Towards a holistic modeling framework for embodied carbon and waste in the building lifecycle

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Climate change has become a global focus in the world. Governments of many countries take great efforts to prevent climate hazard through laws, policies, and technological strategies. Reducing carbon dioxide emission and waste production is one of technological approaches to energy efficiency for green building. Its investigations are fragmented and unbalanced in the built environment. Operating energy is extensively discussed (Sartori, 2007) with available tools such as DesignBuilder for energy analysis. Embodied energy, however, was less emphasized than operational energy. It can be consumed and estimated in the whole building lifetime of production, construction, maintenance, and demolition (Thormark, 2002). Related software tools are still not able to support such holistic design-decision making for low impact buildings. Building information modeling (BIM) is envisaged as having the potential to achieve this aim. It is able to explore embodied energy and waste issues in a unified framework for optimal energy efficiency in the building lifecycle. The aim of this study is to develop a BIM-based framework for assessing embodied carbon and waste.

Current research about embodied energy and waste covered building materials and building lifetime. Research conducted by the University of Bath in the UK (Hammond and Jones, 2008) produced the inventory of carbon & energy (ICE). This ICE-database (The University of Bath, 2008) provides convenience for studying embodied carbon (energy) in the built environment. Research interests are also increasing on energy use in buildings from a lifetime perspective (Huberman, 2008). Moreover, waste estimation and avoidance is reported using different methods, such as building waste assessment score (BWAS) (Ekanayake, 2004), and information technologies like GPS and GIS (Li, 2005) in all phases of the building lifecycle. These versatile practices supply multifaceted considerations for energy efficiency and waste avoidance in a holistic viewpoint of the building lifetime. However, reported methods and techniques focus on one or several building materials, techniques and phases rather than in an integrated manner. This is inconvenient in supporting the overall design-decision making for low impacted buildings’ delivery. This pitfall highlights a synthesized approach to low impacted buildings by adopting BIM technology in a holistic modeling framework.

BIM-driven environments are applicable to the design-decision of low impact buildings because these are maturing in their interoperability with building performance assessment tools including integrated time and cost modeling. Its holistic modeling can be available according to the features of each building lifecycle phase. In the design phase, embodied energy/carbon in building materials can be quantified according to the static building designs in the boundary of cradle-to-gate. In the phases of construction, operation, and demolition, the design decision is a dynamic process that a simulation
approach can deal with embodied carbon and waste analysis. Empowered by BIM for integrated real time analysis, it can evaluate time, cost, embodied carbon, and waste (7D) in the whole building lifecycle.

A holistic nD modelling framework for embodied carbon and waste reduction is proposed to take the advantage of service-oriented architecture (SoA) for the 7D modelling. Within this framework, service requester, service provider and middleware contribute to related modules and functionalities. Existing software like Google SketchUp as the service provider can be used for design concept exploration in the design phase. The middleware of gbXML and BIM file formats like 3DXML and IFC (Industry Foundation Class) is an interpreter between the service provider and the service requestor. It ensures that conceptual green building designs in SketchUp can be exported into other BIM software like Revit or ArchiCAD for detailed design. The refined designs can be further outputted from them to the service requestor for subsequent design-decision making.

The service requester is a nD presenter playing a pivotal role in the framework. Its supportive infrastructure, named integrated modeller, encompasses key modules of building component repository, construction knowledge base, inventory of embodied energy/carbon, and waste analyser. The building component repository stores all green building information obtained from middleware. The construction knowledge base provides possible scenarios or strategies of construction, operation and demolition for dynamic analytical simulation. The embodied energy/carbon inventory contains cradle-to-gate information of construction materials for modelling reference. The waste analyser module represents approaches and mathematical models for waste avoidance. These modules constitute the integrated modeller as 7D presenter’s foundation for embodied carbon and waste analysis in the building lifecycle.

The proposed holistic modeling framework provides a possibility to analyze embodied carbon and waste from different building lifecycle perspectives including associated costs. It brings together existing fragmented embodied carbon and waste estimation into a unified model, so that interactions between various parameters through the different building lifecycle phases can be better understood. The applicability of its related software is anticipated being examined by industrial projects in the near future.

References


