

From Design Automation to Generative Design in AEC

Dieter Vermeulen

Technical Specialist AEC @ Autodesk
Computational Design & Engineering



About me

- Computational Design & Engineering
- Passionate about Generative Design in AEC
- +5 years at Autodesk
- Previous experience in structural engineering
- DJ QuSe @ Autodesk Events ☺



www.facebook.com/quse.dj



[@BIM4Struc](https://twitter.com/BIM4Struc)



www.linkedin.com/in/dietervermeulen



www.youtube.com/user/RevitbeyondBIM



www.revitbeyondbim.wordpress.com



www.autodesk.typepad.com/bimtoolbox/



[AU Online Profile](#)



DEMOGRAPHIC CHANGES

A large crowd of people is gathered at night, their silhouettes visible against a bright, hazy background of city lights and structures. The scene is illuminated by a strong light source, possibly the sun or moon, creating a lens flare effect and casting long shadows.

Number of Cities X2

200,000 people/day

About 13,000 buildings/day



3,600

MORE BUILDINGS PER DAY



MORE
IS INEVITABLE



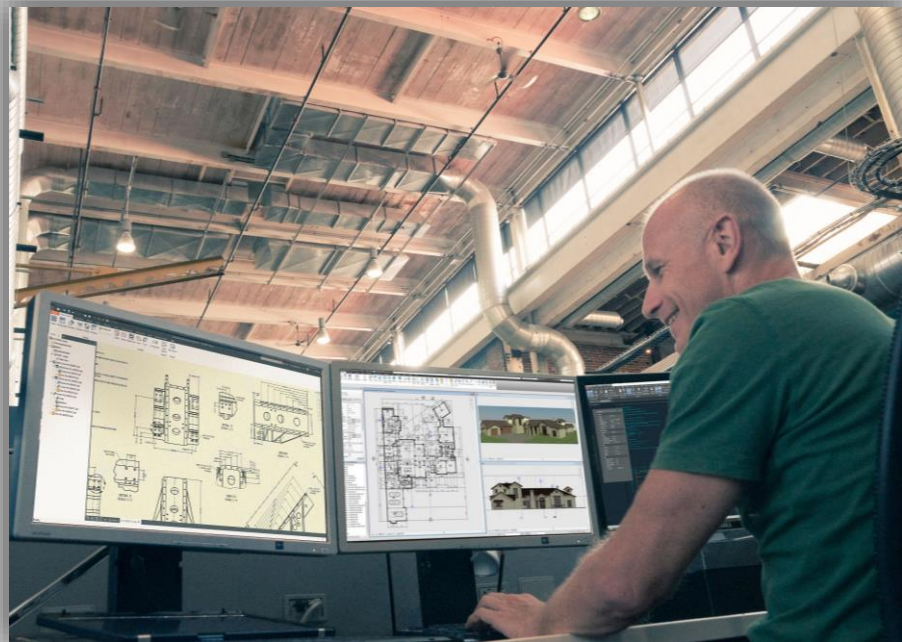
LESS
IS A REALITY

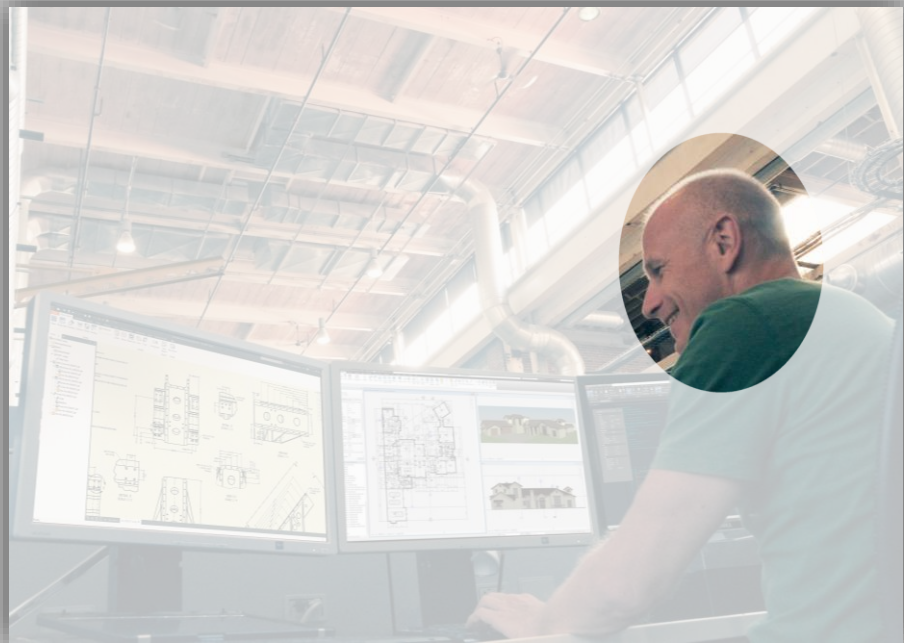


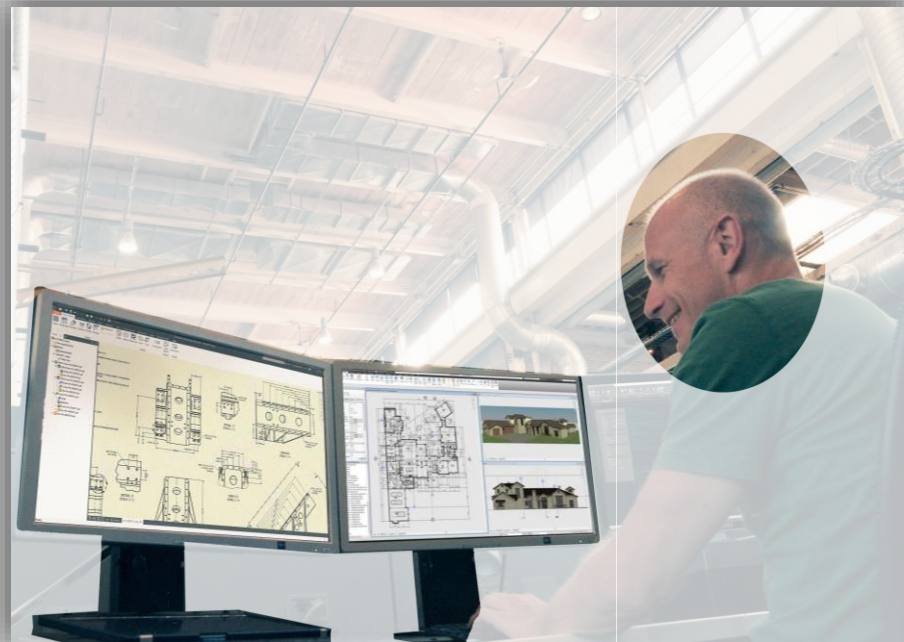
OPPORTUNITY OF
BETTER



DESIGNS TODAY



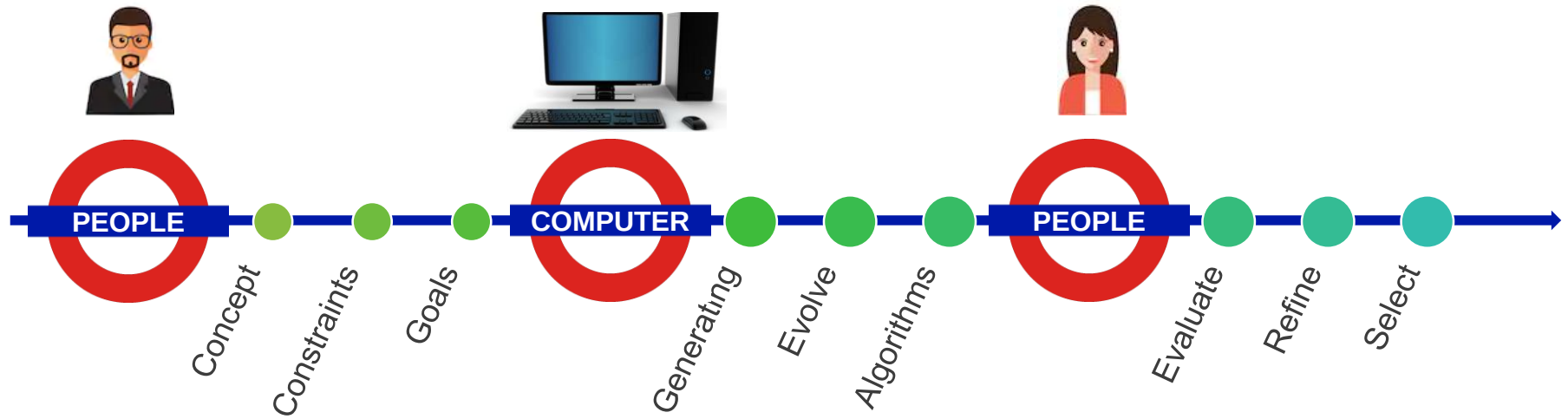




TRADITIONAL DESIGN PROCESS

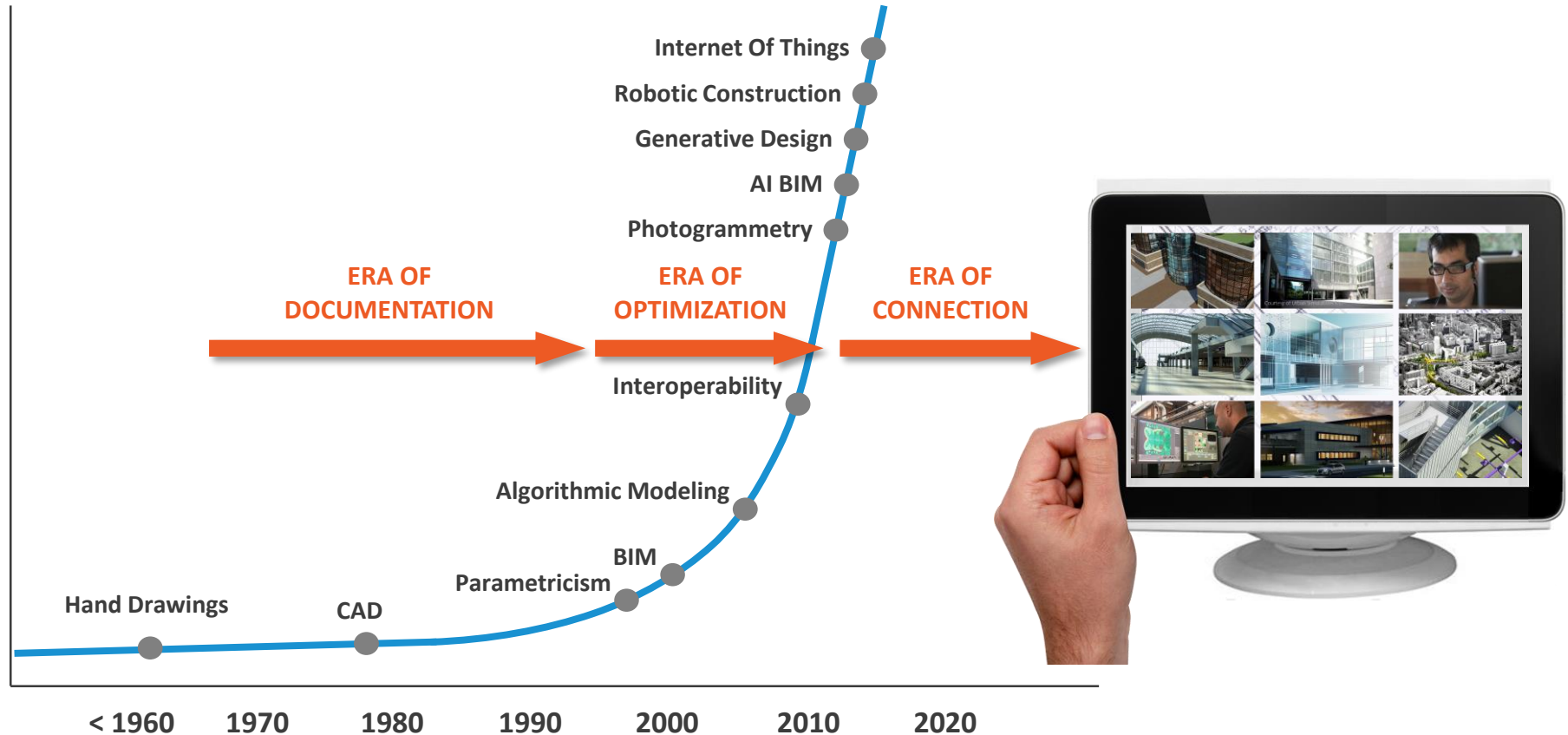


GENERATIVE DESIGN PROCESS

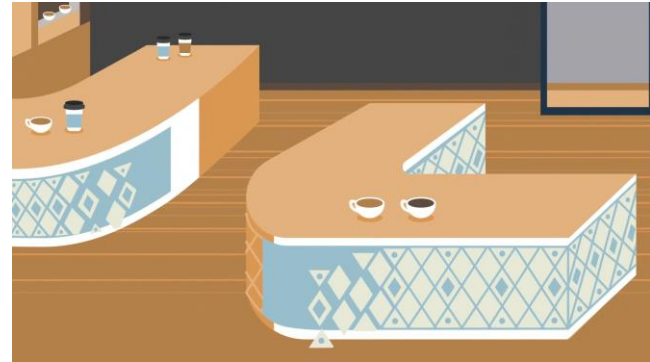
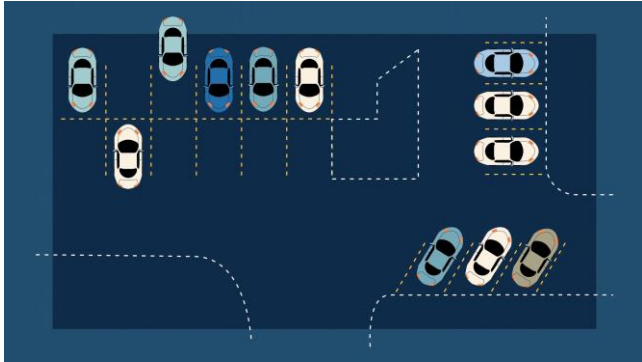
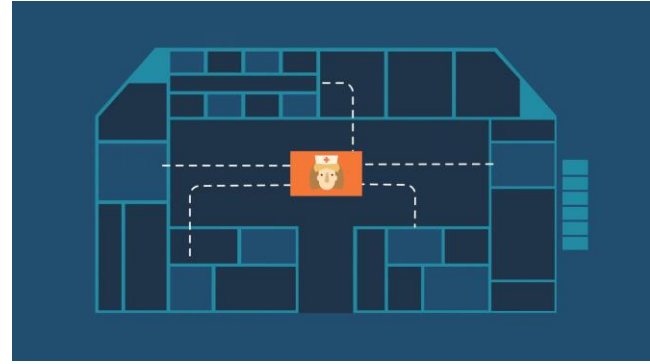


Generative design is a
methodology and a process
more than a singular product
or tool

Accelerating Growth in AEC Technology



Generative Design in Architecture Gives Designers More Options... Faster

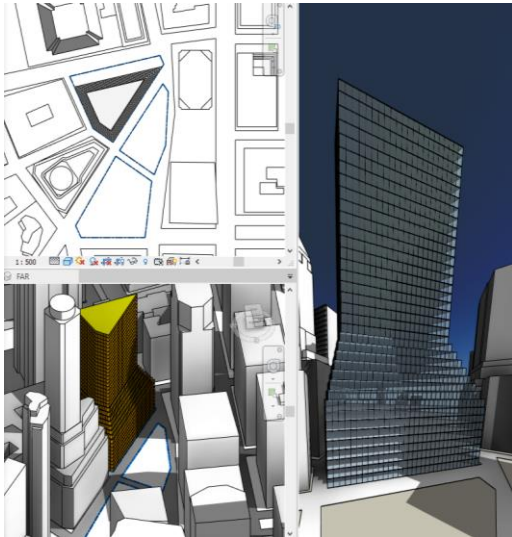


What level of design progression ?

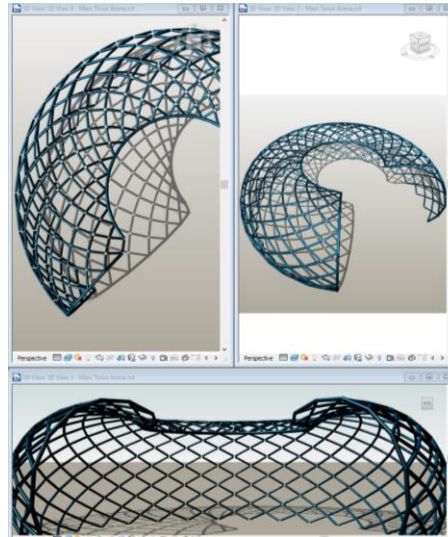


Cases

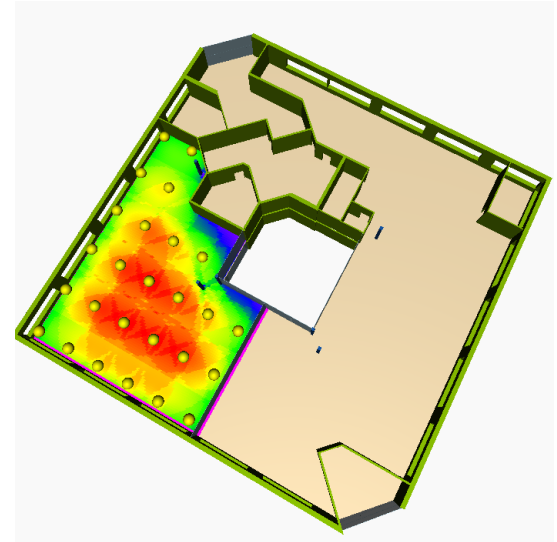
CONCEPTUAL TOWER MASS



STRUCTURE WASTE OPTIMIZATION

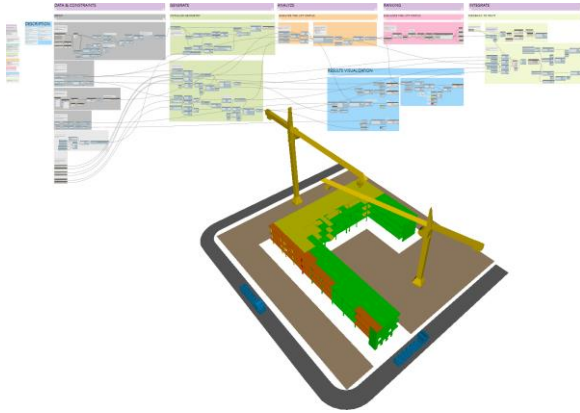


LIGHT DISTRIBUTION

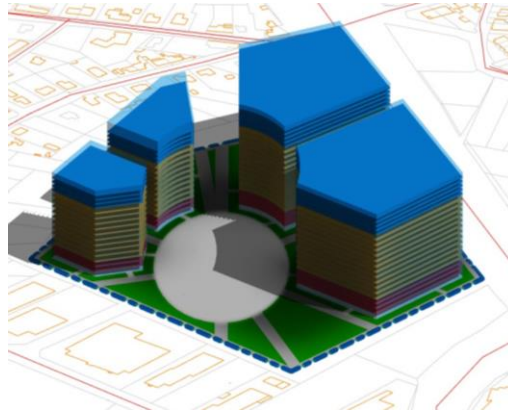


More Cases

TOWER CRANE POSITIONING



URBAN PLANNING



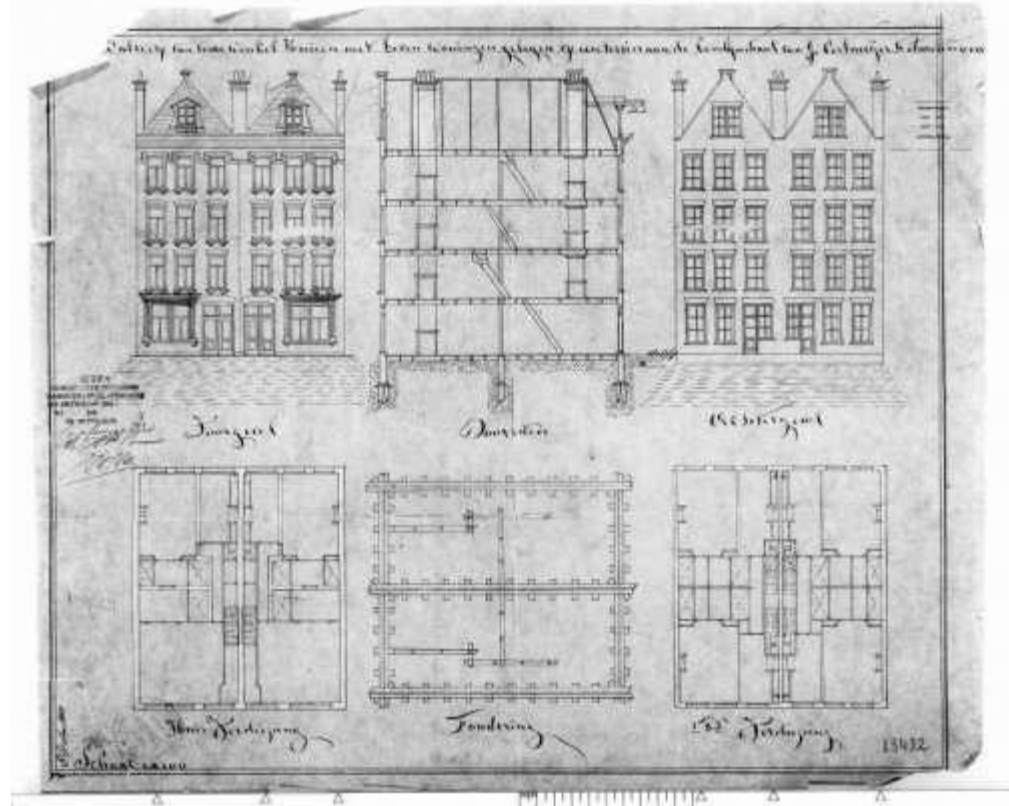
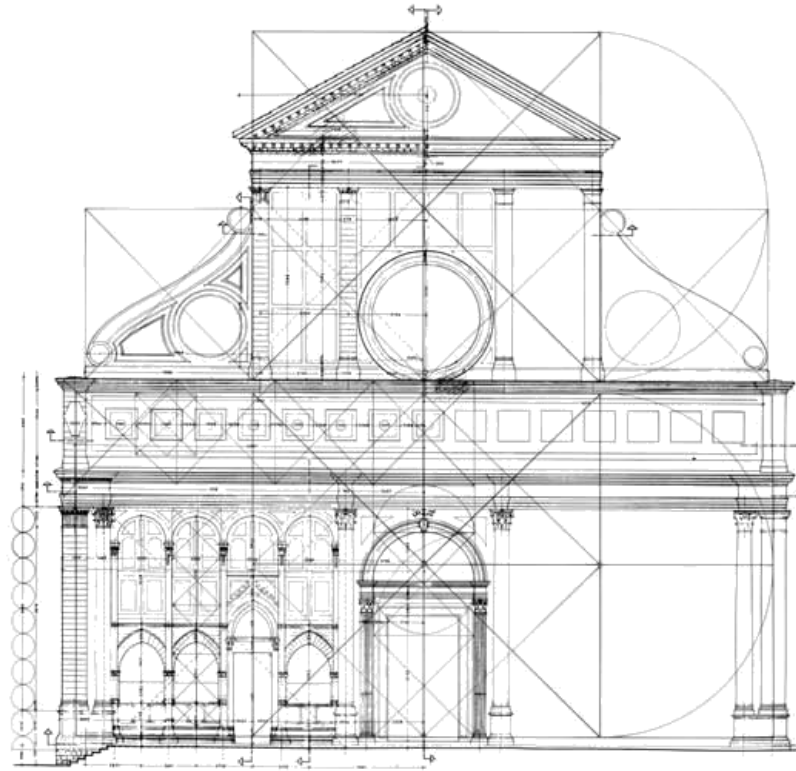
PARKING LAYOUT



