

Getting started with Generative Design for AEC

Kean Walmsley

Platform Architect & Evangelist, Autodesk Research

kean.walmsley@autodesk.com | @keanw | keanw.com





About the speaker

Kean Walmsley

1995-2012 ADN

2012-2016 AutoCAD

2016- ... Research

1995-1998 UK

1998-2000 Switzerland

2000-2003 USA

2003-2005 India

2006- ... Switzerland

2006- ... Through the Interface

Autodesk Research into Generative Design



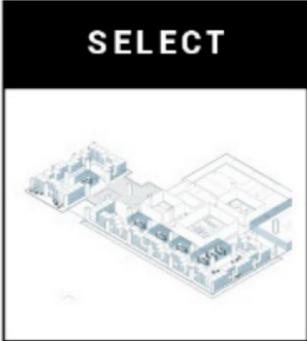
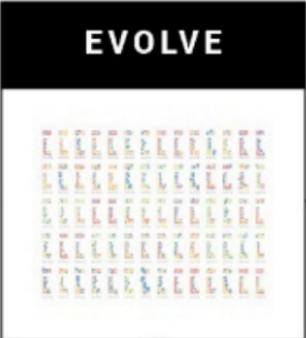
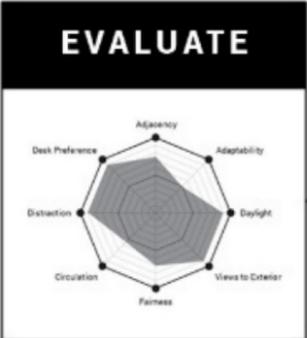
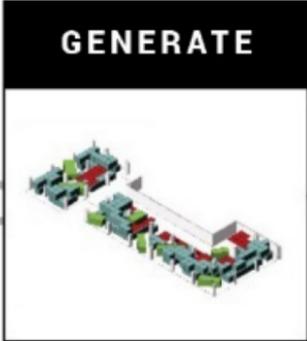
A320 Bionic Partition



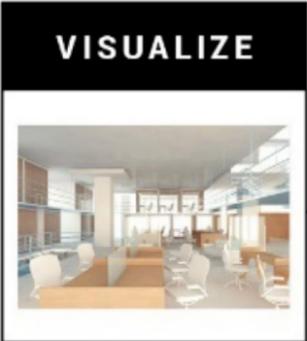
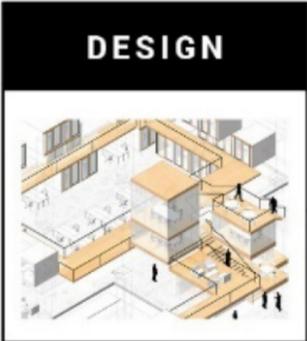
A320 Bionic Partition

GENERATIVE DESIGN

QUANTITATIVE

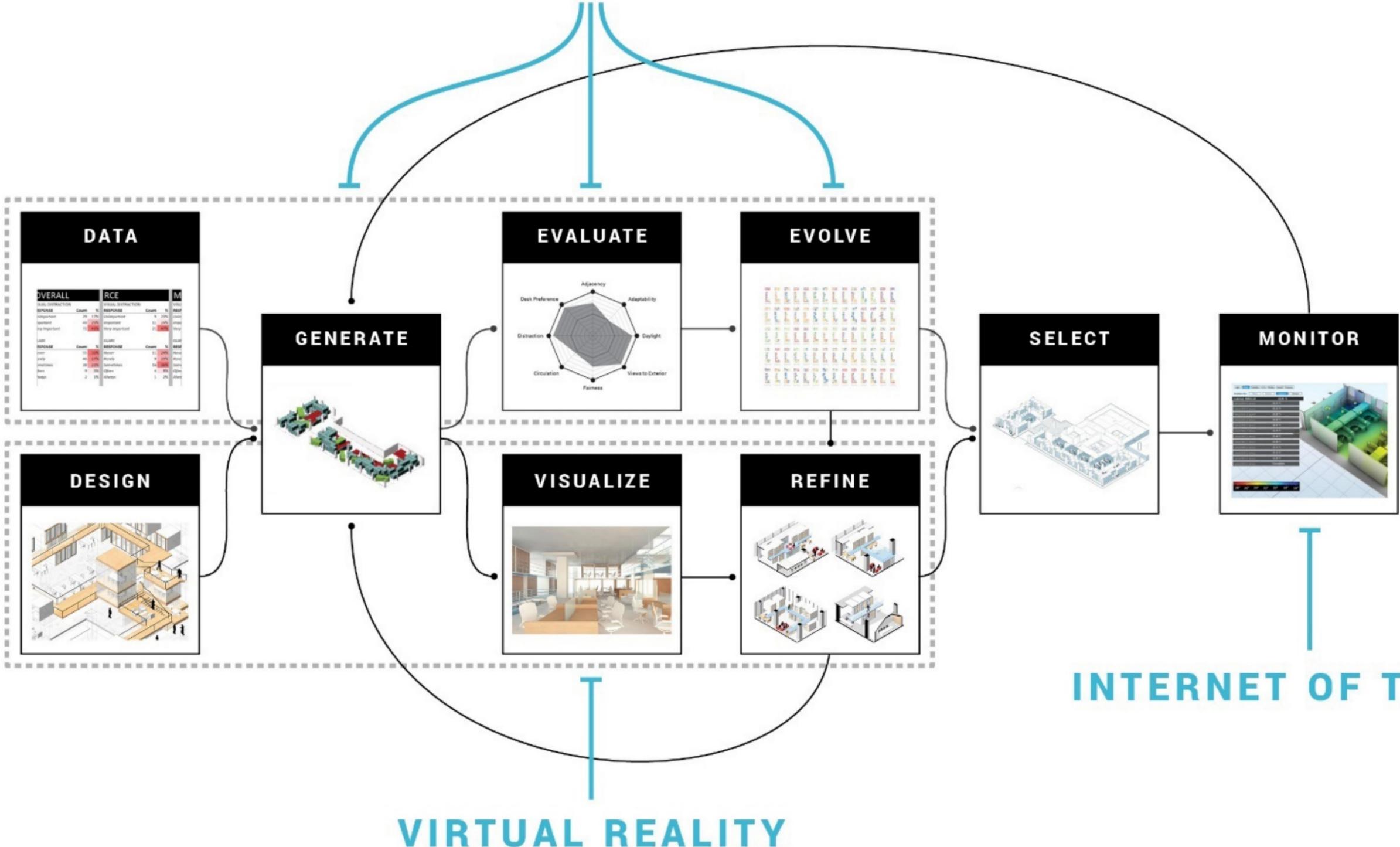


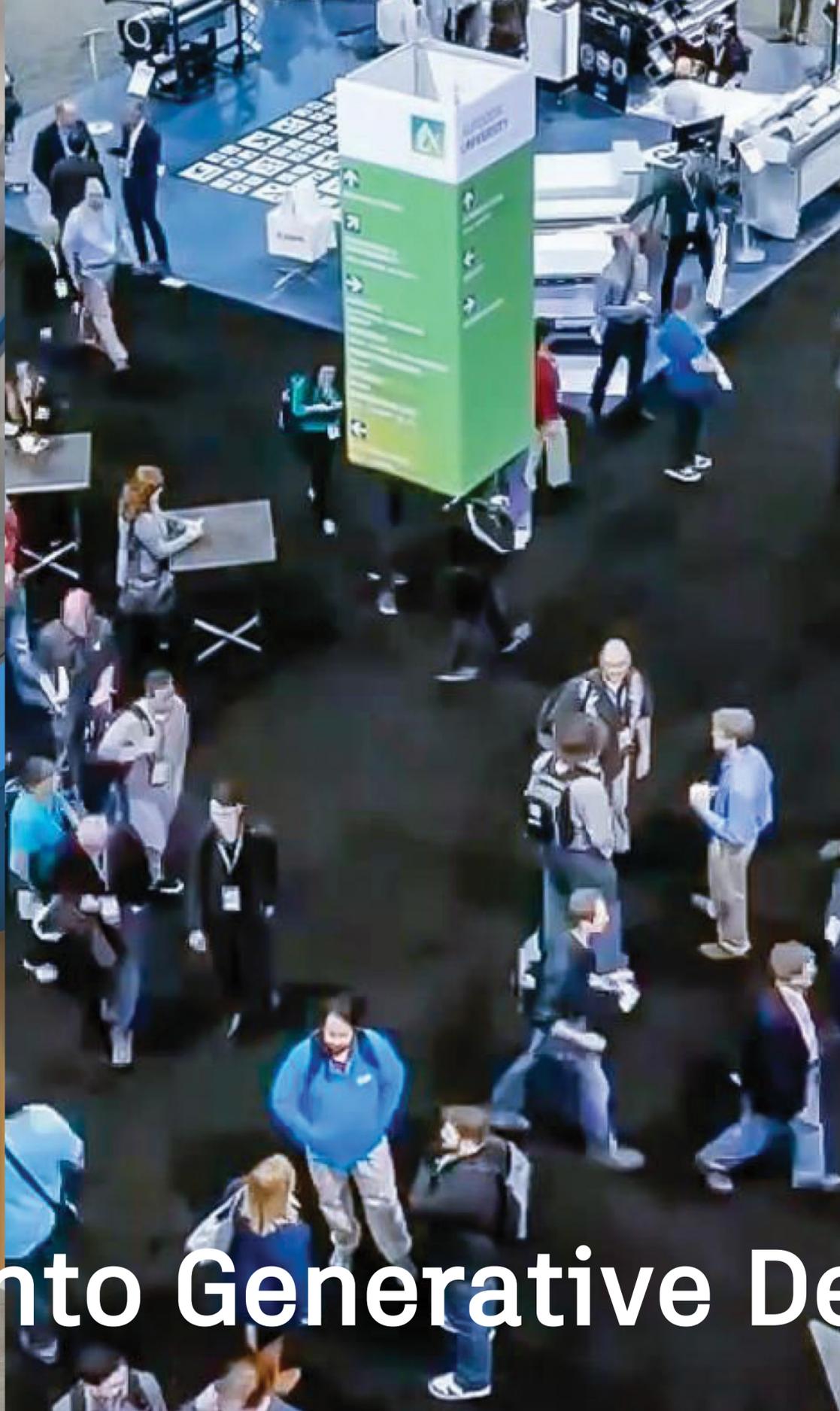
QUALITATIVE



VIRTUAL REALITY

INTERNET OF THINGS

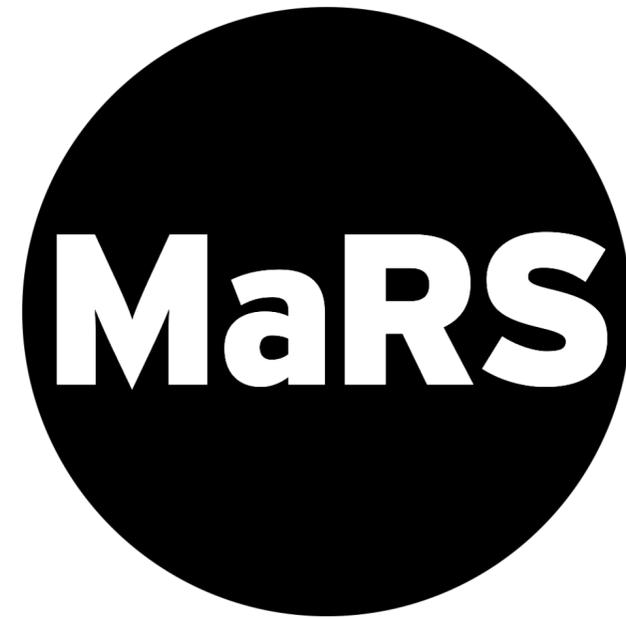




Research into Generative Design for AEC

The image shows a multi-level office space. A central feature is a wide, blue-painted metal staircase with glass railings and wooden handrails. The walls are a mix of light-colored wood paneling and white. In the upper left, a glass-walled office area contains two people working at a desk. Below, a glass-walled meeting room has two people seated at a table. The ceiling is industrial, with exposed white ductwork and long, horizontal light fixtures. The overall atmosphere is bright and modern.

