Streamlining Level(s) circularity and cost indicators estimation using Digital Product Passports

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Abstract
The European Commission will implement Digital Product Passports (DPP) under Ecodesign and Construction Products Regulations to support sustainable goals. Products play a crucial role in sustainable growth, and built entities, such as residential or service buildings, are an assembly of products. Level(s) is a methodology focused on improving built environment sustainability by performing several assessments where product data is relevant. This research article explores how Level(s) estimation can be streamlined using DPPs, focusing on the indicators associated with circularity and cost. The findings suggest that DPPs can provide important Level(s) data and streamline the estimation processes. From a barriers and opportunities perspective, it is concluded that adjusting to existing processes and deliverables is found to be an essential strategy for success. Data availability is a common challenge for Level(s) and DPPs, where manufacturers are key stakeholders. It is upon them that many actions will enable the goal's accomplishment.

Keywords: Twin transition, Efficiency, Data management, Circular Economy, Value chain

1 Introduction

Digital Product Passports (DPP) are envisaged by the European Commission (EU) as the strategic instrument supporting several Green Deal goals and accelerating the transformation towards a Sustainable Built Environment (SBE) (Papadaki *et al.*, 2023). DPPs are governed by the Ecodesign Regulation (European Parliament and European Union Council, 2024). The new version of the Construction Products Regulation (CPR) is the delegated act detailing the specific requirements and processes enabling DPP implementation in this economic activity (BPIE - Buildings Performance and Europe, 2021).

Products, in general, are crucial for sustainable growth as their composition and manufacturing processes can have huge impacts on resource and energy consumption and contribute to an environment with a lower incidence of chemicals and substances of high concern. Level(s) was structured as a methodology pursuing a common language for sustainability in the built environment. Its objective is to improve the state-of-the-art knowledge of the existing built stock, namely buildings. Among the indicators are estimating materials and their relevance, envisioning building elements as resources for other projects, extending their life cycle and fostering a shift from a linear to a circular value chain (Quiñones *et al.*, 2021). To work, this must be compatible with the existing processes and deliverables. In addition, there is also a need for their integration as part of the work processes in all the phases of the construction life cycle and legal frameworks. Given the number of challenges, this research focuses on two main aspects associated with Level(s) methodology: circularity, namely circular material life cycles, and life cycle cost and value. The reasons for this choice are related to the ongoing studies seeking materials estimation in buildings and tackling the continuous struggle to obtain life cycle costs (Bernardino-Galeana *et al.*, 2021). A brief mention is made of one indicator linked to environmental performance to demonstrate the alignment of the data with the DPPs.

Action research using an inductive approach composes the methodology, supported by desk research for data collection and qualitative analysis (Fellows and Liu, 2022). With this strategy, answers to the following research questions are expected:

- To what extent do the EU regulations and instruments foster Level(s) implementation?
- To what extent can Digital Product Passports support estimating Level(s) indicators? And,
- How can these novelties become part of existing processes in construction projects? Evaluation of barriers and opportunities.

The outcomes point to some degree of awareness of how the legal framework must be organised to provide the needed support for implementation. At the practical level, several bottlenecks were observed. From a data point of view, it was possible to achieve findings supporting further developments.

The following years will be very challenging for all economic activities due to the push for sustainability. In this respect, the EU taxonomy for sustainable finance will work as an important market transparency tool, setting a common language across activities and fostering their classification according to sustainability (De Wolf *et al.*, 2023). In the construction sector, the publication of new Regulations will integrate these requirements. These will also impact the activities of stakeholders who have a presence in the EU but are located elsewhere. The implementation of DPPs is critical, and the ability to obtain the data from manufacturers is a game changer. However, this is not a single action as all other stakeholders must understand, use, and take the most advantage of the disclosed data. This work demonstrates how this can be done, approaching specific Level(s) indicators. Although assumed as a limitation, it is also a starting point for breaking resistance to change and fostering clarification by evidencing how to achieve practical accomplishments.

2 Research Strategy Framework

A relatively straightforward framework was adopted for this research, given the gap and the defined questions. The strategy relies on action research using an inductive approach (Williamson, 2018). The desk research involved collecting Level(s) data from reference documents addressing indicators from macro-objectives two and six, and the existing supporting assessment tool (Commission, 2019). DPP research works were also collected.