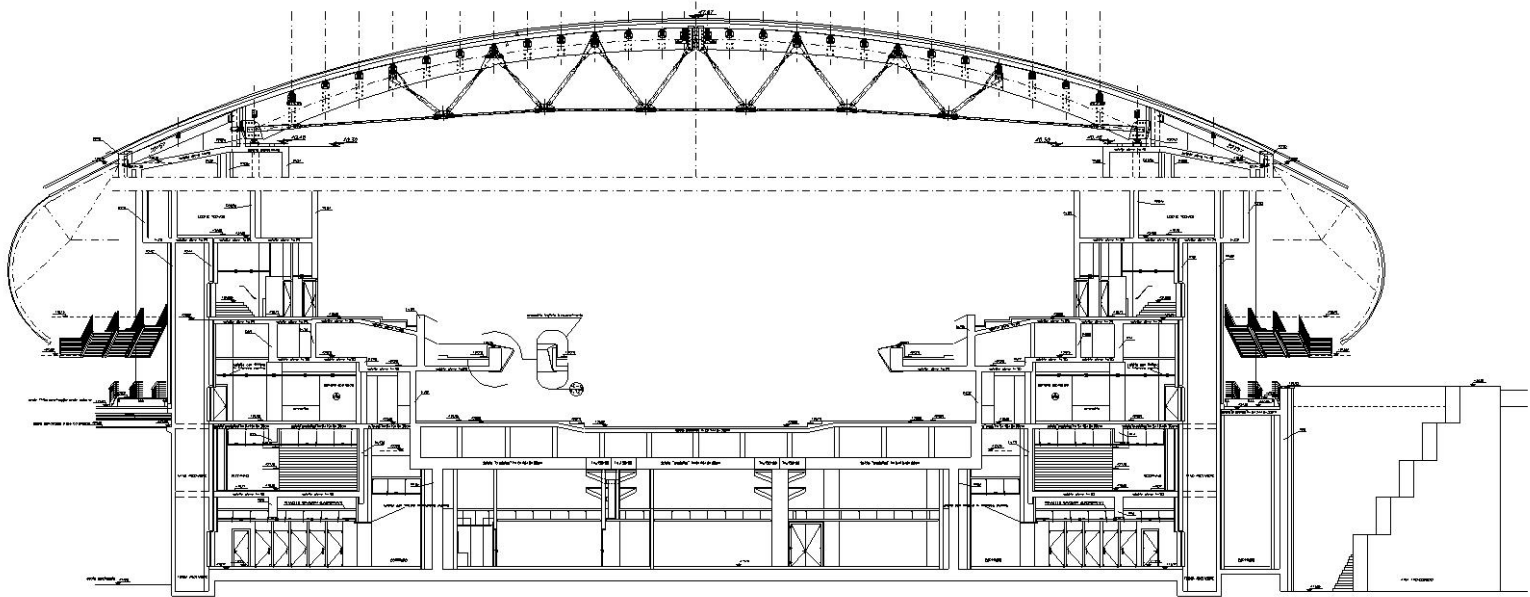


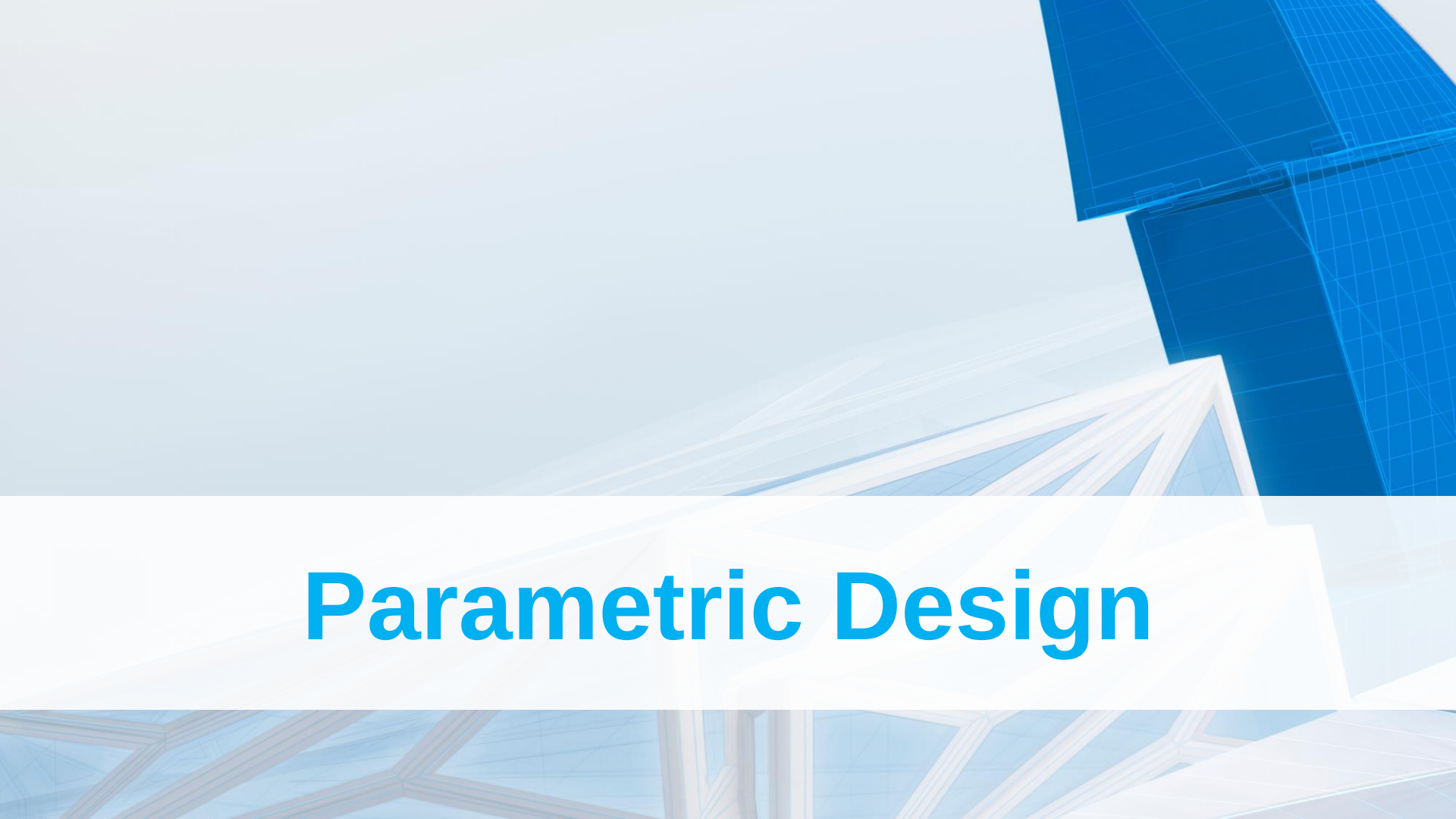
Traditional Design

Sketching



Computer Aided Drafting





Parametric Design

PARAMETRIC DESIGN

Designer/engineer uses computer
as passive machine



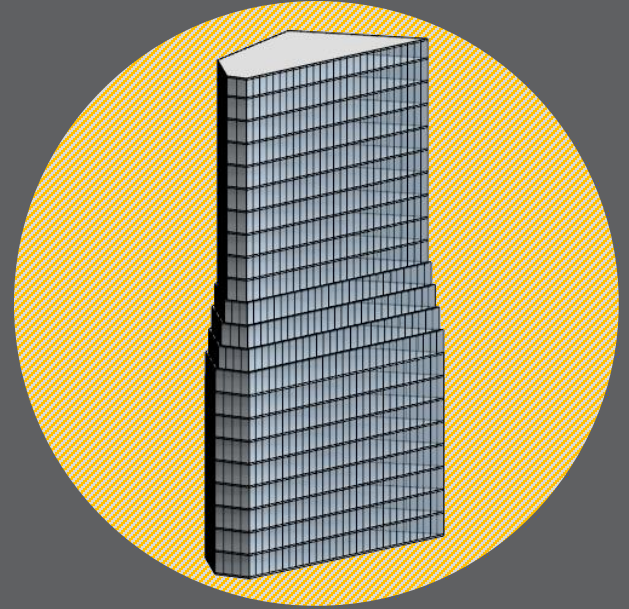
one
human

+



one
computer

=



limited
design



PARAMETRIC MODELING



Parametric Modeling

$$a = 2$$

$$b = 1$$

$$a - b = c$$

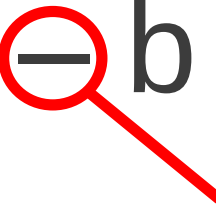
Parametric Modeling

$$a = 2$$

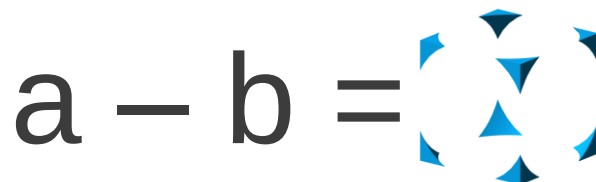
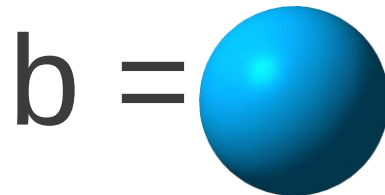
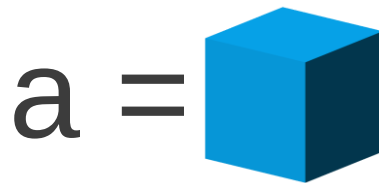
$$b = 1$$

$$a - b = c$$

$f(x)$



Parametric Modeling



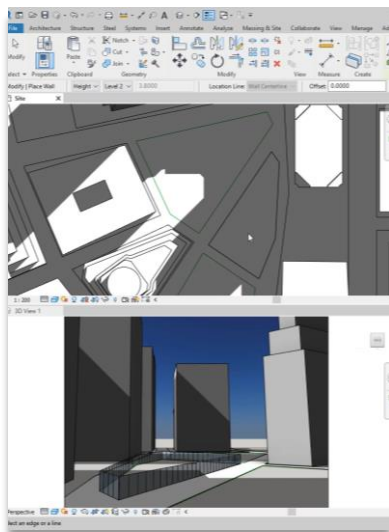
Conceptual Tower Mass – Design Model

AUTODESK®
REVIT®

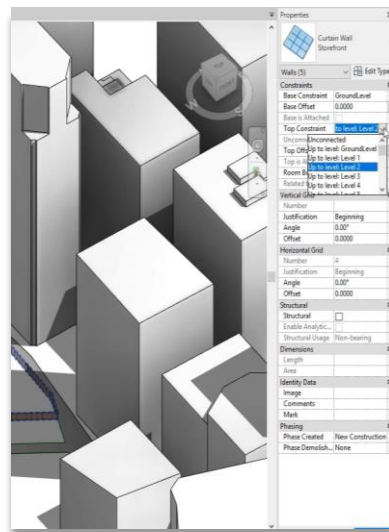
AUTODESK®
REVIT®

AUTODESK®
REVIT®

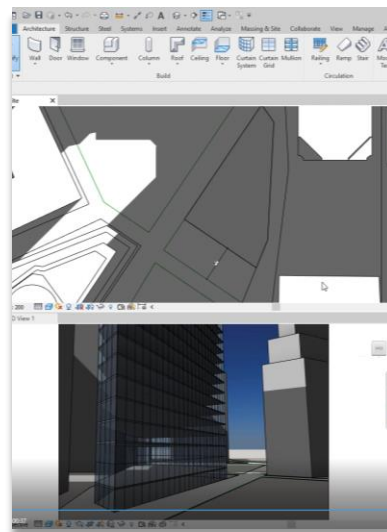
AUTODESK®
REVIT®



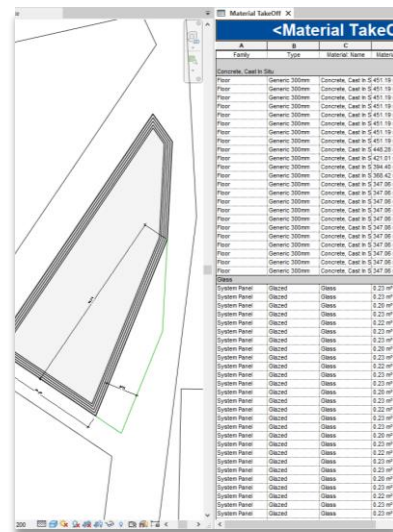
Create Geometry



Assign Parametric
Constraints



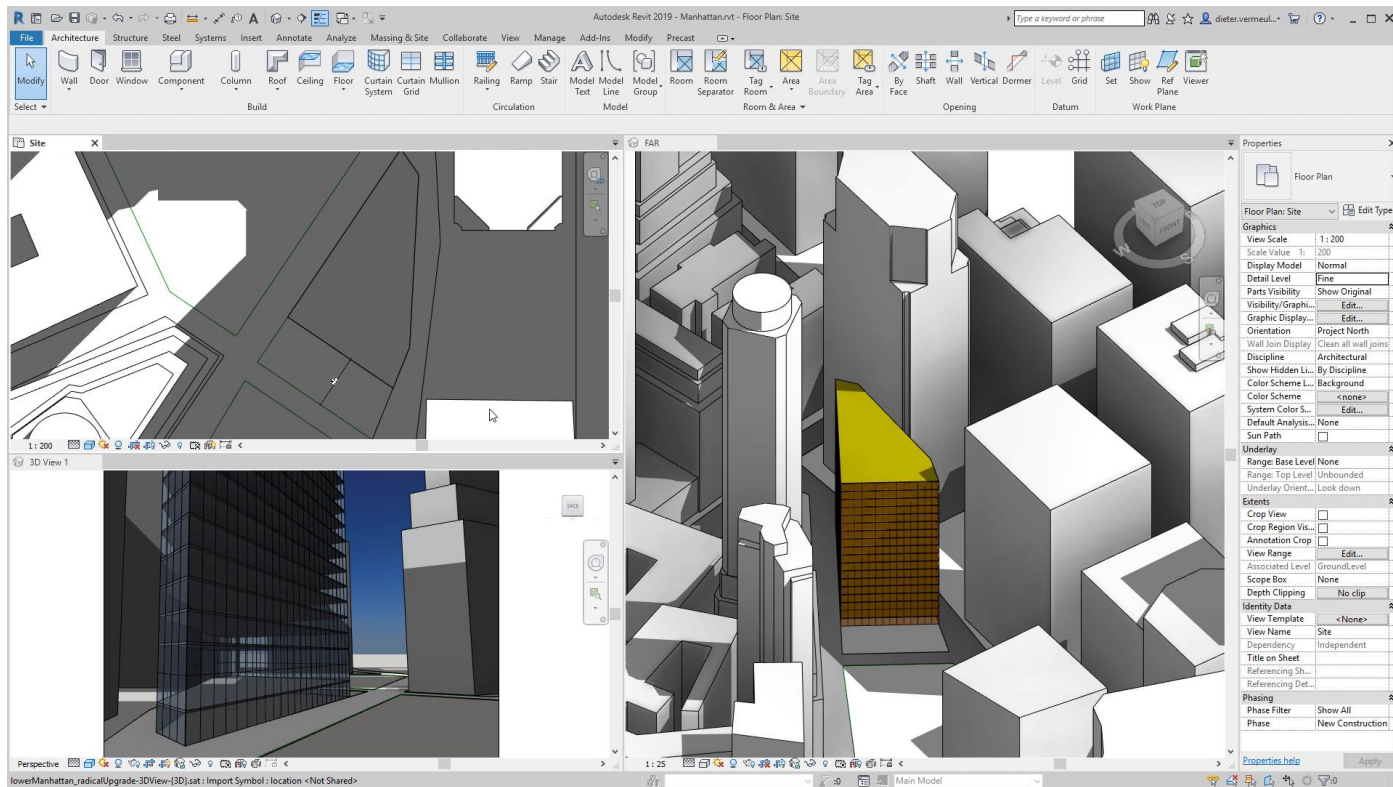
Modify Parameters

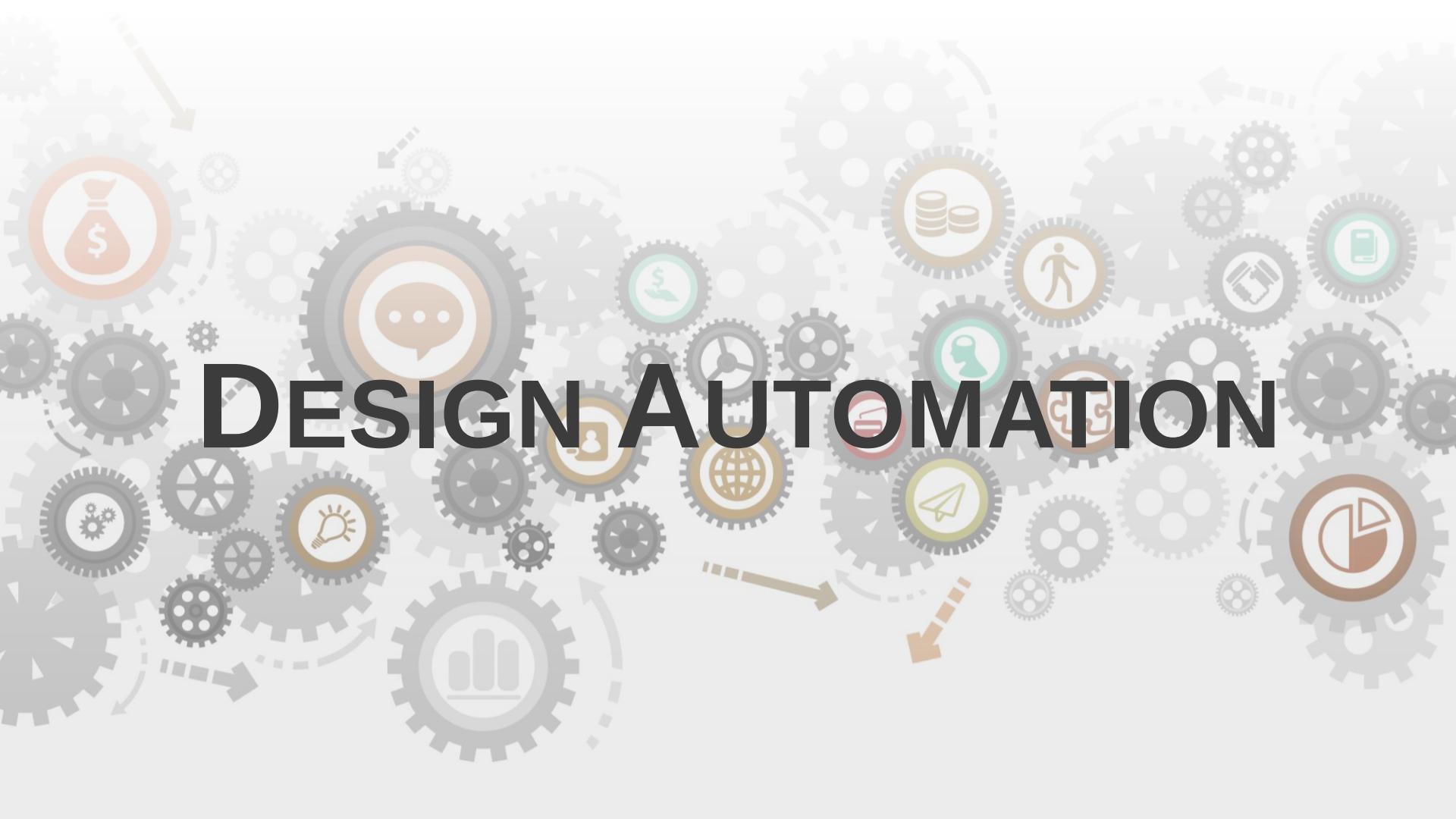


Document the Idea

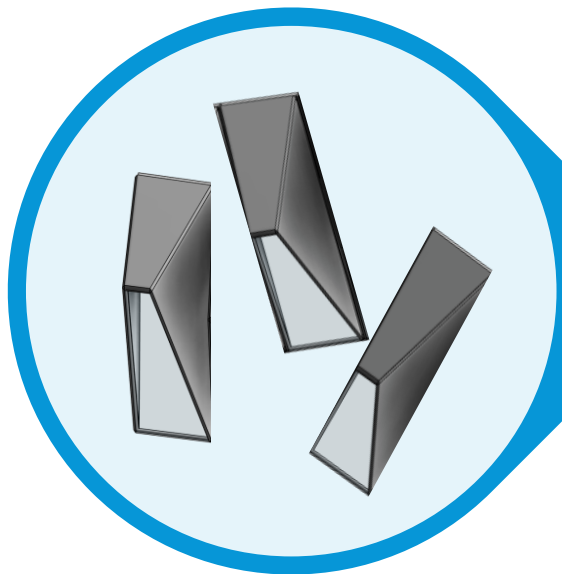
Conceptual Tower Mass – Design Model

Parametric Modeling with Autodesk Revit





DESIGN AUTOMATION



input



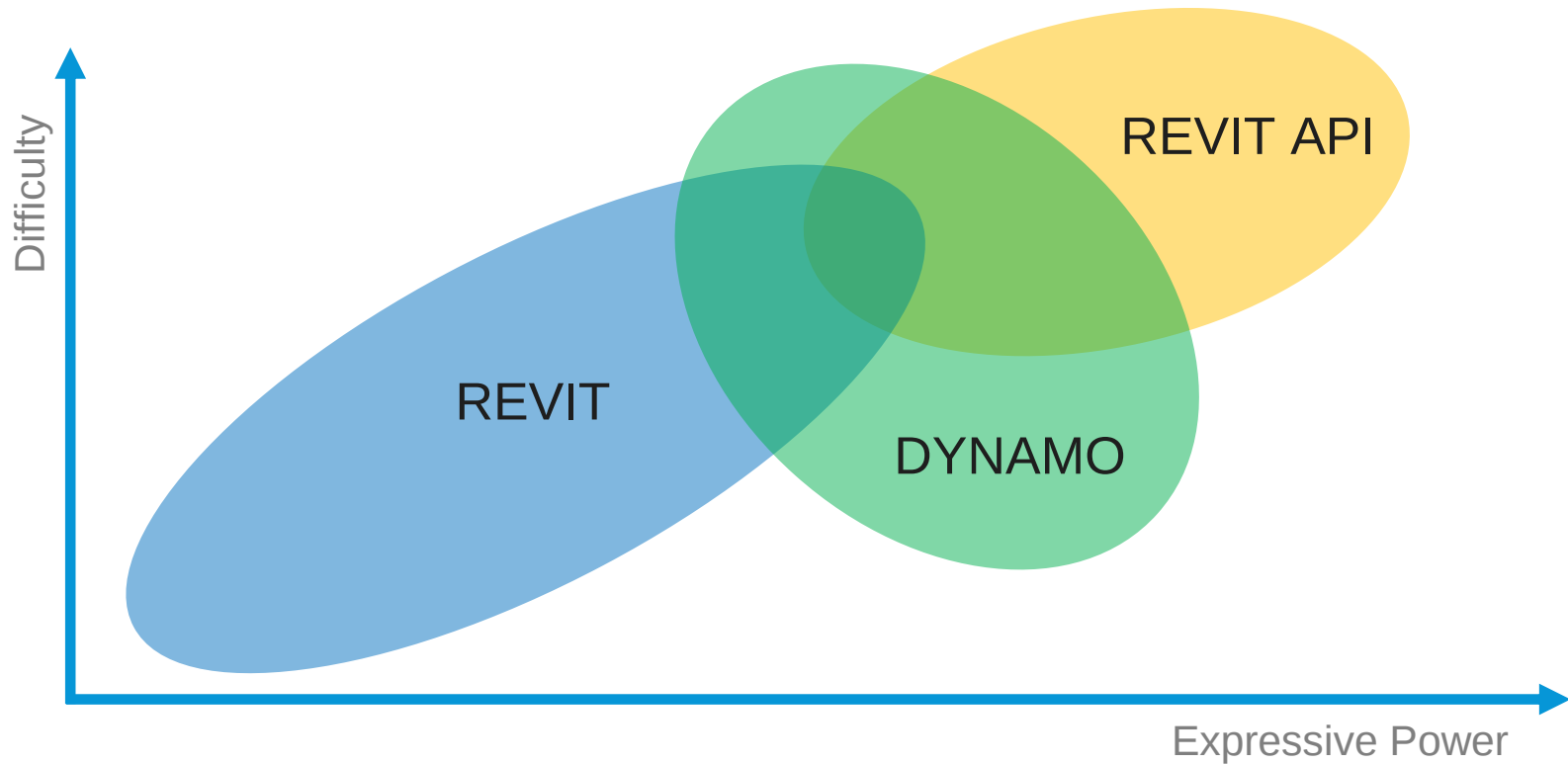
design
automation



output

Dynamo

Ecosystem to increase capabilities



Dynamo to simplify things

PROGRAMMING

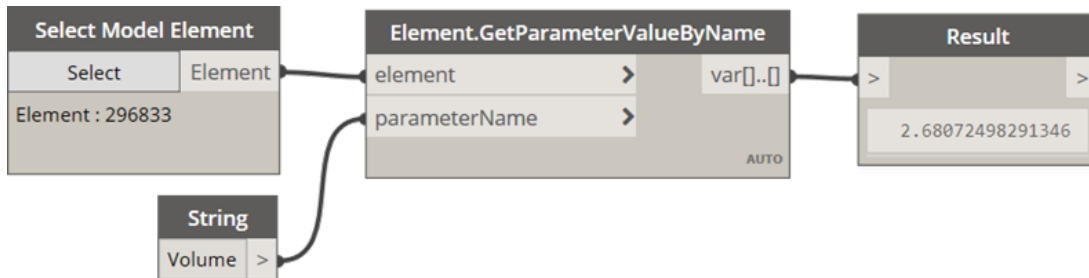
```
void GetElementParameterInformation(Document document, Element element)
{
    // Format the prompt information string
    String prompt = "Show parameters in selected Element: \n\r";
    StringBuilder st = new StringBuilder();
    // Iterate element's parameters
    foreach (Parameter para in element.Parameters)
    {
        st.AppendLine(GetParameterInformation(para, document));
    }

    // Give the user some information
    TaskDialog.Show("Revit", prompt + st.ToString());
}

String GetParameterInformation(Parameter para, Document document)
{
    string defName = para.Definition.Name + "\t : ";
    string defValue = string.Empty;
    // Use different method to get parameter data according to the storage type
    switch (para.StorageType)
    {
        case StorageType.Double:
            //convert the number into Metric
            defValue = para.AsValueString();
            break;
        case StorageType.ElementId:
            //find out the name of the element
            Autodesk.Revit.DB.ElementId id = para.AsElementId();
            if (id.IntegerValue >= 0)
            {
                defValue = document.GetElement(id).Name;
            }
            else
            {
                defValue = id.IntegerValue.ToString();
            }
            break;
        case StorageType.Integer:
            if (ParameterType.YesNo == para.Definition.ParameterType)
            {
                if (para.AsInteger() == 0)
                {
                    defValue = "False";
                }
                else
                {
                    defValue = "True";
                }
            }
            else
            {
                defValue = para.AsInteger().ToString();
            }
            break;
        case StorageType.String:
            defValue = para.AsString();
            break;
        default:
            defValue = "Unexposed parameter.";
            break;
    }

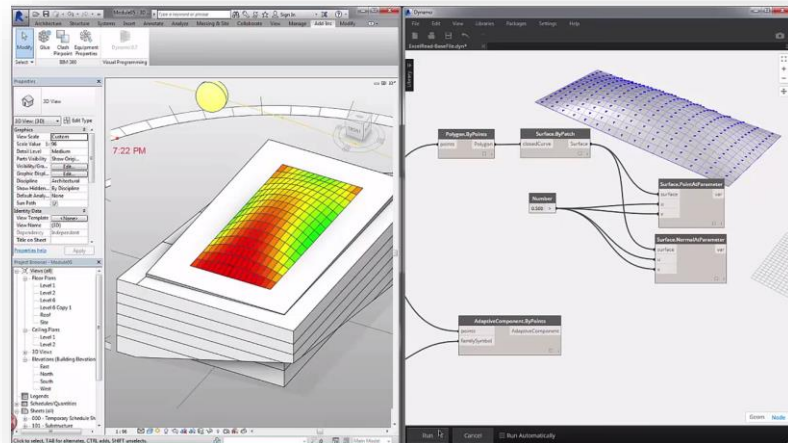
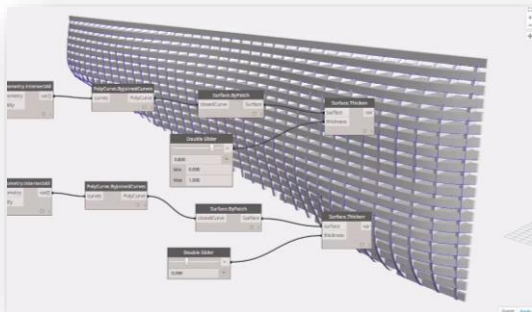
    return defName + defValue;
}
```

