Value enhancement in optioneering through computational structural design

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Introduction

The presentation is split into the following three sections:

- *What we do do*.
- *What we can do.*
- *What we will do*.

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What we do do

Current practice

Do do - Current practice

- Structurally, scheme design based on experience and market trends with influencing factors, such as:
  - building use;
  - location; and
  - size.
- Analysed using hand calculations, span-to-depth tables or simple models.
- Often early stage driven by architectural vision, rather than structural optimisation. Why not both?

Table 10: Span/depth ratio tables for steel beams located in the floor and roof *(from Tata Steel Europe website)*				
Type of beam	**Maximum floor span**	**Depth of floor beam**	**Maximum roof span**	**Depth of roof beam**
Primary beams	15m	Span/20	15m	Span/25
Secondary beams	12m	Span/25	15m	Span/25

Table 2.18
Span-to-depth ratios for flat slabs

Imposed load, Q_k (kN/m^2)	Multiple span
2.5	28
5.0	26
7.5	25
10.0	23

Note
This table assumes a 3 x 3 bay layout. Where there are only 2 bays in one direction the ratio will need to be decreased.

Table 11: Column size estimate based on storey of structure *(from section 5.3 of The Institution of Structural Engineers' Manual for the design of Steel Structures to Eurocode 3)*	
Number of storeys	**Column size**
3	203x203 UC
5	254x254 UC
8	305X305 UC
8-12	356X356 UC

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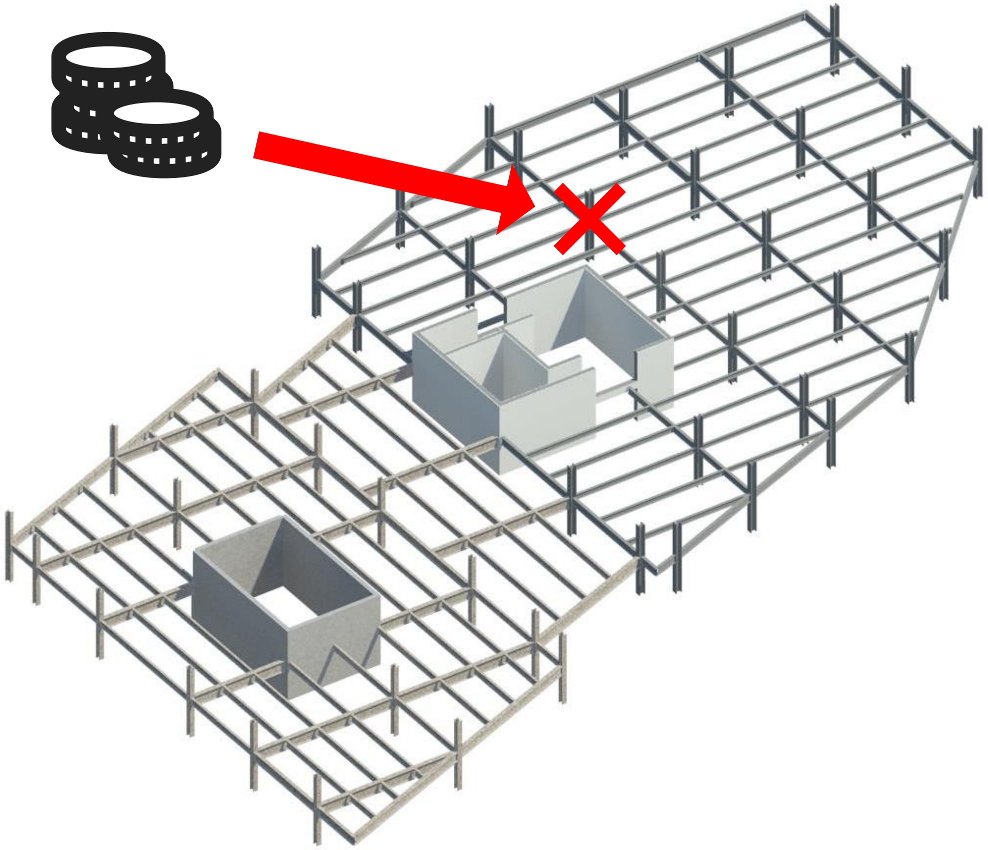
Do do - Client desire

To perform well, our clients need a specific answer to their question as they ask it. To satisfy this we need to provide;

- multiple solutions based on limited knowledge of constraints;
- quantitative data for each solution; and
- an understanding of the potential issues with each option.



Do do - Problem statement

We currently provide:

- Qualitative advice based on our experience as consultants and conservative design calculations.

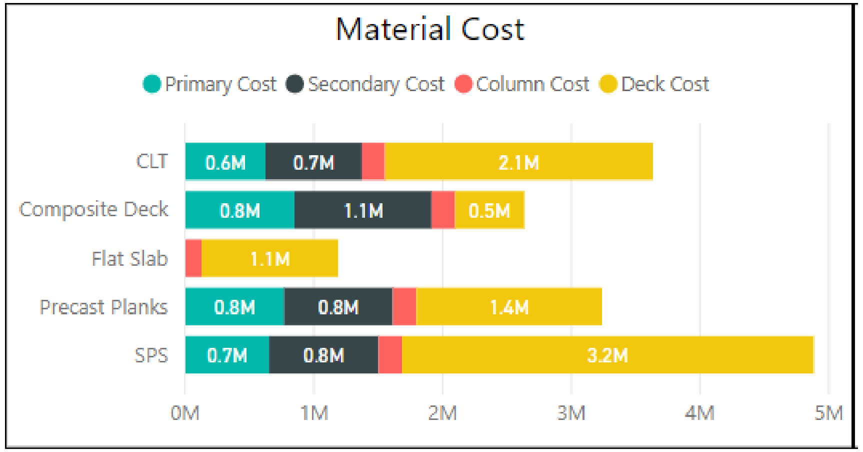
What our clients want:

- Quantitative, transparent data on all possible options.

12.7.2 LATERAL STABILITY

Horizontal loads due to wind action and imperfections in the fabrication and construction of the structure must be resisted by the lateral stability system. Dowels will be provided at the movement joints which, as highlighted in the previous section, transfer horizontal loads in one direction.

Lateral stability is provided by reinforced concrete cores cantilevering from the raft foundation and diaphragm action of the post-tensioned concrete slabs. The core walls will typically be 300mm thick, around both the stairs and lifts.



Do do – Going forwards

- Computers are getting better, and we are getting better at using them!
- Structural engineers need to be involved in the tool development to ensure it is fit for purpose.
- This will bring a solution to our problem, giving quantitative, transparent data to our clients in a fraction of the time.

