Semantically Enriched BIM Life Cycle Assessment to Enhance Buildings’ Environmental Performance

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UCL – IEDE – Institute for Environmental Design and Engineering
1. LCA

LCA – Life Cycle Analysis

A Framework for the evaluation of the environmental impact of products and processes from cradle to grave
1. LCA

The LCA Framework (ISO 14040, 2006)
1. LCA
1.1 The Life Cycle of Buildings

- Raw material extraction
- Transport
- Building material production
- Transport
- Construction
1. LCA
1.1 The Life Cycle of Buildings

- Raw material extraction → Transport
- Building material production → Transport
- Construction
- HVAC, Hot water, Lighting, Home appliances
1. LCA
1.1 The Life Cycle of Buildings

1. Embodied
   - Raw material extraction
     - Transport
   - Building material production
     - Transport
     - Construction

2. Use
   - HVAC, Hot water, Lighting, Home appliances
     - Demolition
     - Transport

3. End of life
   - Landfill
1. LCA
1.1 The Life Cycle of Buildings

1. Embodied
   2-46%

   - Raw material extraction
   - Transport
   - Building material production
   - Transport
   - Construction

2. Use
   51-97%

   - HVAC, Hot water, Lighting, Home appliances

3. End of life
   1-3%

   - Demolition
   - Transport
   - Landfill
1. LCA

1.1 The Life Cycle of Buildings

1. Embodied

- Raw material extraction
- Transport
- Building material production
- Transport
- Construction

2-46%

2. Use

- HVAC, Hot water, Lighting, Home appliances

51-97%

3. End of life

- Demolition
- Transport
- Landfill

1-3%
1. LCA
1.2 Calculating Embodied Energy / Carbon
1. LCA
1.2 Calculating Embodied Energy / Carbon

Pre-Calculated Databases
1. LCA
1.2 Calculating Embodied Energy / Carbon

Pre-Calculated Databases

INVENTORY OF CARBON & ENERGY (ICE)
Pre-Calculated Databases

+ Save time
+ Easy to use
+ Accessible and widely available
  - Building materials (rather than components or manufacturers data)
  - "Static"
1. LCA

1.2 Calculating Embodied Energy / Carbon

EPD – Environmental Product Declaration
EPD – Environmental Product Declaration

+ Standardized (ISO 14025)
+ Provides a more accurate evaluation
+ Transparent
- Not widely available
- Harder to use
2. BIM and LCA Tools
Characteristics for BIM-LCA integration

- Avoidance of manual data re-entry
- Enabling real-time appraisal
- Implementation of whole building assessment
- Adoption of an intuitive and easy-to-use interface

* Diaz and Anton, 2014
BIM models can be considered as constantly-evolving building material databases, to minimise their embodied energy and carbon.
Study aim:

Explore the potential utilisation of building materials EPD within BIM, to improve the specification of buildings components, and minimise buildings life cycle environmental impacts.
Study objectives:

A. Set a framework for the semantic representation of a BIM model in the context of LCA.

B. Use **Ontology** logic principles and **Semantic Web Language** for EPD data mining, to enhance the evaluation of the Embodied Environmental Impact of building materials.
Ontology

- Project teams currently exchange information in different ways for the same purpose (paper-centric process, email, phone etc.)
- To automate information handling through computer based systems
- The formal description of the properties and relationships between different entities within a knowledge domain.
- Ontology can be utilized through a classification systems to support information exchange or to find new knowledge.
Ontology
Formal Language

A set of symbols, constrained by rules, from which a language can be formed.
Semantic Web

• A web of linked data that can be used and understood by both man and machine.
• An extension of the World Wide Web (WWW), that allows sharing data across various applications, through standardised data format protocols.
Semantic Web and Ontology

- Semantic Web data is expressed in a computer-readable format using ontology.
- Ontology formally describes various concepts and their interrelationships, whilst enabling automatic reasoning between different data sources.

Ontology engineering is a key feature in dealing with semantic interoperability. Ontologies specify the semantics of terminology systems in a well defined and unambiguous manner.

Intended meanings of terminologies and logical properties of relations (rules) are defined using ontology, in a formal language such as OWL.
Semantic Web and Ontology In the Construction Sector

- Environmental Impacts
- Cost
- Availability (in/out stock)
Semantic Web and Ontology In the Construction Sector

- At present - no official common ontologies in the construction sector
- IFC (Industry Foundation Classes file format) and XML (eXtensible markup language) are the most used ontologies for AEC
- Governments in Denmark, Finland, Norway and USA are or have mandated the use of IFC
Problem Formulation

- EPDs are often represented in HTML language or in Excel/PDF
- Detailed manufacturers EPD is not automatically parsed within current modeling application. Instead, it is manually entered.
Building Elements in BIM environment

Quantities/schedules

Steel data provided by the manufacturer not accessible by BIM software

Embed the EPD information within BIM structure

Proposed: An Extended BIM Ontology Framework

The framework has two components:

The **BIM** ontology and the **EPD** ontology.
4.0 Research Approach

The proposed data flow

- Manufacturers' List
- Life Cycle Stages
- Object Properties
- General Information

EPD Ontologies

- Materials and Families Classification
- Export ifc/ifcXML schema

BIM Design Model

- Material Optioneering

Data Structure in Protégé

- BIM Ontology

Semantic Inference and Consistency Check

- Extension of OWL - Semantic Reasoning
Developing the EPD ontologies

EPD ontology has been developed by using Protégé-OWL (Web Ontology Language) editor - a free open source platform developed by Stanford University.
4.0 Research Approach

General ontology structure

[Ontology structure diagram]

- 2.3 Background Data
- 2.4 Product Category Rules
- 2.5 Scope
- 2.6 Functional Unit
- 3.1 Environmental Impacts Results
- 3.2 Resource Use Results
- 3.3 Output Flow Results
- 3.4 Waste Results
- 3.5 Registration Number
- 1.4 Product General
- 1.3 References
4.0 Research Approach

General ontology structure
4.0 Research Approach

Part of the proposed Ontology for Concrete_Block_1 Instance
5.0 Implementation of the proposed framework: Test Cases
5.1. Semantically Enriched BIM using IFC

- A simple BIM model was constructed in Revit 2014.
- Pellet 1.5.2 - an OWL-based reasoner in Protégé-OWL - has been used for inconsistency ontology checking.
- In total, more than 25 rules were developed in the proposed ontology.

- Model data was export from BIM via a commonly used IFC schema.
- Though at present BIM and IFC have known communication-problems (IFC model imported to BIM might lose valuable data), it is assumed that in the near future, the enriched model could be exported back to the BIM authoring tool.
5.0 Implementation of the proposed framework: Test Cases

5.1. Semantically Enriched BIM using IFC
5.0 Implementation of the proposed framework: Test Cases

5.2 EPD Ontology within BIM

- A small database of EPDs has been constructed using the proposed ontology.
- An online materials Embodied CO₂ was then drawn into the BIM model (within the BIM interface) directly from the EPD database.
5.0 Implementation of the proposed framework: Test Cases

5.2 EPD Ontology within BIM

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Grand Total: 54

Overall Embodied CO2: 28633.05454
Examining the application of semantic rules on BIM using IFC

The study has shown that semantic representation of BIM models can be utilised for material EPD specifications.

However - BIM and IFC communication problems is a major limitation

EPD Ontology within BIM

The study has shown that EPD databases can be accessed through the BIM interface.

However – This requires an infrastructure of a standardised EPD database that follows the proposed ontology, where all EPDs will be assembled
Thank you very much

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