VISUAL SCRIPTING



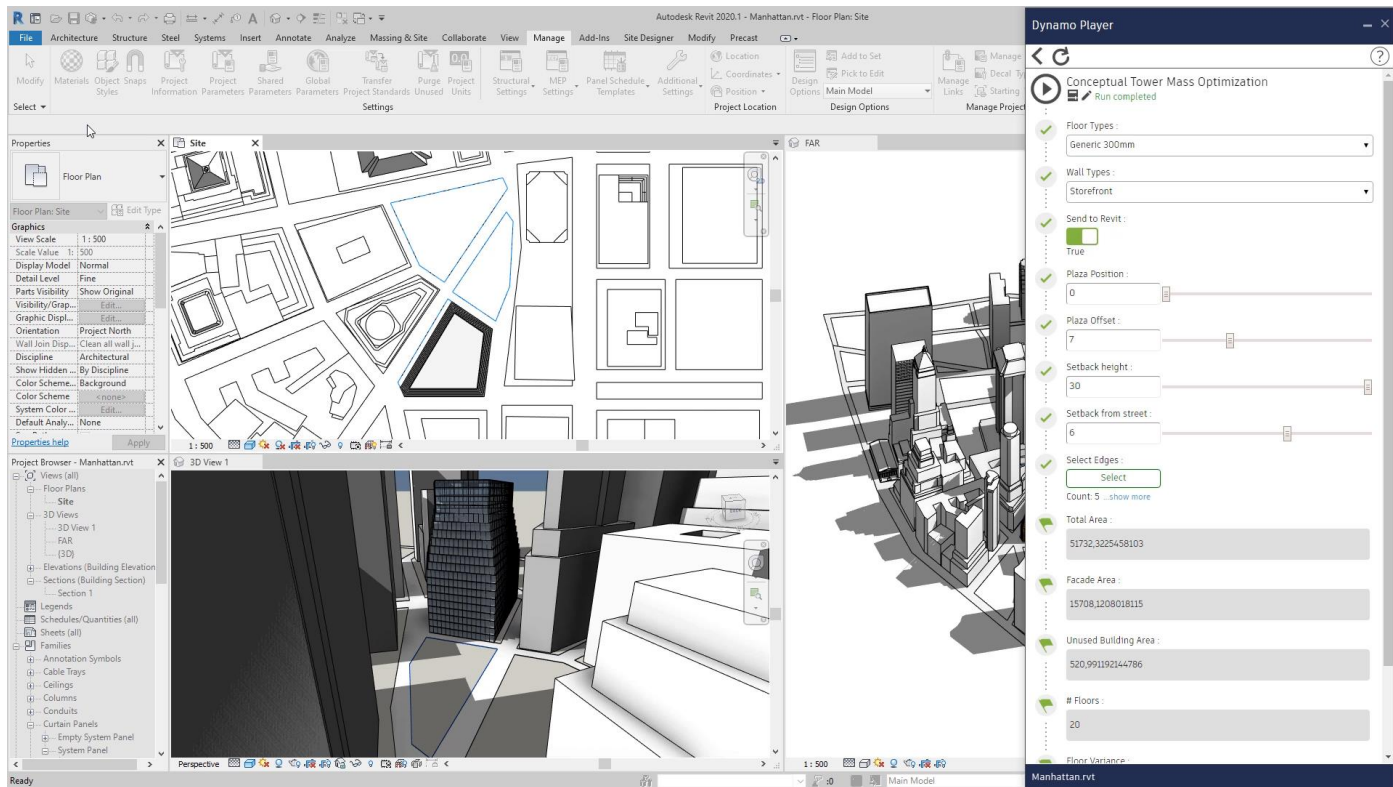
Dynamo offers more benefits

- Provide simple, coherent, and capable programming tools for people who make things
- Foster a collaborative design computation ecosystem
- Share tools within teams and across disciplines
- Generate sophisticated designs from simple data
- Automate repetitive tasks



Conceptual Tower Mass - Automated Placement

Design Automation with Revit and Dynamo Player

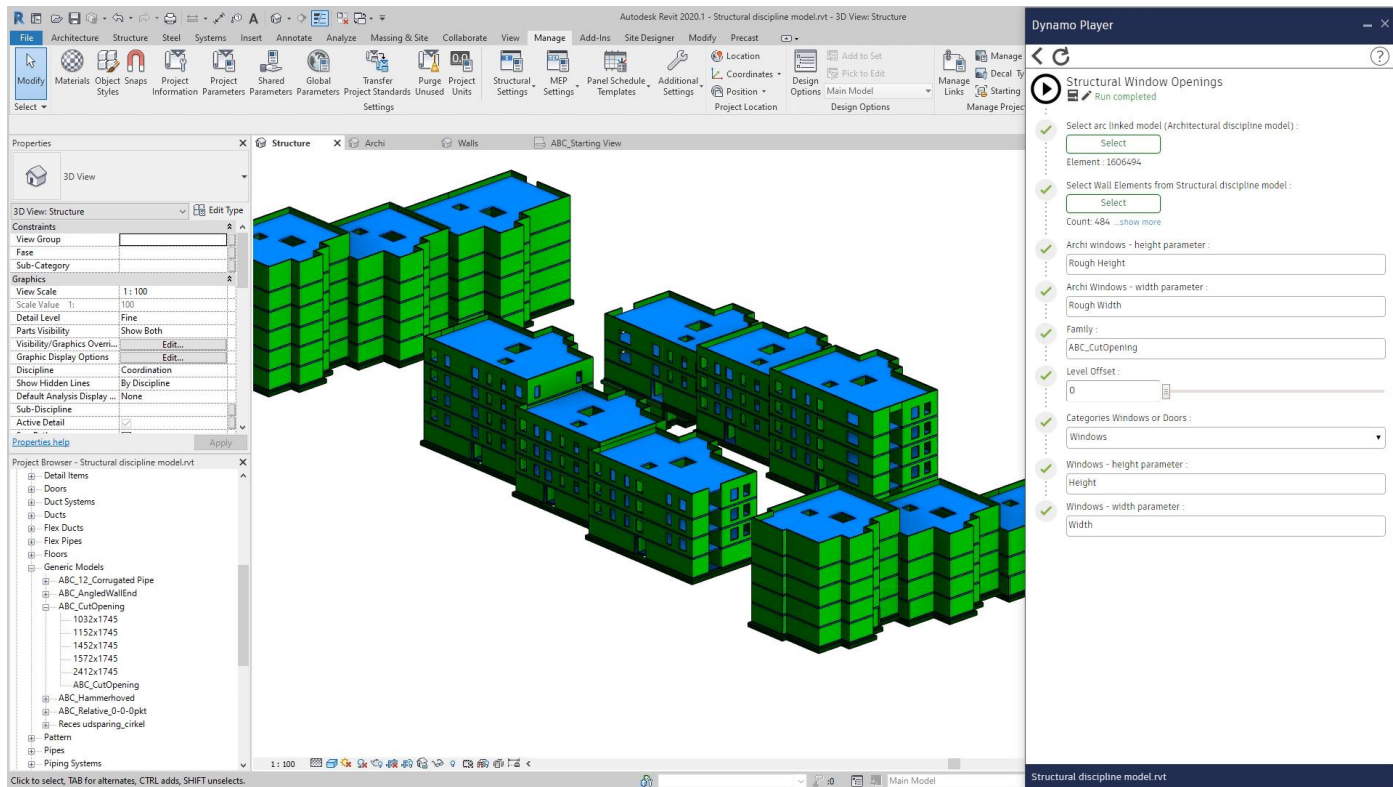


Cut Openings in Structural Walls

Design Automation with Revit and Dynamo

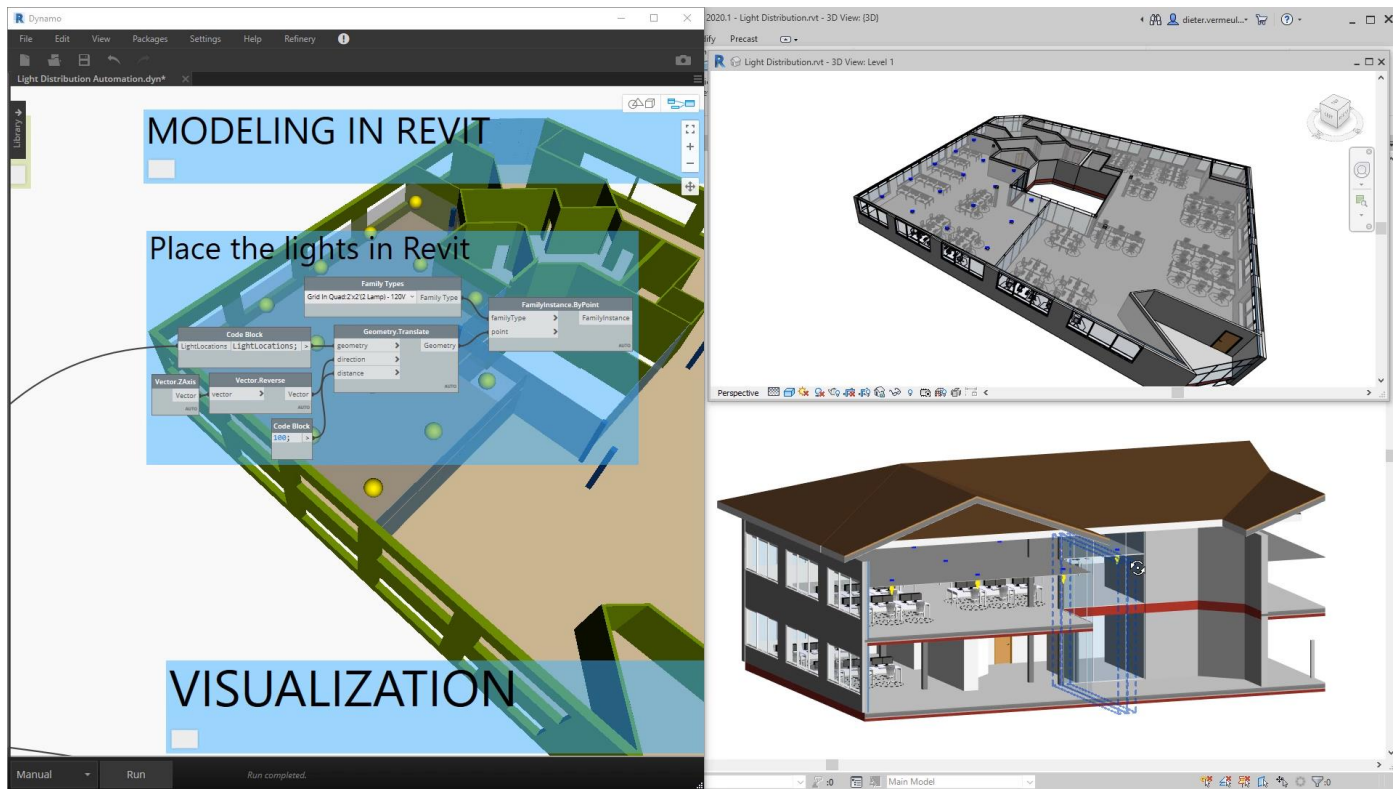


Thanks for contributing:
Jesper Wallaert, AB Clausen, Denmark



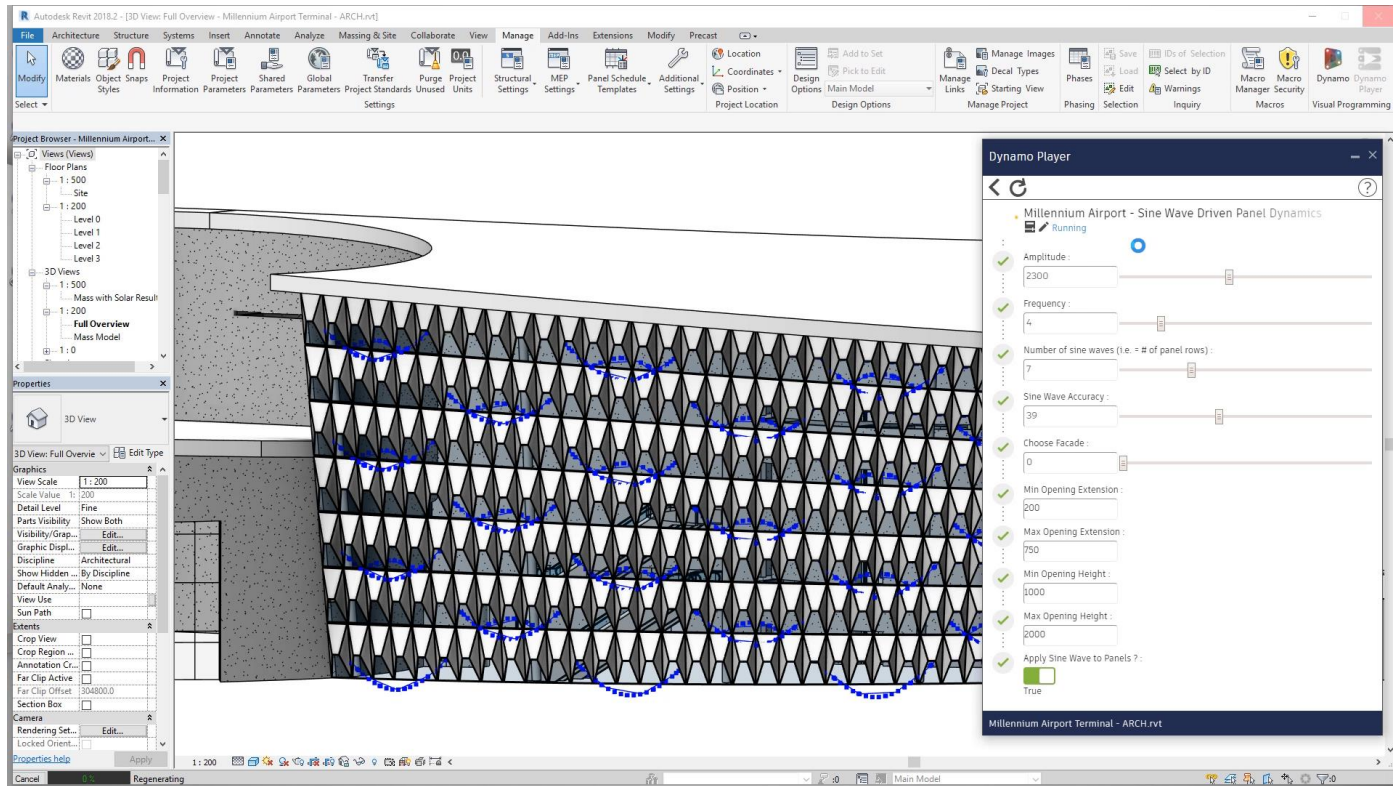
Light Placement Automation

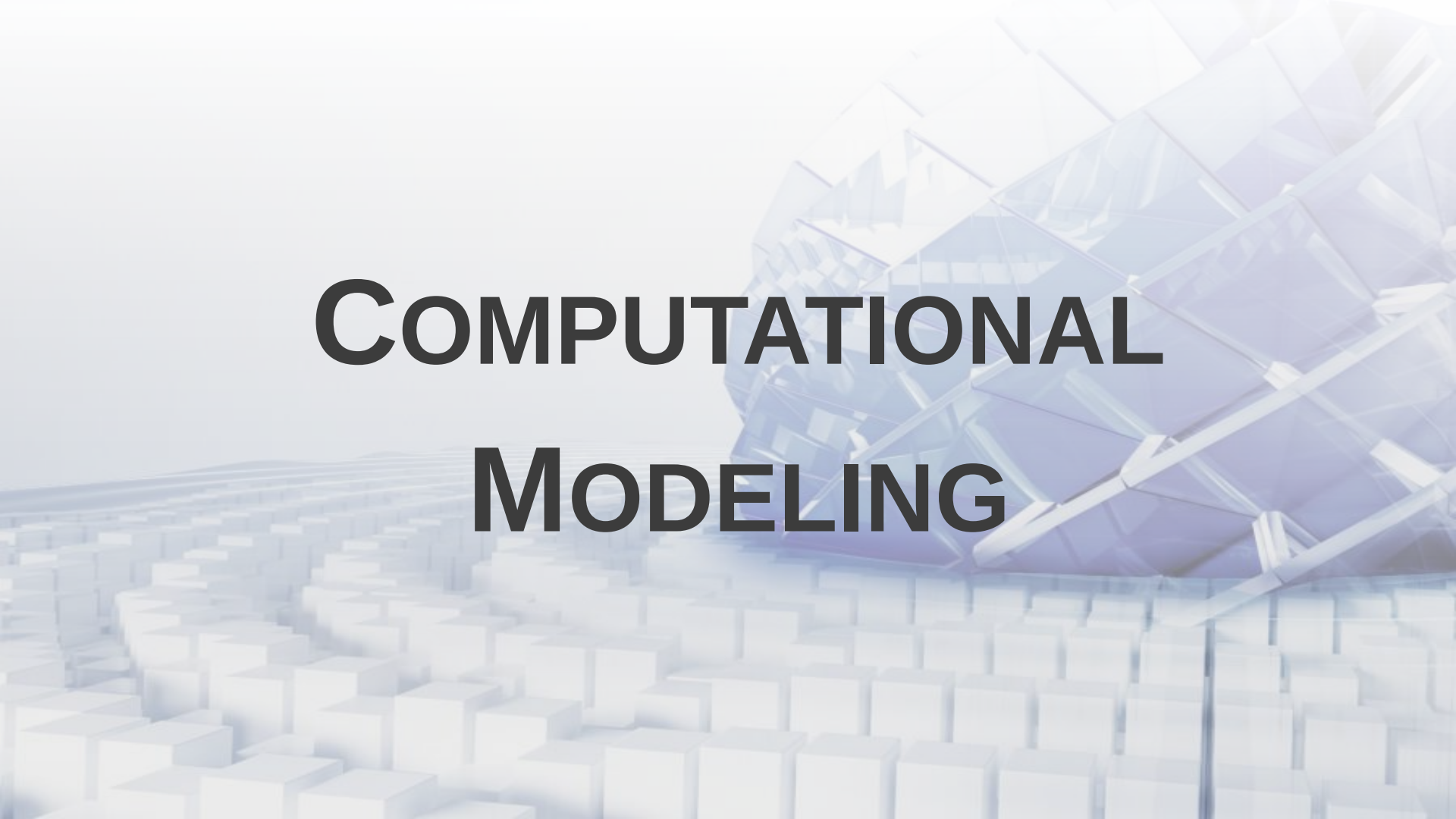
Design automation with Revit and Dynamo



Façade Panels with Mathematical Influence

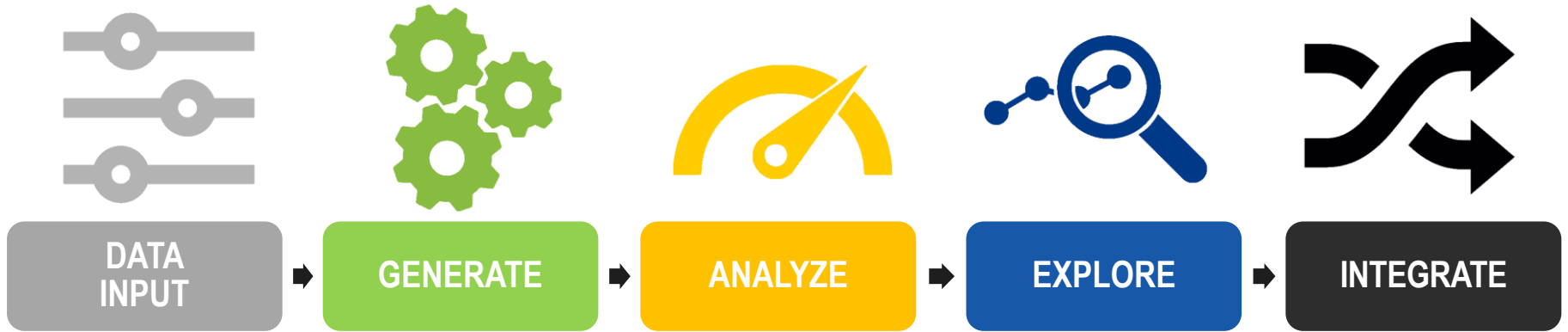
Design Automation with Revit and Dynamo Player



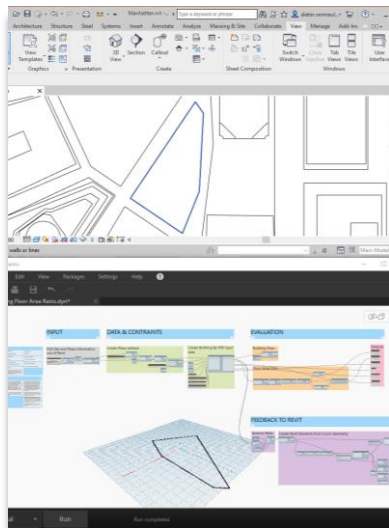


COMPUTATIONAL MODELING

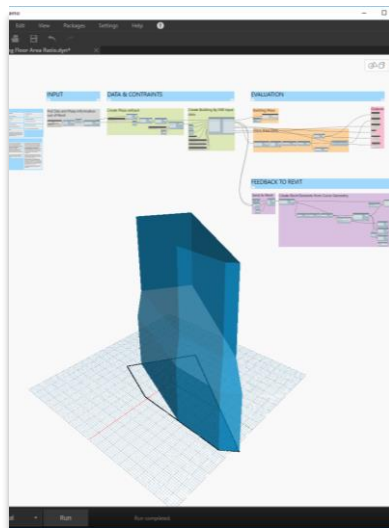
Computational Modeling Process



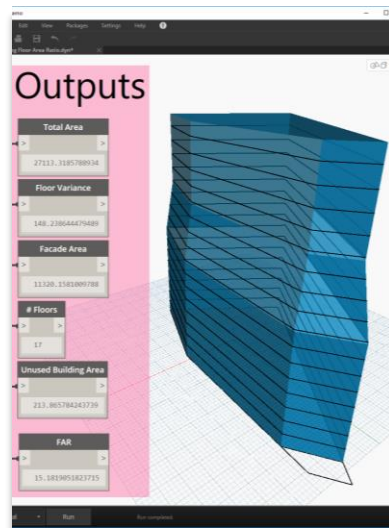
Conceptual Tower Mass with Computational Modeling



