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TOWARDS AN APPLICABLE DIGITAL BUILDING LOGBOOK DATA MODEL: EVALUATING THE RELEVANCE OF CURRENTLY AVAILABLE DATA MODELS IN DBL FUNCTIONS

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Abstract

A Digital Building LogBook is a practical framework for capturing and managing essential information. The main purpose of this ongoing research is to identify the main Building LogBook functions and to evaluate the relevance of the current recommended Building LogBook data models in those functions. The results show that the contribution percentage of the data models in different functions is low. The investigation of the functions of the representative element reveals that modeling building energy is the most common Building LogBook function. The findings of this research clearly demonstrate that to create a functional Building LogBook data model, determining the key specifications of each function is required.

Introduction

Digitization in the construction sector has opened up new opportunities to develop a digital information system that stores building monitoring data and evaluates structural conditions through regular assessments. Collecting building data throughout its life cycle ensures that the data is accessible and well organized for specialists to analyze and support their efficient use in decision making (UNEP, 2020). Building data can be used to optimize resource allocation, define strategies to minimize environmental impact, and improve overall building performance (Hung et al., 2019).

The Digital Building LogBook (DBL) is a comprehensive repository for capturing and managing building data through the design, construction, and operation stages of buildings (Commission, 2023). It enables a straightforward and cost-effective transition to a circular and zero-energy built environment, extending the service life of buildings through improved maintenance and repair coordination (De Wolf et al., 2024). Energy Performance of Buildings Directive (EPBD) (Directive, 2023) defined the DBL as a central repository for all pertinent building data, including the Energy Performance Certificate (EPC), the Renovation Passport, and smart readiness indicators. It enables informed decision making and efficient information sharing among building owners, occupants, financial institutions, and public authorities. DBL can include both static information (e.g., administrative documents, building plans, material bills) and dynamic information (e.g., maintenance logs, operational energy use) (Hartenberger et al., 2021).

The main DBL function is to be a flexible repository to capture and maintain comprehensive building data throughout the design, construction, operation, and demolition stages (AbouHamad and Abu-Hamd, 2019), (Commission, 2023). European DBLs follow a diversity of legal and market contexts, various levels of maturity, and targeted audiences (De Wolf et al., 2024). CLÉA DBL[1] classified information into different categories, including: property cadaster details, HVAC system maintenance alerts, and energy usage monitoring. The Flemish DBL[2] classified building data into building information (cadastre information), EPC, and installation characterization. Chimni DBL[3] included visual content such as floor plans, geolocation integration, and a utility dashboard.

Collecting and storing massive amounts of data requires a significant amount of energy and has a considerable influence on the environmental footprint[4]. A review of the data models mentioned above and an in-depth review of the currently recommended data models (Karami et al., 2024), revealed that DBL key functions have not yet been firmly defined (De Wolf et al., 2024). Various elements have been proposed, categorized into different groups, and designed to serve different purposes. The primary DBL use cases should be determined to capture the right information, rather than capturing every single piece of data; afterwards, the main elements should be defined based on the needs of each function. Understanding these requirements enables the repository to efficiently address unique operational demands.

To ensure that any data captured for the DBL is relevant and useful for current and future building evaluation, it

[1]https://clea.qualitel.org
[2]https://woningpas.vlaanderen.be/
[3]https://chimni.com
[4]https://opnbuildings.com/the-cost-of-data-the-hidden-expenses-in-building-monitoring/

is important to ensure that the data models used within the DBL can actually meet the data requirements of these functions. This paper sets out to do this in two ways: we first identify the stated purposes of the DBL (as per the DBL documentation) and review existing DBL data models against the data requirements for these purposes. We then start with the DBL data models and identify the functions for which they are actually suitable. The most representative elements; which are common among at least three DBL models, are identified and their functions have been investigated. Finally, the stated purposes of the DBL are compared against the functions that are actually enabled by the DBL data models to determine whether they are aligned.