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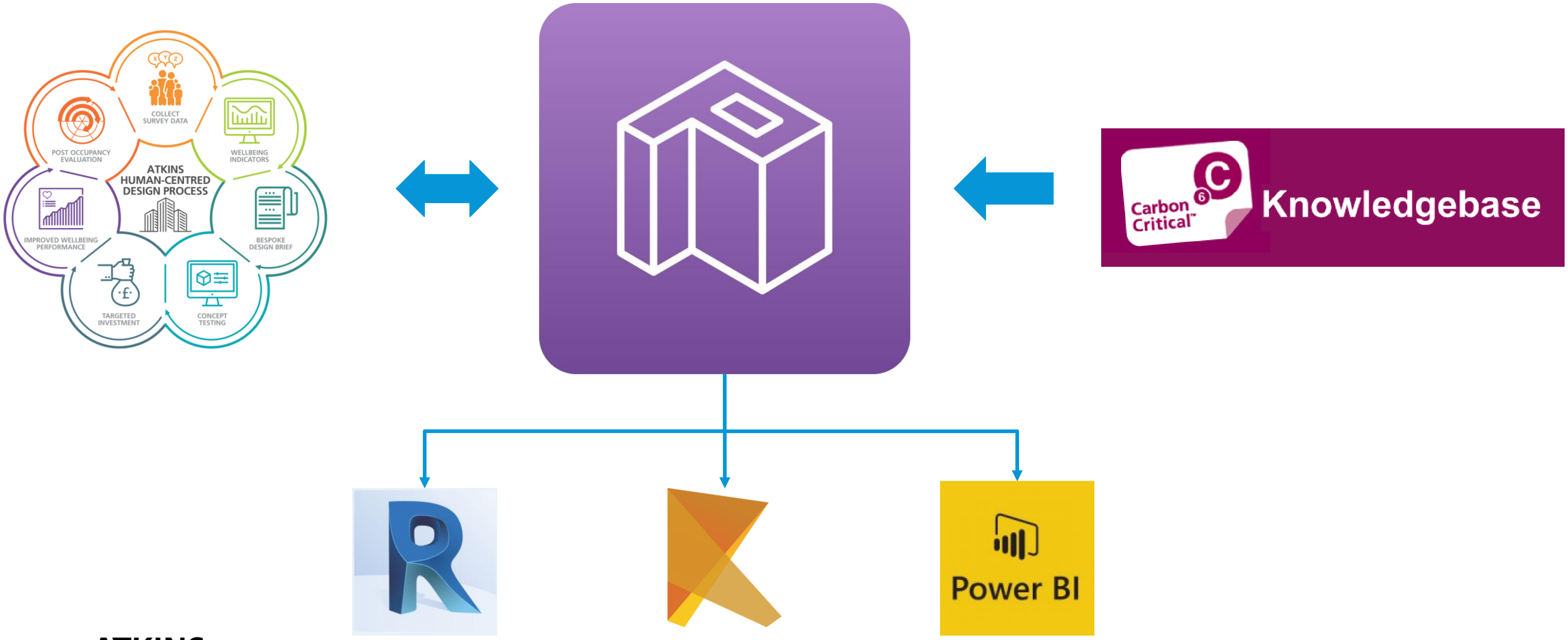
What we can do

Basic computational optimisation

Can do – Parametric Scheme Design tool



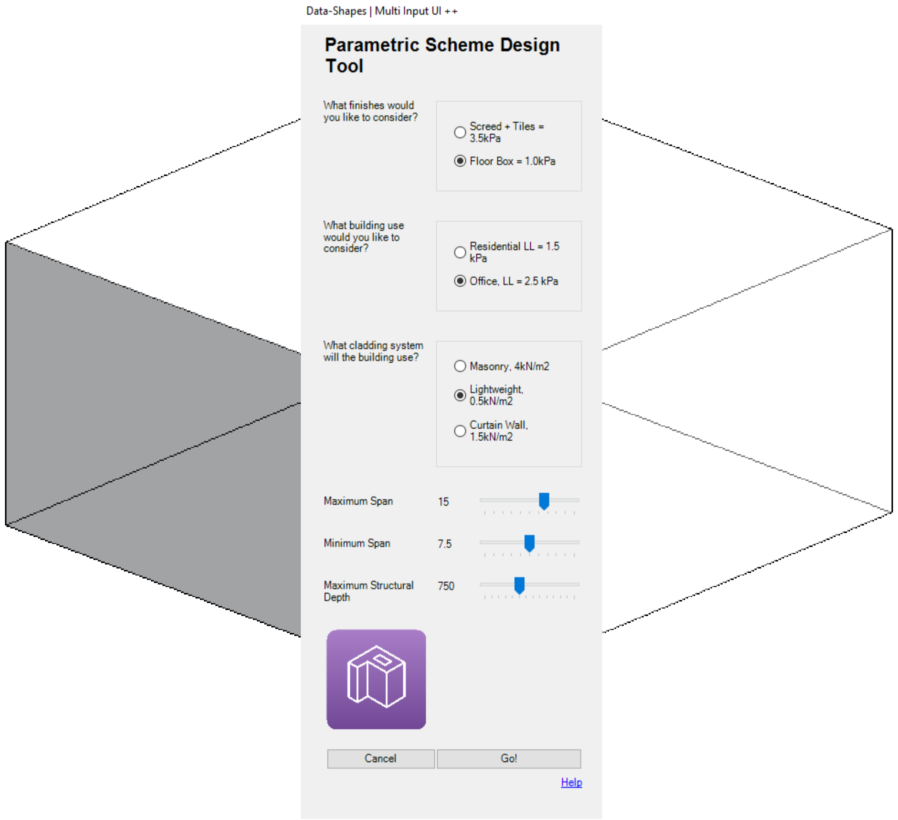
Can do - Potential solution

To solve this problem using a brute force method, we created a tool known as the Parametric Scheme Design (PSD) tool. This:

- utilises Revit, Dynamo and Robot to rapidly produce scheme designs;
- provides raw data to allow for better understanding of the influence of material choice; and
- brings better value to clients by allowing them to make timely decisions about framing options with a better understanding of implications.

