Parametric Urban Design

Interactive tools for supporting urban design decision making

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City induction

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FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

TU Delft

FACULDADE DE ARQUITECTURA
UNIVERSIDADE TÉCNICA DE LISBOA

UTL

City Induction research project (PTDC/AUR/64384/2006) is funded by Fundação para a Ciência e Tecnologia, Portugal and hosted by ICIST.

The City Induction research project aims at defining an urban design support tool consisting of 3 related parts:

3 modules:

to define appropriate urban programmes for given contexts

Formulation

to generate design solutions that match the defined urban programmes

Generation

to guarantee that evolving programmes and design solutions match the given context

Evaluation

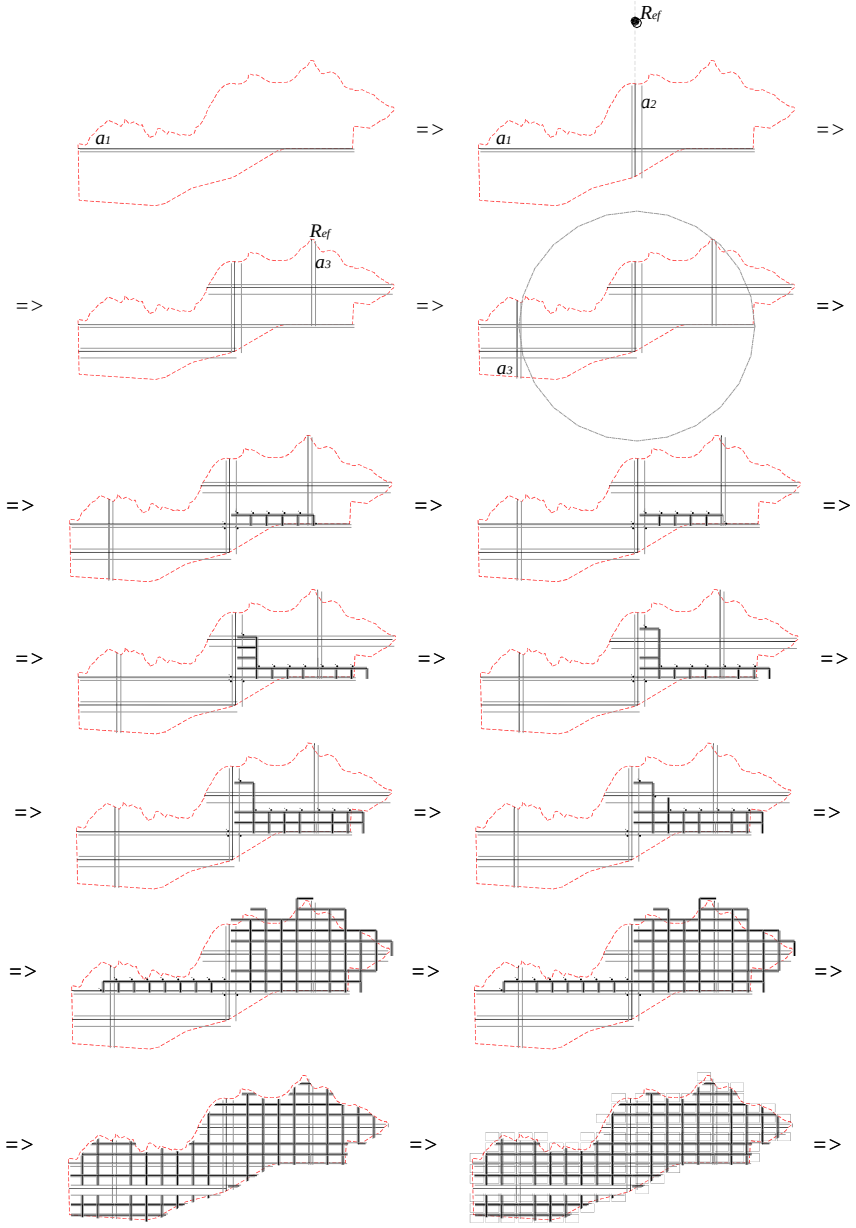
City induction

Coordination – José Pinto Duarte

Formulation – Nuno Montenegro

Generation – José Nuno Beirão

Evaluation – Jorge Gil



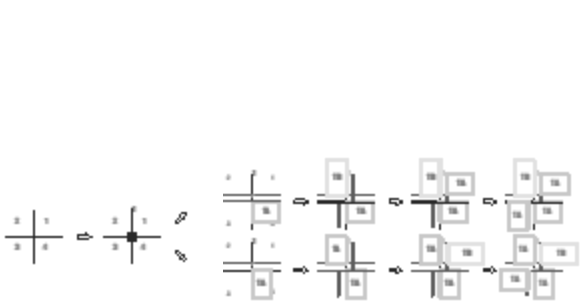
The generation module for City Induction

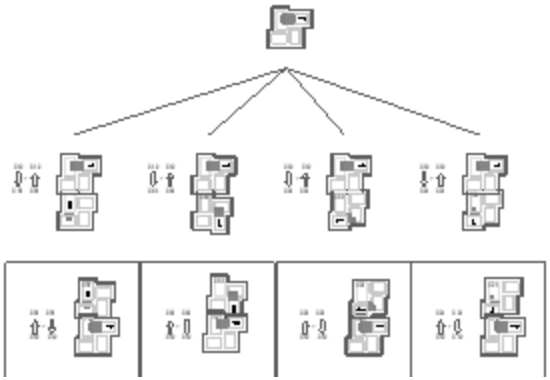
1. Previous work

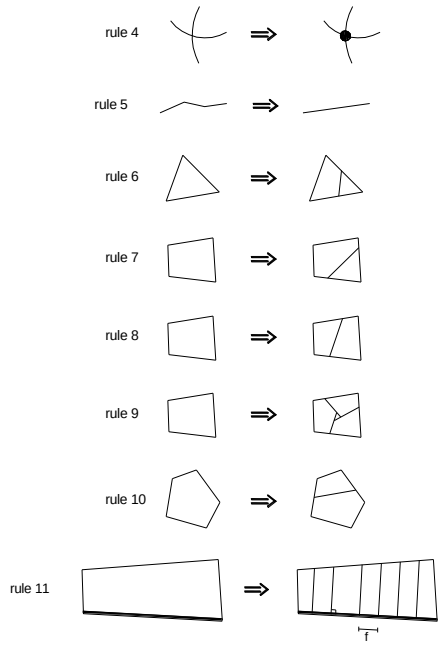
2. The generation module
   a. problem
   b. concepts
   c. examples
   d. implementations

José Nuno Beirão

1. Previous work



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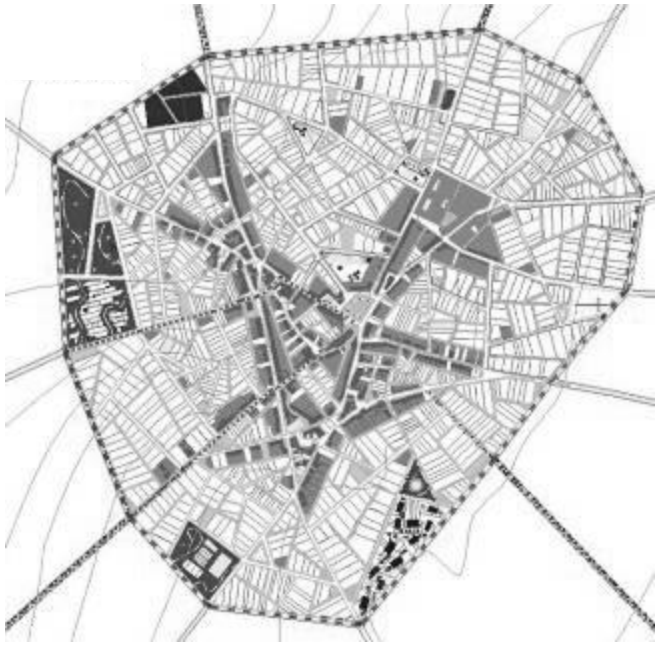
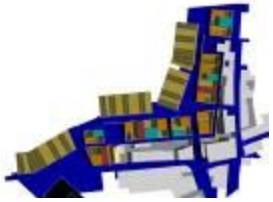
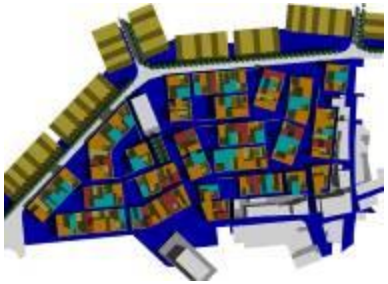
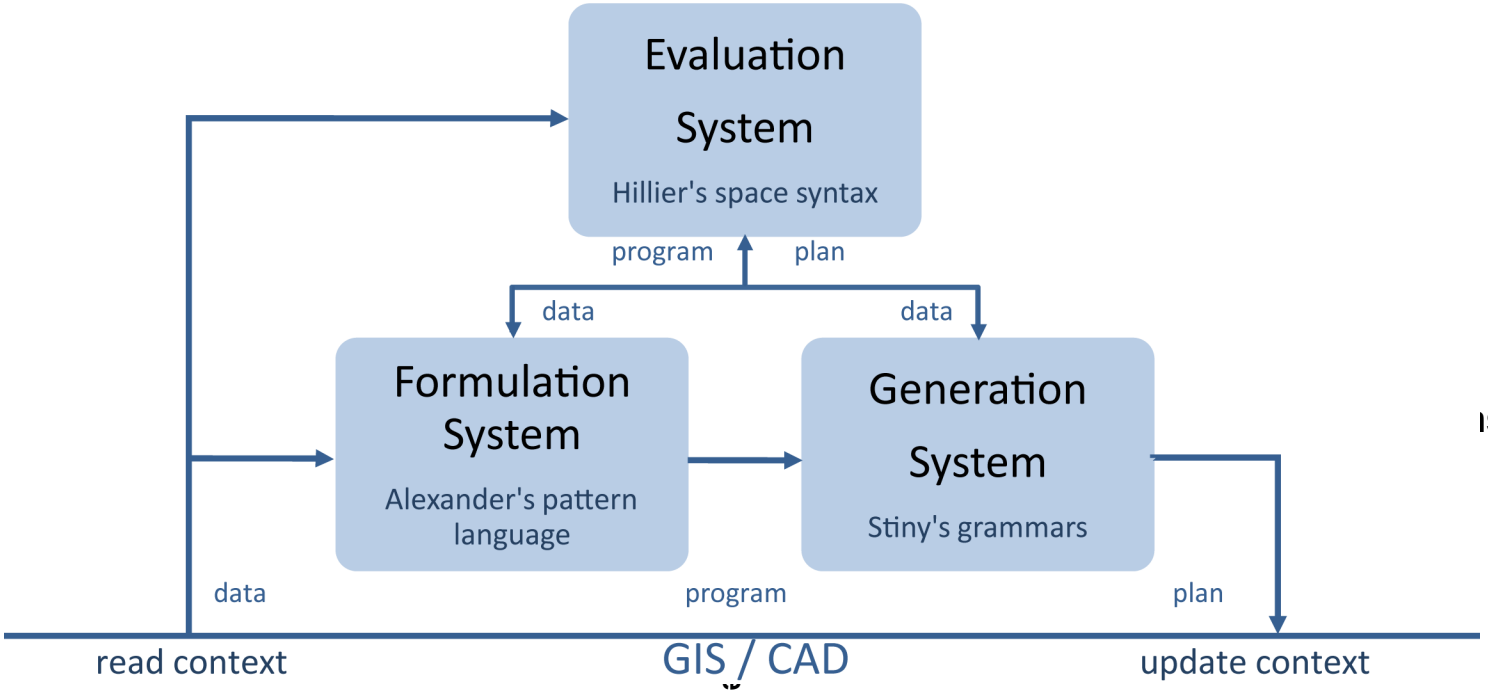
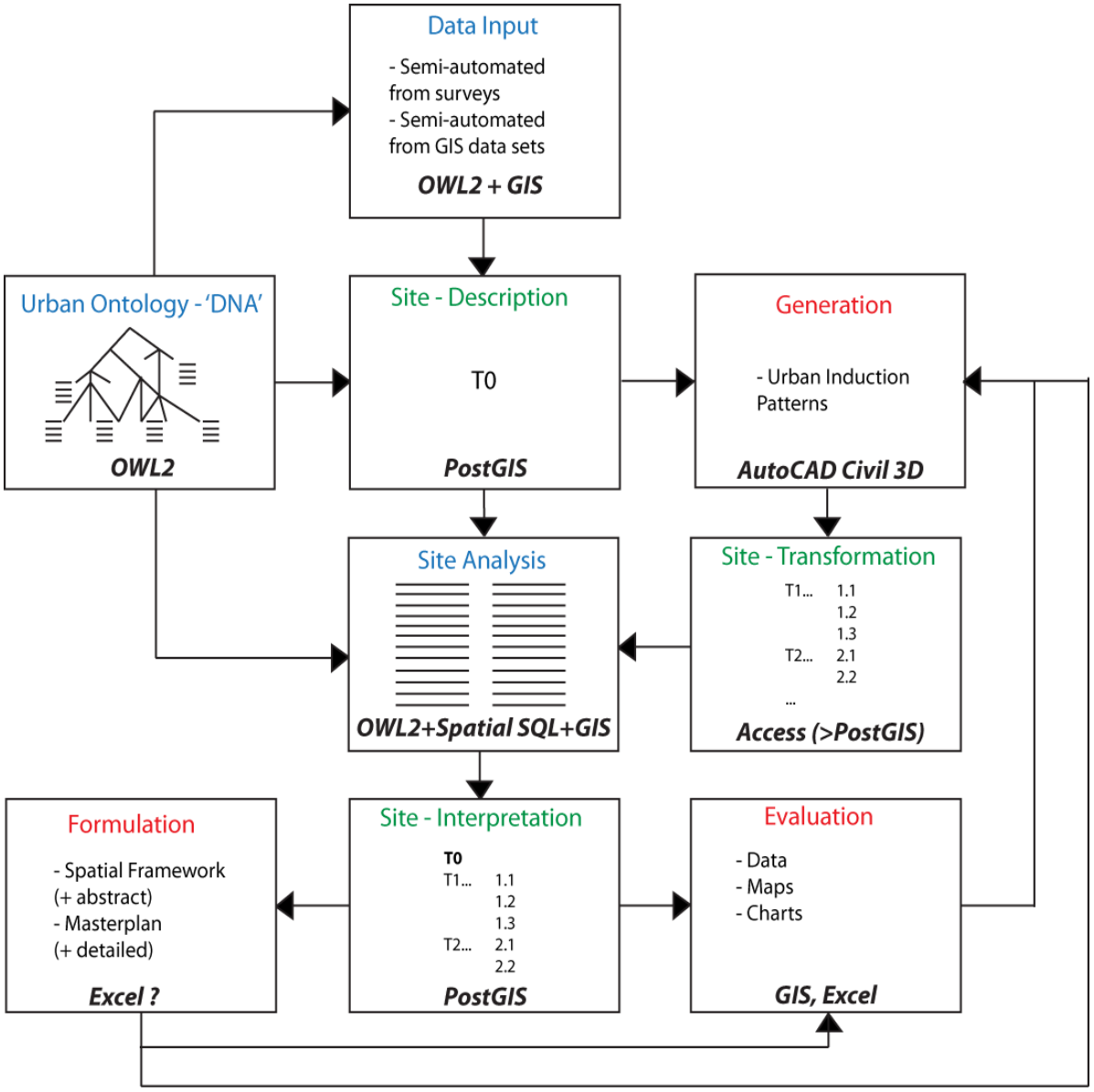