Previous attempts at DBL functions

There are a few attempts to review the main DBL functions and their main requirements. Commission (2023) identified the various building Renovation Passport aspects, including building identification, general, legal and finance, dimensions, performance, structure and material, and building services. For each aspect, different properties have been specified. Gómez-Gil et al. (2023) investigated the main data sources in Spain and Italy, including: Cadaster, Land registry, and EPC. The results showed that they were not fully aligned with the relevant indicators of the current recommended for a European DBL. Mêda et al. (2024a) compared the existing datasets in Portuguese databases and deliverables with the EU DBL framework, including: Property Registry, Urban planning operations indicator system, Technical housing data sheet and Energy Certificate. The results showed there are efficient match between models. Gómez-Gil et al. (2024) proposed a DBL model with a specific focus on building renovation purposes. Further investigation is required to identify the main elements of building renovation. Mêda et al. (2024b) investigated the synergies and challenges in integrating Digital Building Permits and DBL for building data management.

Karami et al. (2024) deeply reviewed the main static elements and categories of the current recommended DBL models (Table 1), including EU (Jonathan Volt Zsolt Toth, 2020), X-tendo (Toth et al., 2021), EUB (Malinovec Puček et al., 2023), ALDREN (Sesana et al., 2020), iBRoad (Libório et al., 2018), UKGFI (Small-Warner and Sinclair, 2022), and DBL report (van der Ende et al., 2023). The data models were originally in PDF format. To perform semantic analysis, the models group by categories were inserted into Excel sheets and the availability of their metadata was evaluated. The semantic comparison process was not as straightforward due to the lack of efficient metadata and data description. Knowledge-based (Chandrasekaran and Mago, 2021) and semi-automatic (Yang et al., 2021) methods were used to calculate the percentage of similarity between them. The results showed that the percentage of similarity between models was extremely low, due to the proposal of elements in different categories and elements with the same meaning but different terminology.

Table 1: Summary of identified DBL data models

Name	Summary	Metadata available	Categories	Elements
EU	Proposing a DBL model to achieve energy efficiency and sustainability	Partially	7	85
X-tendo	Proposing a DBL model to inspire the next generation of EPCs information	No	7	185
EUB	Proposing a data structure for DBL to achieve energy efficiency and sustainability	Partially	7	657
ALDREN	Proposing a Building Renovation Passport (BRP) model to understand the technical energy performance status of non-residential buildings	No	6	83
iBRoad	Proposing a framework for managing energy performance, executed maintenance activities, and building plans, linked to a renovation	Partially	4	84
UKGFI	Proposing a green BRP model to improve energy efficiency	No	8	85
DBL report	Proposing a semantic DBL data model	No	8	86

Methodology

This research carried out two different approaches (Figure 1): 1) investigating the quantity of information provided by the current DBL data models for various DBL functions 2) investigating the main functions of current DBL data models. The overall approach was organized as follows:

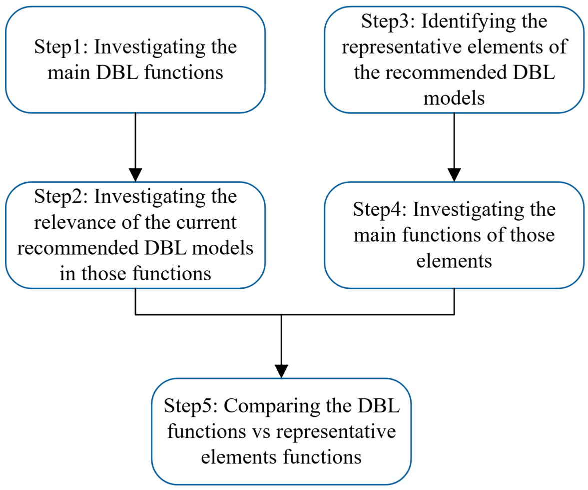

Figure 1: Overview of our research methodology

Step1: Review of DBL functions

To ensure that DBL is an effective and useful tool, its main functionalities should be investigated. European Commission report 2 (Giulia Carbonari, 2020) proposed DBL functions according to the current applicable initiatives (Min vila[5], Woningpas[6], property register[7] and home report[8] . To investigate the main DBL functions, the Global

[5]https://minvilla.villaagarna.se
[6]https://woningpas.vlaanderen.be
[7]https://skra.is/english/individuals/real-properties/aboutthe-property-register
[8]https://www.gov.scot/policies/homeowners/home-reports

Alliance for Buildings and Construction (GlobalABC) report (UNEP, 2020), Technical guidelines for digital building logbooks (Commission, 2023), Malinovec Pu, et al (Malinovec Puček et al., 2023), and (De Wolf et al., 2024) were compared and a list of the main DBL functions was created.

