# Multi-objective optimisation of high-performance façades


University of Cambridge Department of Engineering

glass & façade technology research group

Research Student: Qian Jin   Supervisor: Dr Mauro Overend


## 1. Background

High-performance façades, such as switchable glazing, have the potential to provide an optimal balance of performance, whole-life cost, and environmental impact, by responding to the variations in the outdoor environments and occupants' requirements.

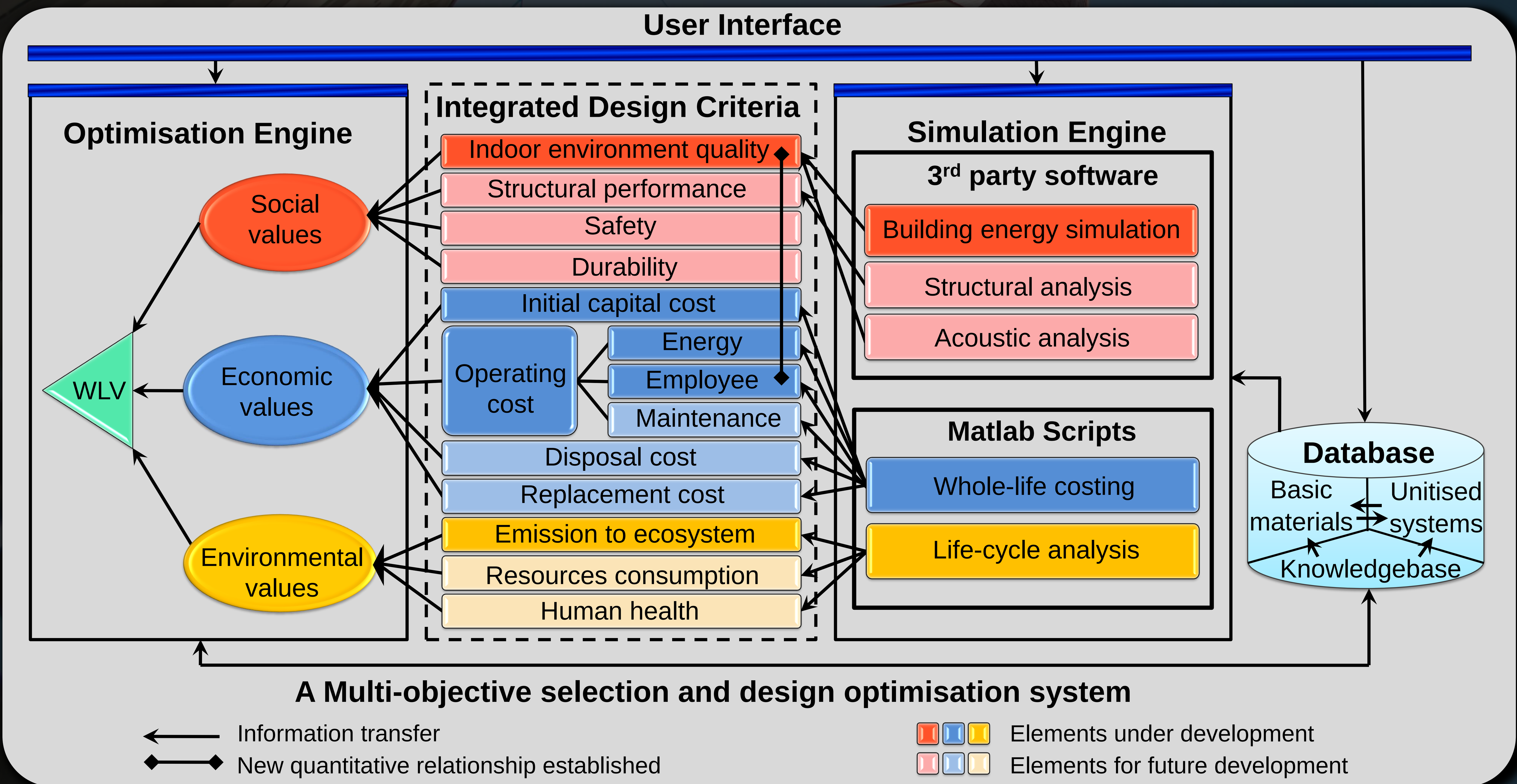
The major barrier to devising an optimal façade solution is the evaluation of the true values of alternative façade designs. A simple selection approach is to focus on some design criteria that can be evaluated through mono-disciplinary commercial software, while overlooking other cross-disciplinary design criteria. Moreover, the lack of a systematic automated process makes the design process a time-consuming trial-and-error process.


