The Future of Structural Design and Analysis: Conventional or Computational?

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About the speakers

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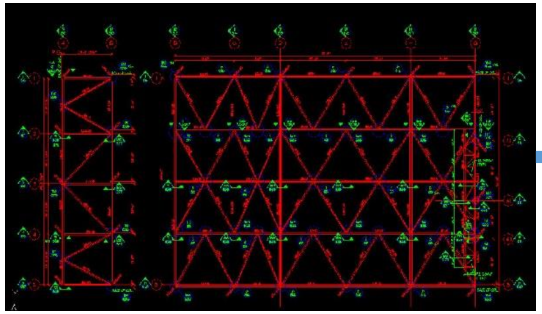
Agenda

- CONVENTIONAL DESIGN
- COMPUTATIONAL DESIGN PROVIDES EFFICIENCY TO:
  - Workflow → Integrated BIM model
  - Structural analysis → Scripting allows for better/faster designs
    - Dynamo a new paradigm
    - Complex geometry
    - Parametric scheme design tool
  - Design delivery: modularisation
- WHAT’S NEXT?
- Q&A

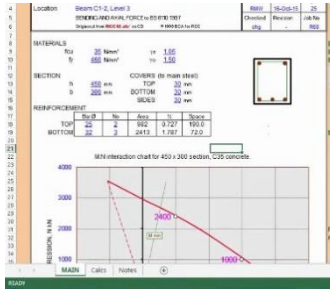
Conventional Design

Conventional Design workflow 2D

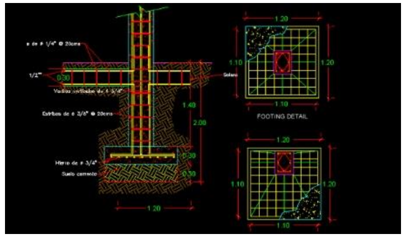
Architectural Drawings



Structural Drawings



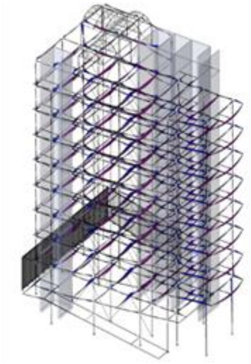
Structural Analysis



Structural Detailing

- Time-consuming
- Prone to error
- Disintegrated
- Inflexible to accommodate variation

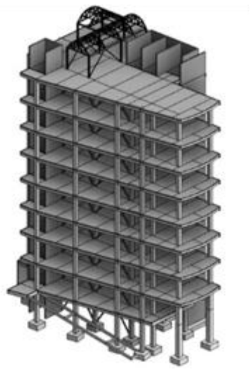
Conventional Workflow 3D



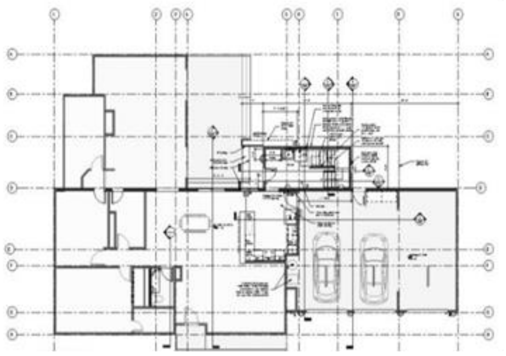
1 Analytical Model

2 CAD Preliminary Framing Layout

1 Sketch Preliminary Framing Layout

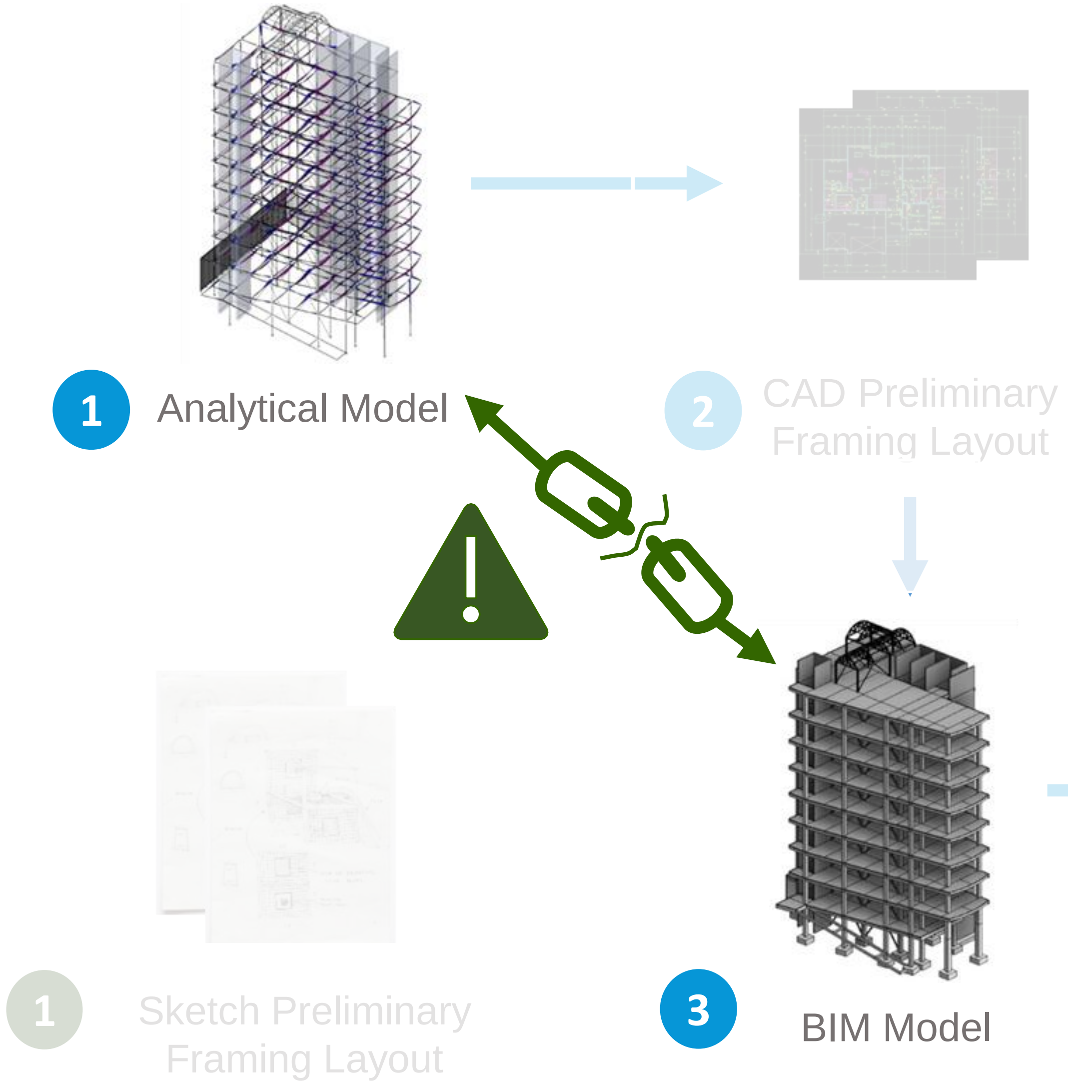


3 BIM Model



4 CAD Preliminary Framing Layout

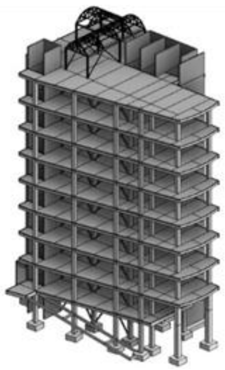
Conventional Workflow 3D



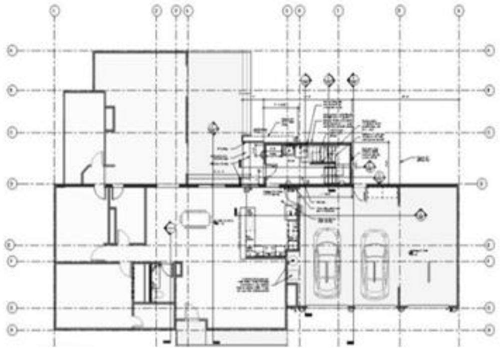
- Non bi-directional
- Reliance of intermediate file formats
- Unable to manipulate geometry instantly
- Loss of information

Computational Design BIM Workflow

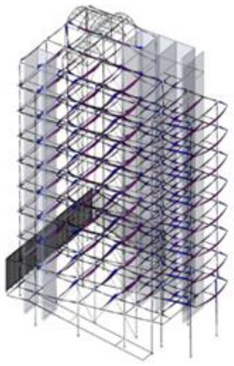
1 Sketch Preliminary Framing Layout



2 BIM Model



3 CAD Preliminary Framing Layout



Analytical Model

- Bi-directional
- Able to manipulate geometry instantly
- No loss of information

Computational Design:

- Computational design aims to enhance the design process by encoding design decisions using a computer language.
- In a broader sense any technology that augments the design process that relies on coding.
- Application Programming Interfaces (API) provides an easy way to code extending the functionality and interconnectivity of software.

Computational Design

BIM WORKFLOW	COMPLEX STRUCTURES	CONCEPT AND DETAILED DESIGN	MODULAR DESIGN
No loss of information, improves coordination.	Use of scripts to process information.	Parametrical design provides rapid information for structural optimisation.	Standarisation is the key feature, ability to rapid delivery of multiple similar designs.

Roof Canopy Case Study

40%

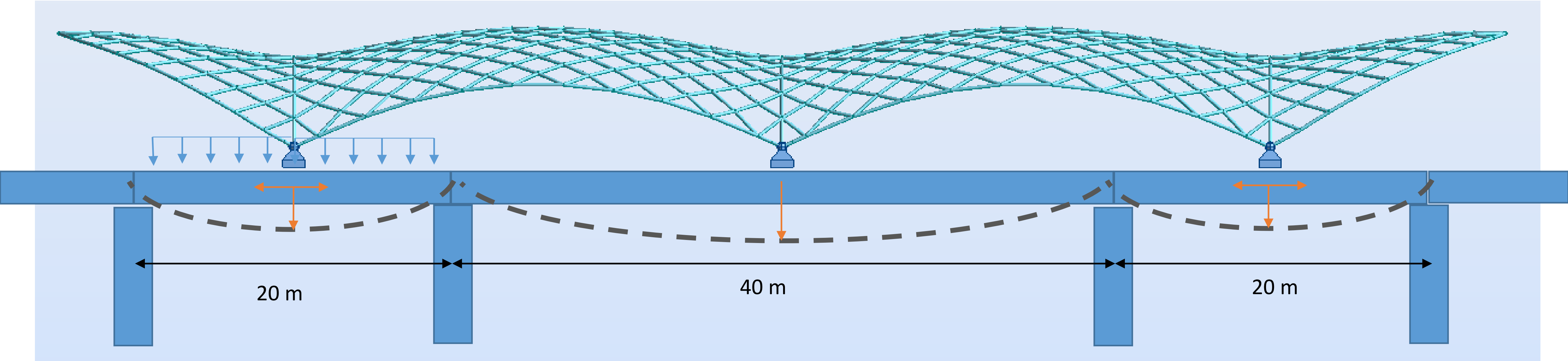
STEEL WEIGHT SAVING

£130,000

SAVING PER DESIGN

£1,4 M

TOTAL SAVING



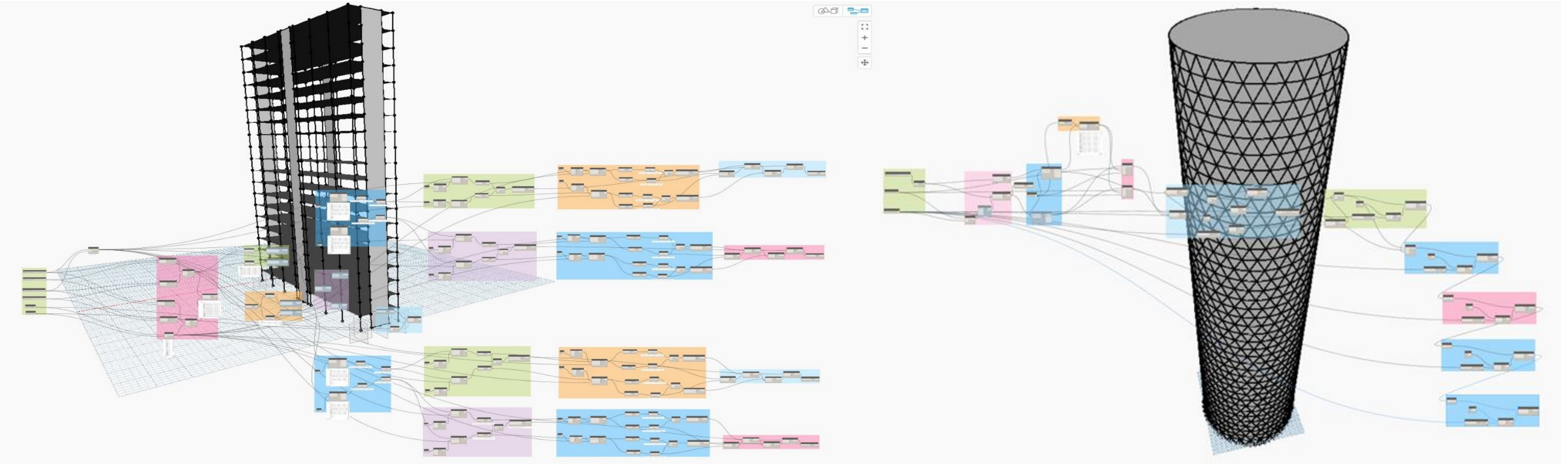
Computational Design:

Dynamo a new paradigm

What is Dynamo?