City Induction





City Induction urban design method: technical implementation

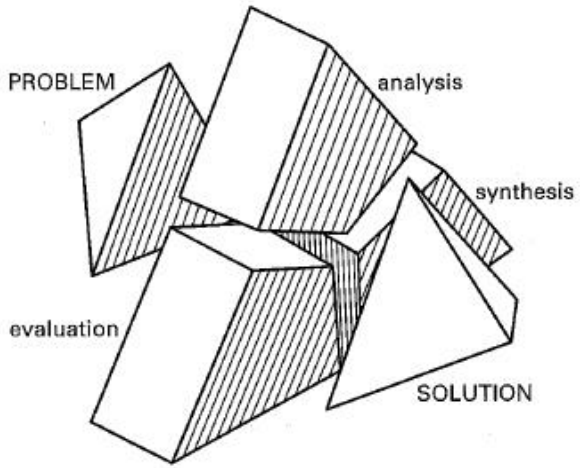
Problem:

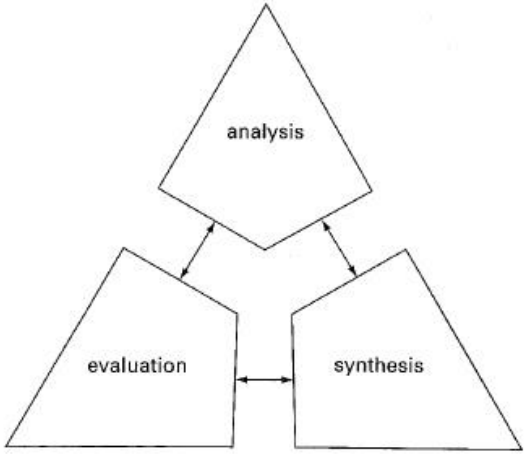
defining a structure for an urban design generation tool

- the logic of design;
- features of the urban space;
- urban design process;
- new ways of approaching urban design;

Who is the tool user?	Designer / design team
What is its purpose?	Enhancing the awareness on design decisions
Who does it address to?	Stakeholders needing visual information

the logic of design;





Design as negotiation between problem and solution through the activities of analysis, synthesis and evaluation (source: Lawson, 2006).

See → Move → See

Knowing-in-action

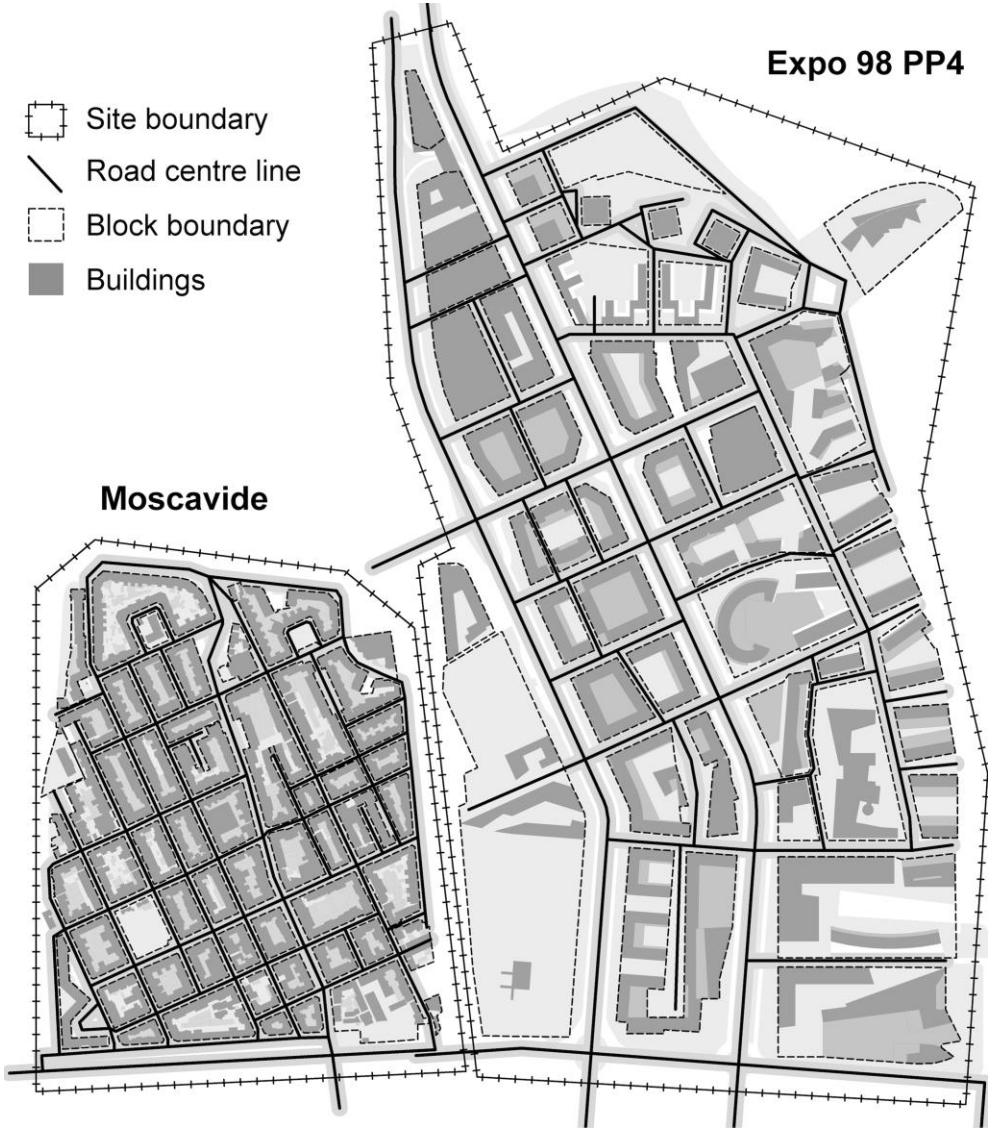
Reflection-in-action

(Schön, 1983, 1987)

Tacit knowledge

(Polanyi, 1967)

features of the urban space;



new ways of approaching urban design;

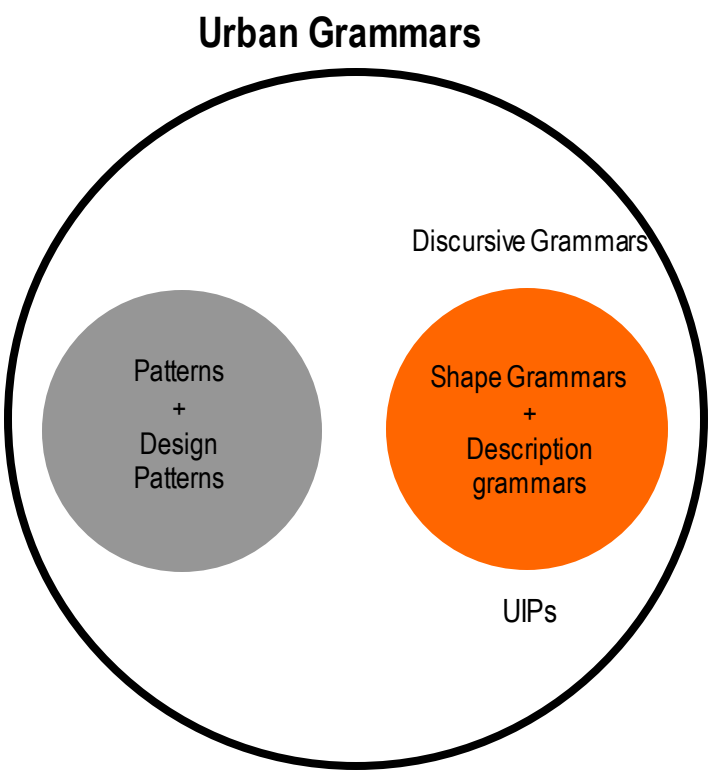
Incrementality
Malleability
Participation
Flexibility and change

should be some of the qualities of an urban design process (Charles Correa, 1999; Archer, 2001)
design tools should embed and foster such qualities