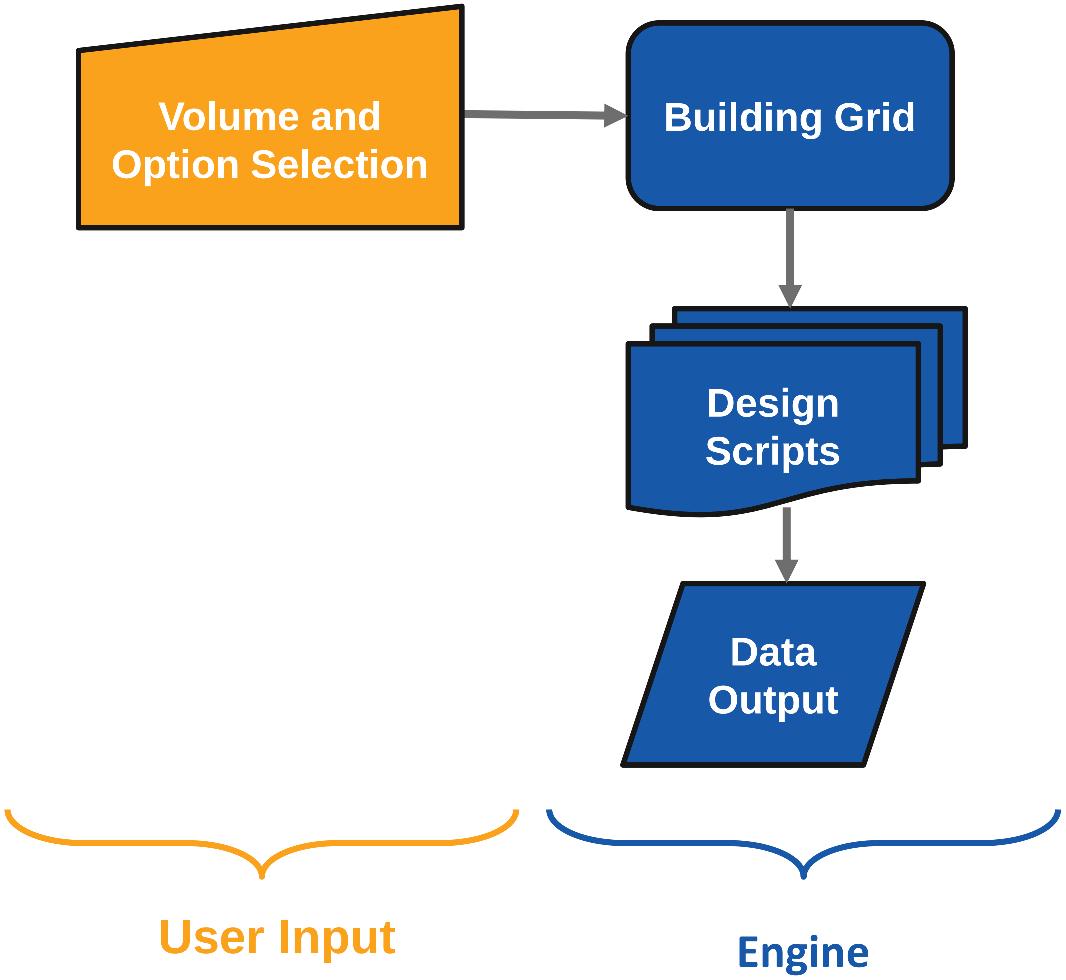
Can do - Logic breakdown

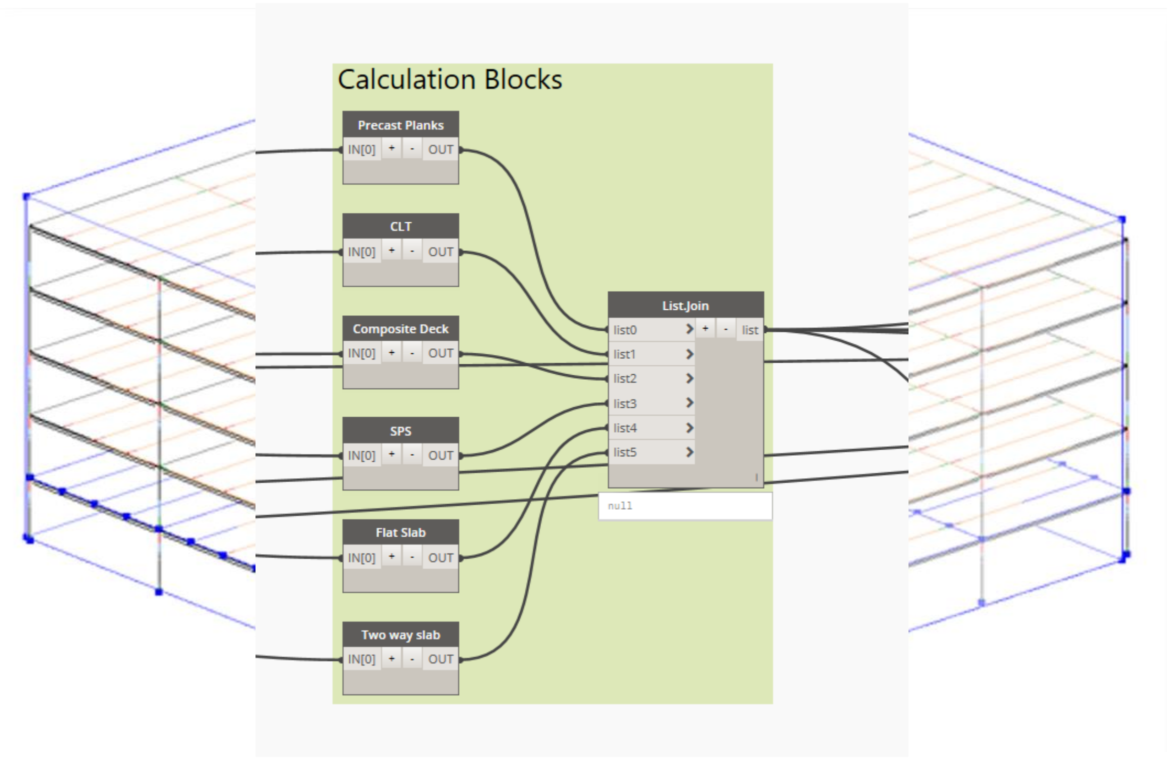
Volume and Option Selection



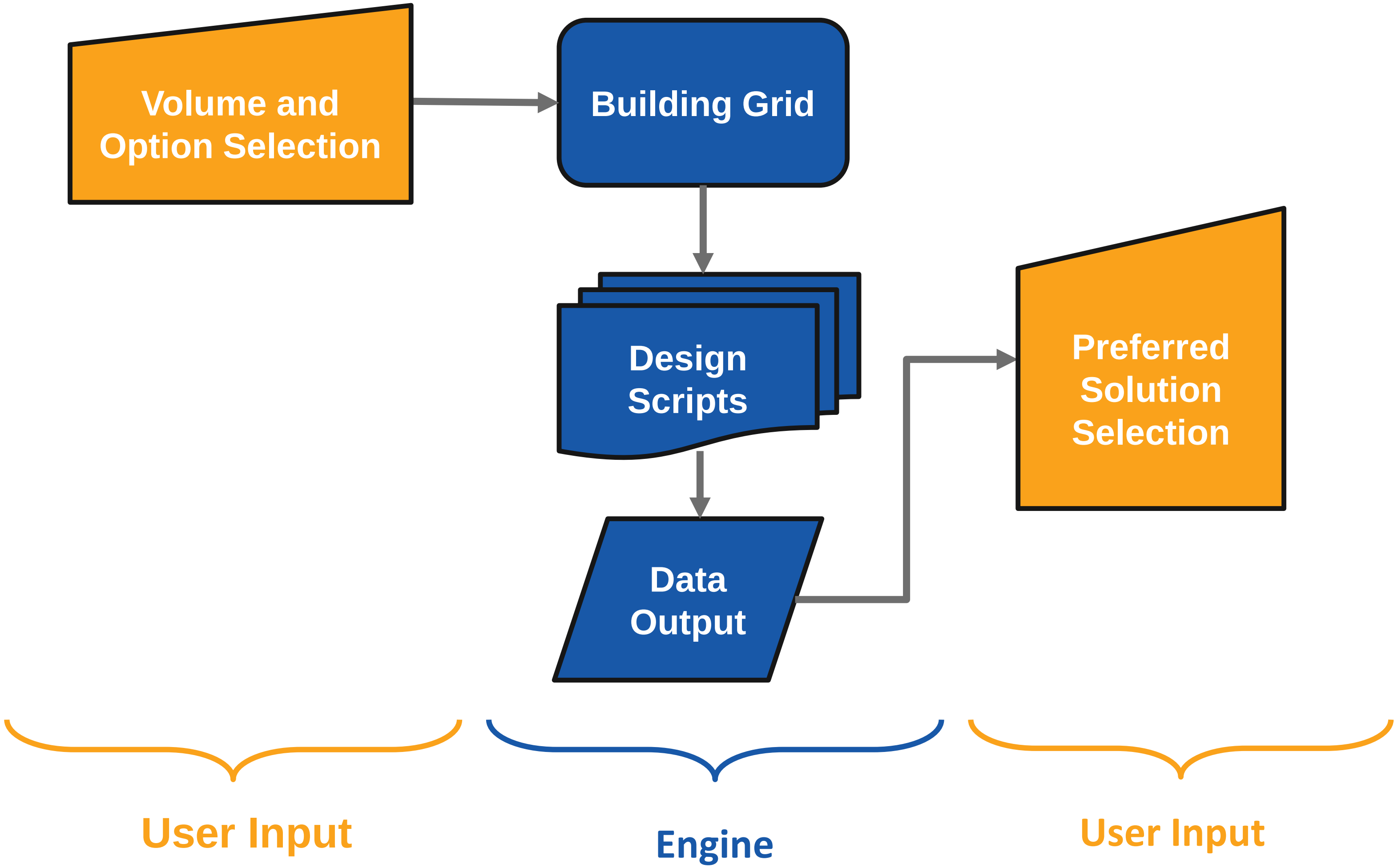
User Input

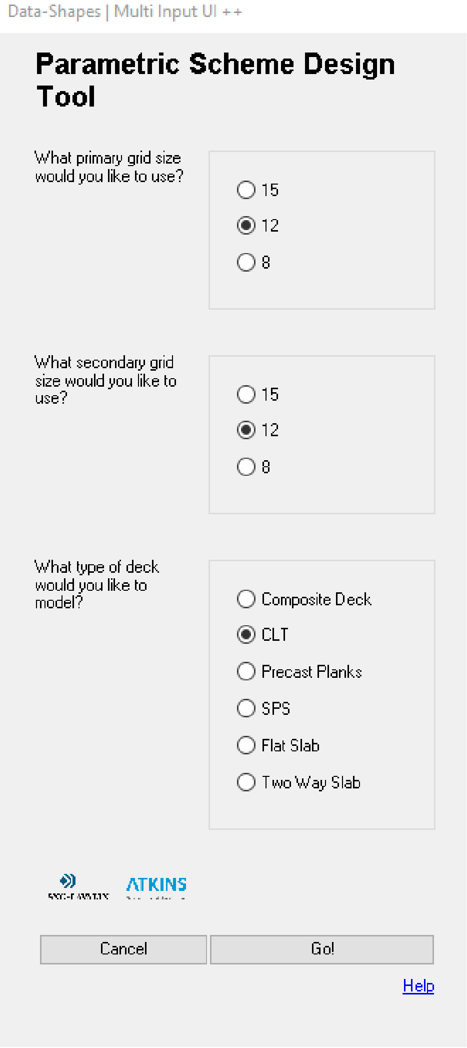
Can do - Logic breakdown



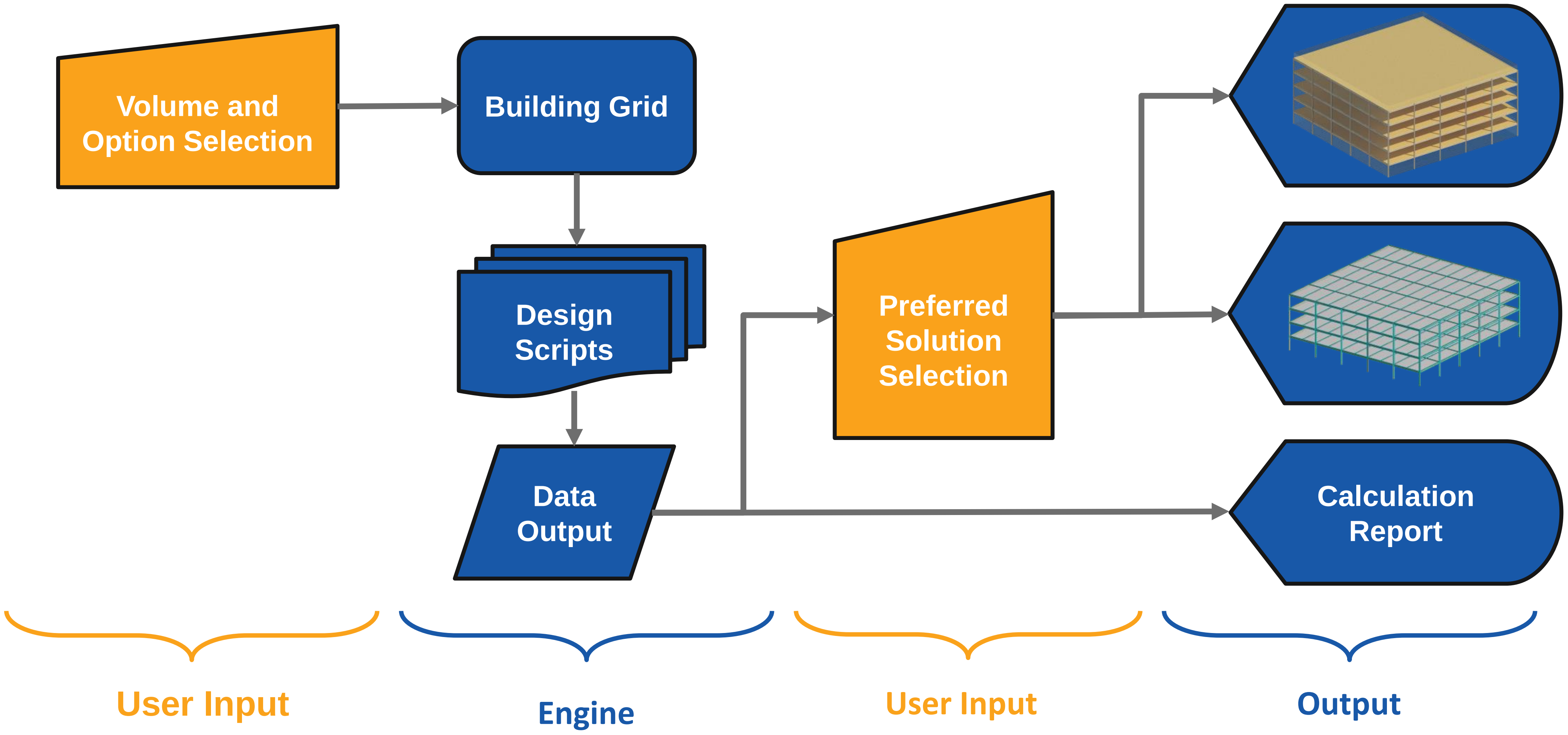


Can do - Logic breakdown

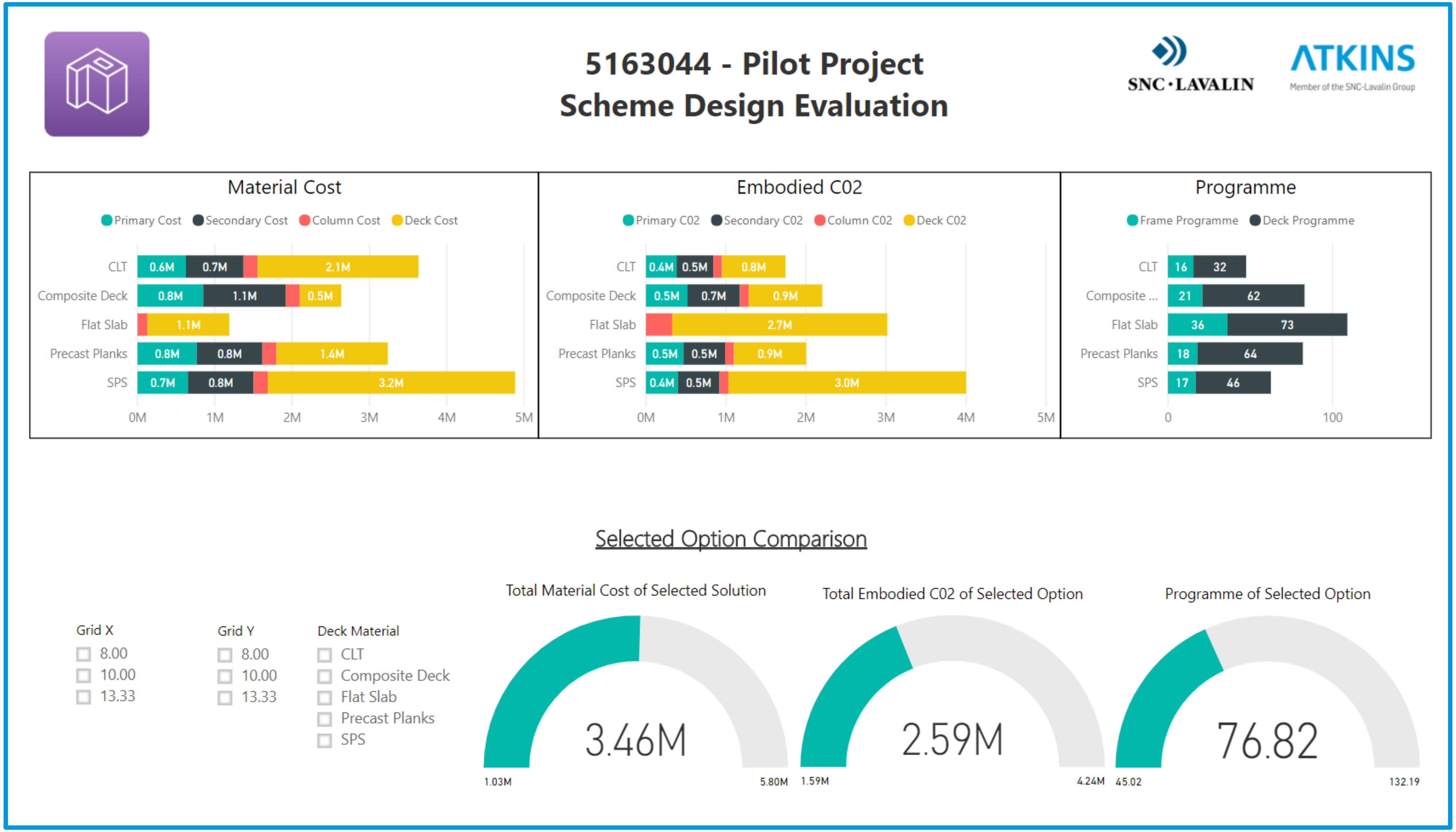




Can do - Logic breakdown



Can do - Logic breakdown



Can do - Future expansion