The qualitative analysis comprises the authors' debate, advocacy, and refutation to observe the results and identify barriers and opportunities. Although this second part might constitute a limitation, the awareness of DPPs and Level(s) is still shallow among stakeholders engaged in real projects. Therefore, it is assumed from the beginning that the following actions must be devoted to stakeholders' realisation to launch surveys that can capture interesting viewpoints and insights.

3 Overview and reflections on Level(s) and DPP

3.1 Level(s)

Level(s) is a common framework proposed by the EU and developed by the Joint Research Centre (JRC) seeking the sustainability assessment of buildings (Dodd *et al.*, 2017). Although inspired by other methodologies for assessing building sustainability, such as LEED or BREEAM, its objective is not to support excellence (Ferrari *et al.*, 2022). In fact, Level(s) was developed to promote the assessment of all European buildings and set a comparable landscape from which priorities for their upgrade/renovation can be drawn. Eventually, in some cases, excellence can be set as the goal. For this to happen, unified indicators were established, making sustainable building comparisons more accessible. Consistent with this objective, the initial objectives set for Level(s) were as follows (European Union, 2019):

- Encourage the "traditional" market to incorporate the sustainability dimension
- To increase awareness and demand for sustainable buildings
- Grow the market for sustainable buildings
- Target a variety of building types, but particularly the residential market where sustainable practices are less widespread
- Encourage public authorities to think about and use Level(s) in developing their policy initiatives so that there is alignment at a European level

This ambition anticipated the publication of several strategic documents and trends, such as the Green Deal or the Action Plans for Circular Economy, many focusing on the construction sector. Level(s) is considered one of the instruments supporting the cut of embodied carbon emissions in the built environment between 60 and 80% by 2050 (BPIE - Buildings Performance and Europe, 2021). For this to happen, the indicators and the estimation tools must become widespread. In addition, the supporting processes should become part of the value chain and be compatible regarding time and affordability from an investment/added value perspective.

Before discussing the implementation challenges of Level(s), it is worth presenting an overview of the macro-objectives and indicators to focus in more detail on the indicators that constitute the scope of this work. The methodology elects six macro-objectives in three thematic areas, from Resource use and environmental performance to Cost, value and risk, including Health and comfort. For each macro-objective, several indicators were defined. There are situations, such as macro-objective "3. Efficient use of water resources", where only one indicator exists: "3.1 Use stage water consumption (m3/occupant/year)". However, for other situations, a macro-objective, such as "2. Resource efficient and circular material life cycles", has several indicators to be estimated. For this specific case, the methodology sets the following four: "2.1 Bill of quantities, materials and lifespans", "2.2 Construction and demolition waste", "2.3 Design for adaptability and renovation", and "2.4 Design for deconstruction". Figure 1, based on (European Union, 2019), provides an overview of the different indicators. The ones with a full and dashed blue frame are within the scope of the study.