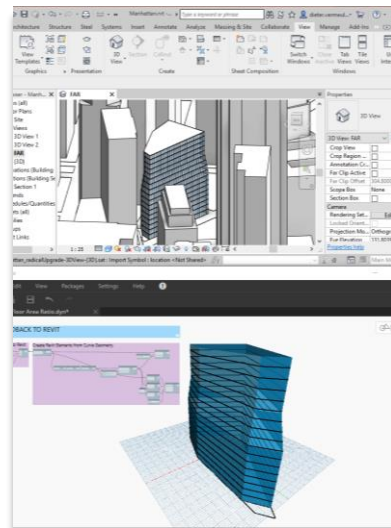
Get Boundaries



Generate
Geometry



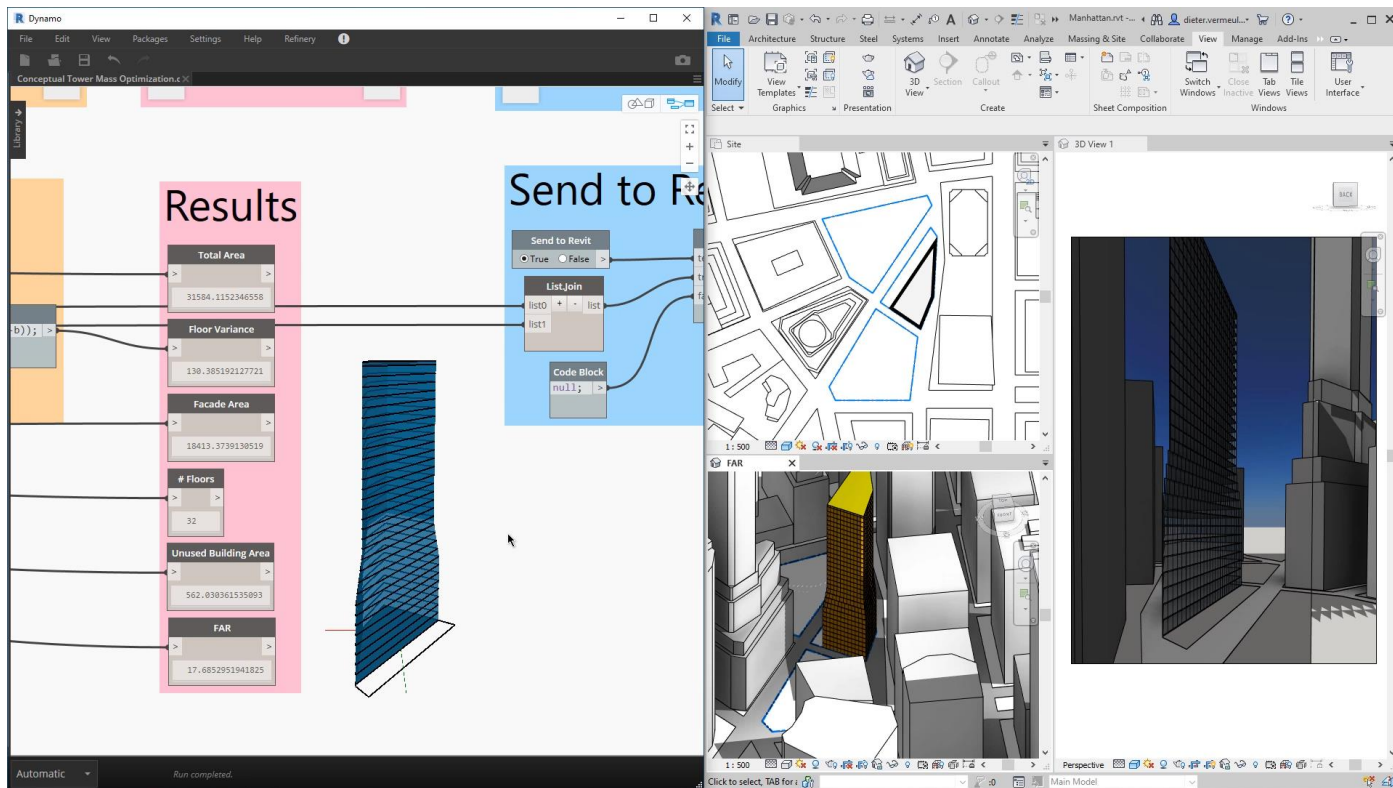
Analyze & Evaluate



Model
Integration

Conceptual Tower Mass

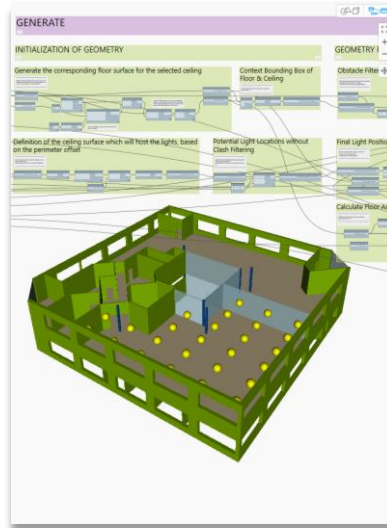
Computational Modeling with Revit and Dynamo



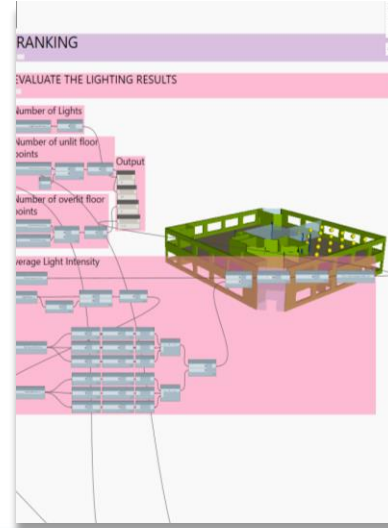
Light Distribution Analysis



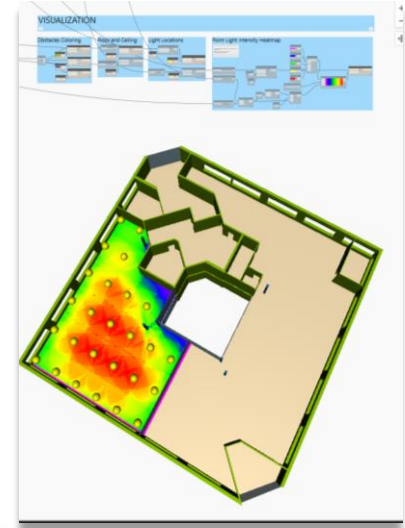
Get Revit Context



Generate Option for
Light Distribution



Conceptual Analysis
Point Intensity

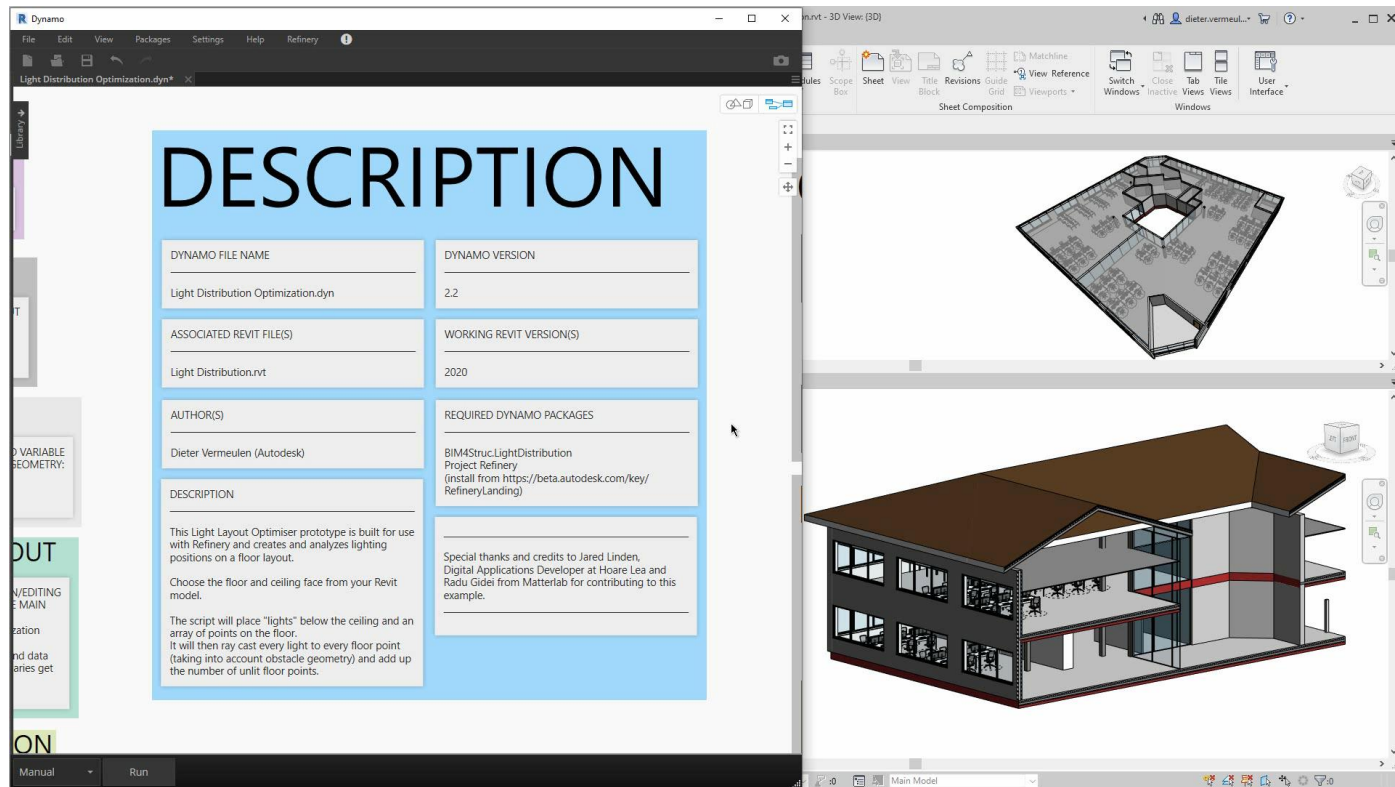


Evaluation

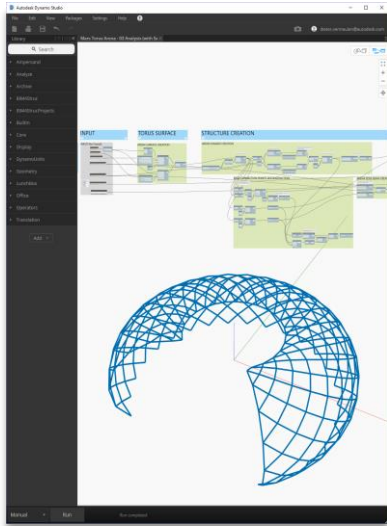
Light Distribution Analysis

Computational Modeling with Revit and Dynamo

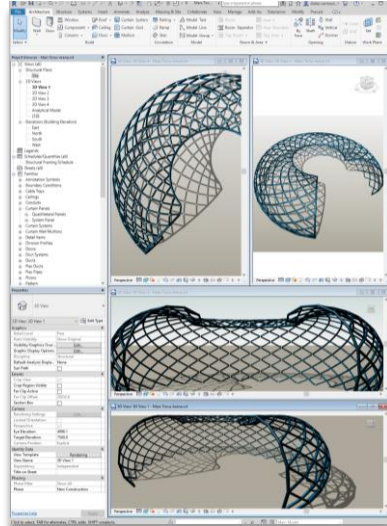
*Special thanks for contributing:
Jared Linden, Hoare Lea, UK
Radu Gidei, Matterlab, UK*



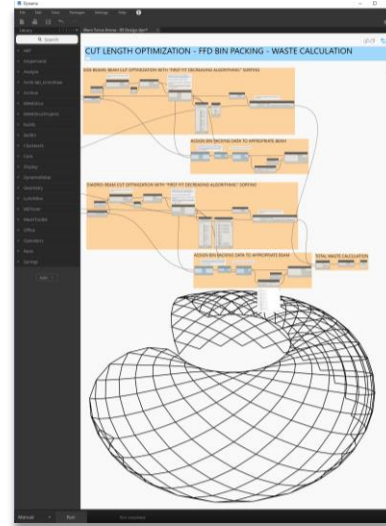
Steel Diagrid Waste Evaluation



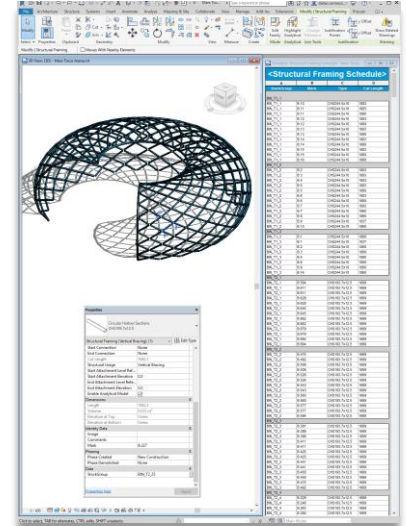
System Definition



Automate
Structural Design



Cut Length
Optimization



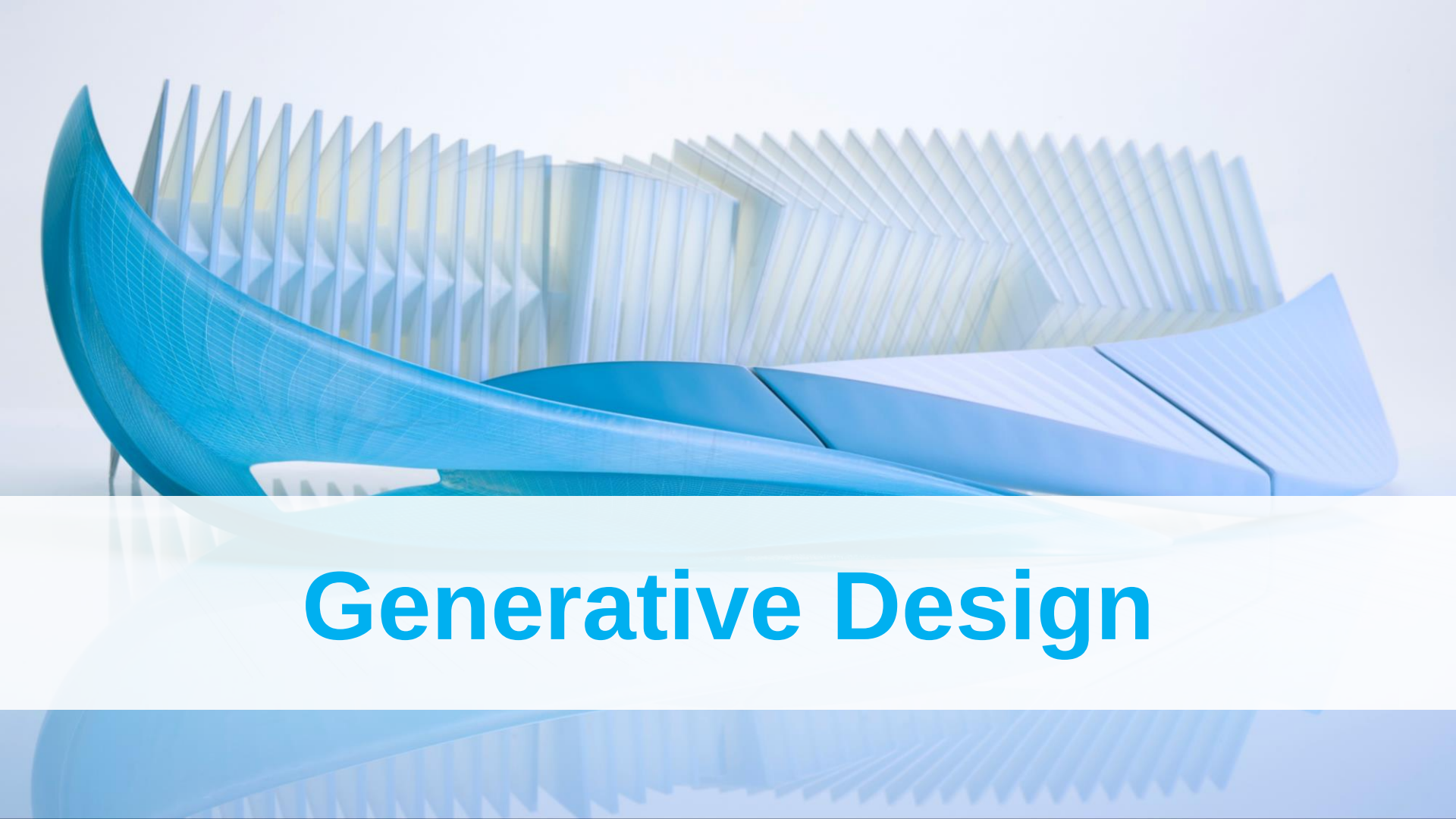
Integration of Results

Steel Diagrid Waste Evaluation

Computational Modeling with Revit and Dynamo

The screenshot displays the Autodesk Revit 2020.1 interface with a 3D model of a steel diagrid structure. The model is shown in three views: 3D View 1 (top right), 3D View 2 (top left), and 3D View 3 (bottom left). The 3D View 1 shows a perspective view of the structure, which is a complex, curved, and segmented steel diagrid. The 3D View 2 shows a top-down view of the structure. The 3D View 3 shows a side view of the structure. The Properties panel on the left shows the 3D View 2 properties, including the 3D View type, Graphics, Extents, and Camera. The Project Browser on the left shows the project structure, including Views (all), Structural Plans, Site, 3D Views, and Elevations (Building Elevation). The Structural Framing Schedule table is displayed in the bottom right corner, showing the schedule for the structure.

BlockGroup	Mark	Type	Cut Length
BN_T1_1			
BN_T1_1	B.13	CHS21 3x3.2	1494
BN_T1_1	B.14	CHS21 3x3.2	1494
BN_T1_1	B.15	CHS21 3x3.2	1494
BN_T1_1	B.16	CHS21 3x3.2	1494
BN_T1_1	B.17	CHS21 3x3.2	1494
BN_T1_1	B.18	CHS21 3x3.2	1494
BN_T1_1	B.19	CHS21 3x3.2	1494
BN_T1_1	B.20	CHS21 3x3.2	1492
BN_T1_2			
BN_T1_2	B.5	CHS21 3x3.2	1494
BN_T1_2	B.6	CHS21 3x3.2	1494
BN_T1_2	B.7	CHS21 3x3.2	1494
BN_T1_2	B.8	CHS21 3x3.2	1494
BN_T1_2	B.9	CHS21 3x3.2	1494
BN_T1_2	B.10	CHS21 3x3.2	1492
BN_T1_2	B.11	CHS21 3x3.2	1492
BN_T1_2	B.12	CHS21 3x3.2	1494
BN_T1_3			
BN_T1_3	B.1	CHS21 3x3.2	1492

An abstract 3D architectural rendering featuring a series of blue, curved, ribbed structures that resemble a modern building facade or a large, stylized letter 'C'. The structure is composed of many thin, vertical, blue ribs that curve around a central white space. The overall color palette is light blue and white, with a soft, ethereal lighting effect. The structure is reflected on a glossy surface below it.

Generative Design

GENERATIVE DESIGN

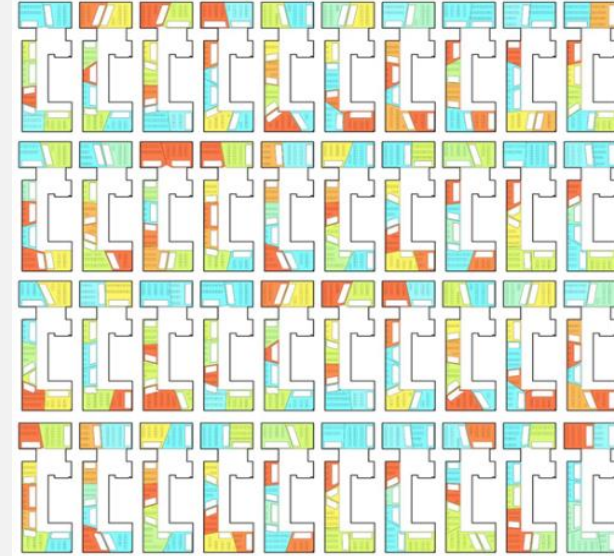
Computer and designer/engineer
unite as cocreators

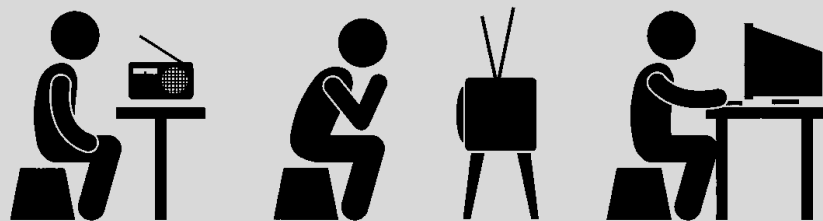


one
human + computational
algorithms +

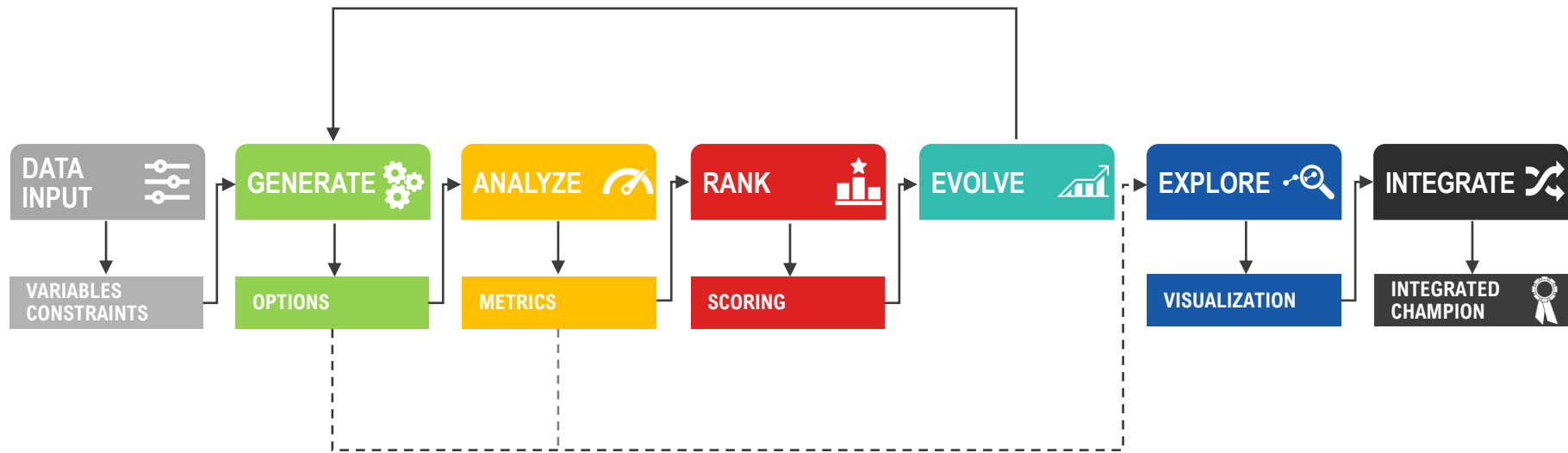
computing
power =

100s to 1000s
of
design options

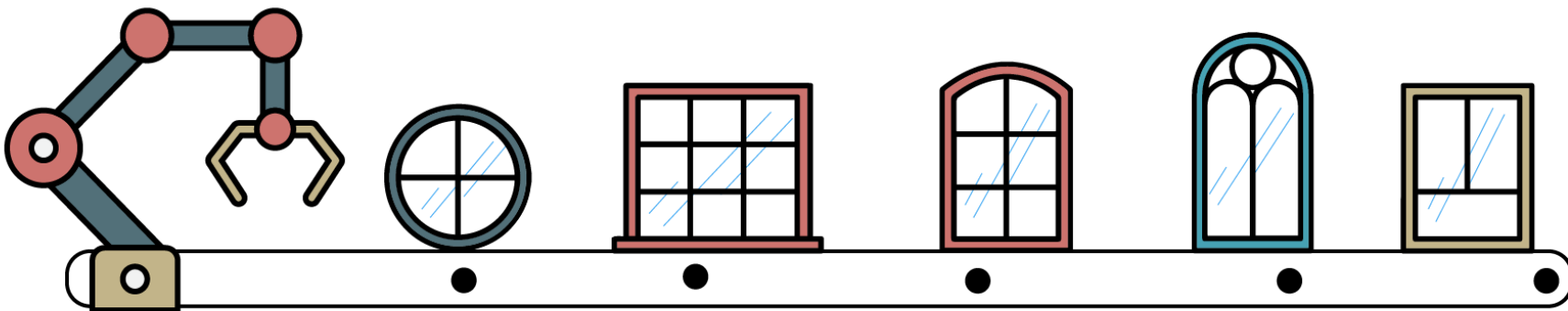




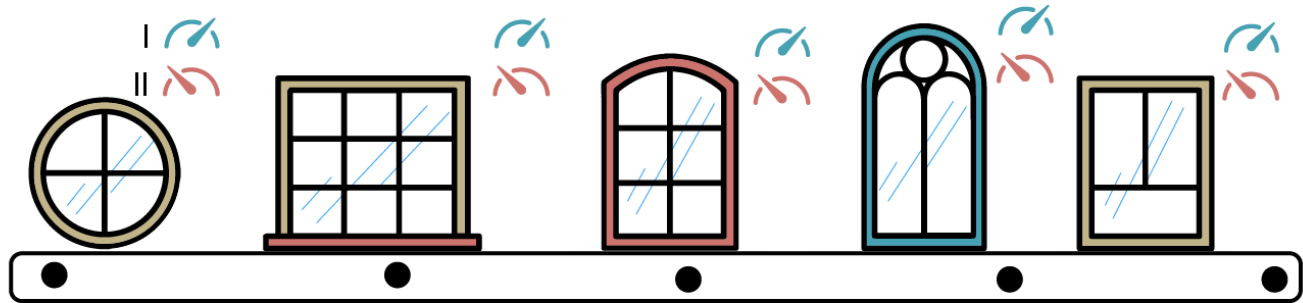
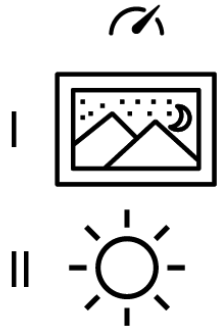
Generative Design Process



