AUTODESK UNIVERSITY

AS500585

# How Generative Design Can Help Optimize New Neighborhoods


Dieter Vermeulen
Technical Specialist AEC @ Autodesk
@bim4struc

Jacob Small
Technology Consultant @ Autodesk
@JacobWSmall


# Class Resources

**Getting access to all information ?**

- This presentation contains videos, which are not embedded in the PDF version.
- The session has also been recorded.
- You can get access to the full presentation including videos, the handout, recording and full datasets on this link below or through the QR code on the right.

  https://autode.sk/NeighborhoodOptimization

# Dieter Vermeulen

- Technical Sales Specialist AEC
- Structural Engineer
- Specialized in Generative Design
- 8 years at Autodesk

# Jacob Small

- Technical Consultant
- Architecture Background
- Dynamo and Generative Design Expert
- 4 years at Autodesk

# Class Description

The need for affordable housing has never been so high worldwide. One possible solution is to optimize the development of new neighborhoods. But how can you get a maximum number of residential buildings on your plot in a sustainable way while still providing comfort?

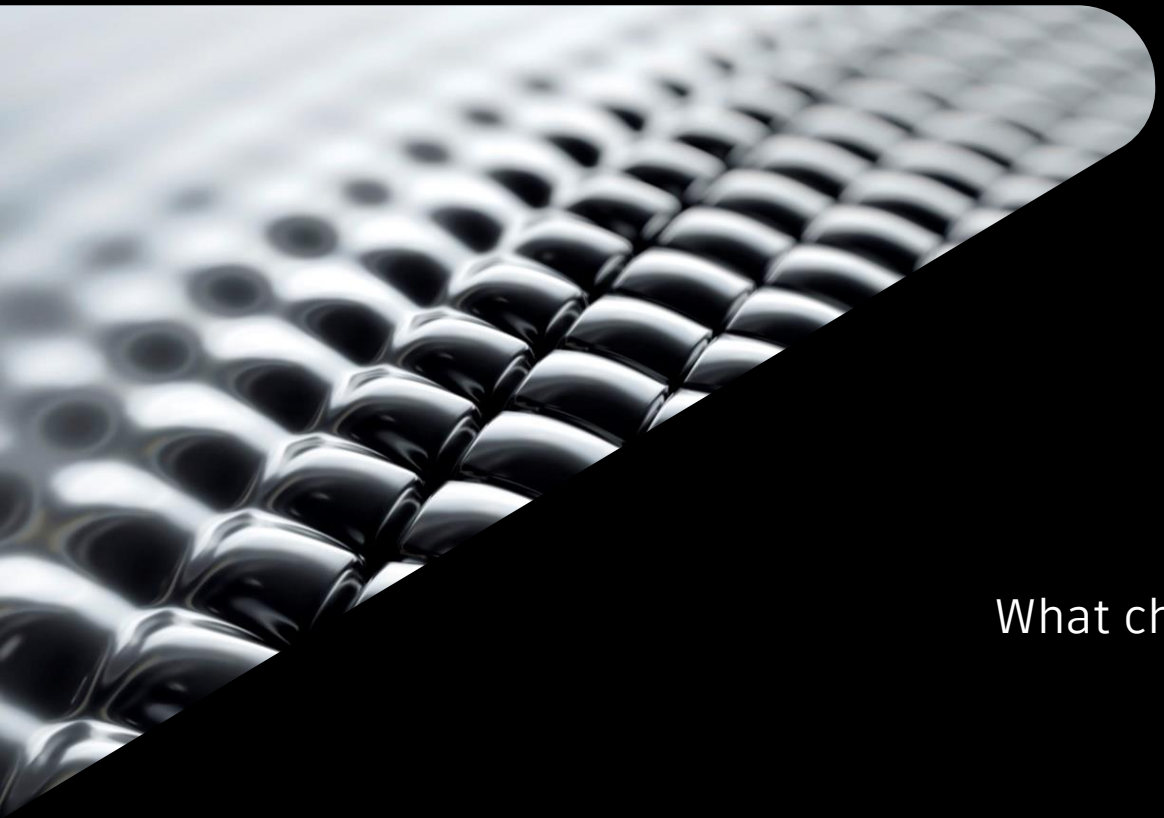
In this class, we'll teach you step by step how you can use *Generative Design in Revit* and *Dynamo* to optimize the planning of neighborhoods of single-family residential buildings, including plot subdivision, land-use assignment, and placement and shape of structures. We'll then review how *Spacemaker* brings even more value into this complex exercise for the optimization of single family residential buildings.

# Learning Objectives

1. Learn step by step **how to build** your own Generative Design **script** for dwelling layout optimization.
2. Learn about the **value and positioning** of Dynamo, Spacemaker, and Generative Design for Revit.
3. Learn **why, how, and when** to use Spacemaker for residential planning optimization.
4. Discover how Generative Design in Revit can **effectively be used** for neighborhood planning.

# AGENDA

- Industry Context
- Why Generative Design ?
- Process Overview
- Workflow Overview
- Other Analysis Results
- Customization & Continuation
- Closing



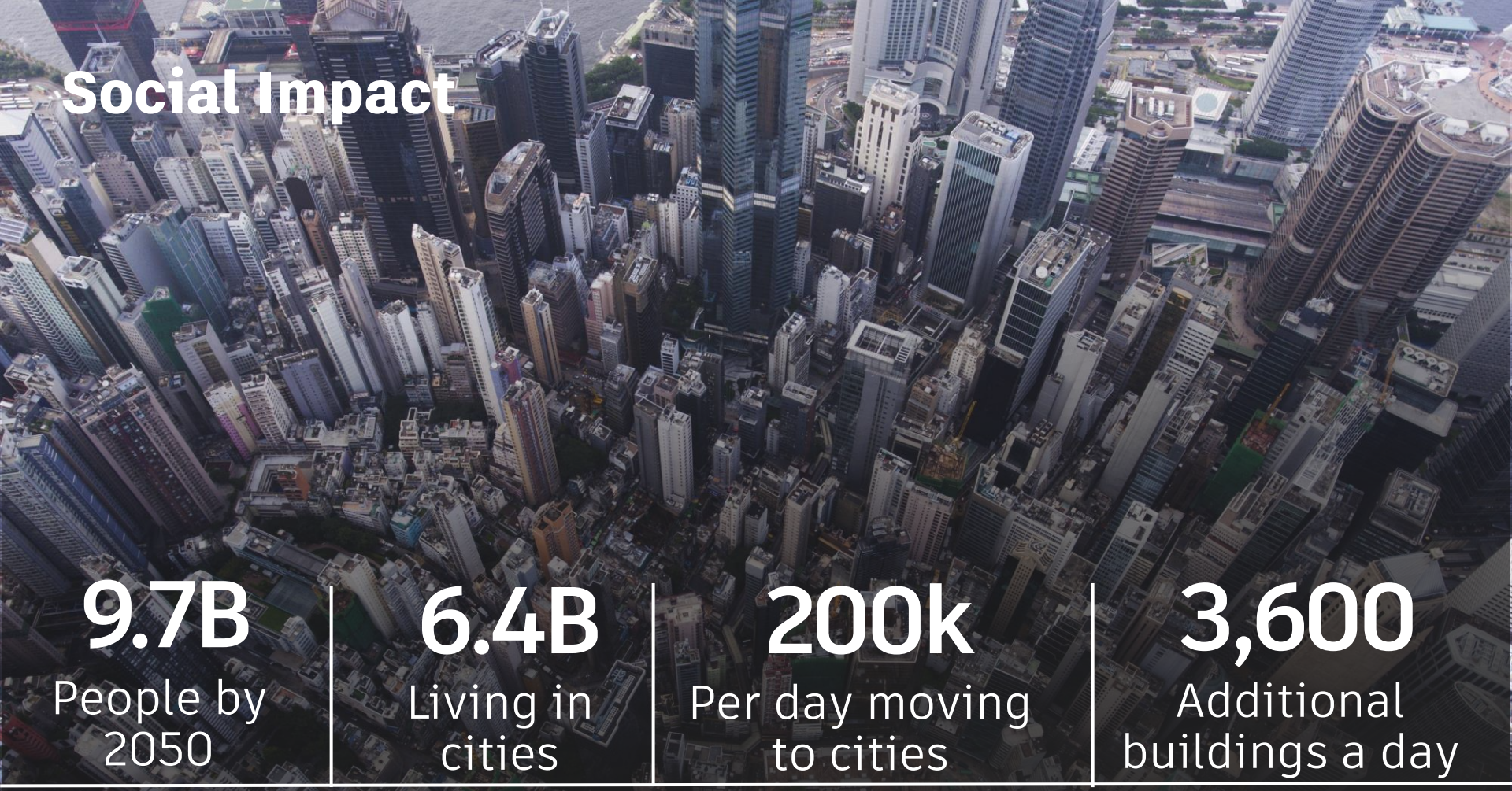
# Industry Context

What challenges do we face and what is it that we want to solve ?

# Environmental Impact



# Social Impact



**9.7B**
People by 2050

**6.4B**
Living in cities

**200k**
Per day moving to cities

**3,600**
Additional buildings a day

Sources: The World Bank, World Economic Forum

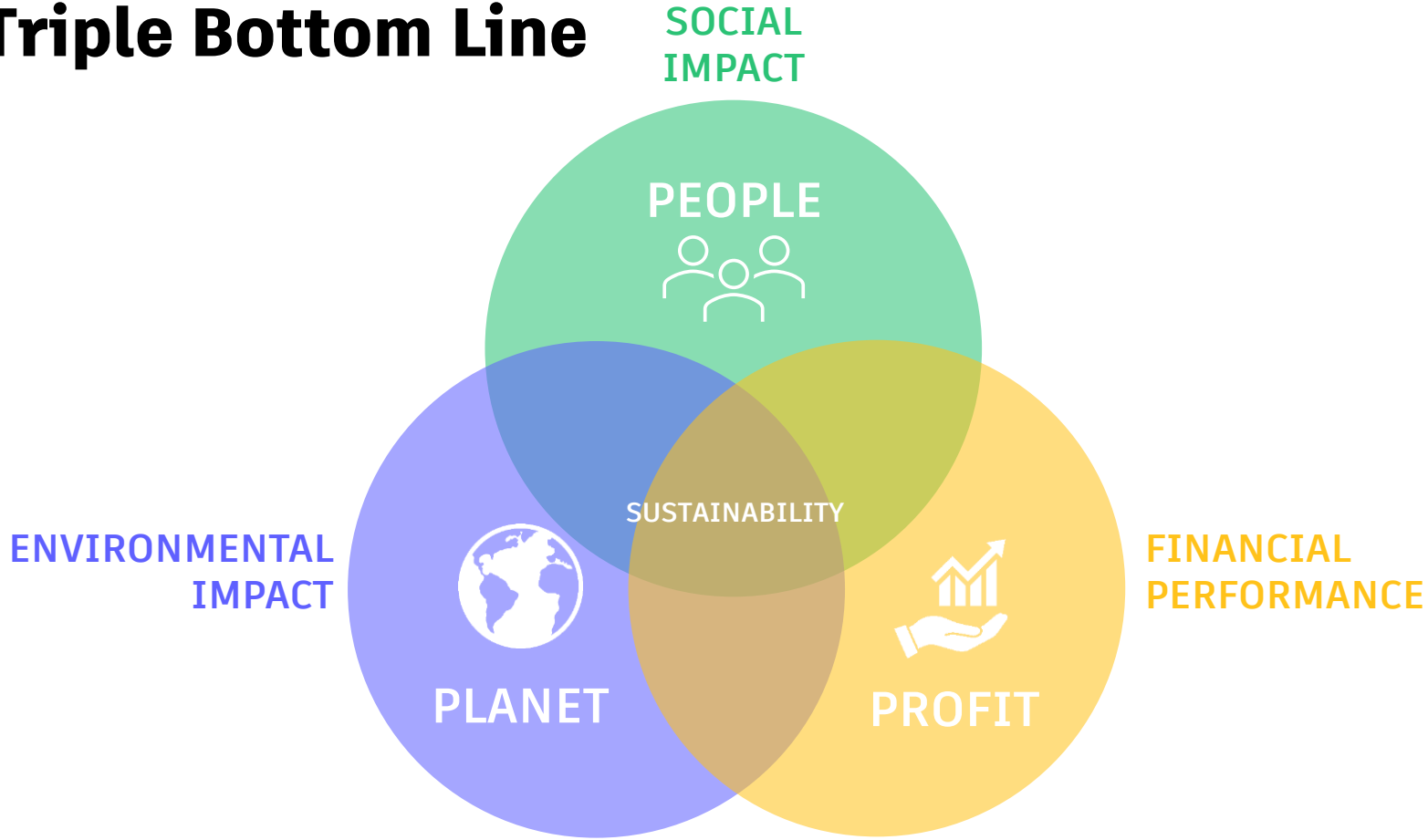
# Financial impact

Land scarcity

Increased Revenue

Affordable Housing

# The Triple Bottom Line



# Neighborhood Planning

## Definition

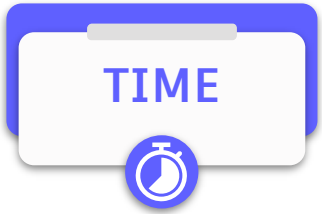
*Neighborhood planning is **a form of urban planning** through which professional urban planners and communities seek to shape new and existing neighborhoods.*

# Neighborhood Planning

## Typical Process

# Challenges to plan-writing


Lots of data to process such as 2D, 3D, reports, specifications, ...




Optimization of a site takes a lot of time due to many manual iterations.


Need to get buy-in from the planning committees and local residents.


Uncover the social and economical potential of the new neighborhood.

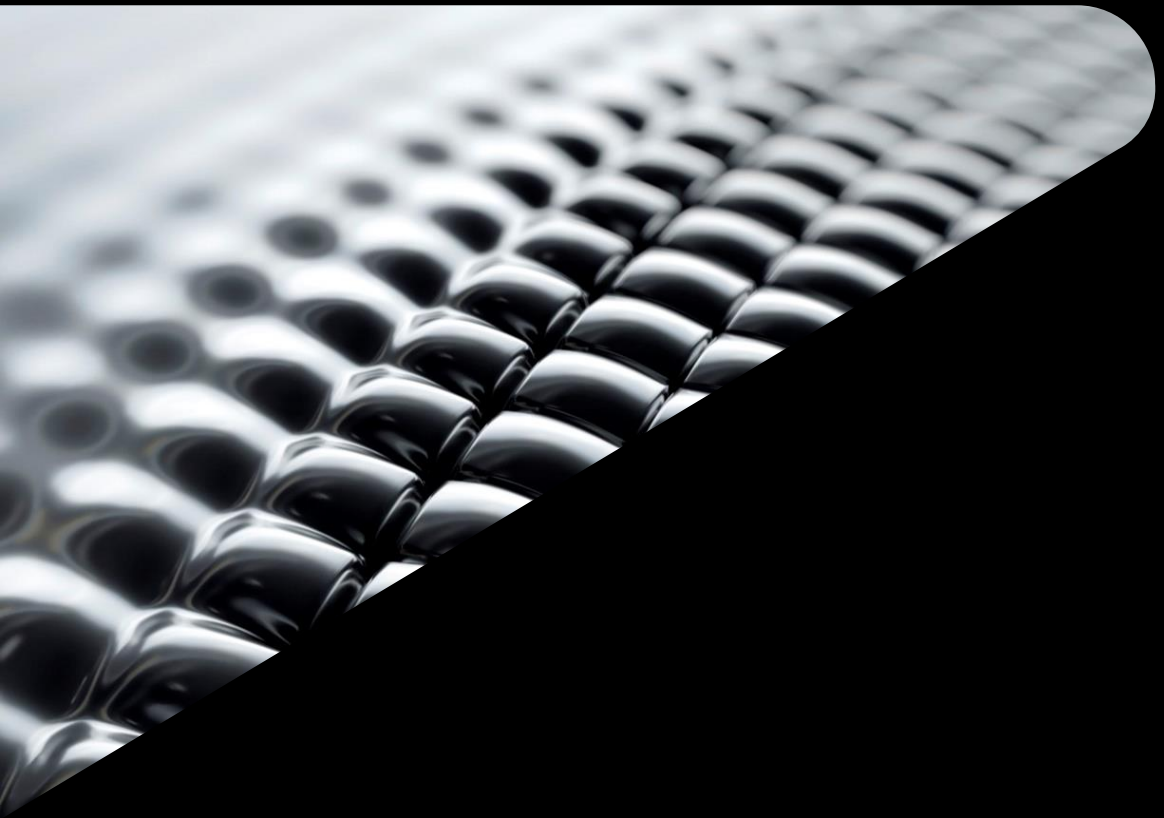

Understand risks like geotechnical issues, environmental impact and comfort of living (noise, daylight, traffic)

# Challenges to urban design and development

- Urban Sprawl
- Sustainability
- Public Transport
- Social aspect
- Single vs Mixed Use
- Accessibility
- Affordability
- Environmental Site

# Sustainable Neighborhood Planning


UN-HABITAT

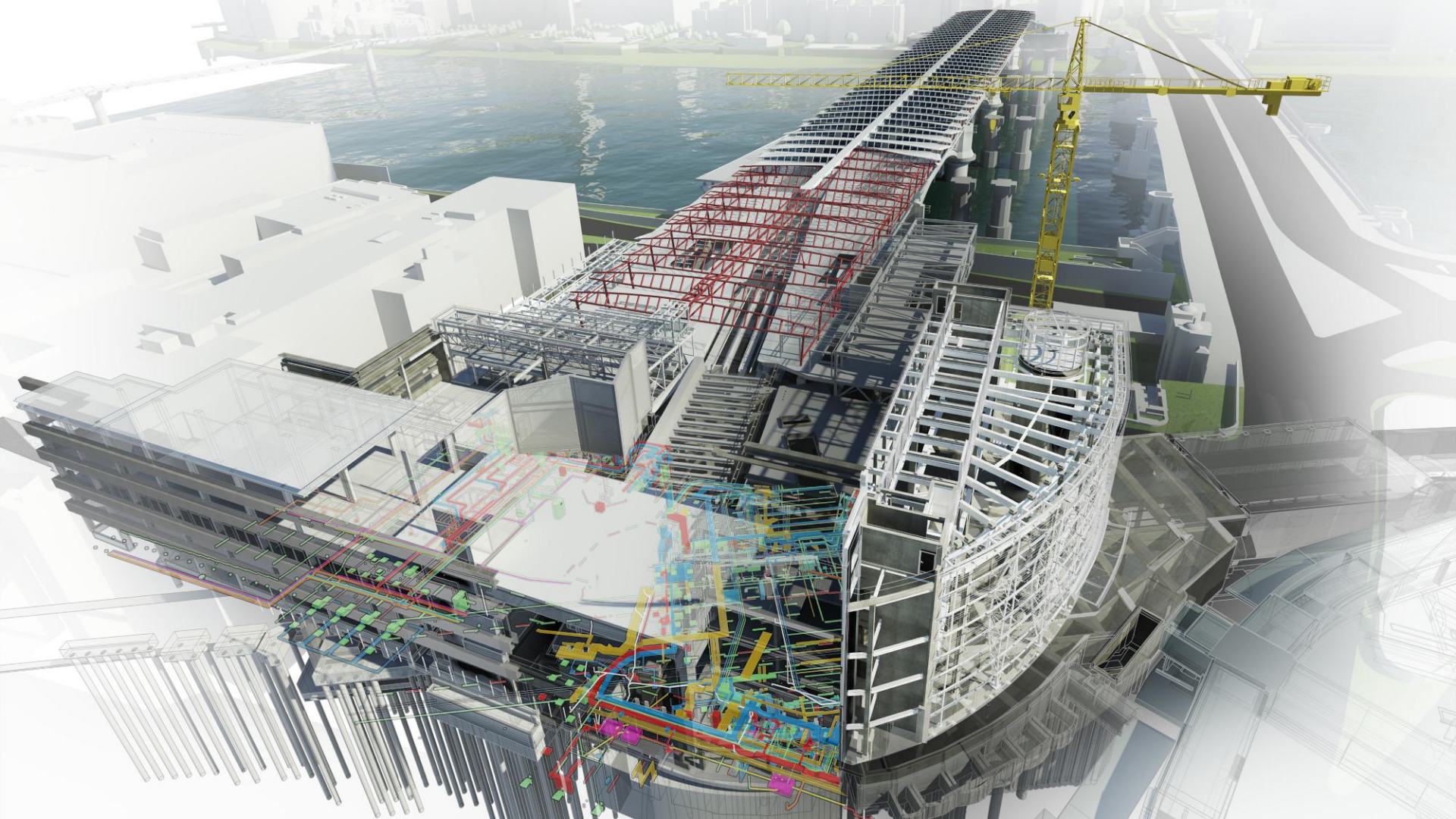


# Generative Design

Why using this approach?