Generative Architectural Layout Autodesk Toronto at MaRS

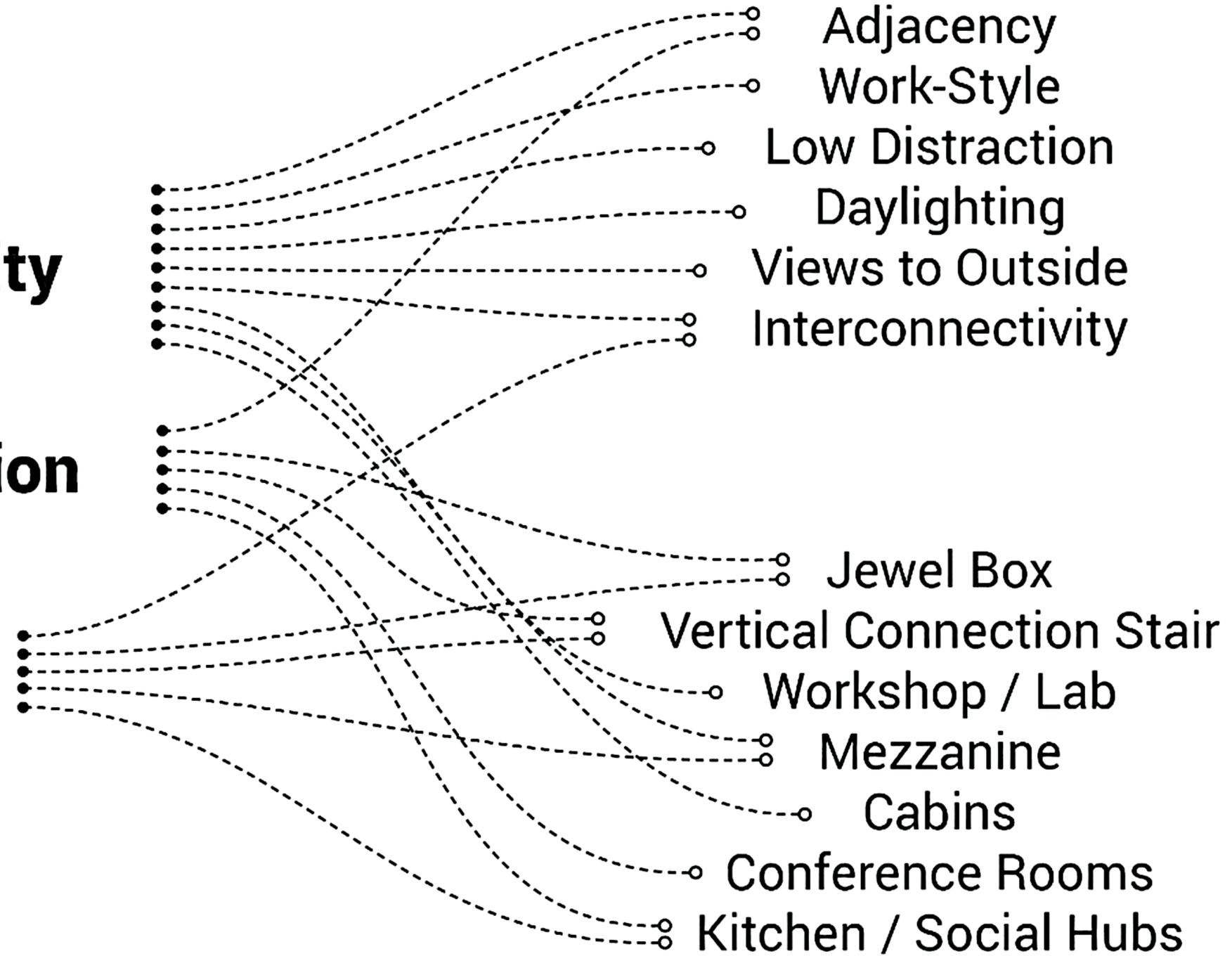


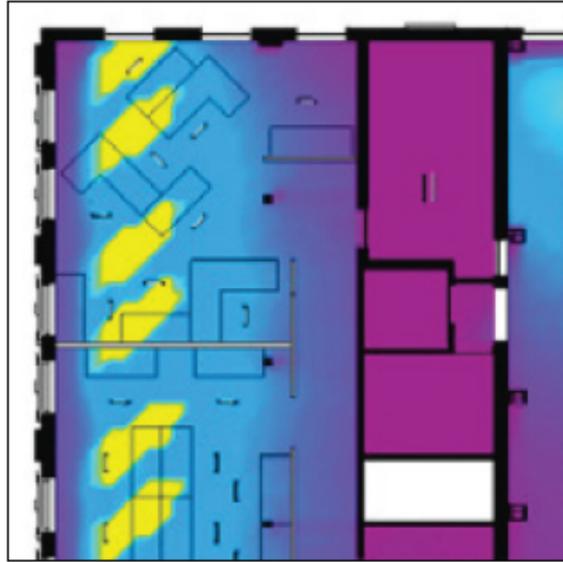


+ Productivity

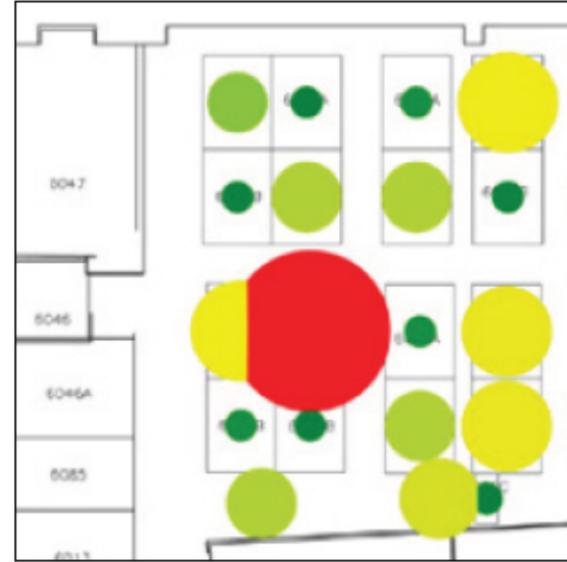
+ Collaboration

+ Buzz





1. Daylight



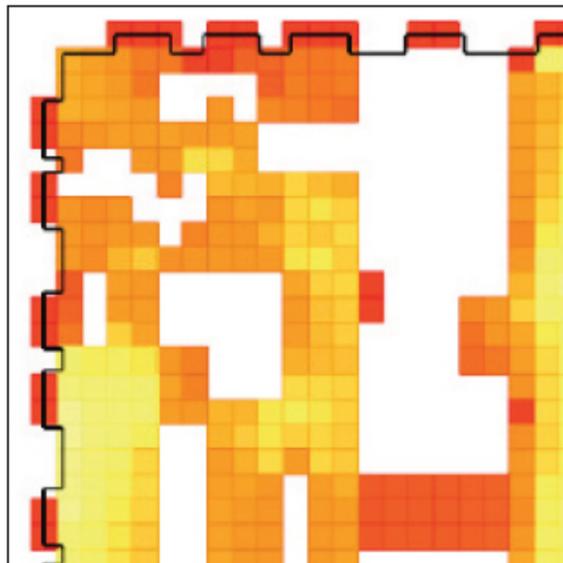
2. Low Visual Distraction



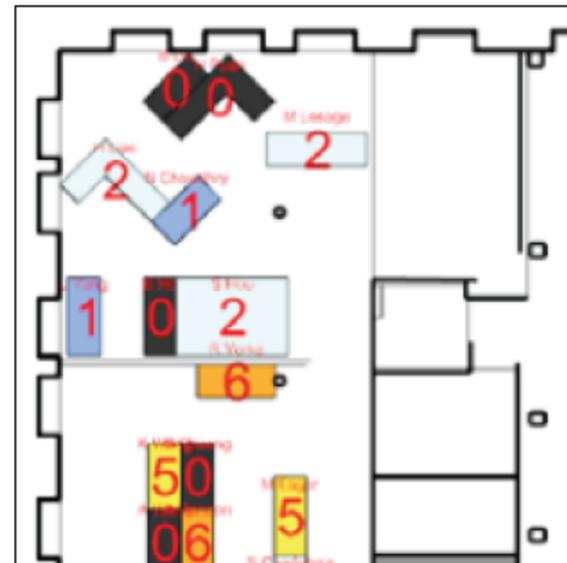
3. Views to Outside



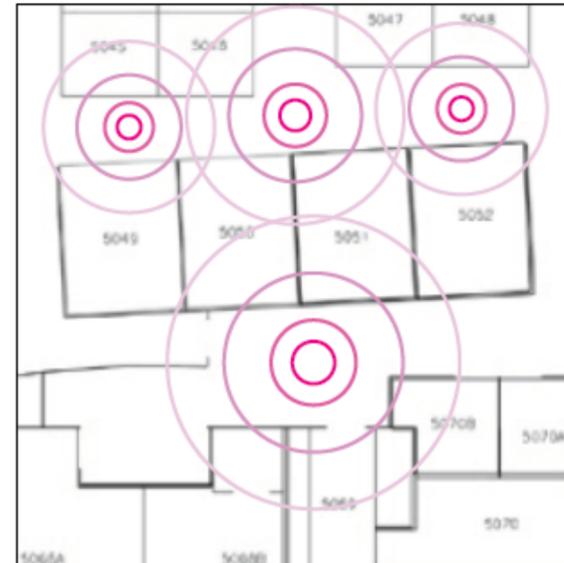
4. Adjacency Preference



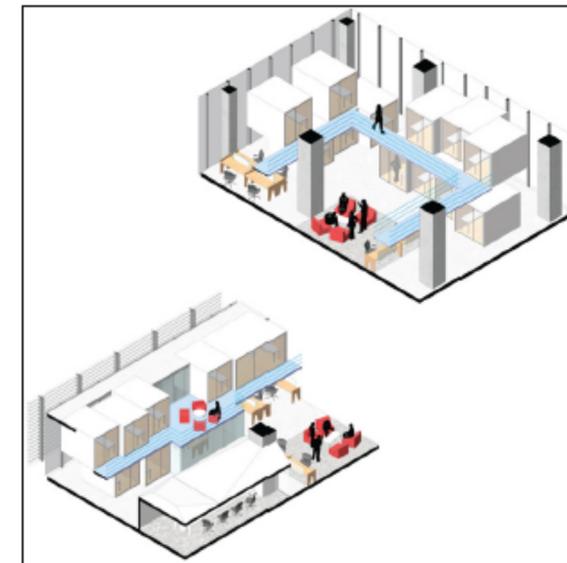
5. Circulation



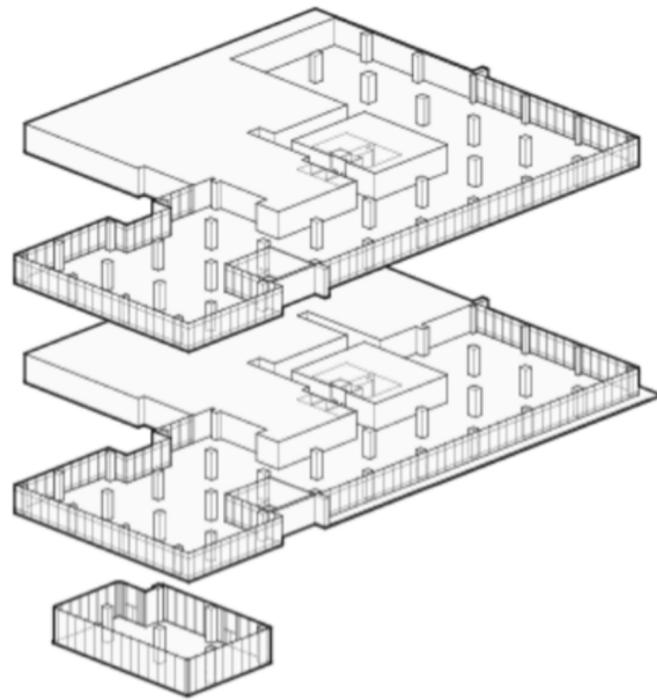
6. Work Styles



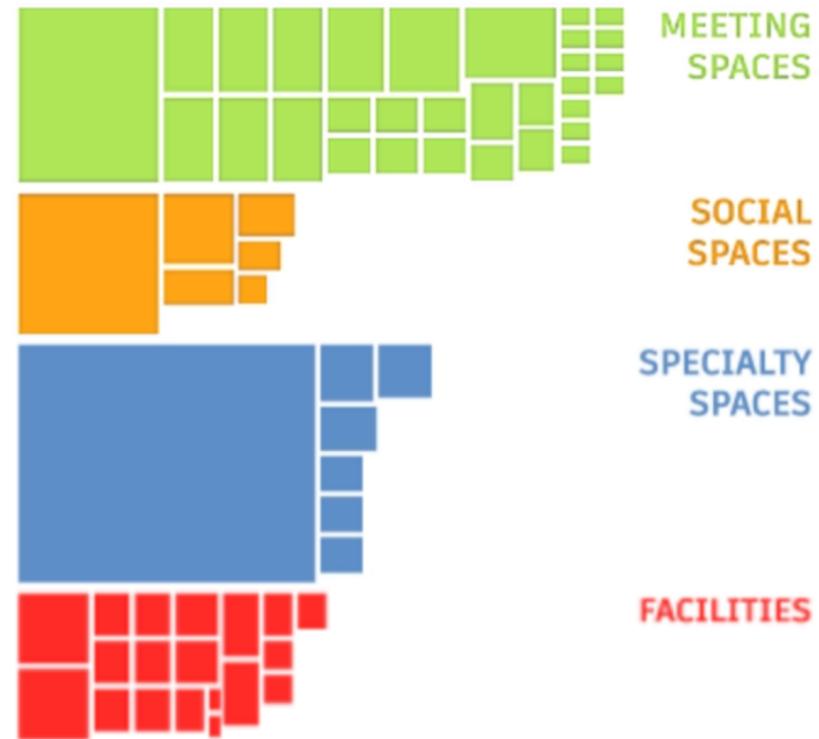
7. Low Acoustic Distraction



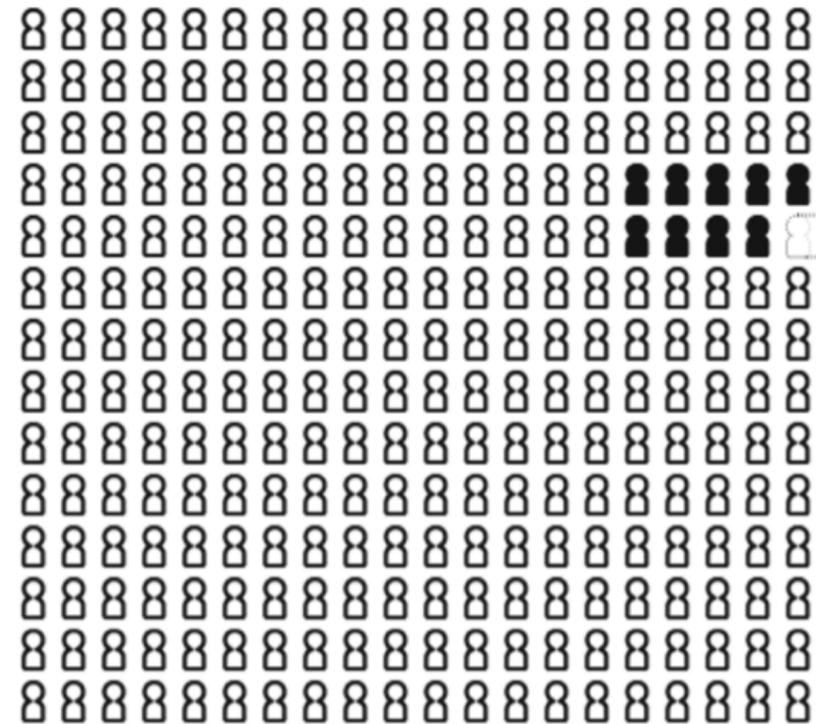
8. Low Density



3 floors
48,000 square feet



11 meeting rooms
6 multi-purpose rooms
11 phone booths



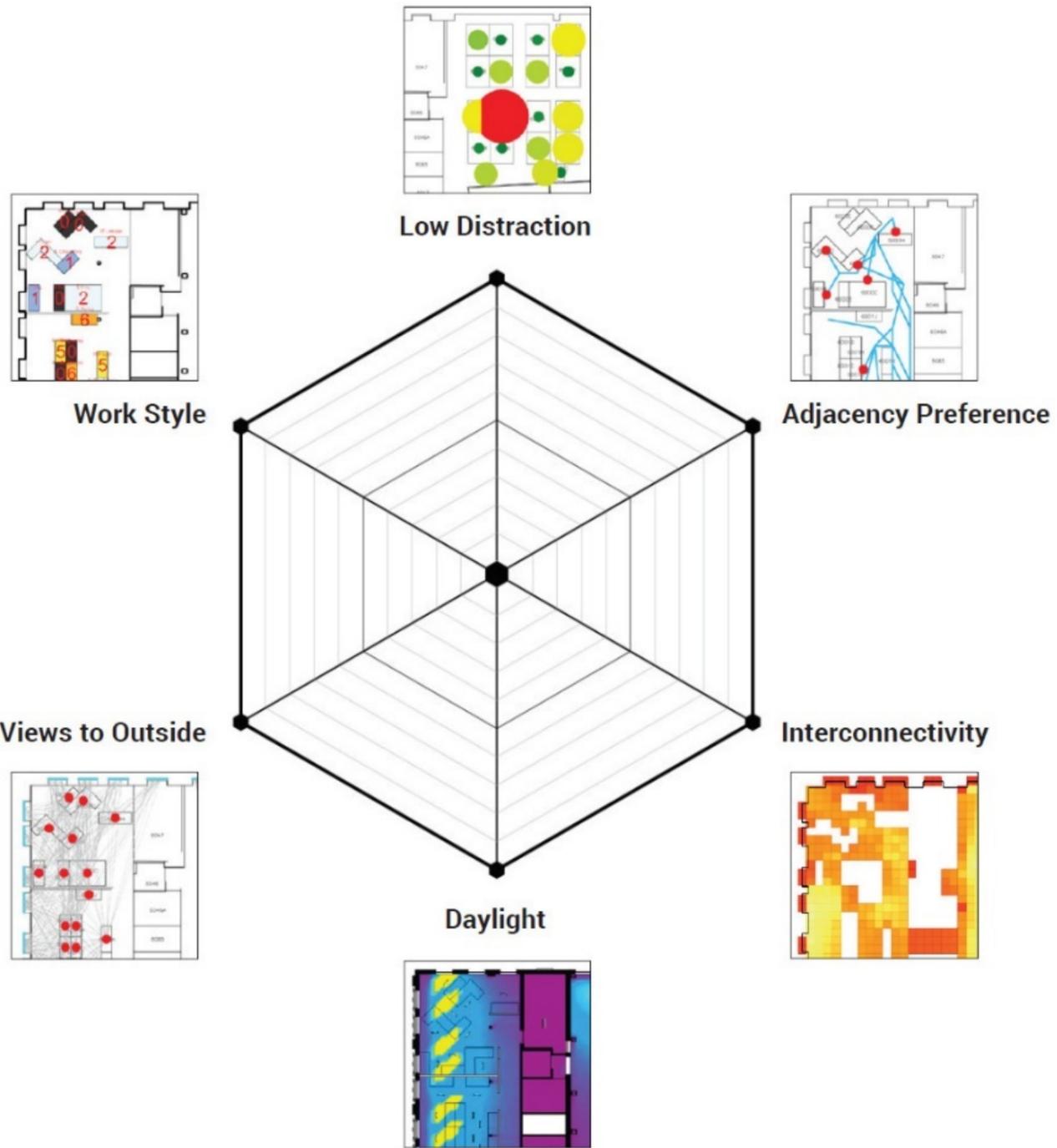
Name: John Villaggi

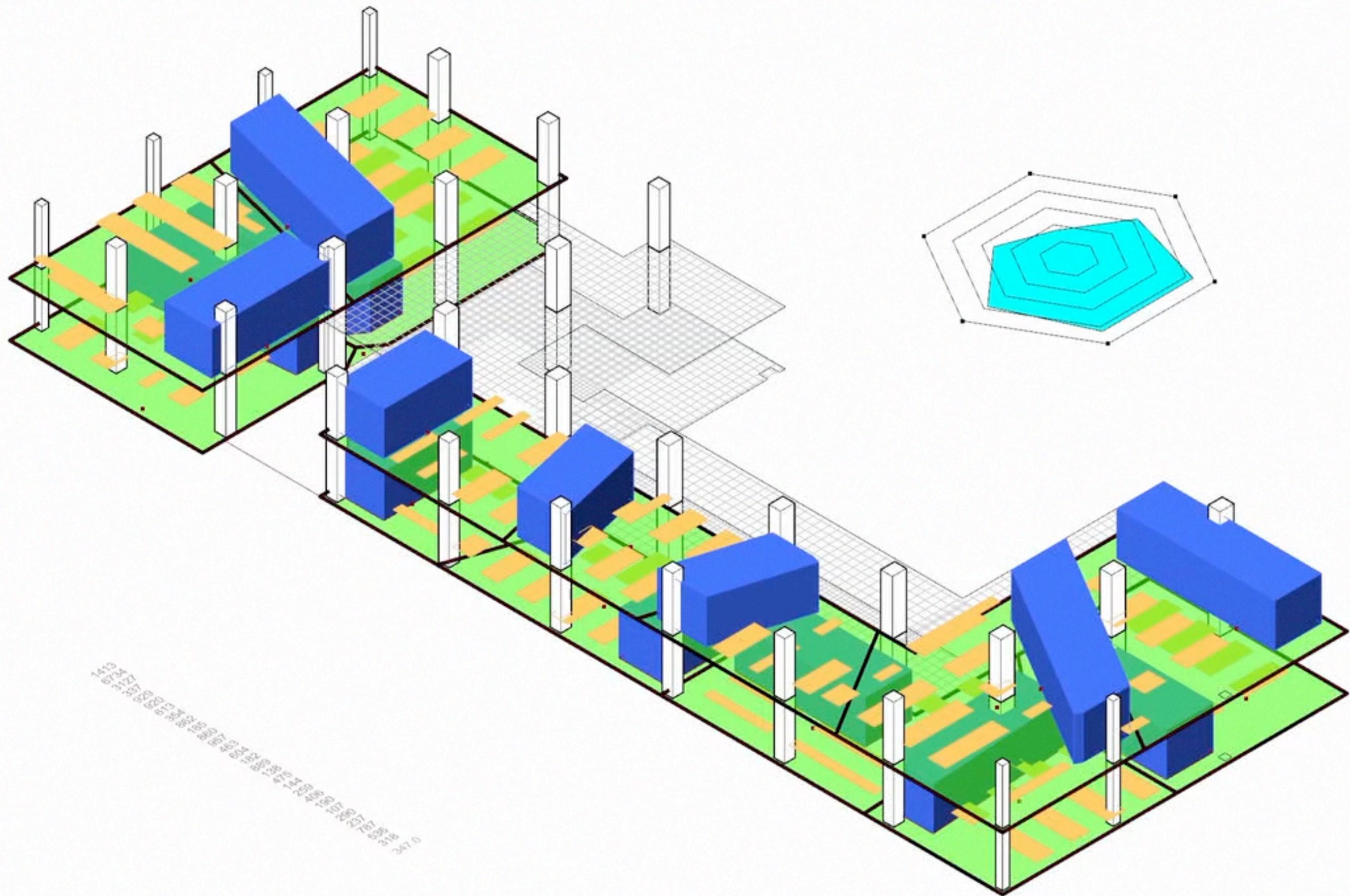
TEAM
 Division: CTO
 Manager: David Lau
 Size: 8
 Interns: 2

PREFERENCES
 Daylight: 8.0
 Acoustic: 4.0

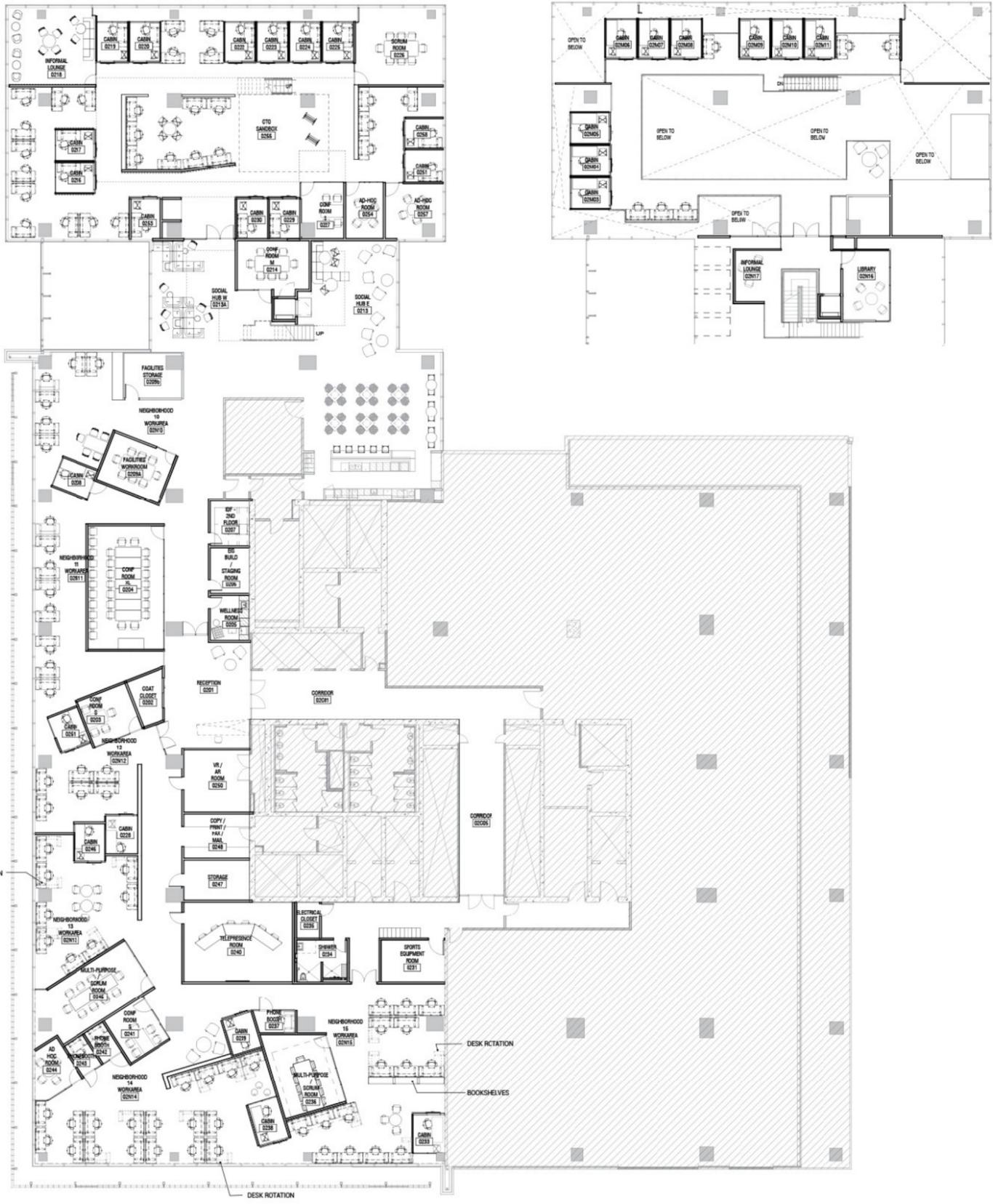
ADJACENCIES
 Teams: Ray Nagy
 Dale Locke
 Amenity: Telepresence
 SCRUM
 Fabrication Lab
 AR/VR Lab