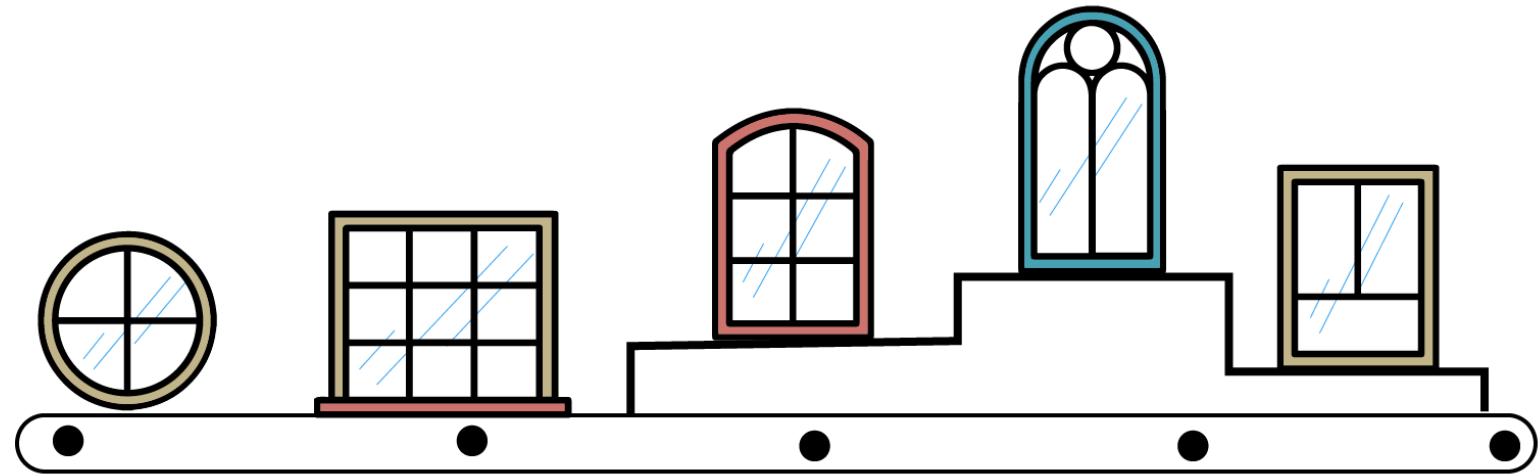
GENERATE 



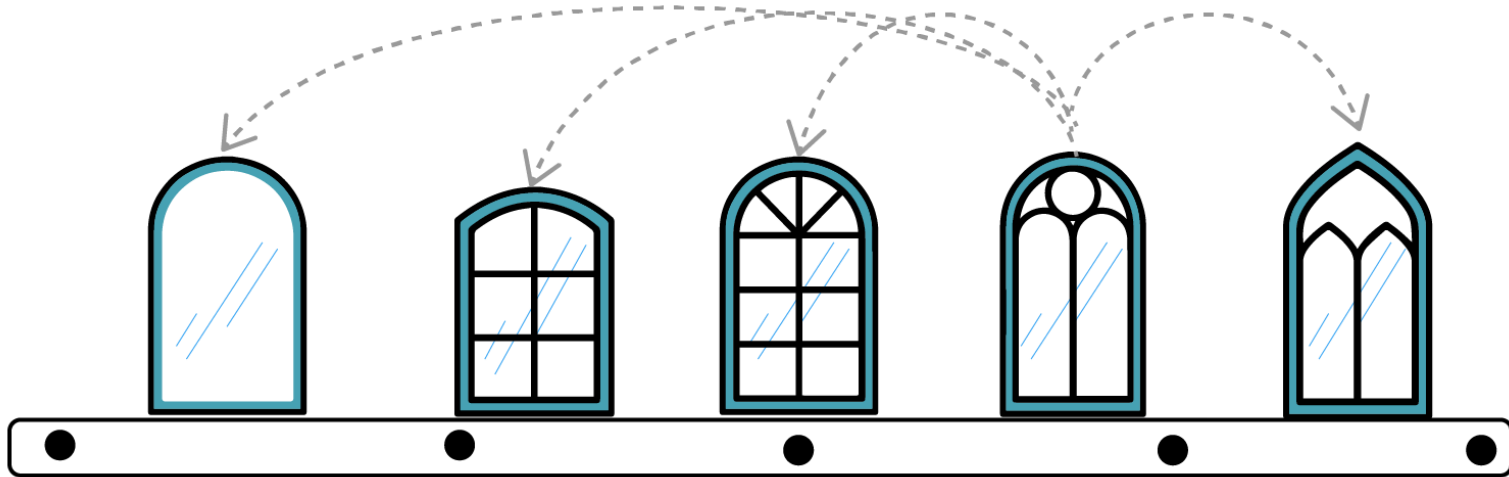
ANALYZE



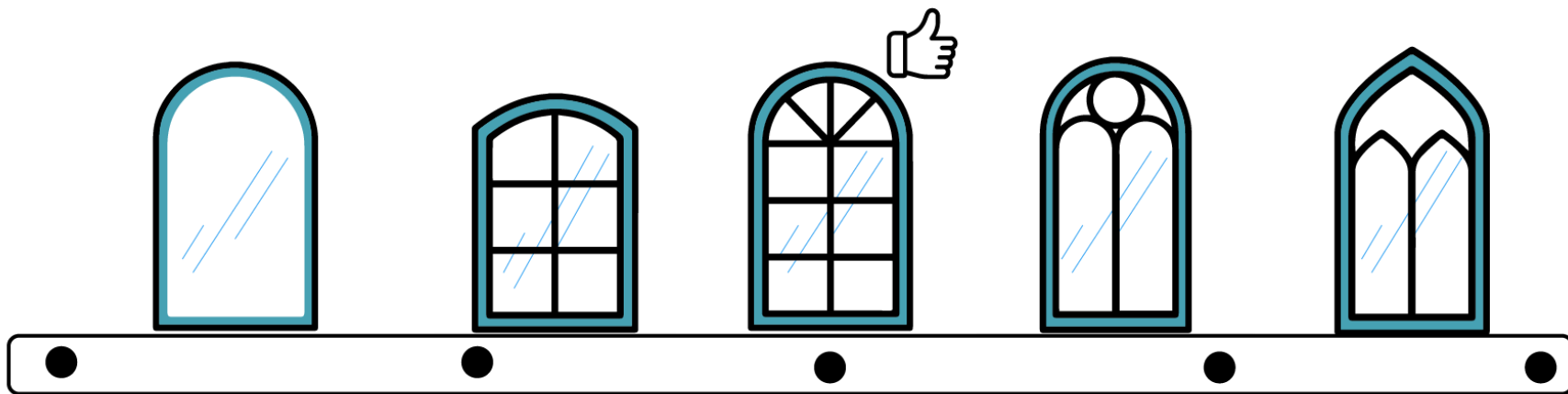
RANK



EVOLVE



EXPLORE 



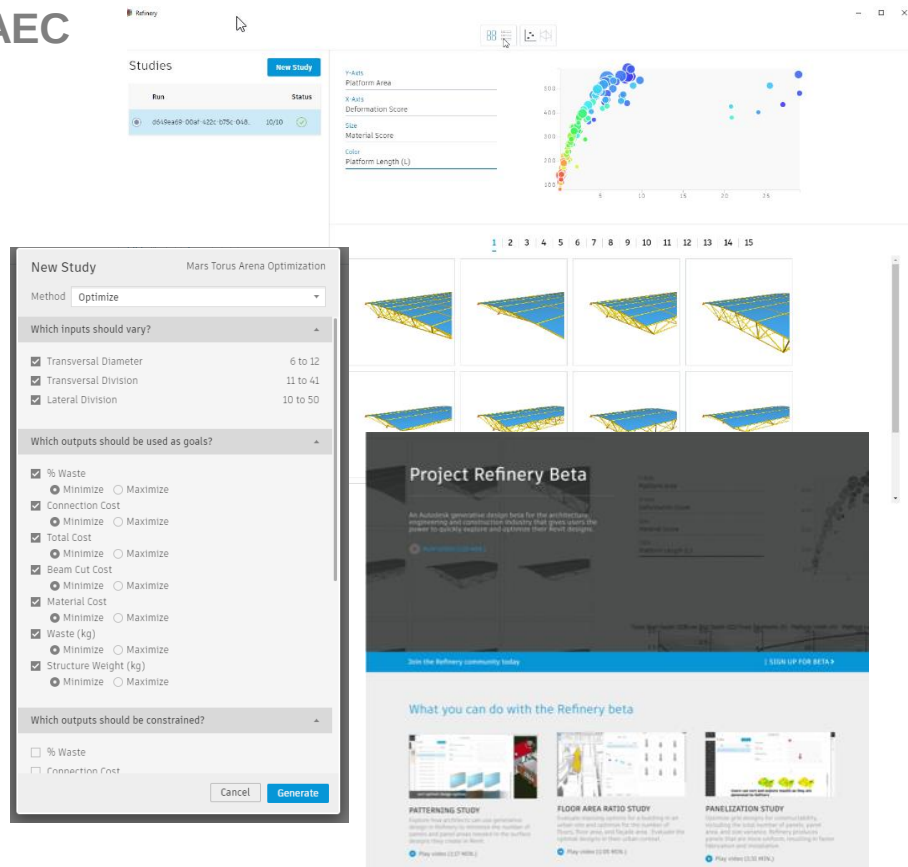
INTEGRATE 



Refinery

Public Beta Project for Generative Design in AEC

- Explore and optimize designs
- Uses NSGA-II optimization algorithm
Learn more here:
https://www.iitk.ac.in/kangal/Deb_NSGA-II.pdf
- Advanced results display
- Syncing selected option back to Dynamo
- More information and beta access:
www.autodesk.com/solutions/refinery-beta



Types of studies | Generation Methods

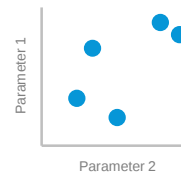
4 TYPES

RANDOMIZE

INPUTS



DESIGN SPACE



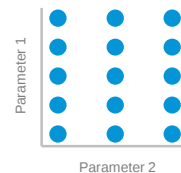
OUTCOME

5 DESIGNS

defined by user

CROSS PRODUCT

5x
3x

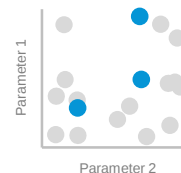


5 x 3 = 15 DESIGNS

user defines sampling density

OPTIMIZE

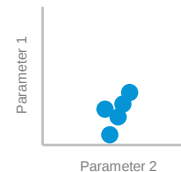
generation 1 population of 3
generation 2 population of 3
...
generation 6 population of 3



3 x 6 = 18 DESIGNS

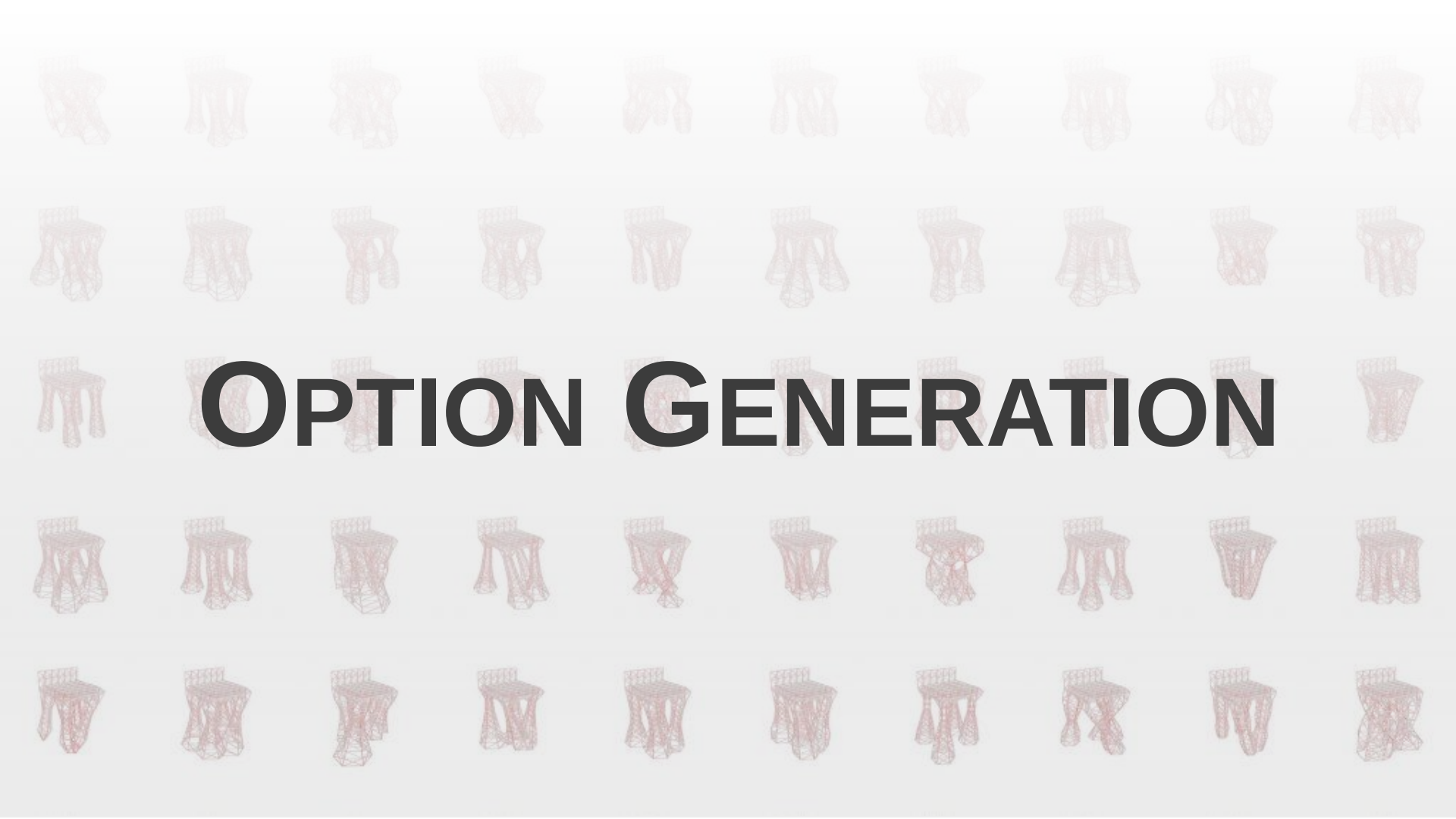
user defines population size
and number of generations

