2025 European Conference on Computing in Construction

CIB W78 Conference on IT in Construction

Porto, Portugal
July 14-17, 2025

INFORMATION REQUIREMENTS AND CRITICAL ASSESSMENT OF LEVEL(S) FRAMEWORK INTEGRATED WITH THE LEVEL OF INFORMATION NEED (LOIN)

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Abstract

The Architecture, Engineering, Construction, and Operation (AECO) sector needs to shift from linear to a Circular Economy (CE) to address environmental challenges and promote sustainability. This study critically assesses the Level(s) framework through a two-part methodology: (1) procedural analysis of Macro-Objective 2 ("resource efficient and circular material life cycle") and its indicators -Bill of Quantity (BoQ) and Construction and Demolition Waste (C&DW)- and (2) a simplified numerical case study. It integrates the Level of Information Need (LOIN) to define Information Requirements (IRs) revealing gaps in automation and precision. Findings highlight the need for digital tools and standardized data flows to improve circularity assessments. The study provides actionable insights for refining Level(s) implementation and stakeholder collaboration.

Introduction

The Architecture, Engineering, Construction, and Operation (AECO) sector plays a crucial role in shaping the built environment, as a response to a global population increase to reach around 10.1 billion by 2050 and a demand for approximately 230 million square meters of new buildings (Amarasinghe, Hong and Stewart, 2024), but it also has a significant impact on global resource consumption, energy use, and environmental degradation. Despite significant investments aimed at reducing resource and energy consumption, the AECO industry is still far from meeting its decarbonization targets set for 2050 (Environment, 2022).

This lag is primarily due to the sector's continued reliance on a traditional linear economic model (take-make-dispose) without consideration for the long-term impacts of waste and resource depletion. This linear model contributes to the scarcity of resources and intensifies environmental challenges such as Construction and Demolition Waste (C&DW) (Keena and Friedman, 2024).

In contrast, the Circular Economy (CE) model offers a sustainable alternative, focusing on R strategies (Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, and Recover). By promoting these practices, CE aims to create a regenerative system where materials retain their value in the economy for as long as possible, ultimately reducing environmental impact (Ho *et al.*, 2024).

However, the adoption of CE principles within the AECO sector faces several challenges. These barriers include a lack of standardization, inadequate regulations, limited education and training, and a general lack of awareness among industry professionals (Munaro and Tavares, 2023).

One key initiative designed to address these challenges is the Level(s) framework, launched by the European Commission (EC) to support the transition to a more sustainable and circular construction sector. Unlike existing certification systems such as BREEAM (Building Research Establishment Environmental Assessment Methodology), and LEED (Leadership in Energy and Environmental Design), Level(s) is a framework that provides a structured approach for assessing sustainability performance in construction projects across Europe. It focuses on key sustainability objectives such as resource efficiency, circularity, life cycle performance, and the management of C&DW, offering a clear path to achieving CE goals (Ferrari *et al.*, 2022). The framework aims to unify sustainability assessment methods across Europe, fostering better practices and standards within the AECO sector.

Despite its promise, the practical implementation of Level(s) is not without its challenges. The AECO sector is characterized by fragmented and often inconsistent data regarding building materials, their composition, quality, and availability, which complicates efforts to optimize resource use and manage material flows effectively throughout the construction lifecycle (Kovacic *et al.*, 2020).

To address this issue, the integration of advanced digital tools, such as Building Information Modelling (BIM) and Industry Foundation Classes (IFC) as openBIM, is increasingly seen as essential. These tools can streamline data collection, facilitate the tracking of material circulation, and enable better decision-making processes throughout the construction supply chain (Tomczak *et al.*, no date).

Furthermore, the Level of Information Need (LOIN) plays a critical role in improving data integration and supporting decision-making by standardizing Information Requirements (IRs) across stakeholders. LOIN ensures that stakeholders have access to the right information at the right time, thereby enhancing collaboration and enabling more efficient implementation of CE practices (International Standard Organization, 2024). By leveraging these digital tools and standardizing IRs, the AECO sector can more effectively implement circular strategies and work towards meeting its sustainability and decarbonization targets.

Despite the potential of Level(s) and digital tools, the framework's complexity and the fragmented nature of available information present significant obstacles to its widespread adoption. These challenges highlight the need for further refinement of the Level(s) framework, as well as better integration with existing sustainability assessment methods and digital technologies. By addressing these barriers, the AECO industry can move closer to a CE, optimizing the use of resources, reducing waste, and contributing to a more sustainable built environment.