250+ people
25+ teams

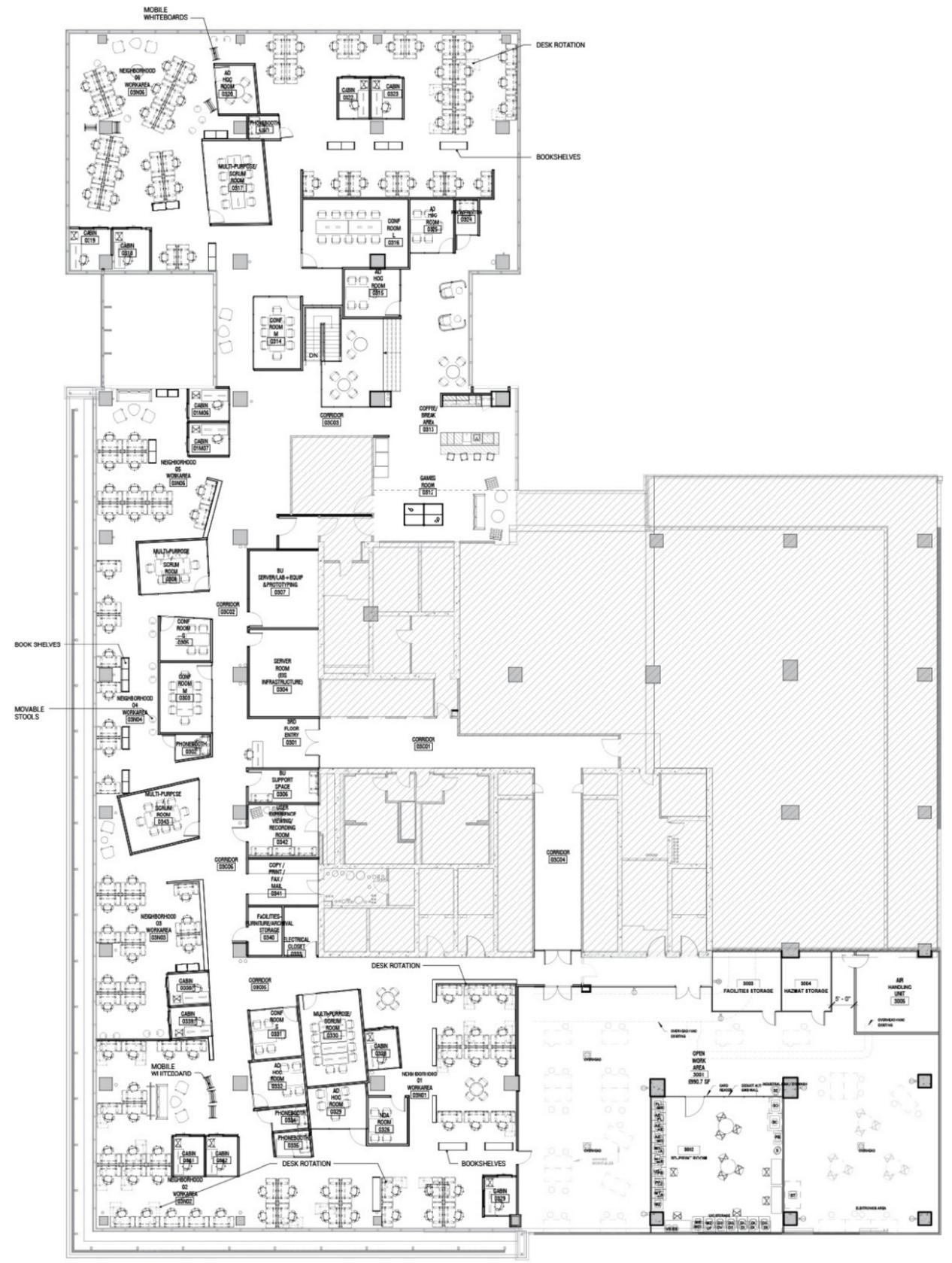




© 2010 清华大学出版社
ISBN 7-302-22111-0



MaRS AUTODESK RELOCATION
SECOND FLOOR PLAN - 20160916



MaRS AUTODESK RELOCATION
THIRD FLOOR PLAN - 20160916



1. Multiple types and sizes of amenity spaces surround each neighborhood to break up space and reduce distraction, leading to better scoring for productivity

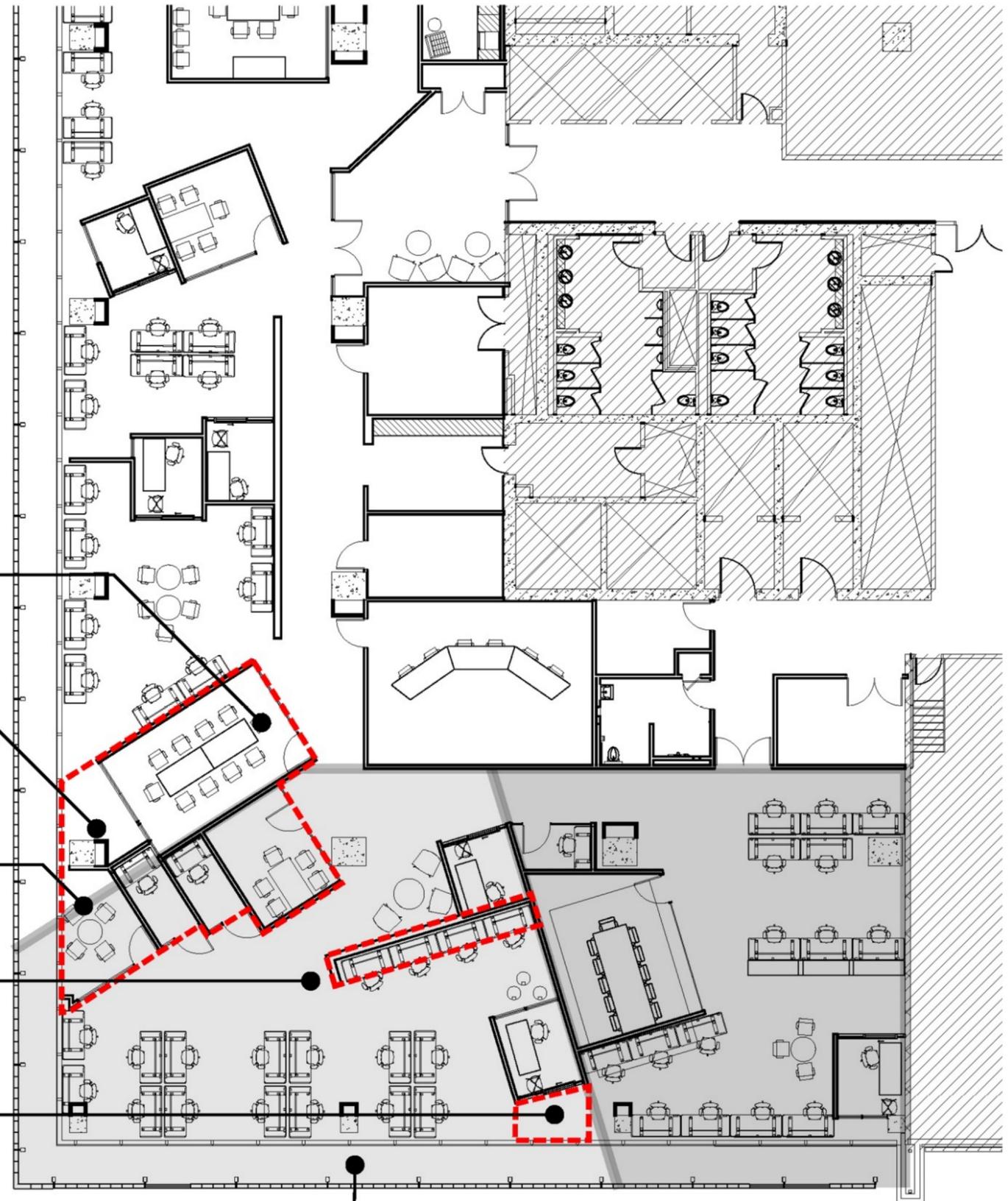
2. Residual irregular-shaped areas become semi-private informal social spaces that, while performance neutral, were unexpected, interesting design elements and well-received by the clients

3. Diagonal line between neighborhoods allows fitting more meeting rooms while giving each neighborhood its own character

4. Non-orthogonal, non-parallel boundaries obscure sources of distraction (desks in adjacent neighborhoods & high buzz corridors) to improve productivity scores.

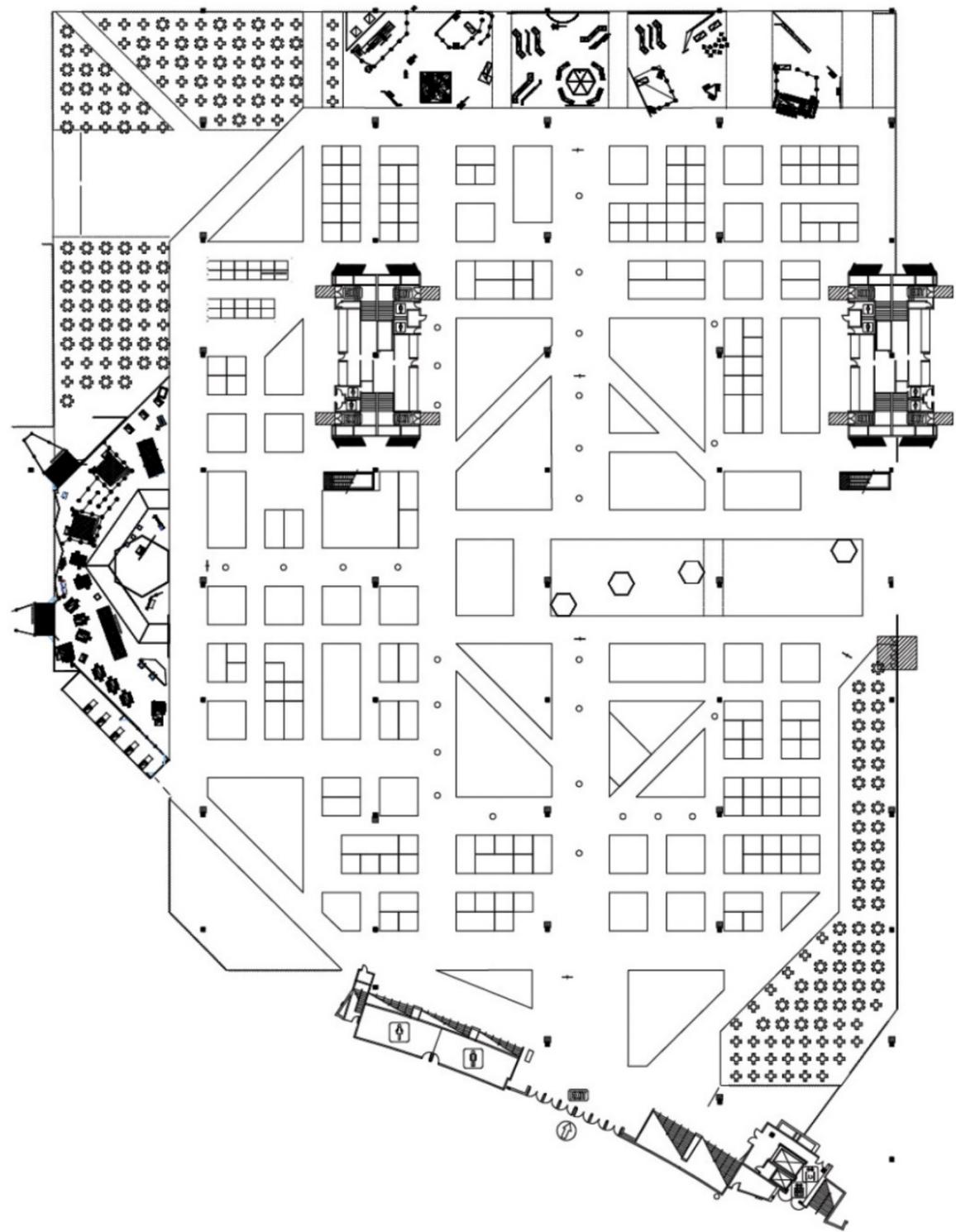
5. Back alley connection between neighborhoods, leading to better score for adjacency preference

6. Neighborhood expanding out toward window because team prefers natural light

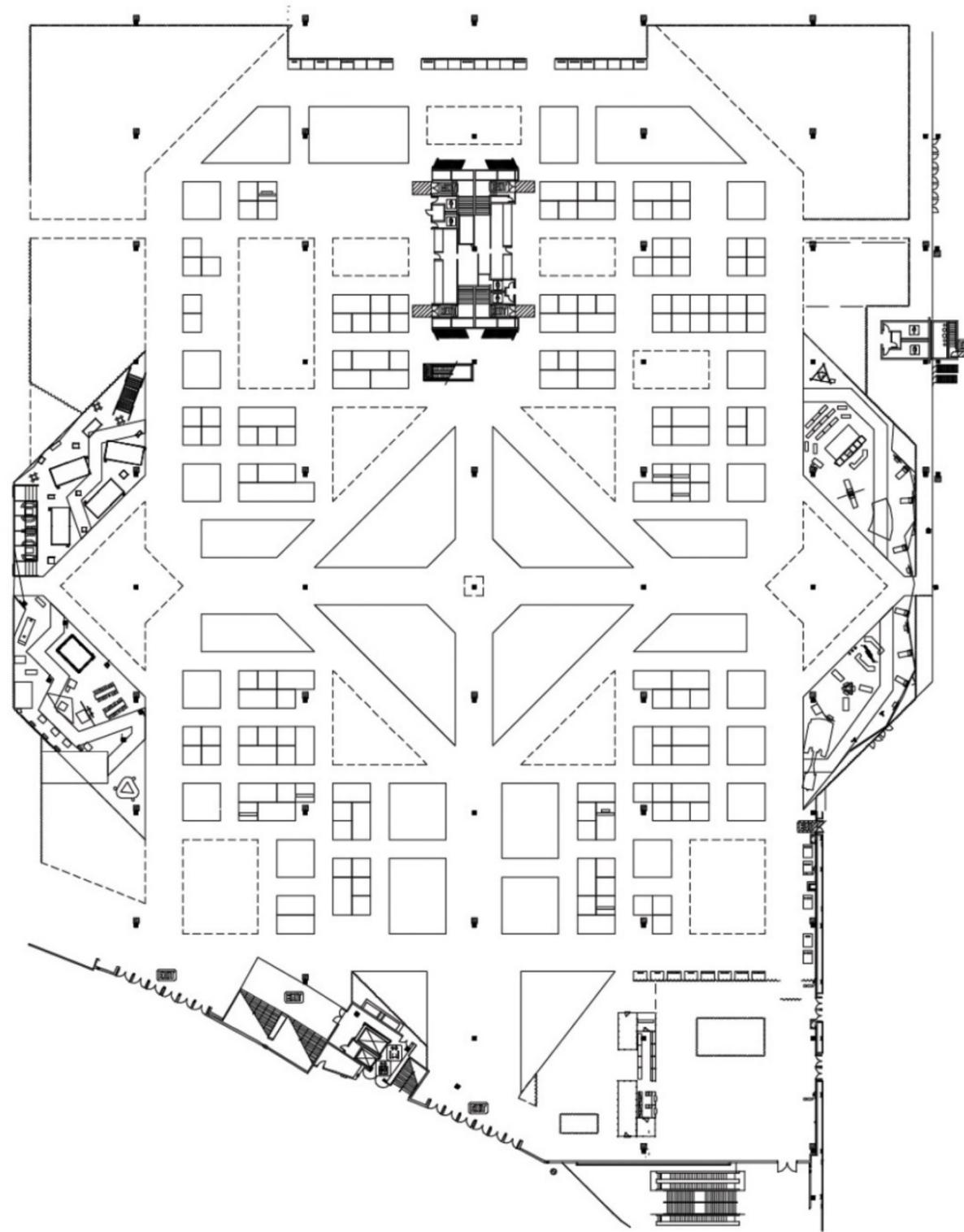


An aerial, high-angle photograph of a large, crowded exhibition hall. The floor is dark, and the space is filled with people of various ages and ethnicities. In the center, a tall, green and white sign stands prominently. To the left, there are several white, box-like structures. In the bottom right corner, a large red triangle is visible. The overall atmosphere is busy and professional.