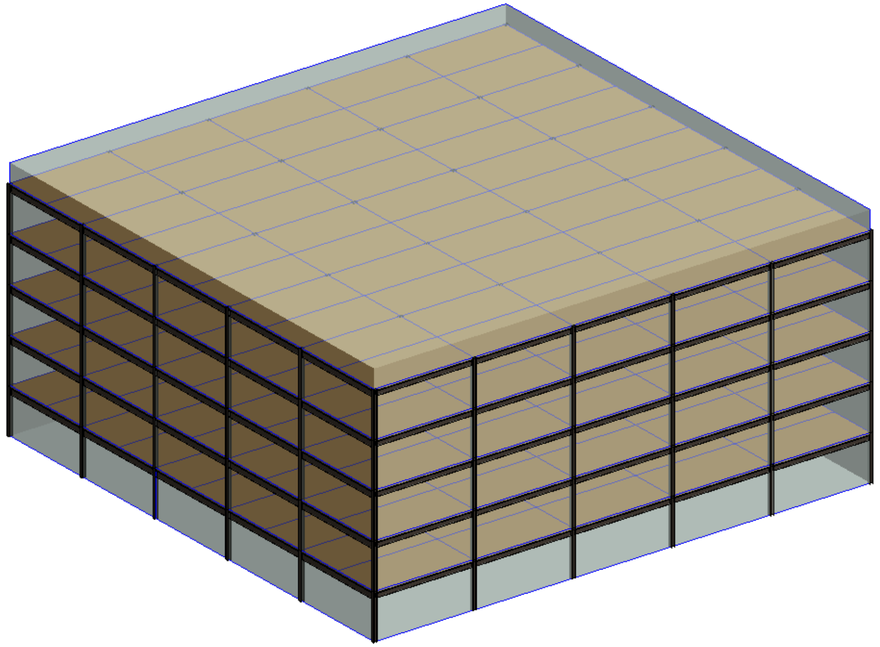
The tool is being continuously developed and the following additions are planned:

- additional building types;
- additional frame/material types;
- adding consideration of stability;
- foundation type comparison; and
- better metrics (including construction activity carbon impact).

Can do - Current limitations

The tool is based on a brute force approach and therefore is only capable of solving simple problems with limited possible solutions. As such it can only consider:

- cuboid building volumes;
- regular grids; and
- no recesses or atriums.



What we will do

Intelligent computational optimisation

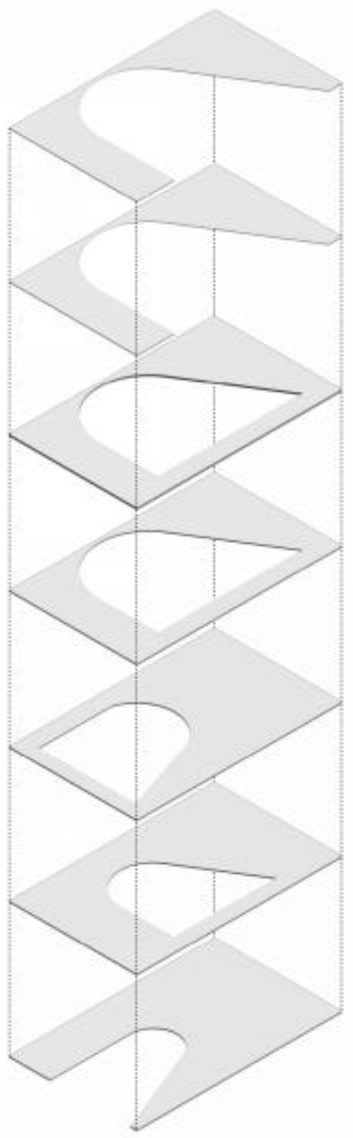
Will do – Building layout

Most buildings are:

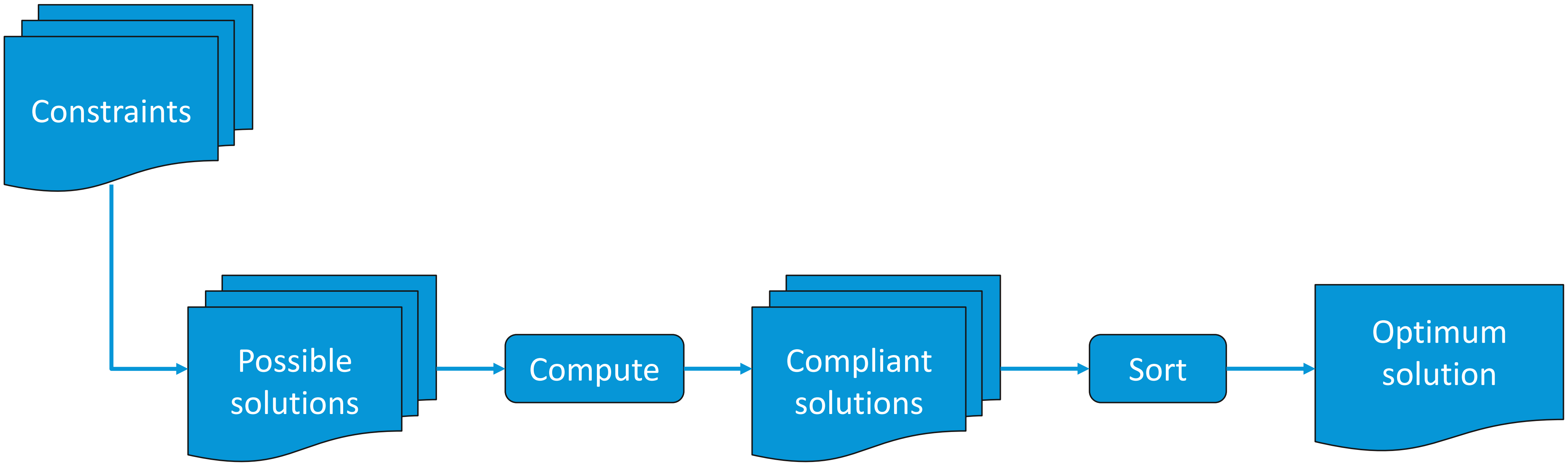
- *not rectangular forms; and*
- *the structural optimum is not the best solution.*

The 'best' building will be mostly influenced by:

- *space planning;*
- *architecture; and*
- *servicing.*



Will do – Problem domain (Simple)



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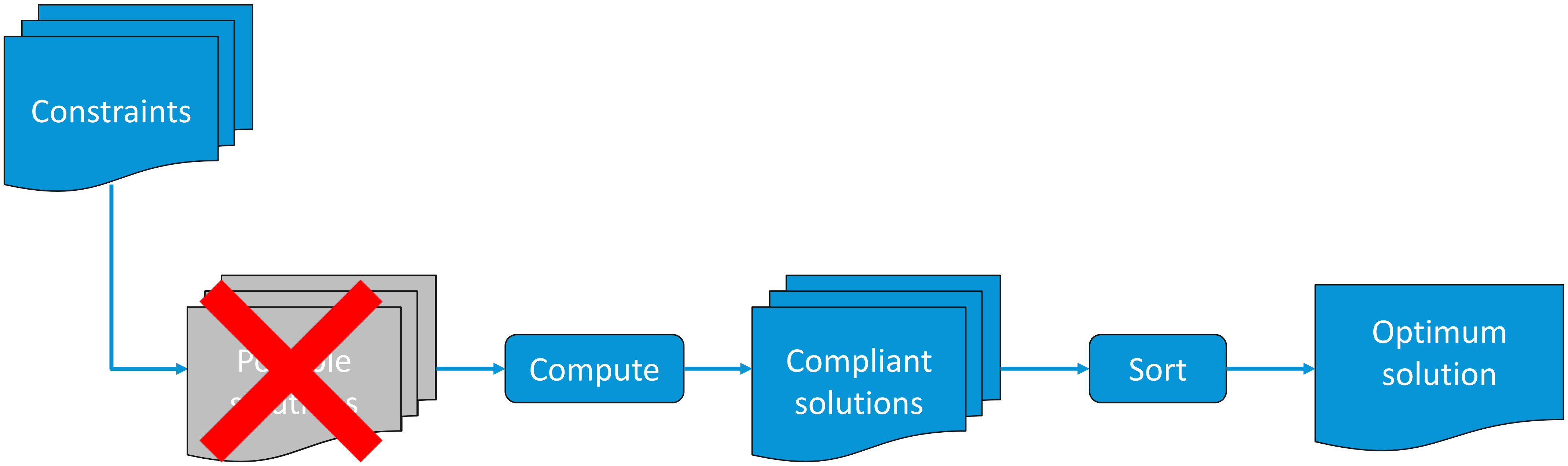
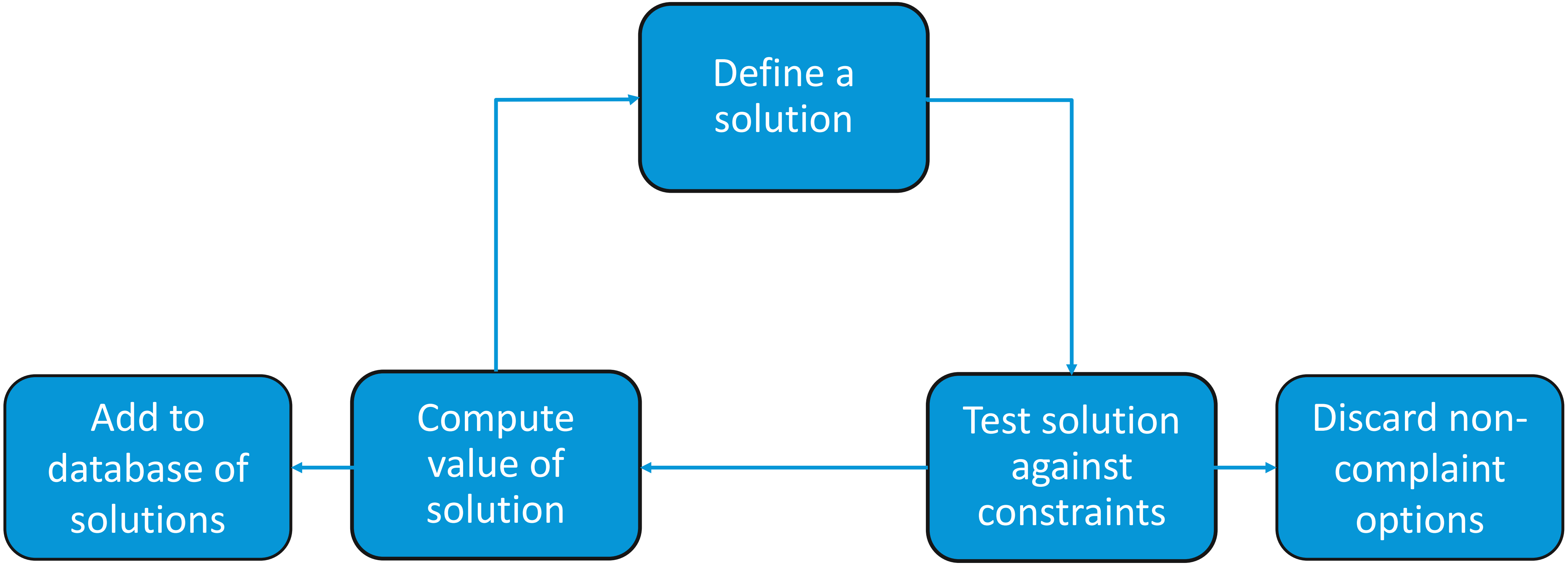
Will do – Problem domain (Simple)



Will do – Problem domain (Complex)



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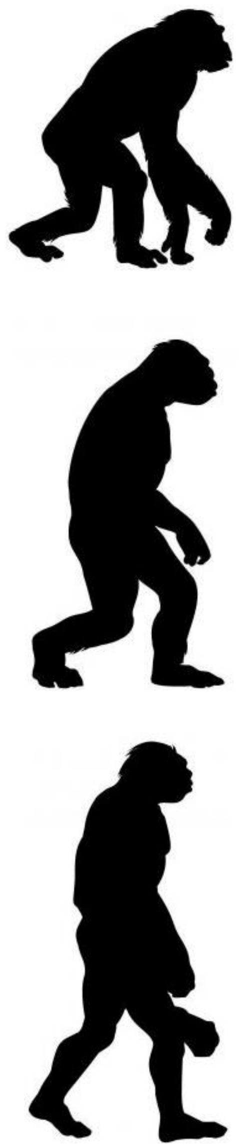
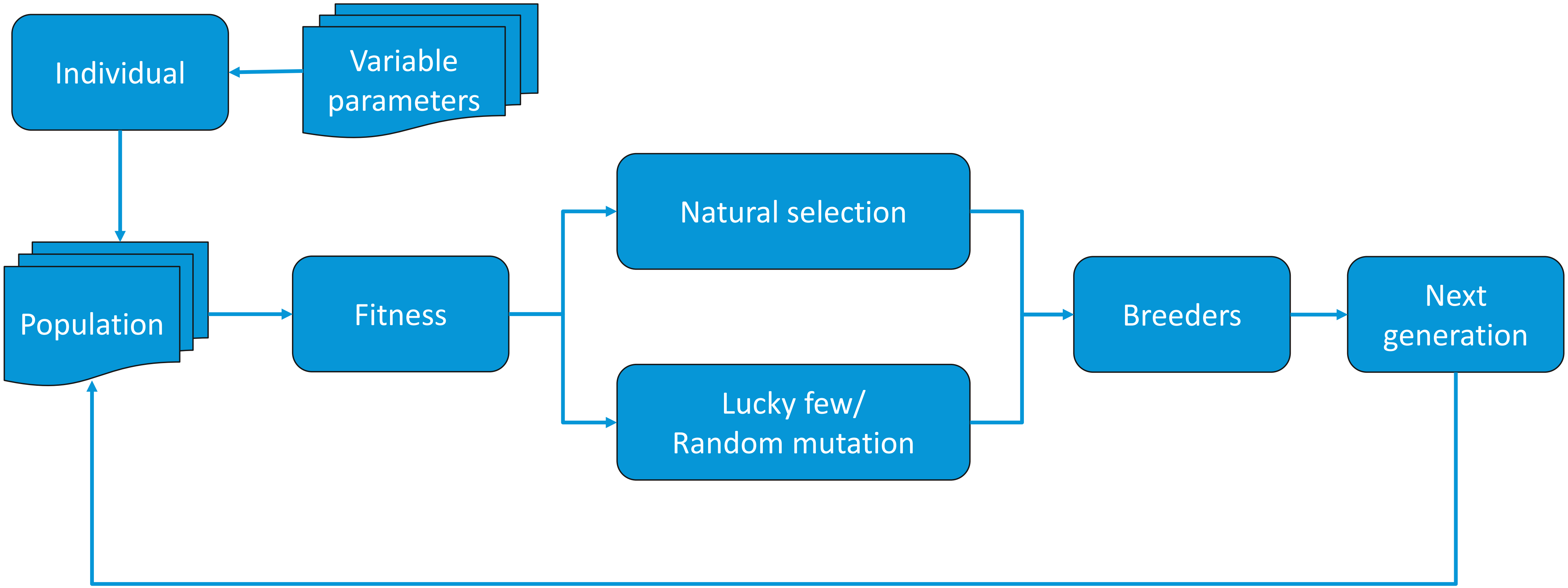
Will do - Algorithmic solutions