Dynamo

- *"Dynamo is a visual programming environment that enables designers to create visual logic to explore parametric conceptual designs and automate tasks"*

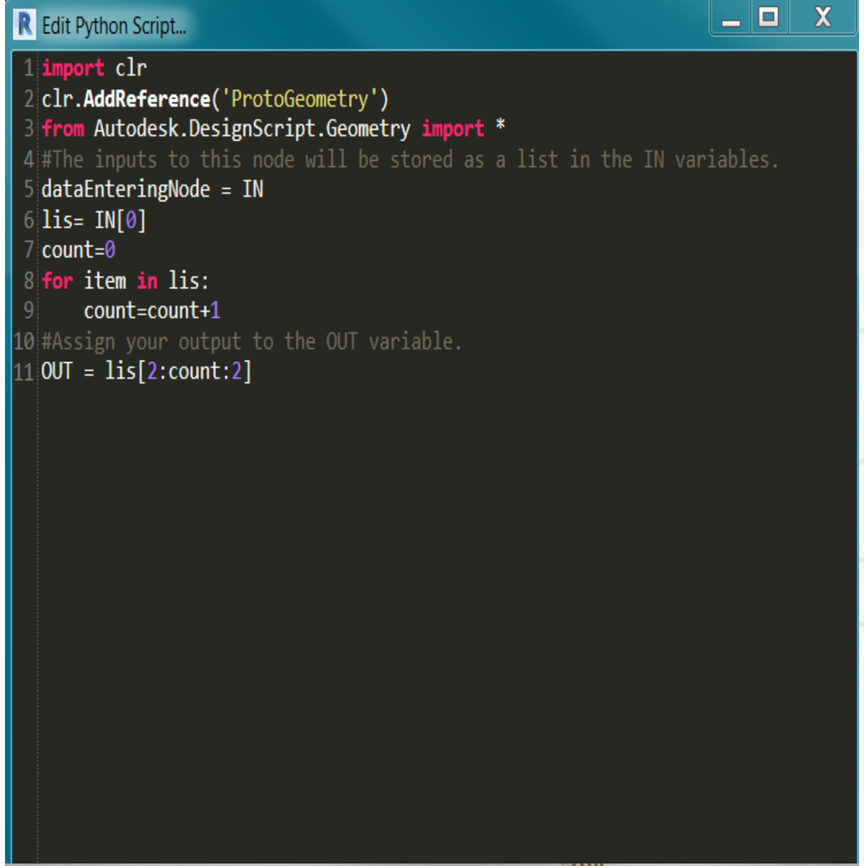


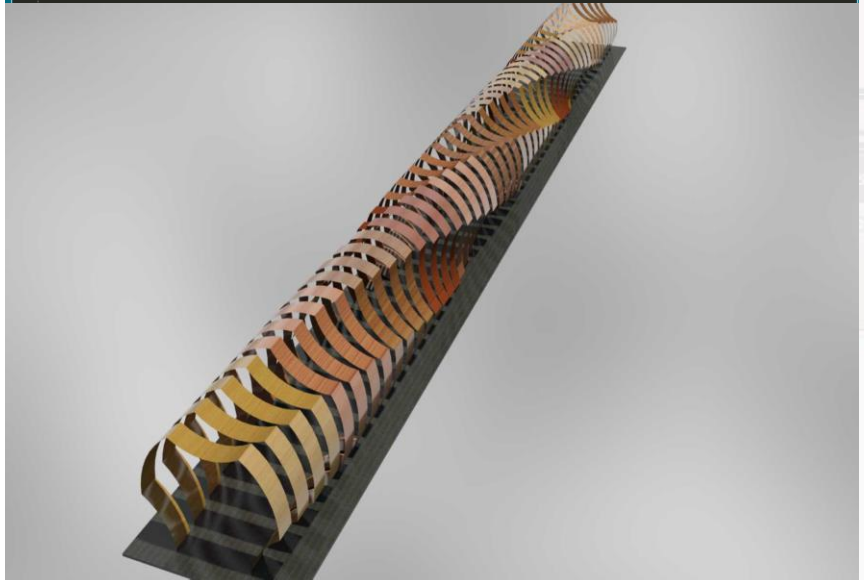
- Advanced Python coding and a seamless Revit/Dynamo/Robot interface has the potential to revolutionise the industry

- It introduces high-levels of automation, therefore reducing human errors

- Allows any variations throughout conceptual and analysis stages – Particularly relevant when dealing with unusual/complex geometry

- Optimises project resources allocation and increases productivity





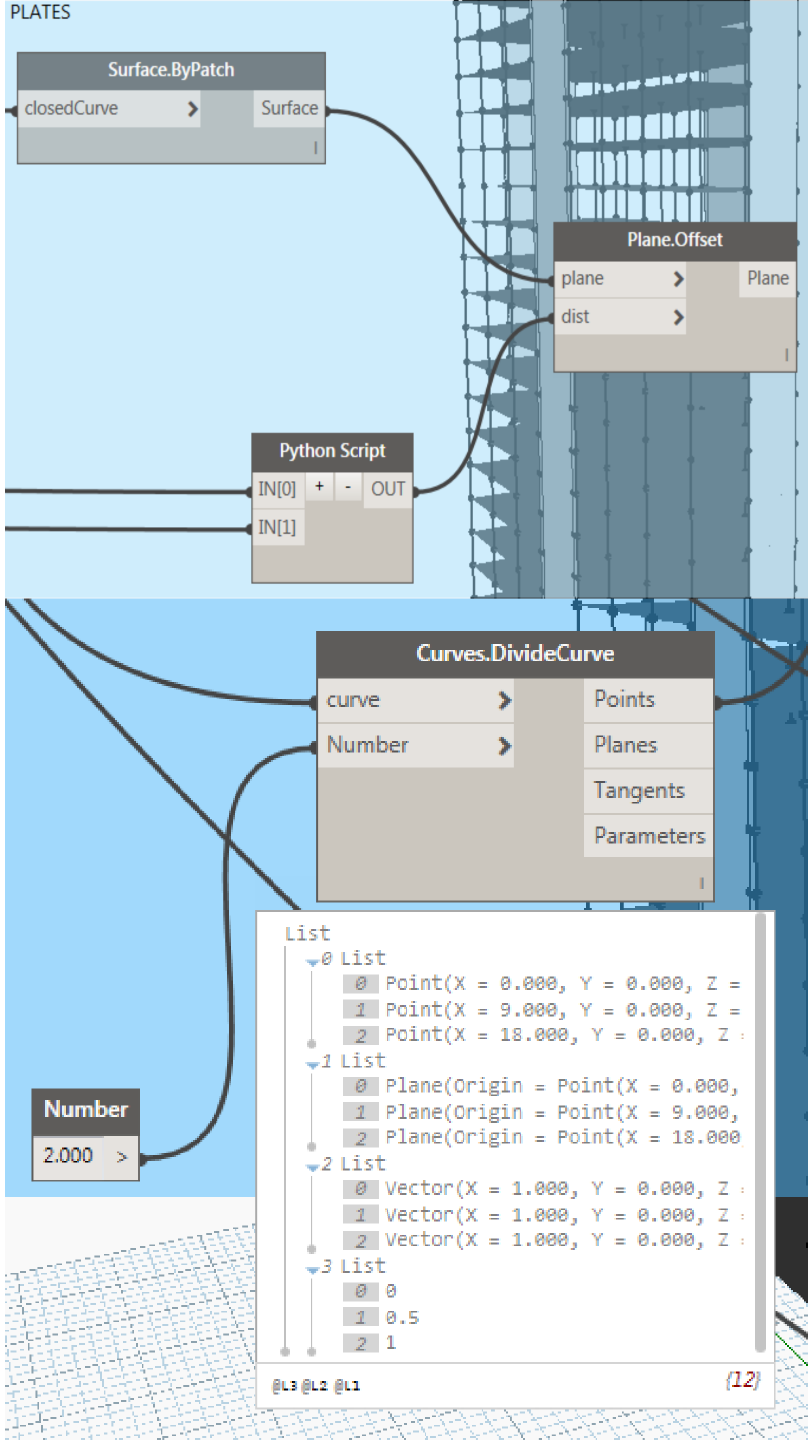
Dynamo

Dynamo's building blocks are:

- Nodes – contain the Python code
- Wires – convey the code and connect the nodes through Input and Output ports

The code:

- Python is a High-Level language i.e. uses syntax and grammar crudely approximating a natural language
- It's been used for a range of application types, including Web Development, Scientific Computing and Education (Google, Instagram, Abacus and 3DS Max are among the many users)
- Faster and Easier to write/read – Requires less effort than C++ or Java
- Portable - can be run on different operative systems

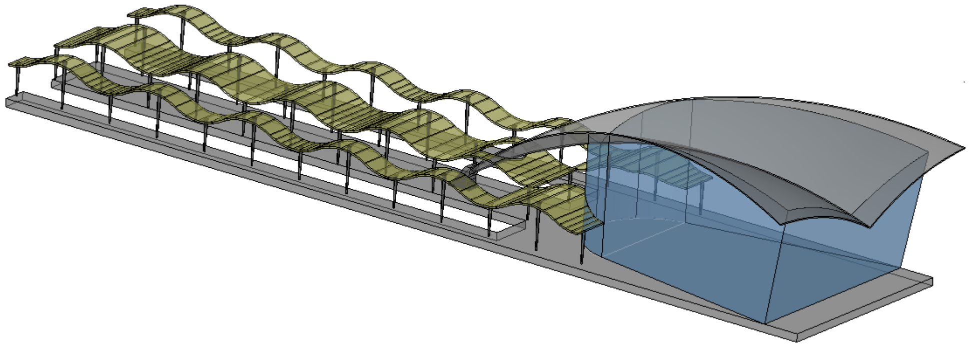


Complex Surfaces Case Study

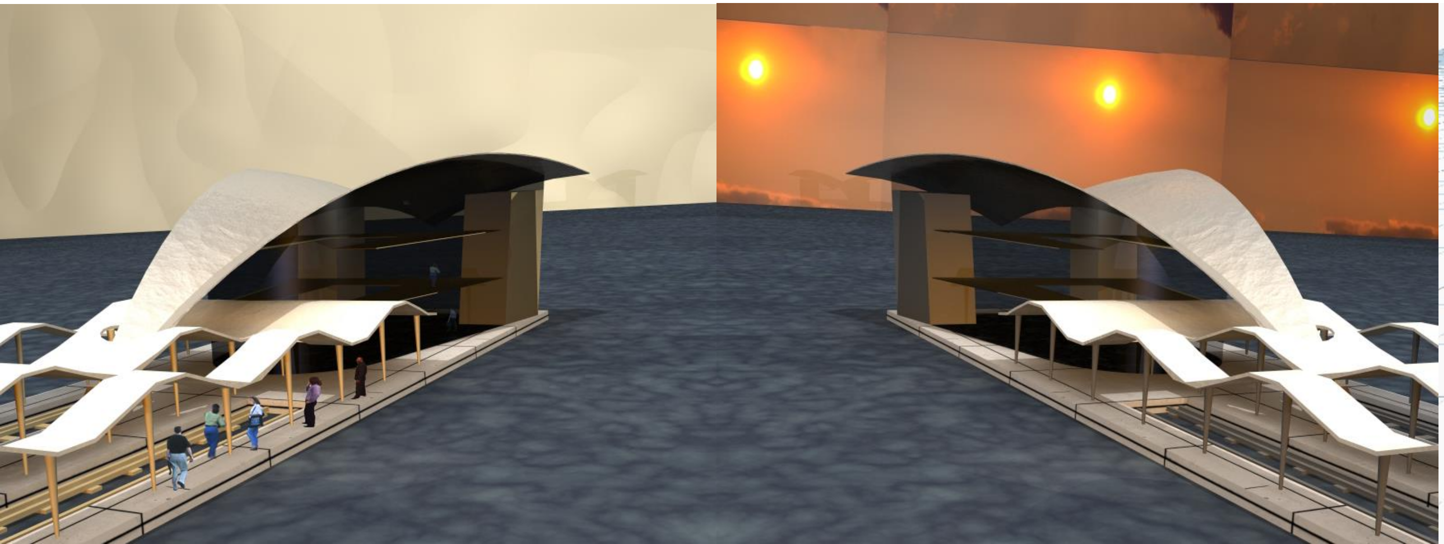
Complex surfaces

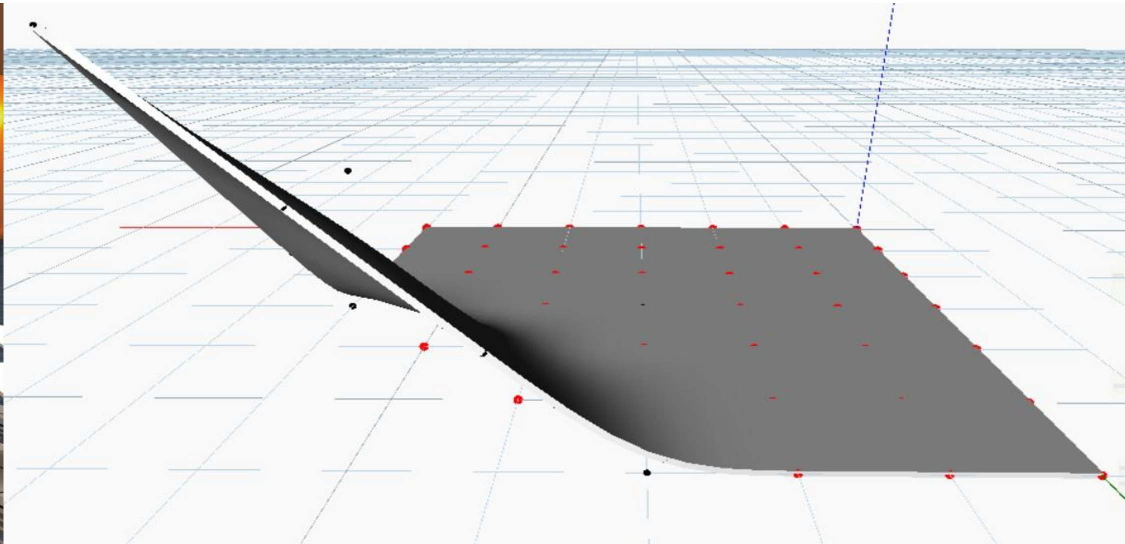
Two algorithms have been developed:

1) Complex surfaces defined by closed boundaries
2) Complex surfaces defined by NURBs- Non Uniform Rational Basis Splines



$$R_{i,j}(u,v) = \frac{N_{i,n}(u)N_{j,m}(v)w_{i,j}}{\sum_{p=1}^{k}\sum_{q=1}^{l} N_{p,n}(u)N_{q,m}(v)w_{p,q}}$$