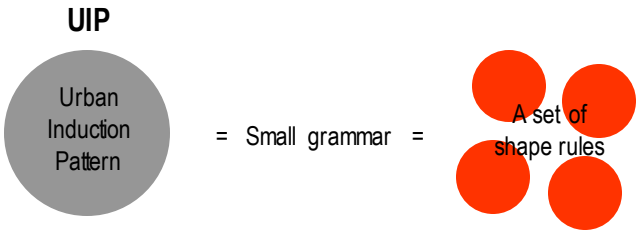
Diversity
Exploration of change as an opportunity for urban design

The generation module

concepts

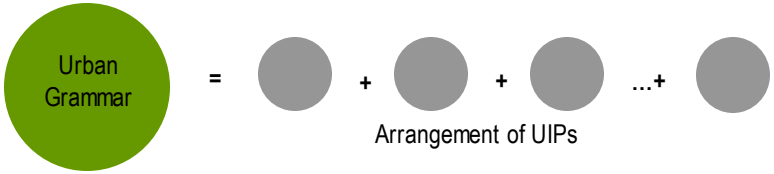


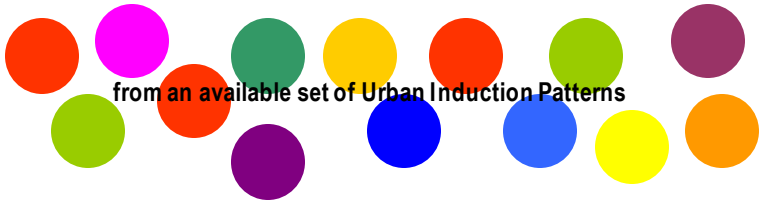
Patterns (Alexander, C. et al, 1977)
Design patterns (Gamma et al, 1995)
Shape Grammars (Stiny and Gips, 1972)
Description Grammars (Stiny, 1981)
Discursive Grammars (Duarte, 2001)

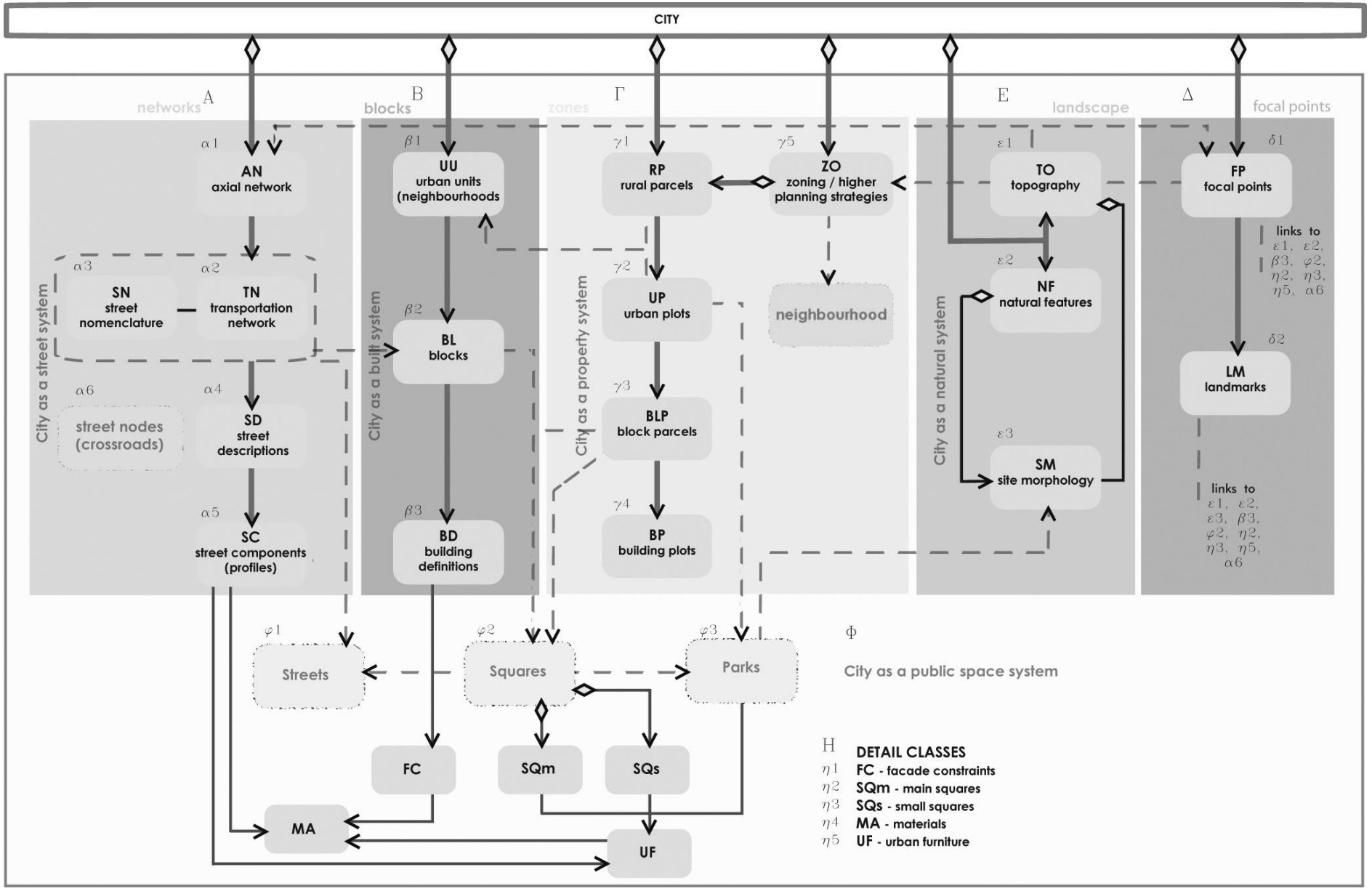


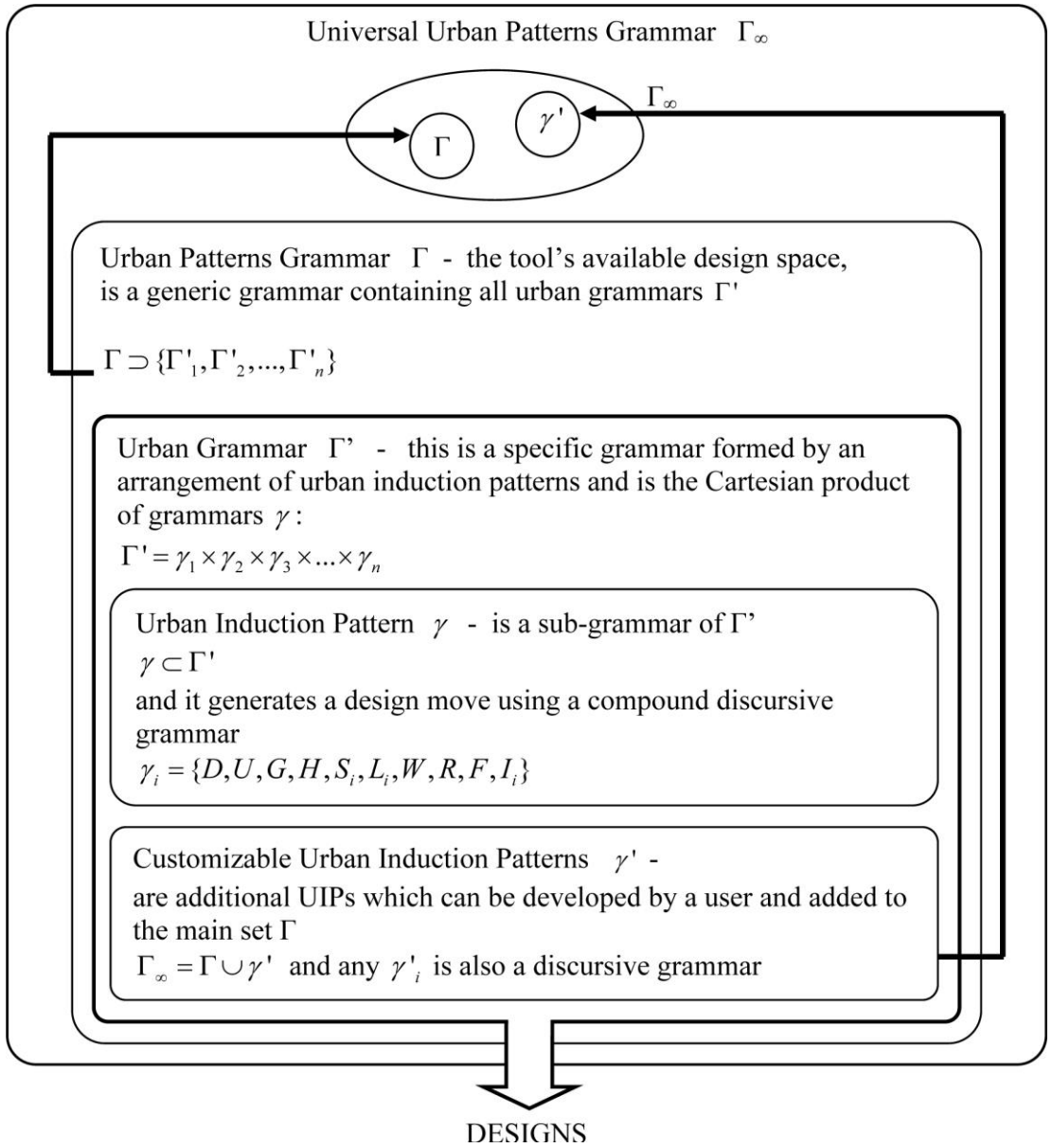
UIP is a typical urban design procedure or design move (Schon, 1983) recurrently used by urban designers in their design process.