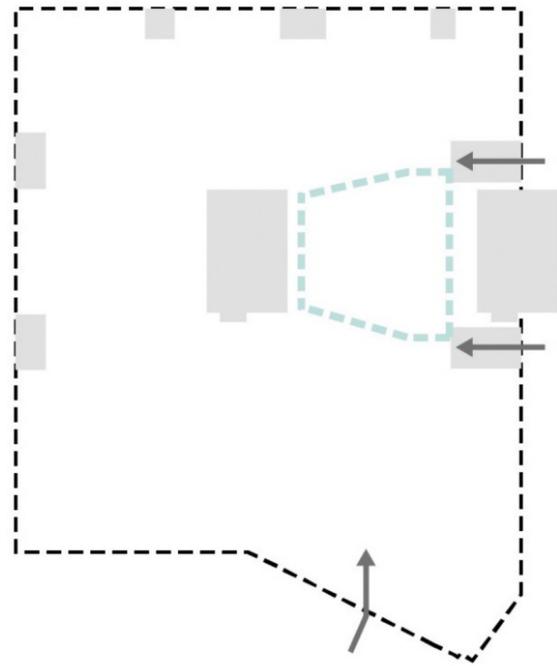
Generative Space Planning AU 2017 Exhibit Hall



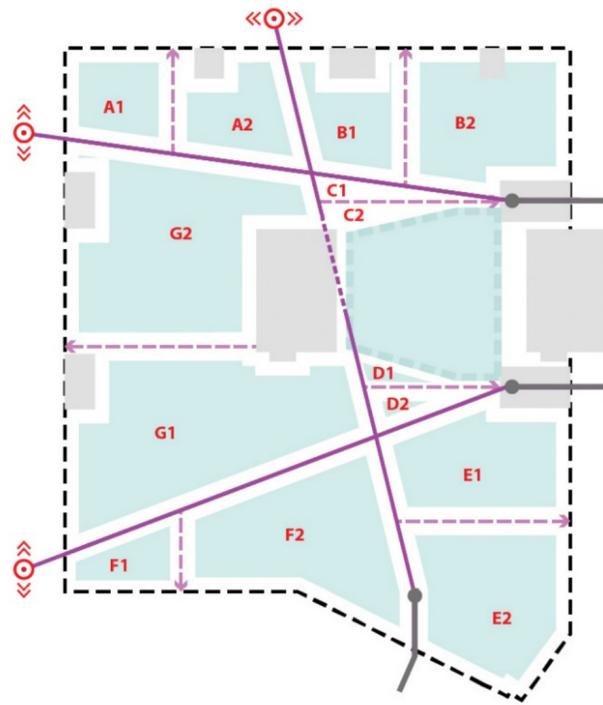
2015



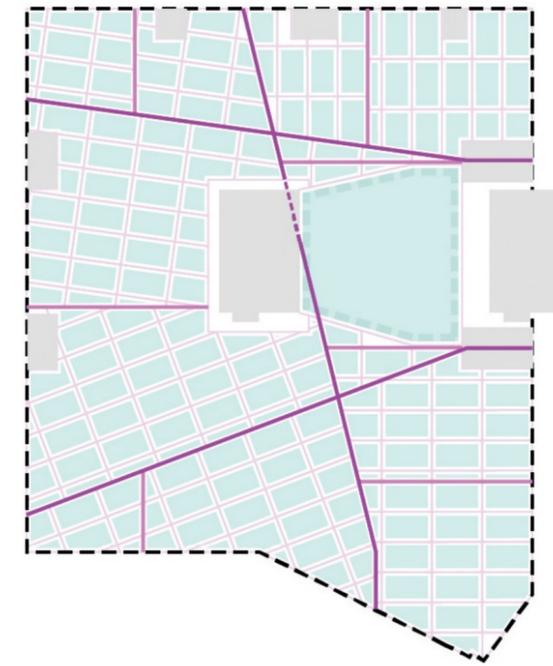
2016



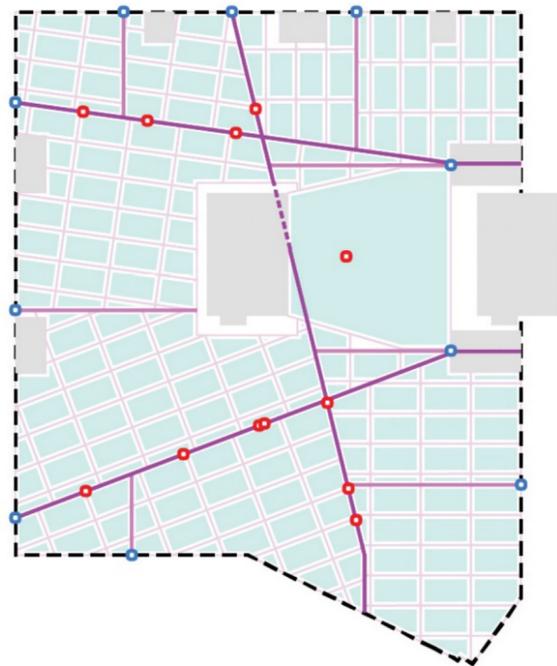
1) Define boundary conditions



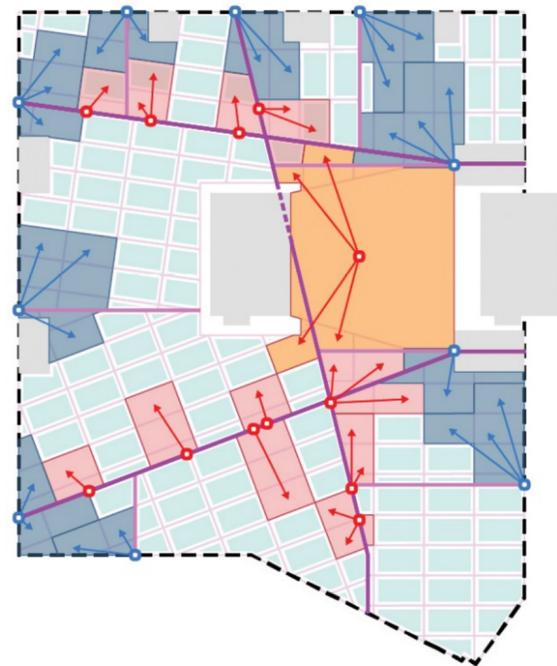
2) Generate primary routes



3) Subdivide regions with minimal grid



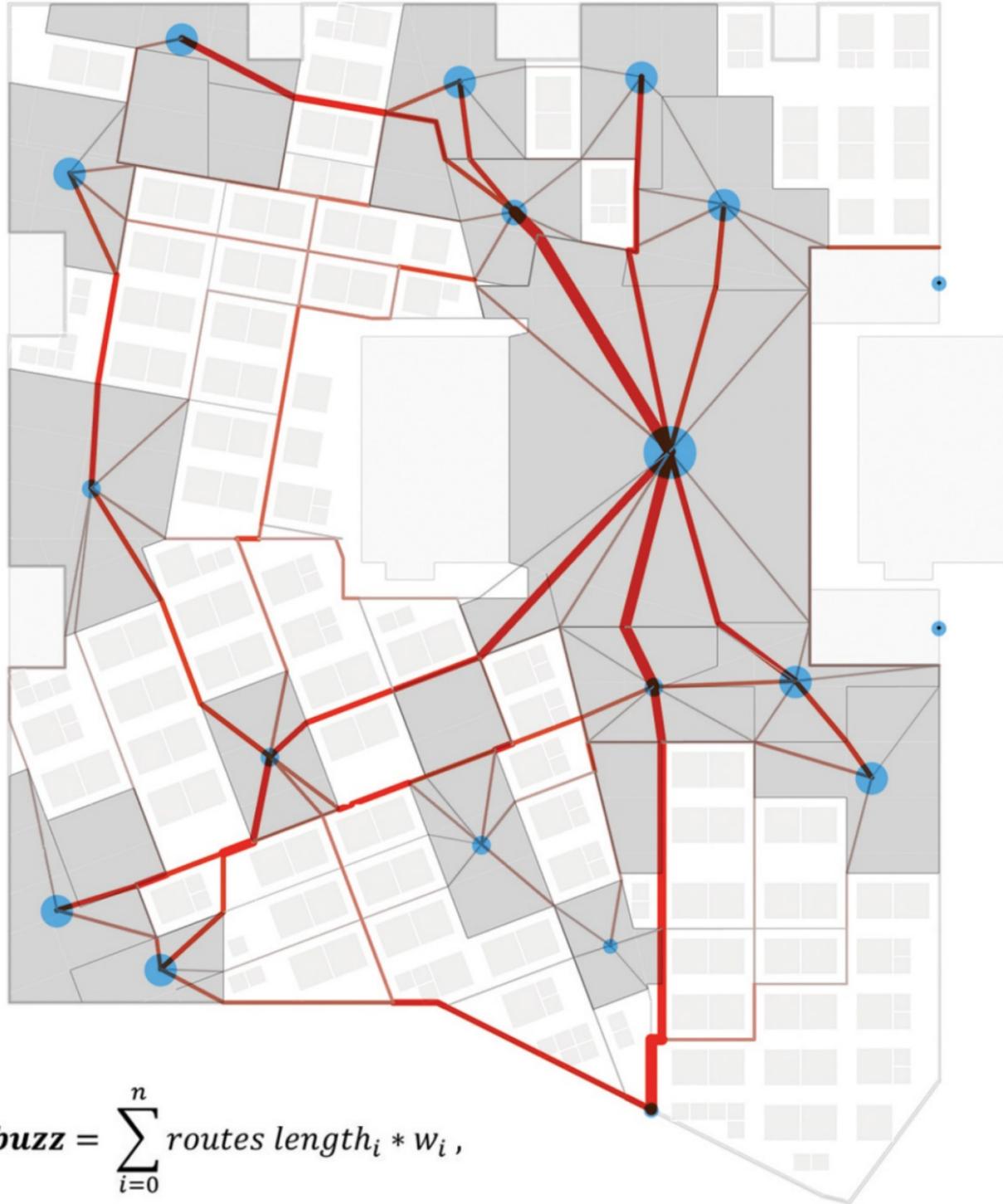
4) Locate anchor programs



5) Join grid cells to accommodate anchor program area requirements



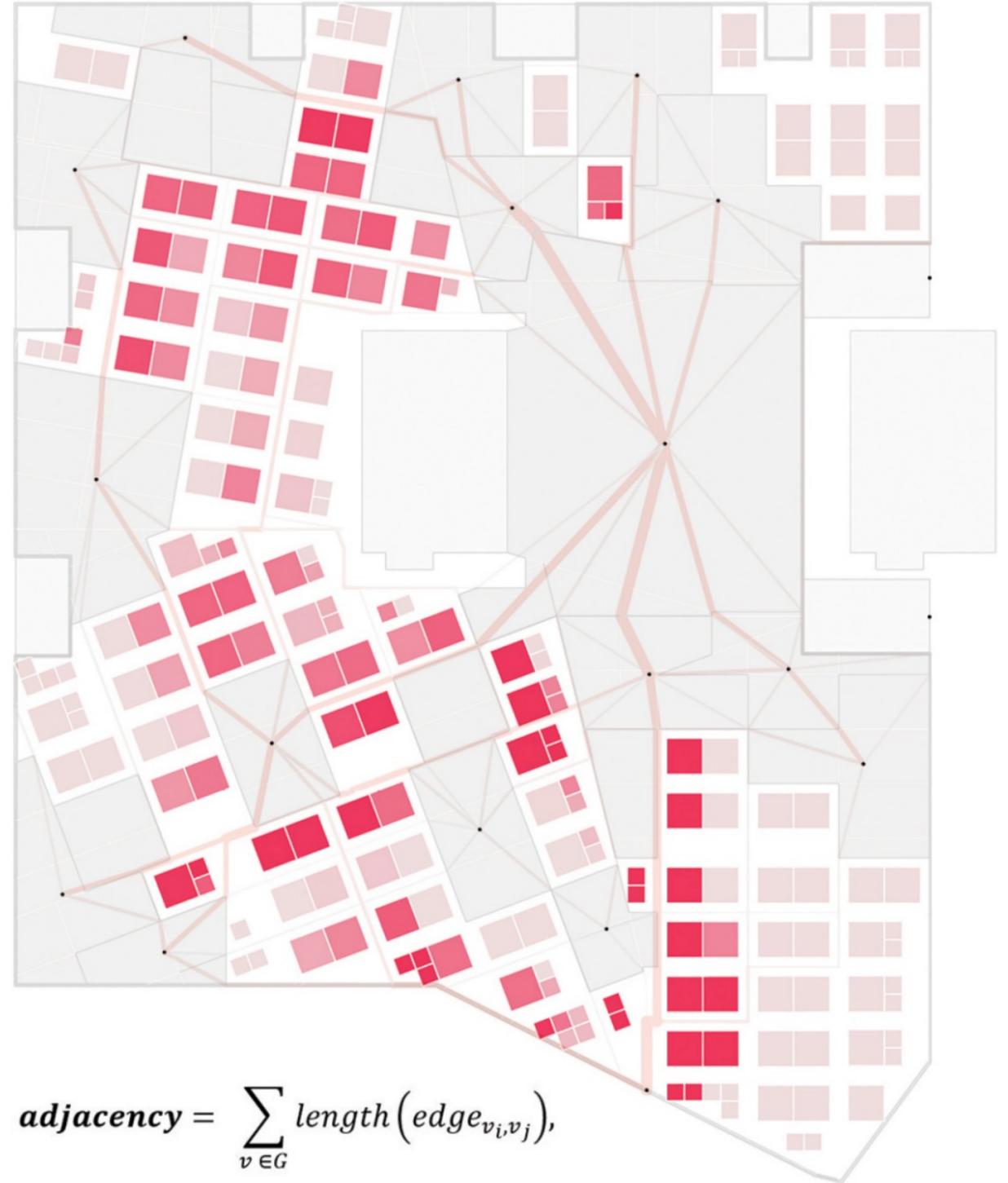
6) Allocate remaining cells to small programs



$$\mathbf{buzz} = \sum_{i=0}^n \text{routes length}_i * w_i,$$

w = amount of traversals in each route

n = number of nodes

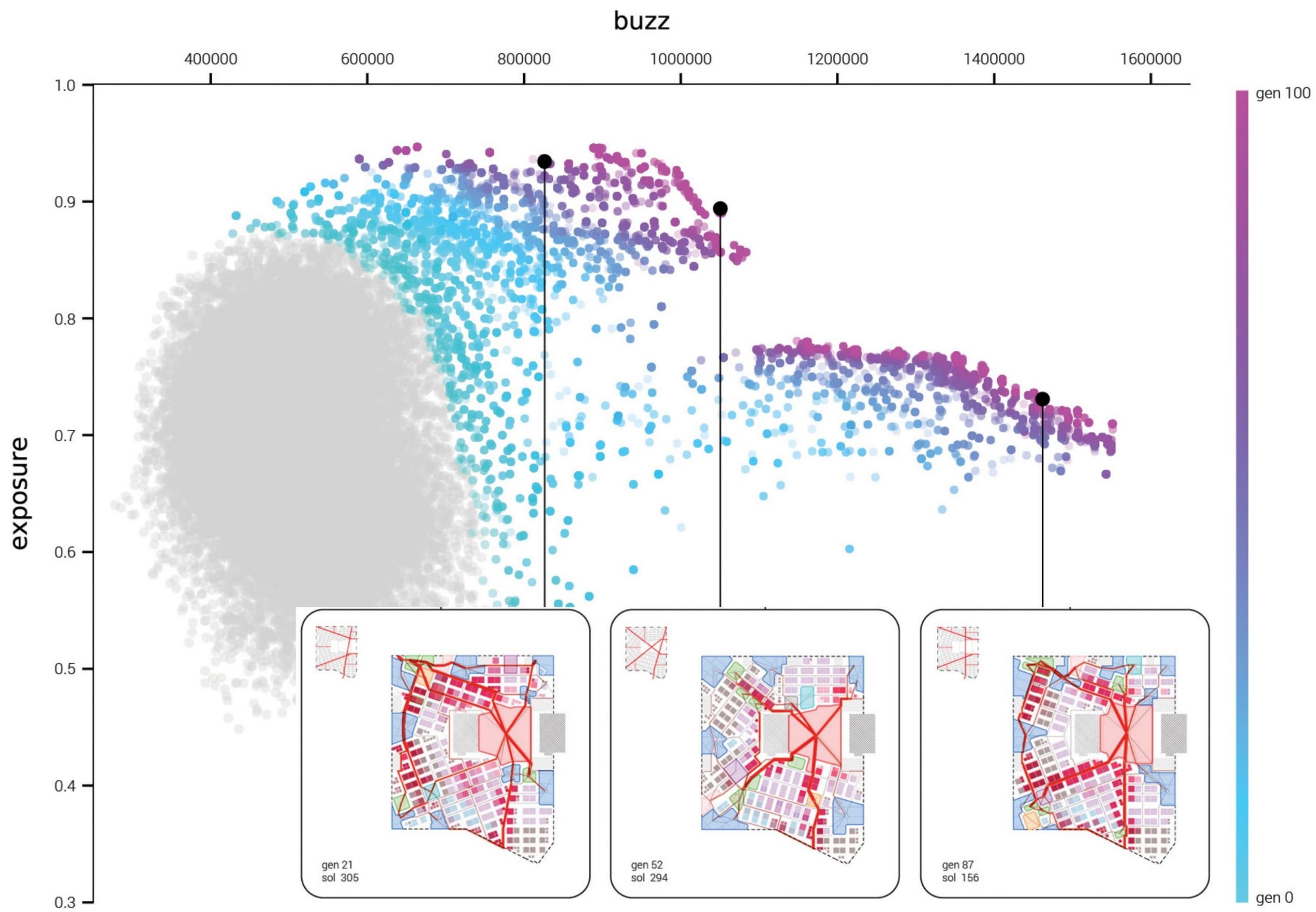


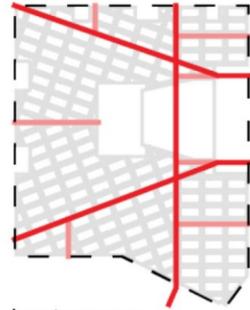
$$\mathbf{adjacency} = \sum_{v \in G} \text{length}(\text{edge}_{v_i, v_j}),$$

v = vertices

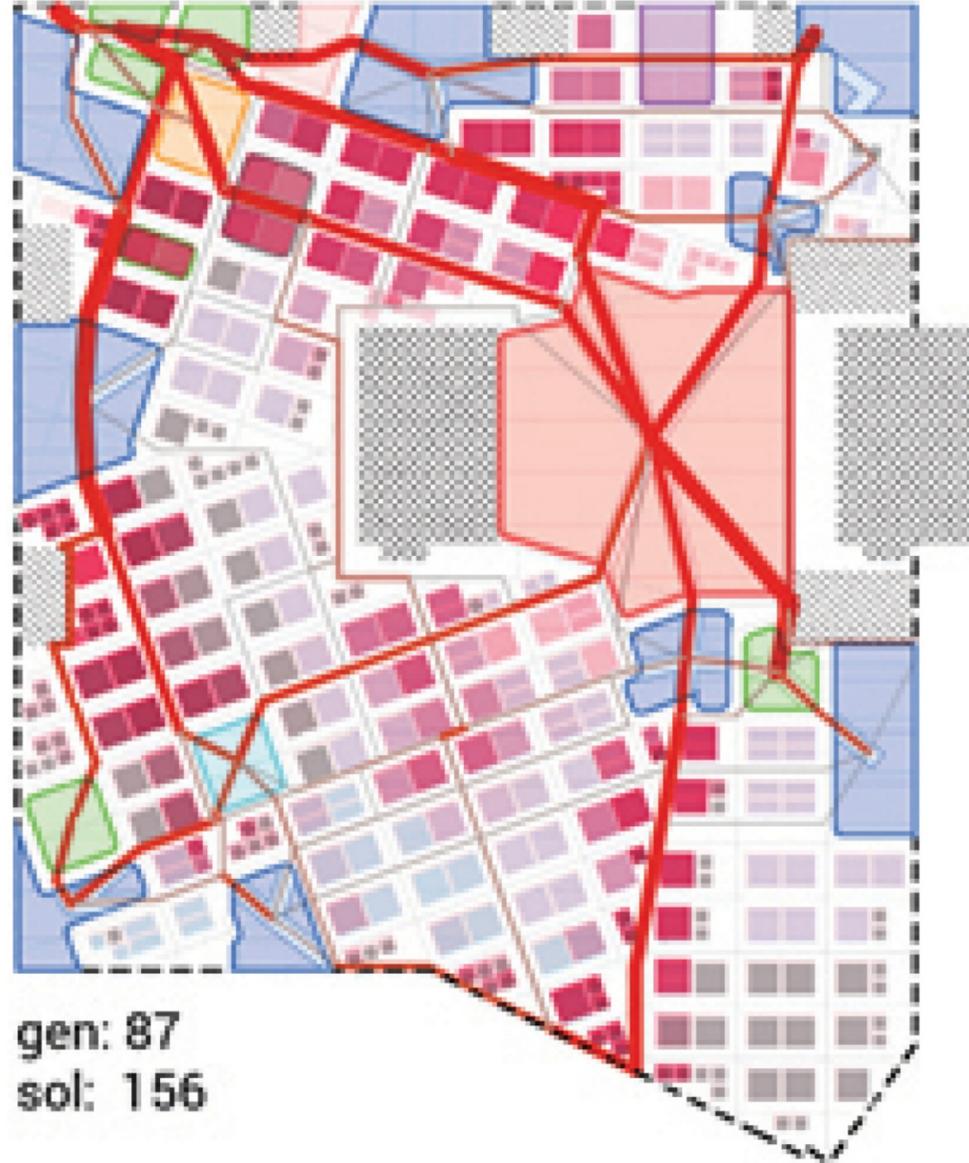
G = graph of all sites with adjacency requirements