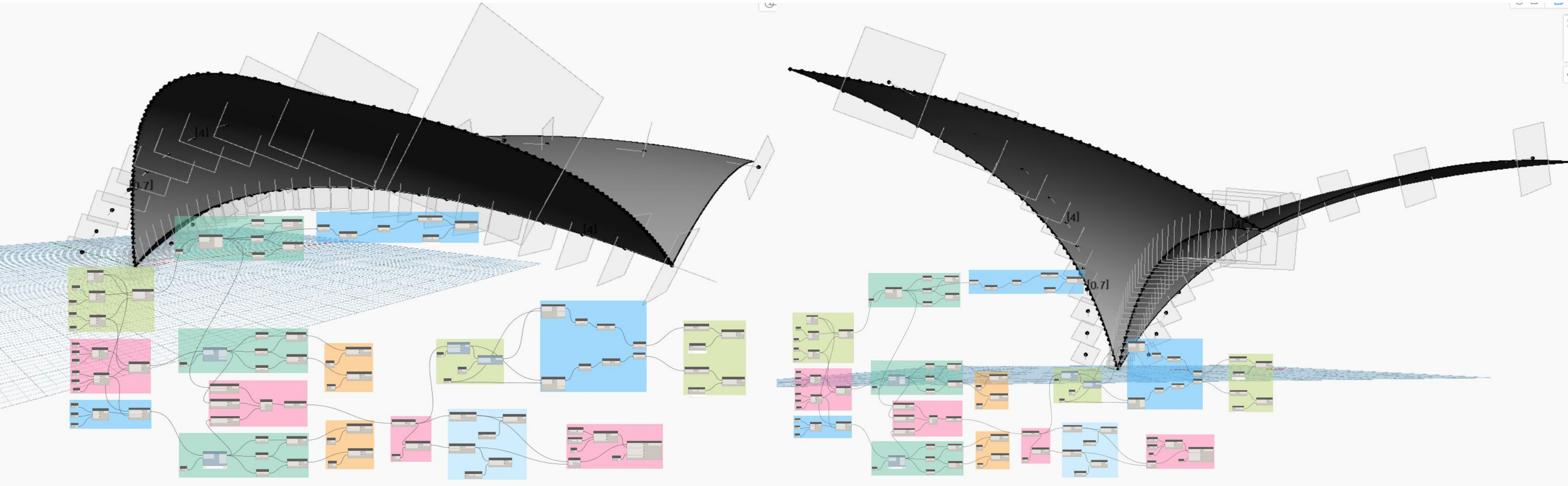




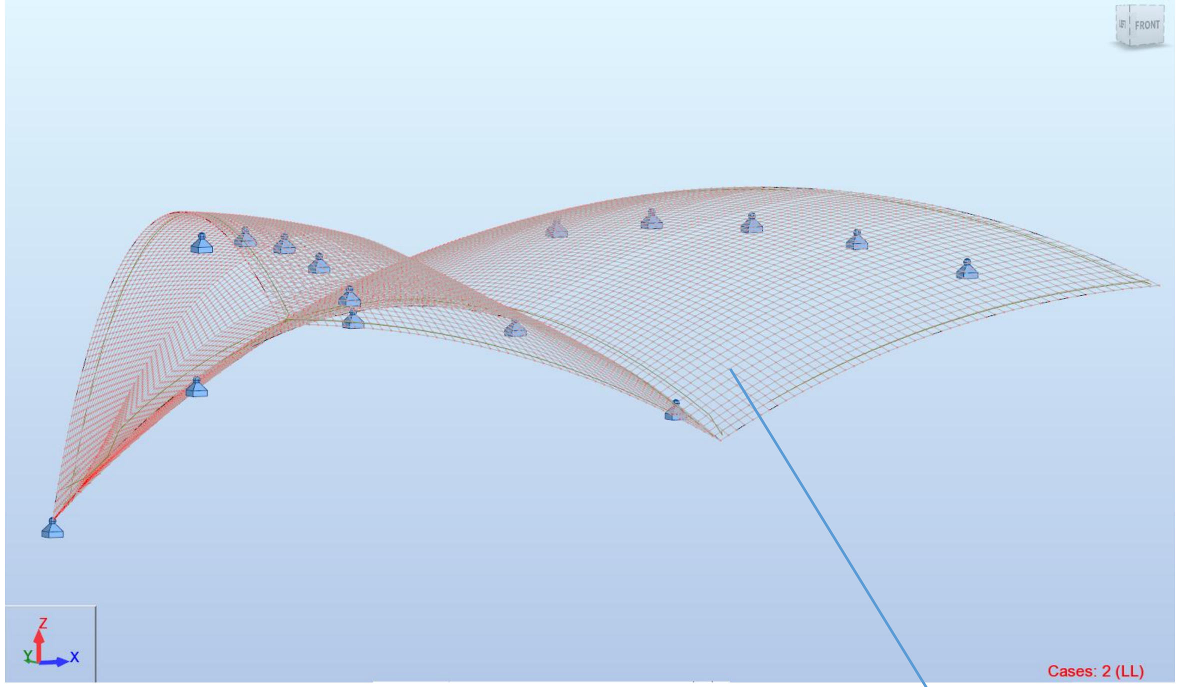
1) Complex surfaces defined by closed boundaries

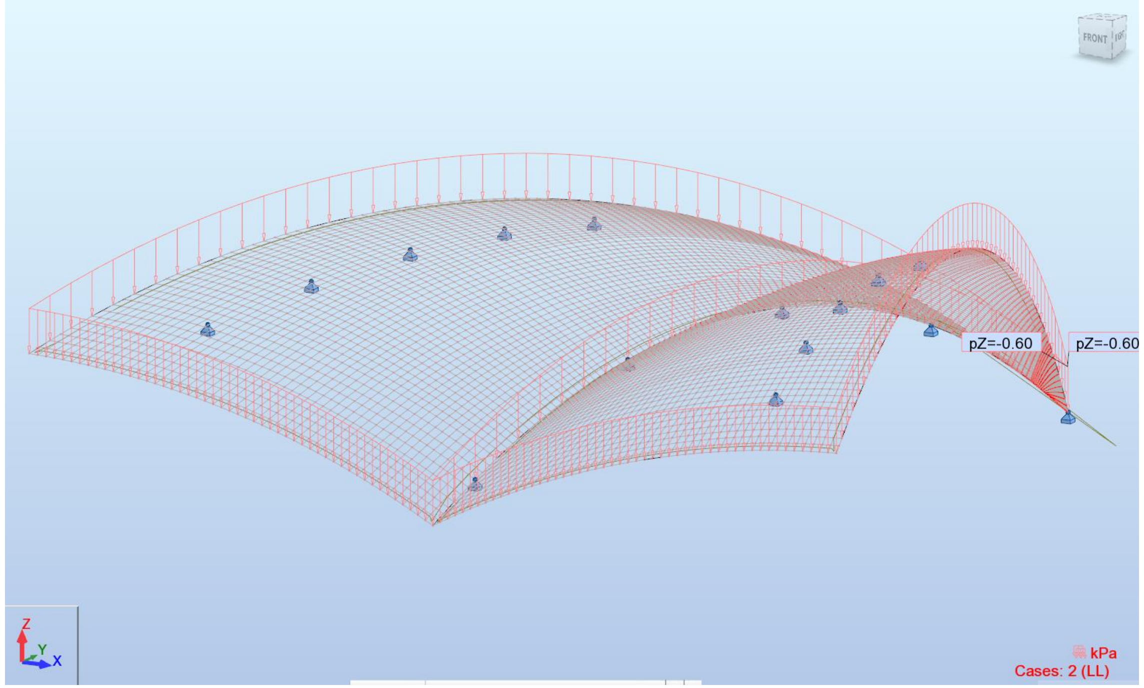
- Double curvature reinforced concrete roof shell

- The algorithm comprise all the key **geometric and structural parameters** required to generate a fully parametric surface and run the structural analysis (arch radius, spans, material properties, support conditions, load cases)



1) Complex surfaces defined by closed boundaries





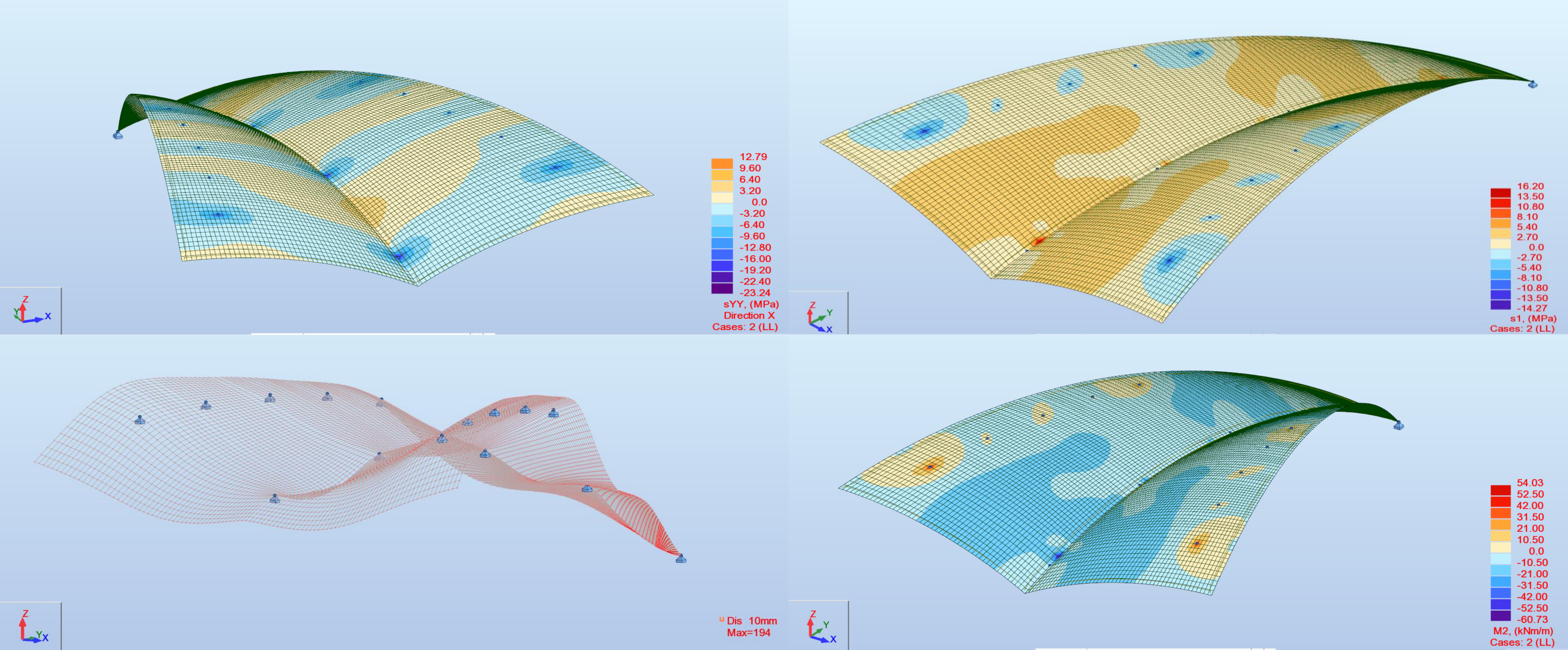
Support Conditions - automatically generated by algorithm and fully parametric

Coons meshing methodology, using 4 nodes quadrilaterals

Load cases - automatically generated by algorithm and fully parametric (Live Load = 0.6 kN/m^2)

1) Complex surfaces defined by closed boundaries

Finite Elements Analysis Results (Shell Thickn. =150mm) - Principal Stresses, Moments and Displacements



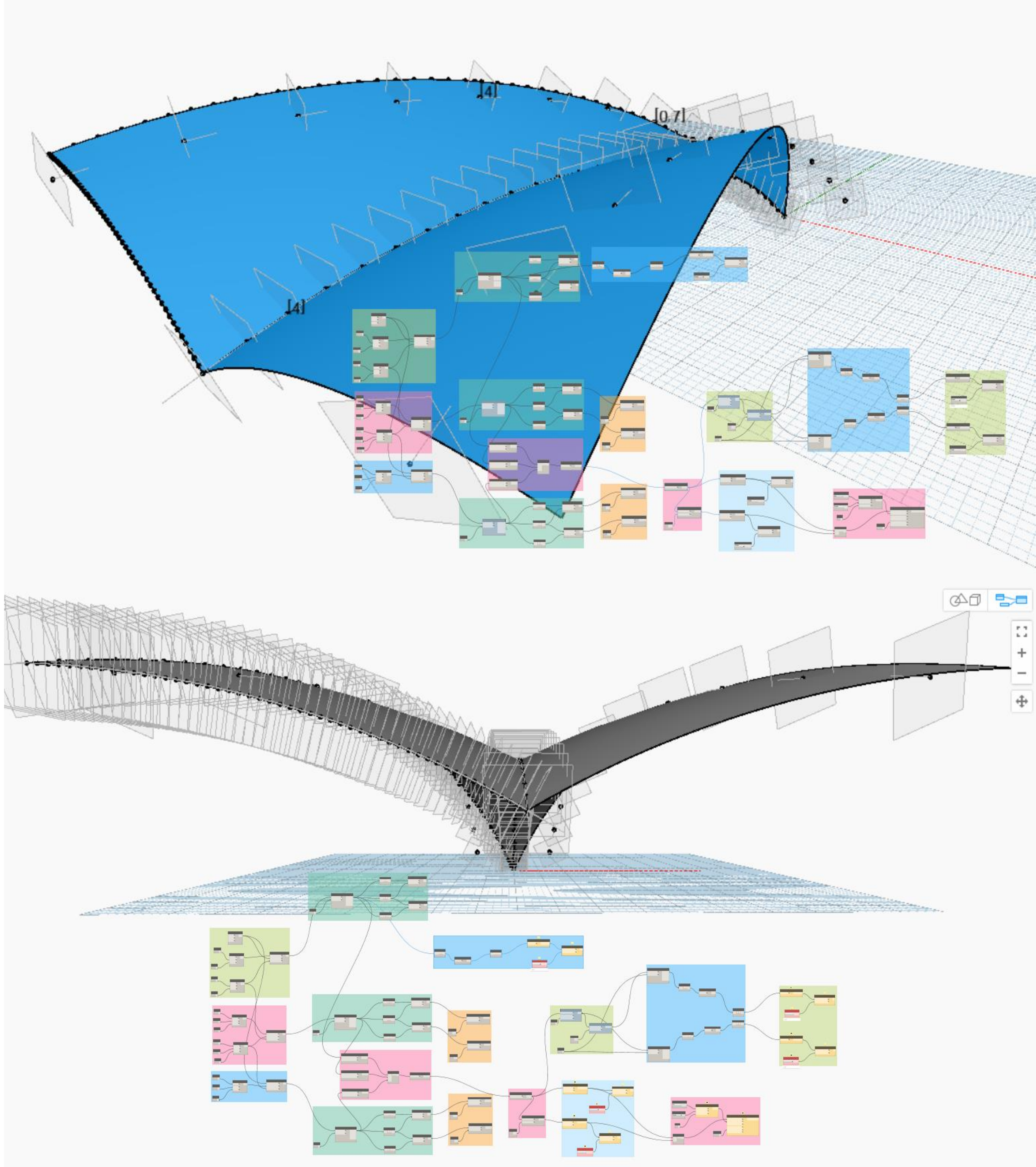
1) Complex surfaces defined by closed boundaries