Independent urban design instructions






CITY
networks
A
blocks
B
zones
Γ
landscape
E
focal points
Δ
α1
AN
axial network
α3
SN
street nomenclature
α2
TN
transportation network
α6
street nodes (crossroads)
α4
SD
street descriptions
α5
SC
street components (profiles)
City as a street system
β1
UU
urban units (neighbourhoods
β2
BL
blocks
β3
BD
building definitions
City as a built system
γ1
RP
rural parcels
γ5
ZO
zoning / higher planning strategies
γ2
UP
urban plots
neighbourhood
γ3
BLP
block parcels
γ4
BP
building plots
City as a property system
ε1
TO
topography
ε2
NF
natural features
ε3
SM
site morphology
City as a natural system
δ1
FP
focal points
links to ε1, ε2, β3, φ2, η2, η3, η5, α6
δ2
LM
landmarks
links to ε1, ε2, ε3, β3, φ2, η2, η3, η5, α6
φ1
Streets
φ2
Squares
φ3
Parks
Φ
City as a public space system
FC
SQm
SQs
MA
UF
H
DETAIL CLASSES
η1 FC - facade constraints
η2 SQm - main squares
η3 SQs - small squares
η4 MA - materials
η5 UF - urban furniture


Universal Urban Patterns Grammar Γ_∞
Γ_∞
Γ
γ'
Urban Patterns Grammar Γ - the tool's available design space, is a generic grammar containing all urban grammars Γ'
$\Gamma \supset \{\Gamma'_1, \Gamma'_2, ..., \Gamma'_n\}$
Urban Grammar Γ' - this is a specific grammar formed by an arrangement of urban induction patterns and is the Cartesian product of grammars γ:
$\Gamma' = \gamma_1 \times \gamma_2 \times \gamma_3 \times ... \times \gamma_n$
Urban Induction Pattern γ - is a sub-grammar of Γ'
$\gamma \subset \Gamma'$
and it generates a design move using a compound discursive grammar
$\gamma_i = \{D, U, G, H, S_i, L_i, W, R, F, I_i\}$
Customizable Urban Induction Patterns γ' -
are additional UIPs which can be developed by a user and added to the main set Γ
$\Gamma_\infty = \Gamma \cup \gamma'$ and any γ'_i is also a discursive grammar
DESIGNS

An object class corresponds to the shape set of a parallel grammar.

An Urban Grammar is composed of several parallel grammars.

Parallel representations allow for an integration into a GIS topology.

The generation module

c. examples

4 case studies

A guiding framework towards diversity

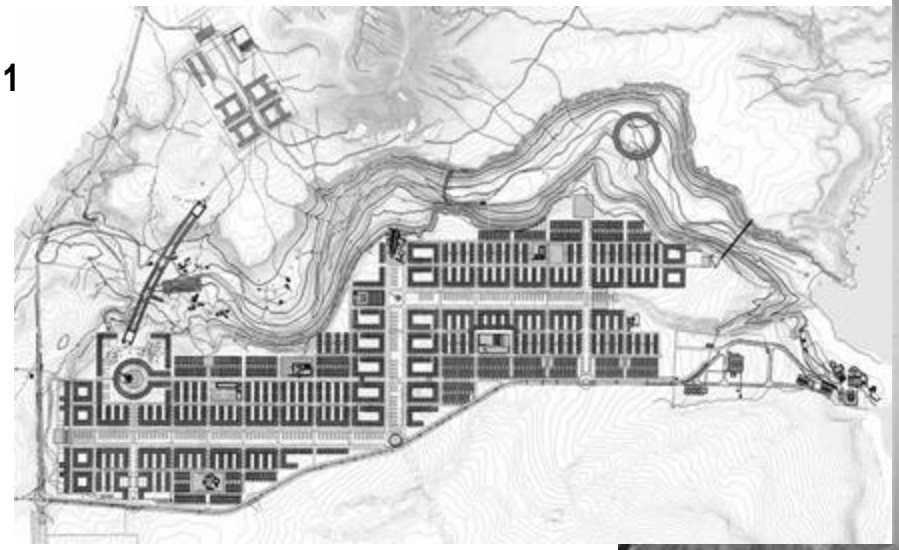
(1) - Cidade da Praia (CP) in Cabo Verde by Chuva Gomes

(2) - Qta da Fonte da Prata (QFP)) by Chuva Gomes

(3) - Ijburg/Haveneiland plan by Frits van Dongen, Felix Claus and Ton Schaap which is a detailed plan for a part of a larger plan by Palmbout;

(4) - Ypenburg also by Palmbout (Palmboom and van den Bout)

1



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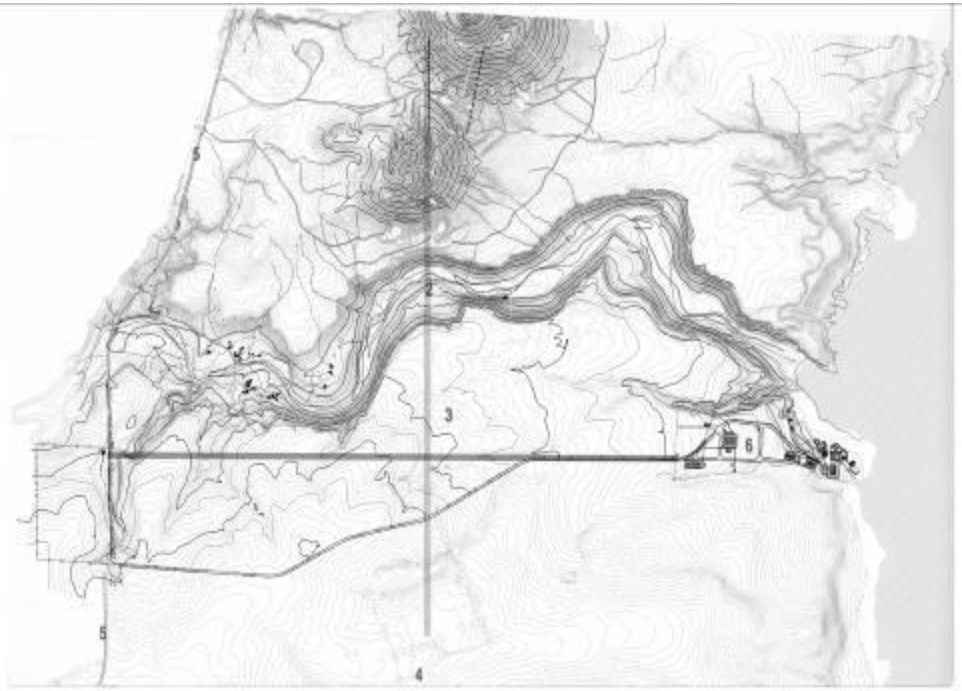
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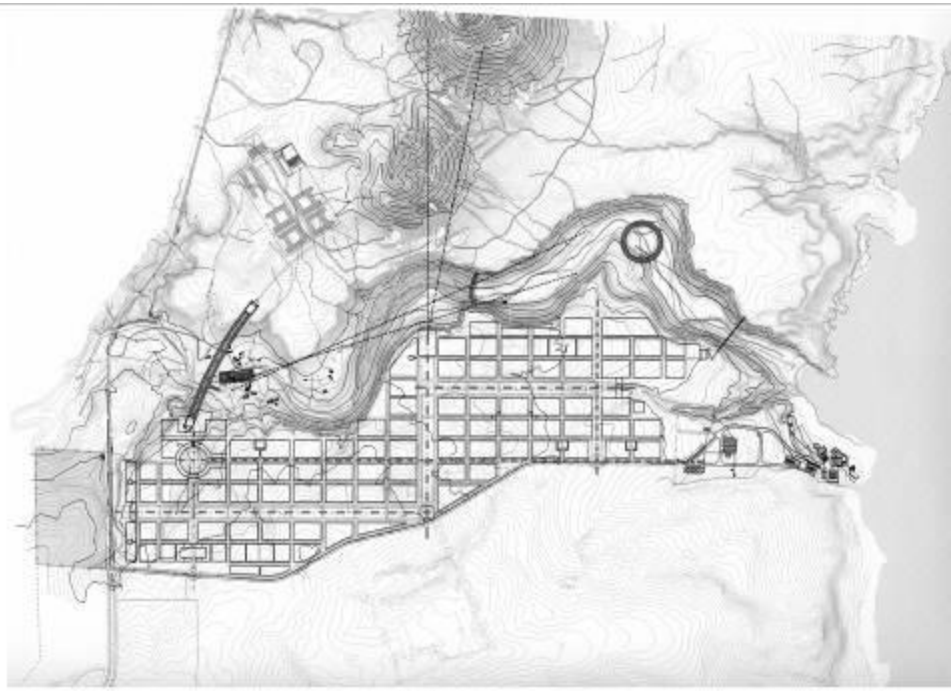
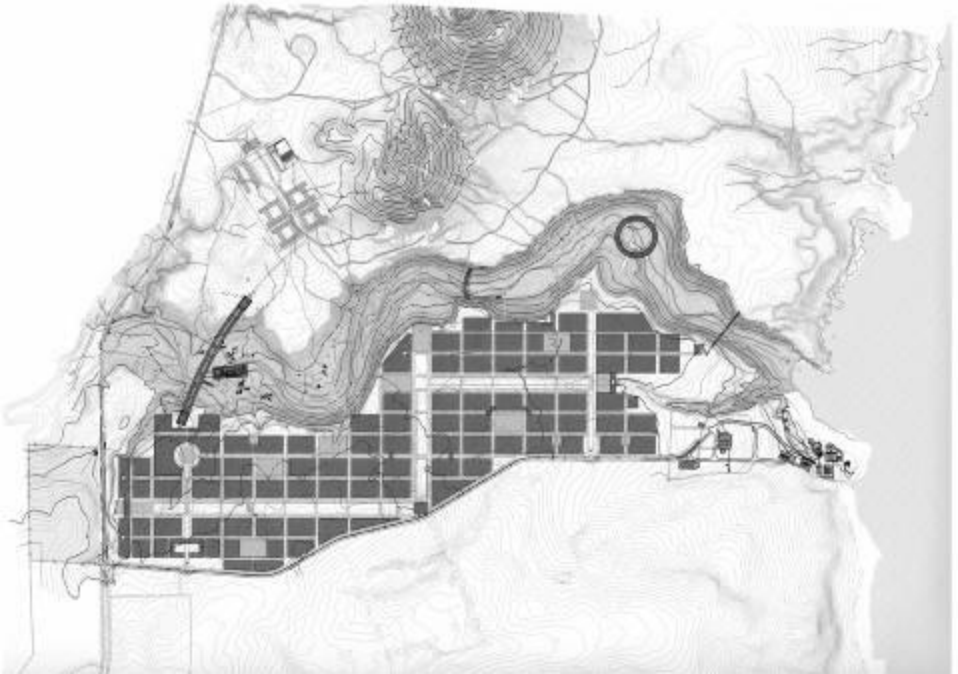
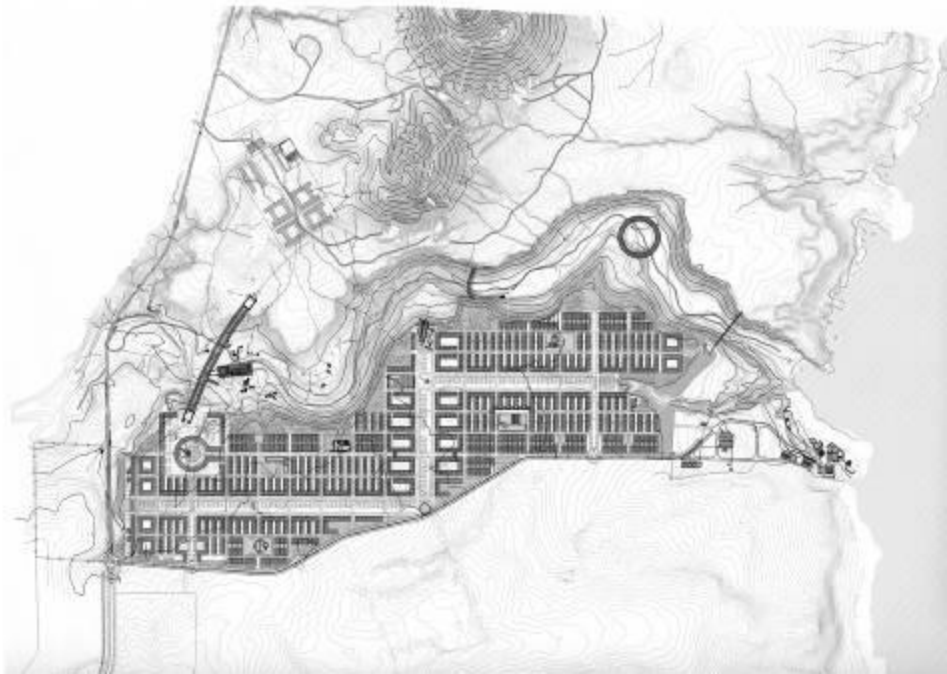