This paper critically assesses the Level(s) framework by focusing on two key indicators: Bill of Quantities (BoQ), Materials, and Lifespans (Indicator 2.1) and Construction and Demolition Waste Management (Indicator 2.2). The study identifies challenges related to automation, precision, and data integration. It integrates the LOIN concept to improve information flow and enhance collaboration among stakeholders.

The paper makes a significant contribution by defining the IRs for each indicator, providing a structured framework for data flow among stakeholders. Additionally, it clarifies how information is exchanged between stakeholders throughout the construction process. By proposing solutions for integrating digital tools like BIM and IFC with Level(s), this research aims to enhance the adoption of CE practices, improve sustainability in the AECO sector, and help the industry meet its decarbonization targets.

Methodology

This study aims to critically assess the practical application of the Level(s) framework through the lens of its key stakeholders, who are directly involved in its utilization. The objective is to identify the challenges and obstacles encountered during its implementation process. A structured, step-by-step approach is employed, complemented by a numerical example, to gain an in-depth understanding of the issues that arise. This systematic approach enables a clearer identification of areas for improvement and opportunities to refine the framework.

The research specifically focuses on Macro-Objective 2 "Resource Efficient and Circular Material Life Cycles". Within this objective, the analysis centers on two critical indicators:

Indicator 2.1 – Bill of Quantities, Materials, and Lifespans

Indicator 2.2 – Construction and Demolition Waste and Materials

By conducting a detailed examination of these indicators, the study provides a critical assessment of the Level(s) framework's efficacy. It highlights both the strengths and the limitations that stakeholders encounter, offering insights into actionable improvements for its practical application.

To operationalize the methodology, a list of IRs for implementing each indicator will be developed and integrated with the LOIN framework to demonstrate that each IR should be provided by. This integration is designed to address and answer five key questions:

1. **WHAT** objects in a breakdown structure should be considered?
2. **WHY** are these specific IRs necessary?
3. **WHO** are the relevant information providers and receivers?
4. **WHEN** is the information required during the project lifecycle?
5. **HOW** should the information be presented or delivered (e.g., as geometrical data, alphanumeric data, or documentation)?

Given the scope of the study, the answer to the questions "WHY" and "WHEN" is framed by the overarching goal of Macro-Objective two. However, the answers to the remaining questions are illustrated in the Figure 1.

This figure demonstrates how LOIN and Level(s) can be integrated as suggested by this study. For instance, it shows that in Level 1, the Producer, Designer, and Constructor must provide Information Requirements 2 and 4 in the form of geometrical and alphanumerical information.

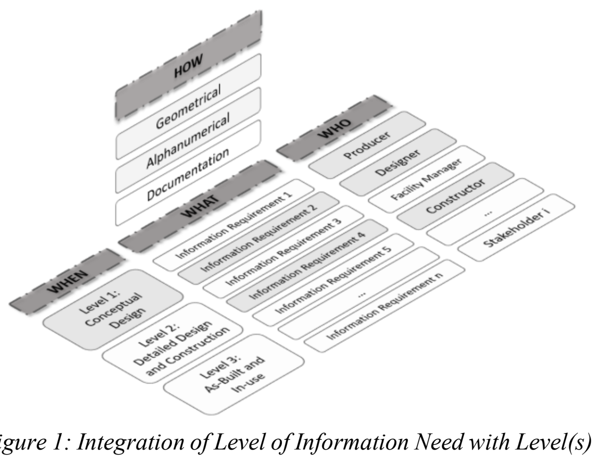

Figure 1: Integration of Level of Information Need with Level(s)

Although this study primarily applies the integration of LOIN and Level(s) to Indicators 2.1 and 2.2, the methodology is intended to be scalable. This approach can also be applied to other indicators in the Level(s) framework by identifying the relevant IRs for each one and connecting them to the appropriate stakeholders, lifecycle phases, and means of information delivery.

By providing this structured methodology and demonstrating its application, the research not only assesses the current implementation challenges but also proposes a replicable and adaptable framework for enhancing the broader applicability of Level(s) in practice, which connects closely to the BIM and IFC concept by defining the appropriate amount of data granularity, enhancing the collaboration and decision-making.

Results and Discussion

The results of this study are provided in this section which is divided in three sub-sections to explain the challenges for each of those two Indicators 2.1 and 2.2 and the IRs for them.

Indicator 2.1. Bill of Quantities, Materials and Lifespans

The process of assessing the Indicator 2.1 of Level(s) can be shown in a diagram like the Figure 2. This indicator provides the BoQ organized by the main building parts and elements. This indicator will categorize building elements in three tiers and then convert the quantities to kg by using conversion factor to have the Bill of Materials (BoM).