Key findings

- No issues were encountered when coding, generating and exporting the analytical model to Robot

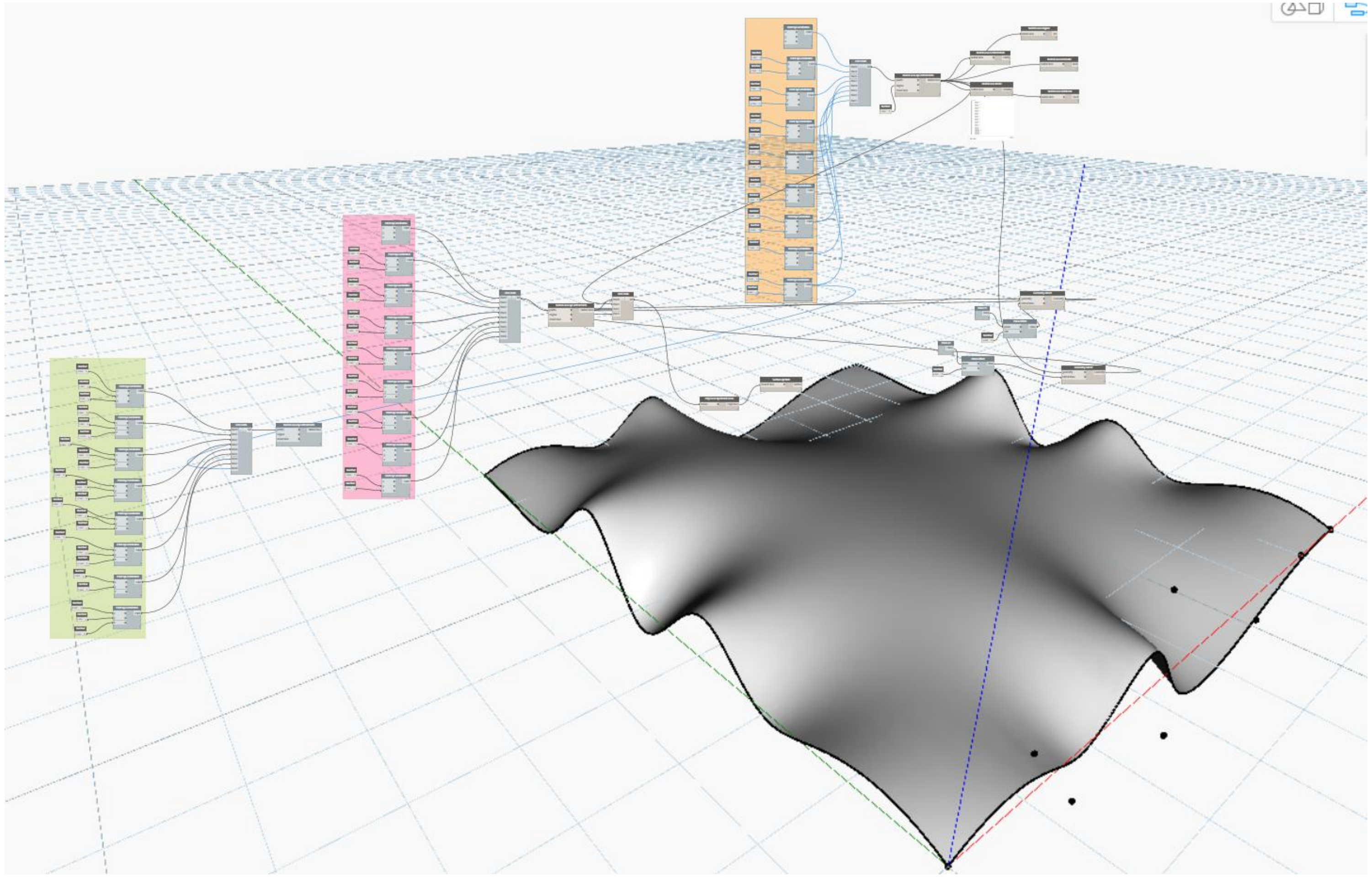
- Seamless, effective, powerful Revit/Dynamo/Robot interface

- Any variation introduced in the parameters is automatically fed into the Robot model

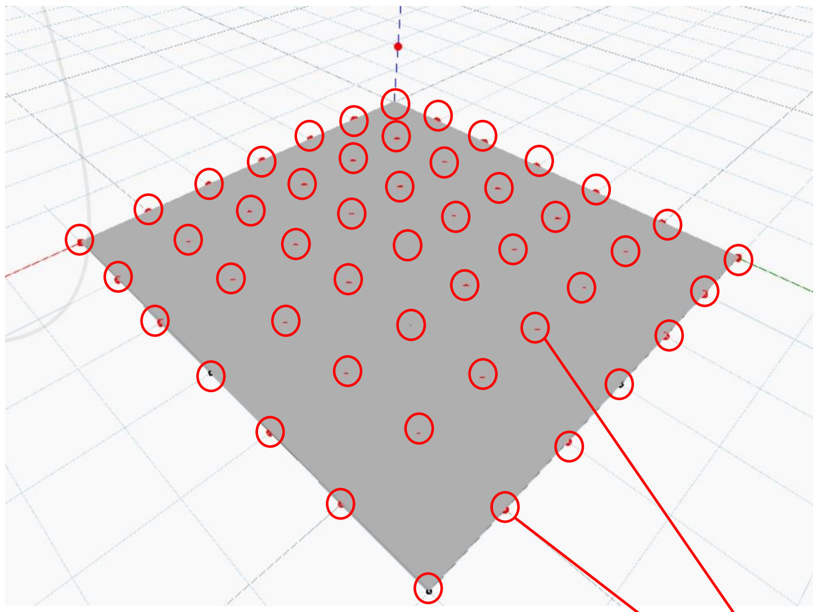


2) Complex surfaces defined by NURBs

- NURBs are complex entities defined by Degree and Control Points
- They are mathematical representations of three-dimensional complex geometry
- Used predominantly for Aeronautical Engineering but also has potential applications for Structural Engineering e.g. Tensile Structures and RC Shells

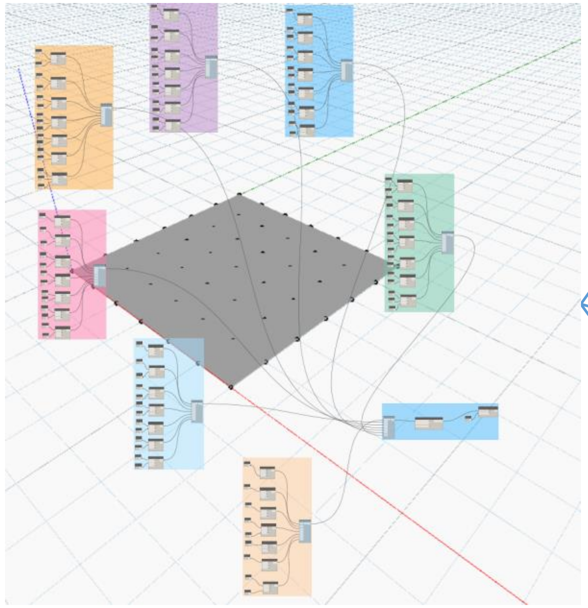


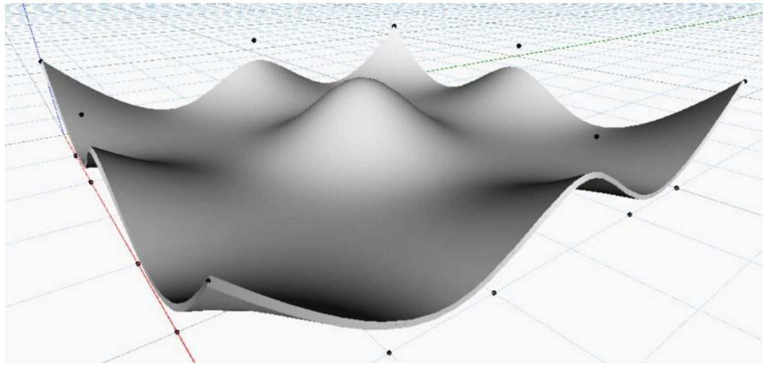
2) Complex surfaces defined by NURBs

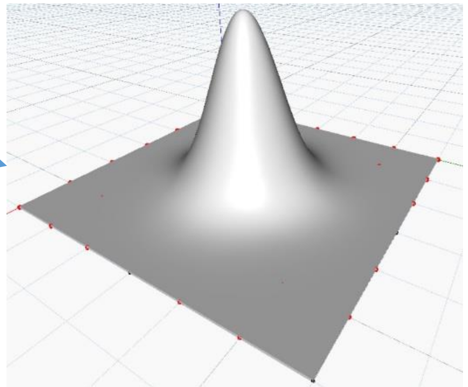


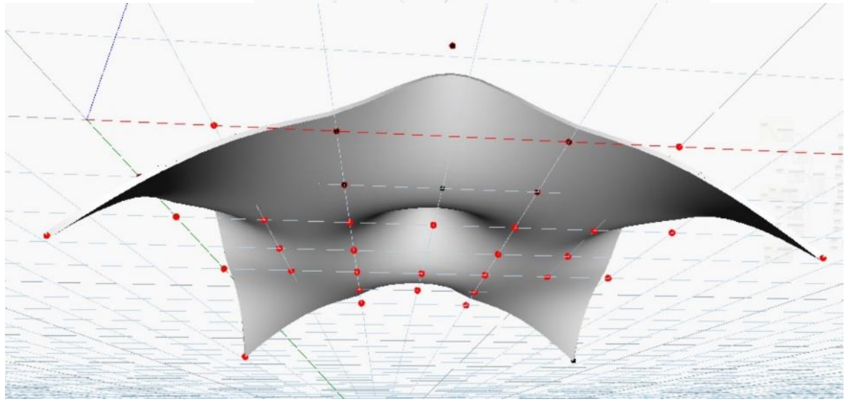
A plane NURB surface comprising 49 control points can be used to generate multiple complex surfaces

Control points









Caeiro Correia, Luis

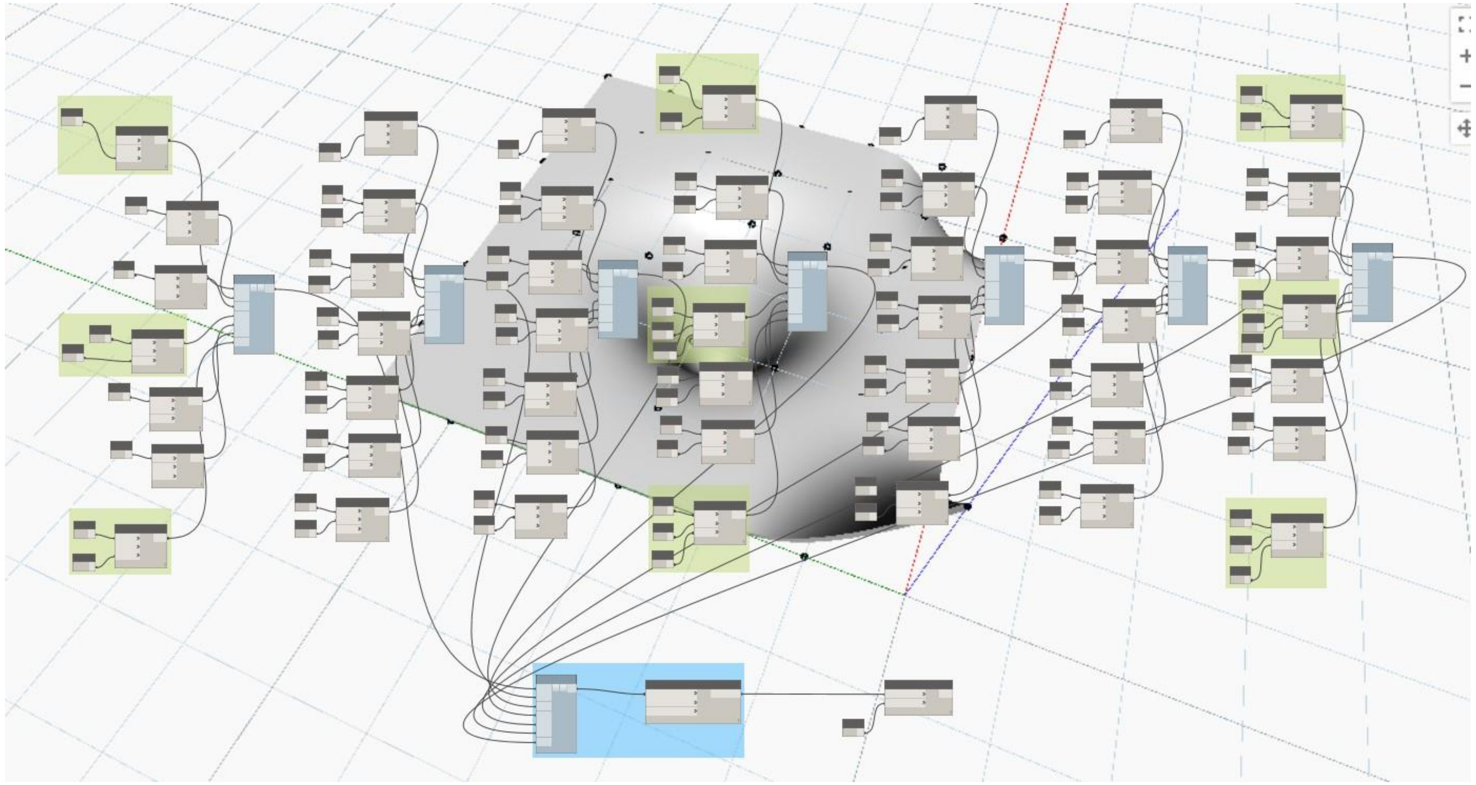
Meeting start time: 11 June 2018 12:15:34