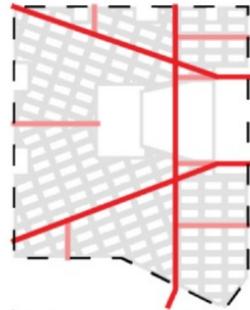


Input avenues
and regions subdivision



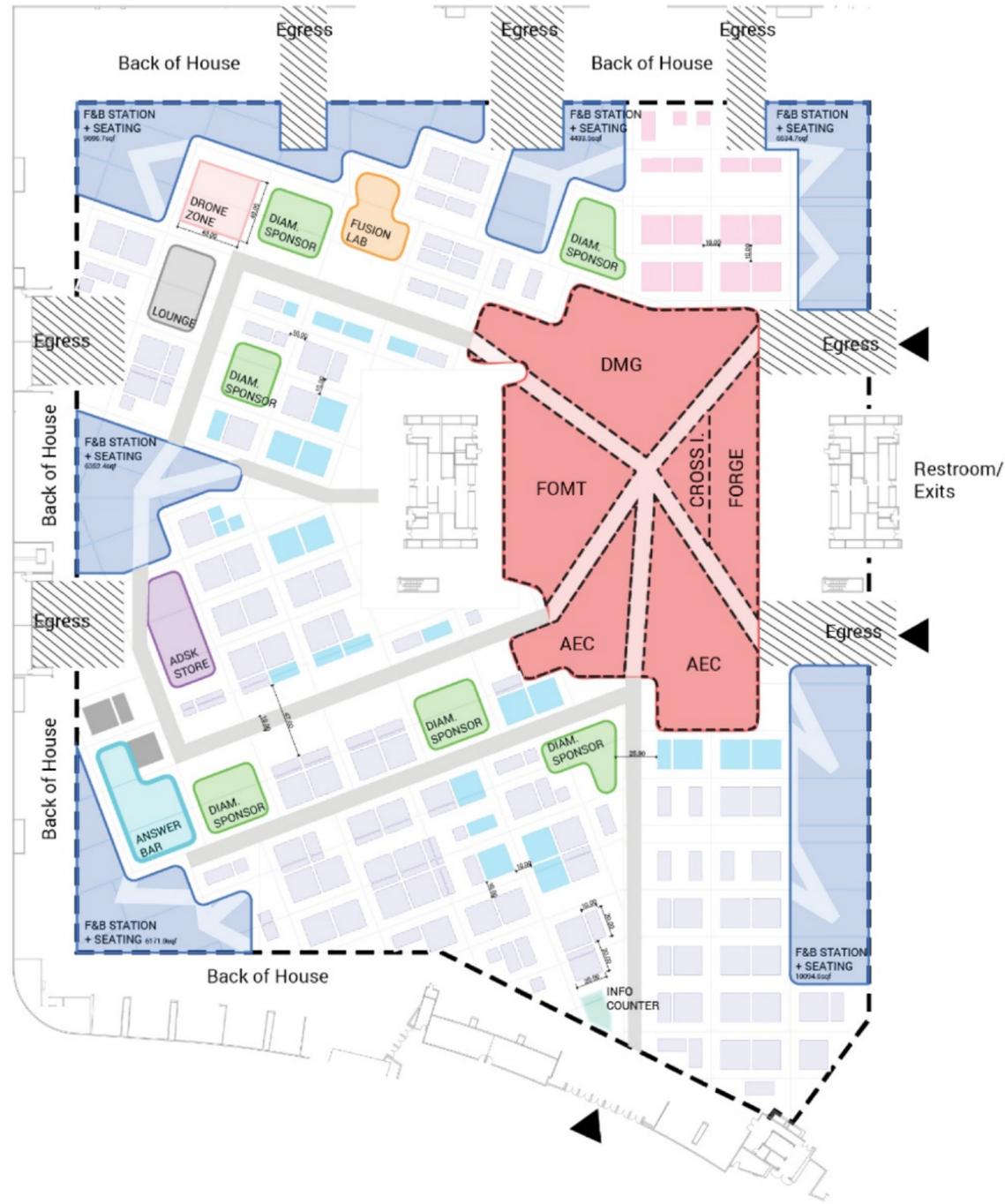
gen: 87
sol: 156

b: 9.5
e: 8.9



Input avenues
and regions subdivision

- low buzz
- high buzz
- high booth exposure
- low booth exposure
- F&B Seats + Stations
- Fusion 360 Lab
- ADSK
- ADSK Store
- Diam/Platinum Sponsors
- Lounge
- Drone Zone
- Answer Bar



- Autodesk areas
- Future of Making Things Customer exhibits
- Sponsor booths
- Building design & fabrication exhibitors
- Construction & operations exhibitors
- General design & technology exhibitors
- Product design & manufacturing exhibitors
- Food and beverage areas



Video Start: 2017-04-27T16:11:17.593Z
Video End: 2017-04-27T16:11:24.113Z
Video Time: 983 / 6520
Time: 2017-04-27T16:11:18.575Z
Network: IDLE
Paused: true

[Toggle cam-0 sensor labels](#)

- pi-pier9-bridge-strain-2-left-s-0

- pi-pier9-bridge-accel-5-9-a-7

- pi-pier9-bridge-strain-2-right-s-0

- pi-pier9-bridge-accel-5-9-a-6

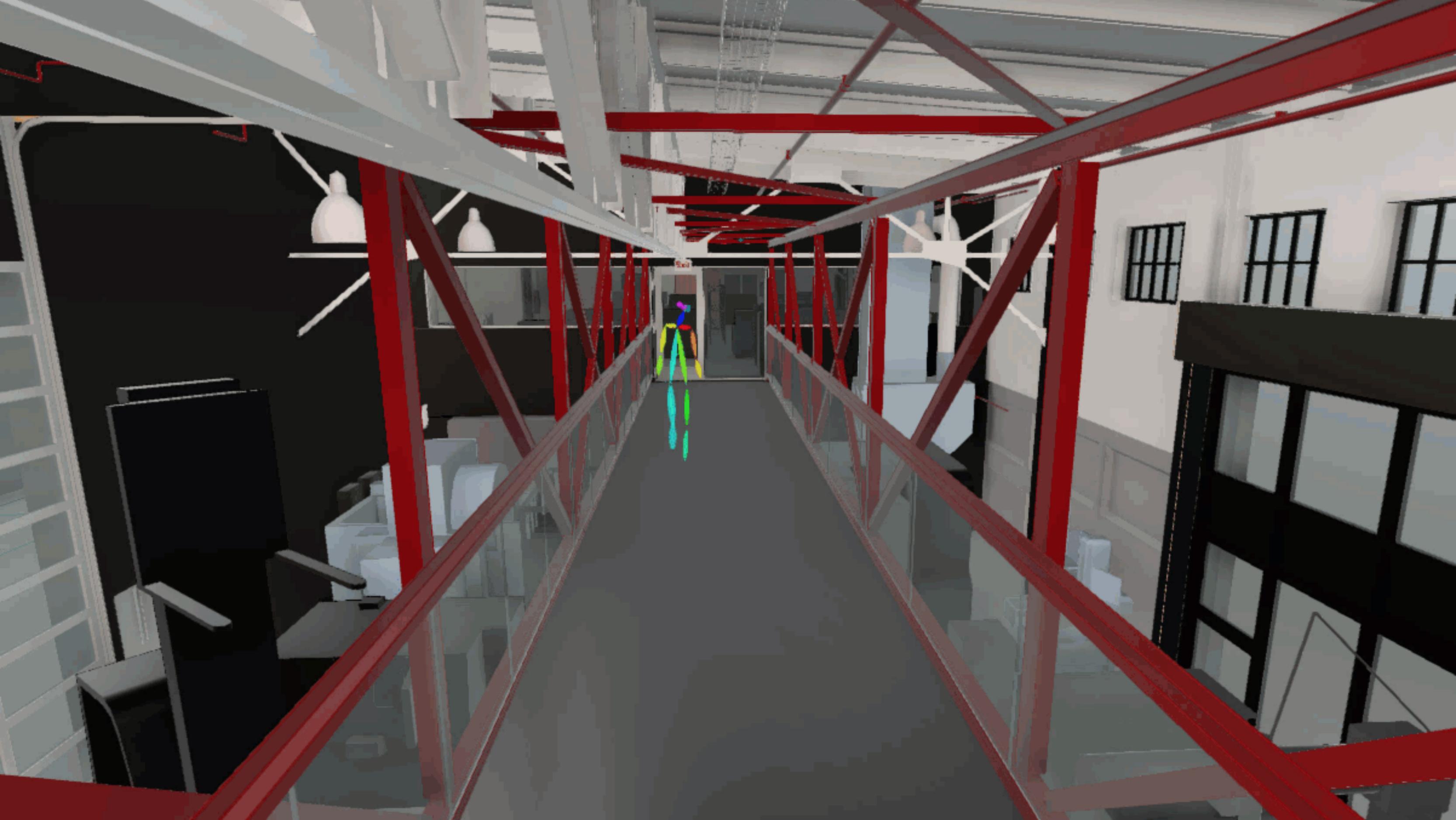
- pi-pier9-bridge-accel-5-9-a-5

- pi-pier9-bridge-strain-1-left-s-0

- pi-pier9-bridge-strain-1-right-s-0

- pi-pier9-bridge-accel-0-4-a-4

- pi-pier9-bridge-accel-0-4-a-3



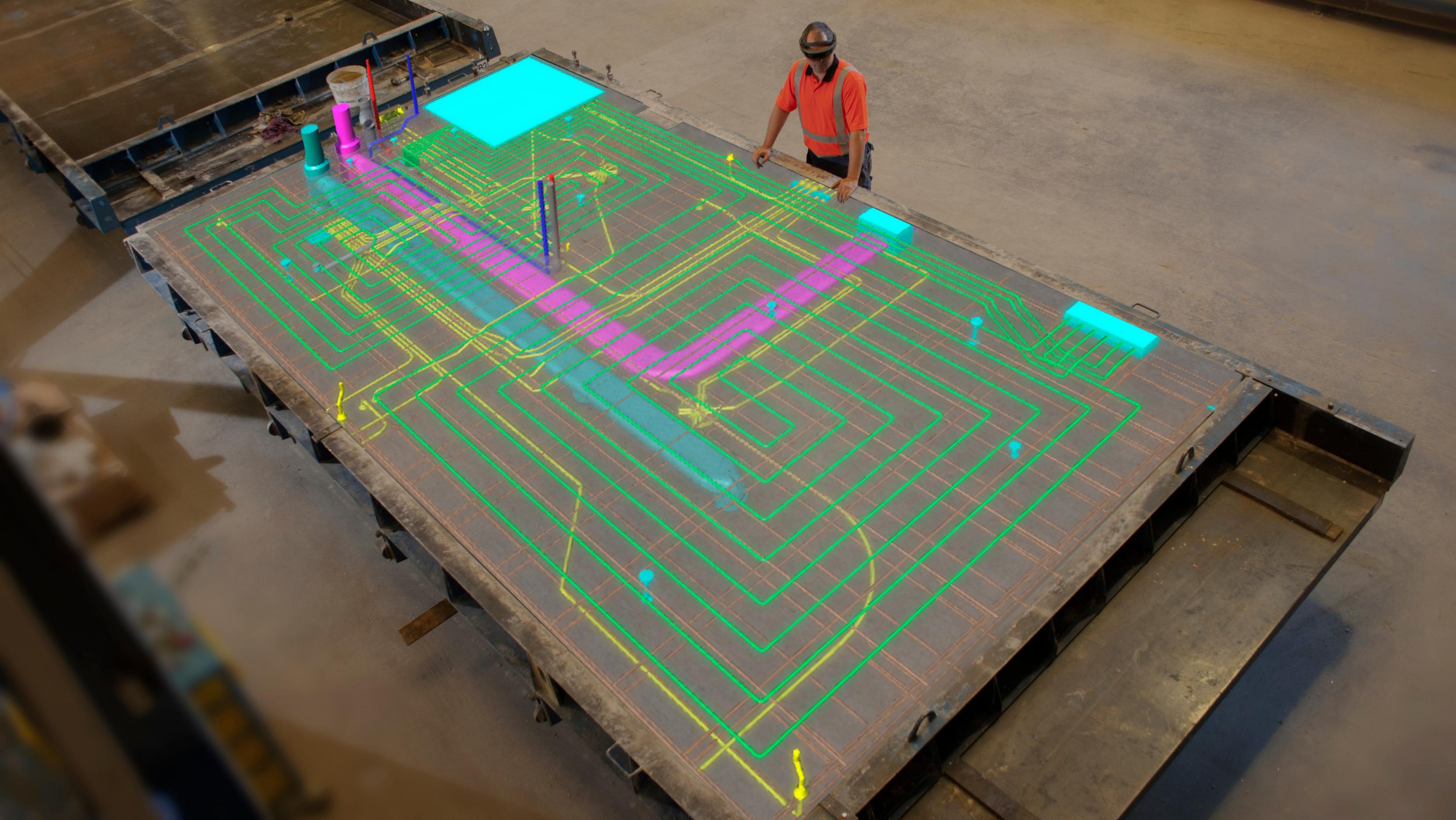
An aerial architectural rendering of a modern residential development. The scene features several three-story brick buildings with dark, gabled roofs and multiple skylights. The buildings are arranged around a central courtyard area with paved walkways, green lawns, and various outdoor furniture like tables and umbrellas. Small figures of people are scattered throughout the courtyards, suggesting a vibrant community. The surrounding area includes a paved road, more trees, and other residential structures in the background. The overall aesthetic is clean, modern, and community-oriented.