Step2: Evaluation of the relevance of the identified DBL data models

As explained in the previous attempt section, after a thorough review of each DBL data model, a categorized list of elements was developed. Semantic similarity methods were used to find similar words between two short texts (elements) (Yang et al., 2021). The Lexical (Farias et al., 2016) method with the knowledge-based approach (Chandrasekaran and Mago, 2021) computes the semantic similarity between two short texts. The knowledge-based method model the human common sense and the Lexical method finds the text with sequence character. The percentage of contribution of different data models was computed in the identified functions. It was calculated by dividing the total number of elements that could be assigned to each function by the total number of elements in each data model.

Step3: Identification of the most representative elements

The result of semantic similarity allowed us to identify elements with a high percentage of similarity. A list of similar elements was created; which were replicated by at least three data models.

Step4: Evaluation of the relevance of representative elements

The main functions of representative elements were examined. The elements' name was searched in all fields of publications, including titles, abstracts, keywords, and the complete text of the papers, using the Google Scholar engine. The publications that used elements for technical objectives from 2010 to 2024 were selected.

Step5: Comparison of DBL functions versus representative element functions

The results of Step 2 and Step 5 were a list of DBL functions and representative element functions, respectively. They were compared to evaluate how well the currently recommended DBL elements fit the DBL purpose.

Results

Step1: Identifying the main DBL functions:

The main functions of DBL have not yet been fully established and different initiatives have proposed various use cases (De Wolf et al., 2024). GlobalABC report (UNEP, 2020) classified DBL functions, including: structuring and managing relevant building information, improving information quality, and meeting the demand for information from third parties. The European Commission study (Jonathan Volt Zsolt Toth, 2020) defined the main functions of DBL, including operational management, monitoring, and maintenance planning (including notifications), along with a comprehensive overview of building performance encompassing resource consumption throughout its life cycle, adaptability and flexibility, visualize potential future energy and cost savings, as well as life cycle cost analysis. Commission (2023) defined the main use cases of building Renovation Passport including: building identification, general, legal and finance, dimensions, performance, structure and material and building services. Figure 2 shows a summary of DBL functions, which incorporate (UNEP, 2020), (Commission, 2023), (Malinovec Puček et al., 2023), (Jonathan Volt Zsolt Toth, 2020), and (De Wolf et al., 2024). To avoid mentioning the function name, each function was labeled (e.g. A, B, C, etc.).

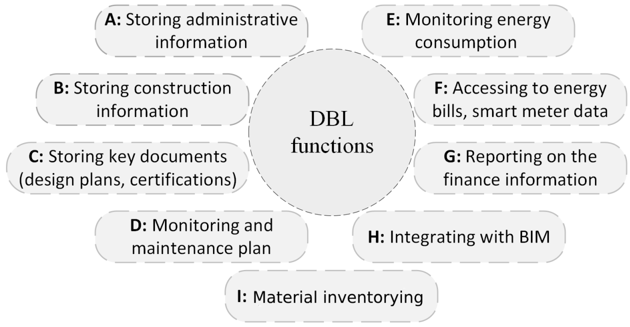

Figure 2: Summary of the main DBL functions

Step2: Evaluating the relevance of the identified DBL data models:

The current DBL data models did not specify the crucial inputs and requirements for each function. To assign the appropriate elements to each function, the following approach was carried out:

- elements with terminology similar to the function name: The semi-automatic method was used to find terminology similar to the function name. The LIKE SQL query (Date, 2011) was executed per each element and the elements with the same consecutive character to the function names were identified. The knowledge-based method was used to prove all textual elements similar to the source element. For instance, the "Maintenance log" element and "Material– Location" were considered input for the "Monitoring and maintenance plan" and Recycling of materials" functions, respectively.
- elements with category names similar to the function name: The output of the previous work provided elements with the associated category. Elements with a similar category name to the function name were identified as an applicable input for that function, by using the aforementioned method. For example, elements of "Building Documentation BIM" and "Administrative information" categories were assigned to

the "Integrating with BIM" and "Storing administrative information" functions, respectively.