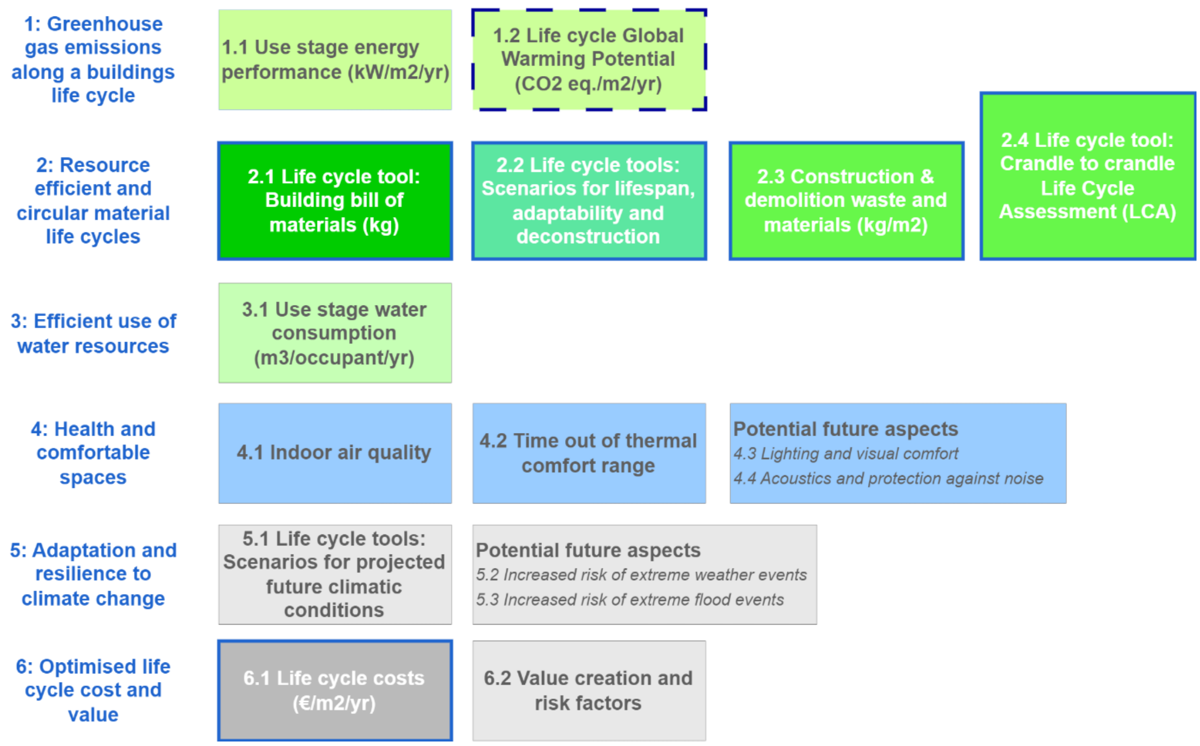

Figure 1. Level(s) macro-objectives and indicators and the ones considered for the scope of the research (blue full and dashed frame).

The name Level(s) originates from the different delivery possibilities for the methodology. The assumption is that Level(s) must follow the construction process life cycle, meaning that the indicator estimation should be worked on from the concept stage. At this moment, the deliverables will be primarily qualitative. A more detailed level, Level 2, should be practised during the design and construction stage, producing quantitative deliverables. Level 3 represents the most detailed level. It should be set before the handover and the beginning of the building's use (Dodd *et al.*, 2017). Presently, a tool supports Level(s) assessment (Commission, 2019). Although very intuitive and with various support materials detailing the indicators and guiding the work processes on the platform, there is a considerable need for improvements, particularly in terms of interfaces to speed up data entry. As mentioned, this work focuses mainly on the macro-objectives "2. Resource efficient and circular material life cycles" and "6. Optimised life cycle cost and value" (particularly in indicator 6.1) and seeks to understand to which extent DPPs can provide data and streamline the indicators estimation when delivering Level 3. The indicators and data requirements for each will be detailed and presented later.

Regarding Level(s), it is relevant to mention that its successful implementation relies on supporting policies already in force and under development. The sustainable finance and its EU taxonomy are examples of the first case. Although with different objectives, Level(s) and EU Taxonomy are initiatives that share the ambition to provide a common language at the European level on building sustainability. In contrast, the new versions of the Energy Performance of Buildings Directive (EPBD) and Construction Products Regulation (CPR) are expected to enter force in 2024. As it will be explored, a new set of regulations will govern the DPP.

3.2 Digital Product Passport

A Digital Product Passport (DPP) is a set of data specific to a product that includes, at minimum, relevant information for performance, environment and waste dimensions and it is accessible via electronic means through a data carrier. The DPP is governed by the new version of the Ecodesign Regulation that works as a framework legislation from where other delegated acts, specific to each economic activity or group of products, will detail singularities and priorities (European Parliament and European Union Council, 2024).

Although recent in terms of concept, the DPP has its roots in the foundational principles of the EU and results from continuous work that has been going on for decades. In fact, this new step is also motivated by the realisation that stakeholders are more capable of dealing with new requirements and digital methods, as similar abilities have been tested with EU-scale developments in areas such as chemicals and energy efficiency (Adisorn, Tholen and Gotz, 2021). However, there is the intuition that product passports might raise some fear across sectors due to the introduction of significant changes in how trade is processed and how product information is managed among all involved in the different value chains.