- We need to look outside of structural engineering and engineering in general for a solution.
- Our solution comes from computer science (and evolutionary biology).
- Similar solutions are also used in other disciplines (e.g. generative design).

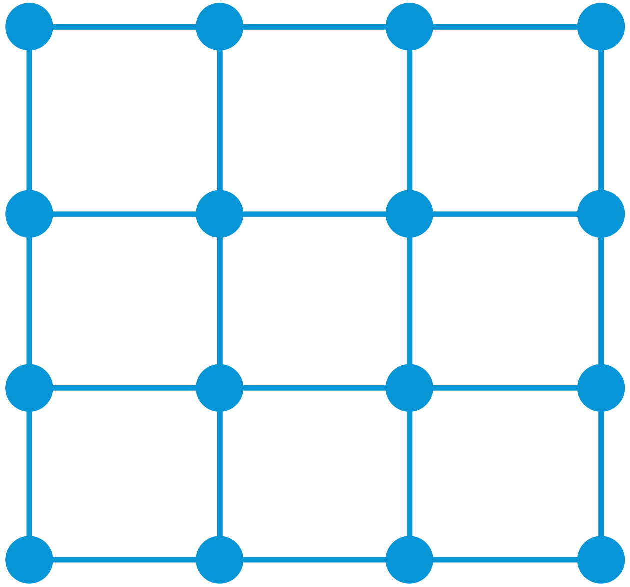


Will do - Genetic algorithms



Will do - An approach

I have developed an approach to our scheme design problem based on genetic algorithms. This aims to optimise floor grids based on a number of possible criteria:



Will do - An approach

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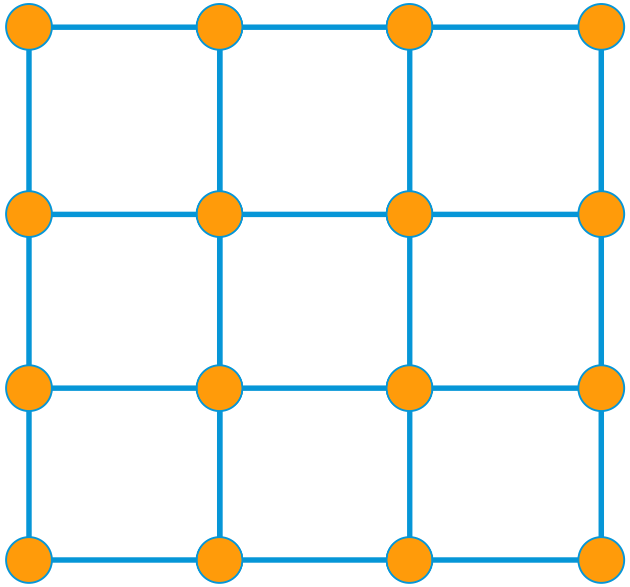
- minimising number of columns;



Will do - An approach

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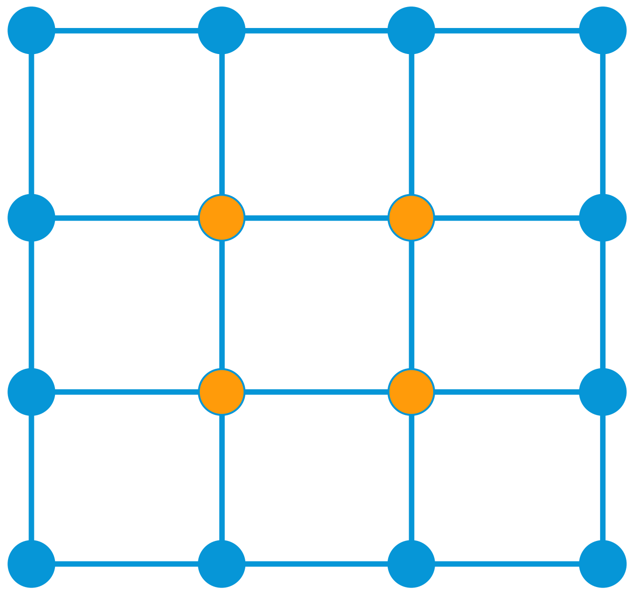
- minimising number of columns;
- minimising ‘inbound’ columns; or



Will do - An approach

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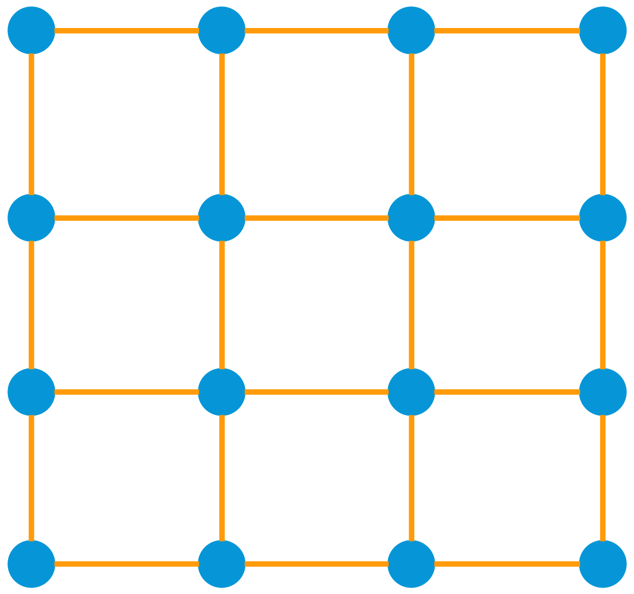
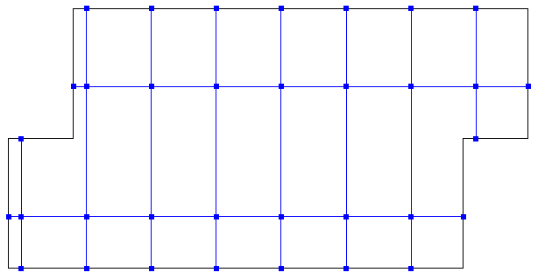
- minimising number of columns;
- minimising ‘inbound’ columns; or
- minimising frame ‘metrics’.