Urban Induction Patterns

MainAxisistheLongerLine

Cardus

Decumanus

OrthogonalAxis

Promenade

Grid by *AddingAxes*

Grid by *AddingBlockCells*

AddBlocktoCells

AdjustingBlockCells

AddPlaza

GeneratePlaza

SquarefromBlockSubtraction

SquarefromBlockTrim

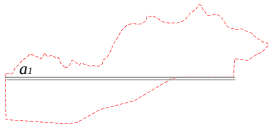
SquarefromCornerTrim

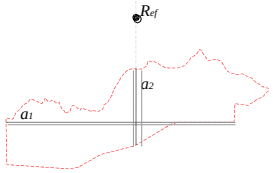
TrimPublicSpaceinBlock

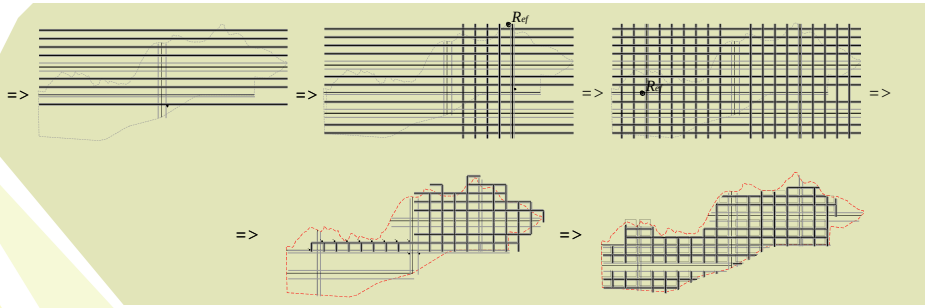
BuildingHeadingAxis

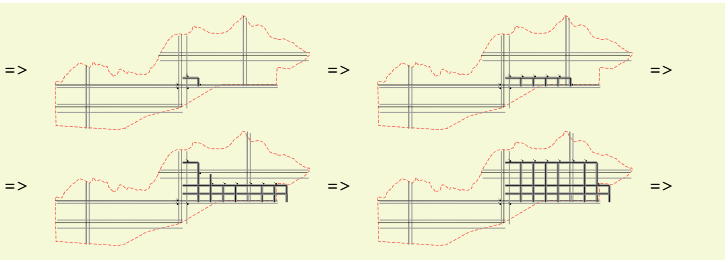
AddArches

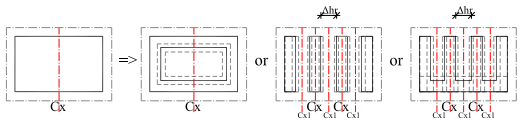
AddBlockType



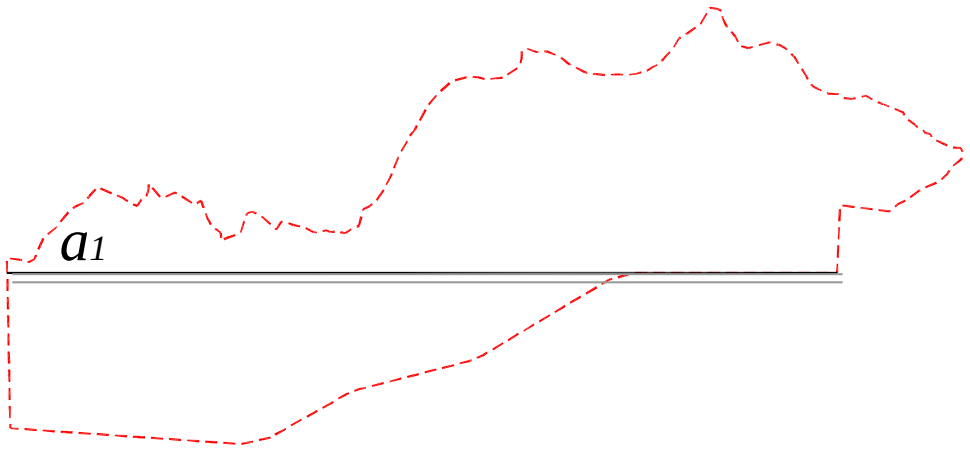








AddingBlockCells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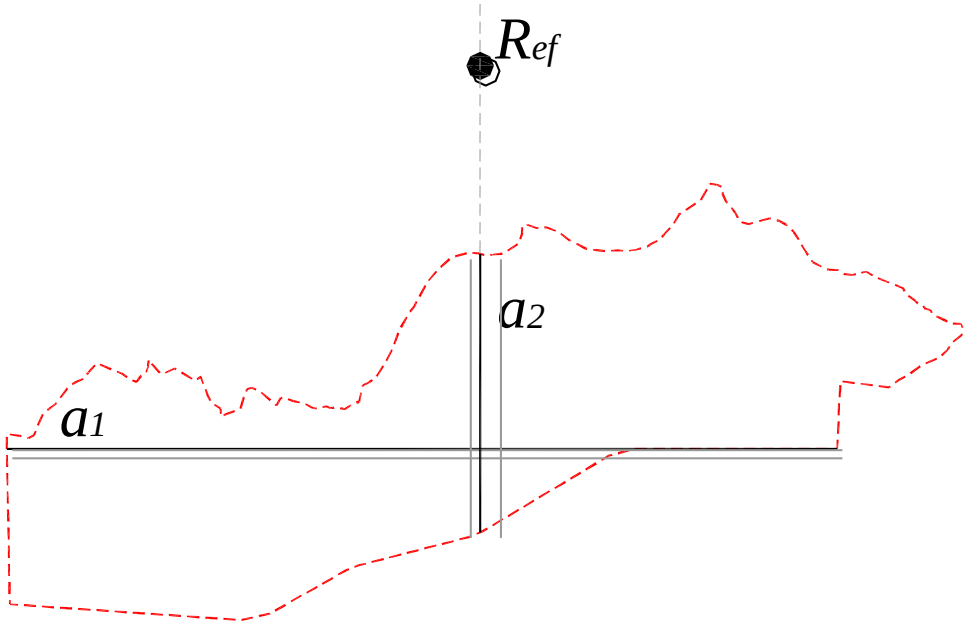
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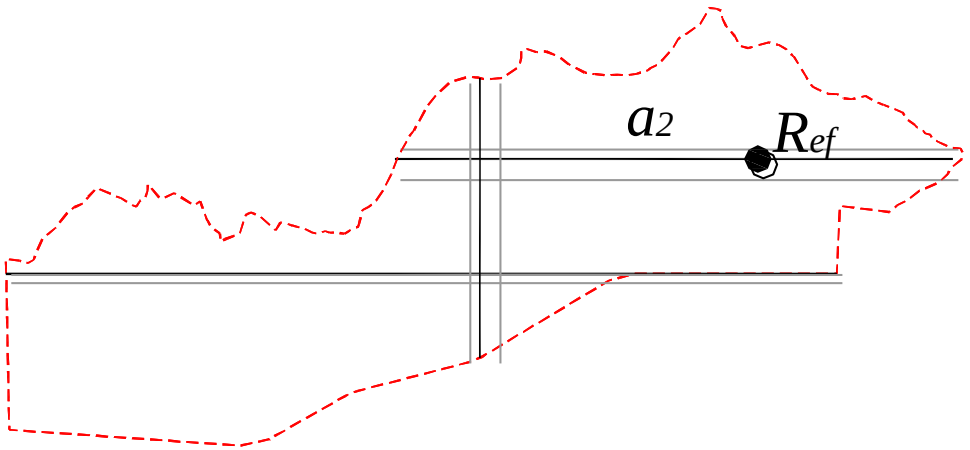
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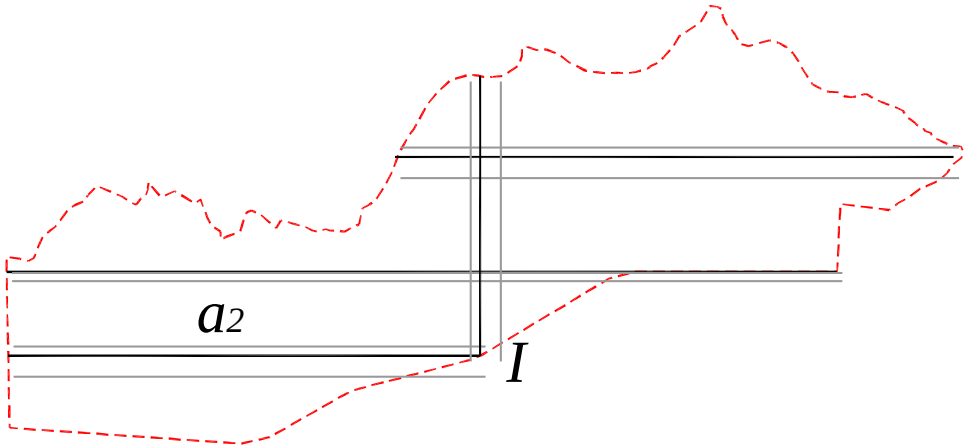
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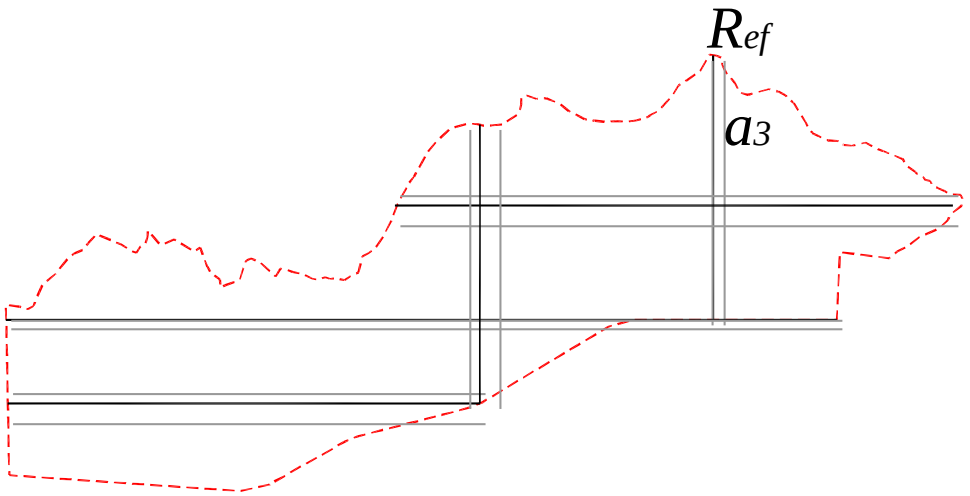
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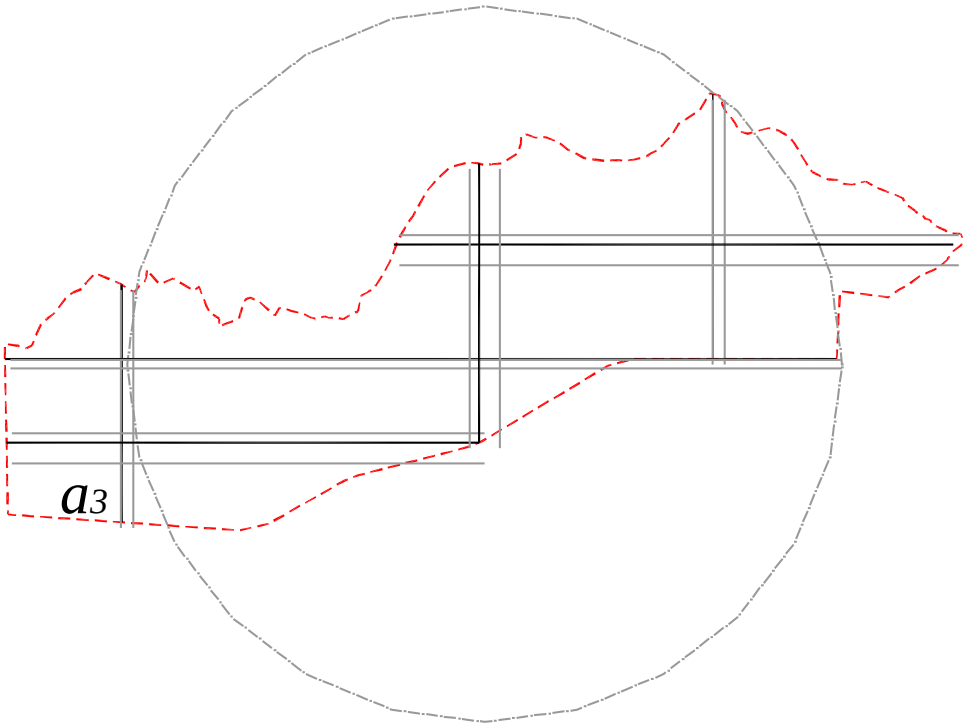
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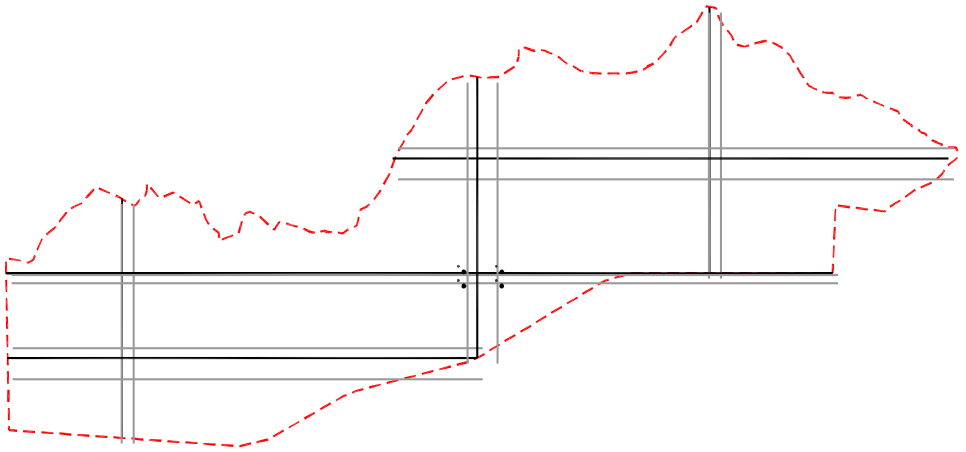