Several researchers have devoted their efforts to understanding and defining an ecosystem for generic DPPs (King, Timms and Mountney, 2023; van Capelleveen *et al.*, 2023). In the construction sector, the existing harmonised standards are a good starting point for the industry, along with the dynamics of developing and delivering Environmental Product Declaration (EPD) for products. Adjustments will be needed, and new requirements will set foot. Among the implementation strategies should be the ability to explain to what extent DPPs are already a reality in terms of datasets and what the requirements are from a digital systems perspective and additional data realisation. It is observed that not all aspects are peaceful, meaning that awareness and anticipation are found to be critical (Mêda *et al.*, 2023).

Regarding DPP's realisation, it is also relevant to work on the added value they can bring, not just related to the new regulations but mainly to the existing processes, namely at the data traceability level and supporting streamlined evaluations (Honic, Meda Magalhães and Bosch, 2024). This effort combines existing processes with the EU proposals and Building Information Modelling (BIM) standards. Figure 2 represents a reflection combining the standardisation level, composed of existing ISO and CEN standards and the meaningful concepts with the most recent and publicly available proposals for the new Ecodesign and CPR regulations. To underline the alignment, it is worth highlighting how data dictionaries, as per ISO 23386, are mentioned in CPR Recital 93. The requirements to align and ensure interoperability between the construction products' digital product passport systems and BIM reinforce how future delegate acts must consider existing CEN and ISO standards. In terms of data structure (Honic, Meda Magalhães and Bosch, 2024) and information requirements, ISO 23387 on Data Templates and ISO 7817-1 on the Level of information need (LOIN) are crucial (Gragnaniello *et al.*, 2024). It is recognised that the new CPR will strengthen the CE mark and expand the requirements. The EN harmonised standards will increase their relevance, and their boundaries will be a topic for future discussion. This might impact the ISO standards on EPDs, as it is still under discussion to which extent the EPD data is relevant and/or if it should become part of the DPP. DPP data modularity is essential to support these conditions. Setting properties and groups of properties in ISO 23386 and 23387 makes it very easy to comply with these requirements.

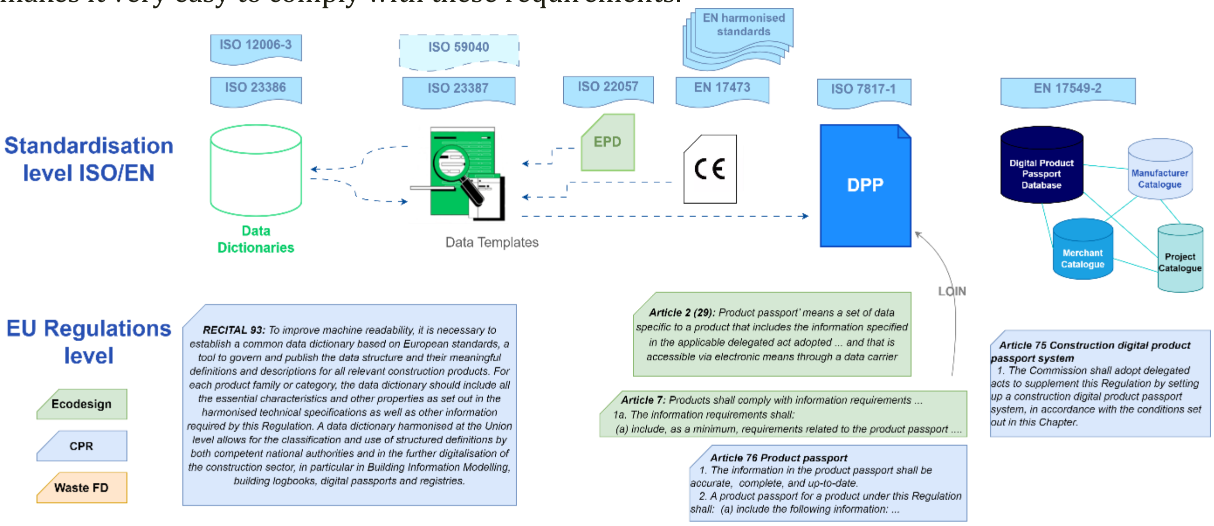

Figure 2. Alignment between EU legal framework governing DPPs and the existing ISO and EN standards associated with data structures, information management, CE mark and BIM.