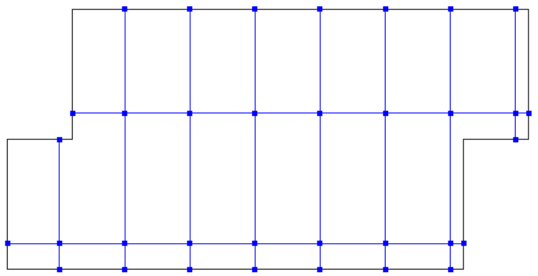


Will do - Genetic algorithms

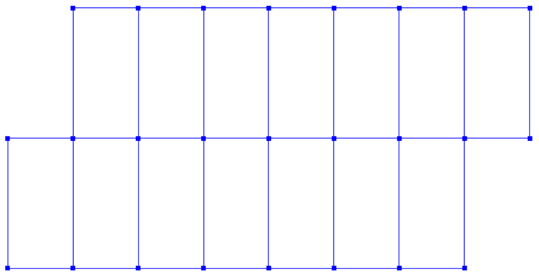
Random choice



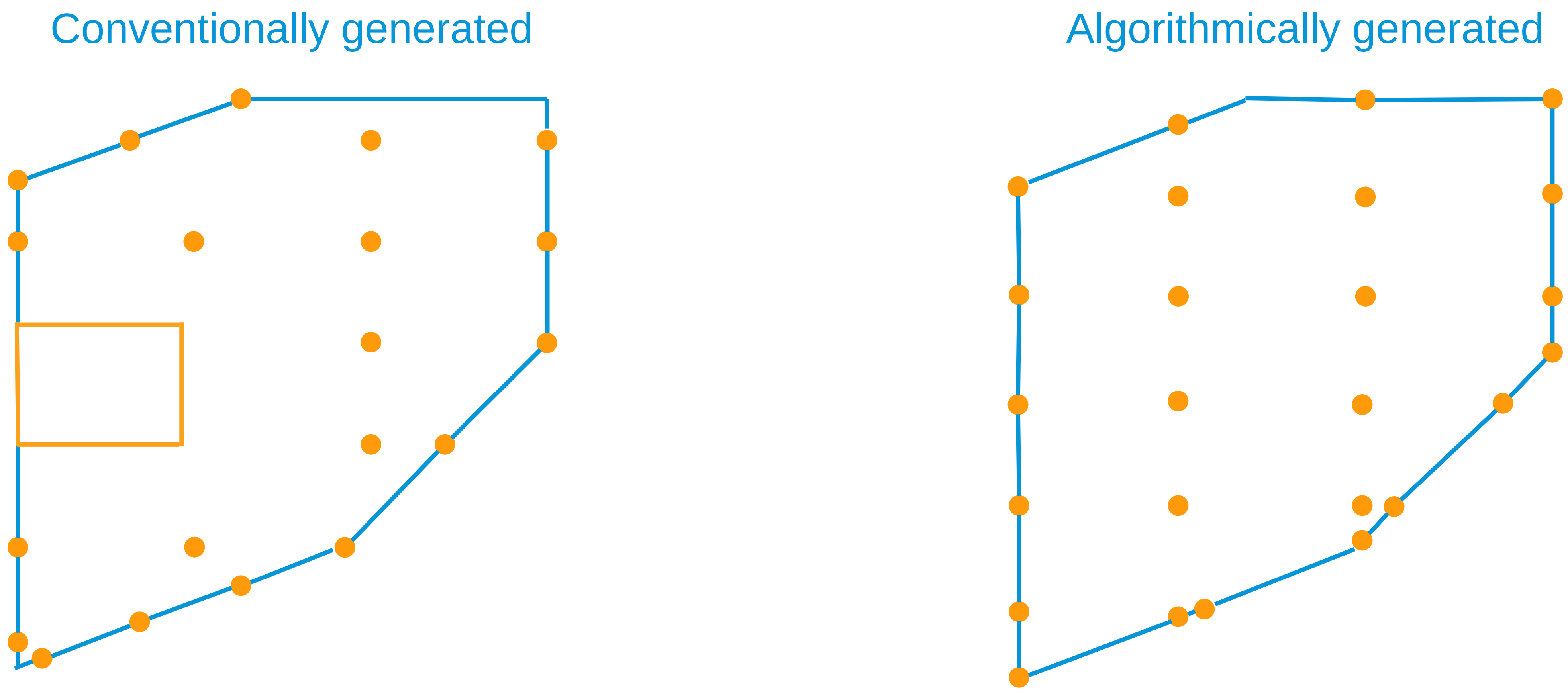
Mid-process



Final



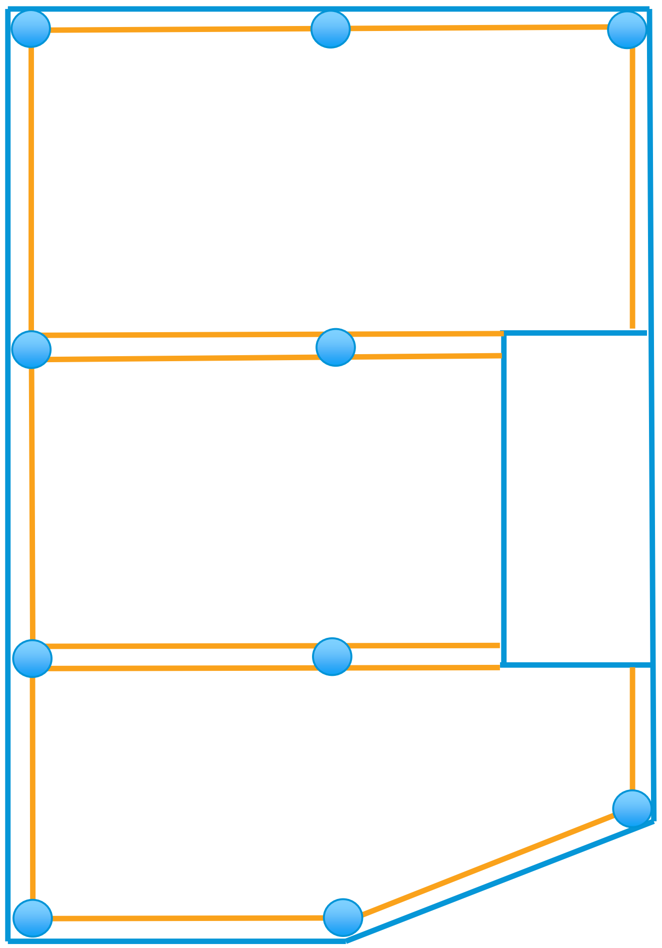
Will do – Genetic Algorithms



Will do – Next steps

In order to solve the problem that first brought us here, there are a few final steps.

- Adapt the fitness function to ‘mask’ architectural layout to favour solutions which hide columns.
- Integrate this with previous tool to provide valuable metrics on potential solutions.
- Interface with other disciplines to allow them to utilise this intelligence during their work so they can quickly understand the implications of their decisions.



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What then?...

Implications on the role of a structural engineer

What then?

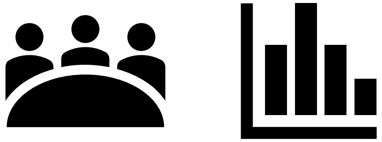
The role of the structural engineer in the future will be:

- still providing qualitative advice;
- focusing on intangible benefits of various options; and
- investing time in creative solutions to tough construction challenges.

Summary

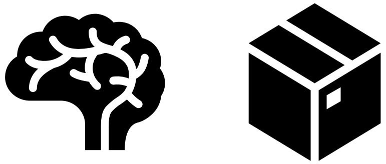
Summary

- Truly informed client at every stage.



- Free up head space for difficult problems.

- Think outside of the box!



Q&A / Discussion

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Make anything.