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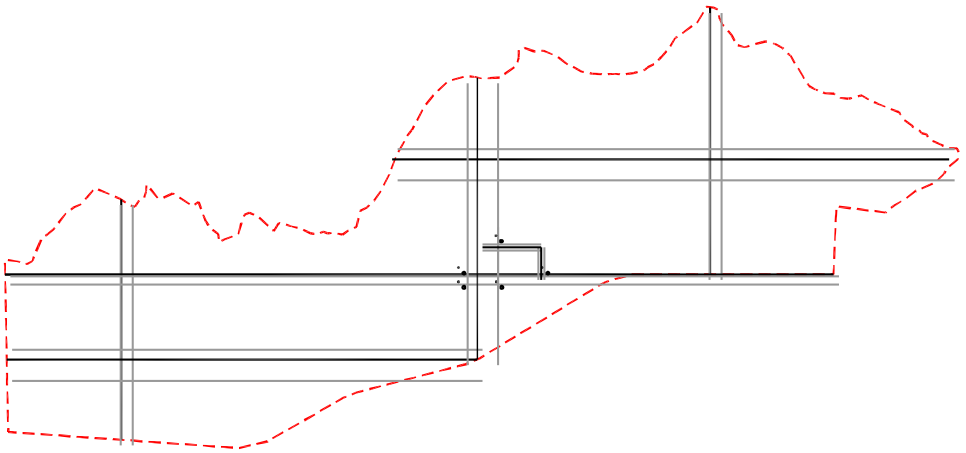

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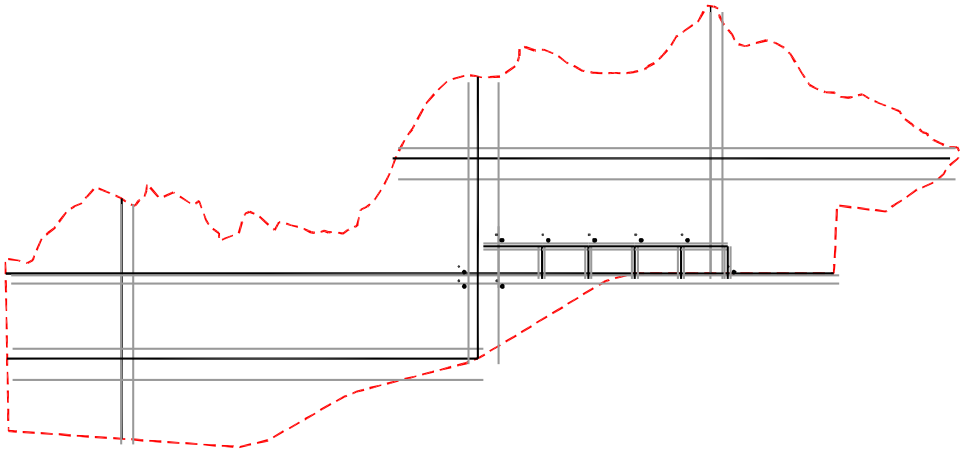

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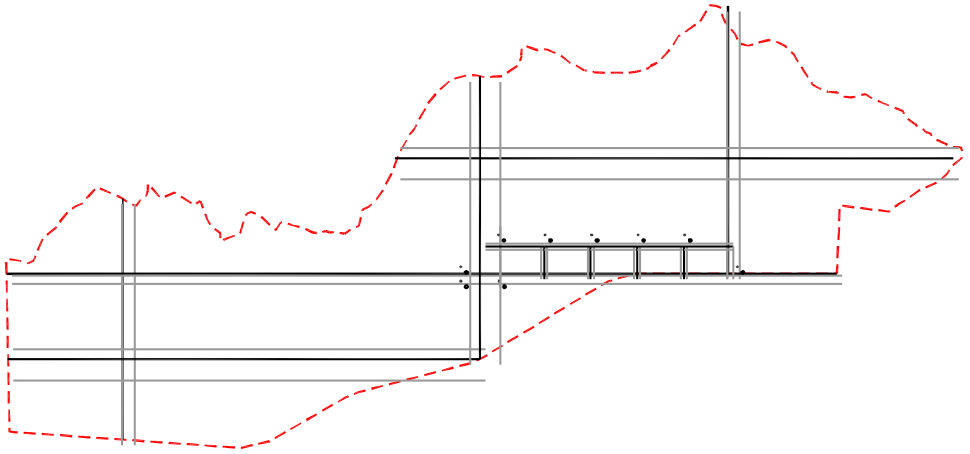

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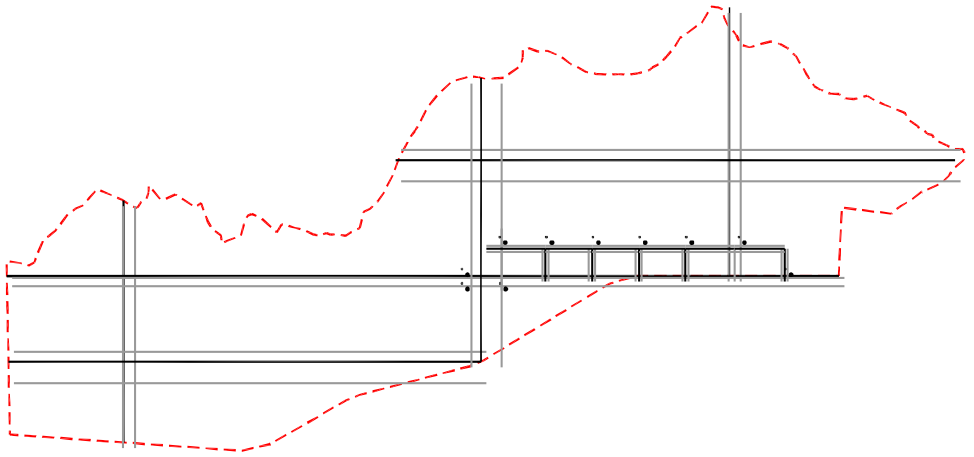

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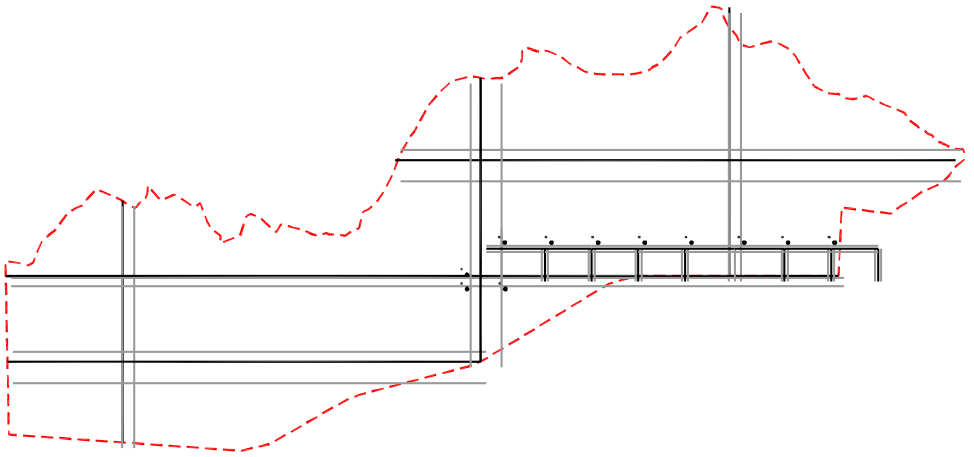

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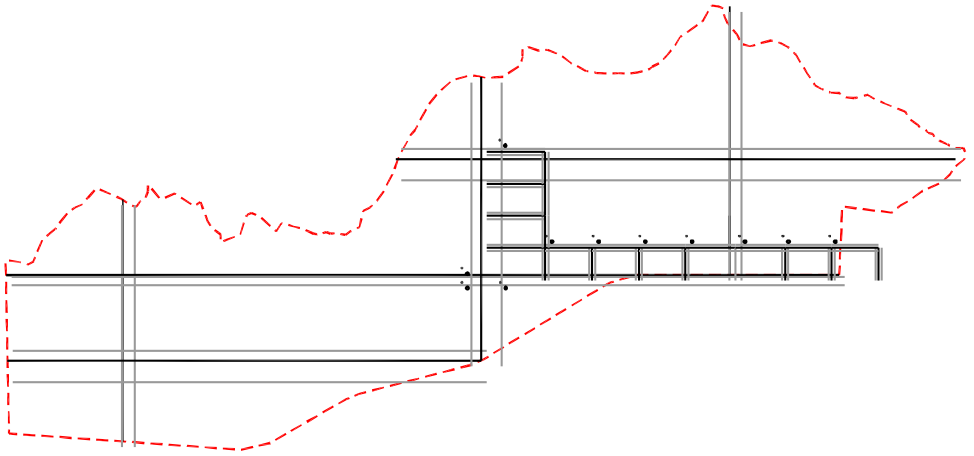