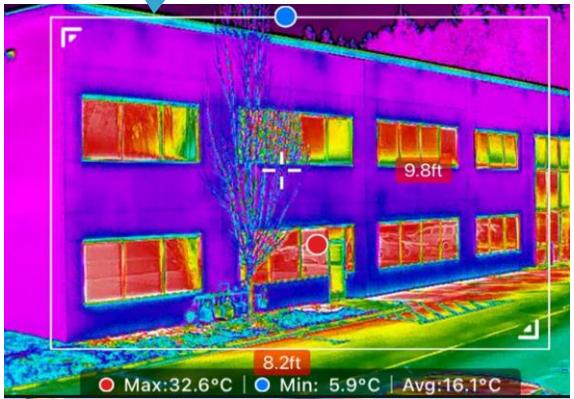
General Motors Technical Center in Warren Michigan.

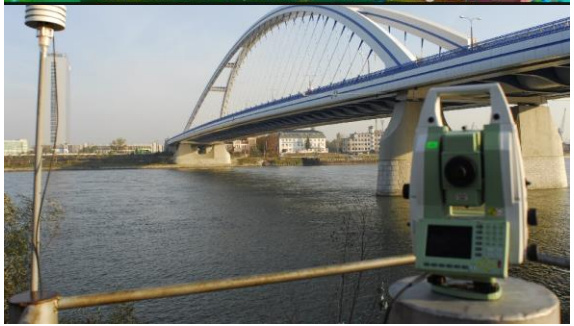

Stair Detail
AUTOCAD USER REFERENCE



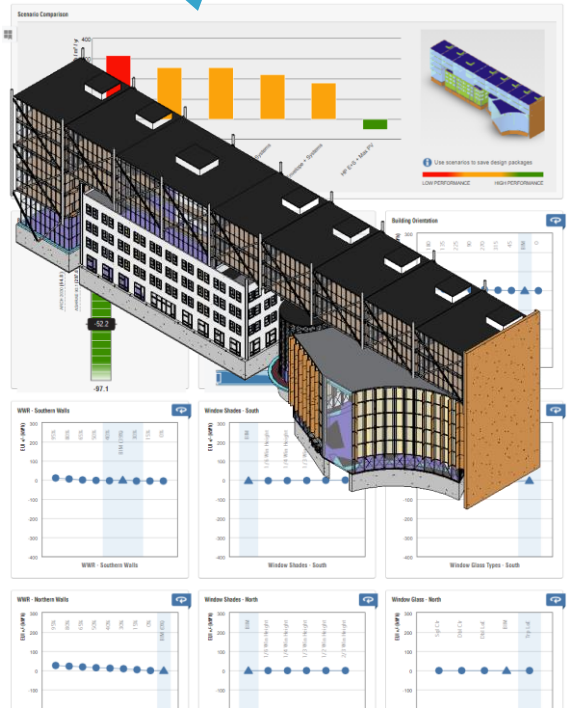

HANSENYUNCKEN
HANSENYUNCKEN

"How is the project performing ?"



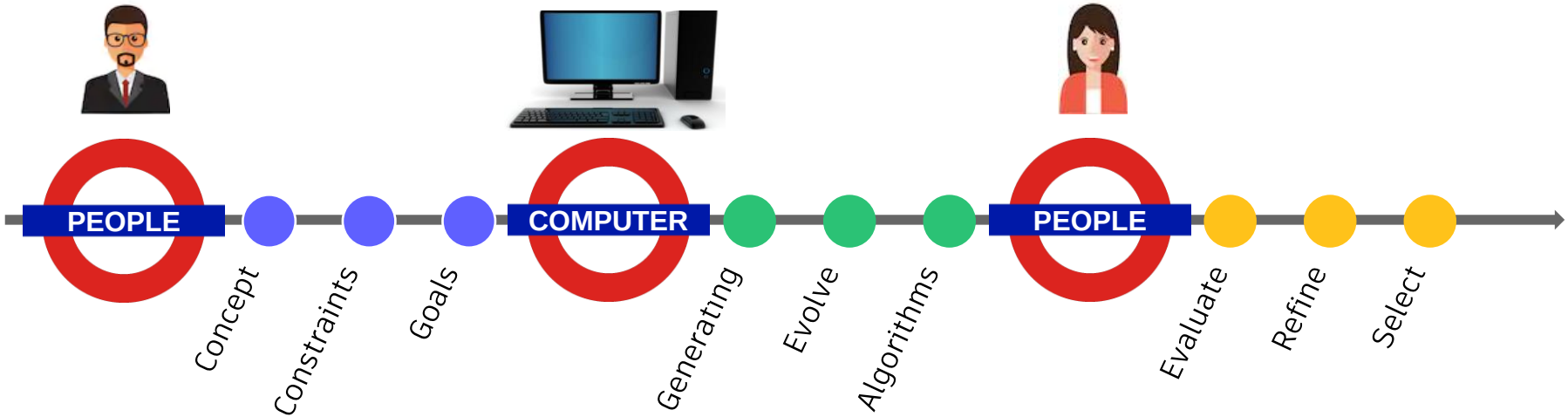
"How will this design perform?"



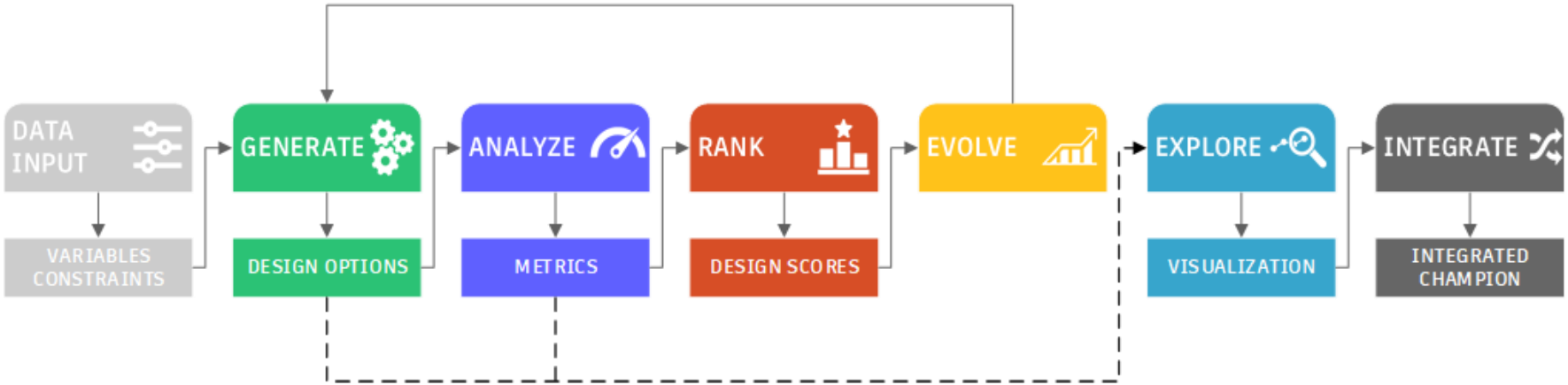
"What's the best design?"