Based on these assumptions, to further demonstrate DPPs potential, this exercise combining Level(s) is proposed.

4 Working Level(s) indicators together with DPP datasets

4.1 Indicator 2.1 – Bill of quantities, materials, and lifespans

Indicator 2.1 is crucial for better building designs as it is a foundation for other indicators, such as 2.2 and 1.2 (Commission, 2021). This indicator uses the Bill of Quantities (BoQ) as a starting point. The BoQ serves many purposes, especially during the conceptual and design phases. Depending on the procurement approach and type of owner (public/private), the BoQ can govern the construction phase. Despite their differences, it is clear that BoQs are widespread in construction projects and, in addition to cost assessments, others can be done using the typical organization or by setting additional data sets (Mêda and Sousa, 2023). BoQs usually describe construction tasks. These include not only products and materials but also labour and equipment. BoQ tasks can have, more or less explicitly, the element they address. This indicator aims to organise and assess material percentages and lifespans using the BoQ.

The strategy followed is interesting from an implementation perspective because the result originates from a well-known deliverable, where additional requirements must be set at organization and dataset levels. Despite the effort, the supporting background is well established, leaving little room for resistance to change or significant procedure changes. Following this rationale, Figure 3 combines what can be assumed as a “traditional BoQ” structure, adding the requirements for Indicator 2.1 and where DPPs can contribute by providing the needed data. The specific needed properties and values from the products there proposed/referred. As it is possible to observe, except for the “Building element” that should be part of the BoQ, all other information requirements can be delivered by DPPs. According to Level(s), aligning BoQs with indicator 2.1 requirements leads to a Bill of Quantities and Materials (BoQ&M).

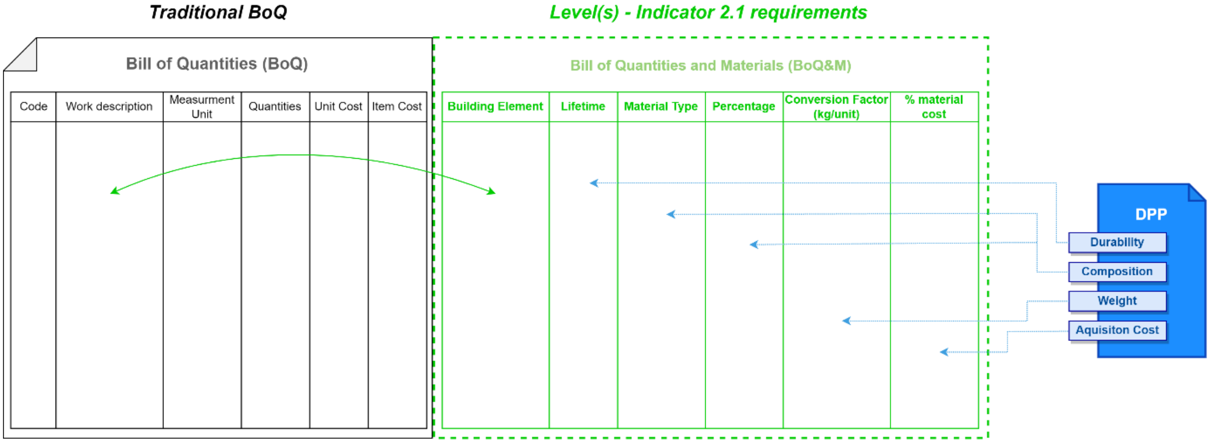

Figure 3. Level(s) Indicator 2.1 requirements aligned with "traditional BoQ" structure and DPP contributions to streamline estimation.

4.2 Indicator 2.2 – Construction and Demolition Waste

Indicator 2.2 aims to prompt professionals to systematically plan to reuse and recover materials through segregated collection during construction, renovation, and demolition activities (Commission, 2021). According to ongoing developments in waste-related guidelines, the demolition concept is to be replaced by deconstruction. As mentioned, this indicator uses indicator 2.1 outcomes and focuses on the waste dimension. Like Figure 3, Figure 4 follows the same reasoning, adding the data requirements to estimate indicator 2.2. Considering the waste audit guidelines document (European Commission, 2018), it is possible to observe that the requirements are mainly the same. Related studies on this topic reveal how DPPs can support this data and how a pre-deconstruction audit can become part of the design deliverables as a forecast demonstrating a vision of design-for-disassembly and state-of-the-art ideas on potential outlets, among other aspects (Mêda and Calvetti, 2023).