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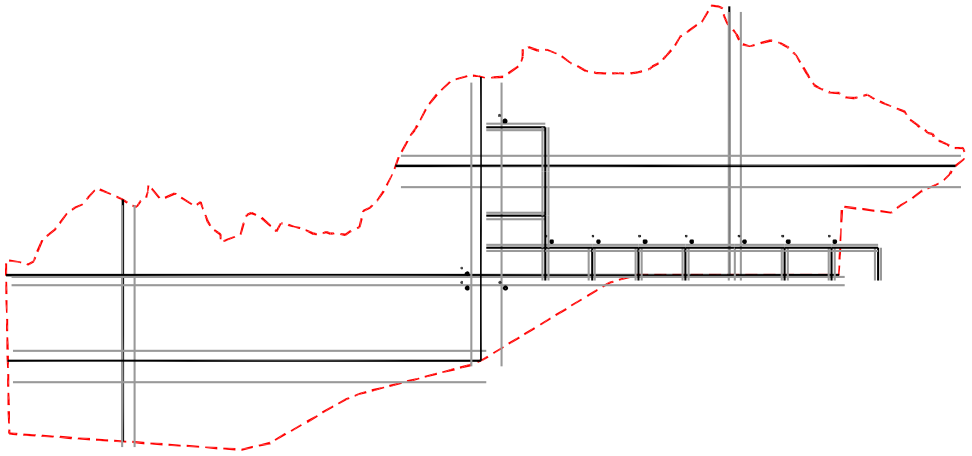

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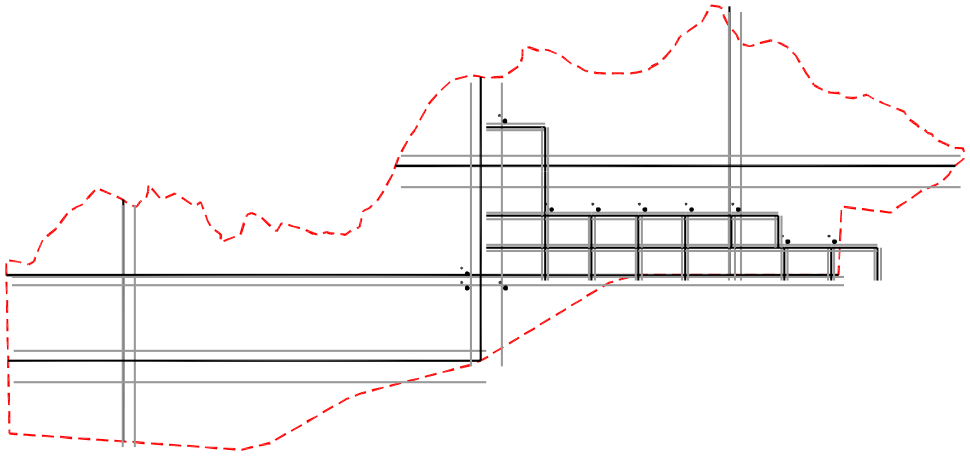

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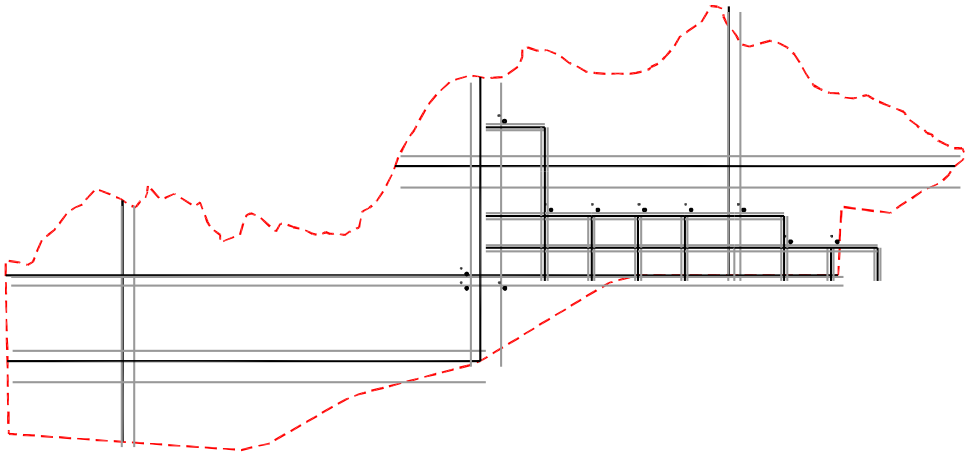

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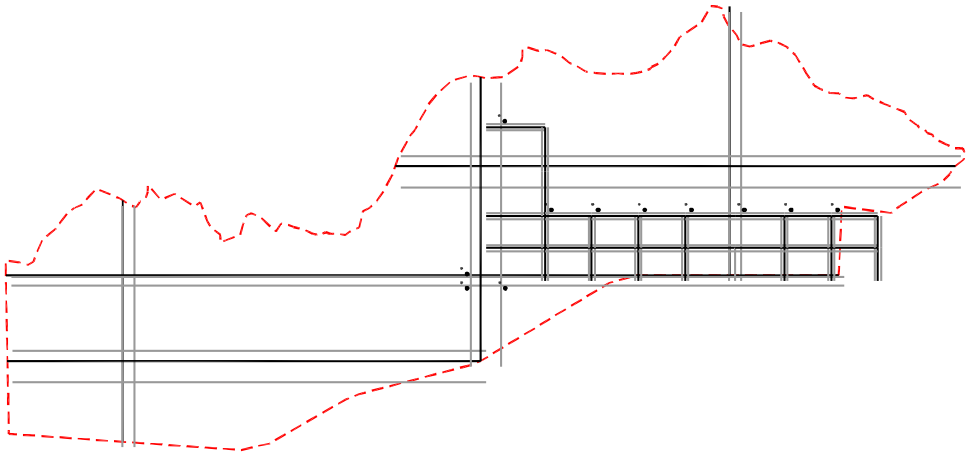

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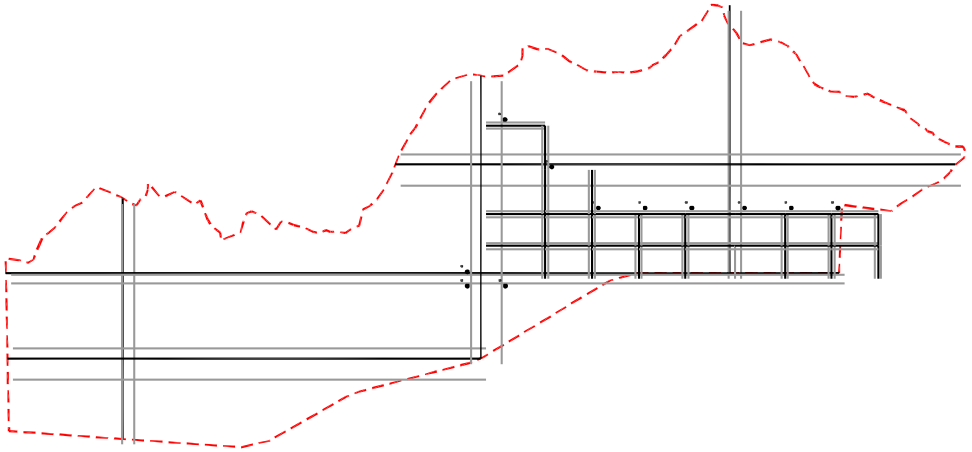

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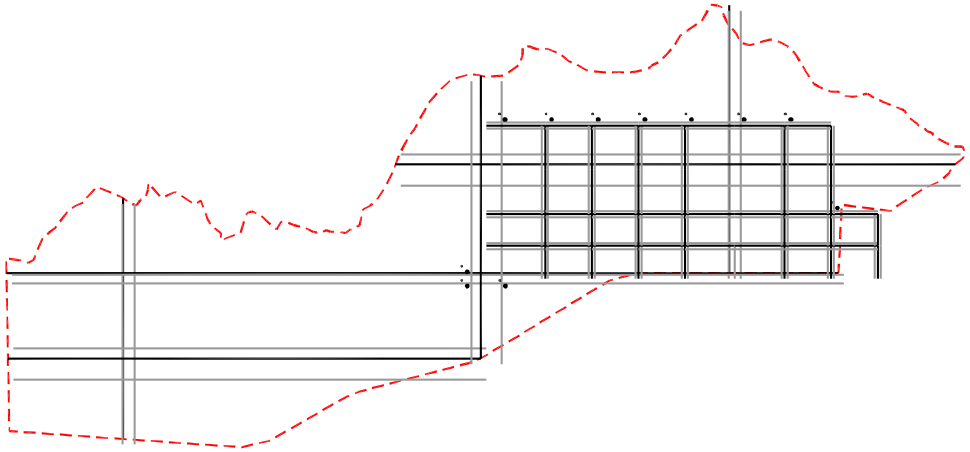

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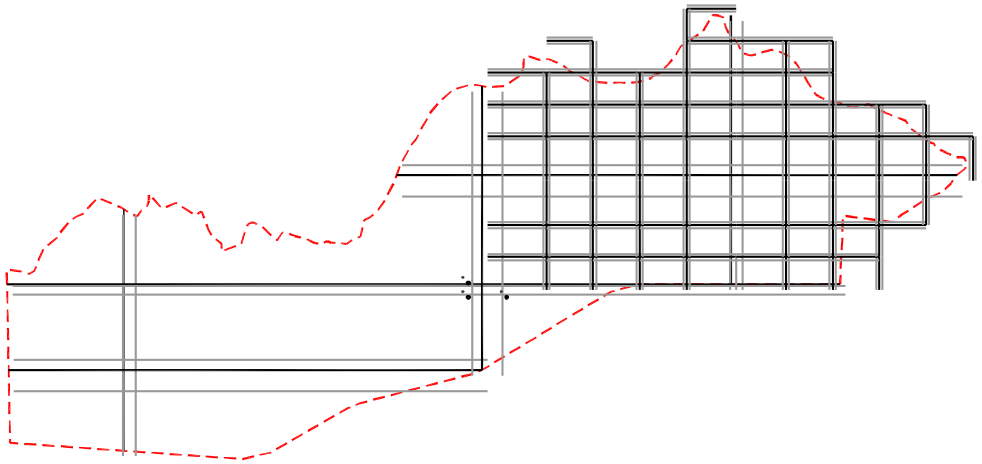