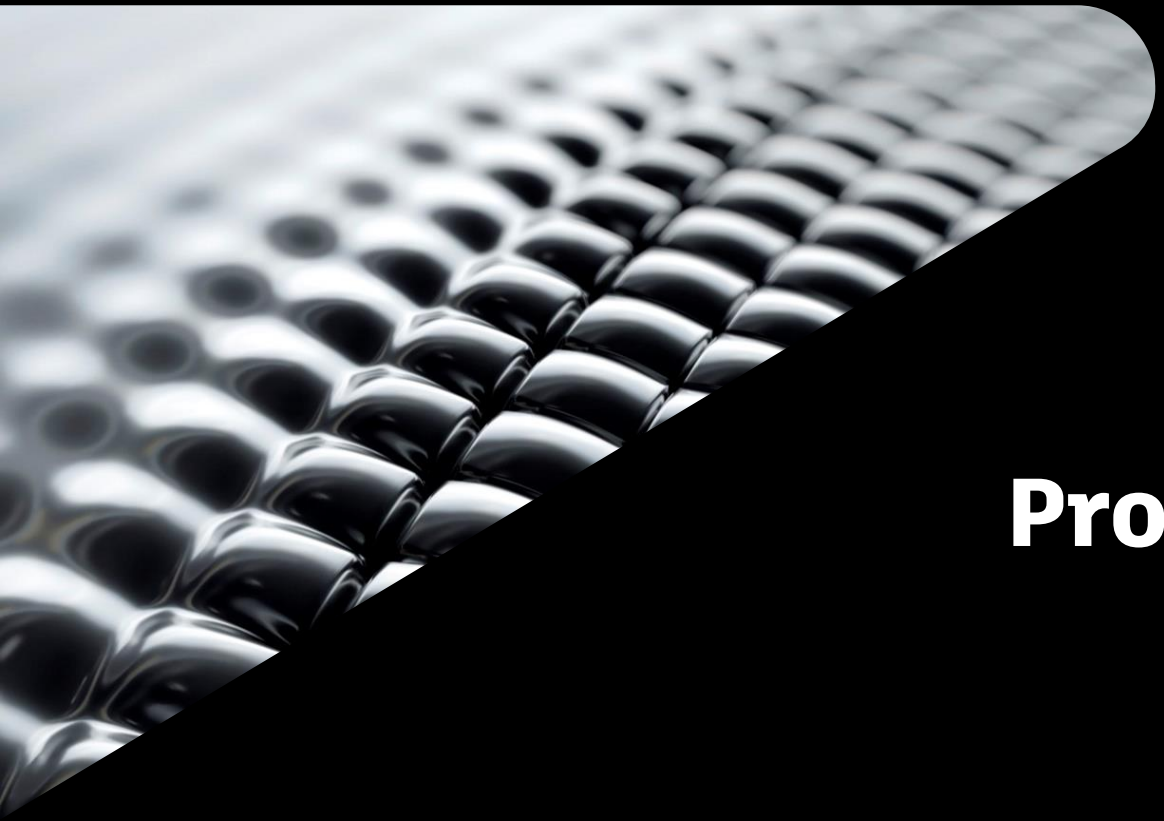
# Generative Design Process

## Combining human and computer intelligence



# Generative Design Process



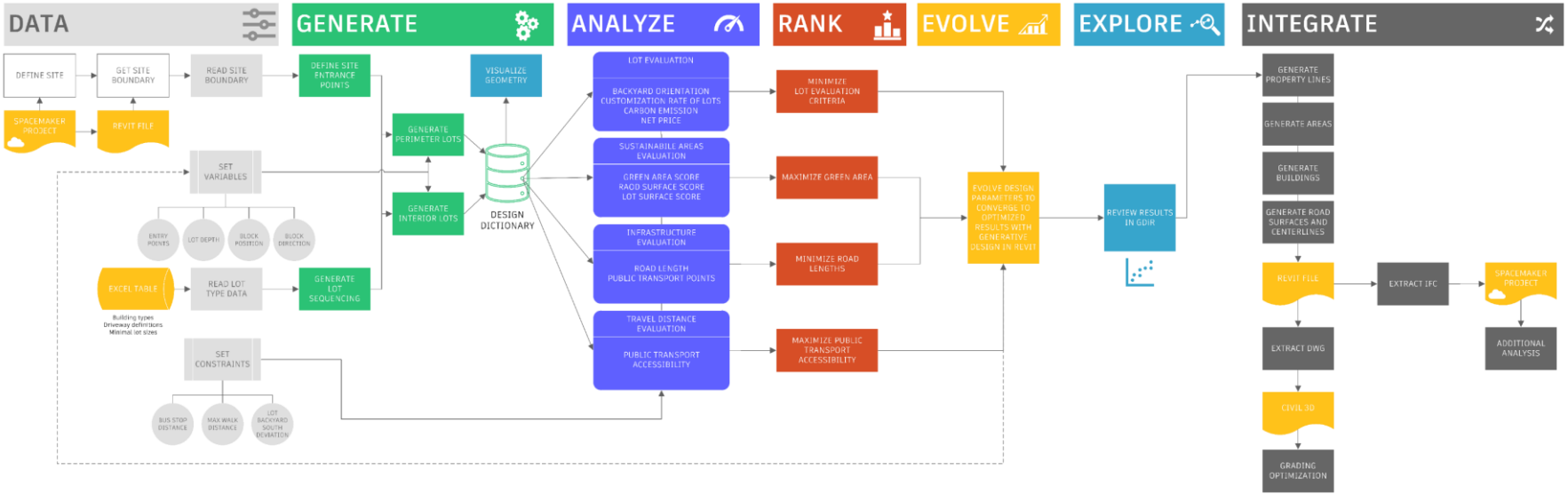


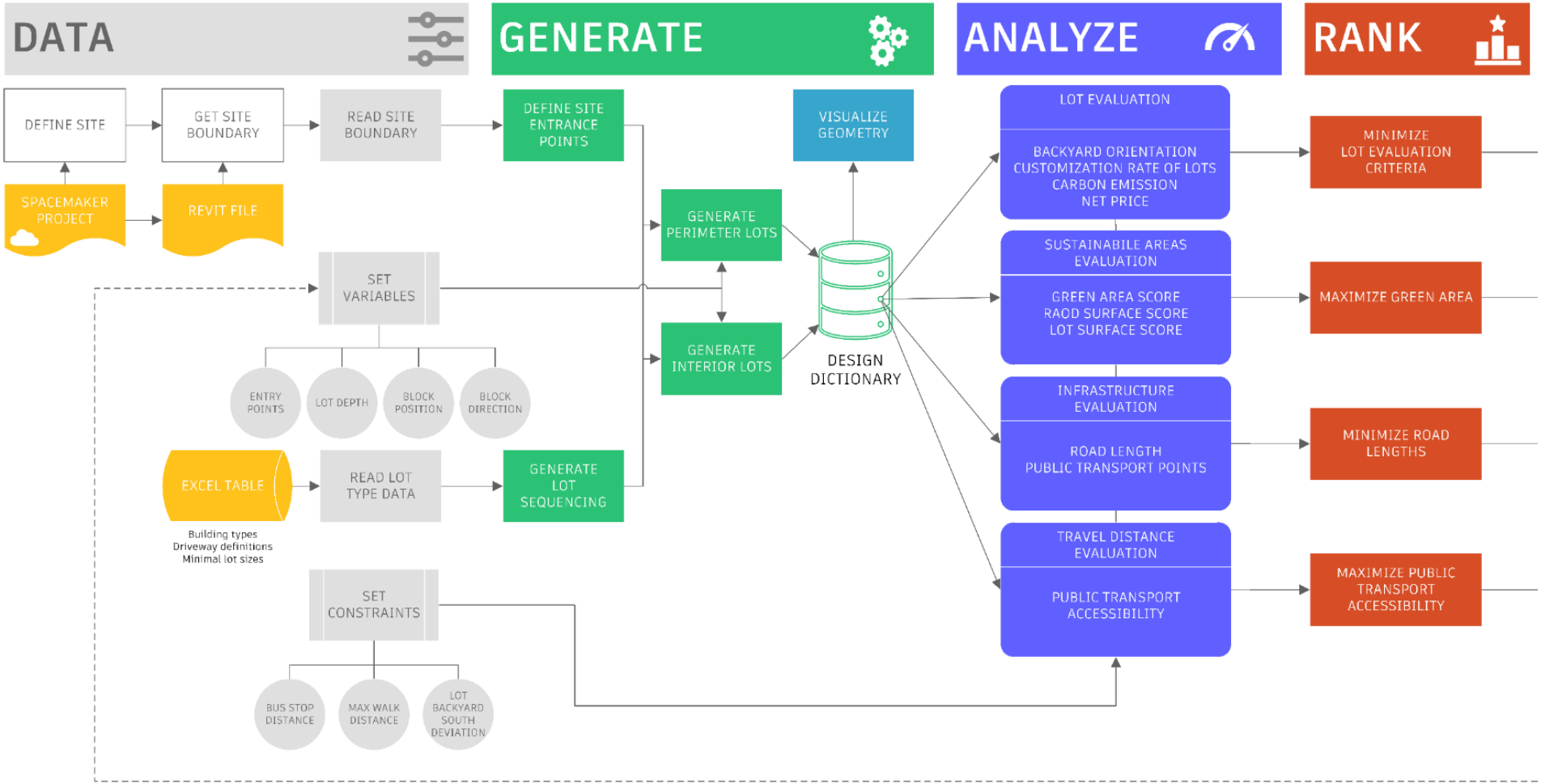
# Process Overview

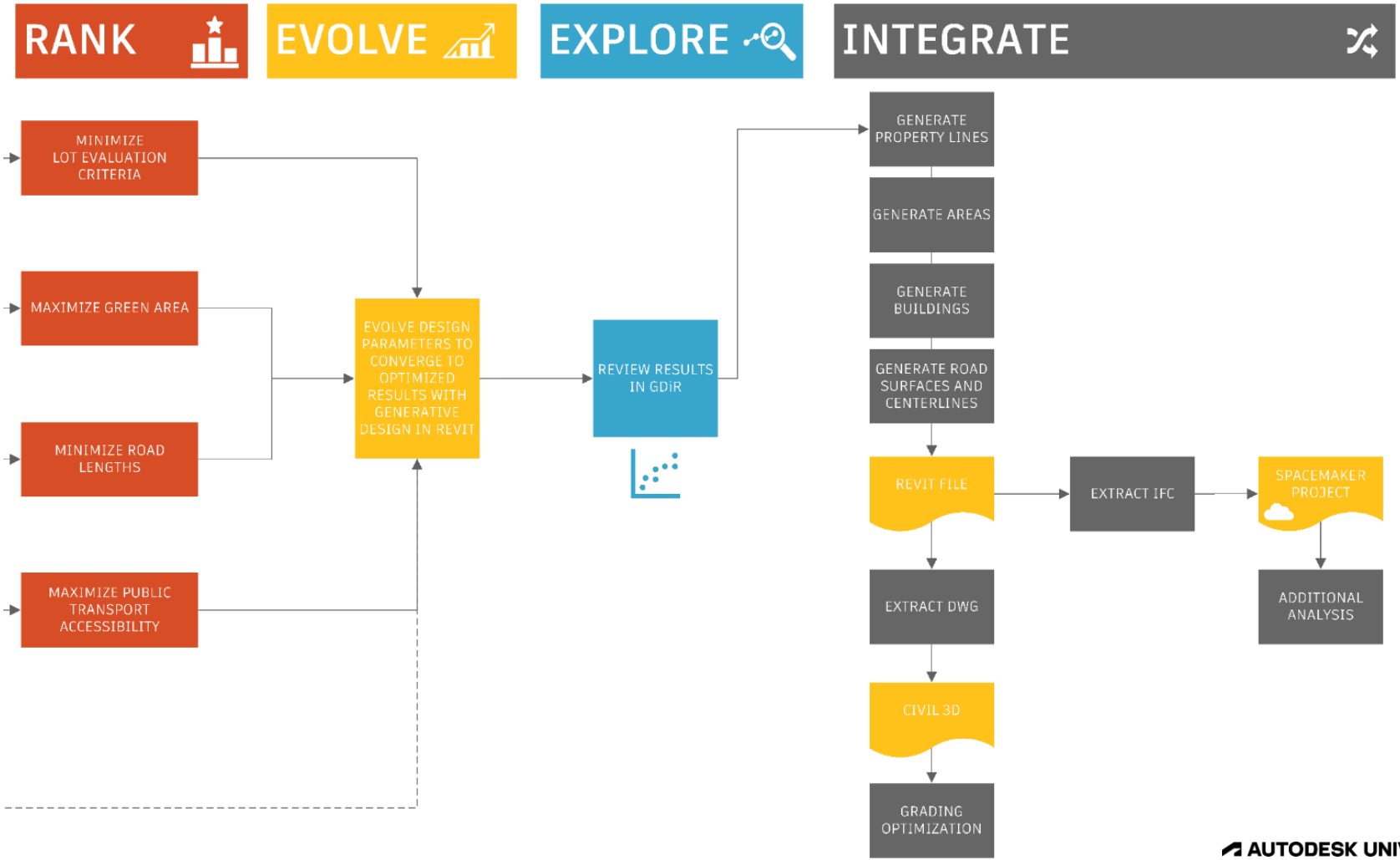
Satellite View

# Process Overview

## A satellite view on how to build up the script




DATA
GENERATE
ANALYZE
RANK
DEFINE SITE
GET SITE BOUNDARY
READ SITE BOUNDARY
DEFINE SITE ENTRANCE POINTS
VISUALIZE GEOMETRY
SPACEMAKER PROJECT
REVIT FILE
GENERATE PERIMETER LOTS
SET VARIABLES
GENERATE INTERIOR LOTS
DESIGN DICTIONARY
ENTRY POINTS
LOT DEPTH
BLOCK POSITION
BLOCK DIRECTION
EXCEL TABLE
READ LOT TYPE DATA
GENERATE LOT SEQUENCING
Building types
Driveway definitions
Minimal lot sizes
SET CONSTRAINTS
BUS STOP DISTANCE
MAX WALK DISTANCE
LOT BACKYARD SOUTH DEVIATION
LOT EVALUATION
BACKYARD ORIENTATION
CUSTOMIZATION RATE OF LOTS
CARBON EMISSION
NET PRICE
SUSTAINABILE AREAS EVALUATION
GREEN AREA SCORE
RAOD SURFACE SCORE
LOT SURFACE SCORE
INFRASTRUCTURE EVALUATION
ROAD LENGTH
PUBLIC TRANSPORT POINTS
TRAVEL DISTANCE EVALUATION
PUBLIC TRANSPORT ACCESSIBILITY
MINIMIZE LOT EVALUATION CRITERIA
MAXIMIZE GREEN AREA
MINIMIZE ROAD LENGTHS
MAXIMIZE PUBLIC TRANSPORT ACCESSIBILITY


RANK
EVOLVE
EXPLORE
INTEGRATE
MINIMIZE LOT EVALUATION CRITERIA
MAXIMIZE GREEN AREA
MINIMIZE ROAD LENGTHS
MAXIMIZE PUBLIC TRANSPORT ACCESSIBILITY
EVOLVE DESIGN PARAMETERS TO CONVERGE TO OPTIMIZED RESULTS WITH GENERATIVE DESIGN IN REVIT
REVIEW RESULTS IN GDiR
GENERATE PROPERTY LINES
GENERATE AREAS
GENERATE BUILDINGS
GENERATE ROAD SURFACES AND CENTERLINES
REVIT FILE
EXTRACT IFC
SPACEMAKER PROJECT
EXTRACT DWG
ADDITIONAL ANALYSIS
CIVIL 3D
GRADING OPTIMIZATION

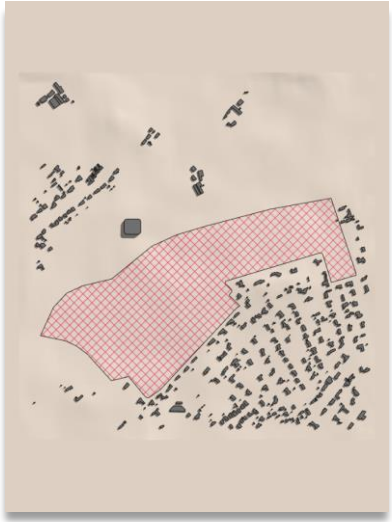
# Overall Optimization Workflow

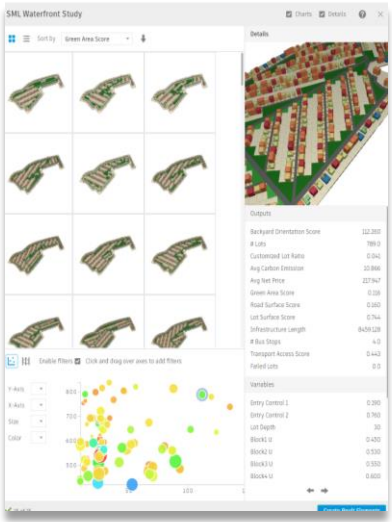
SPACEMAKER

Revit

Generative Design

SPACEMAKER





Prepare site

Import existing site conditions

Optimization of the new neighborhood

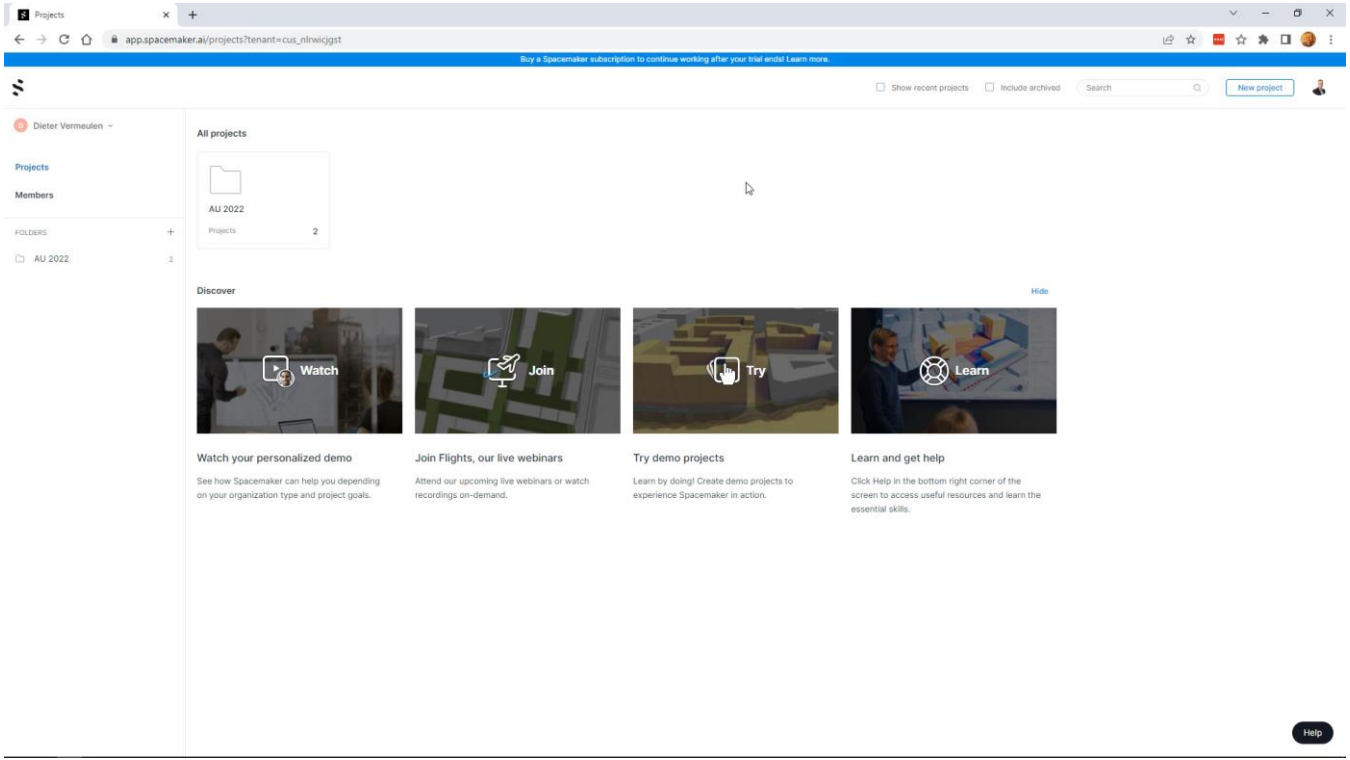
Import and analyze the designed neighborhood

# Workflow Overview

Boots on Ground View

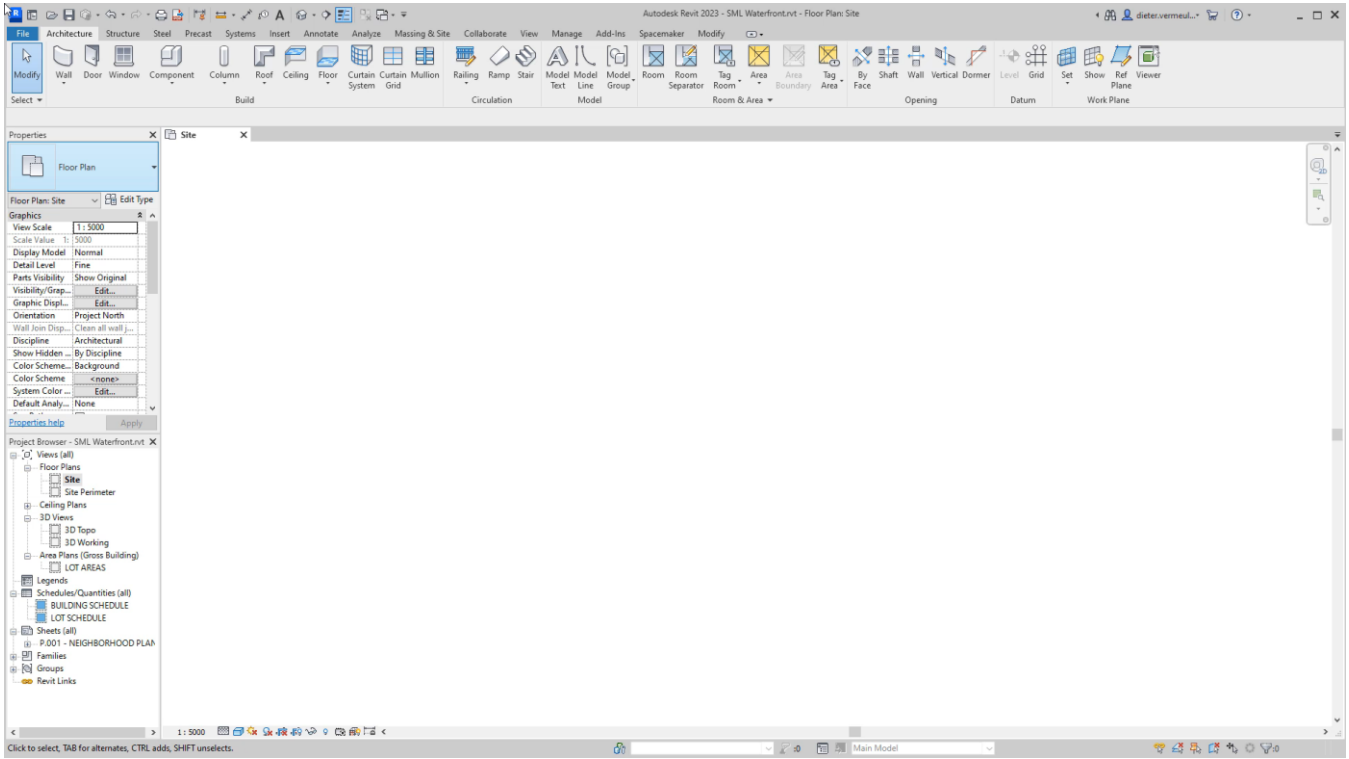
# Prepare site

## Spacemaker



# Import site data

## Autodesk Revit

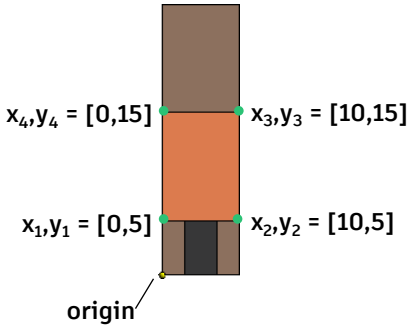


# Building Definitions

## Define building types to be used

Excel

| ID | Type | Lot Width | Min Lot Depth | Building Shape | Driveway Shape | Height | Building Colo | Net Price | Carbon Emission |
|---|---|---|---|---|---|---|---|---|---|
| A | Townhouse 1 | 10 | 25 | [[0,10,10,0],[5,5,15,15]] | [[2,5,5,2],[0,0,5,5]] | 15 | 252,141,89 | 150 | 7 |
| B | Townhouse 2 | 12 | 25 | [[0,12,12,0],[5,5,15,15]] | [[5,9,9,5],[0,0,5,5]] | 12 | 254,224,139 | 200 | 9 |
| C | Detached | 15 | 35 | [[3,7.5,7.5,12,12,3],[5,5,9.5,9.5,17,17]] | [[7.5,12,12,7.5],[0,0,9.5,9.5]] | 7 | 230,245,152 | 320 | 12 |
| D | Villa | 20 | 45 | [[4,16,16,10,10,4],[6,6,18,18,13,13]] | [[12,16,16,12],[0,0,6,6]] | 6 | 153,213,148 | 420 | 14 |
| E | Commercial | 15 | 30 | [[2,13,13,2],[6,6,16,16]] | [[2,13,13,2],[0,0,6,6]] | 12 | 213,62,79 | 250 | 20 |
| F | Amenity | 20 | 36 | [[4,7,7,13,13,16,16,4],[6,6,10.5,10.5,6,6,20,20]] | [[4,16,16,13,13,7,7,4],[0,0,6,6,10.5,10.5,6,6]] | 6 | 50,136,189 | 360 | 25 |

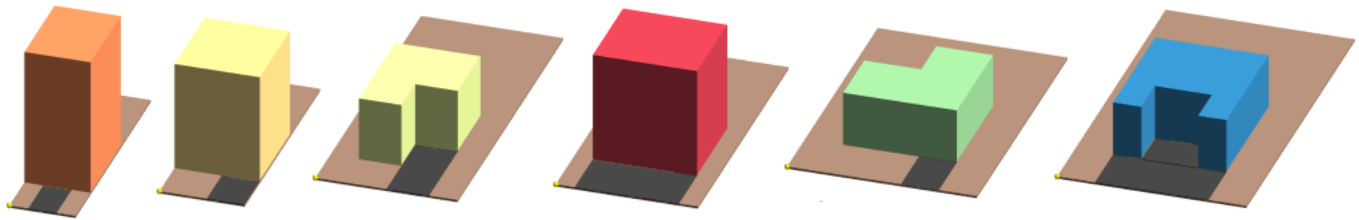



Shape Syntax

$[[x_1,x_2,x_3,\ldots x_n],[y_1,y_2,y_3,\ldots,y_n]]$

Sequencing

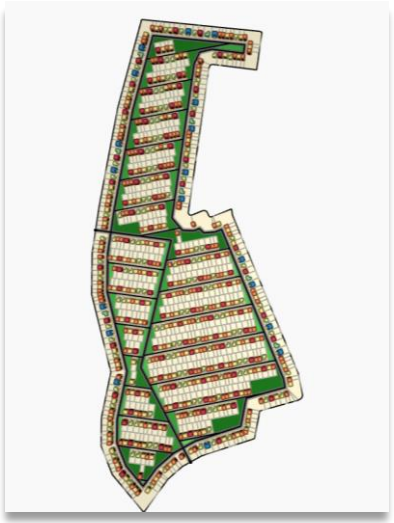
| Perimeter | Interior |
|---|---|
| A | A |
| A | A |
| B | B |
| A | E |
| C | B |
| B | A |
| E | B |
| C | C |

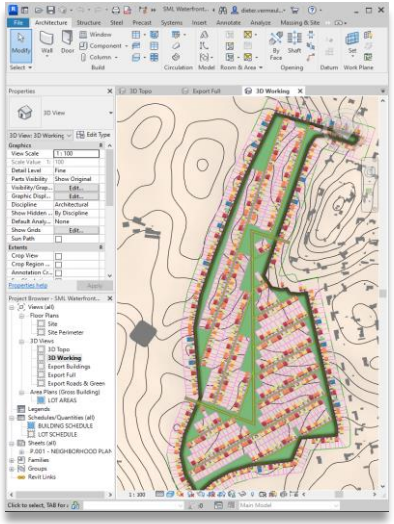


TYPE A TYPE B TYPE C TYPE D TYPE E TYPE F

# Build the graph

Dynamo | Dynamo | Dynamo | Revit

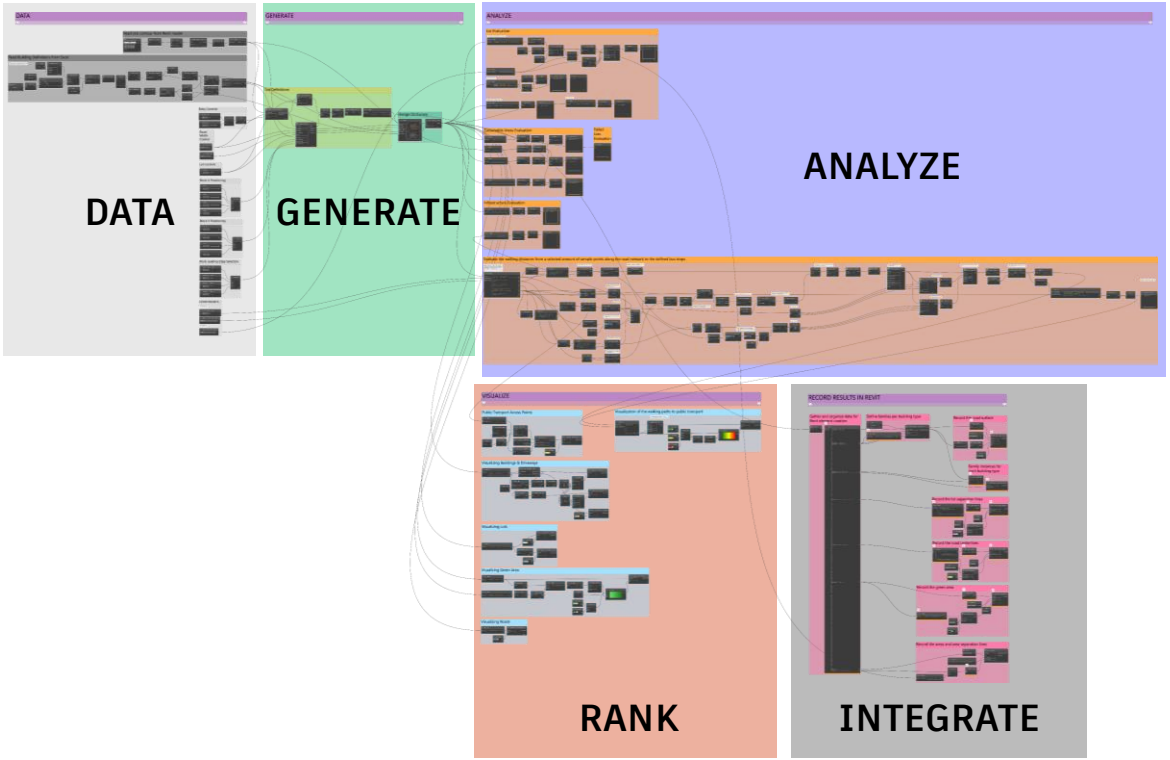




Import Data → Generate Site → Analyze Site → Generate Buildings

# Logic behind the scene

## Autodesk Dynamo for Revit




# Neighborhood Optimization

**DYNAMO FILE NAME**

Neighborhood Optimization.dyn

**DYNAMO VERSION**

2.12 or 2.13

**ASSOCIATED REVIT FILE(S)**

SML Waterfront.rvt

**WORKING REVIT VERSION(S)**

2022

**AUTHOR(S)**

Dieter Vermeulen (Autodesk)
Jacob Small (Autodesk)
Published: 2022.09.28

**REQUIRED DYNAMO PACKAGES**

- GenerativeNeighborhoods
- Toplologic 1.4
- Generative Design

**DESCRIPTION**

Generate an optimized neighborhood with roads, green areas, several building types and lot sizes based on an existing site and building conditions defined in Excel.