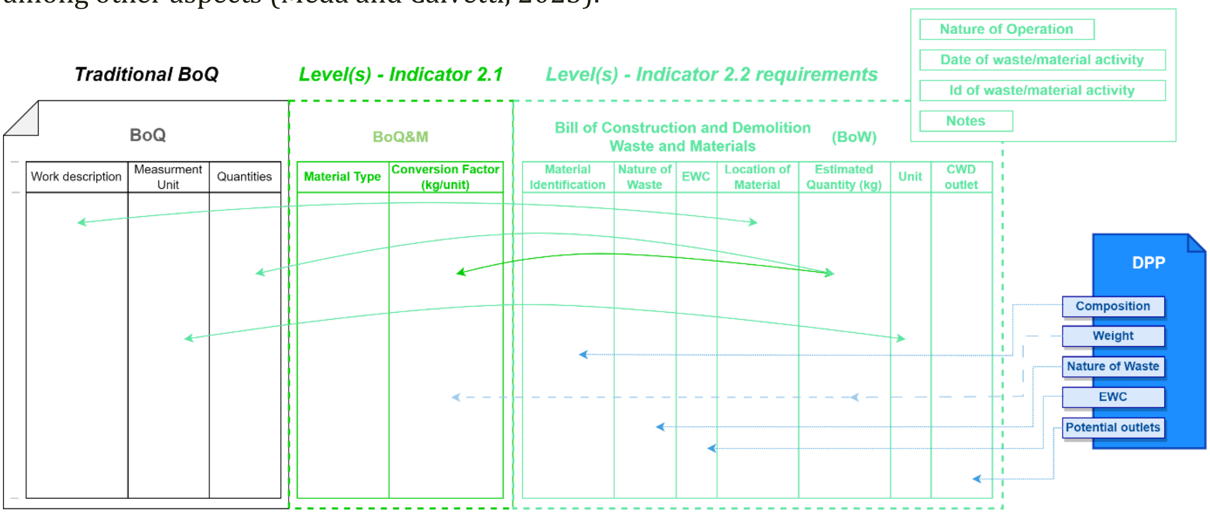

Figure 4. Level(s) Indicator 2.2 requirements aligned with "traditional BoQ" structure, Level(s) Indicator 2.1 relevant landscape and DPP contributions to streamline this estimation.

Indicator 2.2 principles are very similar to what was mentioned when detailing Indicator 2.1. From a data perspective, the DPP can provide relevant properties for estimation, but not all. Several aspects depend on the decisions that must be made when the time comes for the building's deconstruction. One interesting possibility deserving further reflection is to evaluate to which extent a "waste audit" should be delivered together with the design of a new building or, at the moment of handover, preparing the built environment for a Building as Material Banks vision (Benachio, Freitas and Tavares, 2020). From a deliverable and data accessibility perspective, this could be feasible and, more relevant, an essential process to re-evaluate before performing building interventions.

4.3 Indicators 2.3 and 2.4

Indicator 2.3 can help users achieve significant environmental benefits by extending the useful life of buildings, including their structures and facades, which are associated with the most pronounced environmental impacts. Indicator 2.4 supports designers and architects as they consider how materials will be recovered when the building ends. By featuring circular approaches to using materials, they can reduce the construction sector's embodied life cycle impact and natural resource consumption (Commission, 2021).

In practical terms, indicator 2.3 assesses the ability of construction elements to be adapted and renovated. From a DPP perspective, the contributions are few because, for most situations, the indicator is highly project-dependent and requires considering the boundary conditions. Notwithstanding, the exercise is to evaluate, during design or based on the BoQ, the extent to which the solutions can be adapted. An example would be the capacity to adapt partition masonry walls to change room dimensions. A low score for this situation would be achieved because it is challenging compared with other solutions. Adjusting a false ceiling height would be, in comparison, more doable. In brief, this is the kind of evaluation wanted for this indicator.