- elements with a semantic meaning similar to the function name: The knowledge-based method was used to find the elements that did not share the same terms with the function name but were similar in meaning. For instance, "Total energy consumption" identified an applicable input for the "Monitoring energy consumption" function.

The following list illustrates what kinds of element were considered as an applicable input for each function. Due to page number limitation, a summary of samples is provided.

- **A:** General information about the owner of the building, including the owner's name and family name, Email, address, Phone, Type of ownership.
- **B:** Safety manual, Accessibility for people with disabilities, Type of construction, Floor height, Building category, Gross volume, Date of demolition, Number of building units, is described by native BIM, Number of elevators.
- **C:** Utility contracts, Utility bills, Service contract, Insurance document.
- **D:** Maintenance log, Maintenance bills, Maintenance certificate building element including: Name and surname of expert or entity that performed the maintenance, email address, mobile phone.
- **E:** Total calculated heating consumption, Calculated annual energy need for space cooling per useful floor area, Annual energy need for domestic hot water (DHW) per useful floor area, Energy needs for heating.
- **F:** Metered annual delivered energy for each energy carrier (e.g., electricity, natural gas, district heating system), Type of heating system.
- **G:** Annual rent per useful floor area, Maintenance cost, Annual water costs, Renewal costs per useful floor area, Cost of report on the air-condition system inspection, Annual building insurance costs.
- **H:** Fire safety plan (evacuation plan, signalization, alarms), Building permit, 3D model/Architectural plans, Technical Building System (TBS) plan, Report on the inspection of a heating system, Energy audit report.
- **I:** Material: Type, Location, Volume, Weight, Chemical declaration.

Certain functions, such as "estimating the environmental impacts of the building over its lifetime (including deconstruction and recycling of materials),"visualizing future energy/cost saving potentials, visualizing life-cycle costing", "over-view of the building stock", and "tracking of information changes through provision of a chronology", did not have corresponding elements. As can be seen in the list, several samples did not have a clear meaning, for example, the "safety manual", "is described in native BIM". This fact highlights the importance of determining the fundamental specifications for each function.

To investigate the relevance of the current DBL data models, the percentage of contribution of each data model was calculated in different functionalities. As can be seen in Tables 2 and 3, the ALDREN and DBL report data models provided the most information on "Accessing to energy bills, smart meter data" and "Storing construction information" functions, respectively. The EUB data model was only provided with the information on the "Integrating with BIM" function.

Table 2: Contribution of DBL data models in different functions

Main Functions	EU		X-tendo		EUB	
	Category name	Information content [%]	Category name	Information content [%]	Category name	Information content [%]
A	Administrative information	4	Administrative information	2	Administrative information	1
B	General Building Information, Building descriptions and characteristics	18	General Building Information, Building descriptions and characteristics	15	General Building Information	7
C	Administrative information	9	Administrative information	8	Building Performance	7
D	Administrative information	1	Administrative information	1	Building Operation and Use	2
E	Building Performance, Building Operation and Use	9	Building descriptions and characteristics	10	Building Performance/ Building Operation and Use	5
F	Building descriptions and characteristics	9	Building descriptions and characteristics	20	Building Element Information, Building Operation and Use	22
G	Finance	15	Finance	8	Finance	9
H	-	-	-	-	Building Documentation BIM	7
I	Building material inventory	13	Building material inventory	8	Building Element Information	11

As can be seen in Figure 3, "Storing construction information" with average 22%, "Accessing to energy bills, smart meter data" with 14%, and "Monitoring the energy consumption" with 12 % were the most common DBL data model functions, respectively. The percentage contribution of the DBL data models was low due to the lack of definition of the key specifications for each function. This fact clearly demonstrates that in order to develop an operational DBL repository, specifying functional elements in relation to functions requires more effort.