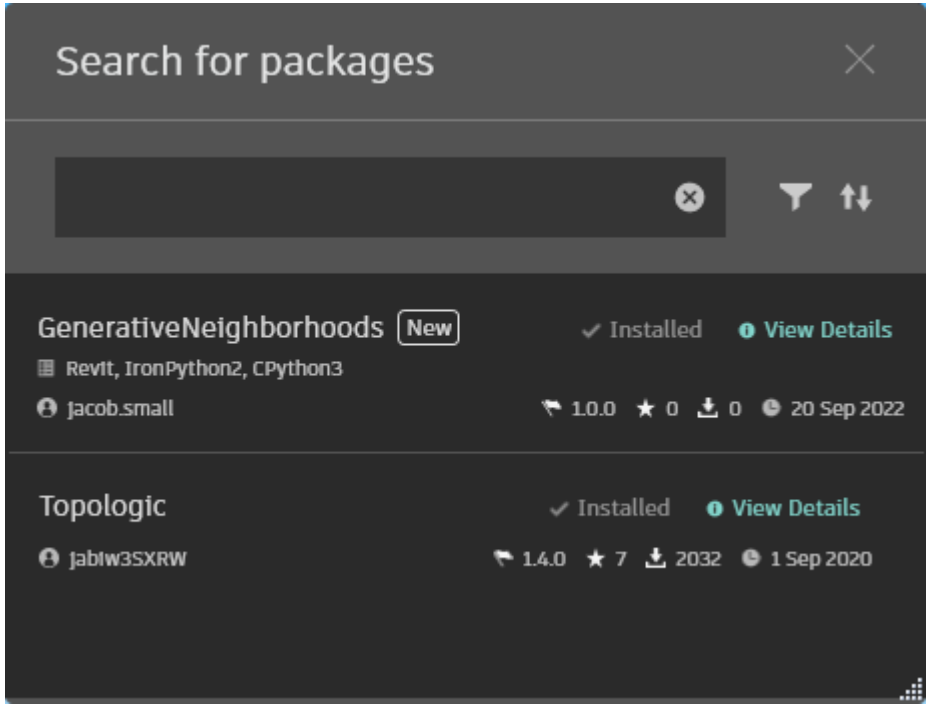
This workflow was presented at Autodesk University 2022 in New Orleans in class AS500585 | How Generative Design Can Help Optimize New Neighborhoods.

Project units are metric [m] !

**INSTRUCTIONS BEFORE RUNNING THE SCRIPT**

1. Choose the site boundaries in Revit. Make sure the results is a closed polycurve.
2. Point to the right Excel file that holds the Building Definitions.
3. Make sure the Data.Gate node is open in the "Record Results in Revit" groups, to get your elements created in Revit.
4. Select the path of the Building Type.rft family template to be used for the building placement in Revit.
5. Choose an Area view where to record the lot areas
6. Select values for the several variables
7. Run the script !

# Packages Used

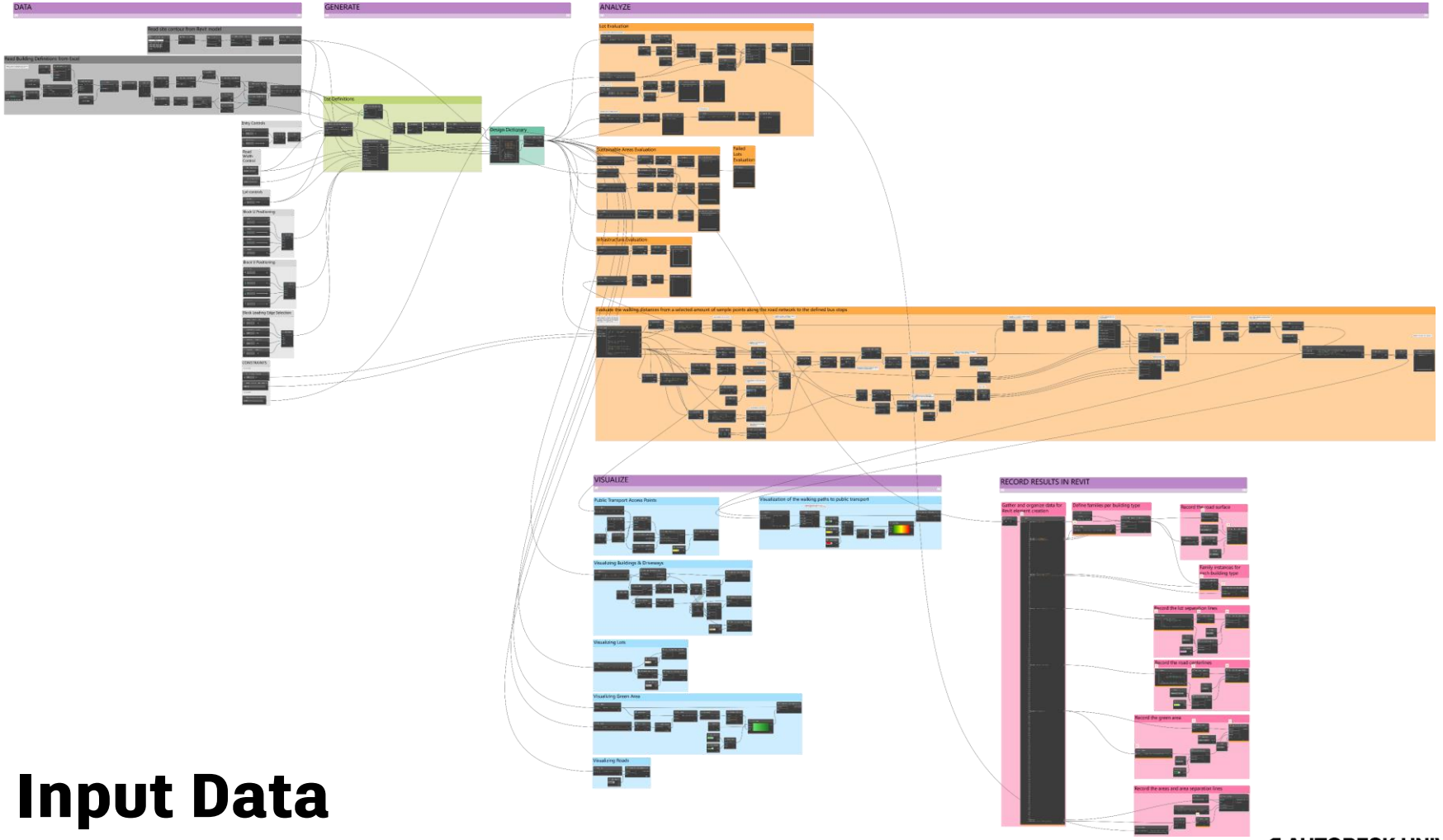



**GenerativeNeighborhoods**

- Contains the nodes for this class

**Topologic**

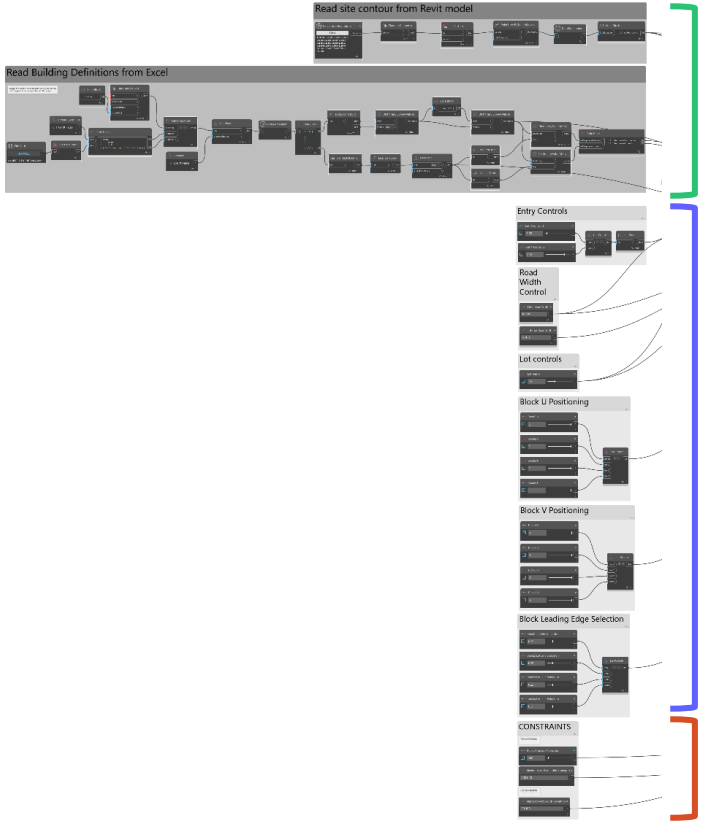
- Used for path analysis




# Input Data

# Input Data

## External input, variables and constraints

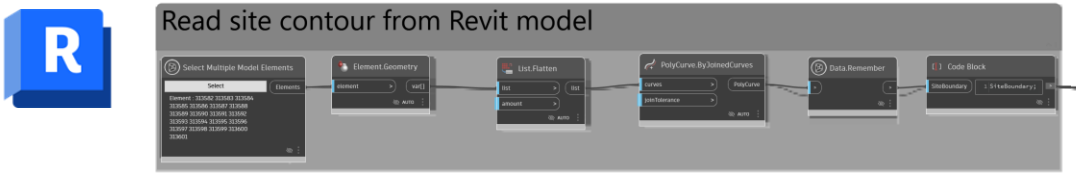


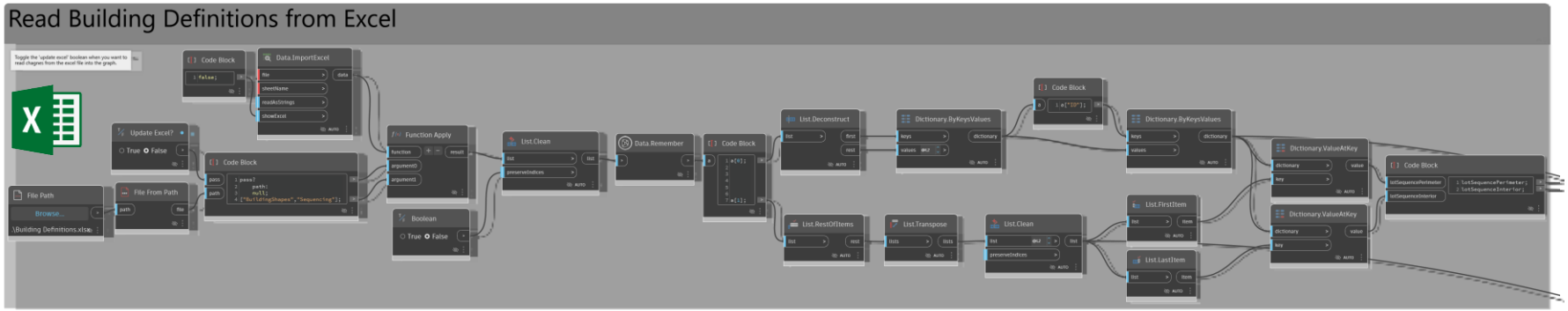

EXTERNAL INPUTS

VARIABLES

CONSTRAINTS

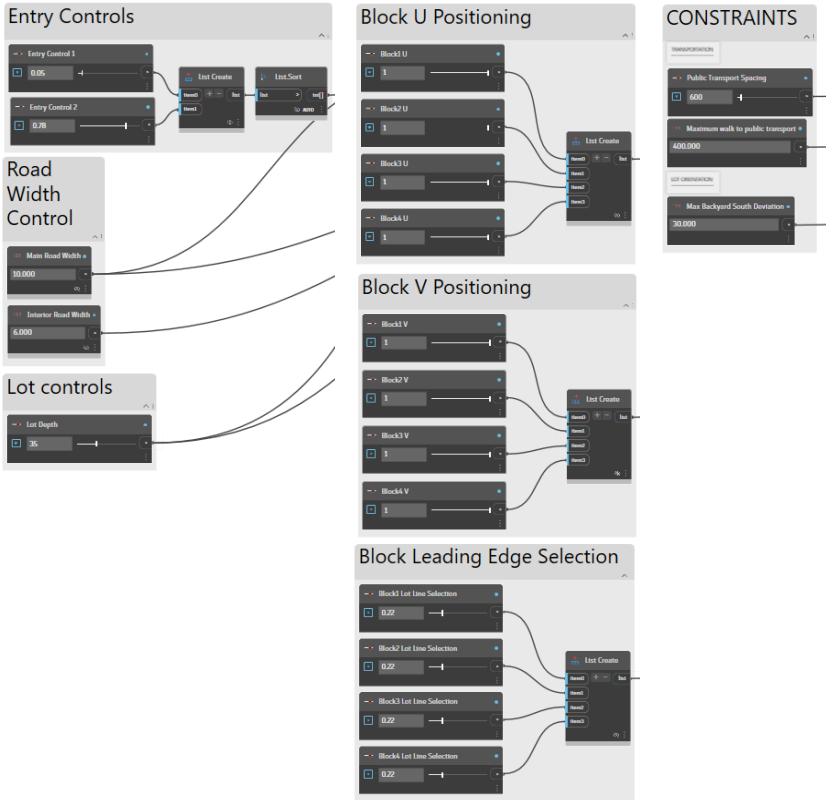
# Input Data : External Inputs



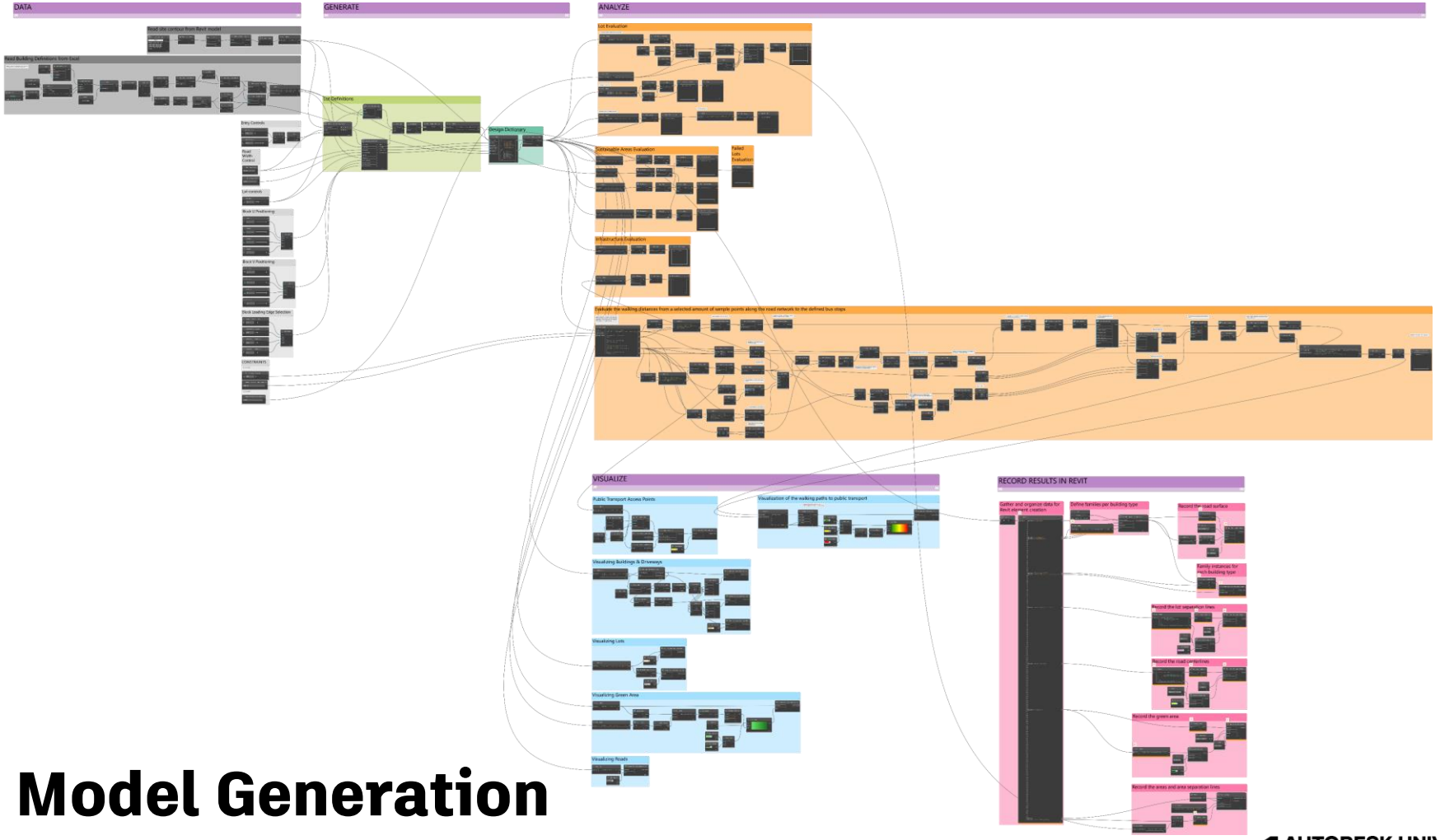

- Read Building Types from Excel
- Import site boundary curves from Revit

# Input Data : Variables & Constraints




- Variables
  - Controls for entrance road
  - Road width control
  - Lot depth
  - Block Control
    - Positions
    - Lead Edge Selection
- Constraints
  - Public transport spacing
  - Maximum walk to public transport
  - Maximum backyard to south deviation

