Optimizing Building Life Cycle Environmental Impact and Cost

CSHub Research Brief | Volume 2020, Issue 2 | By Jingyi Liu | jingyil@mit.edu

MIT CONCRETE SUSTAINABILITY HUB

Streamlining Building LCA

Existing building life cycle assessment tools rely on detailed building models that make it difficult to explore the environmental implications of design strategies in the earliest design phases. Most of these tools are separate from architectural design software tools, which hinders the exploration of a wide range of design solutions and therefore limits opportunities to optimize designs for environmental impacts. We seek to address this gap by developing a plug-in for the design software Rhino that optimizes life cycle environmental impact and cost for early design stage conceptual geometries when only the building shape is specified.

An Accessible Tool for Architects

We are developing our tool in Grasshopper, a plug-in for Rhino. The script inputs include the overall building geometry and a few attributes. These input variables have default ranges, but the user has the option to define specific values. The tool generates building designs to simulate based on the inputs, calculating environmental impact and cost as outputs, thereby enabling an assessment of cost-impact trade-offs for different designs. Grasshopper plug-ins Karamba, Ladybug, and Honeybee are used to support the quantification of both the mass of materials and energy consumption. Embodied and operational impacts and costs are then calculated using associated databases.

The initial focus for the tool is on the embodied impacts associated with structural materials. We designed the "structure module" to optimize the environmental impact (kg CO2 eq) and cost (U.S. Dollars)

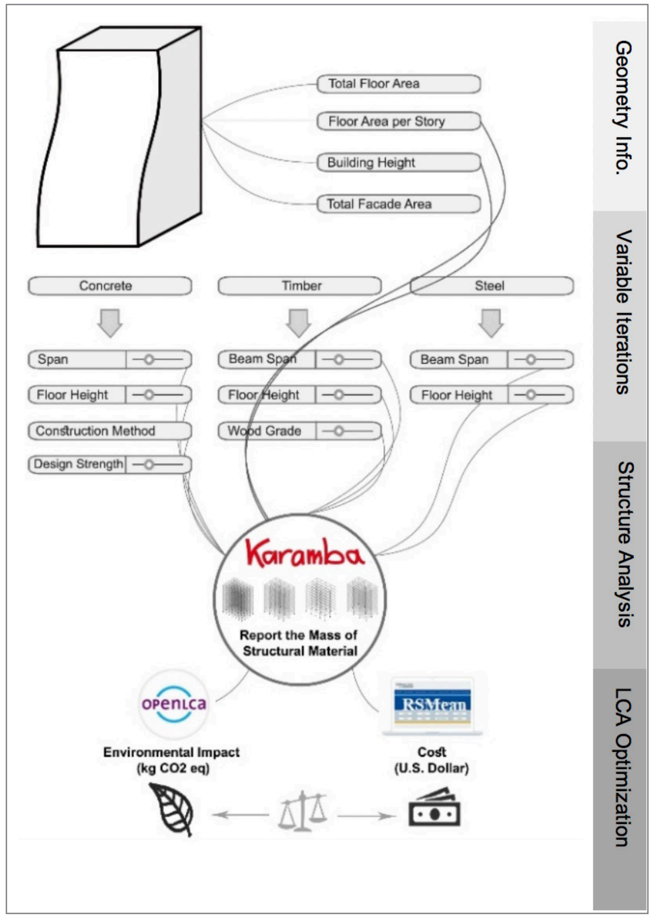

Fig. 1 A flow chart describing the steps involved in the Grasshopper structure script.

of structural material needed for a certain geometry, as outlined in **Fig.1**. The selected structural material (concrete, steel, or timber) for the analysis dictates the approach to calculate the mass of the structure, which depends on floor height, span, and construction method (waffle, joist, or slab for concrete). The tool rapidly evaluates different combinations of construction and structural parameters, thereby enabling a thorough evaluation of the design space.

77 Massachusetts Ave, 1-372, Cambridge, MA 02139 | cshub@mit.edu | cshub.mit.edu

Obtaining Optimal Solutions

In the case of concrete used as a structural material, we found a trade-off between impact and cost, especially for large-span systems.

As shown in **Fig.2**, the tool finds three solutions at a span of 8-13 m that sit on the Pareto frontier (dashed line), meaning they have an optimal balance of cost and impact compared to other solutions (without prioritizing cost or impact). In this case, the two driving variables are span and construction method. Here, solution 1, with a span of 12 m and waffle construction, has less impact than solutions 2 and 3 but costs more. Though solutions 2 and 3 both have a span of 8 m, solution 2 employs a joist beam construction with a lower impact but higher cost than the flat slab construction in solution 3. Depending on how a user weighs impact and cost, these optimal solutions can change.