Step3: Identifying the most representative elements

To evaluate which elements are most important and prevalent in all data models, similar elements with a large number of repetitions in different data models were identified. Figures 4 show a summary of the most representative elements with the number of occurrences by different data models. As can be seen, general building information elements (Floor area, Number of bedrooms, and Date of con-

Table 3: Continued from Table 2

Main Functions	DBL report		iBroad		ALDREN		UKGFI	
	Category name	Information content [%]	Category name	Information content [%]	Category name	Information content [%]	Category name	Information content [%]
A	Legal & Finance	2	General and administrative information	4	Building Feature	1	Ownership & governance	5
B	General, Dimensions	40	General and administrative information	13	Building Feature, Building geometry	29	Building information, Building type	36
C	Performance	7	Building operation and use	30	-	-	Ownership & governance	2
D	-	-	Building Operation and Use	2	-	-	Building Service	2
E	Building Services, Performance	5	Building energy performance, Building Operation and	8	Technical system	4	Energy consumption & use behaviour	14
F	Building Services	2	Building Cunstruction Information	4	Technical system	30	Building Service	5
G	-	-	-	-	-	-	Energy consumption & use behaviour	1
H	General	5	-	-	-	-	-	-
I	Performance	1	-	-	-	-	Circular economy and climate	6

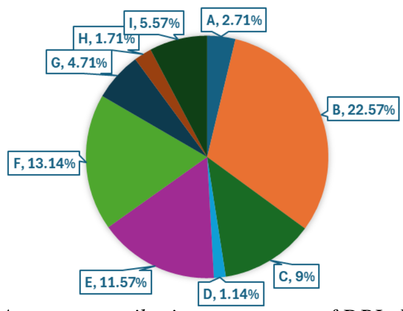

Figure 3: Average contribution percentage of DBL data models in different functions

struction) were the most representative elements.

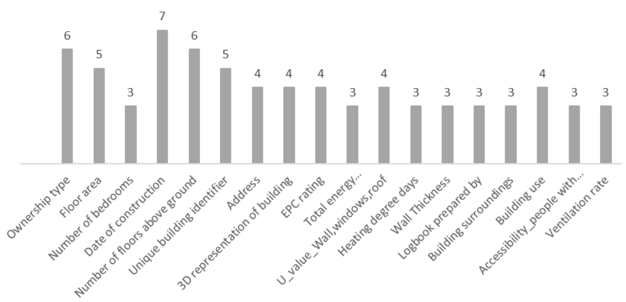

Figure 4: Representative elements with the number of occurrences by different data models

Step4: Evaluating the functions of the representative elements

The main functions of the representative elements identified were investigated. Tables 4 and 5 illustrate a summary of the main functions of the most common elements. As can be seen, the purpose of most publications is related to building energy modeling. This demonstrates the need to identify the important DBL functions. Some elements including "Building usage", "Accessibility for people with disabilities", "Building surrounding", "Logbook prepared by", "DBL last update", "Building name", "Building owner", etc., did not have corresponding applicable functions in the literature.

Table 4: Summary of the main functions of the representative elements

Elements name	Purpose	Source
Ownership type	Analyzing the role of investments in renovation and energy performance, Investigating the role of type of ownership in energy efficiency	Mangold et al. (2018)
Floor area	Predicting annual building energy consumption, Improving energy and environmental performance, Designing a multi-objective optimization framework	Liu et al. (2023)
Number of bedrooms	Identifying the effective factors for residential building energy modeling	Mo and Zhao (2021)
Date of construction	Predicting annual thermal (gas) and electrical energy use of building designs	Paterson et al. (2017)
Number of floors	Enhancing cost estimation of buildings at early stages by performing predictive analytics	Castro Miranda et al. (2022)
Unique building identifier	Representing energy use of urban building-stocks at different levels of aggregation	Österbring et al. (2018)
Address	Simulating building energy systems	Harish and Kumar (2016)
Ventilation rate	Proposing HVAC system design under peak load prediction	Huang et al. (2015)

Step5: Comparing the DBL functions versus representative element functions

The comparison results of Figure 1 and Tables 4, 5 demonstrated that only "Monitoring energy consumption" as one of the most common DBL functions may be considered consistent with "Simulating energy consumption" as the most common function of the DBL elements. Some functions, including "optimizing envelope data" or "predicting load energy", have not been considered in the main DBL functions. The results of both the current and previous stages highlighted the importance of proposing elements based on specific demands.