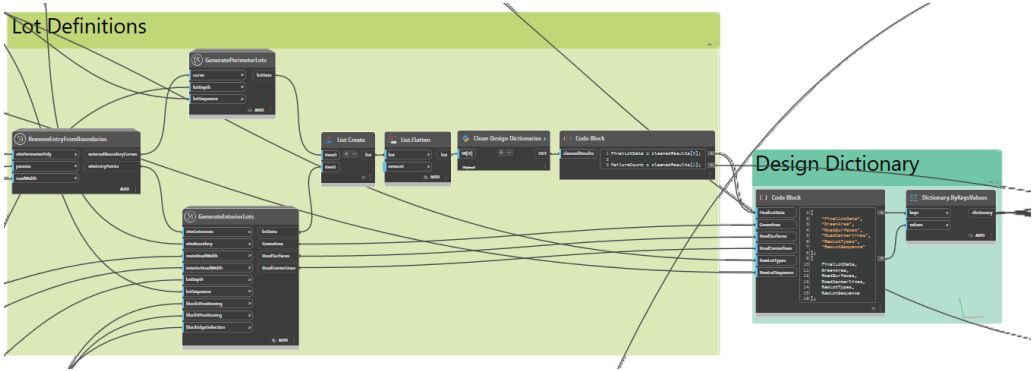

LIVE DEMO

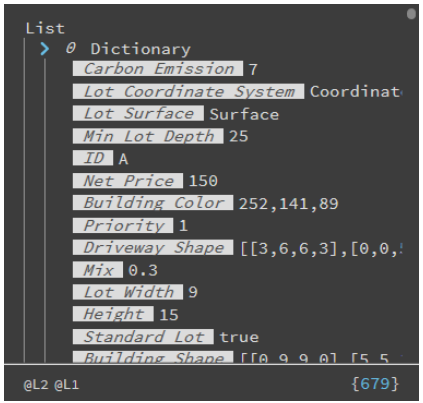



# Model Generation

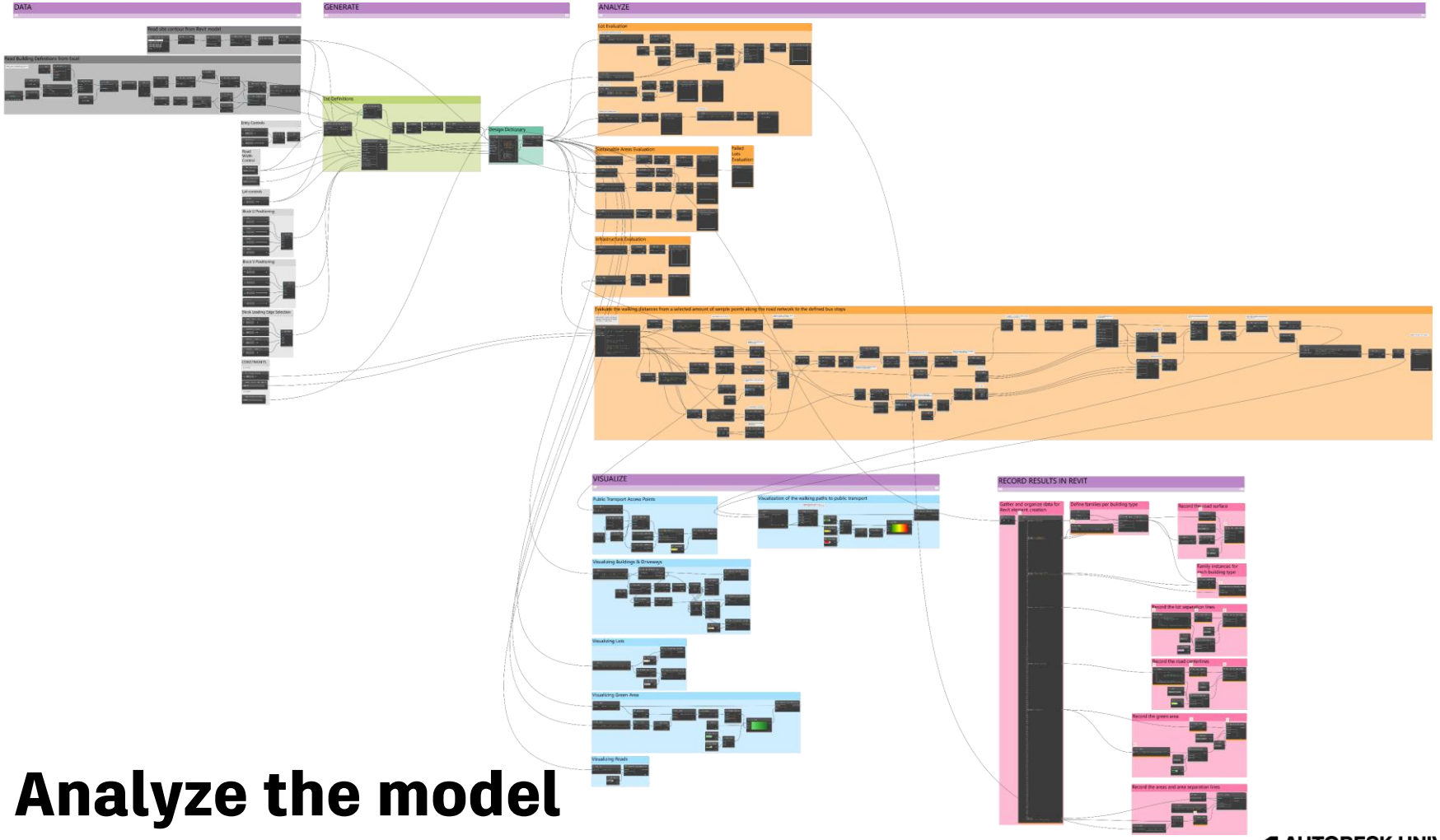
# Model Generation

- Final Lot Data with
  - Building Type + Properties (Carbon Emission, Net Price, …)
  - Lot Surface
  - Standard Lot
  - Building Shape
- Road surfaces & centerlines
- Green Area



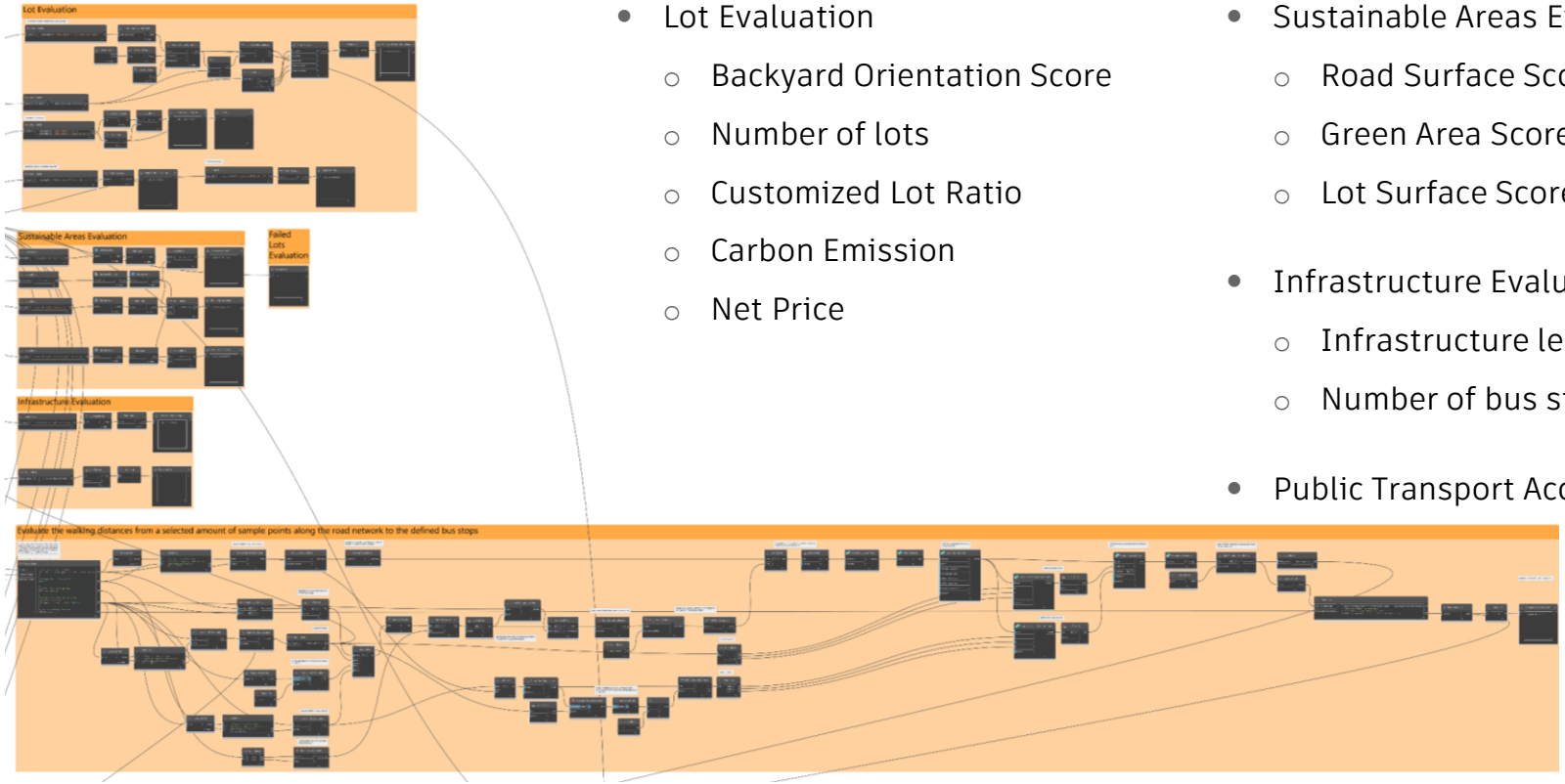

LIVE DEMO




# Analyze the model

# Analyze the model

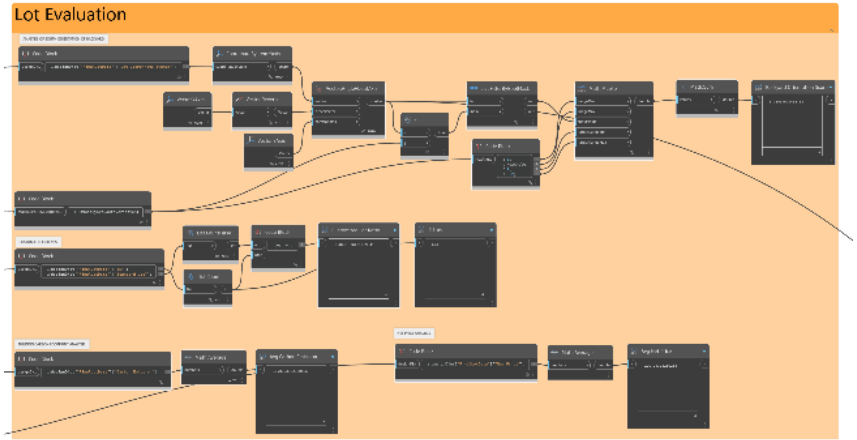
## Define the outputs of the Generative Design UI



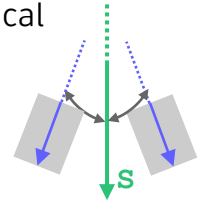

- Lot Evaluation
  - Backyard Orientation Score
  - Number of lots
  - Customized Lot Ratio
  - Carbon Emission
  - Net Price
- Sustainable Areas Evaluation
  - Road Surface Score
  - Green Area Score
  - Lot Surface Score
- Infrastructure Evaluation
  - Infrastructure length
  - Number of bus stops
- Public Transport Access Score

# Lot Evaluation

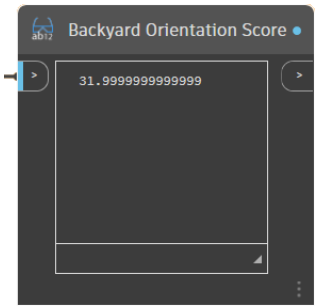
## Evaluate the quality of the generated lots

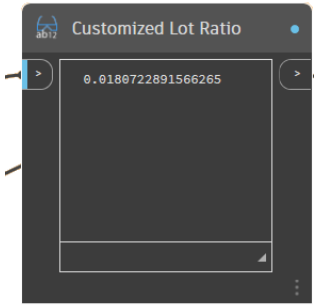


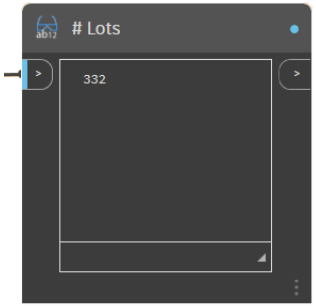

- Maximize the backyard orientation score of lots by minimizing the deviation towards geometrical south.

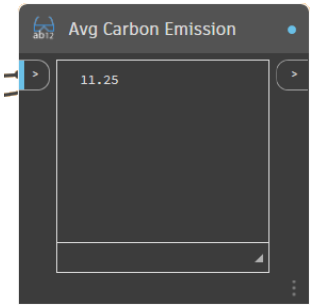


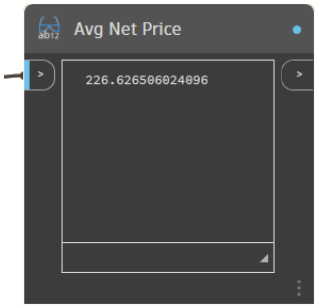

- Maximize the amount of lots
- Minimize the amount of custom sized lots
- Minimize average carbon emission
- Minimize average net price



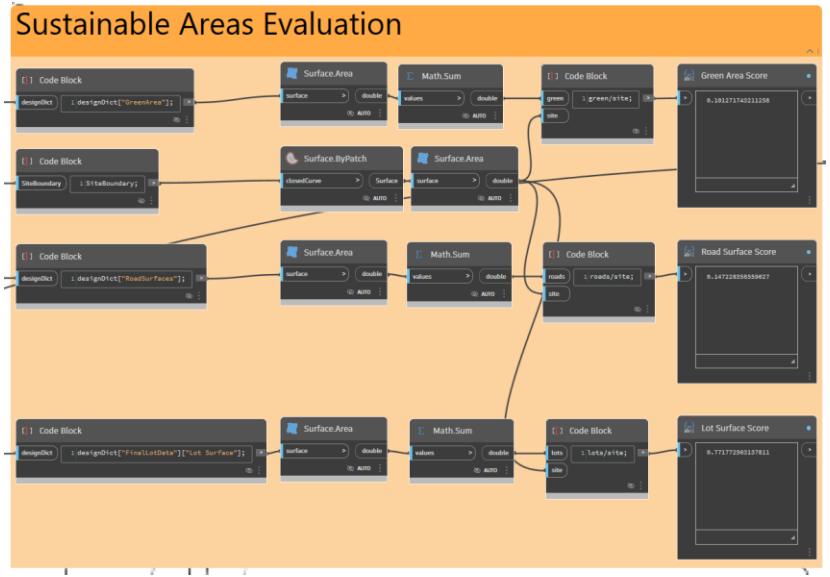



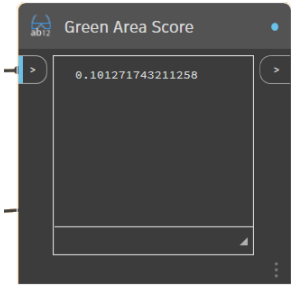



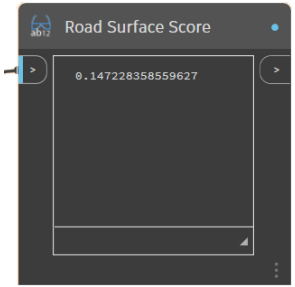



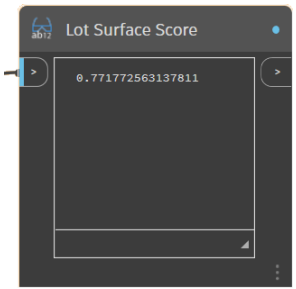
# Sustainable Areas Evaluation



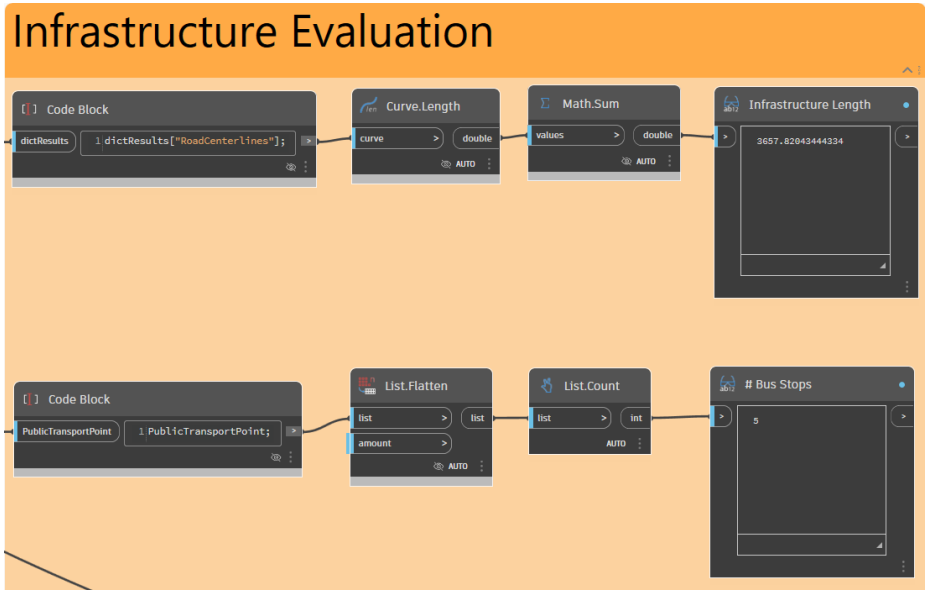

- Maximize the Green Area.
- Minimize the Road Surface
- Maximize the total Lot Surface