Similarly, indicator 2.4 works with the elements level using data from indicators 2.1 and 2.2. The objective is to mark each element with a "circularity coefficient" following the Waste Framework Directive (WFD), where direct reuse has a coefficient of "1.00" and hazardous waste disposal has a coefficient of "0.00". Six other hypotheses can be chosen. Although this exercise can be done at the product level for some situations, what can be noted is that DPPs will always provide several hypotheses to be considered in the project. In addition, the coefficient might change over time due to other options when the element replacement or entity deconstruction time comes. Nevertheless, this can become part of the design deliverables by adding a specific column on the BoQ.

4.4 Indicator 6.1 – Life-cycle cost

Indicator 6.1 aims to measure all building element costs at each life cycle stage of a project. The life cycle stages reflect those used as the basis for the reference standards EN 16627 and ISO 15686-5. This last provides the methodology for calculating the design life of elements and components. The indicator requests the initial costs or acquisition cost for the "Product and Construction stages", where the source is the BoQ, which was already mentioned when detailing indicator 2.1. Annual and periodic costs during the "Use stage" comprise product and element maintenance, repair and replacement costs. DPPs can provide data associated with maintenance requirements, actions, and associated reference costs at this level. This indicator collects also costs with utilities, such as water, communications, and electricity. These depend on the use phase of buildings or reference values not set at the product level. For the "End of Life stage," costs are also requested, and a forecast of the deconstruction costs and the value of elements, components, products, and materials should be balanced. In the resume and from a DPP perspective, meaningful datasets for this indicator are associated with the cost dimension of products, such as unit acquisition cost, maintenance costs, service life, maintenance frequency and value outlook for residual cost. However, these datasets will not be enough to completely fulfil the requirements for its estimation.

5 Findings

From the analysis comes the perception that DPP can provide relevant datasets for accomplishing some indicators, where 2.1 and 2.2 are the most relevant. It is worth highlighting that for the case of indicator 6.1, although not representing the total estimation, the DPPs can provide a relevant set of different costs. Specific research should evaluate inconsistencies in requirements and standards and what stakeholders should provide some datasets such as residual cost. For a sound estimation, datasets such as the ones mentioned are missing, and there should be guidelines on the responsibilities to provide it. Though considered lateral to the scope of this study, when analysing the different indicators, it was observed that DPPs can support indicator 1.2, "Life cycle Global Warming Potential", with datasets originating from EPDs. Figure 5 summarises the meaningful DPP data to "feed" the different Level(s) indicators analysed. The notion of "groups of properties" and "properties" under ISO 23387 is set in the Figure to determine how the Level of Information Need (LOIN) can be structured to deliver meaningful data for each indicator.

Looking at the barriers and opportunities perspective, it can be concluded that one of the major constraints in the construction sector is how to manage and accommodate new requirements and deliverables to projects. Adjusting to existing processes and deliverables is key, and it seems to have been the strategy adopted when developing Level(s). The use of the BoQ to structure, expand and foster the indicators estimation is, in our perspective, crucial for the successful implementation of Level(s) in new projects. Additionally, BoQs have been produced since ancient times, meaning that, if needed, it might be possible to obtain some indicators for existing buildings using legacy data, namely if the BoQ exists. In fact, this observation opens an opportunity not at the practical level but at the science level, where case studies can be set to identify to which extent it is possible to estimate indicators using legacy data. On the side of the barriers, it is worth mentioning that adjustments on how to perform parts of the design and organise Level(s) compliant BoQs seem to be needed, as these do not always strictly follow an element's rationale. Data availability is also an issue. DPPs can streamline processes, namely in new projects and provide relevant data inputs for Level(s) indicators estimation, but they need to have the data that needs to be provided by manufacturers.