This BoM will be used for estimation of construction waste or Over Ordering (OO) and estimation of required materials during lifetime.

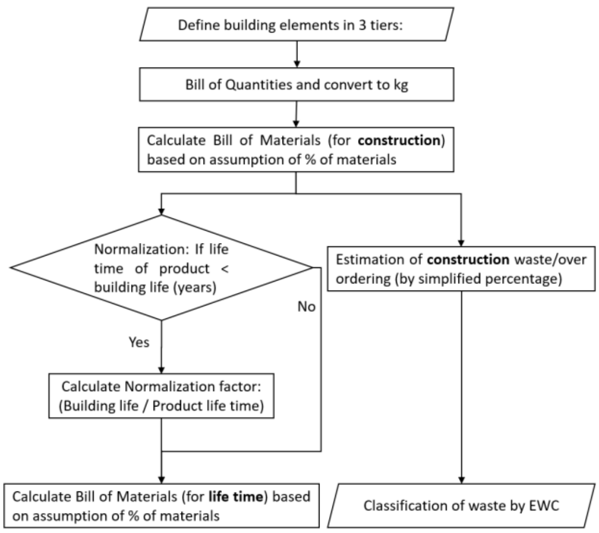

Figure 2: Defined process for Indicator 2.1 by Level(s)

As illustrated in Figure 2, consider a straightforward example involving two materials used in a building, each weighing 1000 kg but differing in lifetimes (75 years for material 1 and 50 years for material 2).

Based on these inputs and assuming 60 years of building lifetime, the normalization factor and the BoM are calculated. Given the definition of the normalization factor by Level(s), which is the ratio of building lifetime to product lifetime, this value for materials 1 and 2 is 0.8 and 1.2, respectively.

This example is better shown in Table 1 and highlights several key challenges and limitations associated with the Indicator 2.1, which can be seen as the following table:

Table 1: Example of two materials used for Indicator 2.1

Material #	Material 1	Material 2
Weight (kg)	1000	1000
Product lifetime (year)	75	50
Building lifetime (year)	60	60
Normalization factor	0.8	1.2
BoM for lifetime (kg)	1000	1200

1) *Automation*
   A major issue lies in the automation of processes, particularly in terms of importing BoM data from external tools like BIM and IFC.
   The current framework lacks seamless integration capabilities, which complicates the conversion of quantities from various units into kg and the automation of related calculations. Ensuring interoperability between systems and minimizing manual data handling are critical for improving efficiency and accuracy.
2) *Precision*
   The Level(s) framework relies on approximate material proportions to calculate the BoM for construction.
   For example, it estimates the relative percentages of metals and concrete in a reinforced concrete element. While this approach provides a general understanding, it lacks precision, especially for projects that demand detailed material tracking. Although the framework suggests using Life Cycle Assessment (LCA) tools and material breakdowns from Environmental Product Declarations (EPDs) to improve accuracy, these enhancements remain optional and require further refinement. Defining robust IRs and enabling data export from BIM or IFC could significantly enhance precision and reliability.
   Additionally, the framework incorporates waste and OO estimations during the construction phase, which are based on simplified percentage assumptions. These approximations do not account for project-specific variations or real-world practices, potentially leading to inaccuracies in material estimation.
3) *Ignoring residual value for materials with higher lifetime*
   As shown in Table 1, when the normalization factor is less than 1 (i.e., the material's lifetime exceeds the building's lifetime, as with material 1 in this example), the BoM for the lifetime is treated as equal to the original material required for

construction.However, this approach disregards the residual value of materials with longer lifetimes.

For instance, in the case of material 1, which has 15 years of remaining life beyond the building's lifetime, the framework does not provide guidance on how to account for this residual value. This omission fails to address opportunities for CE strategies such as reuse, recycling, or repurposing, which are vital for sustainable construction practices.

4) *Understimation of required material for materials with lower life time*

On the other hand, when the normalization factor is greater than 1 (i.e., the material's lifetime is shorter than the building's lifetime, as with material 2 in this example), the BoM for the lifetime is adjusted proportionally.

In this scenario, the BoM increases by 20%, reflecting the added material requirements. However, in practice, when a product reaches the end of its lifetime, it often needs to be fully replaced. This means the actual material requirement could be higher than the calculated BoM. Furthermore, the residual value of replaced materials is also ignored.

For cases where the normalization factor exceeds 1, adjustments should not only reflect multiple replacement cycles (e.g., doubling or tripling the normalization factor based on the number of replacements required) but also account for the residual value of substituted materials.

