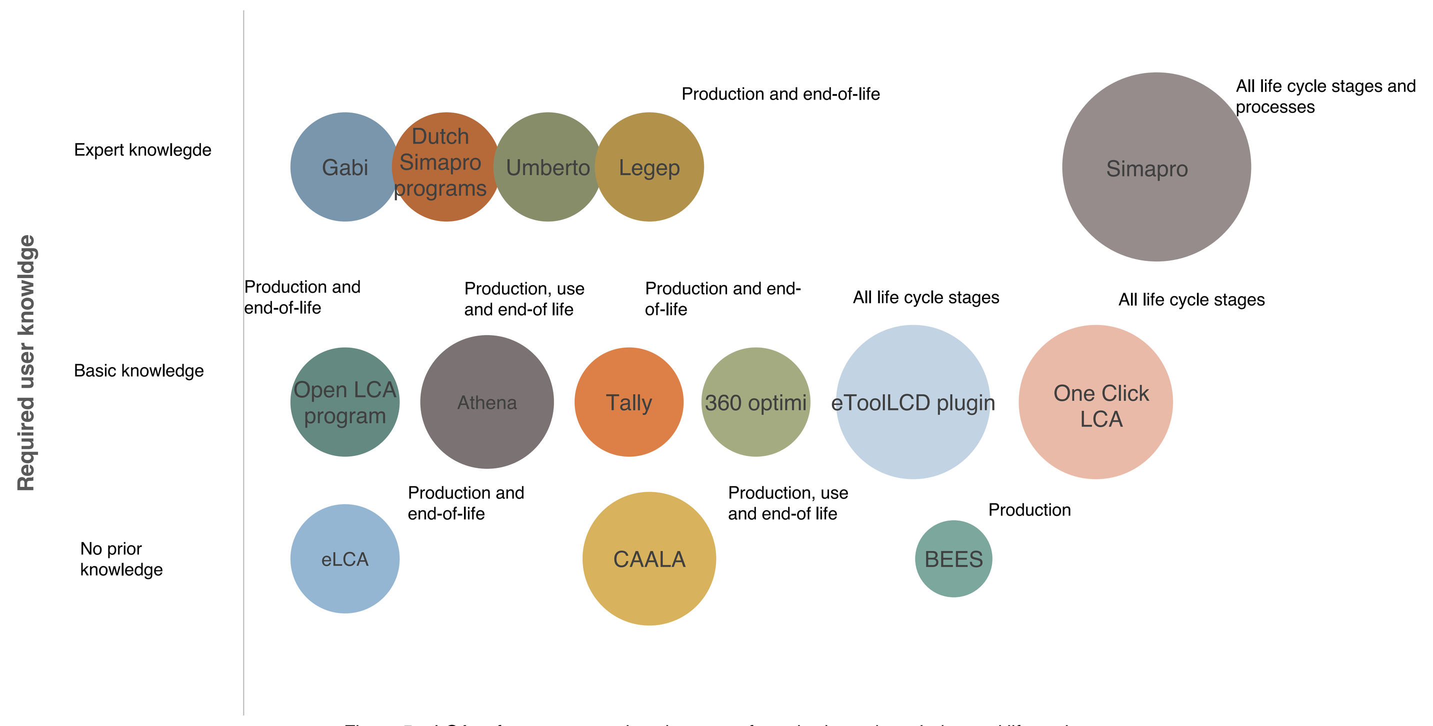


Figure 5 – LCA softwares comparison in terms of required user knowledge and life cycle stages.

Figure 5 presents the Life Cycle stages included in the evaluation of each software and the level of user knowledge required. One Click LCA, eToolLCD plugin and Tally are Revit add-ons, which add extra functionalities to Revit in the matter of LCA, but the limitations on databases and difficulty on the analysis of environmental impacts of processes are disadvantages. Besides that, the reliability of these methods is not known.
SIMAPRO is the more reliable LCA software and it includes all life cycle stages and processes.

Future developments

To achieve the work proposal, the next steps shall be completed:
Development and optimization of the Key Performance Indicators to apply in the matter of Building Condition Assessment.
Do the building survey through laser scanning and 3D modelling in Revit.
Application of the methodology to building inspections and identification of maintenance/rehabilitation proposals
Evaluation of the environmental impacts resulting from the product, maintenance and refurbishment processes by a LCA software system.
Study and collect information about preventive maintenance actions, their periodicity and their cost for each component.
Development of a BIM-based software system that allows associating the maintenance actions to a 3D model. A fully automated system is proposed, supported by Key Performance Indicators (KPIs) and a cost-benefit analysis algorithm, taking advantage of LCA tools integrated with BIM methodology.

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[2] Villegas, J., Gutierrez, J., Colorado, H. (2020) "Active materials for adaptive building envelopes:a review". Journal of Materials and Environmental Science ISSN:2028-2508.
[3] NP EN ISO 14044: (2008) – Norma Portuguesa – IPQ – "Environmental Management Life Cycle Assessment Principles and Framework".

Conclusions

The current work provides an overview of the work done until now, as well as of the expected future developments. The work proposal consists of the development of a BIM-based platform including a BCA strategy along with KPIs and a projection algorithm and LCA methodology. This intends to optimize and prioritize sustainable operations of rehabilitation and maintenance, especially applied to the building stock. To achieve the goal proposed at the end of the thesis, the study started with an extensive comparison with 58 Key Performance Indicators and also with LCA software. From this research, it was possible to conclude about the better strategies to apply in the methodology under development. Besides that, a brief application of Key Performance Indicators in BIM was also developed, which contribute to the future integration of KPI and LCA methodologies into the BIM platform.
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