Generative Urban Design Van Wijnen

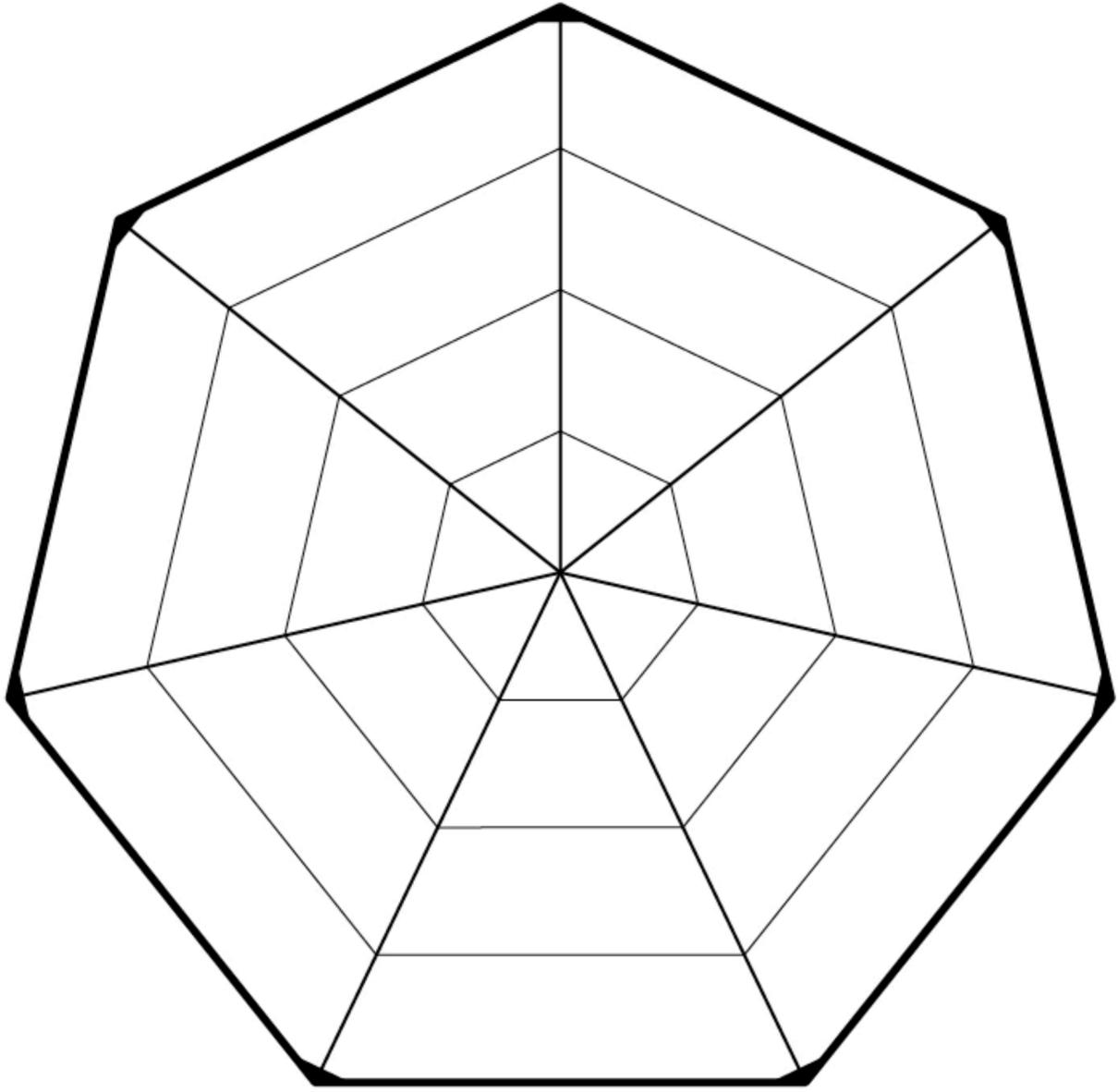


VAN WIJNEN

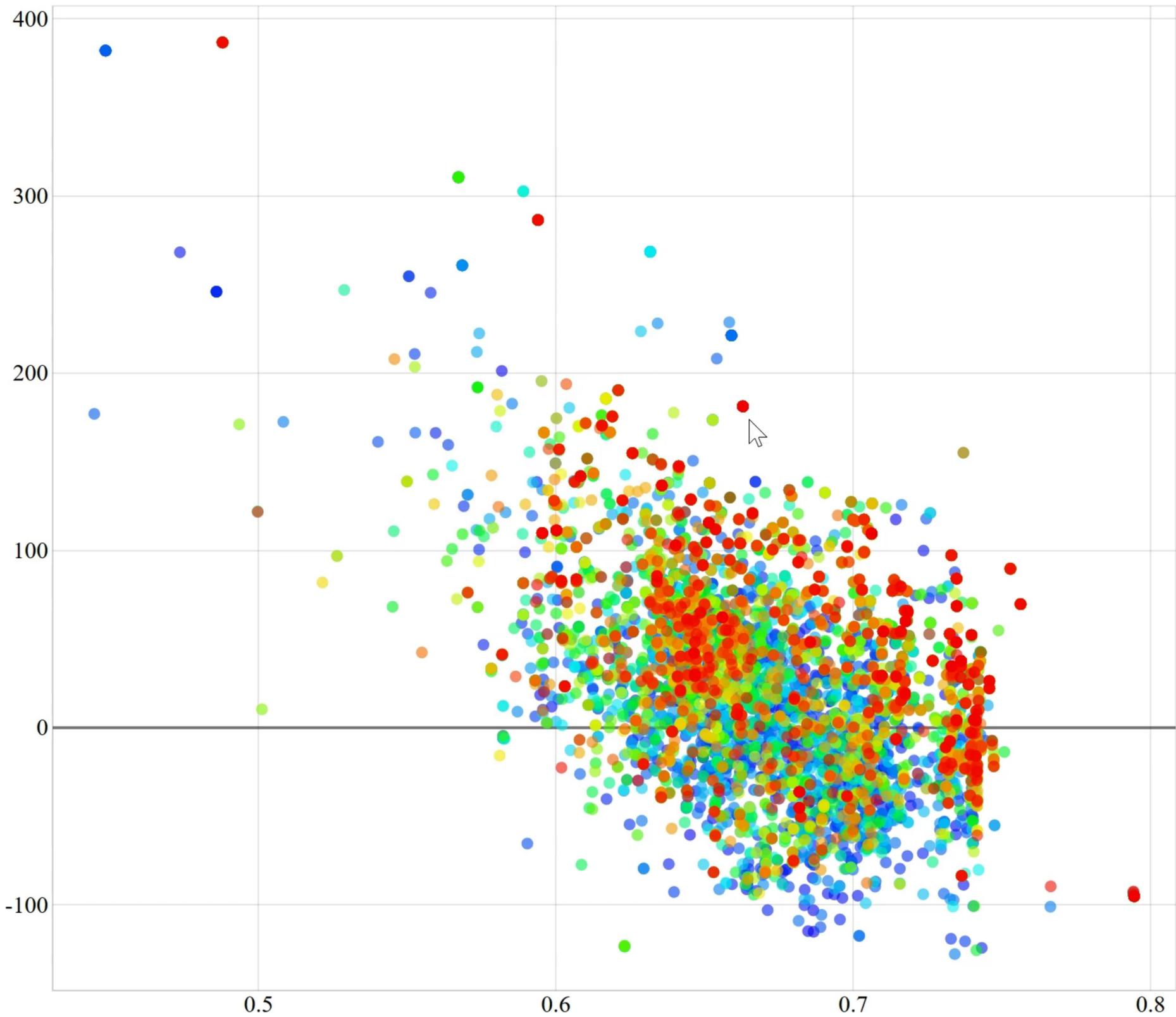












Reload data

Isolate optimal designs

Isolate selected designs

Reset zoom

Reset

Reset

Reset

Export

X-axis

id
 generation
 [in] avenue
 [in] street_1
 [in] street_2
 [in] street_3
 [in] street_4
 [max] solar_radiation
 [max] revenue

Y-axis

id
 generation
 [in] avenue
 [in] street_1
 [in] street_2
 [in] street_3
 [in] street_4
 [max] solar_radiation
 [max] revenue

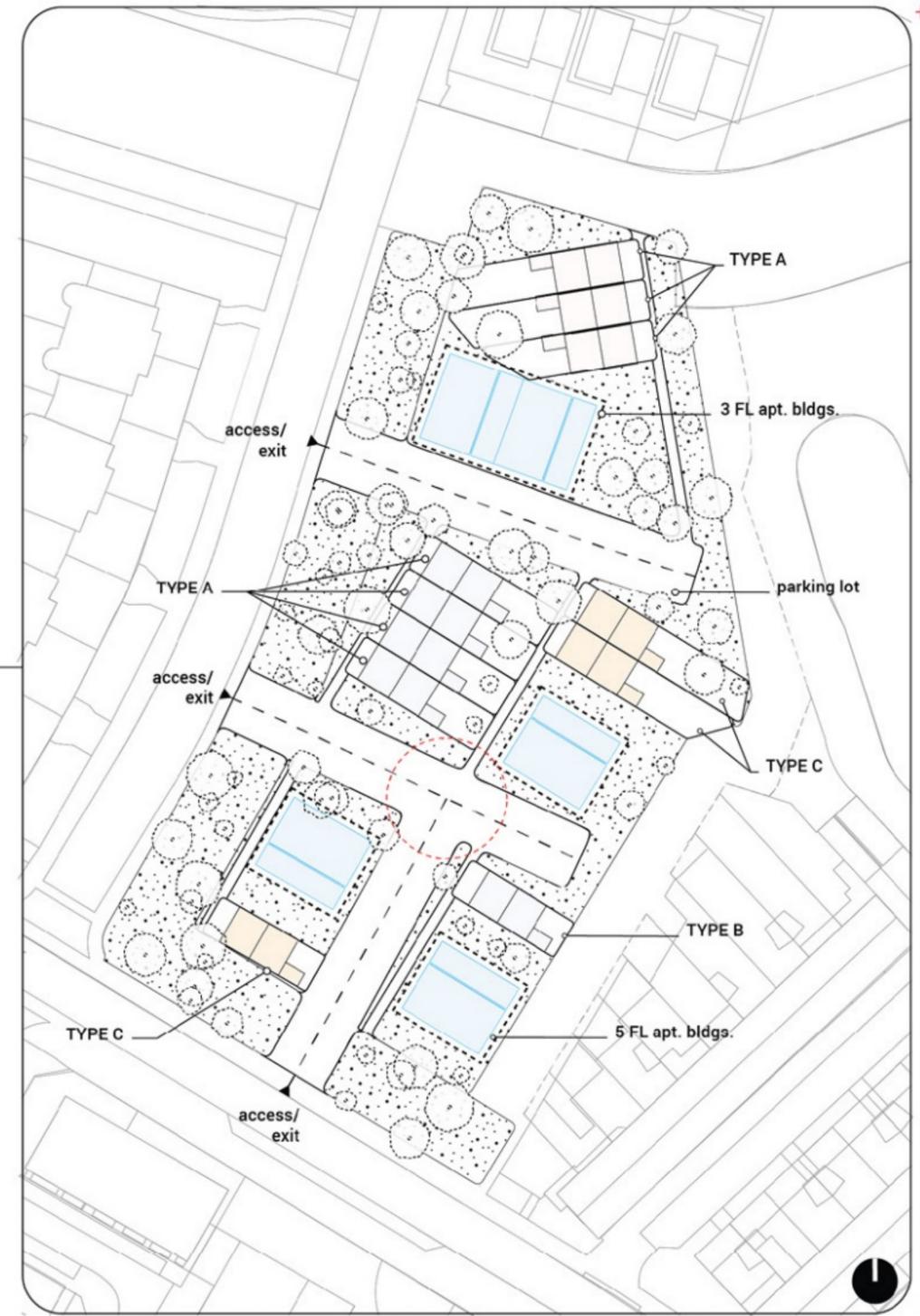
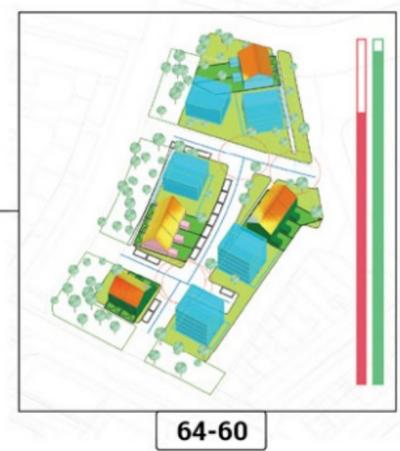
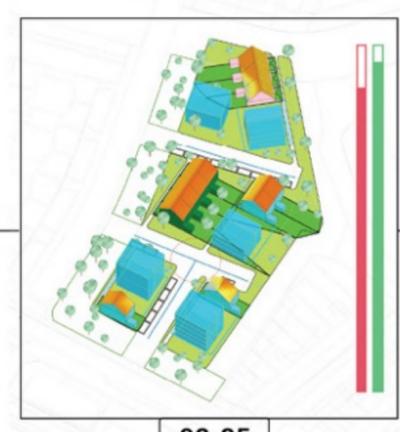
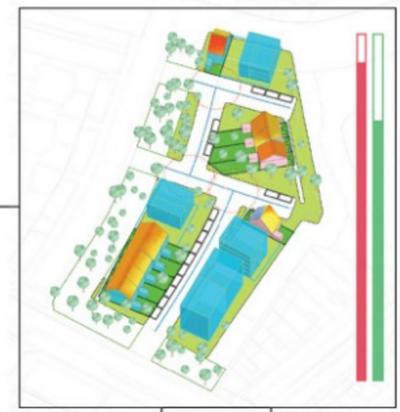
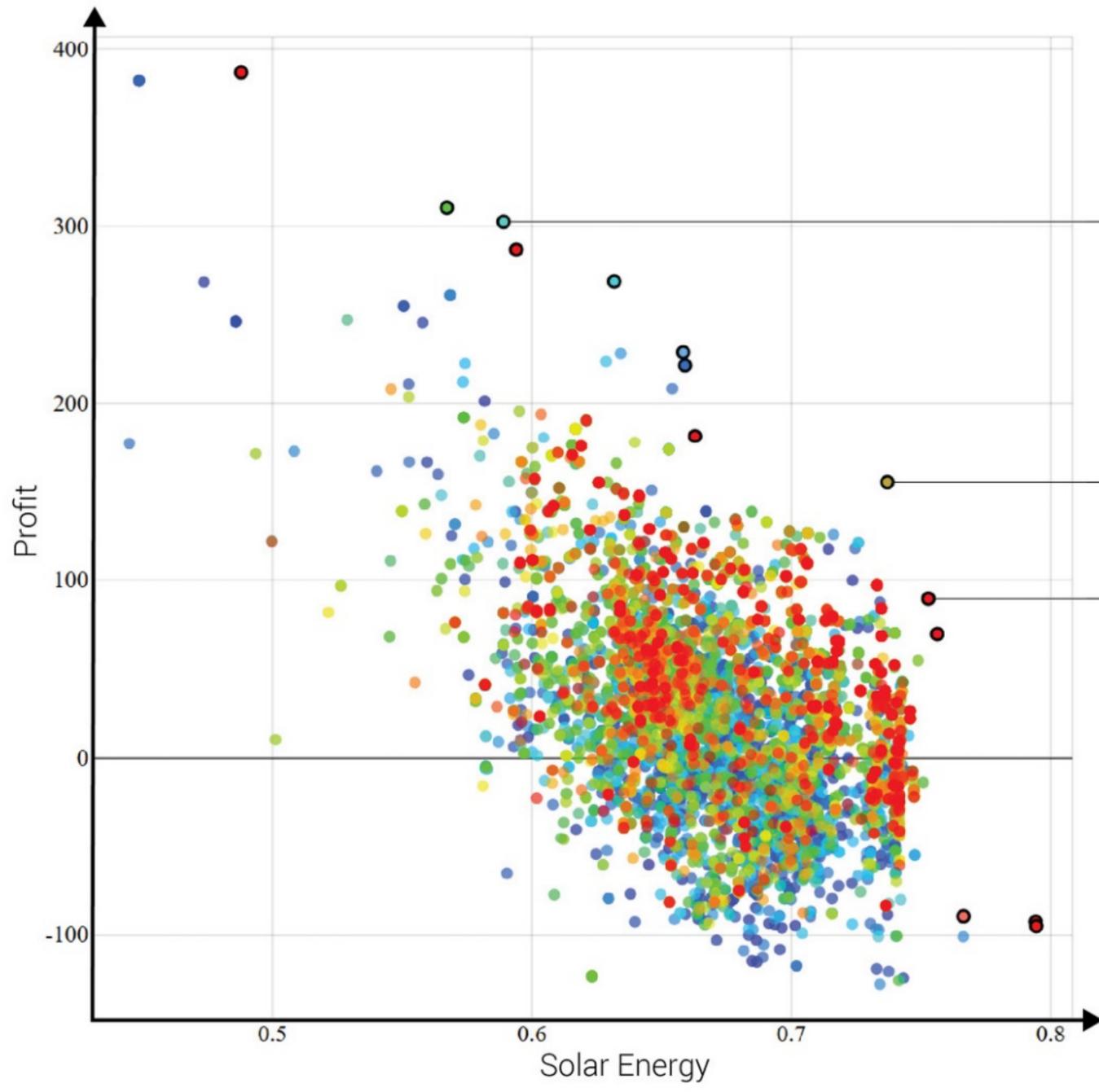
Selected designs

Size

id
 generation
 [in] avenue
 [in] street_1
 [in] street_2
 [in] street_3
 [in] street_4
 [max] solar_radiation
 [max] revenue

Color

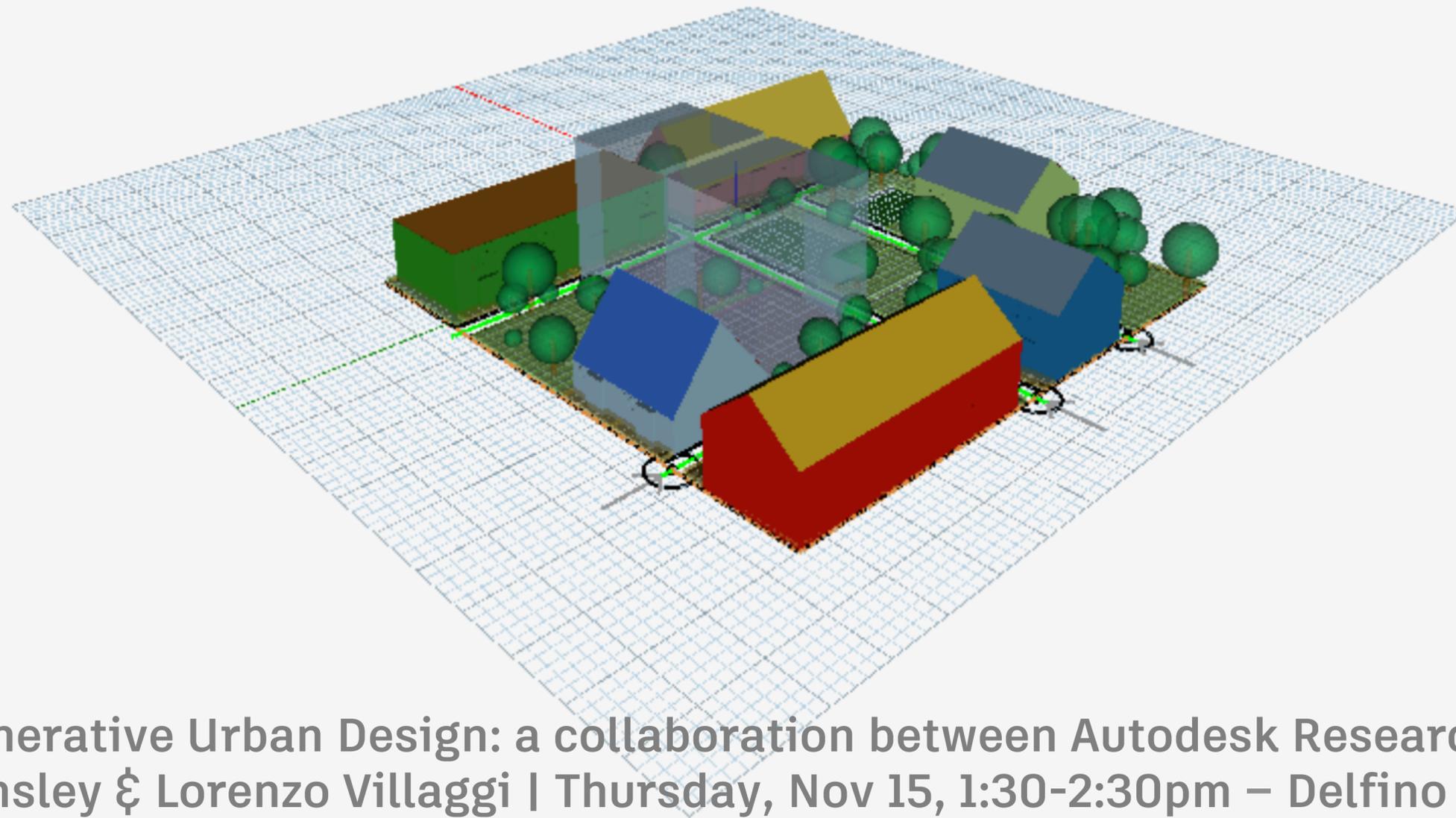
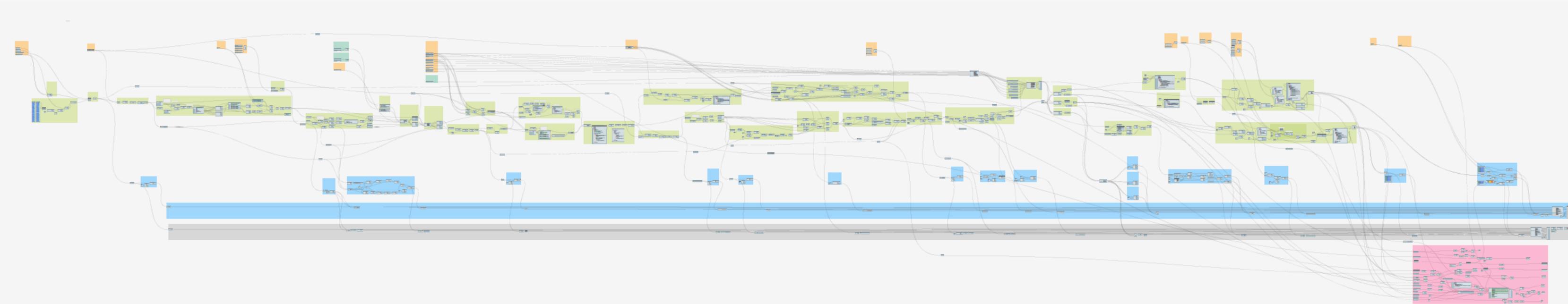
id
 generation
 [in] avenue
 [in] street_1
 [in] street_2
 [in] street_3
 [in] street_4
 [max] solar_radiation
 [max] revenue