Organizer: Caeiro Correia, Luis

2) Complex surfaces defined by NURBs

Key findings

- The algorithm generates virtually any surface within Dynamo's environment regardless of its complexity
- However, difficulties were encountered to export the data to Robot
- This study suggests that Robot cannot produce analytical surfaces/panels originated from NURBs
- If possible Autodesk should try to improve the Dynamo/Robot interface as it would be a giant leap for the analysis and design of complex surfaces



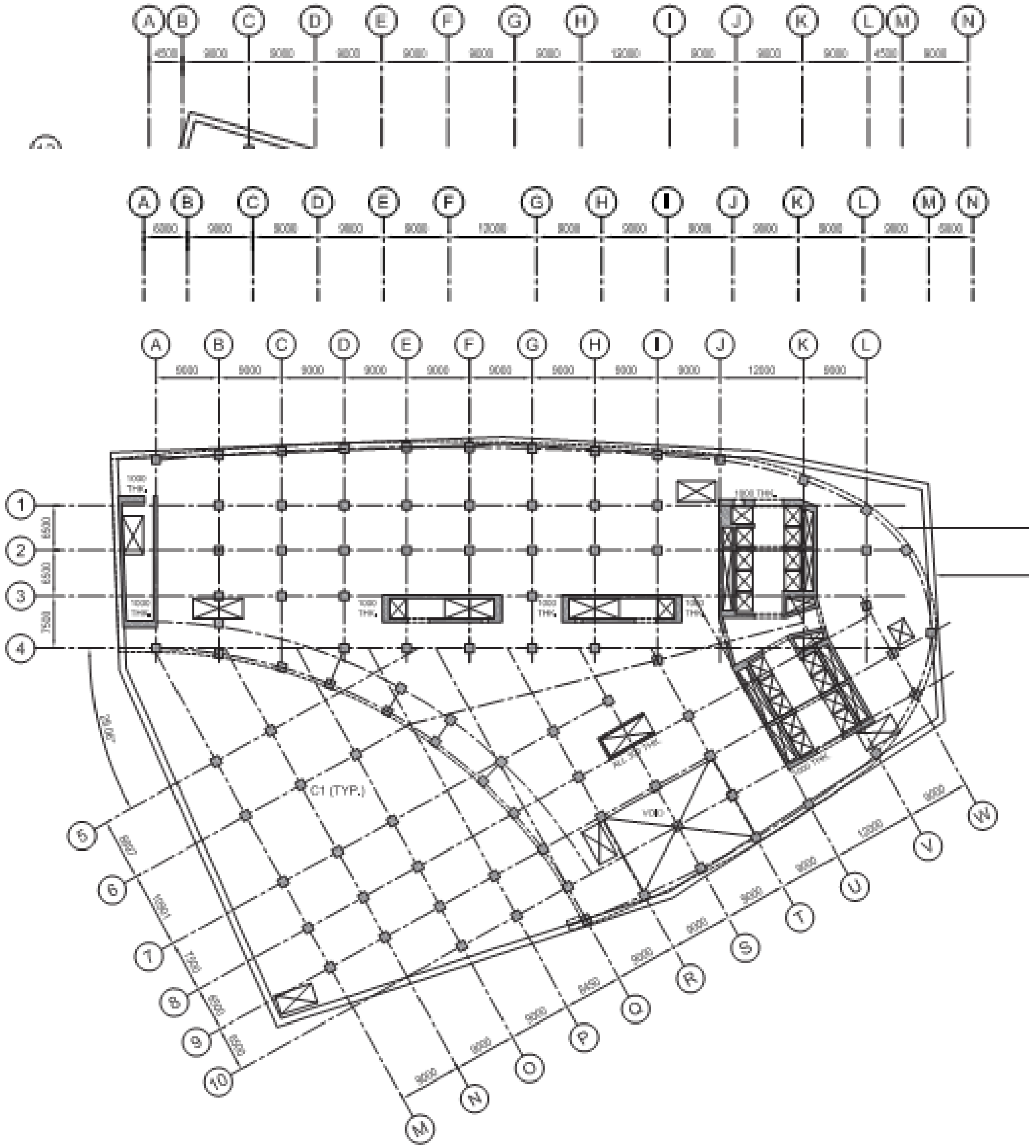
Computational Design:

Parametric Scheme Design

Parametric Scheme Design: Problem

Early stage structural design requires great adaptability due to:

- Ambitious architects
- Adventurous clients
- Huge potential for value savings



Parametric Scheme Design: Solution

We have created a rapid optioneering tool to meet these challenges

- Utilising Revit, Robot and Dynamo to rapidly produce multiple scheme design options
- Providing raw data to allow for a better understanding of influence of material choice and building form
    - This data is broken down into material cost, embodied C02 and programme implications
- Brings better value to clients by allowing them to make timely decisions about structural frame options

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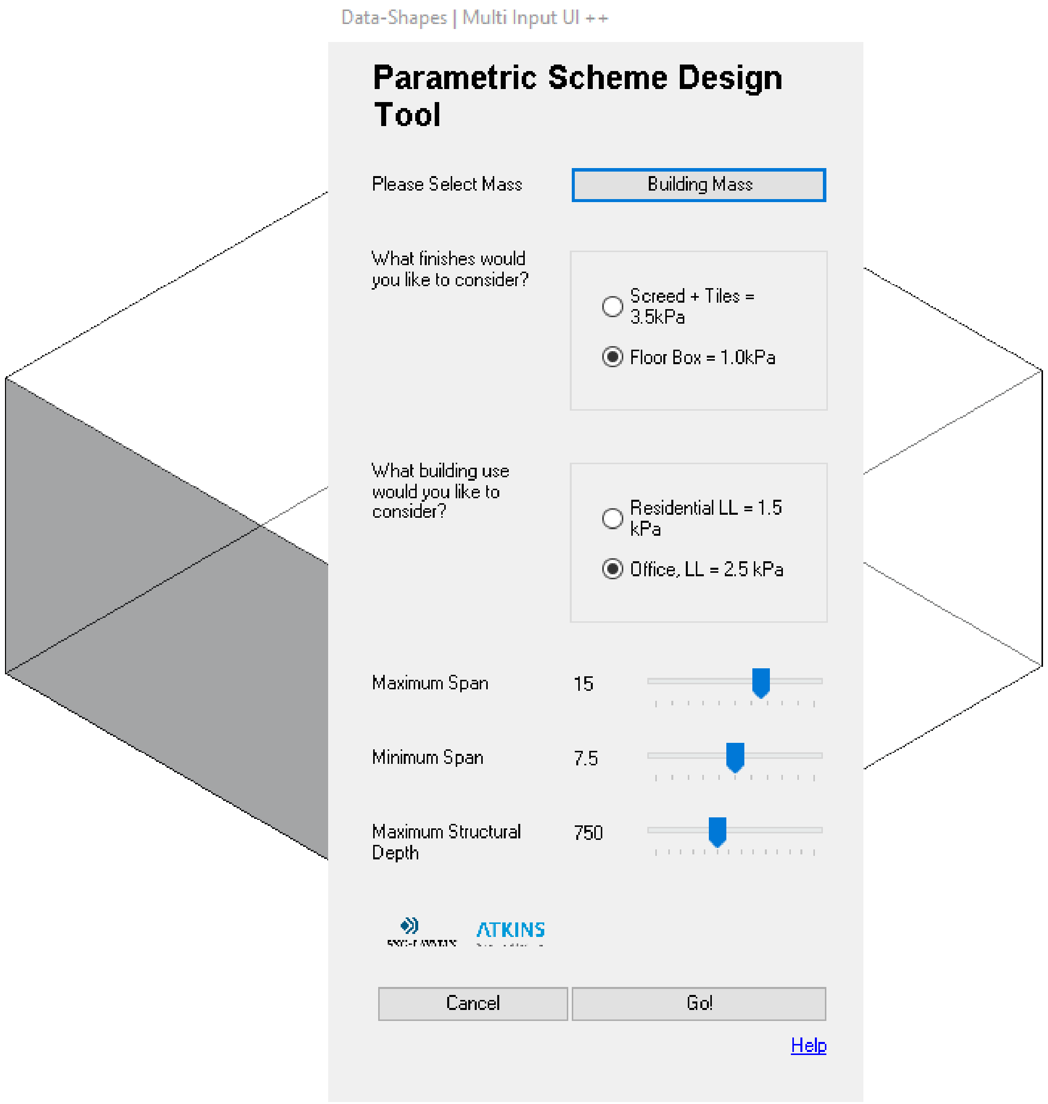
New Civil Engineer TechFest. FESTIVAL OF INNOVATION AND TECHNOLOGY 2018 FINALIST