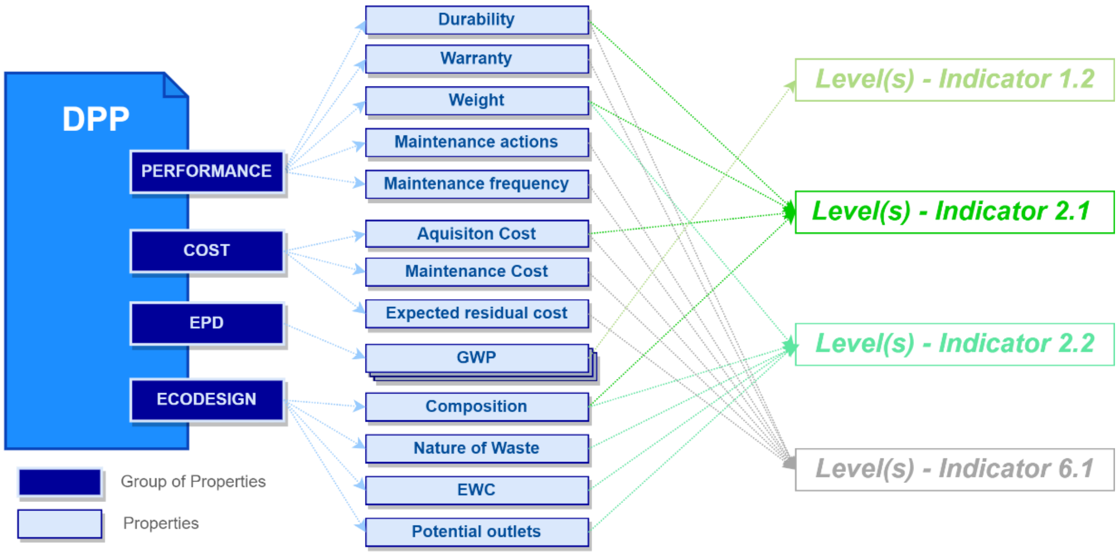

Figure 5. Level(s) indicators relevant datasets from DPPs and the contributions for estimation.

6 Conclusions and Future Research

Considering the research questions, it is possible to conclude that DPPs can provide relevant data to streamline Level(s) indicators estimation, and it was observed that together with a "traditional BoQ", Indicator 2.1 can be easily estimated with DPPs. Level(s) development started before the Green Deal and Circular Economy Action Plan for construction and there should be an update on how it should be positioned in the present strategies.

Future research is needed to improve the understanding of how DPPs can support the estimation of Level (s) indicators. In addition, the existing estimation tool relies on manual input of data. Although this is OK for a test phase, it becomes clear that estimating Level(s) indicators can be accelerated through BIM. DPPs assume BIM standards and interoperability assumptions. In this respect, DPP data must be compatible with or linked with the IFC models or datasets from data dictionaries such as bSDD. This is paramount because Level(s) is in a standalone mode, aside from construction digitalisation trends.

As mentioned, although with different objectives, Level(s) and EU Taxonomy are initiatives that share the ambition to provide a common language at the European level on building sustainability; the Taxonomy aims to provide the financial sector with a definition of sustainable investment, while Level(s) provides the technical methodology for assessing the sustainability of buildings. Unlike the EU Taxonomy, Level(s) is not a regulatory framework. However, its indicators serve as a basis for many European building policies, and compliance with these indicators will increasingly be required at the European level. Therefore, future research will seek how Level(s) and the EU Taxonomy can be further aligned and connected.

The present research clarified the relationship between Level(s) and DPPs but also recognised that delegated acts from the CPR are needed for this to become clearer. Level(s) or at least the studied indicators reveal concerns respecting the adhesion to existing deliverables. It must be recognized that the additional data requirements will impact significantly on the structure of BoQs. However, awareness of how BoQs should be structured to comply with a wider variety of assessments and purposes can motivate positive changes, namely by pushing for the standardisation of its organisation and providing details to be practised with the descriptions. These concerns are aligned, once again, with the ones mentioned for BIM workflow adoption, meaning that if well explained, they are found to increase the momentum that is piloting the transitions in the industry.

Several ideas for future work derived from this research ranged from the expansion of the studied indicators, the use of legacy data to evaluate the estimation ability, the evaluation of difficulties and opportunities associated with obtaining data for DPPs, having stakeholders engaged in delivering typical deliverables together with Level(s) and what must change in Level(s) tools to become more integrated and aligned with the digital construction trends.

Unquestionably, Level(s) provides the assessment requirements for a sustainable built environment, and DPPs provide datasets that can make assessments more straightforward. More than data gaps, there is a technological and governance gap that needs to be bridged. This research is only a small contribution to this awareness.

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