LIKE THIS



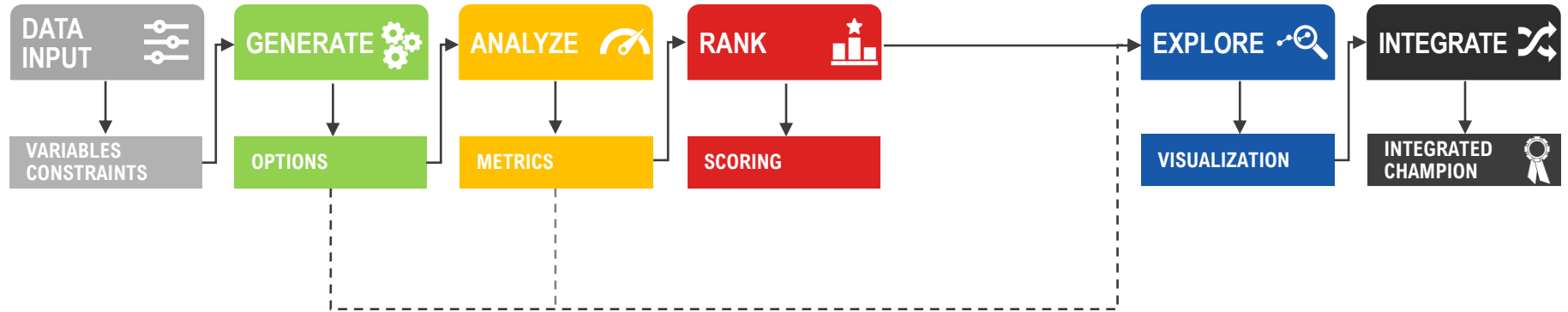
5 DESIGNS

defined by user

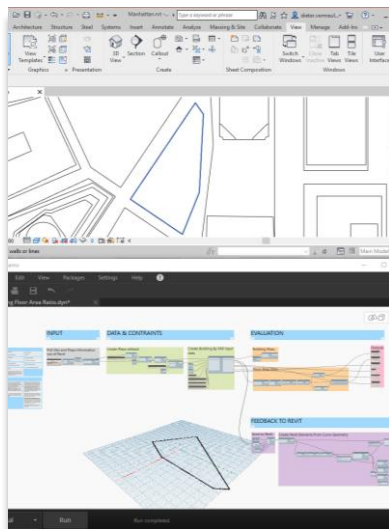


OPTION GENERATION

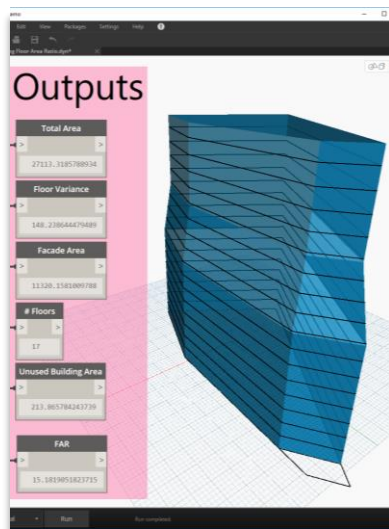
Option Generation Process



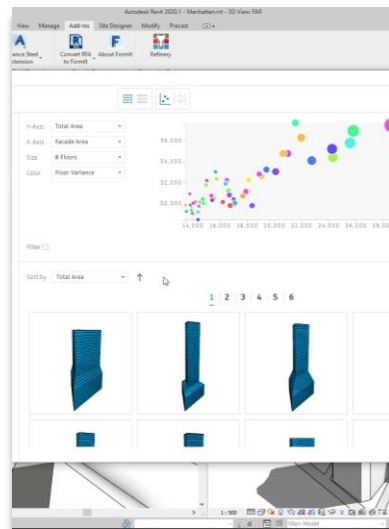
Conceptual Tower Mass Randomization



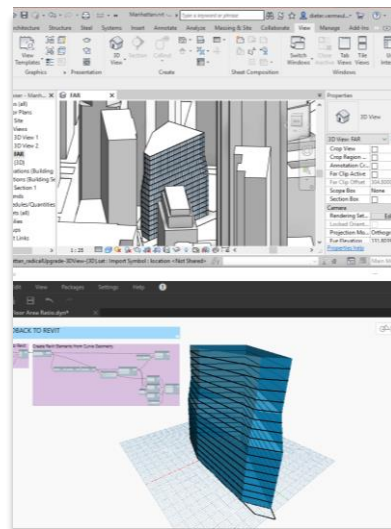
Get Boundaries



Computational Model



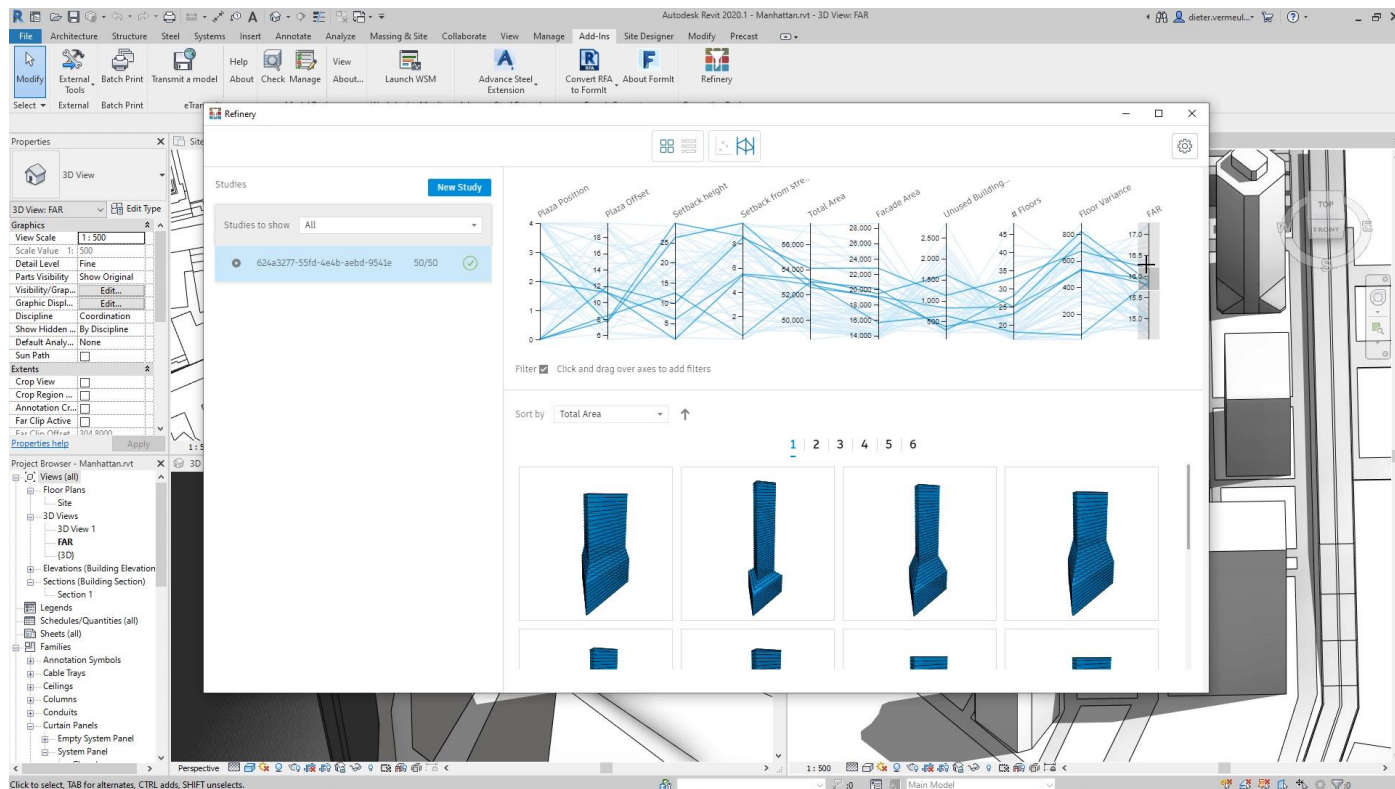
Generate Options

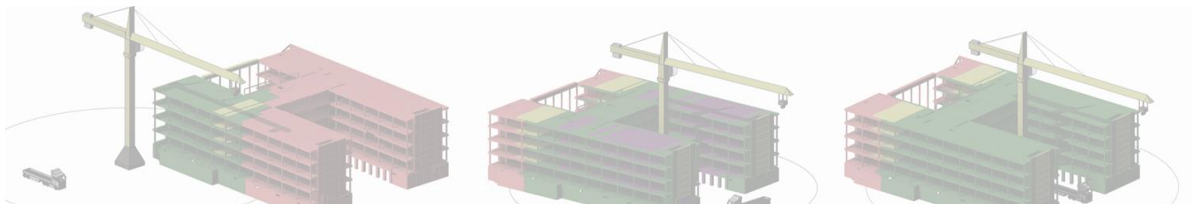


Model Integration

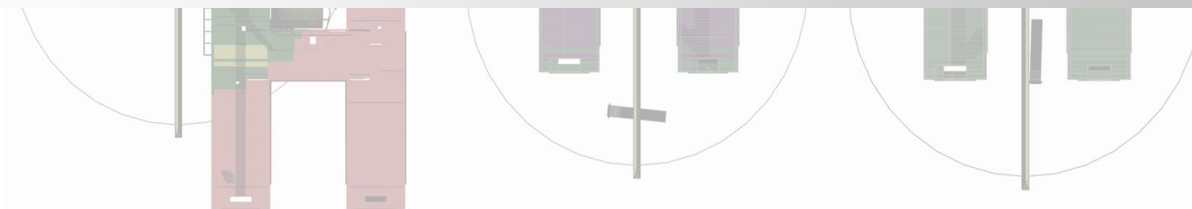
Conceptual Tower Mass Randomization

Option Generation with Dynamo and Refinery





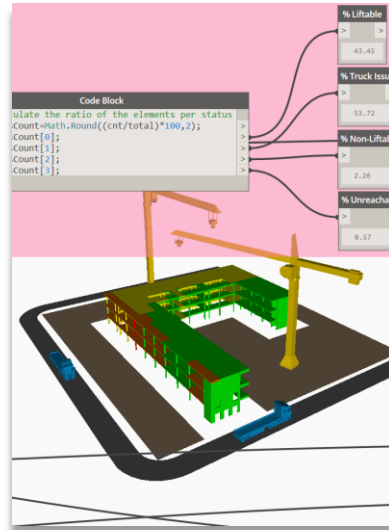
CRANE POSITION OPTIMIZATION



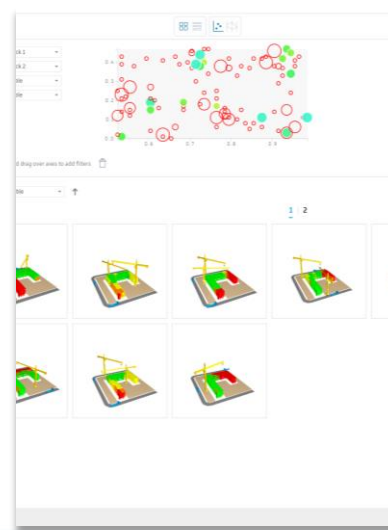
Crane Position Randomization



Create Design Model



Crane Position Analysis



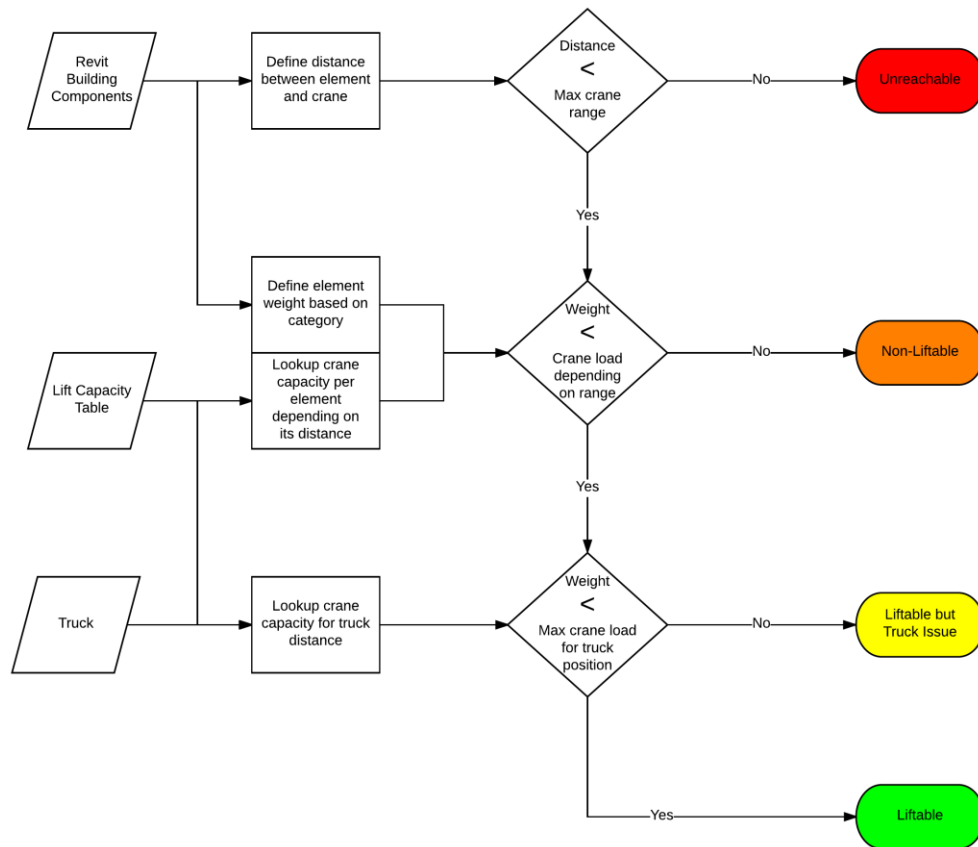
Randomization of Options



Send to Design Model

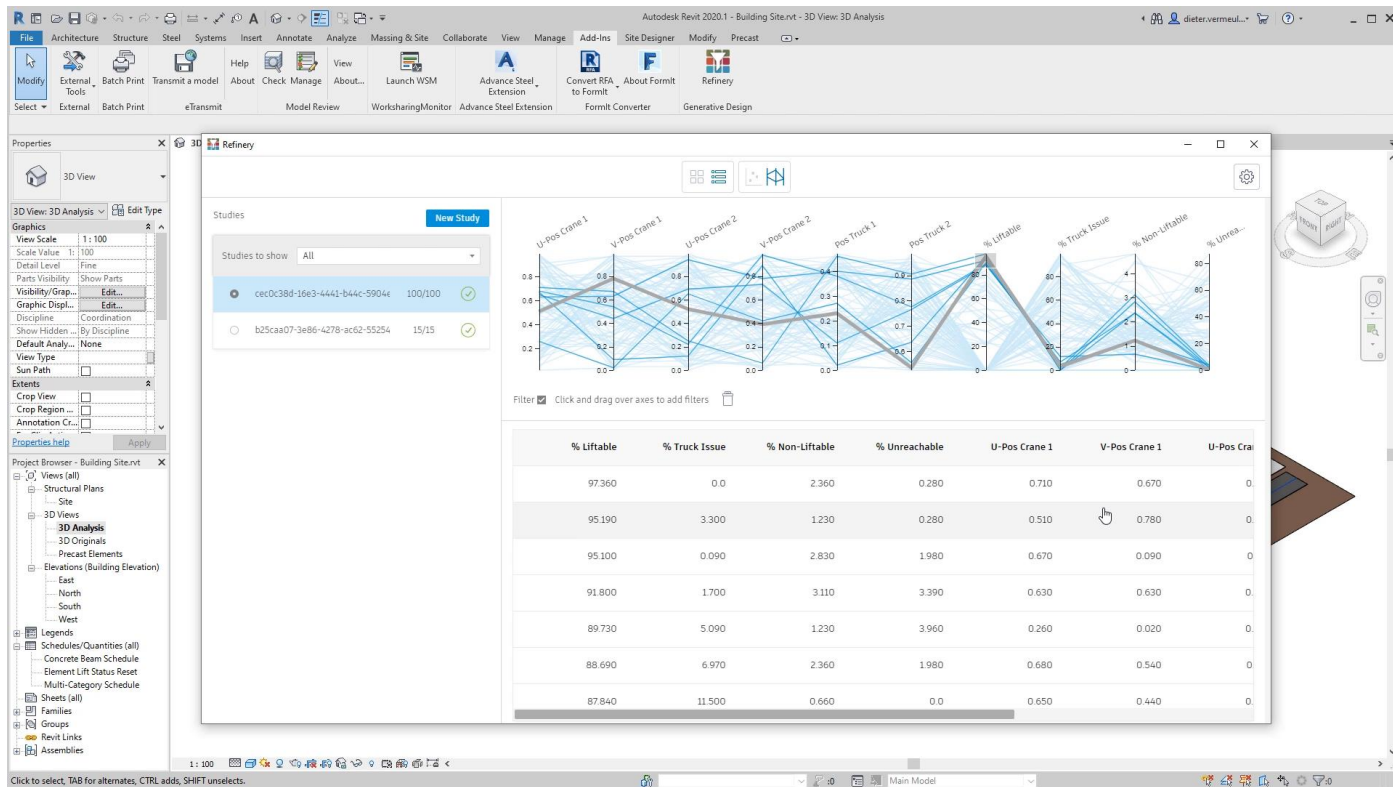
Crane Position Analysis

Flowchart Approach



Crane Position Randomization

Option Generation with Dynamo and Refinery



Y-Axis
Plaza Area

X-Axis
Building Area

Size
Percentage Trees Saved

Color
Forecourt Area



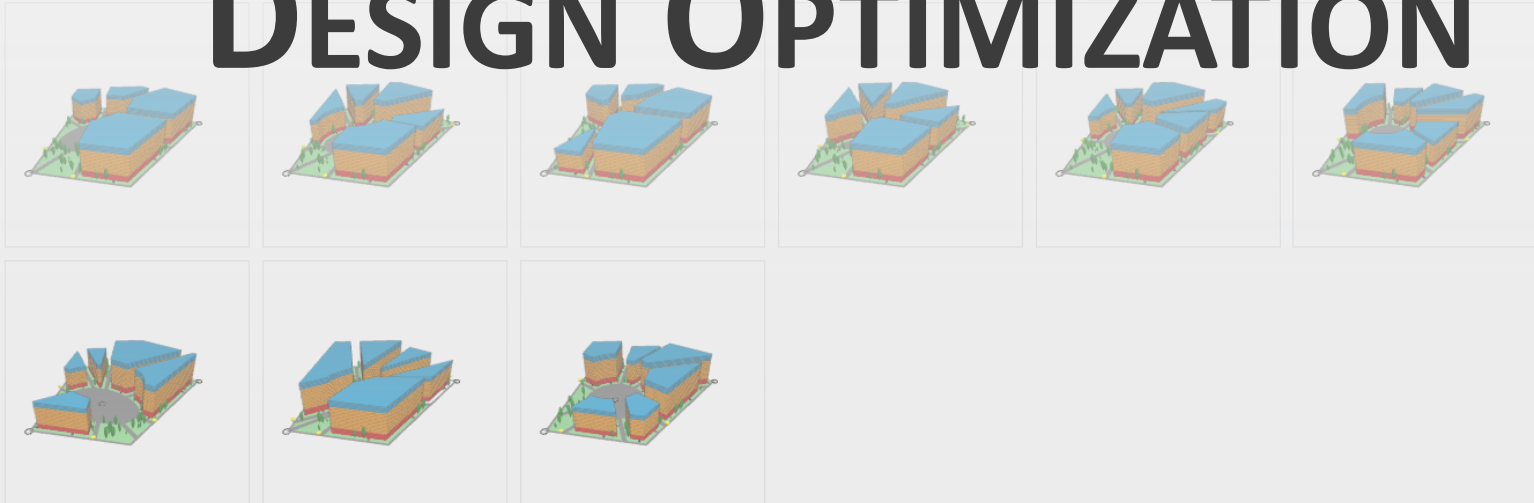
Filter ☐

Sort by Adjacency

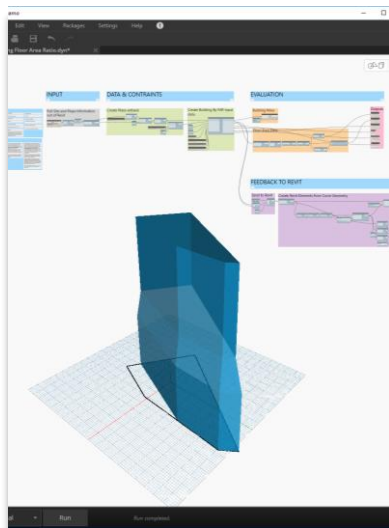


DESIGN OPTIMIZATION

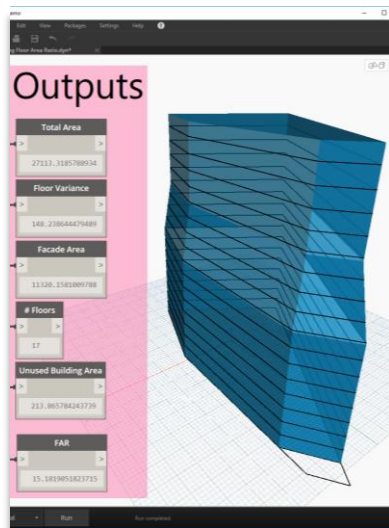
1 2 3 4 5 6 7 8



Conceptual Tower Mass Optimization



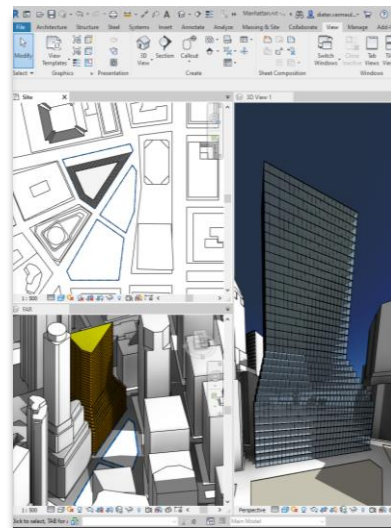
Data and Constraints



Define
Computational
Model



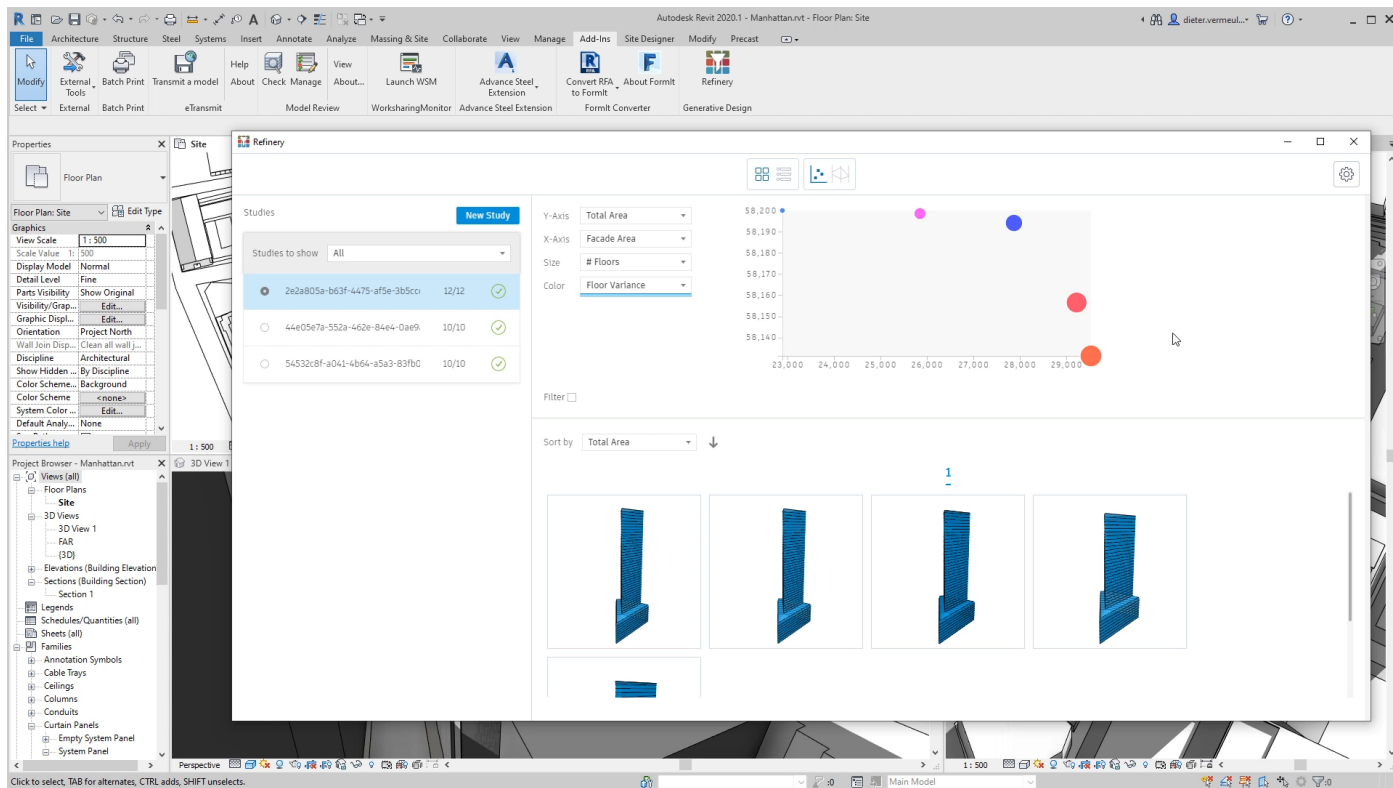
Optimization
Champion Selection



Integrate in design

Conceptual Tower Mass Optimization

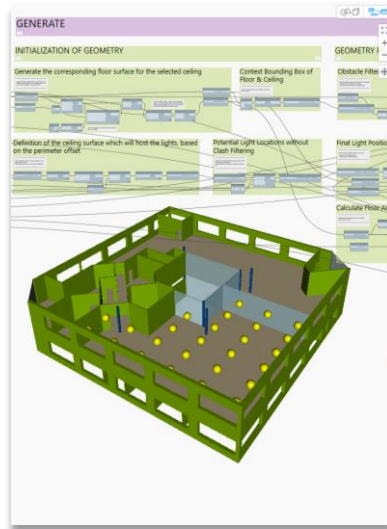
Optimization with Refinery



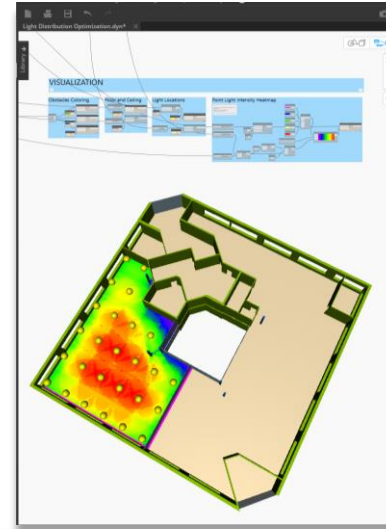
Light Distribution Optimization



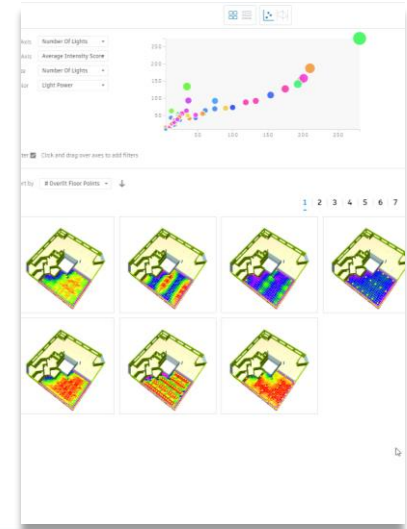
Data & Constraints



Generate



Analyze
&
Ranking

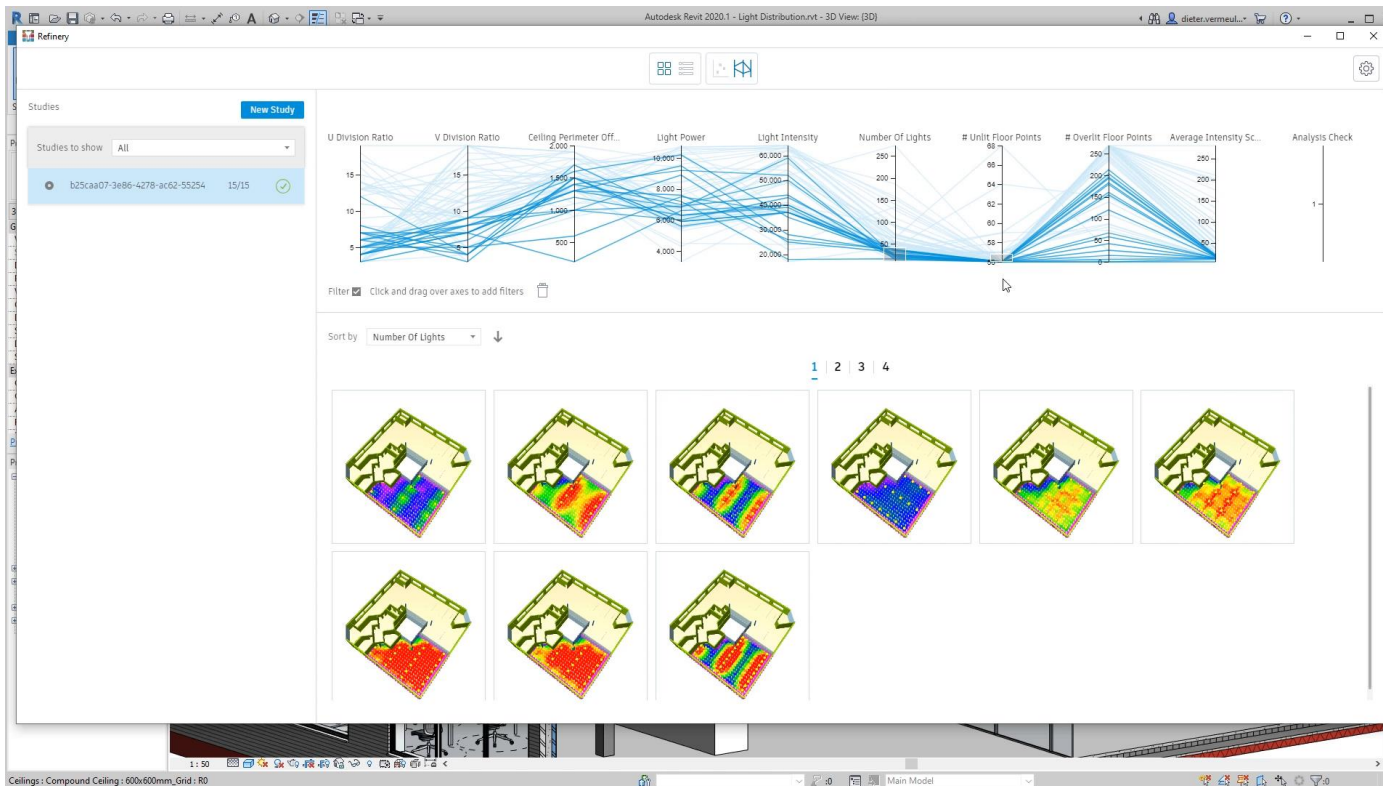


Evolve
Explore Results

Light Distribution Optimization

Design Optimization with Revit, Dynamo and Refinery

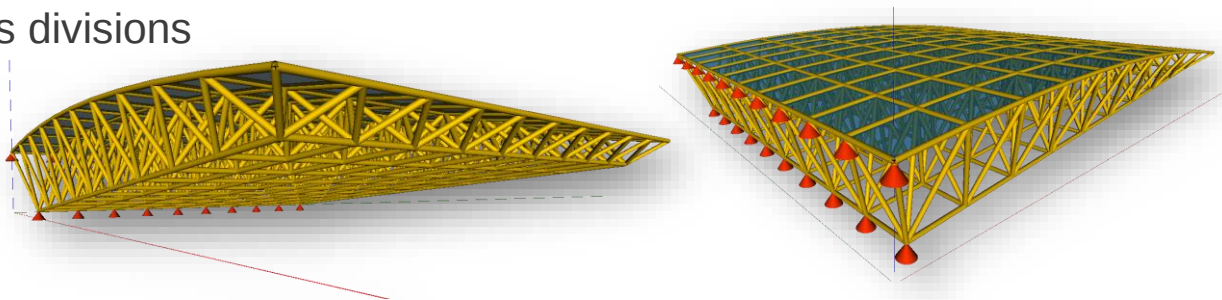
Special thanks for contributing:
Jared Linden, Hoare Lea, UK
Radu Gidei, Matterlab, UK



Spatial Truss Optimization

Design Optimization with Dynamo, DynaShape and Refinery

- Search for the best spatial truss configuration with
 - Maximal Platform Area
 - Minimal Deformation
 - Minimal Structure Weight
- by changing the geometry inputs for
 - Width and length of platform
 - Start depth of the truss
 - End depth of the truss
 - Truss divisions