| Conventional façade | High-performance façade |
|---|---|
| • Lower initial capital cost. | • Higher initial capital cost. |
| • Static shading reduce daylight | • BMS controlled shading |
| • Blinds reduce view-out. | • Better view-out. |
| • Larger HVAC system. | • Smaller HVAC system. |
| • Higher artificial lighting load | • Better use of daylight. |

Computer-aided multi-objective selection and optimisation provides the opportunity to assist the façade design process, by integrating accurate simulation, systematic parametric analysis and automatic design optimisation.

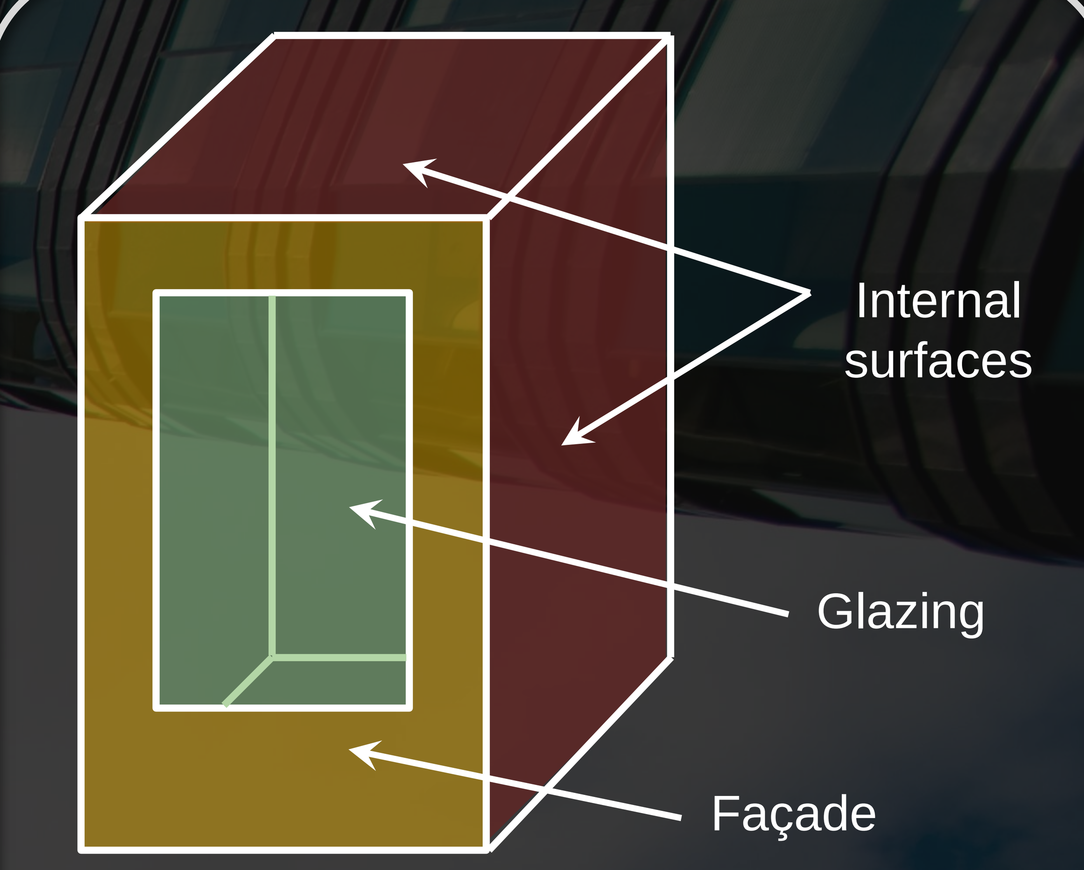
## 2. Methodology

A comprehensive list of design criteria are populated, grouped, and linked to form three main objectives: ***social value***, ***economic value***, ***and environmental value***. They form the basic elements of ***whole-life value (WLV)***. Each objective can be evaluated independently using 3rd party software or a specially developed Matlab script. A prototype multi-objective optimisation engine was developed based on the genetic algorithm NSGA-II.