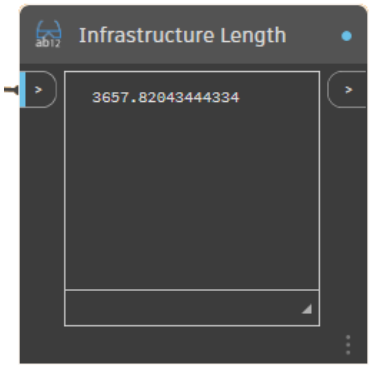



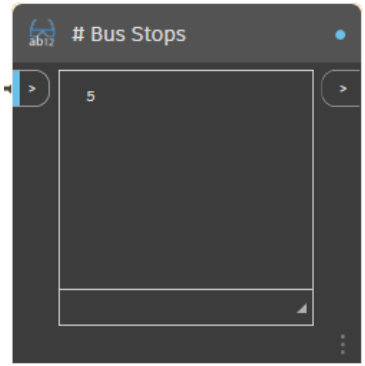



# Infrastructure Evaluation

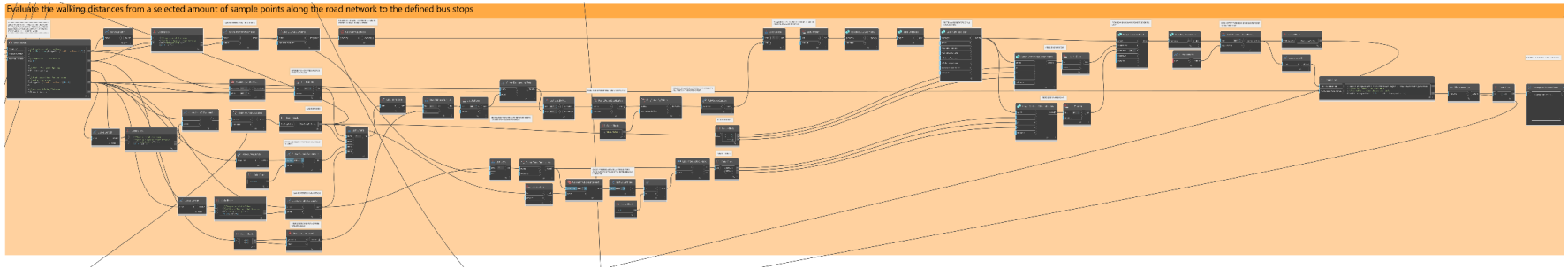


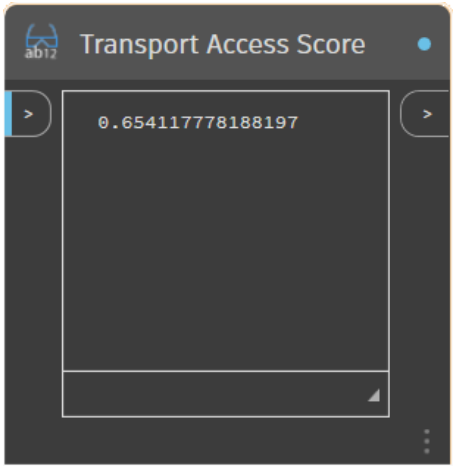

- Minimize the infrastructure length
- Count the amount of bus stops



# Public Transport Access Score




- Sample point
- Target point
- Shortest path from sample to target point

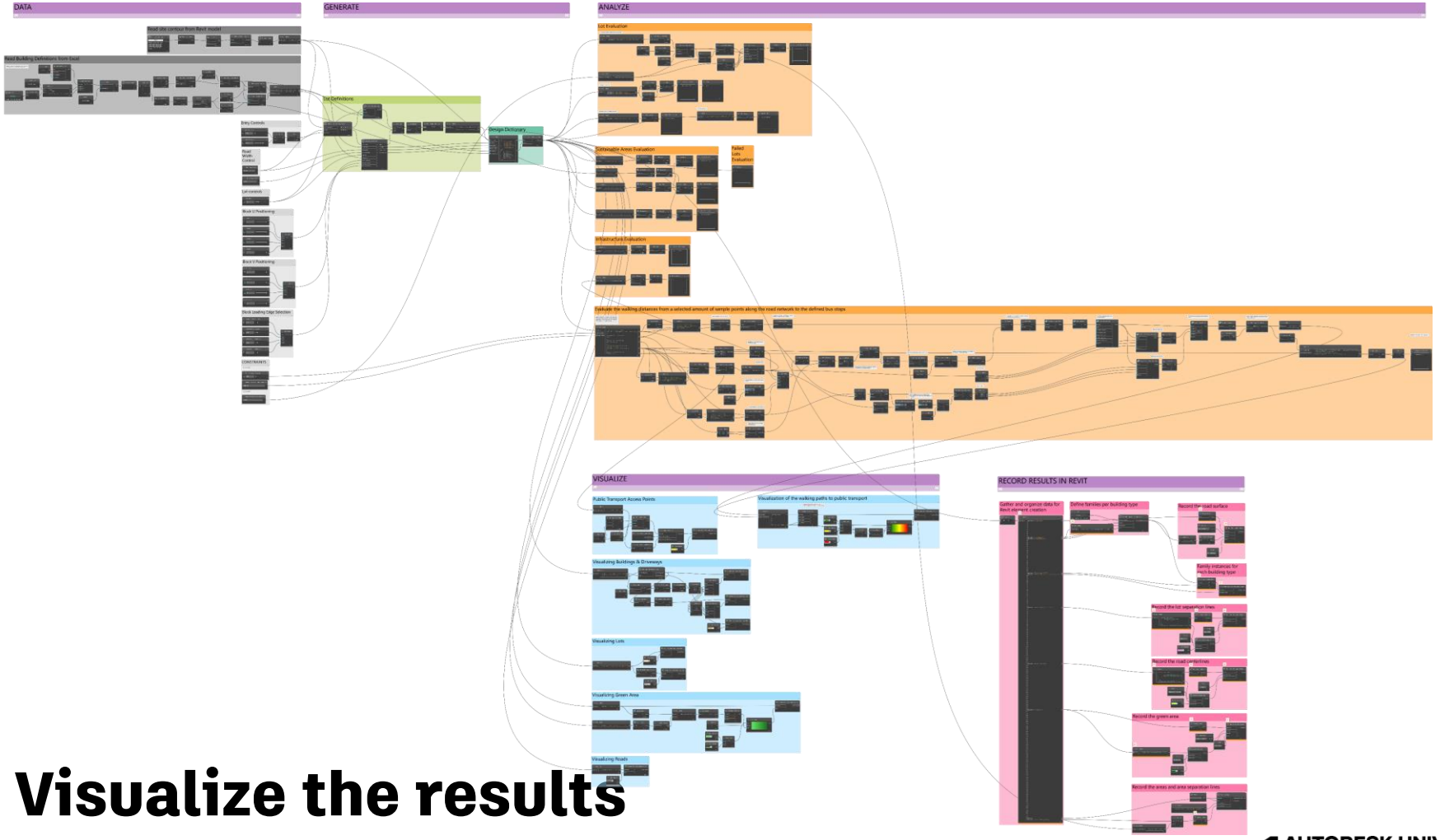
# Path analysis

## Analyze the walking distances to public transport points

Public Transport Access Score

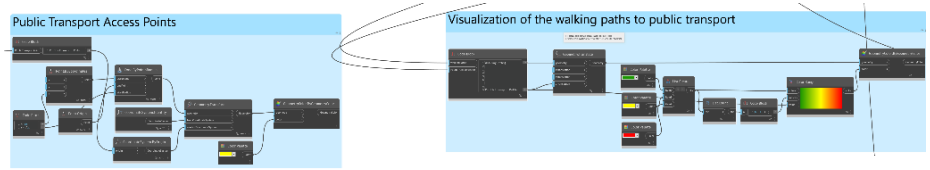
- Score = 1.0
- Score = 0.5
- Score = 0.0

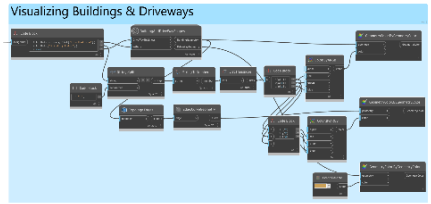

LIVE DEMO

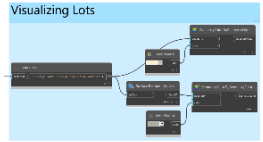


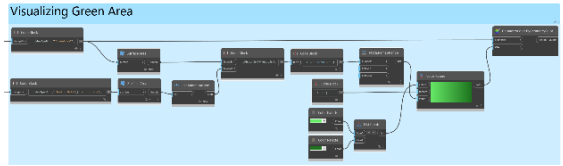

# Visualize the results

# Visualize the result

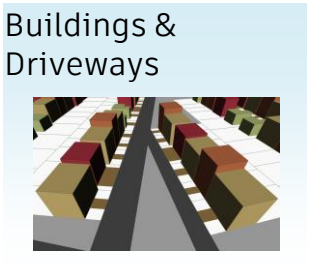


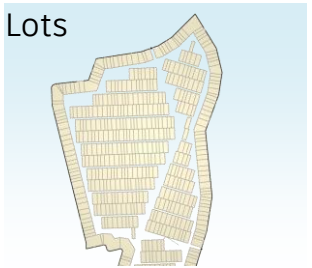



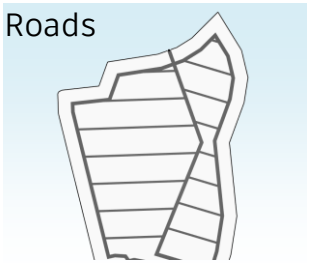







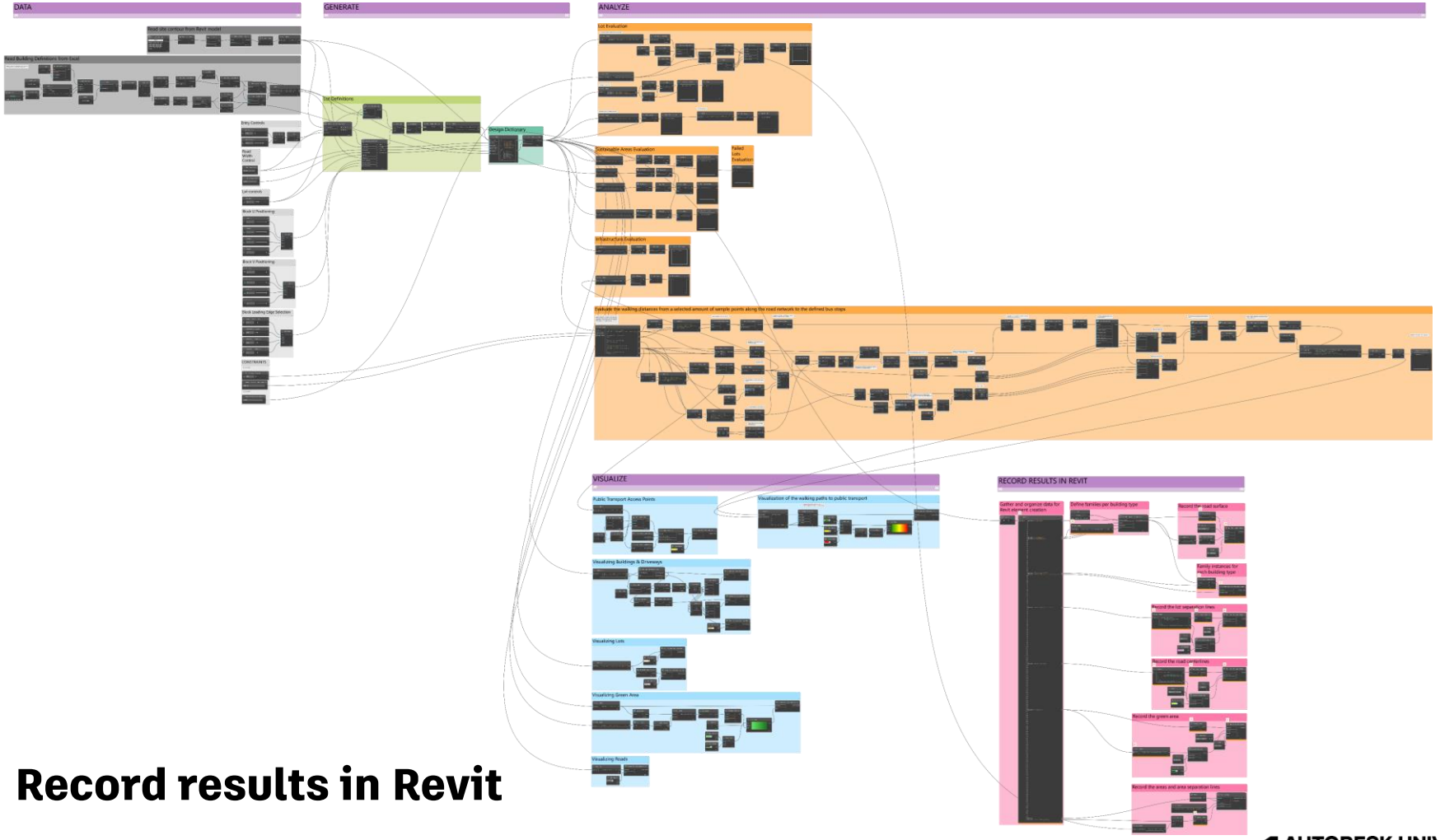






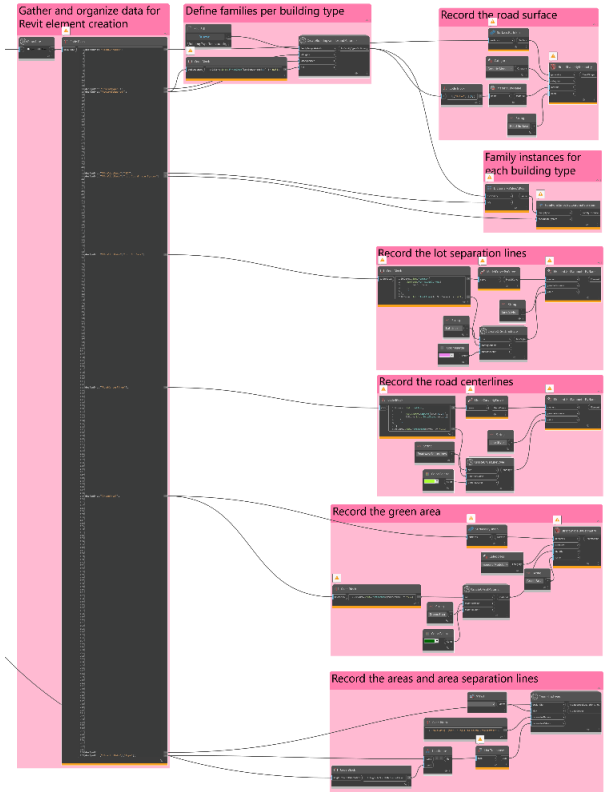
# Visualize the result


LIVE DEMO

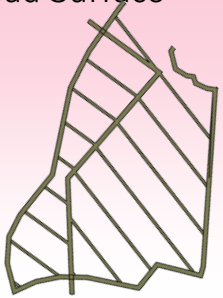



# Record results in Revit

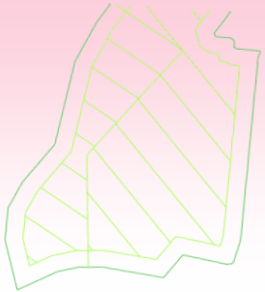
# Record Results in Revit




Road Surface

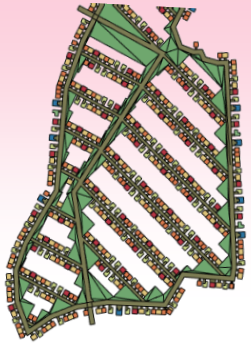


Road Centerlines

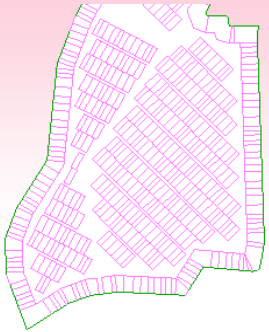


Building Instances

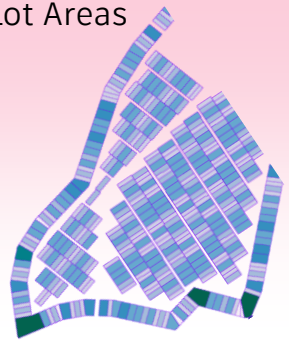
Green Area



Lot Separation Lines



Lot Areas

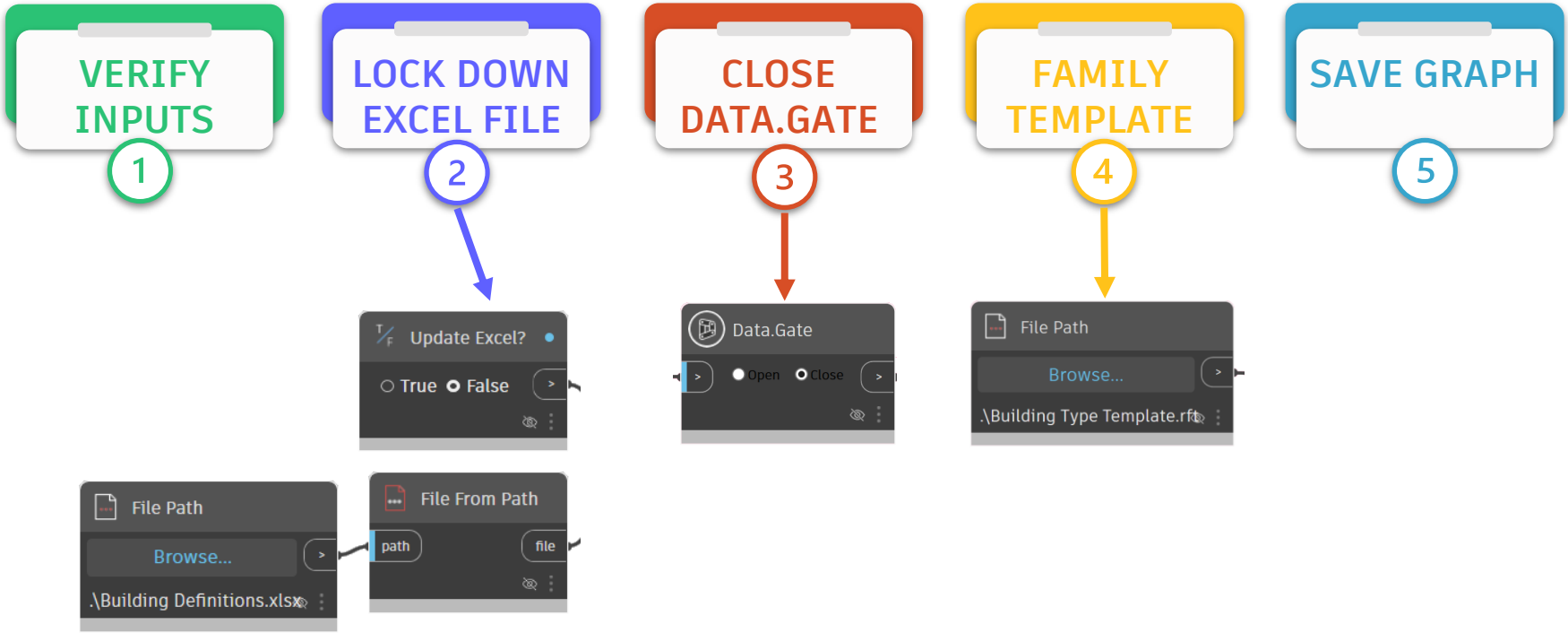


# Record Results in Revit


LIVE DEMO

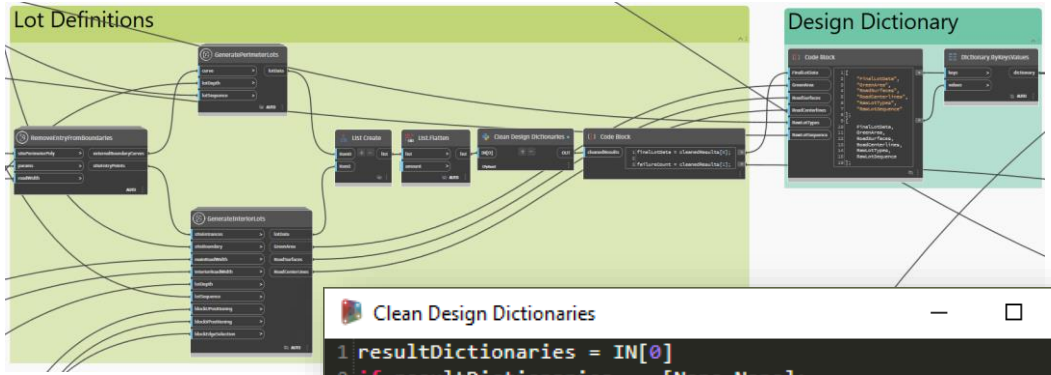
# Prepare for optimization

## What to check before running the optimization ?



# Clean Design Dictionaries

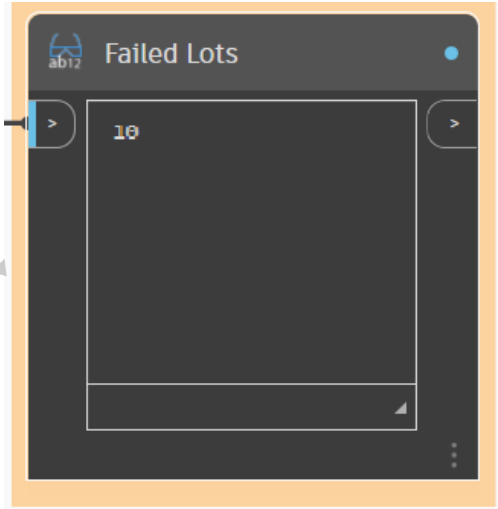
## Catching the amount of lot failures




Clean Design Dictionaries

```
resultDictionaries = IN[0]
if resultDictionaries == [None,None]:
    OUT = [None,10000]
else:
    cleanedResults = []
    failureCount = 0
    for d in resultDictionaries:
        test = [ 1 for i in d.keys() if d[i]==None]
        if sum(test) == 0 :cleanedResults.append(d)
        failureCount = failureCount+sum(test)
    OUT = cleanedResults, failureCount
```