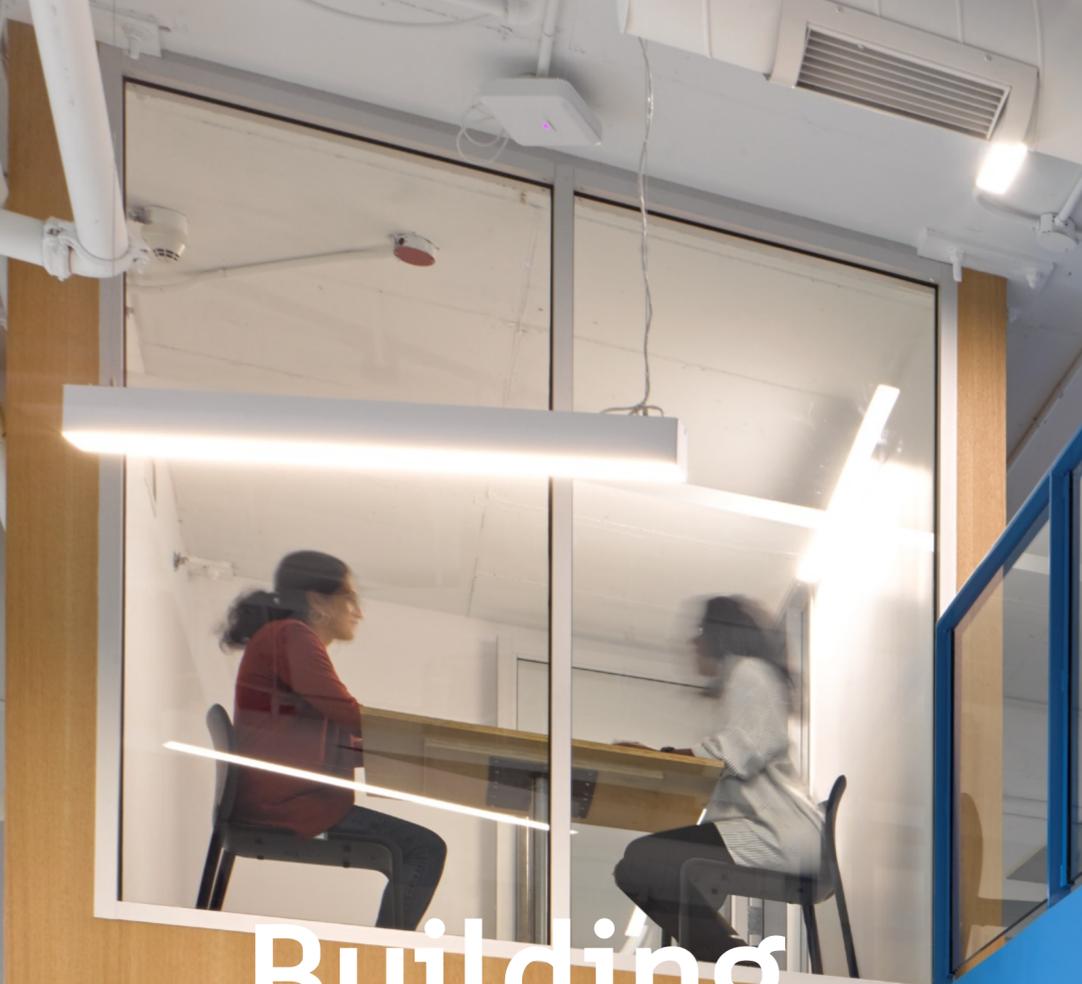
id# 98 - 85

house: TYPE A count: 3	house: TYPE C count: 3
house: TYPE B count: 5	apartment units count: 19 - 4438 sqm





CS239262 – Generative Urban Design: a collaboration between Autodesk Research and Van Wijnen
Kean Walmsley & Lorenzo Villaggi | Thursday, Nov 15, 1:30-2:30pm – Delfino 4004, Level 4



Building



Exhibit Hall



Neighborhood



Autodesk tools for Generative Design in the AEC space

The background features a dynamic, abstract design. It consists of a series of curved, parallel lines that create a sense of depth and movement, transitioning from a light blue at the top to a darker blue at the bottom. The lines are arranged in a way that suggests a curved surface or a perspective view of a grid. The overall aesthetic is clean, modern, and technical, fitting for a presentation on generative design in the AEC industry.

TRADITIONAL DESIGN

RECORDING DECISIONS

GENERATIVE DESIGN

DESCRIBING GOALS + CONSTRAINTS

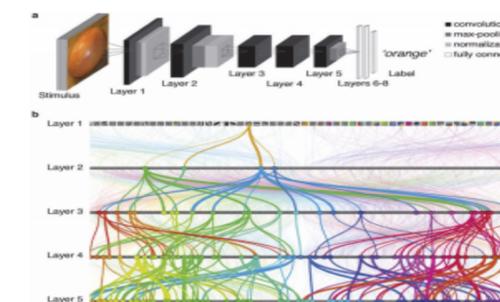
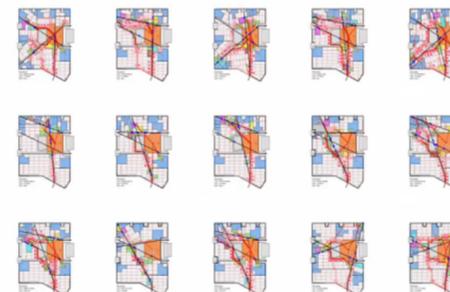
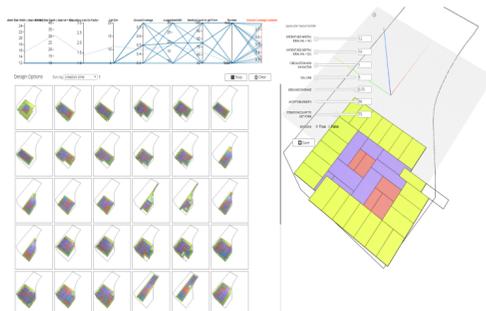
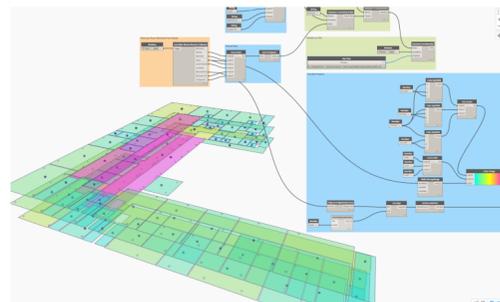
PARAMETRIC MODELING

VISUAL PROGRAMMING

OPTION GENERATION

DESIGN OPTIMIZATION

MACHINE LEARNING



Evolutionary algorithm outperforms deep learning machines at video games

MIT Technology Review

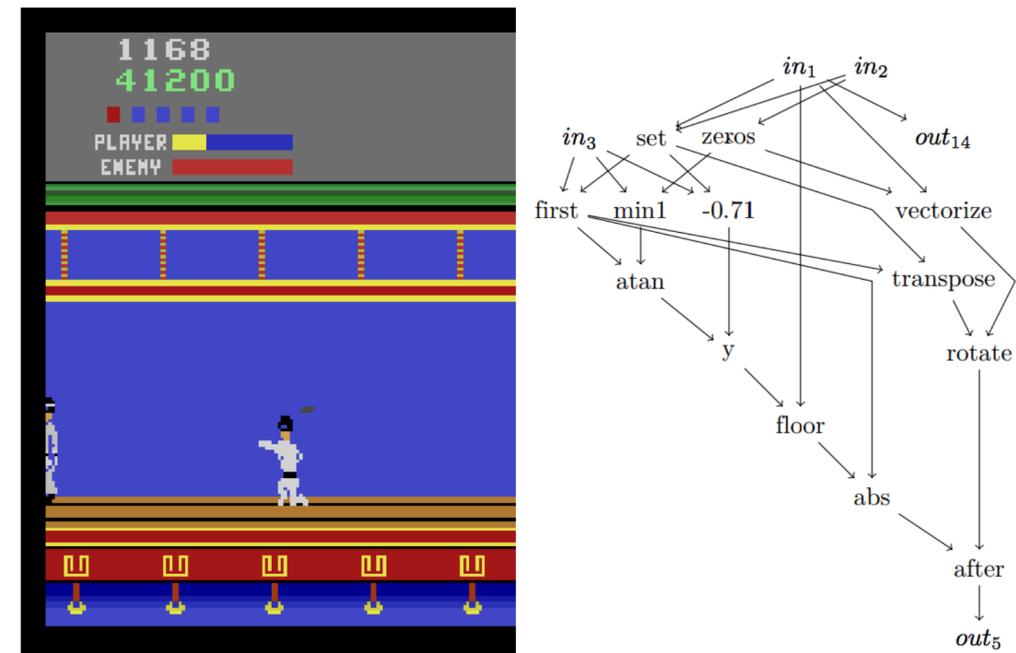
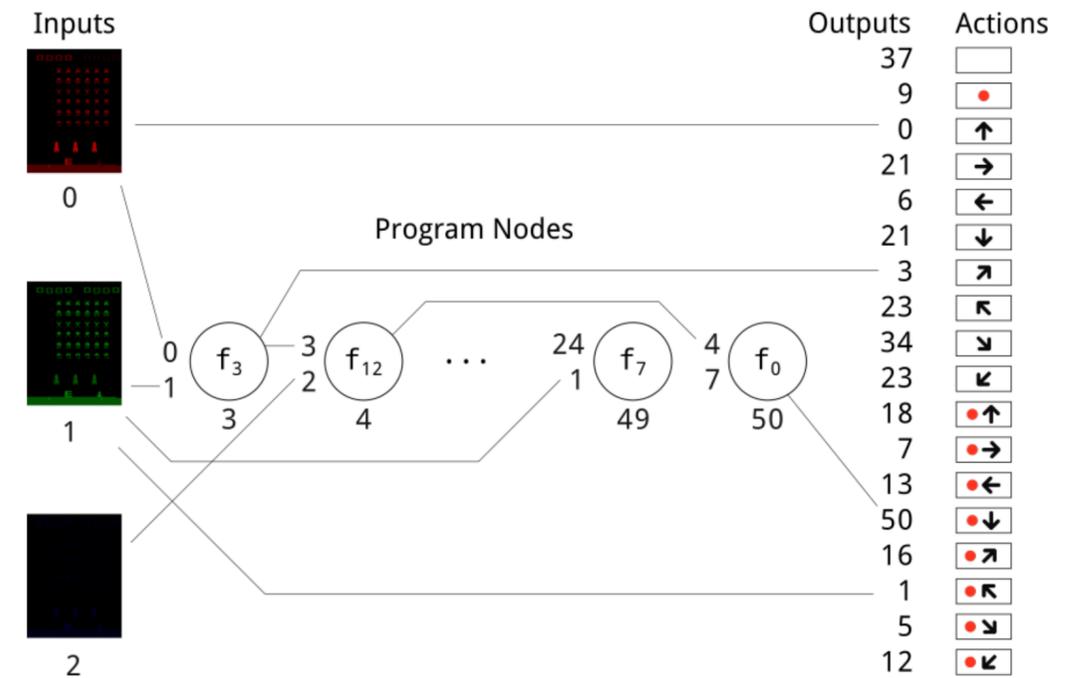
Innovation Leaders Summit Breakthrough to Impact November 30, 2018 Paris, France Attend →

Intelligent Machines

Evolutionary algorithm outperforms deep-learning machines at video games

Neural networks have garnered all the headlines, but a much more powerful approach is waiting in the wings.

by Emerging Technology from the arXiv July 18, 2018



Refinery's Optimization Engine

- Based on the O2 engine developed by Autodesk Research's The Living
 - Used successfully for the various projects shown previously
- Employs the NSGA-II genetic algorithm
 - Meta-heuristic algorithm for multi-objective optimization
- Relies on bio-inspired operators such as mutation, crossover and selection
 - Population-based, so maintains & improves candidate solutions

REFINERY'S OPTIMIZATION ENGINE

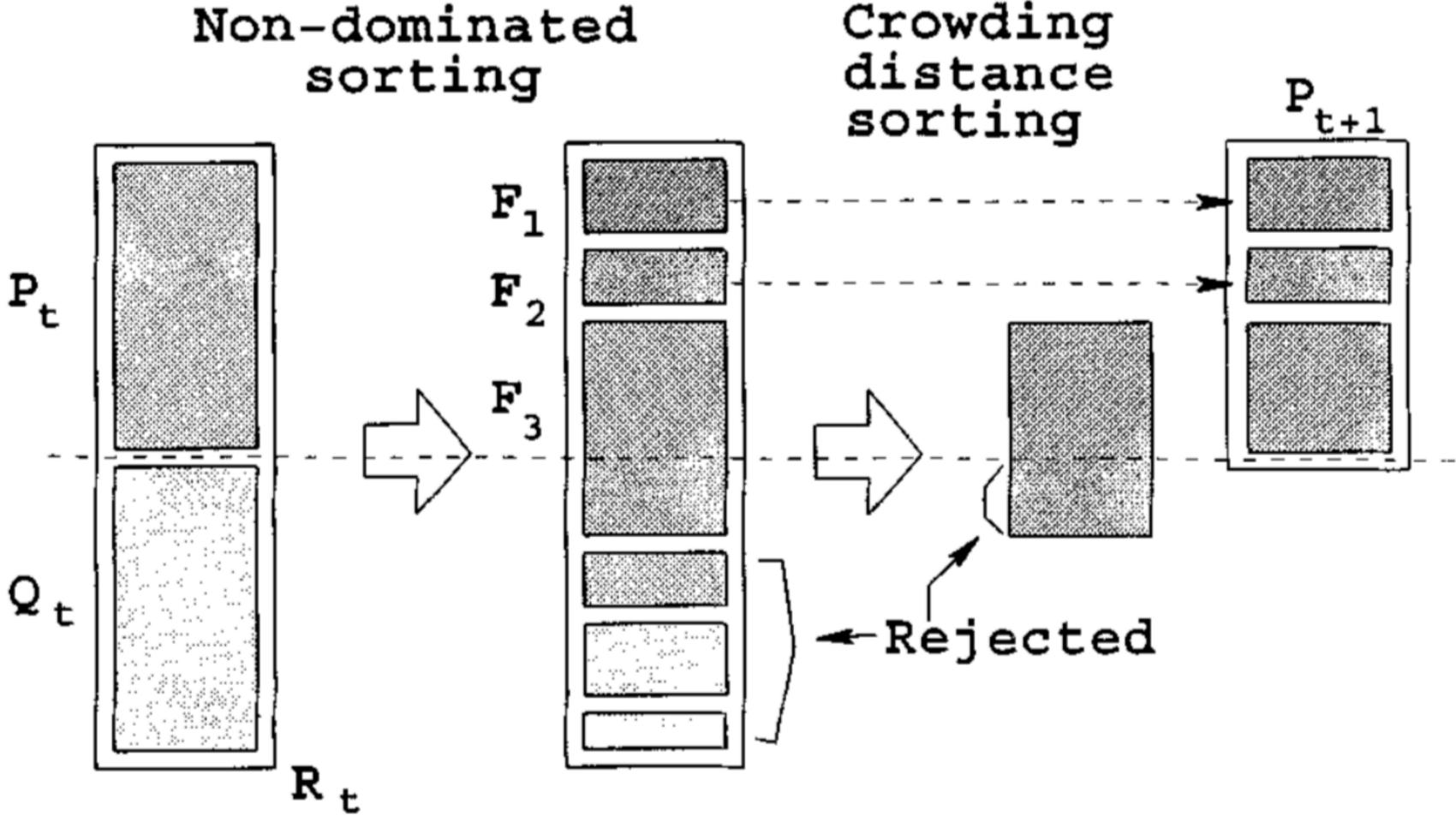
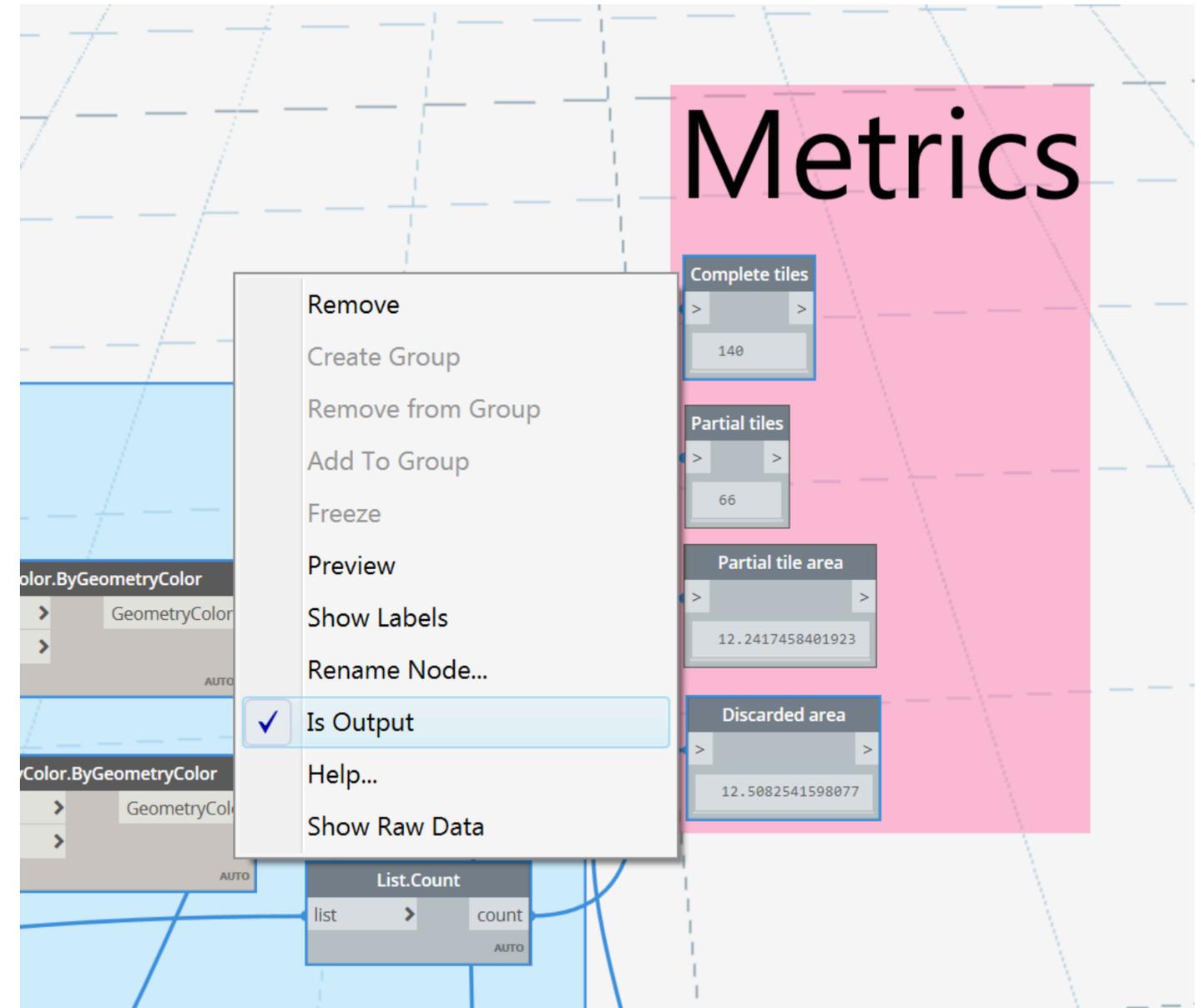
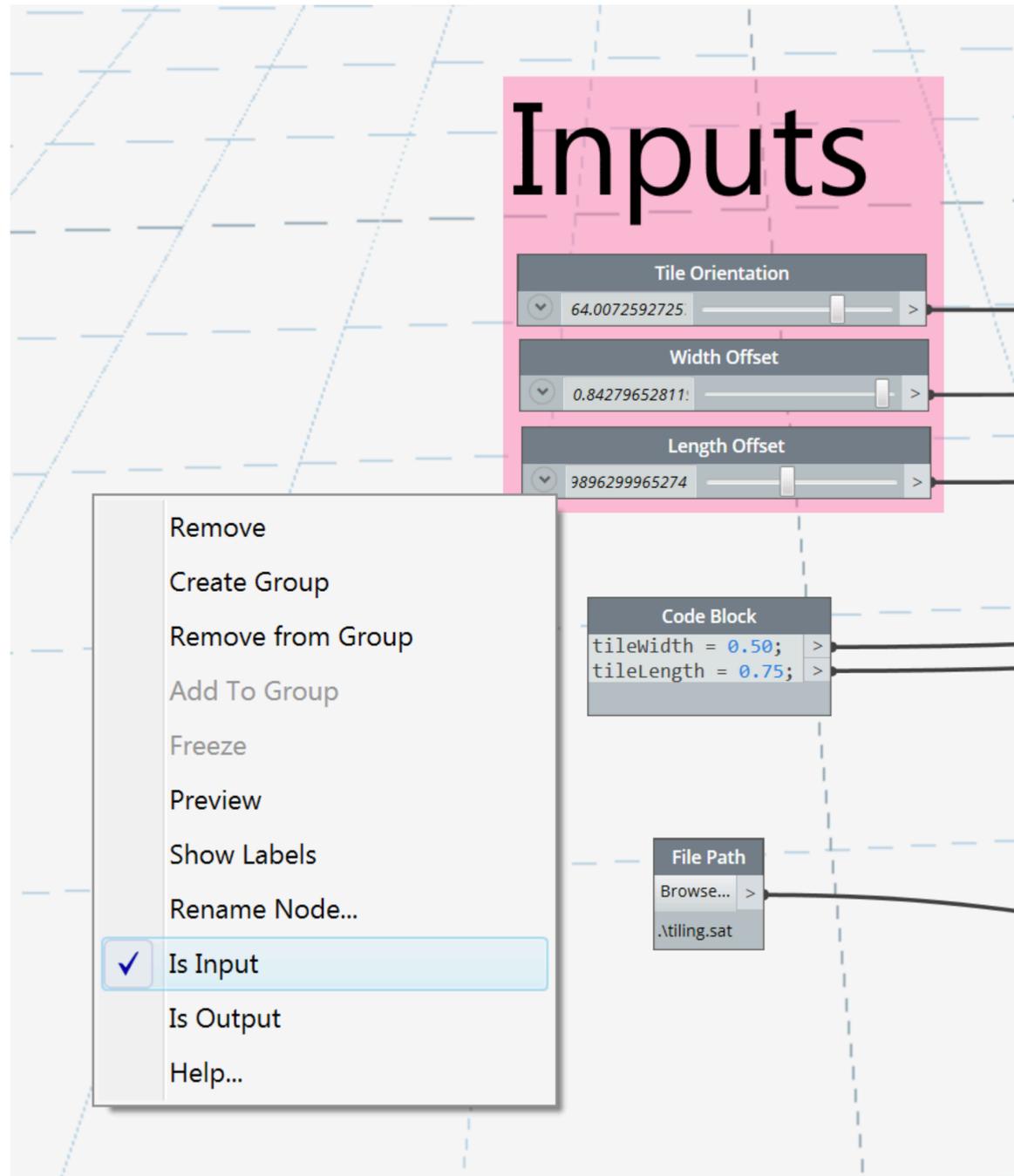