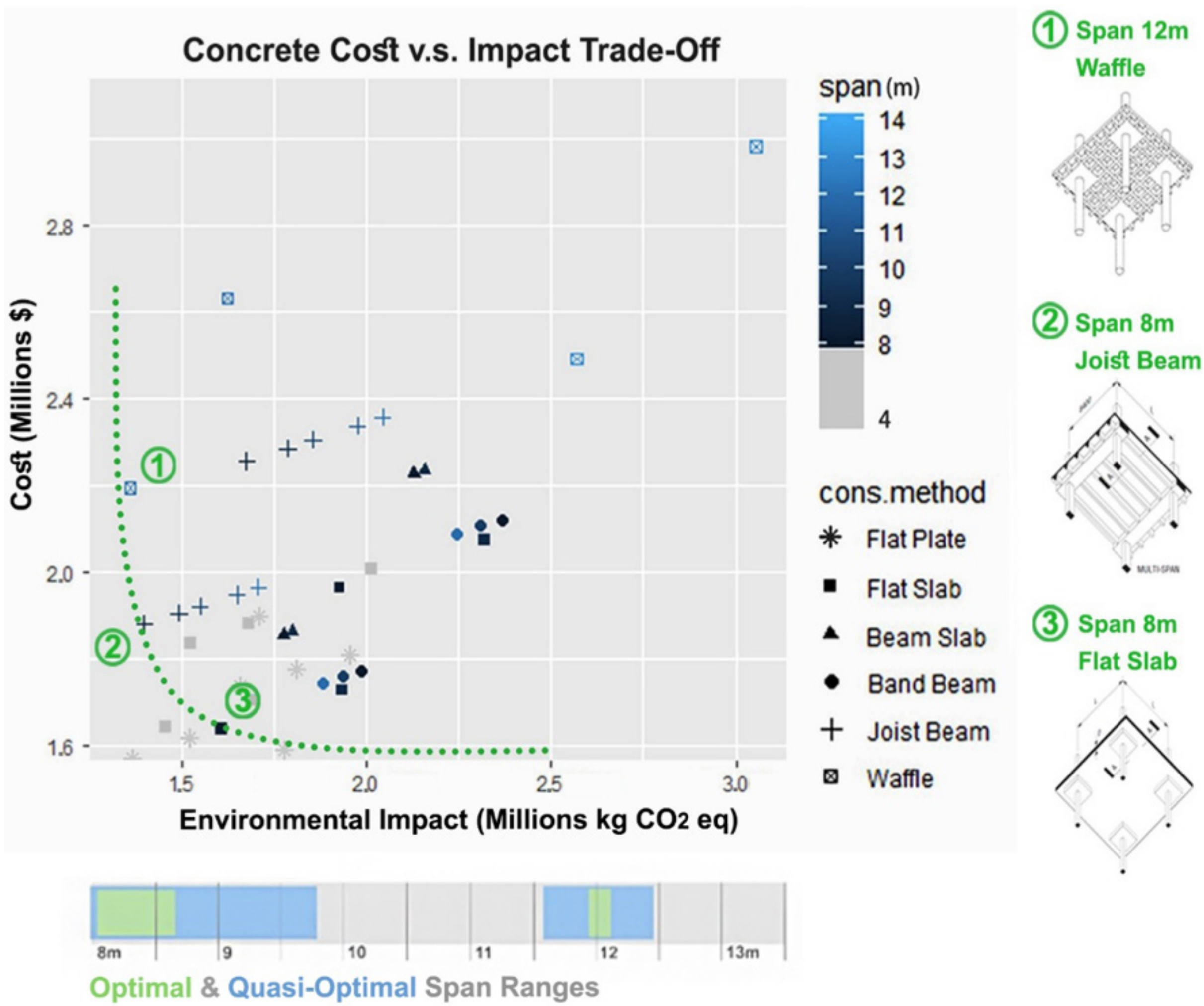

Fig.2: Each dot represents one concrete structure solution with a combination of three variables: floor height, span, and construction method. The latter two are identified as significant. The recommended ranges for span are illustrated at the bottom. Users can check the optimal construction method for each span value.

The analysis also shows the recommended ranges of the key variables, such as span, for minimized environmental impact and cost (both weighted equally). As illustrated in **Fig.2**, green ranges correspond to the best balance between cost and impact. Blue ranges are considered quasi-optimal, with acceptable balance but more design flexibility.

Though in its initial stages, this tool promises to allow architects to rapidly analyze the impacts of their designs. Over the course of its development, it will broaden its scope beyond just structural analysis to consider other aspects of a design, including facade, equipment, heating and cooling, and lighting. The final plug-in can be expected for delivery in the Spring of 2021.

Key Findings

- This tool enables designers to optimize building designs for cost and environmental impact using building attributes and provides guidance on optimal and quasi-optimal values of attributes for design solutions.
- By using a Grasshopper script within Rhino, the tool has the potential to embed seamlessly into the design process.
- This allows architects to conduct LCAs during the early design process where it can have the most impact.

Related Links

- CSHub Building LCA Research
- Topic Summary: Building Life Cycle Assessment

Citation:

Liu, J. (2020) Optimizing Building Life Cycle Environmental Impact and Cost, MIT CSHub, Research brief, Volume 2020, Issue 2

This research was carried out by CSHub with sponsorship provided by the Portland Cement Association and the Ready Mixed Concrete Research & Education Foundation. CSHub is solely responsible for content.

77 Massachusetts Ave, 1-372, Cambridge, MA 02139 | cshub@mit.edu | cshub.mit.edu