Platform Size

Platform Top Edges (Z1)
2.000

Platform Mid (Z2)
2.500

Platform Width (W)
12

Platform Length (L)
15

Truss Dimensions

Truss Start Depth (SD)
2

Truss End Depth (ED)
0.5

Truss Segments (S)
10

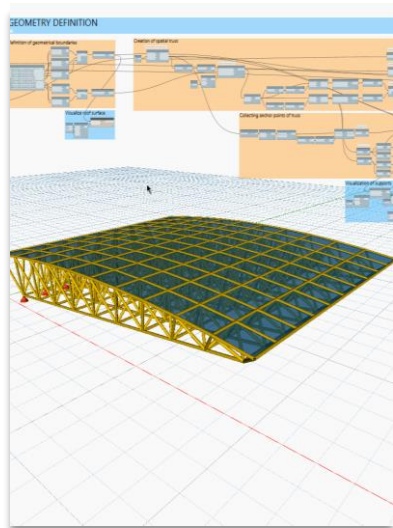
Outputs

Deformation Score
>

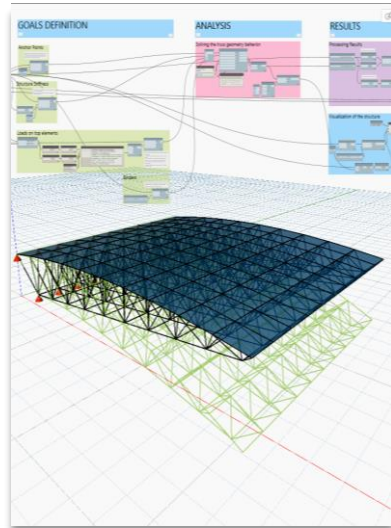
Material Score
>

Platform Area
>

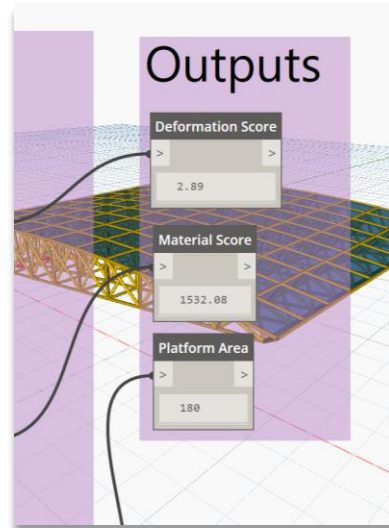
Spatial Truss Optimization



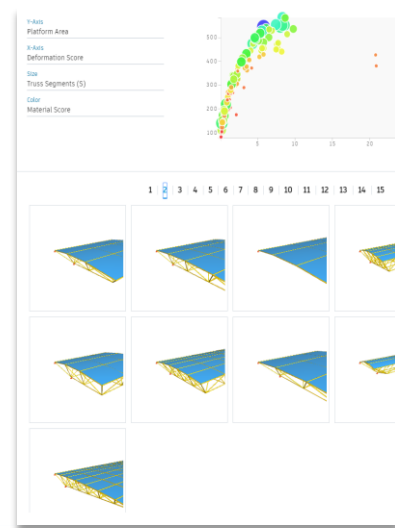
Geometry Definition



Deformation Analysis



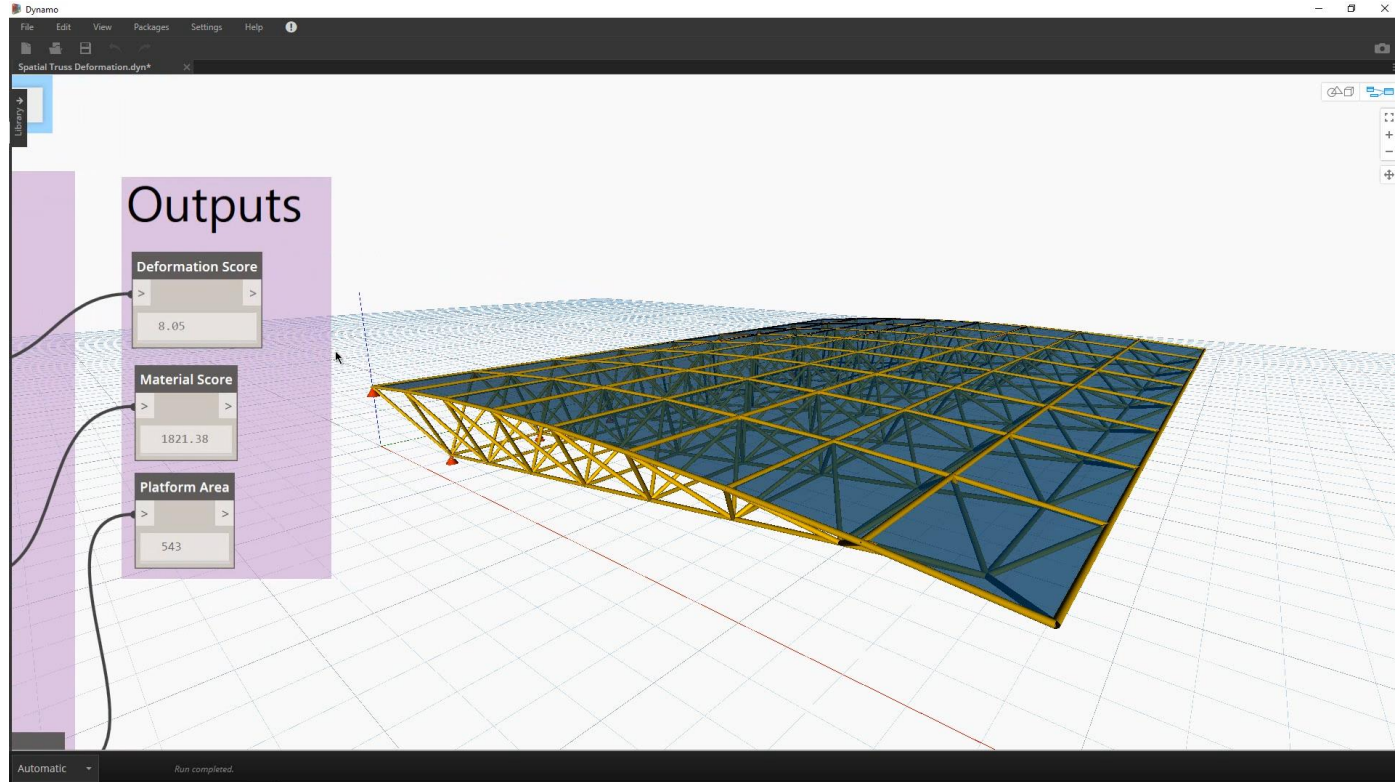
Results Evaluation



Optimization in Refinery

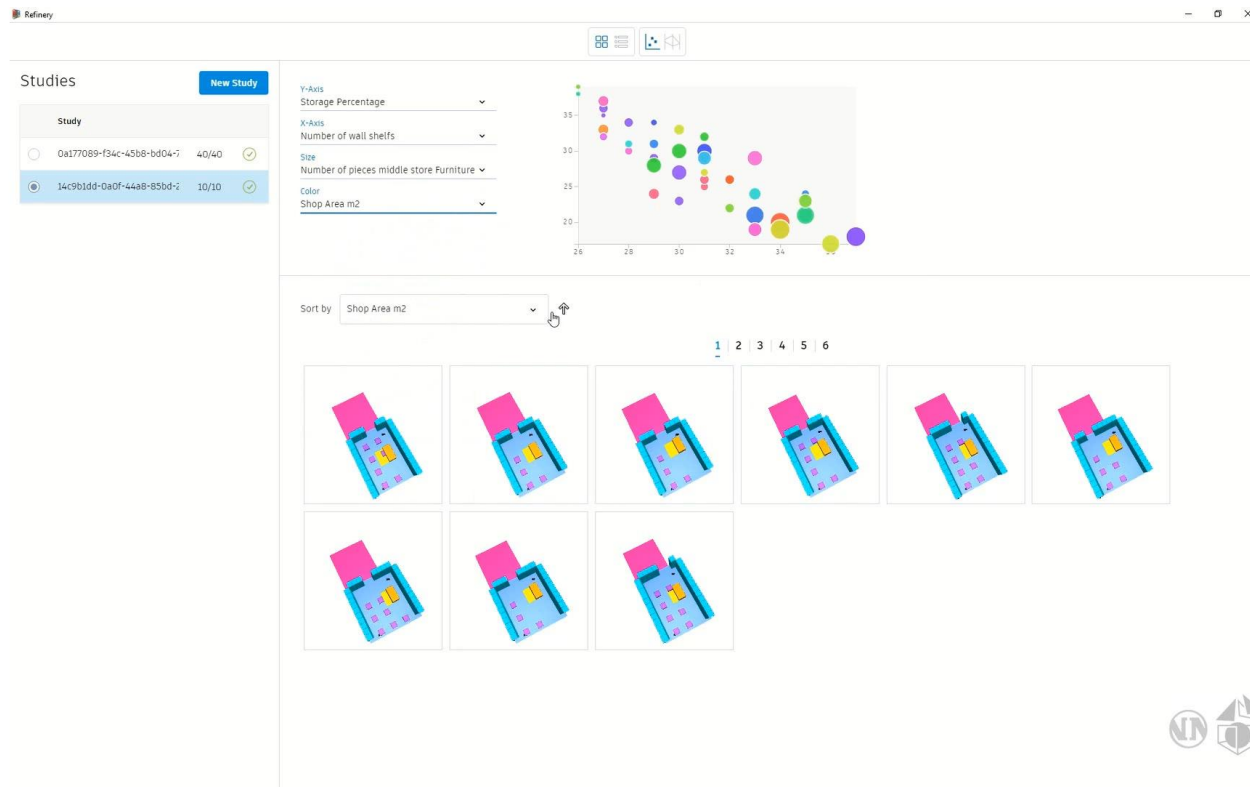
Spatial Truss Optimization

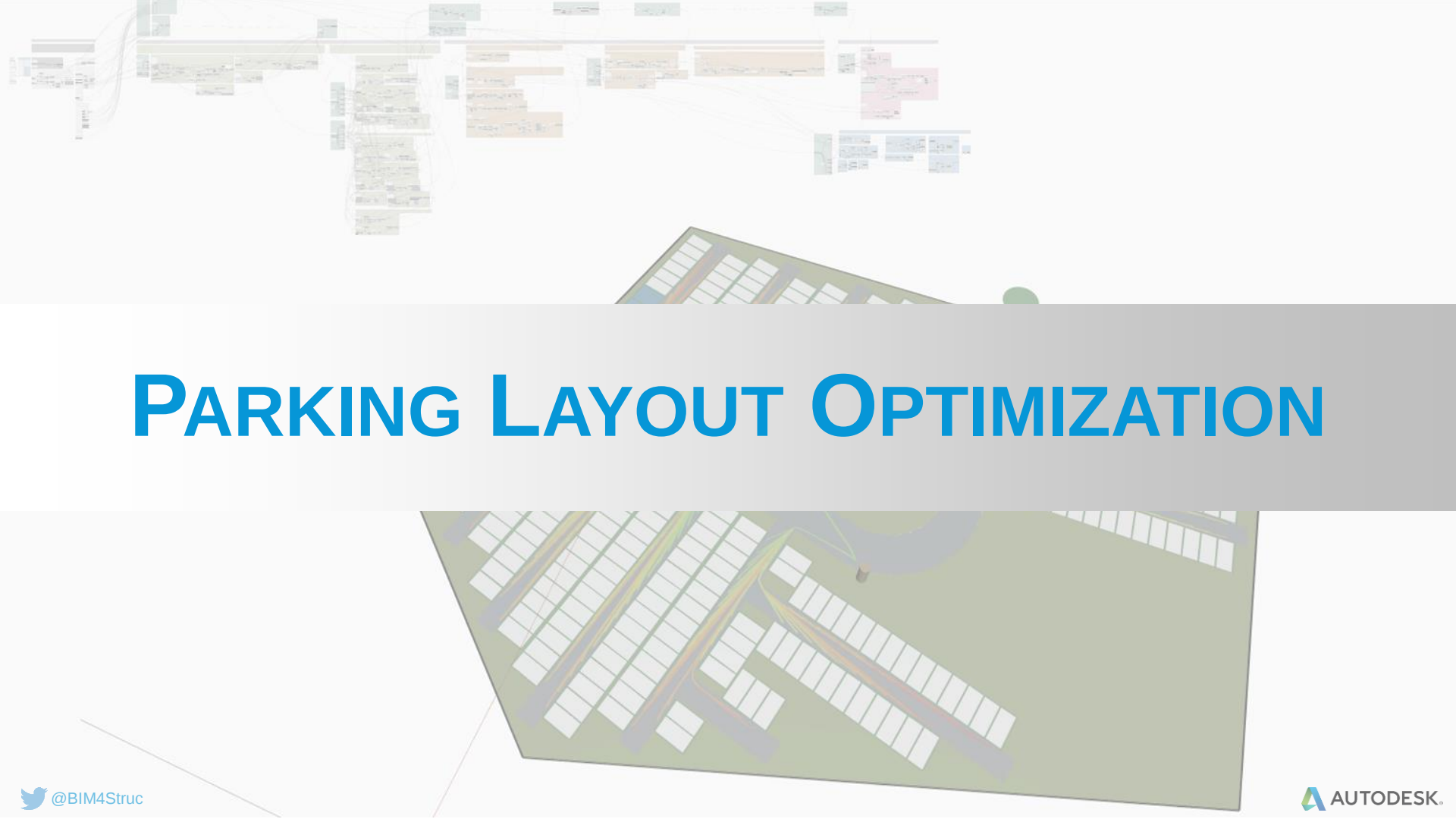
Design Optimization with Dynamo, DynaShape and Refinery



Shop Layout Planning

Optimize the ratio of shop and storage area of a liquor store

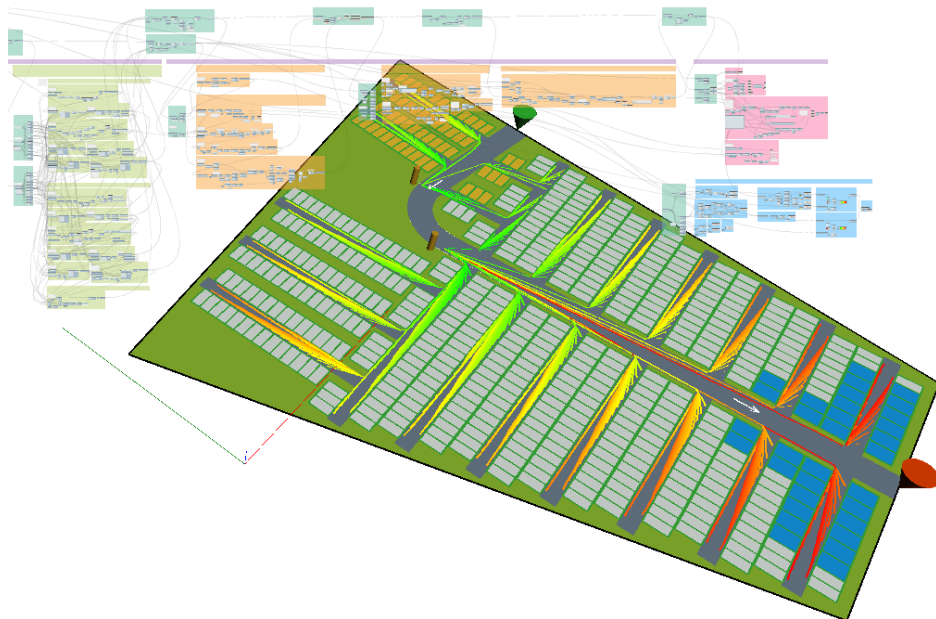


The background of the slide features two architectural diagrams. The top diagram is a complex network of colored rectangular blocks (green, orange, pink, blue) connected by thin white lines, representing a site plan or a data flow. The bottom diagram is a 3D perspective view of a parking lot layout, showing rows of white rectangular parking spaces on a green field, with a small brown structure and a green tree in the distance.

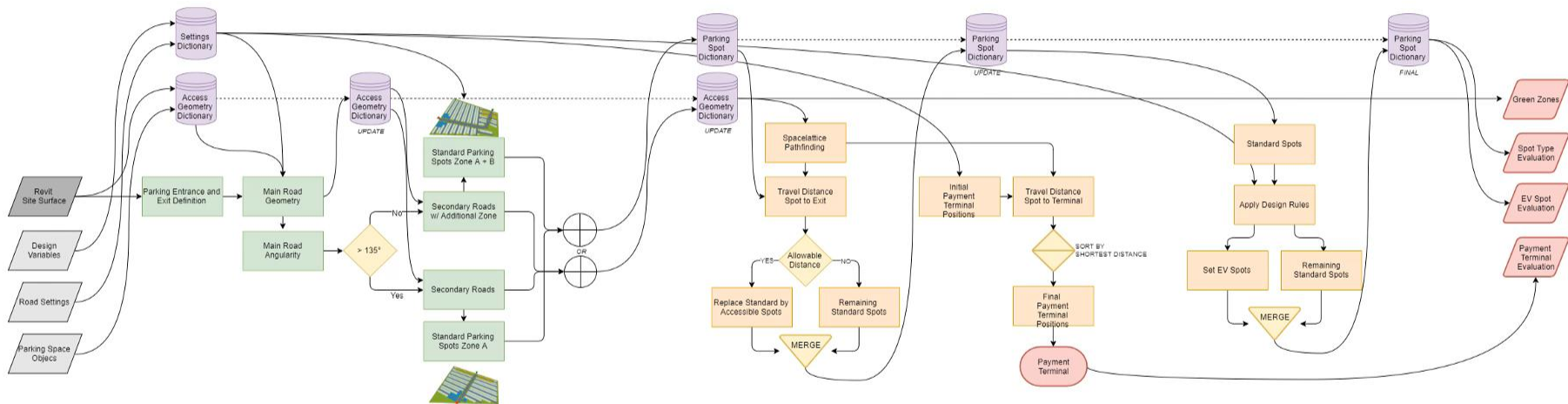
PARKING LAYOUT OPTIMIZATION

Objective of the Optimization

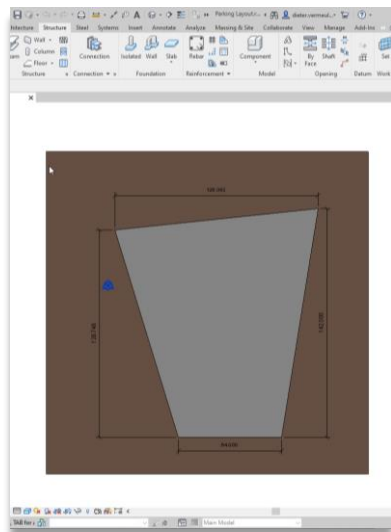
- Layout of main roads, secondary roads
- Number of parking spots
- Assignment of accessible spots
- Concentration of spots for electrical vehicles
- Green zones
- Walking distances to payment terminals