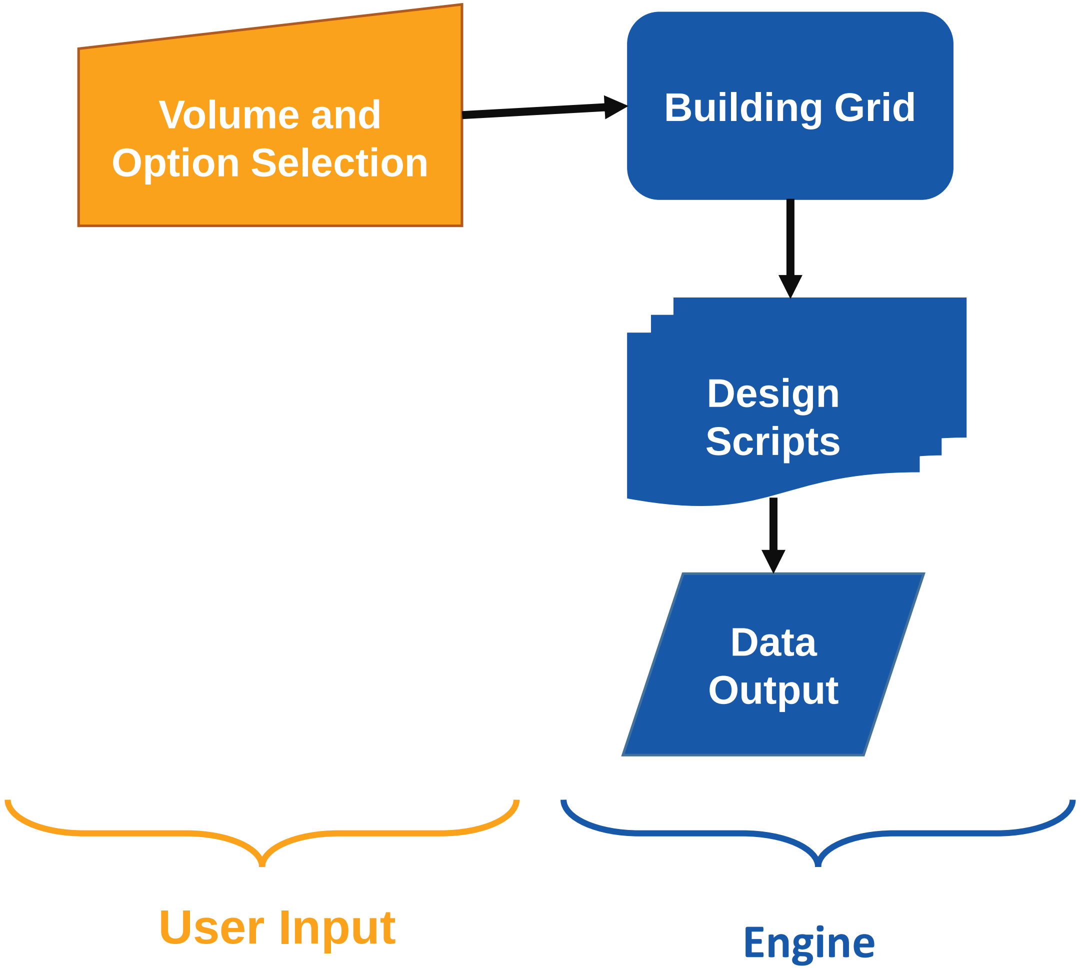
Parametric Scheme Design - Workflow

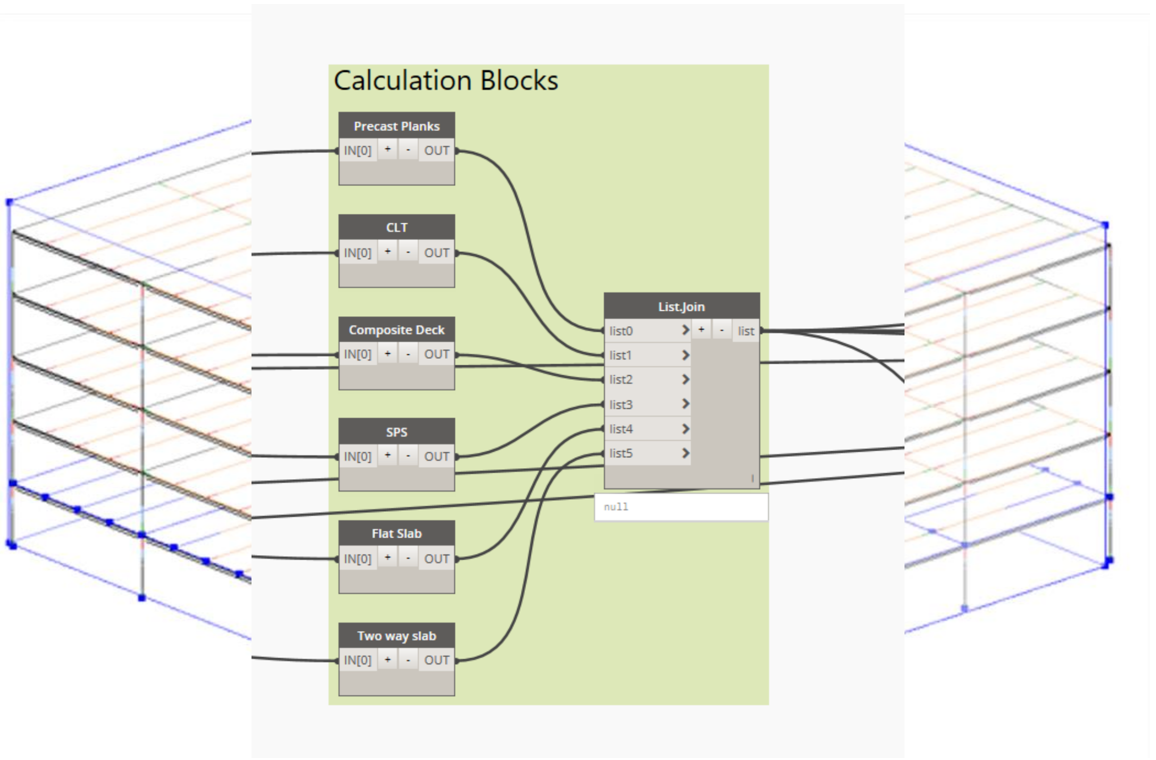
Volume and Option Selection

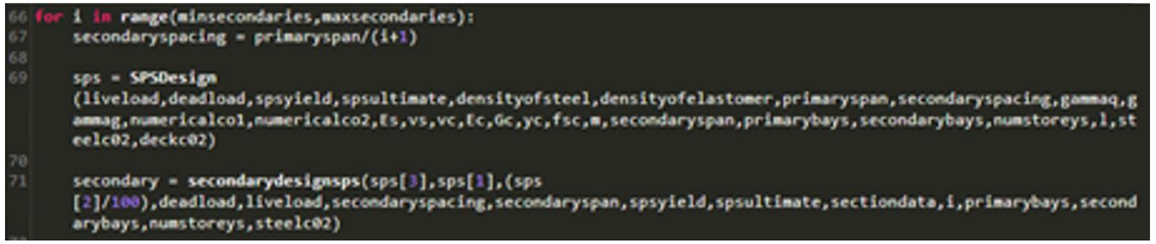


User Input

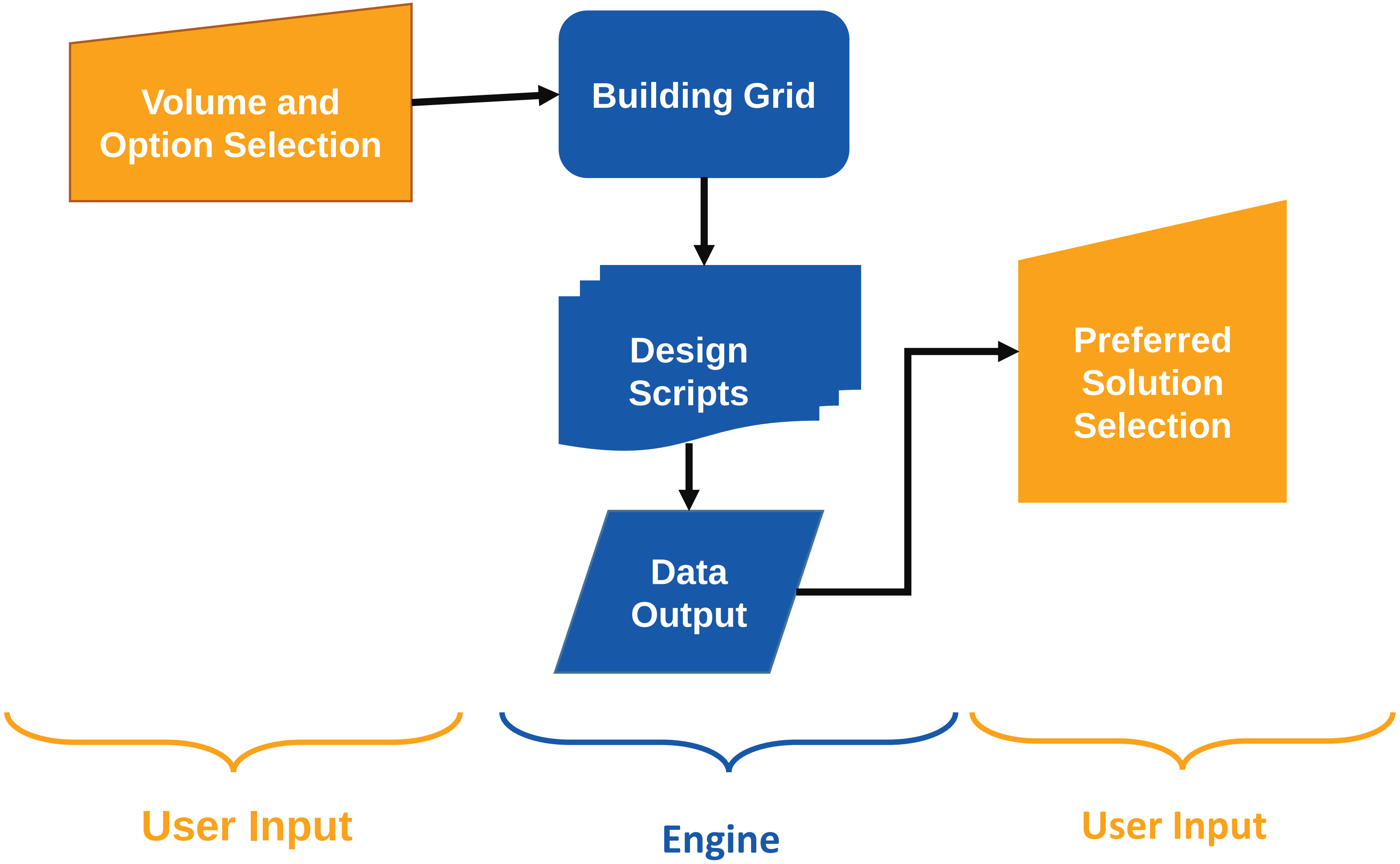
Parametric Scheme Design - Workflow

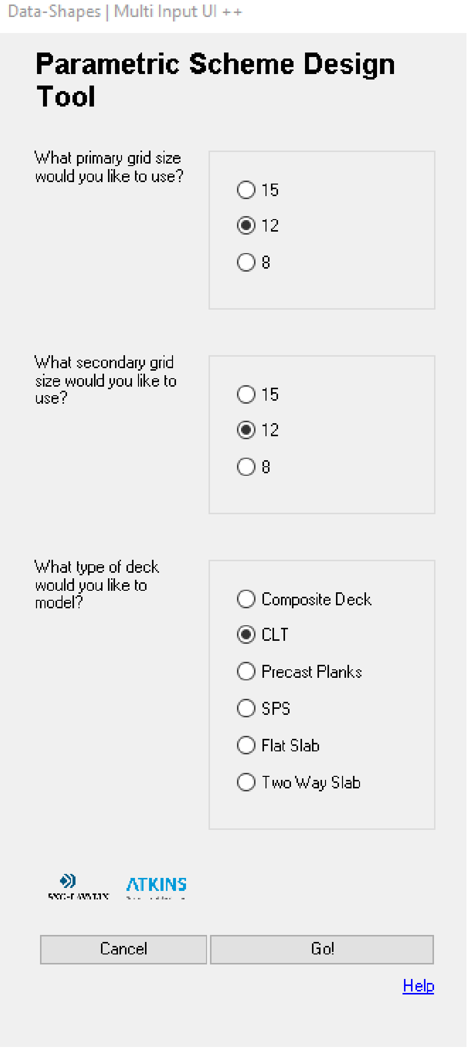




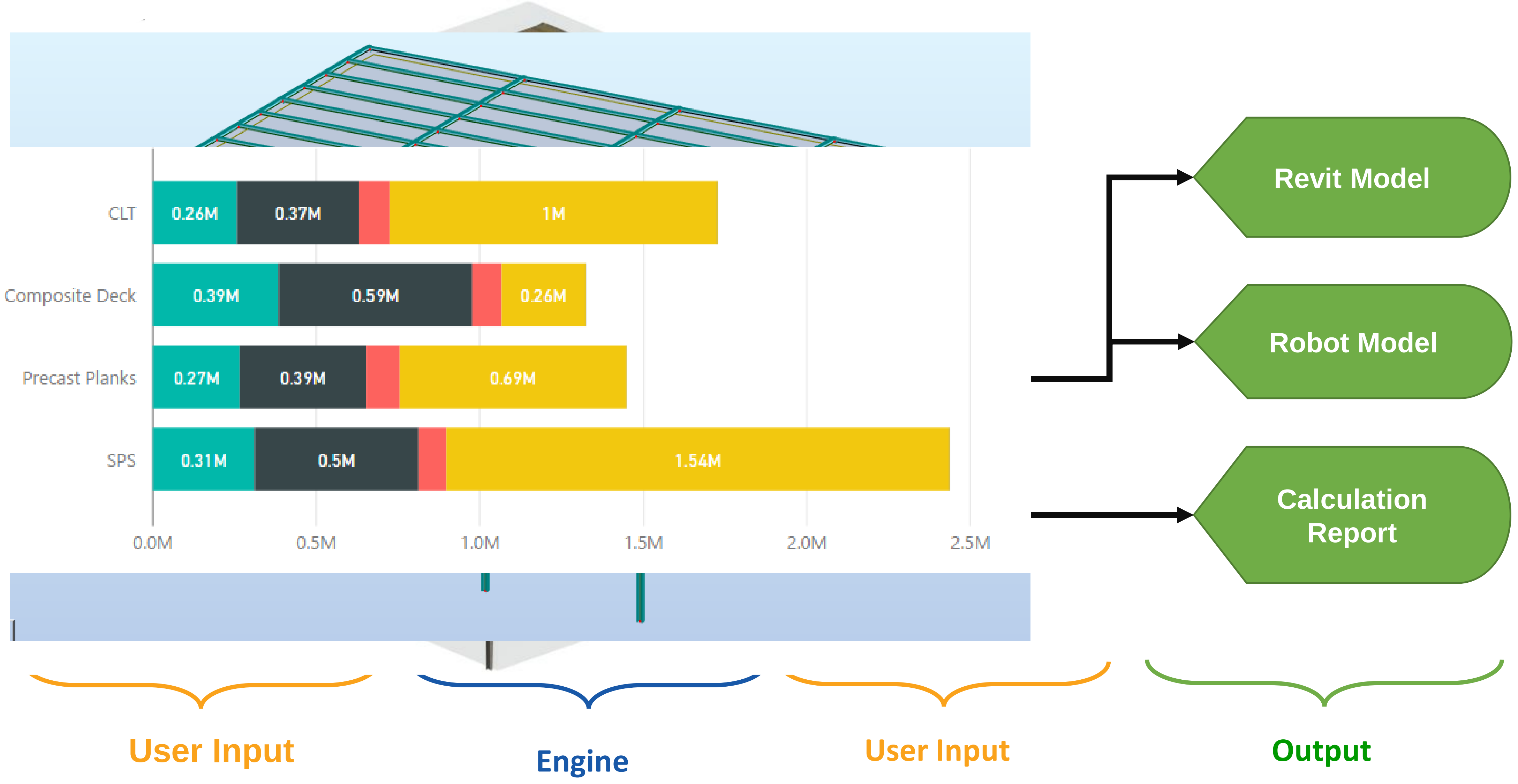


Parametric Scheme Design - Workflow





Parametric Scheme Design - Workflow

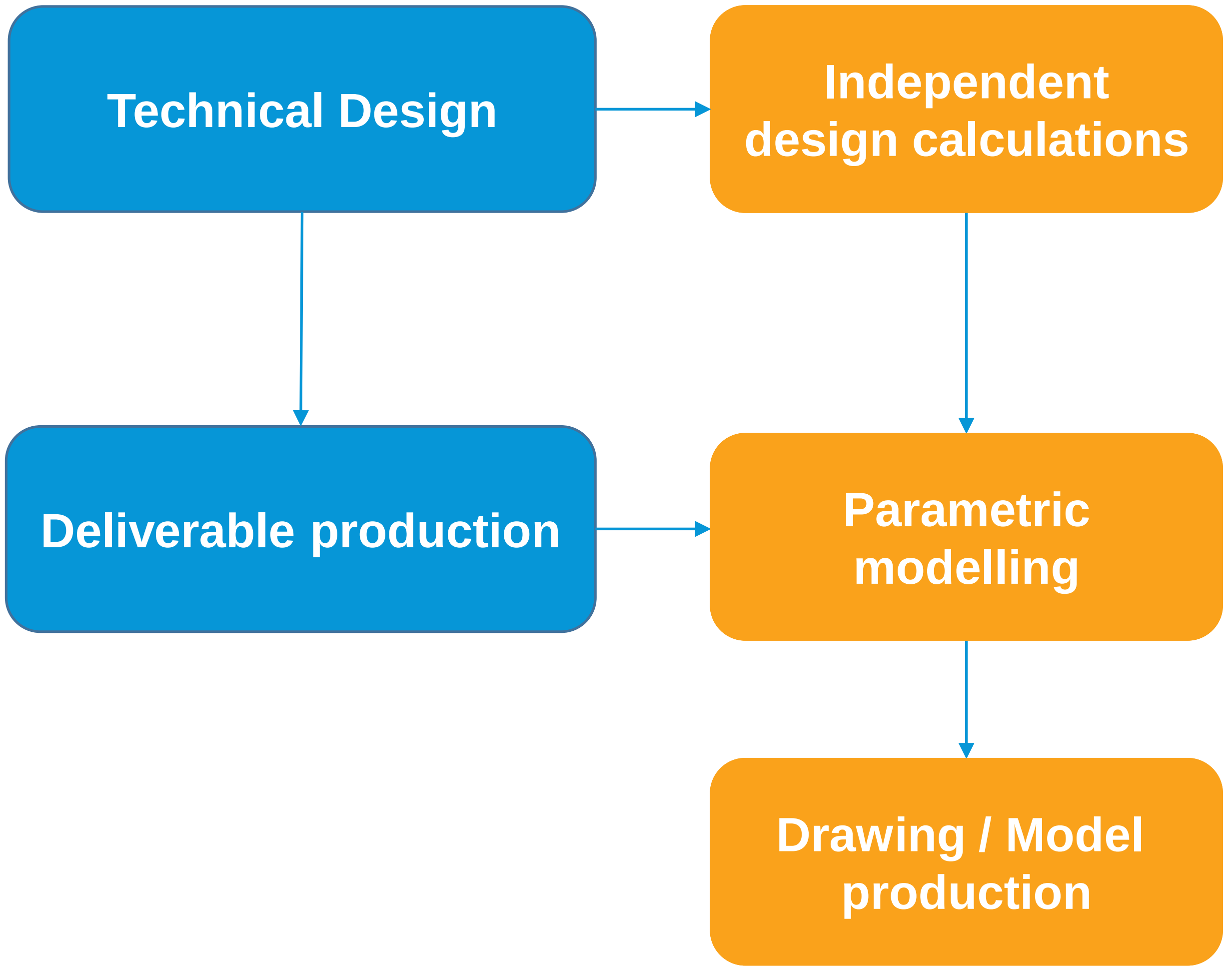


Computational Design:

Design Delivery

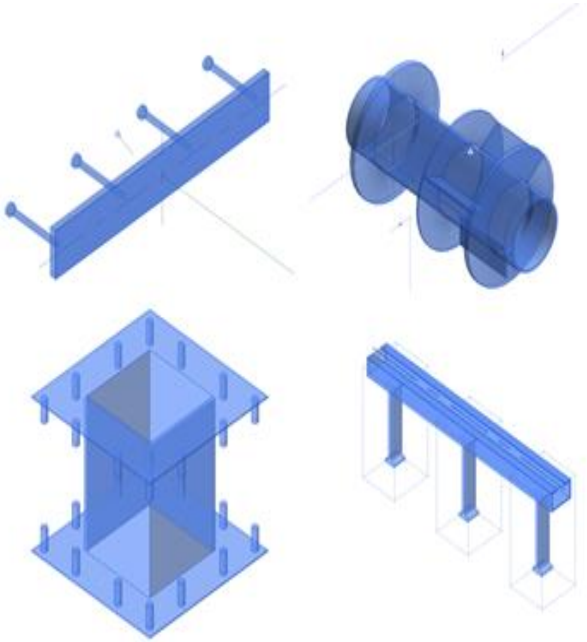
Design Delivery

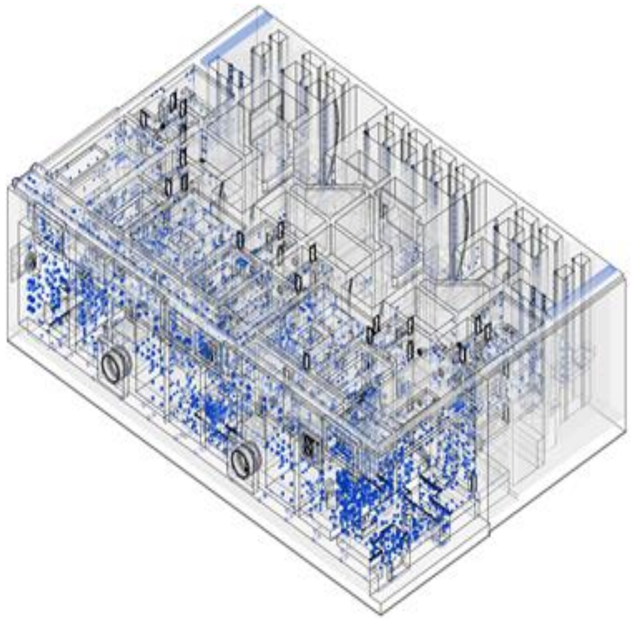
- Traditional design tools can be integrated with parametric delivery tools.
- Parametric analysis links don't always suit your needs.
- Goal is to free up resource and fee for value adding activity.

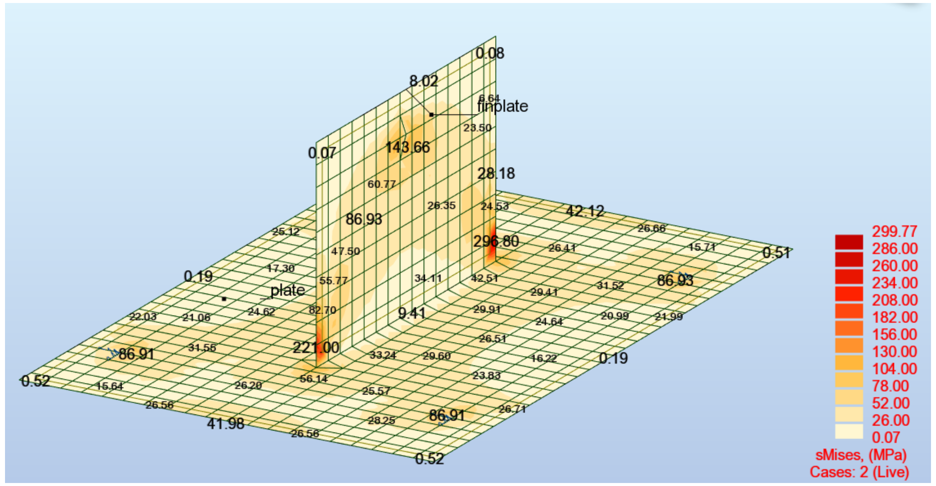


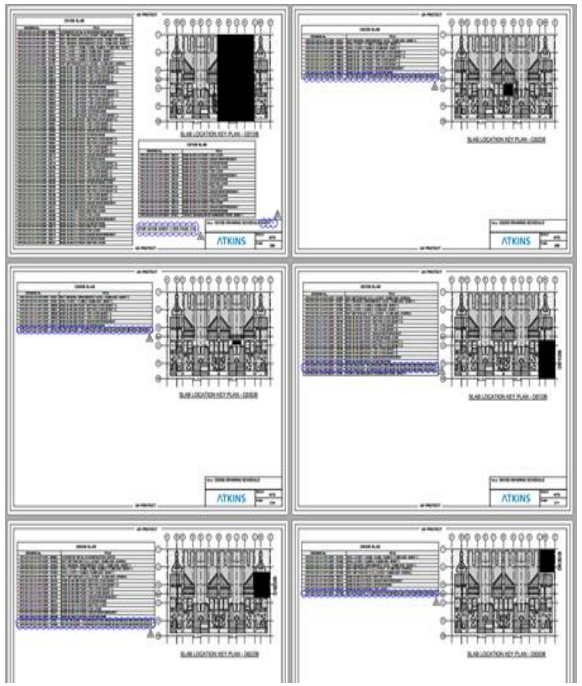
Design Delivery

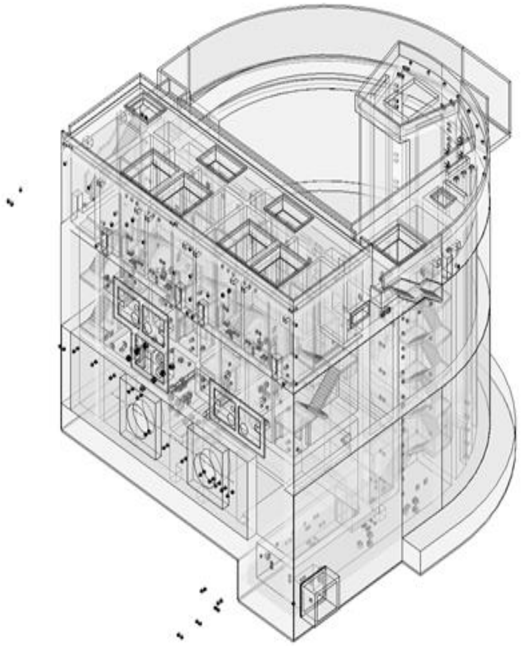
- Use simple scripts - bigger isn't always better.
- Automating repetitive simple tasks often produces massive efficiencies.







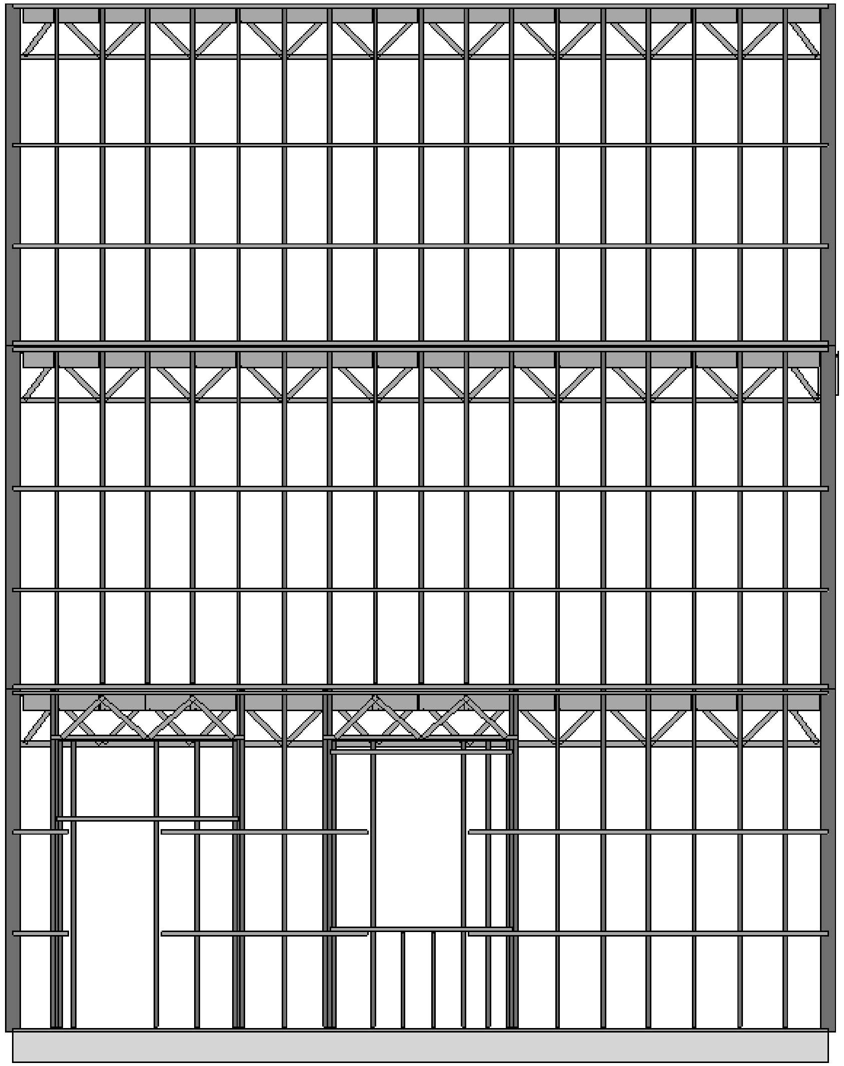




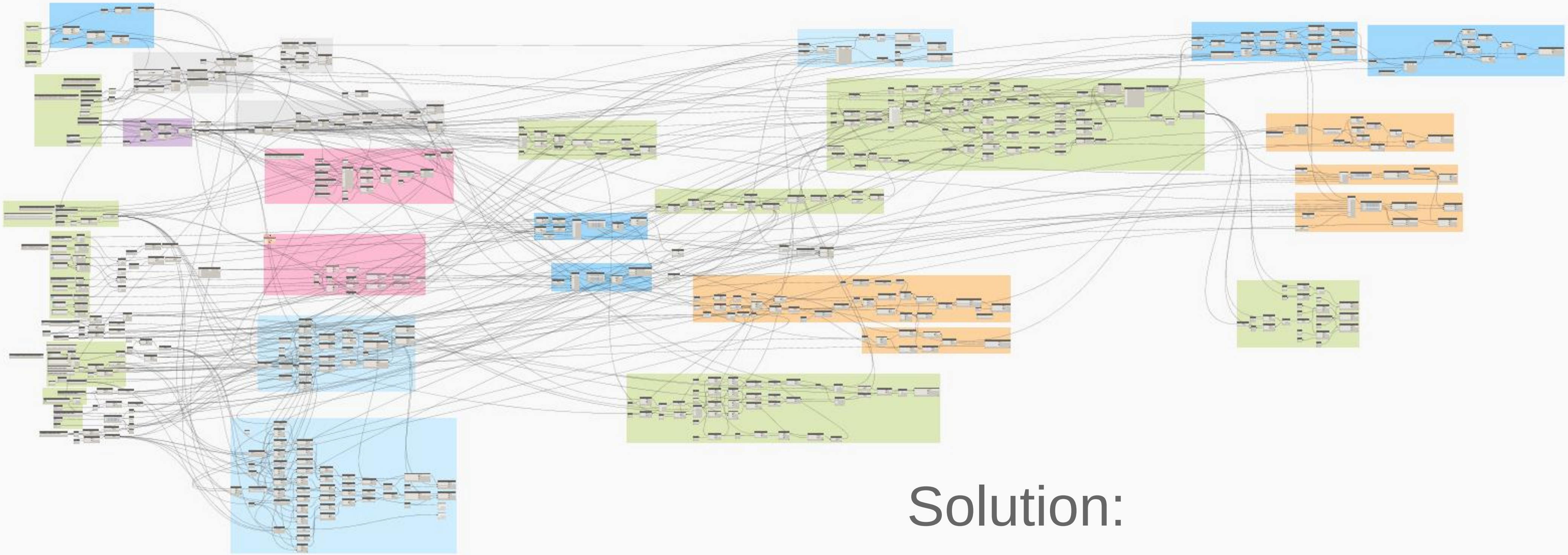

Design Delivery:
Modular Housing

Key Elements:

- Significant modelling effort
- Modular system design
- Design developed independently