Run CPython3

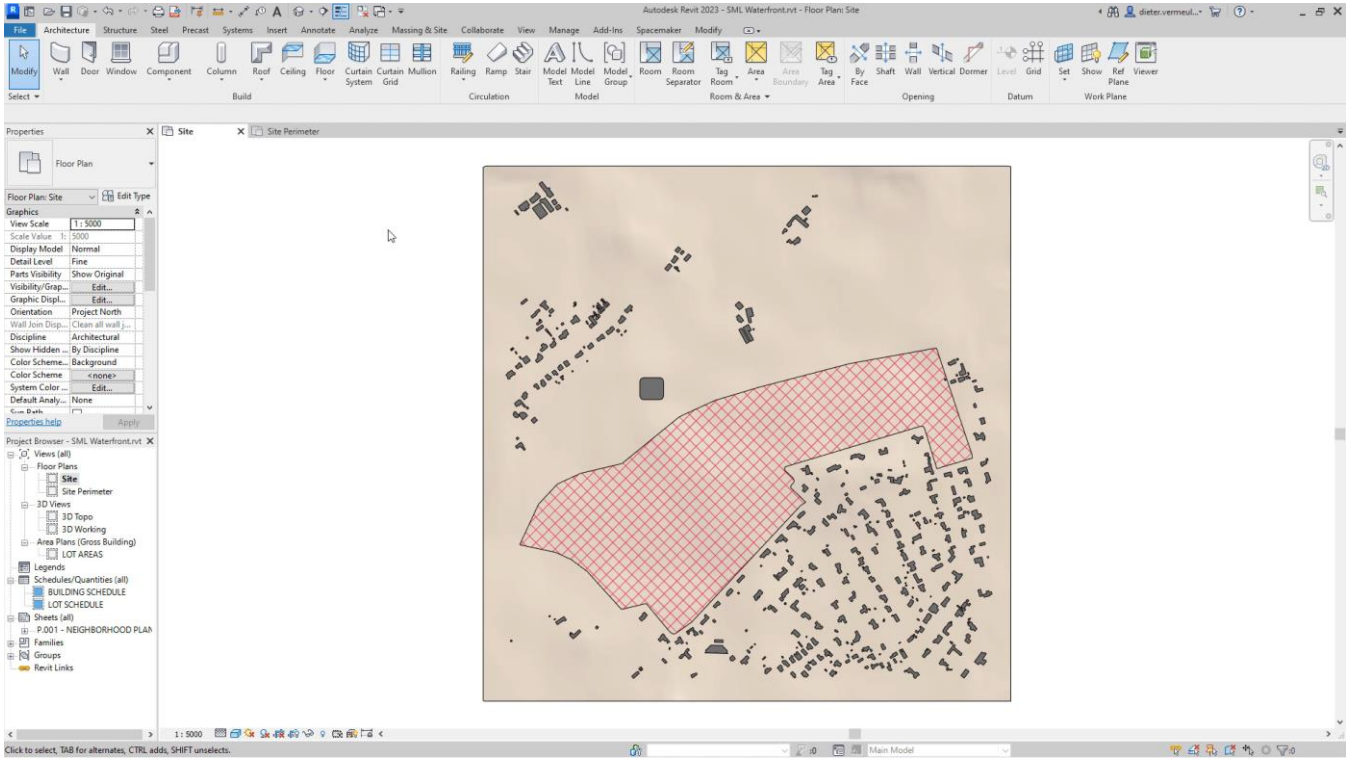



Minimize the amount of failed lots during the optimization process to skip invalid design options.


LIVE DEMO

# Optimization of the new neighborhood

## Generative Design in Revit

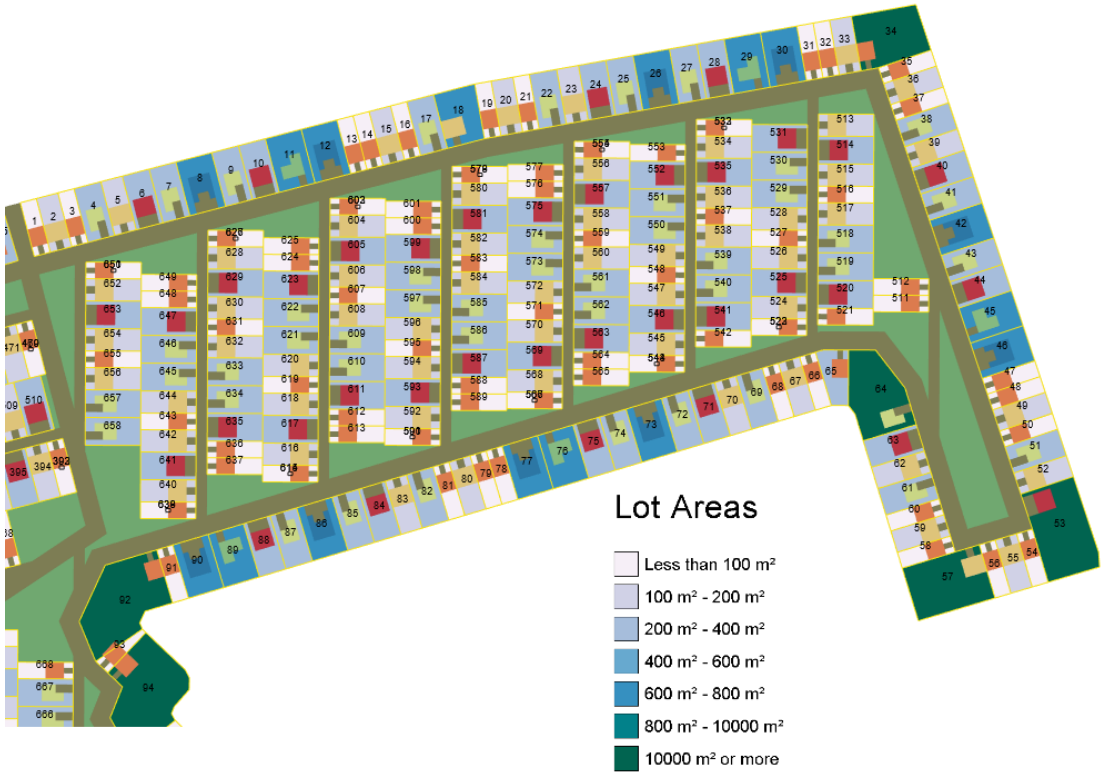


# Create neighborhood from results

## Autodesk Revit

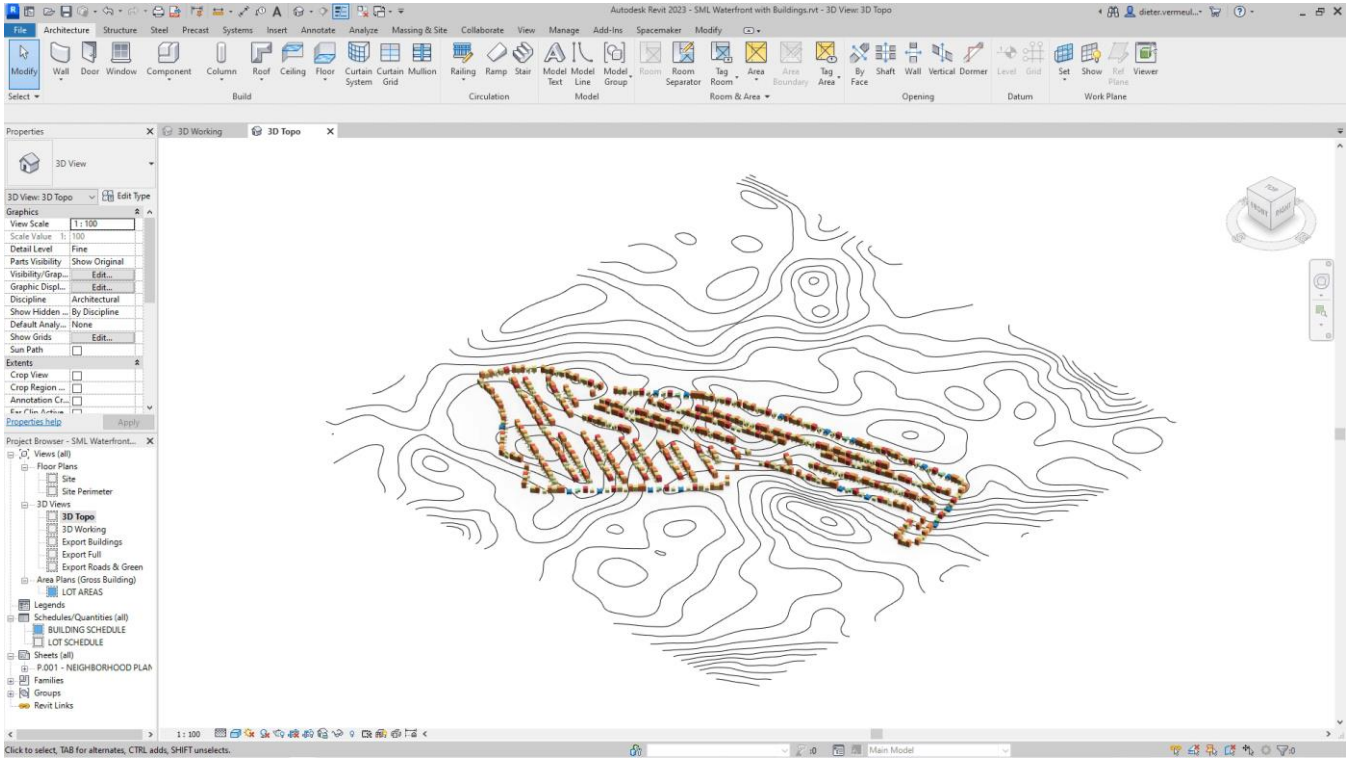
# Area plan

## Lot development plan in Revit



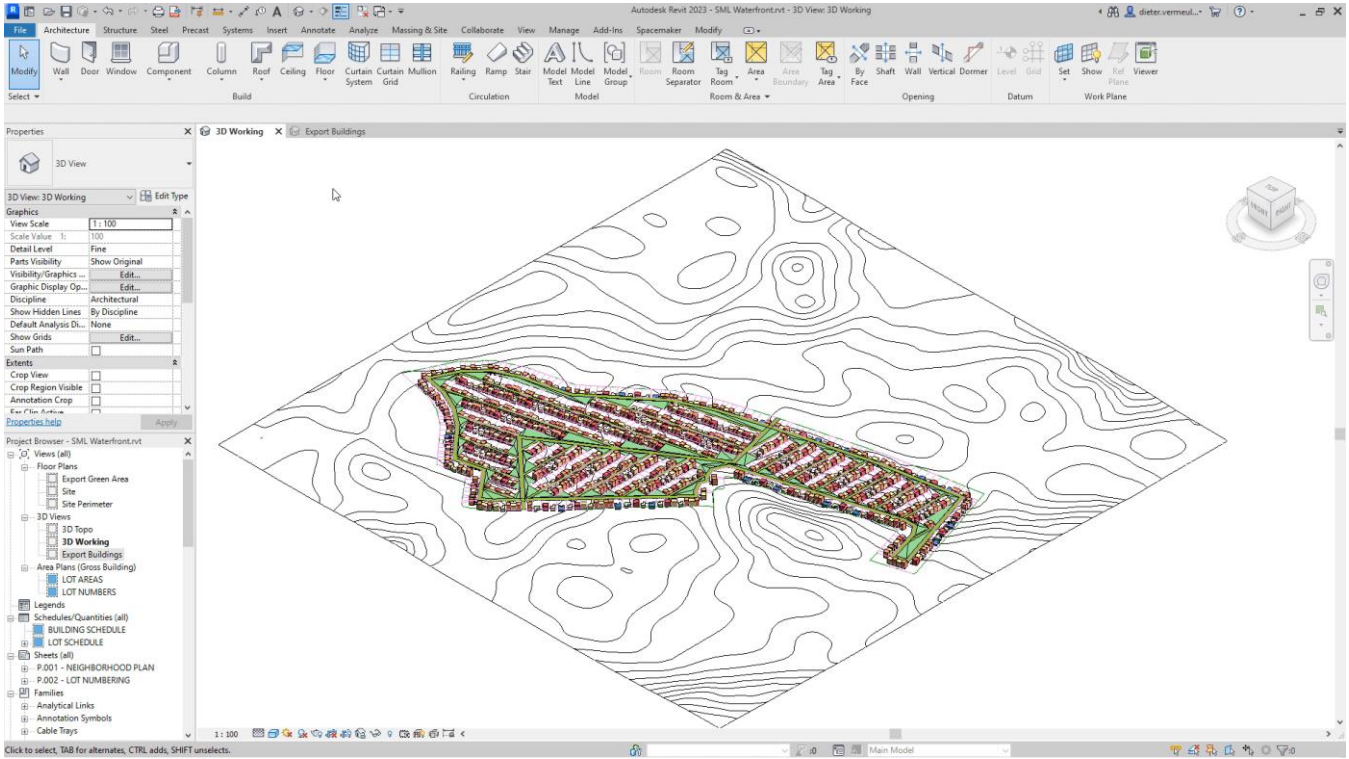

| LOT SCHEDULE | | | | |
|---|---|---|---|---|
| Number | Building Type | Area | Perimeter | Angle to South Orientation |
| 1 | Townhouse 1 | 270 m² | 78 m | 165.36° |
| 2 | Townhouse 2 | 360 m² | 84 m | 165.36° |
| 3 | Townhouse 1 | 270 m² | 78 m | 165.36° |
| 4 | Detached | 450 m² | 90 m | 165.36° |
| 5 | Townhouse 2 | 360 m² | 84 m | 165.36° |
| 6 | Commercial | 450 m² | 90 m | 165.36° |
| 7 | Detached | 450 m² | 90 m | 165.36° |
| 8 | Amenity | 600 m² | 100 m | 165.36° |
| 9 | Detached | 450 m² | 90 m | 165.36° |
| 10 | Commercial | 450 m² | 90 m | 165.36° |
| 11 | Villa | 600 m² | 100 m | 165.36° |
| 12 | Amenity | 600 m² | 100 m | 165.36° |
| 13 | Townhouse 1 | 270 m² | 78 m | 165.36° |
| 14 | Townhouse 1 | 270 m² | 78 m | 165.36° |
| 15 | Townhouse 2 | 360 m² | 84 m | 165.36° |
| 16 | Townhouse 1 | 270 m² | 78 m | 165.36° |
| 17 | Detached | 450 m² | 90 m | 165.36° |
| 18 | Townhouse 2 | 657 m² | 104 m | 165.36° |
| 19 | Townhouse 1 | 270 m² | 78 m | 169.80° |
| 20 | Townhouse 2 | 360 m² | 84 m | 169.80° |
| 21 | Townhouse 1 | 270 m² | 78 m | 169.80° |
| 22 | Detached | 450 m² | 90 m | 169.80° |
| 23 | Townhouse 2 | 360 m² | 84 m | 169.80° |
| 24 | Commercial | 450 m² | 90 m | 169.80° |
| 25 | Detached | 450 m² | 90 m | 169.80° |
| 26 | Amenity | 600 m² | 100 m | 169.80° |
| 27 | Detached | 450 m² | 90 m | 169.80° |
| 28 | Commercial | 450 m² | 90 m | 169.80° |