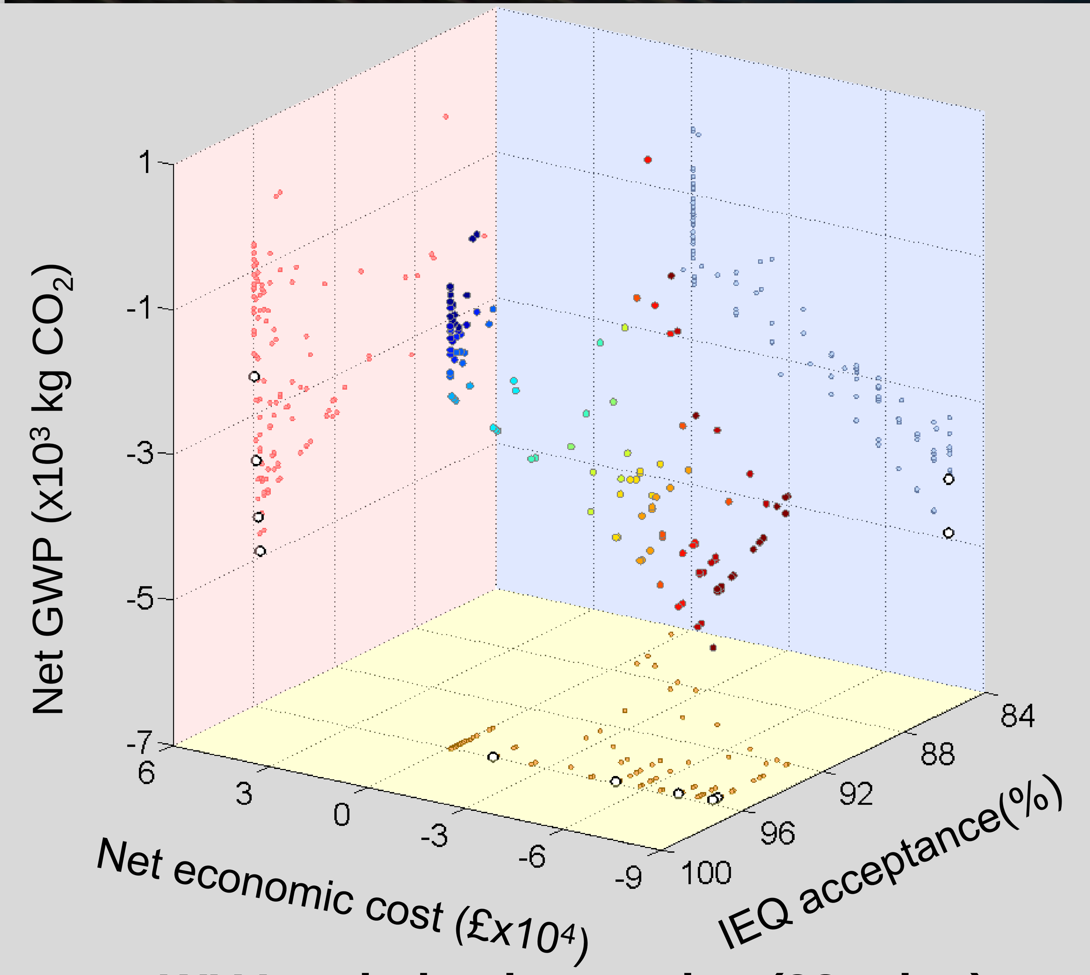



## 3. An application

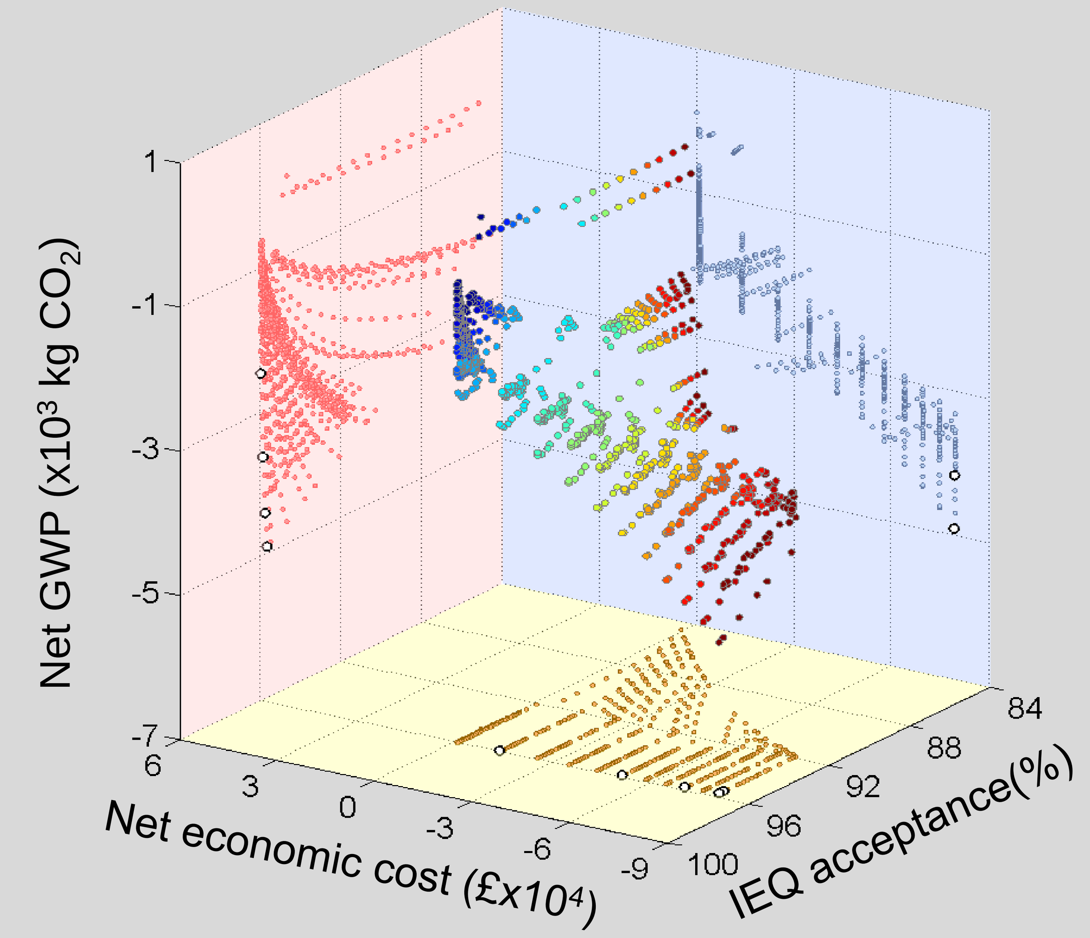
- A typical office room in London, with one external south-facing façade.
- Reference case: Clear double glazing unit. Other glazing types are evaluated w.r.t. the reference case at the same window-to-wall ratio (WWR).
- Two discrete variables:
  (1) Glazing type 1 to 66, including insulated glazing units with: low-e coatings; solar control coatings; different gas layers; different glass types.
  (2) WWRs ranging from 25% to 95%, at an interval of 5%.
- Three objective values:
  (1) Social: evaluated by the acceptance of indoor environment quality (IEQ);
  (2) Economic: evaluated by the sum of initial capital cost, employee productivity and operational energy cost;
  (3) Environmental: evaluated by global warming potential (GWP).




**Office model** (1.5 x 2.3 x 2.3m$^3$)




**WLV-optimisation engine (28 mins)**




**WLV - Exhaustive search (3.5 hrs)**

Projections   WLV Pareto-front set

Window-to-wall ratios 25% 95%

## 4. Conclusions

- The prototype WLV optimisation tool is 7 times faster than the exhaustive search to identify the optimal solutions.
- The optimisation engine successfully identified the WLV Pareto-fronts, which represent the trade-off between the objectives, and thereby provide a series of optimal designs.
- The difference in economic value between the best and the worst design is £80,000. As window-to-wall ratio increases, the benefit of high-performance glazing becomes more evident.

## 5. Future work

- Extend the model to account for the effects of façade frames.
- Improve the optimisation algorithm for faster convergence.
- Deploy the design and optimisation tool to real-world projects, and compare the computed optimal designs with the actual designs.