Fig. 2. NSGA-II procedure.

Implementing your own generative workflows

The background features a dynamic, abstract design. It consists of a series of curved, parallel lines that create a sense of depth and movement, transitioning from a light blue at the top to a darker blue at the bottom. The lines are arranged in a way that suggests a grid or a mesh structure, possibly representing a digital or generative environment. The overall aesthetic is clean, modern, and tech-oriented.

Your Dynamo graph needs to tell Refinery about its inputs and outputs



LIKE THIS
RANDOMIZE
CROSS PRODUCT
OPTIMIZE

Create Study



Generation Method
Optimize

Generate

Inputs



Tile Orientation

64.0072592725752

0 90

Width Offset

0.842796528119514

0 0.9

Length Offset

0.379896299965274

0 0.9

RANDOMIZE

Refinery

Studies New Study

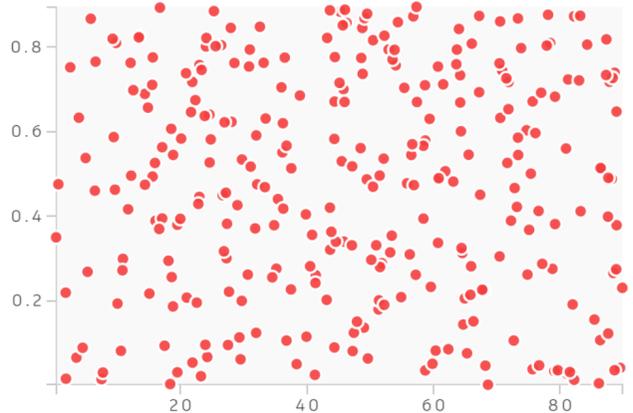
Run	Status
<input checked="" type="radio"/> 95793174-ac7e-4fe8-9b5d-b...	0/0 <input checked="" type="checkbox"/>

Y-Axis
Width Offset

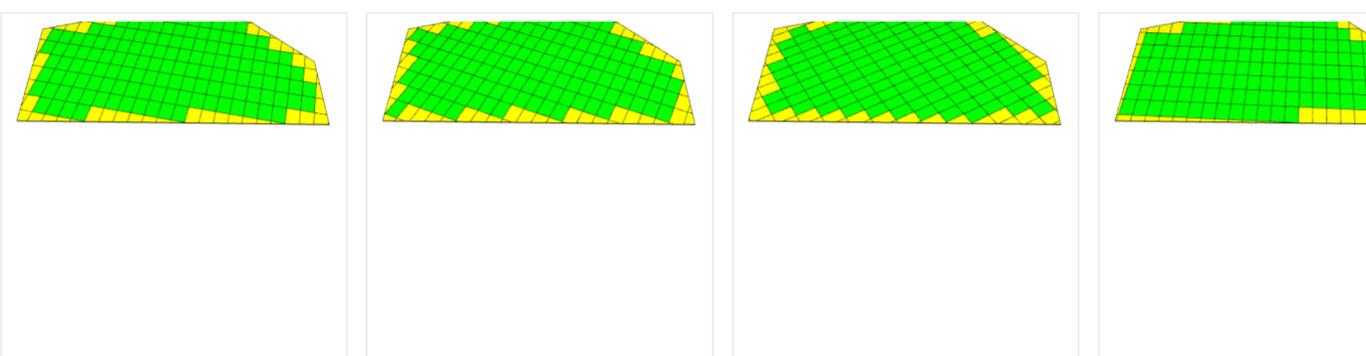
X-Axis
Tile Orientation

Size
Default

Color
Default



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23



RANDOMIZE

Refinery

Studies New Study

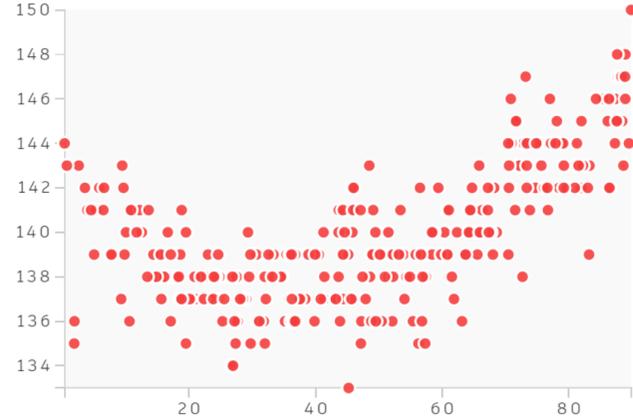
Run	Status
<input checked="" type="radio"/> 95793174-ac7e-4fe8-9b5d-b...	0/0 <input checked="" type="checkbox"/>

Y-Axis
Complete tiles

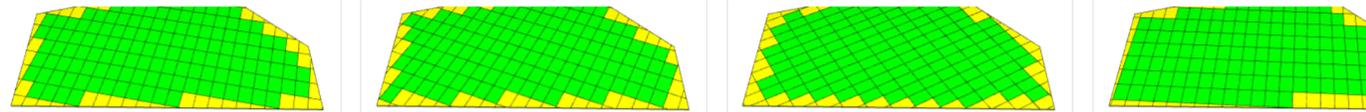
X-Axis
Tile Orientation

Size
Default

Color
Default



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23



CROSS PRODUCT

Refinery

Studies New Study

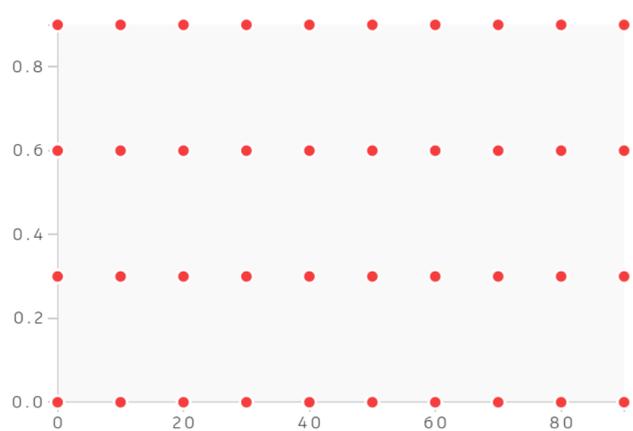
Run	Status
<input type="radio"/> 95793174-ac7e-4fe8-9b5d-b...	0/0 <input checked="" type="checkbox"/>
<input checked="" type="radio"/> 3f55f808-d31c-419a-9aa1-99..	0/0 <input checked="" type="checkbox"/>

Y-Axis
Width Offset

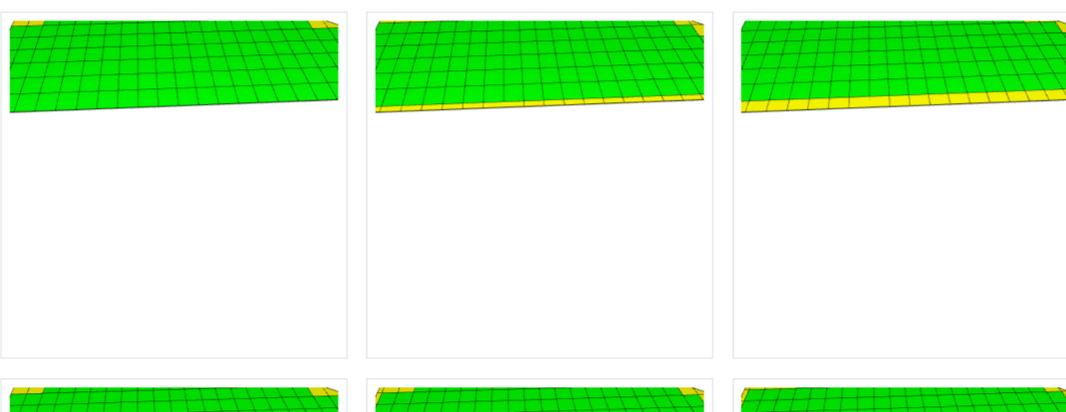
X-Axis
Tile Orientation

Size
Default

Color
Default



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18



CROSS PRODUCT

Refinery

Studies New Study

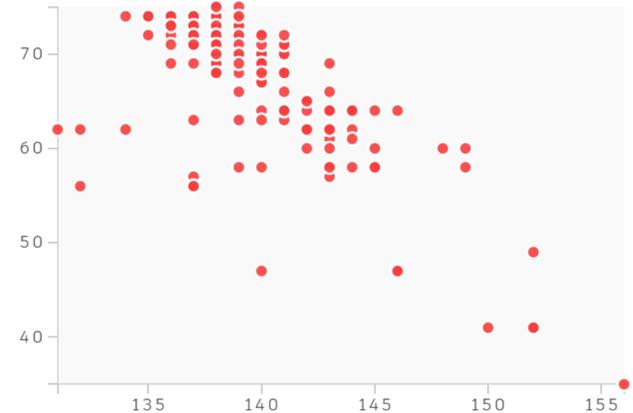
Run	Status
<input type="radio"/> 95793174-ac7e-4fe8-9b5d-b...	0/0 <input checked="" type="checkbox"/>
<input checked="" type="radio"/> 3f55f808-d31c-419a-9aa1-99..	0/0 <input checked="" type="checkbox"/>

Y-Axis
Partial tiles

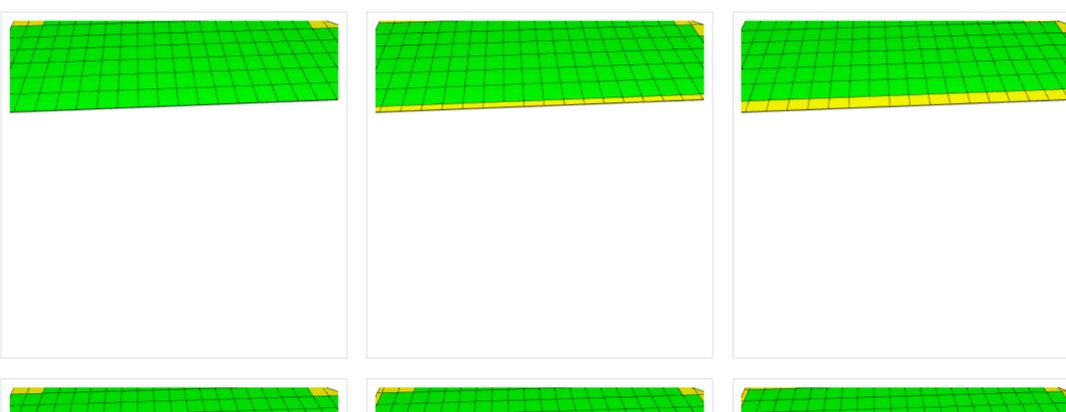
X-Axis
Complete tiles

Size
Default

Color
Default



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18



OPTIMIZE

Refinery

Studies New Study

Run	Status
<input type="radio"/> 3f55f808-d31c-419a-9aa1-99..	0/0 <input checked="" type="checkbox"/>
<input checked="" type="radio"/> 72f53052-d81e-43c4-9500-9...	10/10 <input checked="" type="checkbox"/>
<input type="radio"/> 95793174-ac7e-4fe8-9b5d-b...	0/0 <input checked="" type="checkbox"/>

Y-Axis
Width Offset

X-Axis
Tile Orientation

Size
Default

Color
Default

1 | 2

OPTIMIZE

Refinery

Studies New Study

Run	Status
<input type="radio"/> 3f55f808-d31c-419a-9aa1-99..	0/0 <input checked="" type="checkbox"/>
<input checked="" type="radio"/> 72f53052-d81e-43c4-9500-9...	10/10 <input checked="" type="checkbox"/>
<input type="radio"/> 95793174-ac7e-4fe8-9b5d-b...	0/0 <input checked="" type="checkbox"/>

Y-Axis
Discarded area

X-Axis
Complete tiles

Size
Partial tiles

Color
Tile Orientation

1 | 2

How it works

- You can run Refinery from Dynamo for Revit or Dynamo Sandbox
 - Tasks are executed by Refinery server using DynamoCLI
 - Limits what can be accessed or performed inside Revit
 - Use Data.Remember nodes to cache inputs into the graph
 - Refinery server currently runs locally but will move to the cloud
- Selecting a solution sets the parameters in Dynamo (for Revit)

Demo

The background features a dynamic, abstract design. It consists of a series of curved, parallel lines that create a sense of depth and movement, transitioning from a light blue at the top to a darker blue at the bottom. The lower portion of the image is dominated by a complex, multi-layered grid pattern of thin white lines, which appears to be a perspective view of a grid receding into the distance. The overall aesthetic is clean, modern, and technological.

Getting started

- Download Refinery from the Beta site
 - <https://beta.autodesk.com/key/refinery>
 - Works with Dynamo 2.0.2 or daily builds of 2.1
- Still in Beta, so expect some quirks
 - Known issues include a large amount of graphical data generated
 - Check *%appdata%/Refinery* if running out of disk space
 - Provide feedback on where you want us to go with it!

SPATIAL TRUSS OPTIMIZATION

DYNAMO PROJECT
SPATIAL TRUSS DEFORMATION

DYNAMO VERSION
2.1.0.6544

ASSOCIATED FILE(S)
-

ADDITIONAL COMMENTS
Structure dimensions in [m] units

AUTHOR(S) / CREATION DATE
Dieter Vermeulen, Autodesk / 2018.10.26

REQUIRED DYNAMO PACKAGES
BIM4Struc.Productivity
MeshToolkit
DynaShape: needs to be installed from this link:
<https://forum.dynamobim.com/t/dynashape/11666>

DESCRIPTION
Conceptual evaluation of special truss design options. Use this script with Project Refinery for Multi-Objective Optimization purposes.

Platform S

Platform Top Edges (Z1)
2.000

Platform Mid (Z2)
2.500

Platform Width (W)
12

Platform Length (L)
15

Truss Dimensions

Truss Stiff Depth (SD)
4.2

BES224265 – Structural Dynamics: Optimized Design and Fabrication Workflows with Dynamo
Dieter Vermeulen | Wednesday, Nov 14, 8:30-10:00 AM – Lando 4206, Level 4

Recommendations

- Get started now on building up skills and IP for generative workflows
 - Dynamo expertise will be even more valuable in the future
 - There's a thriving DynamoBIM community to tap into
 - Start small, such as with today's tiling example
 - Graphs get complicated quickly
 - Maintaining discipline will help
 - Relevant learnings from the Van Wijnen project in Thursday's 1:30pm class
 - *CS239262 - Generative Urban Design: a collaboration between Autodesk Research and Van Wijnen (Delfino 4004, Level 4)*
- Think about “closing the loop”: gathering data to help future iterations

Q&A

The background features a light blue gradient with a complex geometric pattern. A prominent element is a curved, grid-like surface that recedes into the distance, creating a sense of depth and perspective. The grid lines are thin and light blue, set against a slightly darker blue background. The overall aesthetic is clean, modern, and technical.



AUTODESK®

Make anything™

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.

© 2018 Autodesk. All rights reserved.