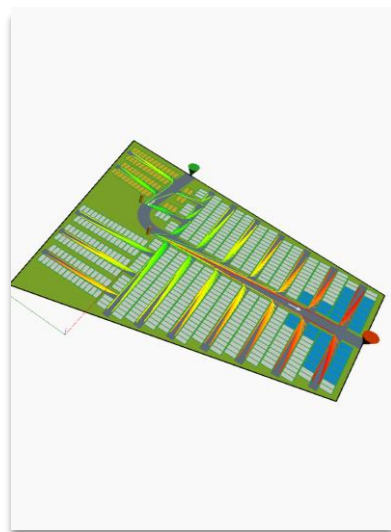
Process



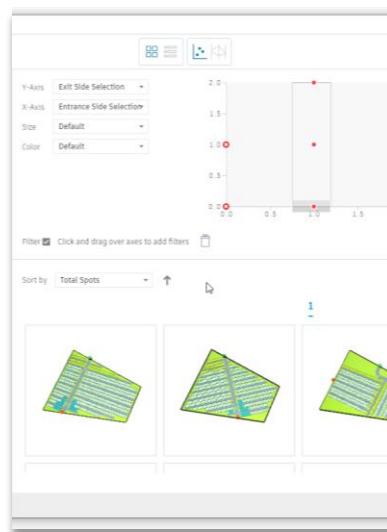
Parking Layout Optimization



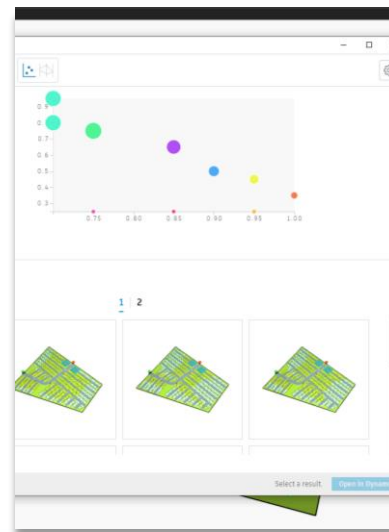
Data & Constraints



Analysis & Ranking



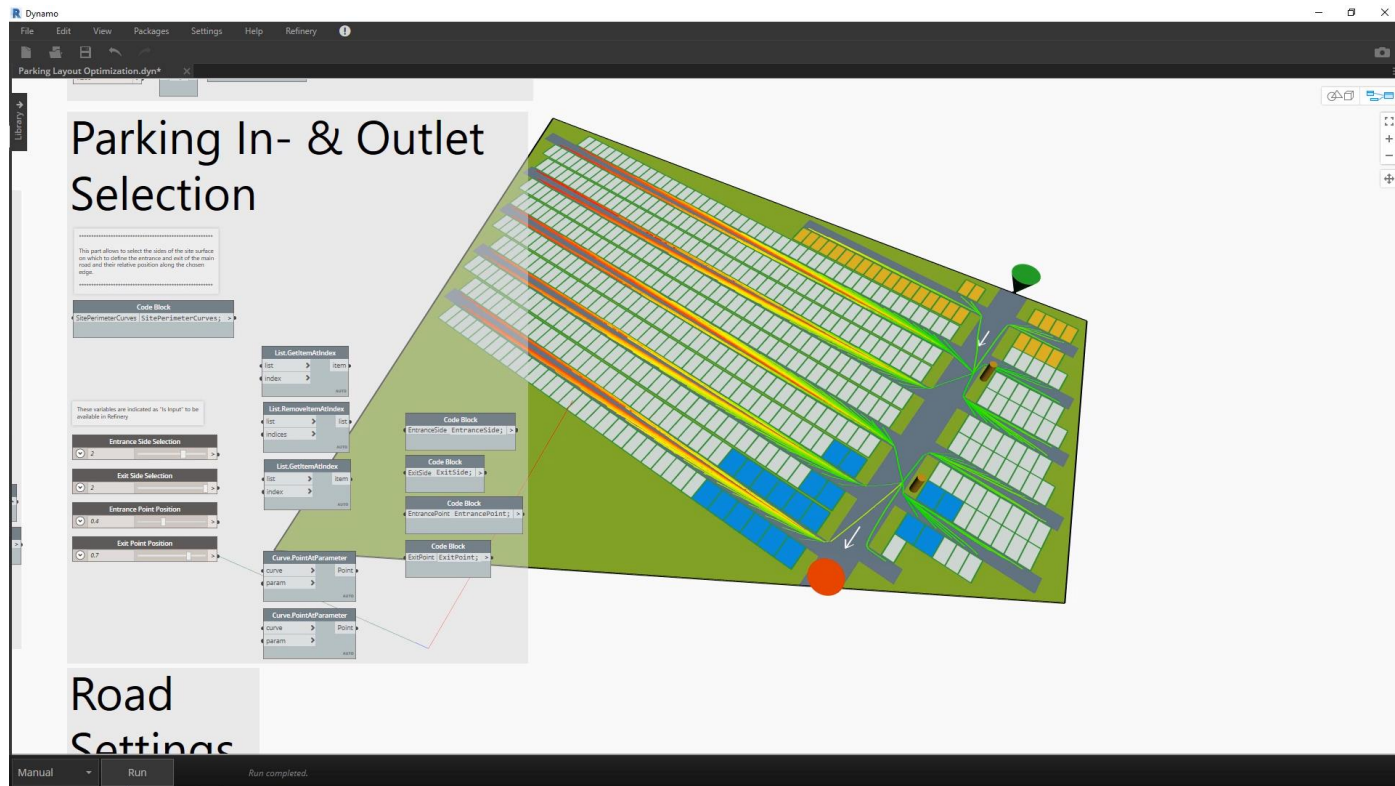
Layout Option
Generation



Optimization of EV
spots and terminals

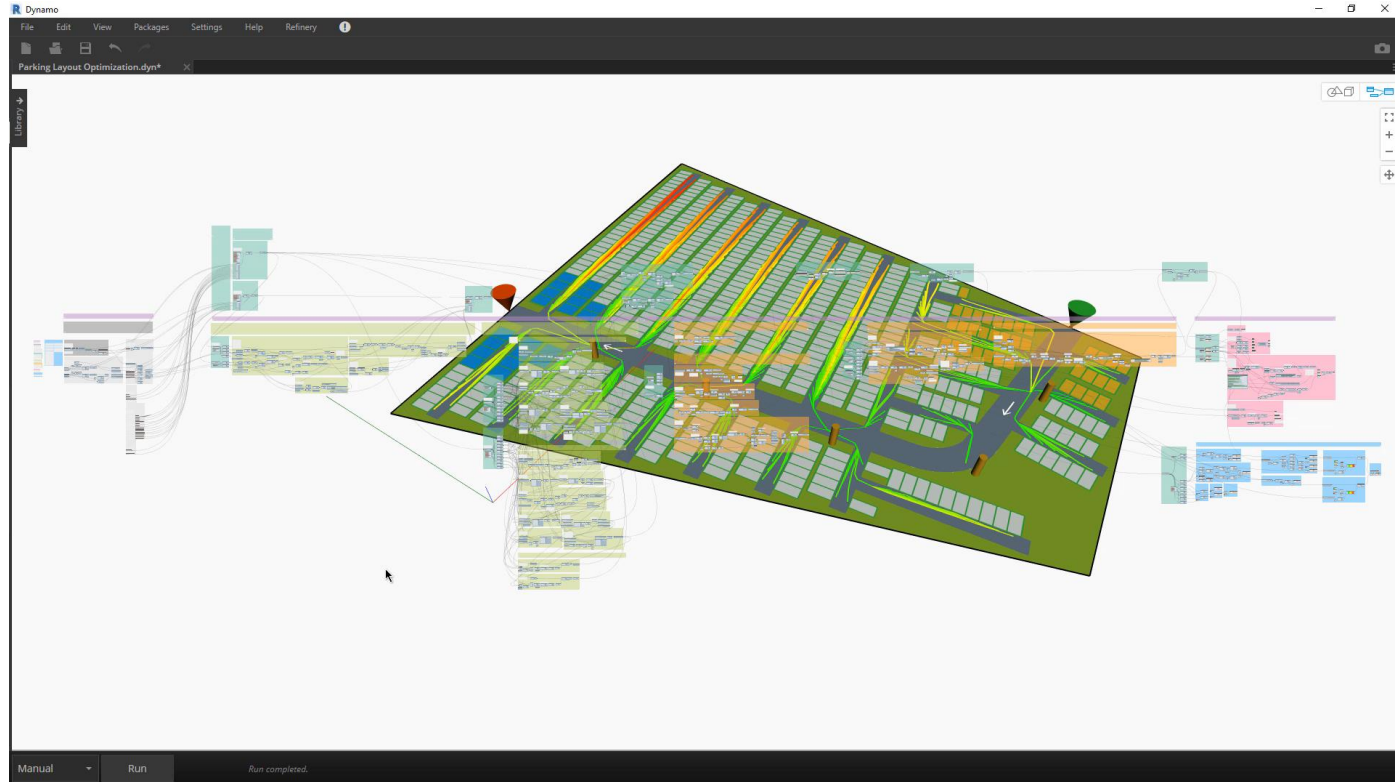
Parking Layout Optimization

Computational Model



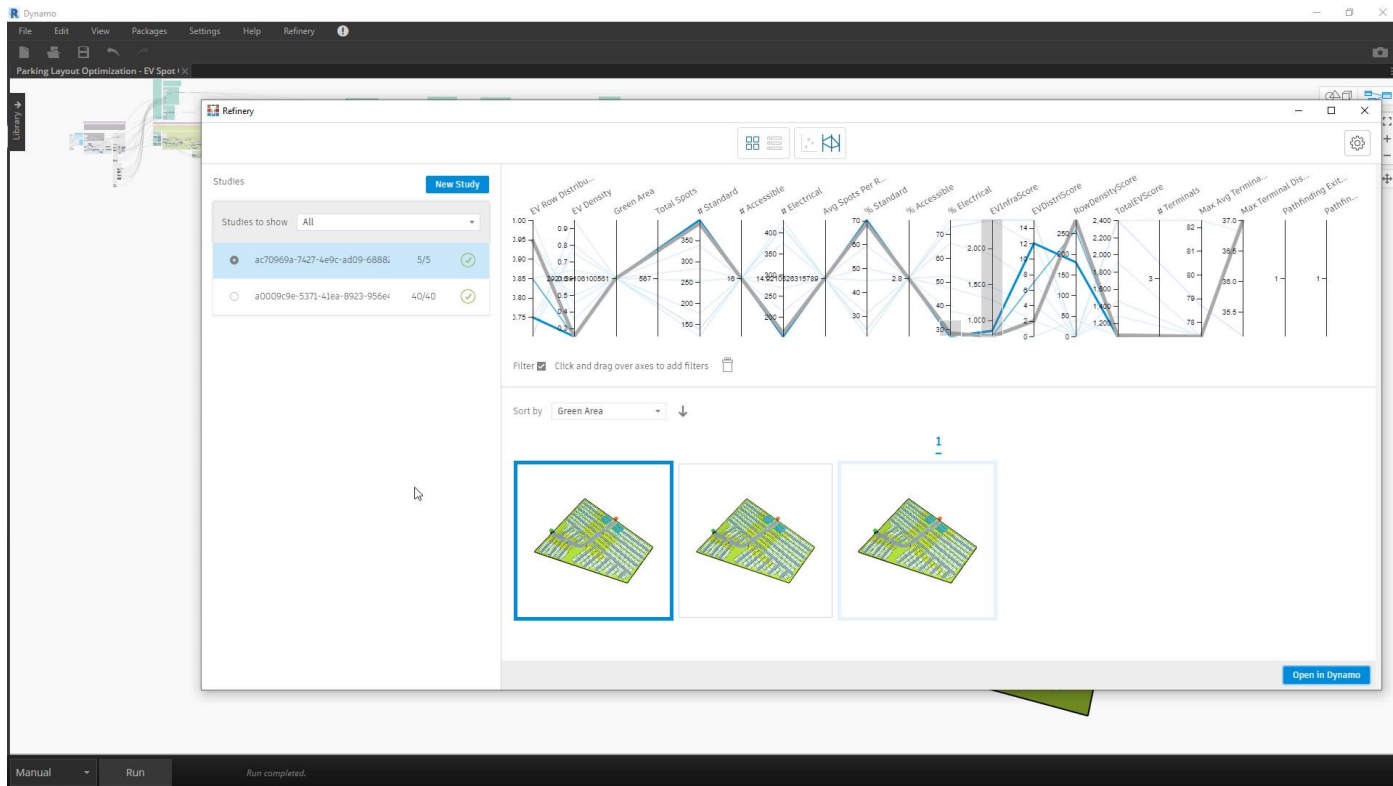
Parking Layout Optimization

Option Generation of Possible Layouts



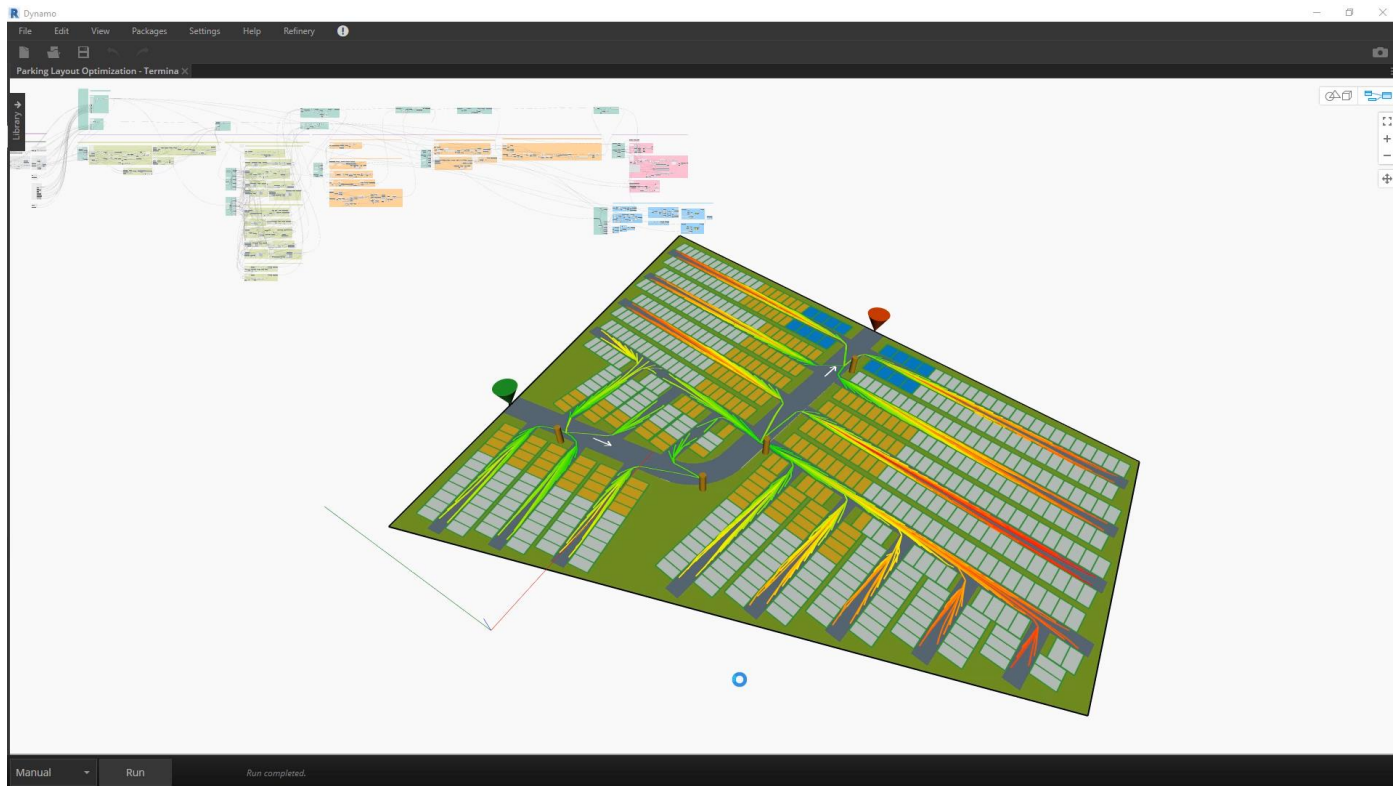
Parking Layout Optimization

Optimization of spots for electrical vehicles



Parking Layout Optimization

Optimization of payment terminals position



Alternative Site Selection

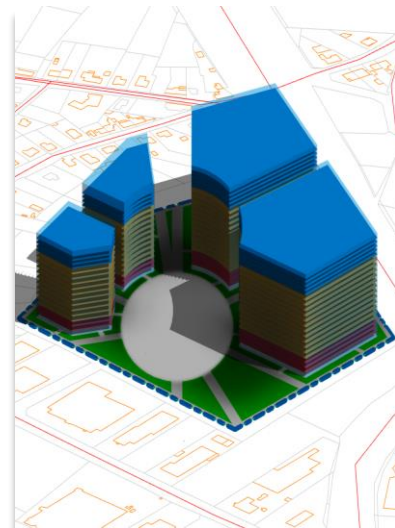
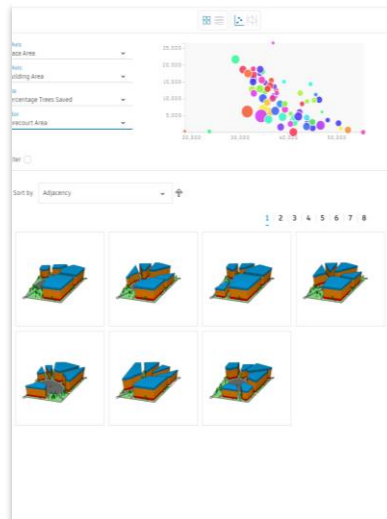
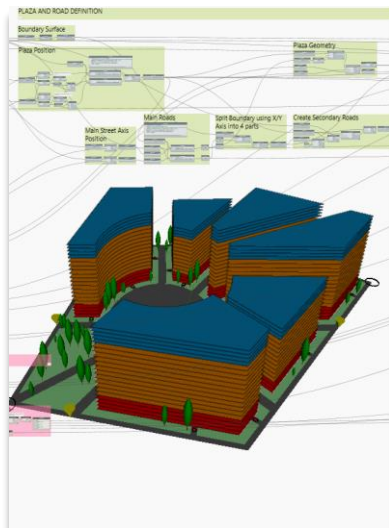
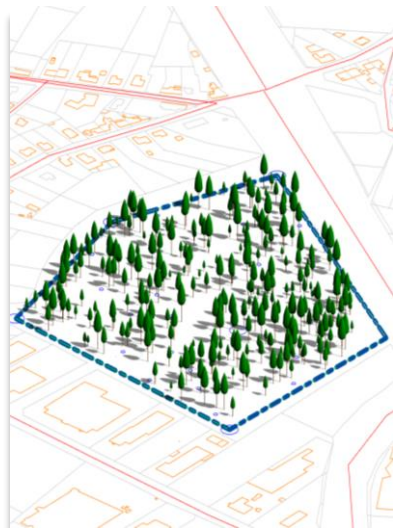
Script is generically useable



The image is a 3D architectural rendering of a city block. In the foreground, there are several blue, multi-story buildings with flat roofs. A central green space, possibly a park or plaza, is visible, surrounded by a low blue wall. The background shows a grid of streets and other buildings, rendered in a lighter, more schematic style. The overall scene is presented in a clean, modern aesthetic.

URBAN PLANNING

Urban Planning



Data and Constraints

Computational Model

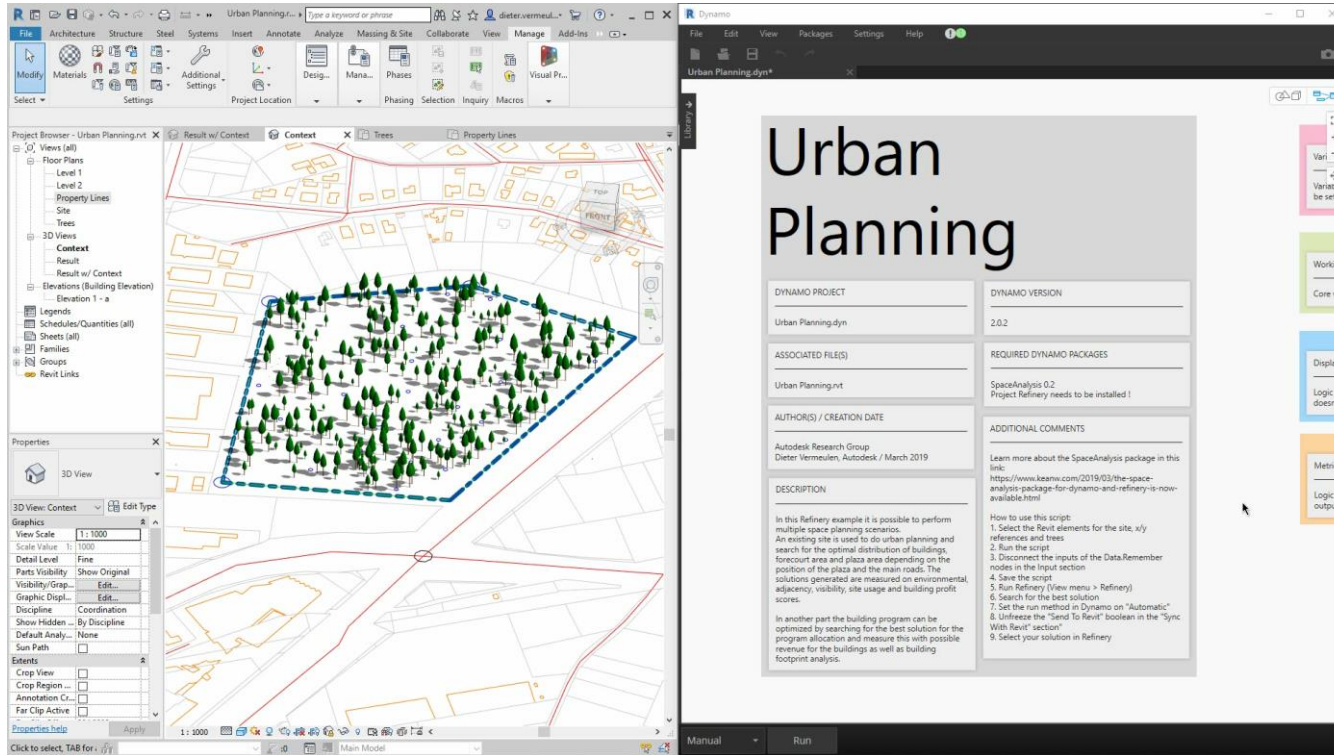
Optimization of
Solutions

Generate model



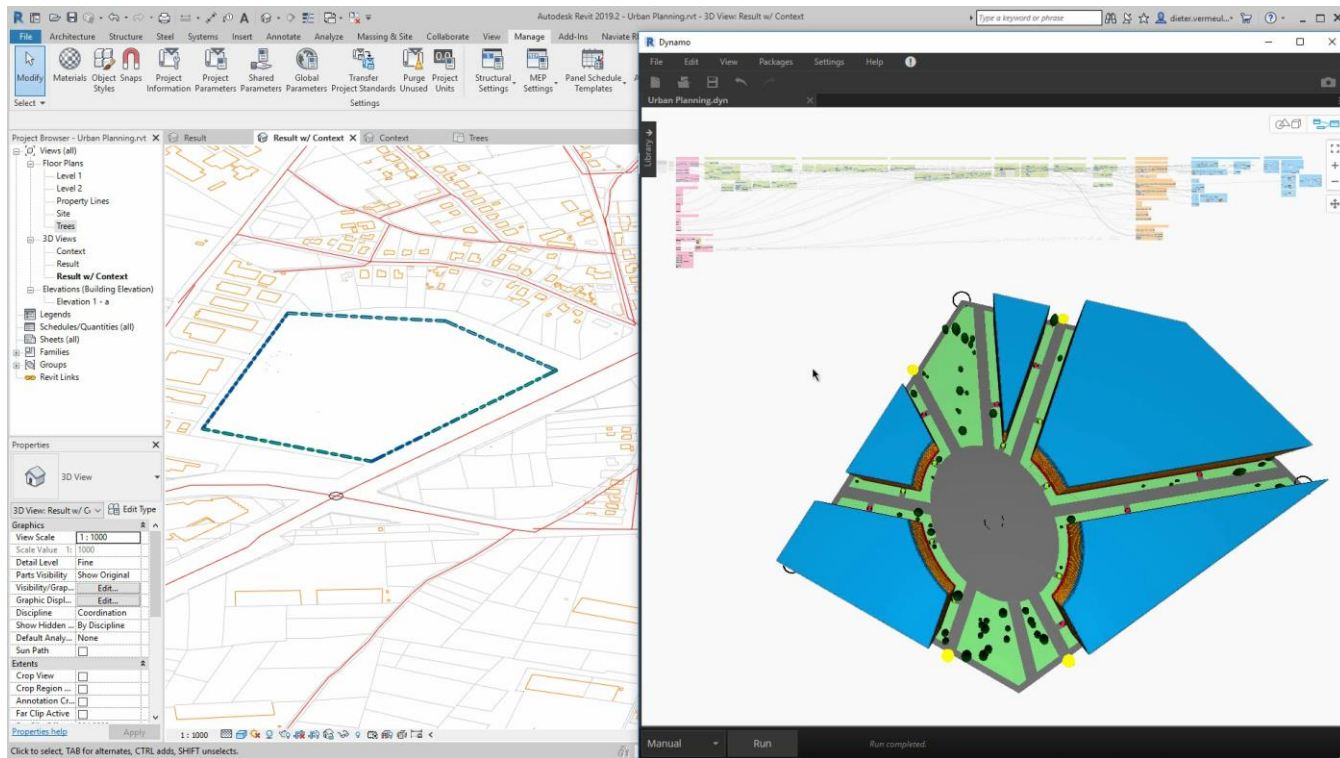
Urban Planning

Computational Model with Dynamo

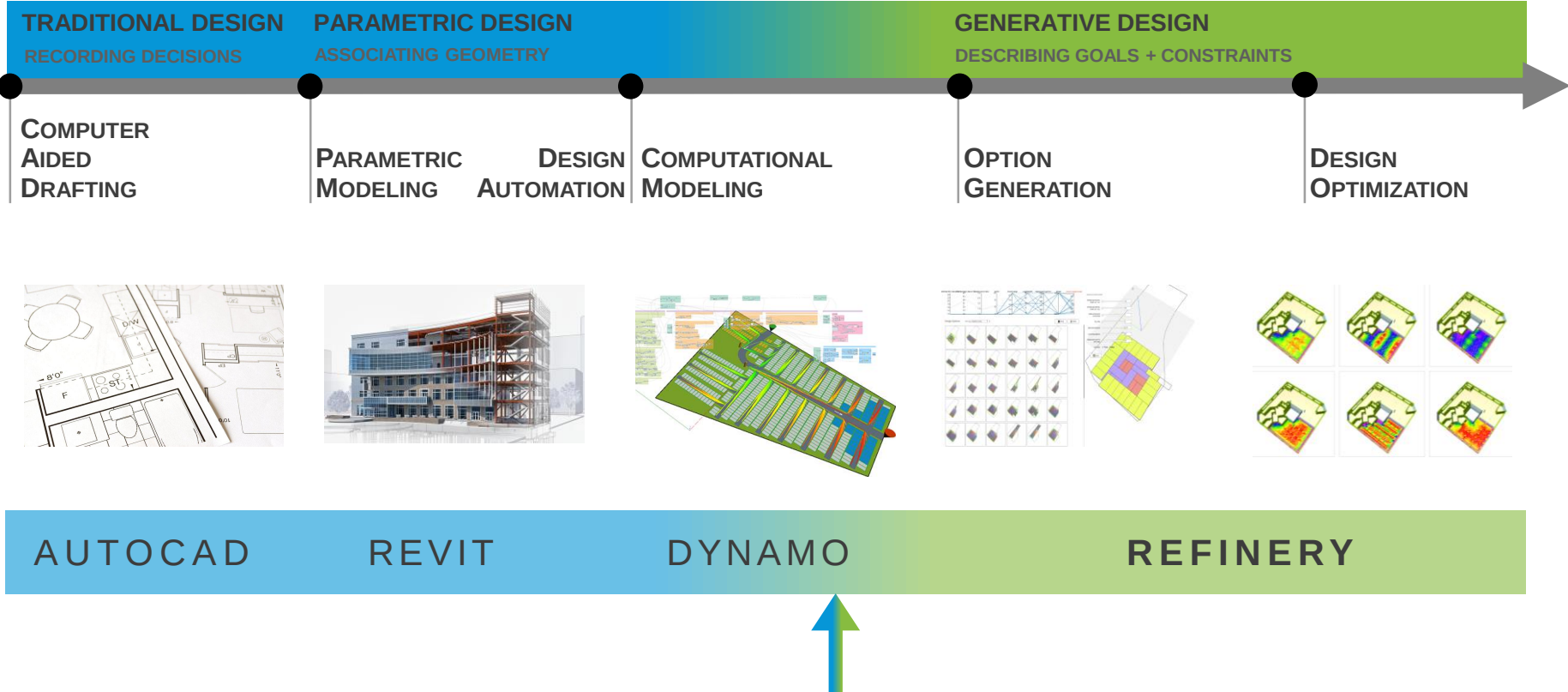


Urban Planning

Optimization with Refinery



Design Technology Progression



Machine
Learning

 **AUTODESK®
BIM 360™**
CONSTRUCTION IQ

Generative
Design



DYNAMO

Project Refinery Beta



**AUTODESK®
FUSION 360™**

Computational
Modeling



DYNAMO



**AUTODESK®
REVIT™**



**AUTODESK®
FUSION 360™**



**AUTODESK®
FORMIT™**

Design Automation



DYNAMO



FORGE



**AUTODESK®
BIM 360™**

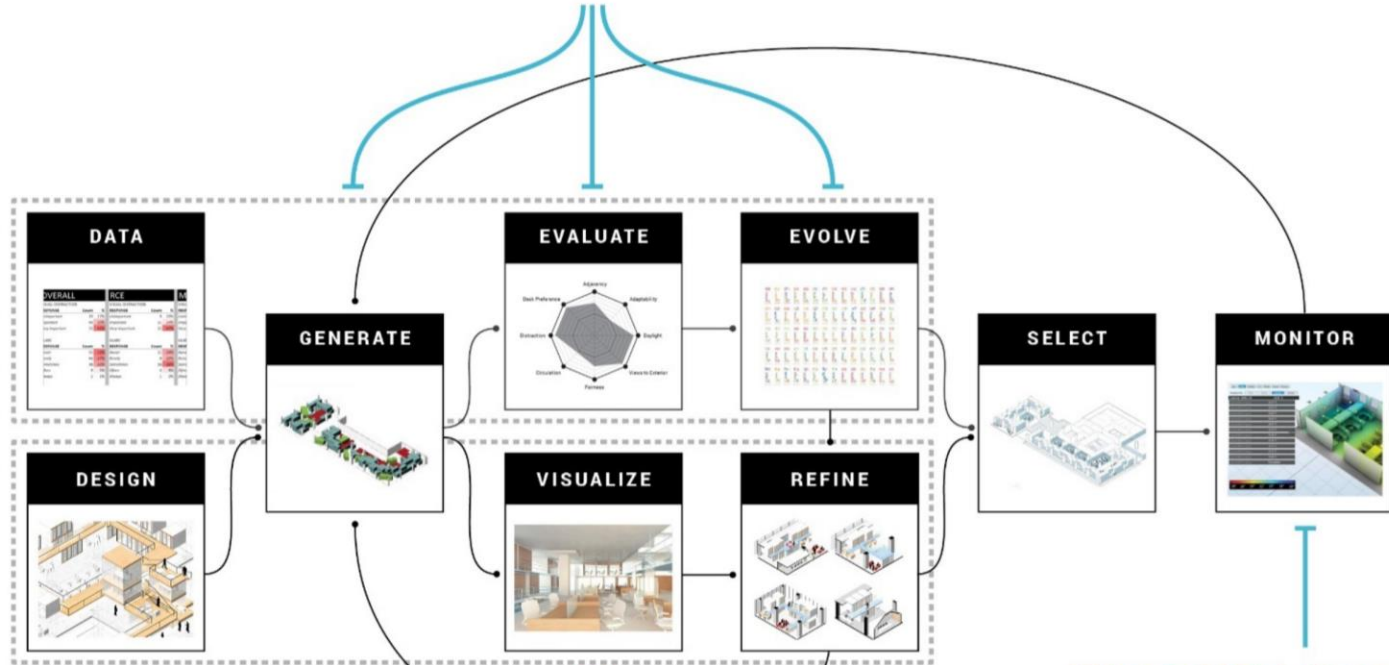


**AUTODESK®
REVIT™**

GENERATIVE DESIGN

QUANTITATIVE

QUALITATIVE



INTERNET OF THINGS

VIRTUAL REALITY

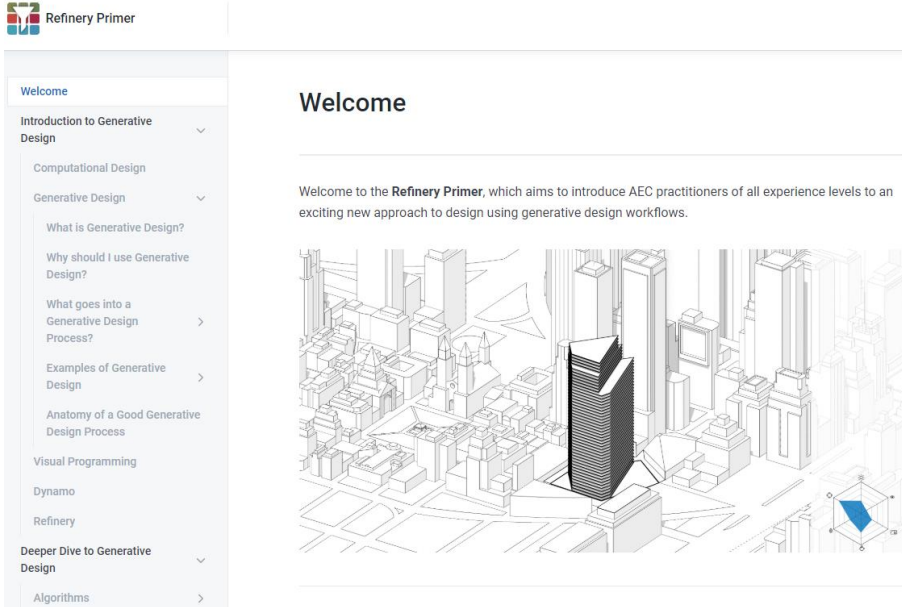
What level of design progression ?



You know what to do ! 

Check this out!

<https://refineryprimer.dynamobim.org/>



The full presentation with embedded videos
will be available for download on



[this link](#)

after November 18th, 2019



Autodesk and the Autodesk logo are registered trademarks or trademarks of Autodesk, Inc., and/or its subsidiaries and/or affiliates in the USA and/or other countries. All other brand names, product names, or trademarks belong to their respective holders. Autodesk reserves the right to alter product and services offerings, and specifications and pricing at any time without notice, and is not responsible for typographical or graphical errors that may appear in this document.