For instance, in the example of material 2, the remaining 10 years of its lifetime after the building's end-of-life could be utilized in future reuse or repurposing efforts. Accounting for such residual values can strengthen alignment with CE principles and improve resource efficiency.

Indicator 2.2. Construction & Demolition Waste and Materials

The process of implementation of the Indicator 2.2 is shown in Figure 3, indicating that BoM will be used for estimation of C&DW. This estimation of C&DW will then be categorized by the European Waste Catalogue (EWC) based on its nature and the best and most possible outlet for it, considering different approaches within the waste hierarchy.

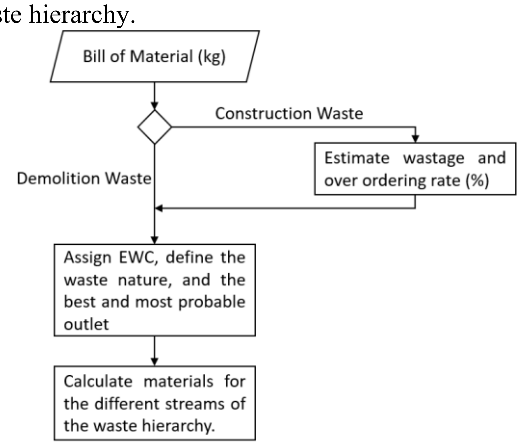

Figure 3: Defined process for Indicator 2.2 by Level(s)

The challenges and issues related to this indicator can be summarized as follows:

1) *Automation*

The implementation of this indicator could significantly benefit from the use of advanced digital and automation tools. For instance, automating the extraction of the BoM from tools like BIM and IFC would streamline the process and improve accuracy. Additionally, the classification of C&DW based on the EWC could be enhanced by employing technologies such as Natural Language Processing (NLP) to analyze and categorize waste more efficiently.

2) *Precision*

Unlike the previous indicator, this one does not account for the share of individual materials within an element. For example, the amount of steel reinforcement in a concrete column or beam is not explicitly considered. This gap in detail could be addressed by improving the flow of information among stakeholders to ensure more precise and detailed data is available.

Furthermore, the estimation of waste and OO is based on assumptions, which may lead to inaccuracies in the overall circularity assessment of the building. Enhancing precision in these areas would significantly improve the reliability of the indicator's outcomes.

3) *Lack of Key Performance Indicators (KPIs) for waste categorization decision-making*

Although the AECO industry has developed various KPIs for CE applications - such as the Building Recyclability Rate (BRR) (Fereydooni Eftekhari *et al.*, 2024) - these KPIs are typically used to evaluate specific R-strategies (e.g., recycling or reuse). The Indicator 2.2 lacks KPIs to guide decision-making on waste outlets systematically. Currently, decisions about waste management are often based on the material's nature and subjective judgment by decision-makers.

To address this, KPIs could be developed to determine potential waste outlets based on quantifiable parameters defined through IRs. For example, maintenance records or the number and condition of interventions for a building component could serve as IRs to decide whether a material is suitable for reuse or should be recycled.

4) *Oversimplified assumption on waste strategy outlet*

The indicator makes the broad assumption that once an outlet strategy is chosen for a material or component, the entire quantity will follow that strategy.

For example, if a wooden frame is selected for reuse, the framework assumes 100% of the frame will be reused. However, in reality, only certain portions of the frame may be suitable for this approach, while other parts may need to be repaired, recycled, or used for energy recovery. A more nuanced approach is needed to account for these variations, incorporating the potential for partial reuse and secondary strategies for residual materials.

5) *Disconnection and poor information flow from previous indicator*

While the previous indicator incorporates detailed information about the lifetime of elements and the building as a whole, this indicator does not consider such data. Specifically, it overlooks valuable records like the maintenance history and remaining service life of materials and components. Incorporating these data points could significantly improve decision-making for waste management and CE strategies.

Tools like the Digital Building Logbook (DBL) (Mêda *et al.*, 2024) could be employed to collect, store, and retrieve this information. Establishing a better connection between the indicators and ensuring proper information flow would enhance the overall framework's effectiveness and accuracy.

Information Requirements for Each Indicator

As previously discussed, the implementation of the indicators faces numerous challenges and issues, many of which stem from inadequately defined IRs, inefficient information flow among stakeholders, and the limited use of advanced digital tools. Without clear IRs, the data exchange processes become fragmented, leading to inconsistencies and a lack of precision in assessing the indicators.

To address these issues, this study proposes a detailed list of IRs for each indicator. These IRs are designed to address gaps in information flow and ensure a systematic and consistent exchange of data among stakeholders. Furthermore, the IRs are integrated with the LOIN framework, enhancing the definition of the information flow required for each indicator.