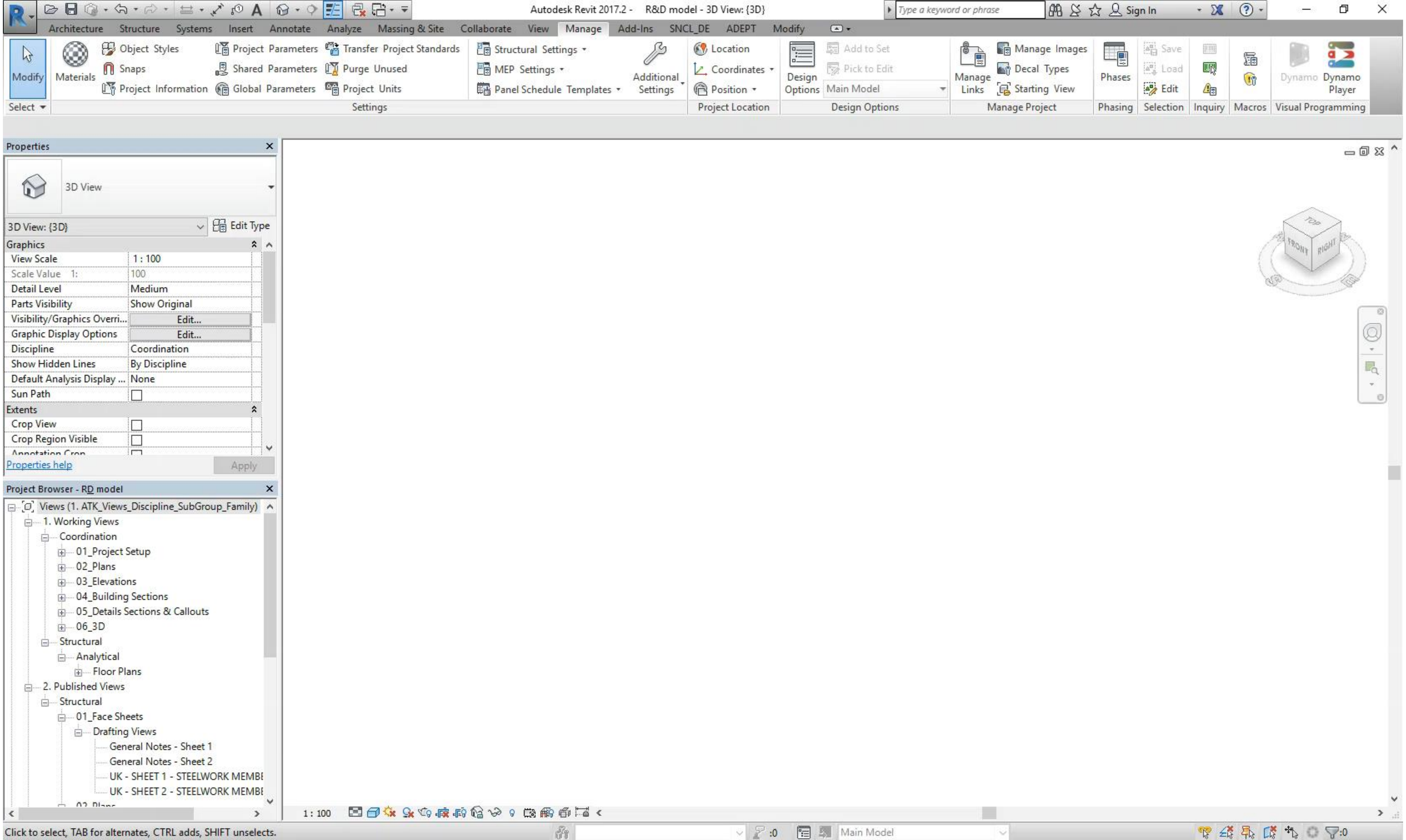


Design Delivery: Modular Housing



Solution:

- Parametric Modelling
- Automated Calculations



Autodesk Revit 2017.2 - R&D model - 3D View: {3D}
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Sign In
Architecture
Structure
Systems
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Shared Parameters
Global Parameters
Transfer Project Standards
Purge Unused
Project Units
Structural Settings
MEP Settings
Panel Schedule Templates
Additional Settings
Settings
Location
Coordinates
Position
Project Location
Design Options
Add to Set
Pick to Edit
Main Model
Design Options
Manage Links
Manage Images
Decal Types
Starting View
Manage Project
Phases
Phasing
Save
Load
Edit
Selection
Inquiry
Macros
Dynamo
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Coordination
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Crop View
Crop Region Visible
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1. Working Views
Coordination
01_Project Setup
02_Plans
03_Elevations
04_Building Sections
05_Details Sections & Callouts
06_3D
Structural
Analytical
Floor Plans
2. Published Views
Structural
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UK - SHEET 2 - STEELWORK MEMBE
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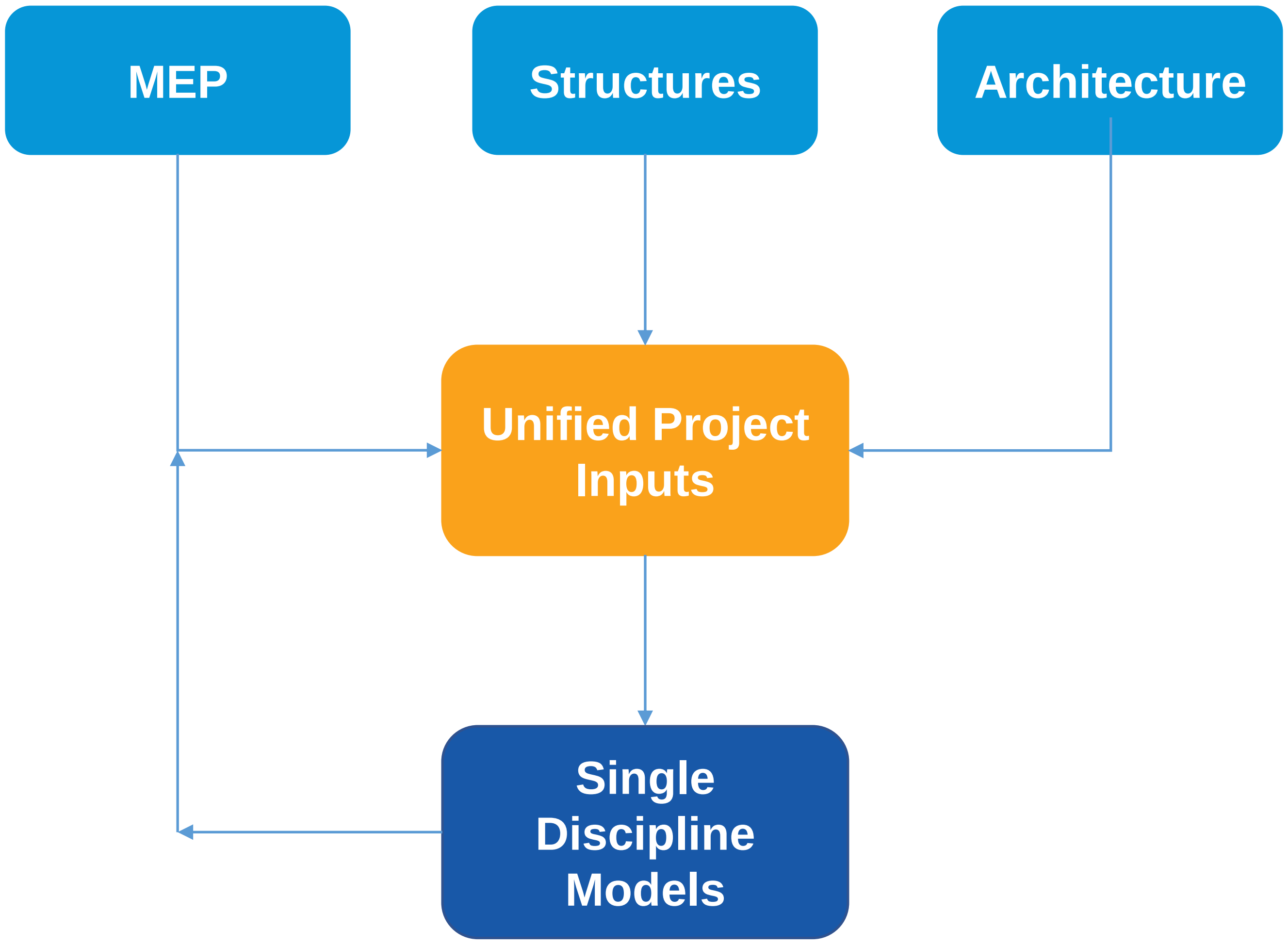
Main Model

Design Delivery: Modular Housing

Lessons Learnt:

- Think multi-disciplinary
- Geometry is complex!
- More detail at early RIBA stages



What’s Next?

What’s Next?

A broader approach

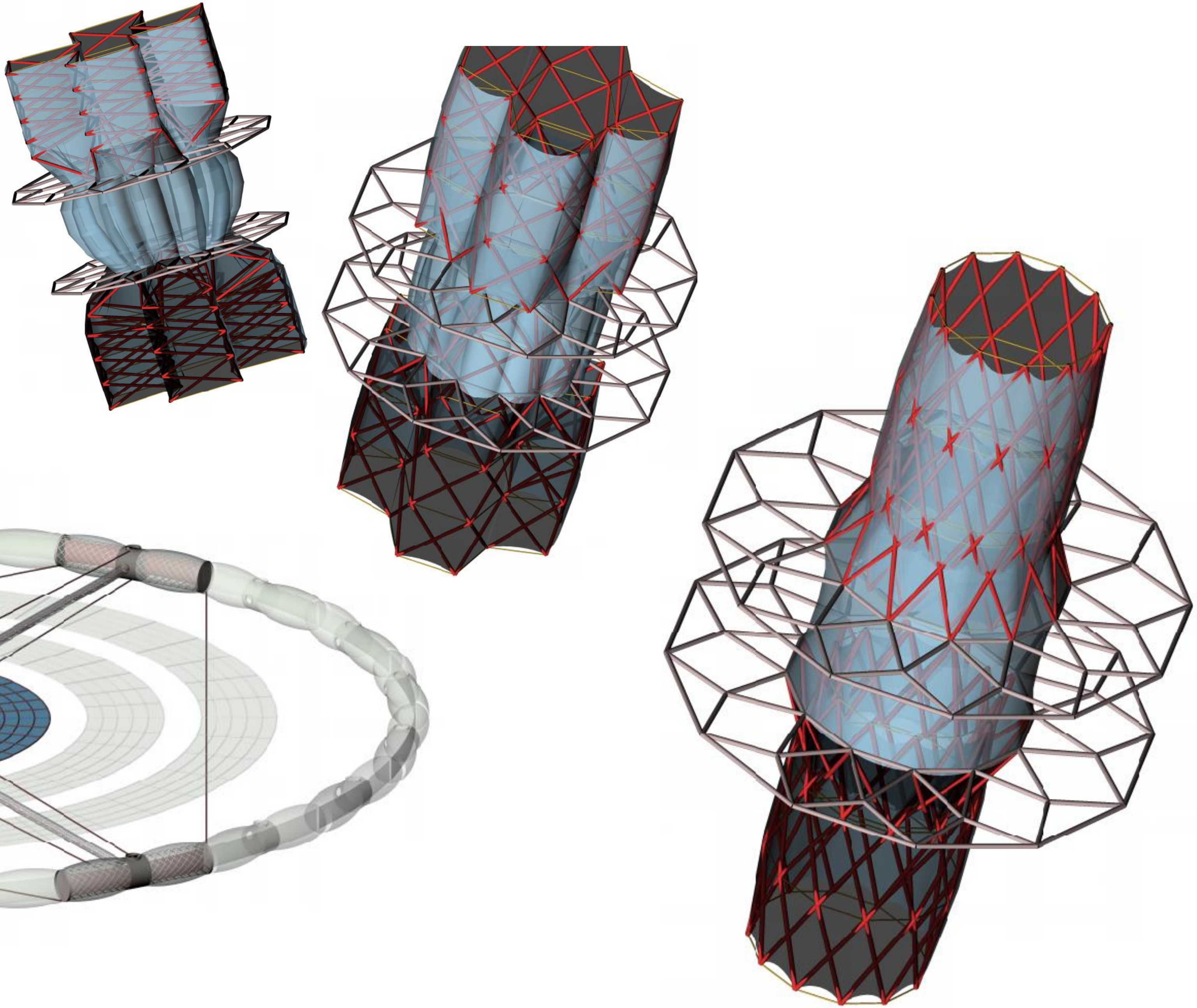
- Standardise approach across projects, teams and offices
- Roll-out tools and methods across projects
- Quality assurance
- Training!

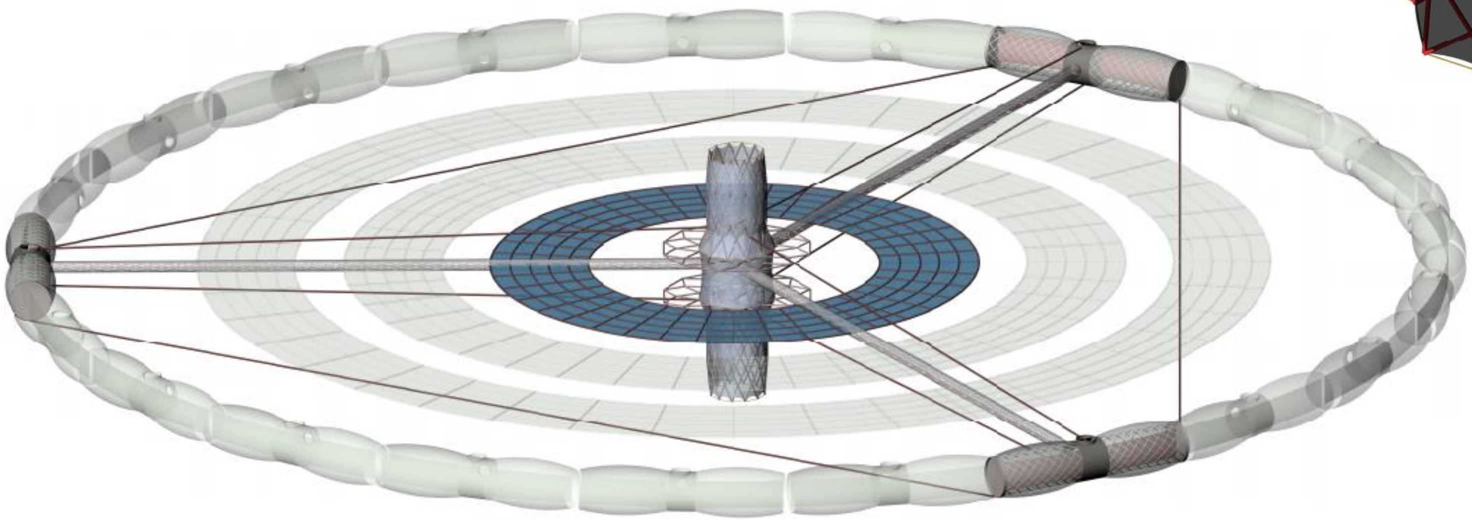
What's Next?

Going further

- Better communication between software
- Smarter treatment of complex geometry
- Automated decision making
- Improving efficiency vs capability

What's Next?





Q&A