Table 5: Continued from Table 4

Elements name	Purpose	Source
3D representation of building	Investigating the impacts of successful BIM technology function on construction projects	Toyin and Mewomo (2022)
EPC rating	Predicting energy performance at the design stage of buildings	Olu-Ajayi et al. (2022)
Total energy consumption	Representing energy use of urban building-stocks at different levels of aggregation	Österbring et al. (2018)
U_value _Wall	Modeling and optimizing building energy performance in the design stage	Li and Chen (2024)
U_value _Roof	Proposing an accurate Artificial Neural Network (ANN) to predict energy consumption	Sharif and Hammad (2019)
Heating degree days	Predicting energy use with machine learning during architectural concept design	Paterson et al. (2017)
Wall thickness	Optimizing insulation and heating systems for social housing in Chile	Larrea-Sáez et al. (2024)

Discussion

Digital platforms are emerging to enable circularity practices such as reusing building materials and components, selling tools or advice, calculating life cycle costs, or even providing a marketplace (De Wolf et al., 2024). The DBL intends to serve as digital tools for capturing and managing all key information about the building in a repository. These information include original design, commissioning and transfer details, and information on its management and energy performance, the material used, sustainability performance, indoor environmental quality, and potential energy throughout its life cycle (Small-Warner and Sinclair, 2022). Enhancement and optimization of energy efficiency in buildings during the use phase; contributes to extending the life span of the building through maintenance and repair (De Wolf et al., 2024).

To achieve the aforementioned goals and propose an applicable DBL data model, the main requirements of each function should be identified. The main purpose of this research was to investigate the main DBL functions and to evaluate the applicability of the current DBL data models in those functions. Semantic similarity methods were used to locate relevant elements for each function due to the lack of function definitions and the types of required information. It caused a low percentage of the information provided by current DBL data models for various DBL functions. The Knowledge-based method was needed to confirm the suitability of each element for each function; which made it not straightforward to assign the appropriate element. The corresponding elements for some DBL functions were not found, including ”estimating the environmental impacts of the building over its lifetime” and ”providing an overview of the building stock”. In addition, some new functions were identified. The most common functions were ”Storing administrative information”, ”Accessing to energy bills”, and ”Monitoring energy consumption” (see Figure 2). The applicability of the most representative elements were investigated to understand the main functions of the current DBL data models. The results indicated that ”simulating energy” and ”improving energy consumption” were the most common functions (see Table 4 and Table 5). Comparison of the results of Table 4, Table 5, and Figure 2 revealed a mismatch between the functions of DBL and elements; only ”Monitoring energy consumption” may be considered align with ”Simulating energy consumption”.

One of the drawbacks of proposing several DBL data models in various categories and elements is that a large amount of data over a long period (50+ years) must be collected, stored, maintained and updated. These data may not align with the main defined DBL functions (Table 4 and Table 5); resulting in the creation of new functions for DBL. Future discussion is required to identify the main actual elements and their definitions that should be included in each function. For instance, the definitions of ”Monitoring and Maintenance Plan” and ”Integrating with BIM” are not well defined. This research investigated the main static functions; to develop a smart model suitable for Digital Twin functions (Landi et al., 2024),(Jonathan Volt Zsolt Toth, 2020) further investigation is needed to identify key elements. The main functions and associate elements above were summarized in this paper on the basis of what is currently available from the literature. More research is required to identify the main requirements of each function and compare them to existing available data.

Conclusions

The Digital Building LogBook is a comprehensive repository of the most important performance characteristics and technical building data throughout the life cycle of the building (Tharma et al., 2018). The main purpose of this research was to take one step towards an actual applicable DBL repository. The most significant DBL functions were identified and the potential of each current recommended DBL data model was determined. The results revealed that due to the lack of well-defined function definitions and their major requirements, the percentage of contribution of the DBL data models was low. The comparison between DBL functions with representative element functions highlighted a gap between what DBL should be used for and what DBL really supports. This fact clearly shows the relevance of defining building elements according to their function.

As far as the investigated DBL data models are concerned, various elements in different categories were provided and may be used by different functions; even so, future work will be required to integrate and evaluate the performance of a single integrated data model in those different functions. A more systematic approach will be required to clearly define the main functions of DBL, to understand the main requirements of those functions, and, if necessary, to incorporate them into DBL repository. As such, it will enable the collection of relevant data, the development of an efficient tool, and the reduction of data collection and storage costs.

Acknowledgments

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