This structured approach ensures that the flow of information is not only comprehensive but also aligned with the specific needs of the indicators. By using this methodology, the study aims to overcome the existing challenges and facilitate the practical application of the indicators in real-world scenarios.The proposed IRs, along with their integration into LOIN, are summarized in Table 2, providing a clear and actionable framework to guide stakeholders in implementing the indicators effectively, using the proper information container.

Table 2: Information Requirements for indicators, integrated with LOIN

Information Requirements (WHAT)	Indicator 2.1	Indicator 2.2	Actor – Data provider (WHO)	Actor – Data user (WHO)	Information container-Documentation (HOW)
BoQ	x	x	Surveyor, Designer, Contractor, BIM Manager	Estimator, Project Manager, Contractor, Sustainability Consultant	BIM, Spreadsheets
Element categorization (in tiers)	x	x	Designer, BIM Manager	Designer, Contractor, Facility Manager, Sustainability Consultant	BIM, MP, EPD
Conversion factor (to kg)	x	x	Supplier, Sustainability Consultant	Surveyor, Estimator, Sustainability Consultant	EPD, MP, Material database, Standards
Building floor area (m^2)	x	x	Designer	Surveyor, Project Manager, Sustainability Consultant	BIM, Drawings
BoM (split by type)	x		Supplier, Surveyor, BIM Manager	Sustainability Consultant, Contractor, Facility Manager	BIM, MP, EPD
Building lifetime (year)	x		Designer, Policy Maker	Sustainability Consultant, Facility Manager	DBL
Product/material lifetime	x		Supplier, Sustainability Consultant	Sustainability Consultant, Designer, Facility Manager	MP, EPD
Assumed wastage/OO	x	x	Contractor, Surveyor, Sustainability Consultant	Estimator, Project Manager, Sustainability Consultant	BIM, Waste Management Plan
Nature of waste	x	x	Contractor, Contractor, Sustainability Consultant	Sustainability Consultant, Policy Maker, Facility Manager	Waste Management Plan, MP
EWC code		x	Contractor, Sustainability Consultant	Sustainability Consultant, Policy Maker, Facility Manager	BIM, Waste Regulatory Databases
Outcome of waste/OO		x	Contractor, Sustainability Consultant	Sustainability Consultant, Policy Maker, Project Manager	MP

Conclusions

The transition of the AECO sector towards a CE is vital to achieving decarbonization and sustainability goals. Despite substantial investments, the sector's adherence to linear economic practices continues to impede its progress. This study critically assessed the potential of the European Commission’s Level(s) framework as a tool to address key challenges and advance CE principles. The findings highlight critical barriers, including insufficient standardization, inadequate integration of digital tools, and poorly defined IRs, which hinder the practical implementation of the framework.

The study identified that effective adoption of Level(s) can be significantly enhanced through the integration of digital technologies such as BIM, IFC, and the Level of Information Need framework. These tools offer opportunities to streamline the information flow, improve data precision, and enable better collaboration across stakeholders, thus addressing current gaps in the management and utilization of resources.

Through a detailed examination of Indicators 2.1 and 2.2, this research sheds light on the challenges in resource efficiency, material categorization, and waste management. The results underscore the need for automation, precise data flows, and the incorporation of decision-making tools like KPIs to facilitate the implementation of R strategies. Furthermore, enhancing Level(s) to address issues such as waste assumptions, residual material value, and real-life service conditions is imperative for its widespread adoption.

By presenting a refined list of IRs and demonstrating how they can be integrated with LOIN, this study provides actionable insights for improving the alignment of the AECO industry with CE principles. While the scope of this study focuses on two specific indicators, the proposed methodology is scalable and can be applied to other indicators and frameworks, offering a pathway for future studies to expand on these findings.

Despite the contributions of this study, it is important to note two limitations. The first one is that the study assessed macro-objective two of the Level(s) framework and its indicators 2.1 and 2.2, however, as the future steps, it can be suggested to assess other macro-objectives and indicators. The other limitation is the application of a simplified numerical case study, though its application can be extended to the real-world case studies. Also the mapping of the provided IRs into the IFC schema can be evaluated to streamline the data flow among various stakeholders.

In conclusion, for the AECO sector to successfully embrace CE and meet its decarbonization targets, a stronger focus on standardizing information, improving stakeholder collaboration, and leveraging advanced digital tools is essential. The study emphasizes that frameworks like Level(s) have significant potential to serve as a unified language for sustainability but require further refinement and integration to overcome practical implementation challenges. By addressing these barriers, the industry can move closer to achieving a truly circular and sustainable future.

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