# Correct building elevations



# Export the new neighborhood

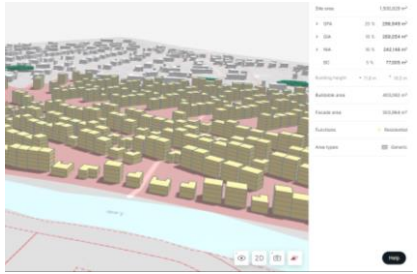
## Autodesk Revit & IFC



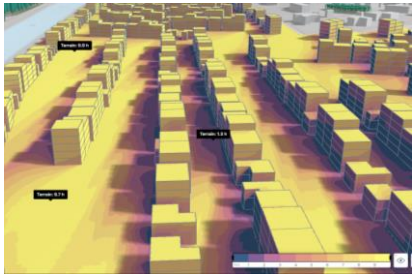
# Analyze the new neighborhood

## What types of analysis in Spacemaker

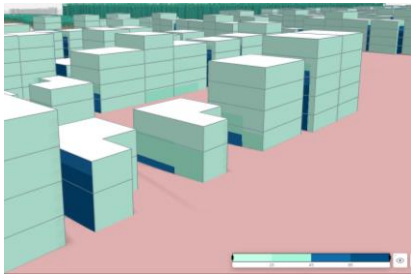
### Buildings



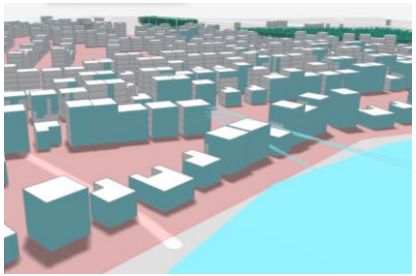
### Sun



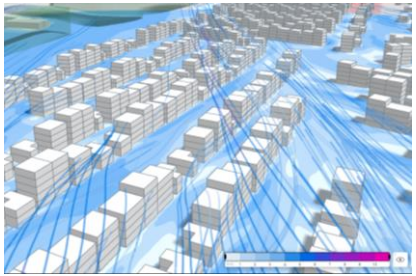
### Daylight



### View

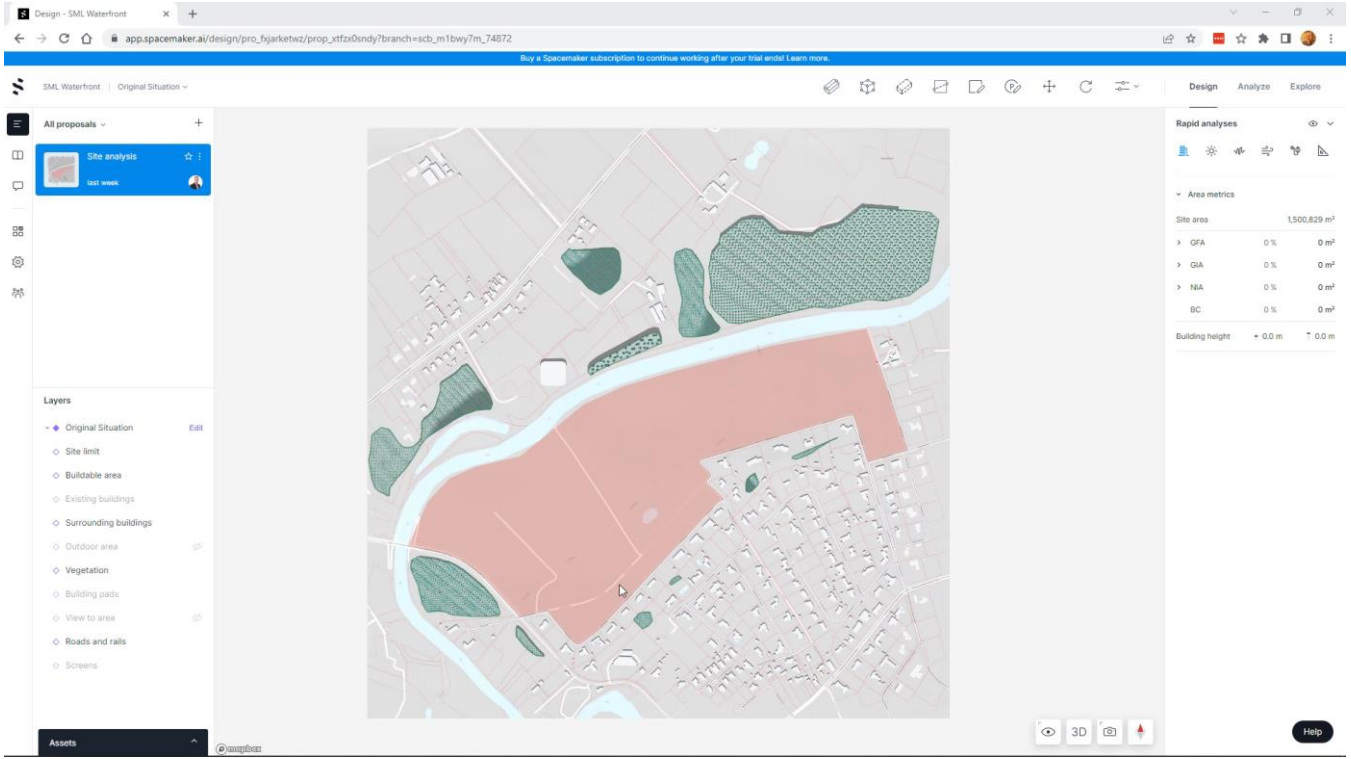


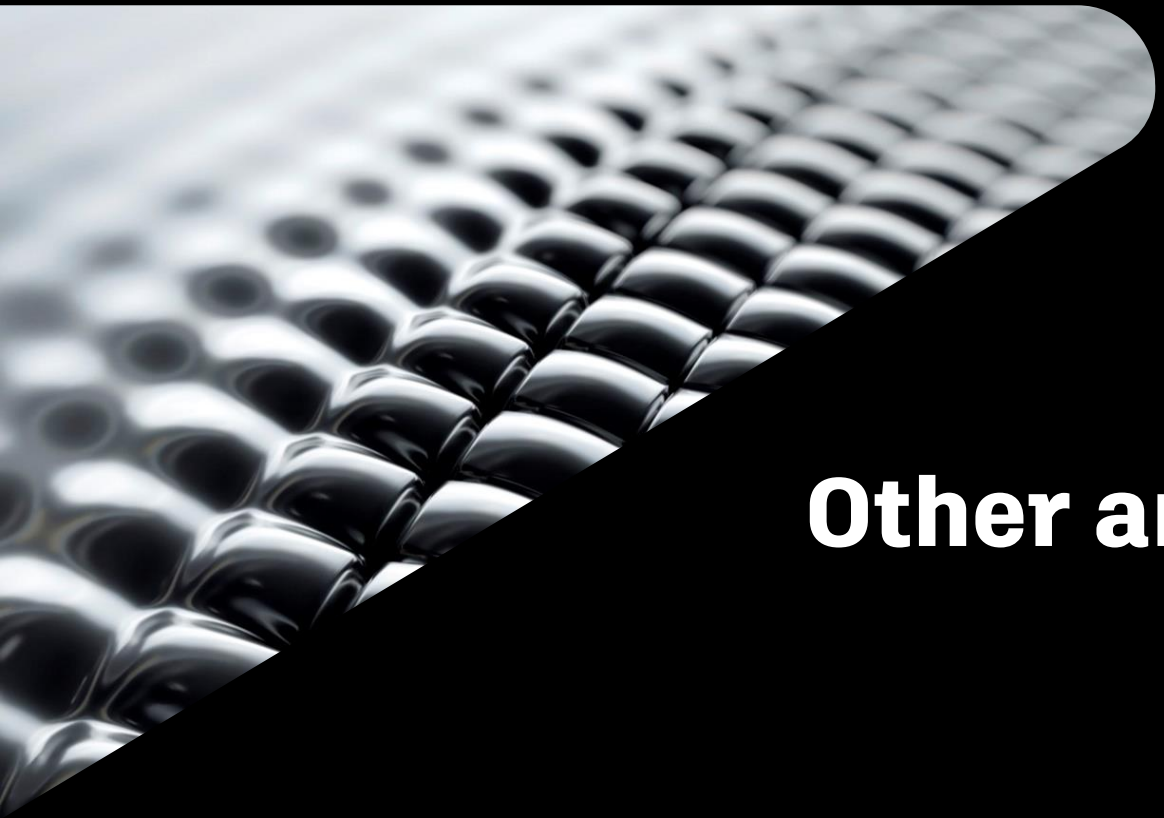
### Wind



# Analyze the new neighborhood

## Spacemaker

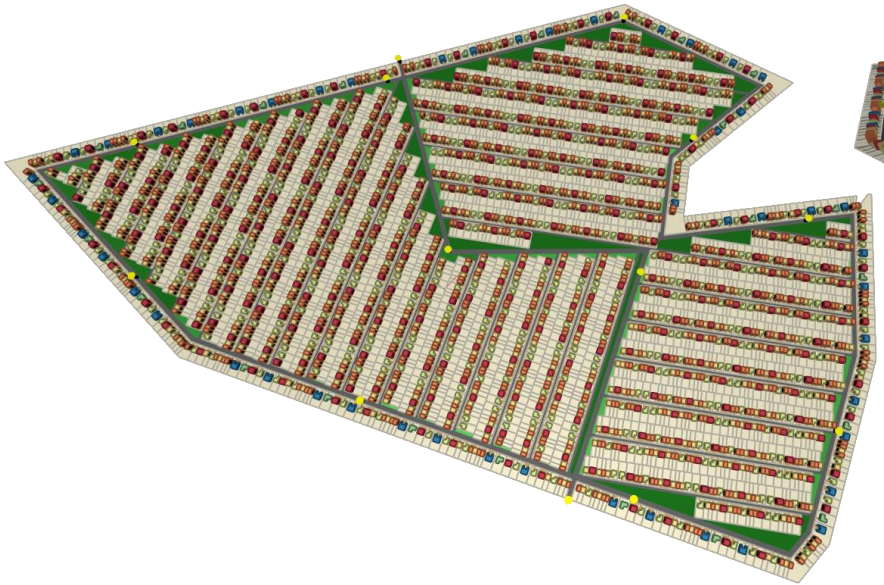


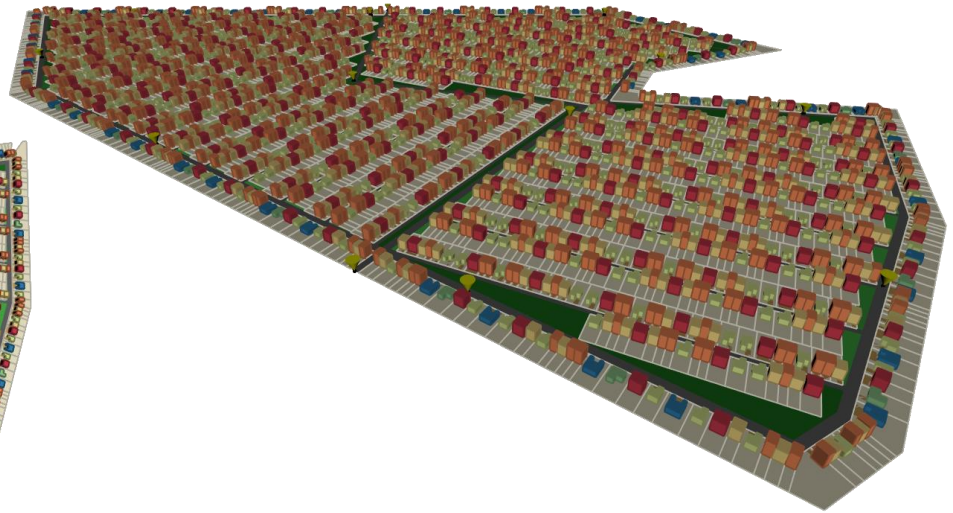


# Other analysis results

Working with different sites

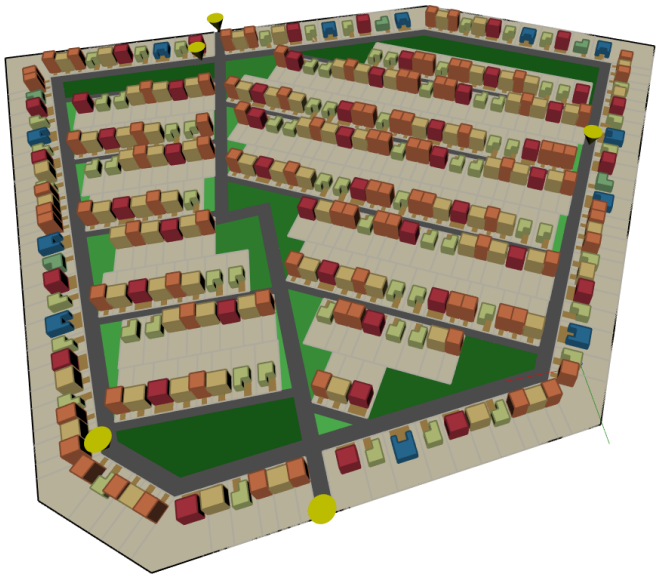
# Other site studies





# Starmountain

Dynamo



Revit

## Lot Areas

- Less than 100 m²
- 100 m² - 200 m²
- 200 m² - 400 m²
- 400 m² - 600 m²
- 600 m² - 800 m²
- 800 m² - 10000 m²
- 10000 m² or more

**LOT SCHEDULE**

| Building Type | Area | Perimeter | Angle to South Orientation |
|---|---|---|---|
| Townhouse 1 | 315 m² | 88.00 m | 0.00° |
| Townhouse 2 | 420 m² | 94.00 m | 0.00° |
| Townhouse 1 | 315 m² | 88.00 m | 0.00° |
| Detached | 525 m² | 100.00 m | 0.00° |
| Townhouse 2 | 420 m² | 94.00 m | 0.00° |
| Commercial | 525 m² | 100.00 m | 0.00° |
| Detached | 525 m² | 100.00 m | 0.00° |
| Amenity | 700 m² | 110.00 m | 0.00° |

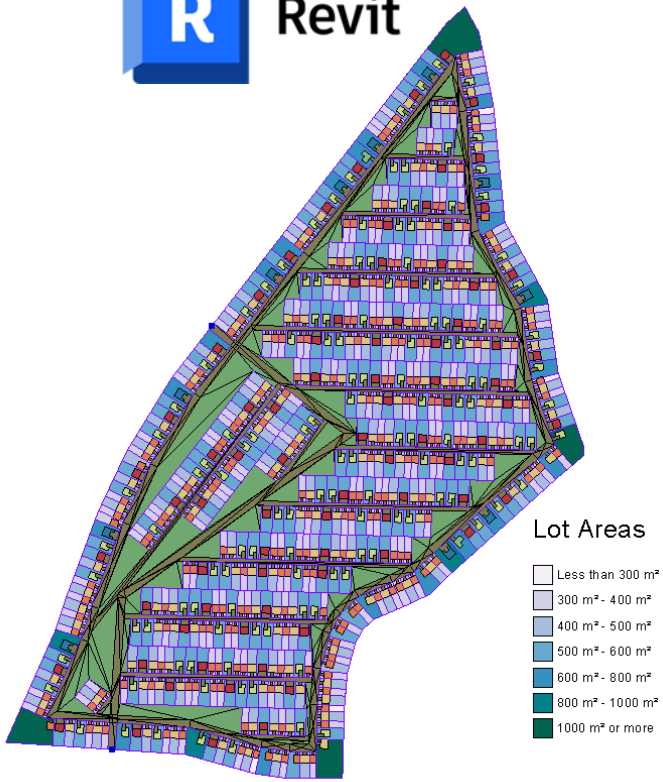
**BUILDING SCHEDULE**

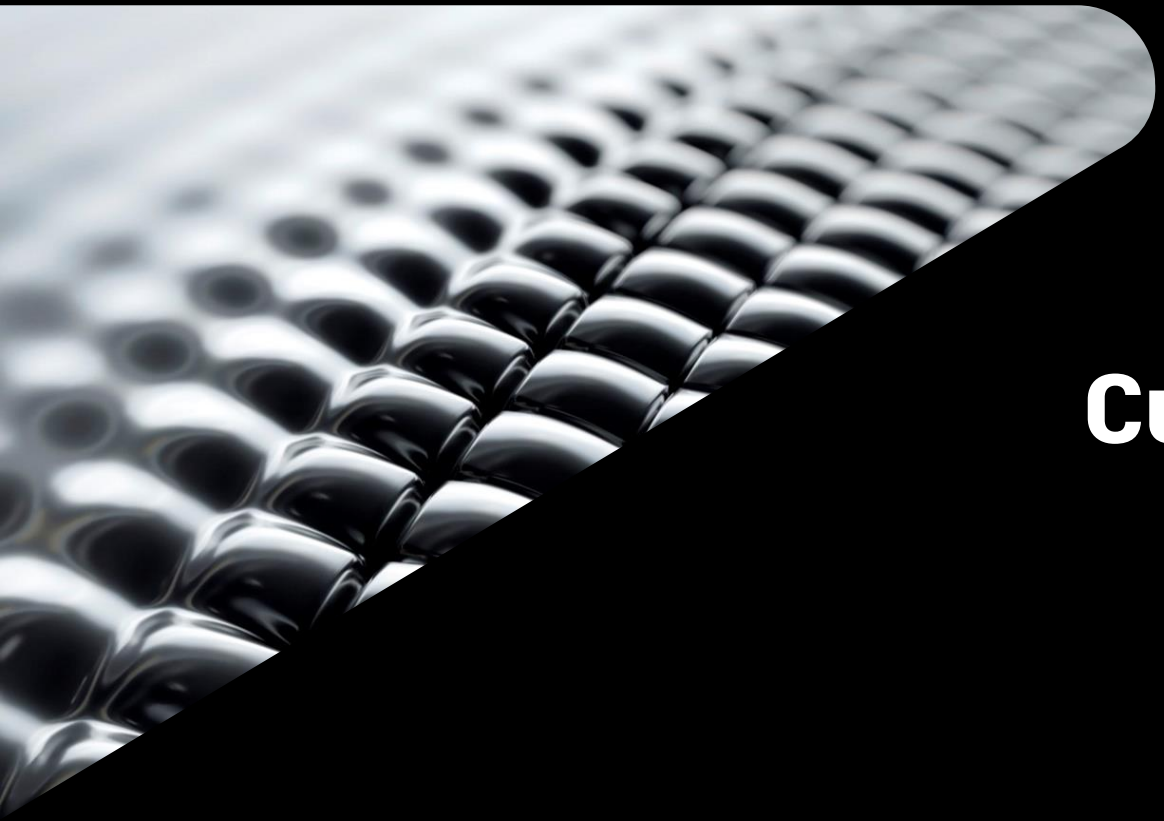
| Building Type | Carbon Emission | Net Price | Count |
|---|---|---|---|
| Amenity | 300 | 4320.00 | 12 |
| Commercial | 1000 | 12500.00 | 50 |
| Detached | 876 | 23360.00 | 73 |
| Townhouse 1 | 784 | 16800.00 | 112 |
| Townhouse 2 | 720 | 16000.00 | 80 |
| Villa | 70 | 2100.00 | 5 |
| TOTAL: 332 | 3750 | 75080.00 | |

# Mansfield Park

Dynamo

Revit





# Customization & Continuation

What’s next ?

# Additional Optimization Opportunities

**Generative Design's use doesn't stop here!**

- Optimization of bus stop locations
- Optimizing planting in the front yards
- Park access
- Optimize infrastructure layout
  - Power
  - Water
  - Fire hydrants
  - Etc
- And many more
  - Limited only by your imagination

# Autodesk Grading Optimization

Autodesk Grading Optimization consists of optimization algorithms that work toward surface smoothness while accommodating user-imposed constraints. These design constraints include grading and drainage elements. The constraints are entered as global parameters and as individual grading element parameters.

# Grading optimization of parcels

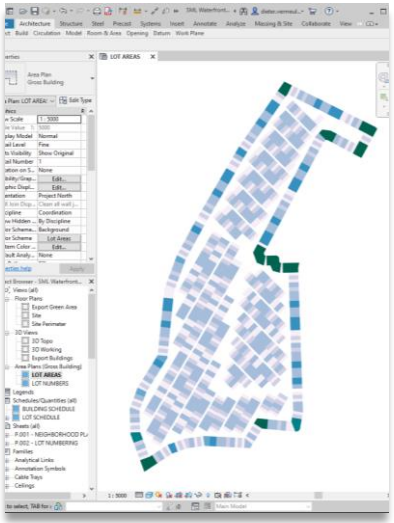
Revit

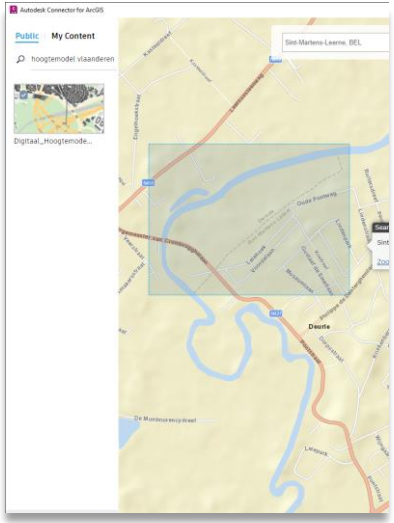
Civil 3D

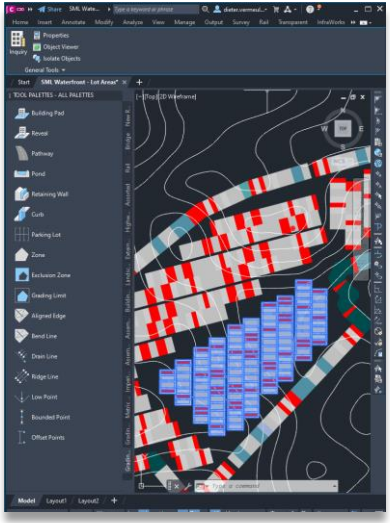
ArcGIS Hub Specialty

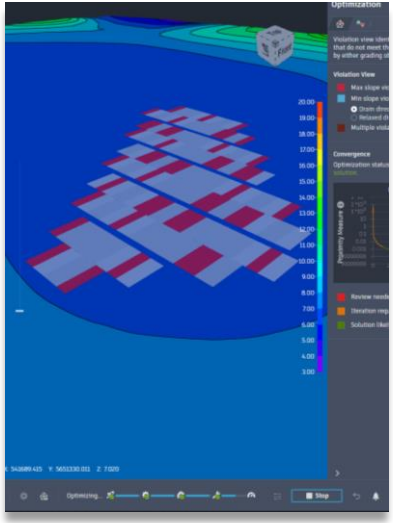
Civil 3D

Grading Optimization







Export Lot Areas to DWG

Import Digital Terrain Model in Civil 3D with ArcGIS

Define Building Pads

Perform analysis

# Grading optimization of parcels