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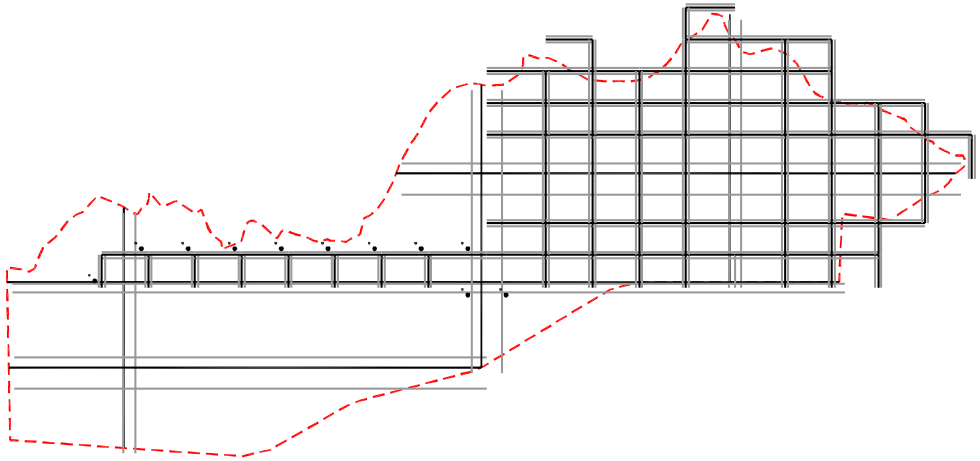

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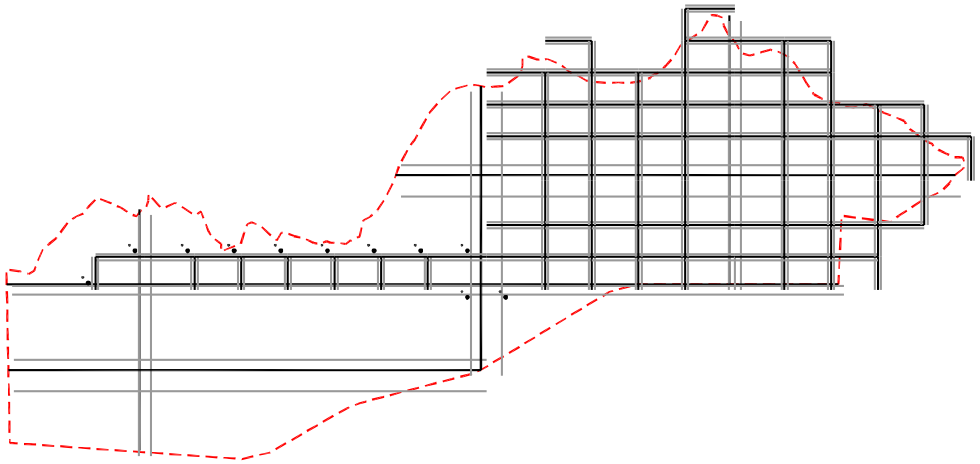

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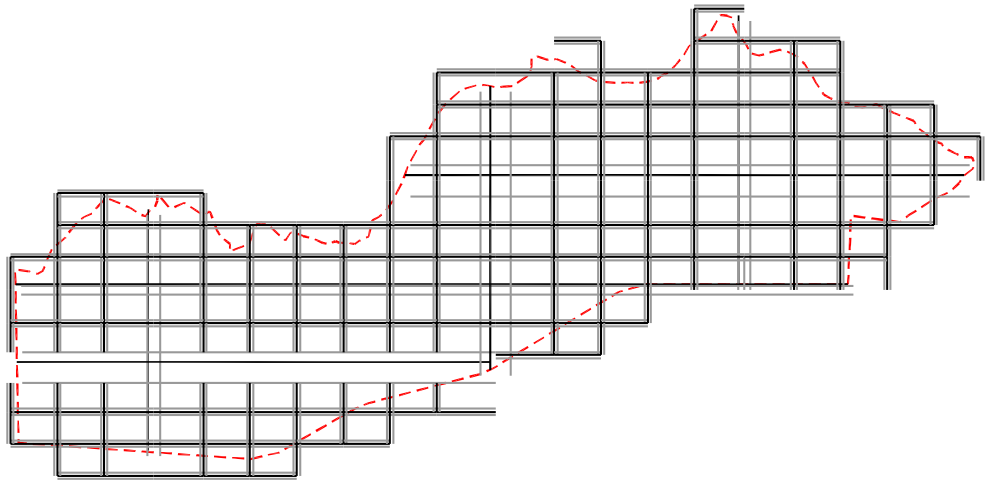

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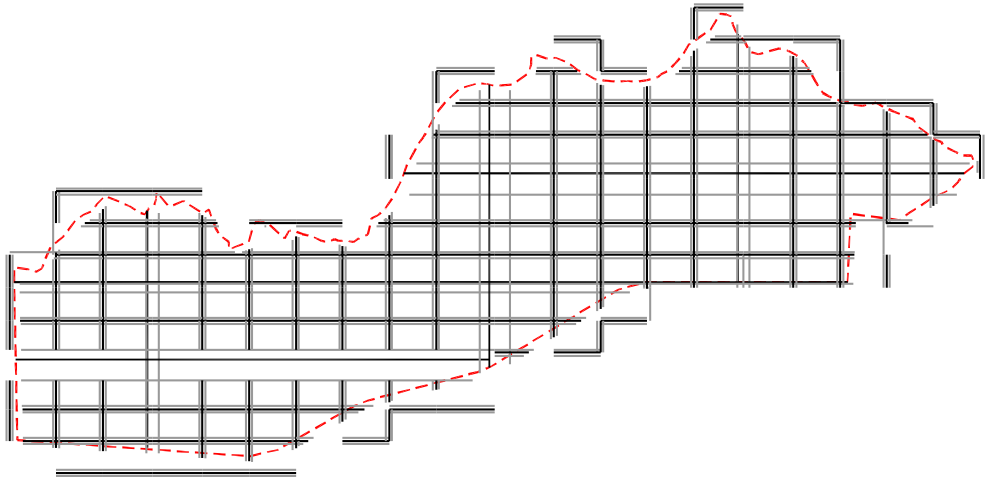

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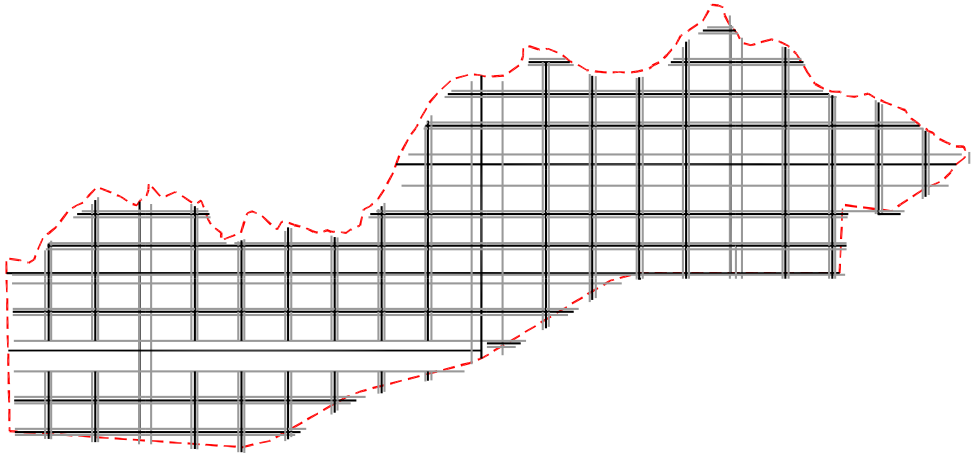

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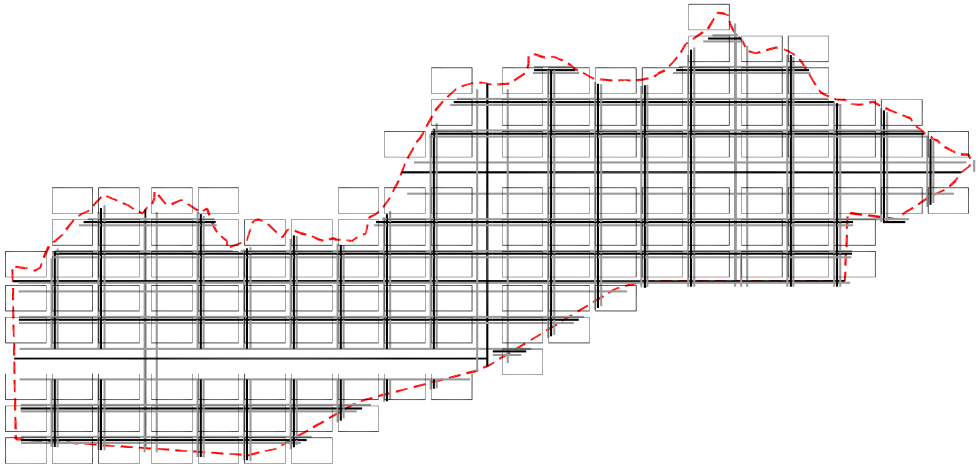

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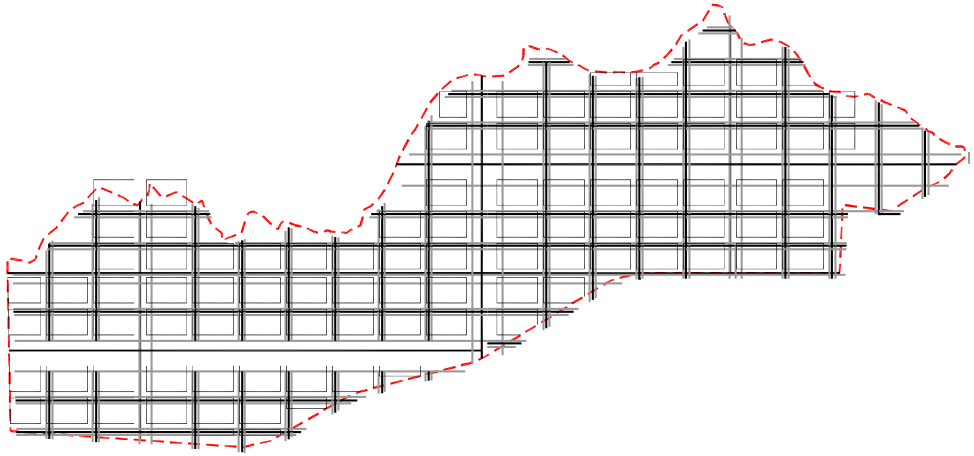

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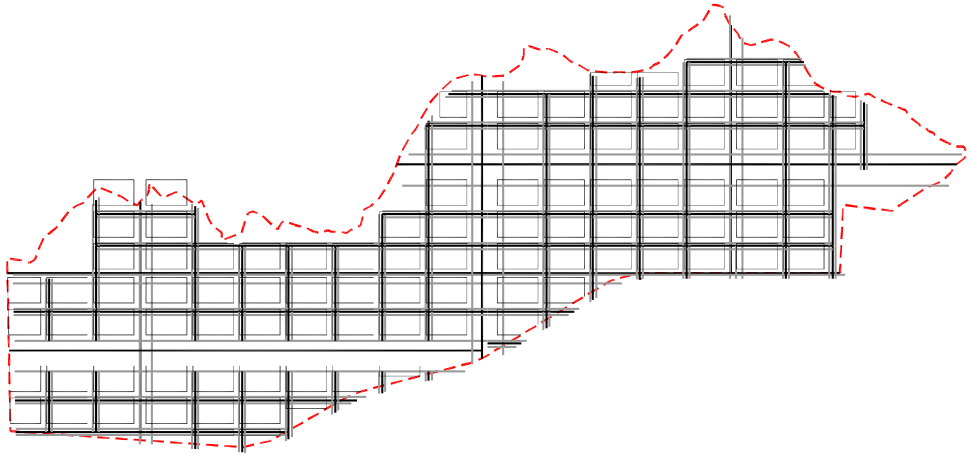

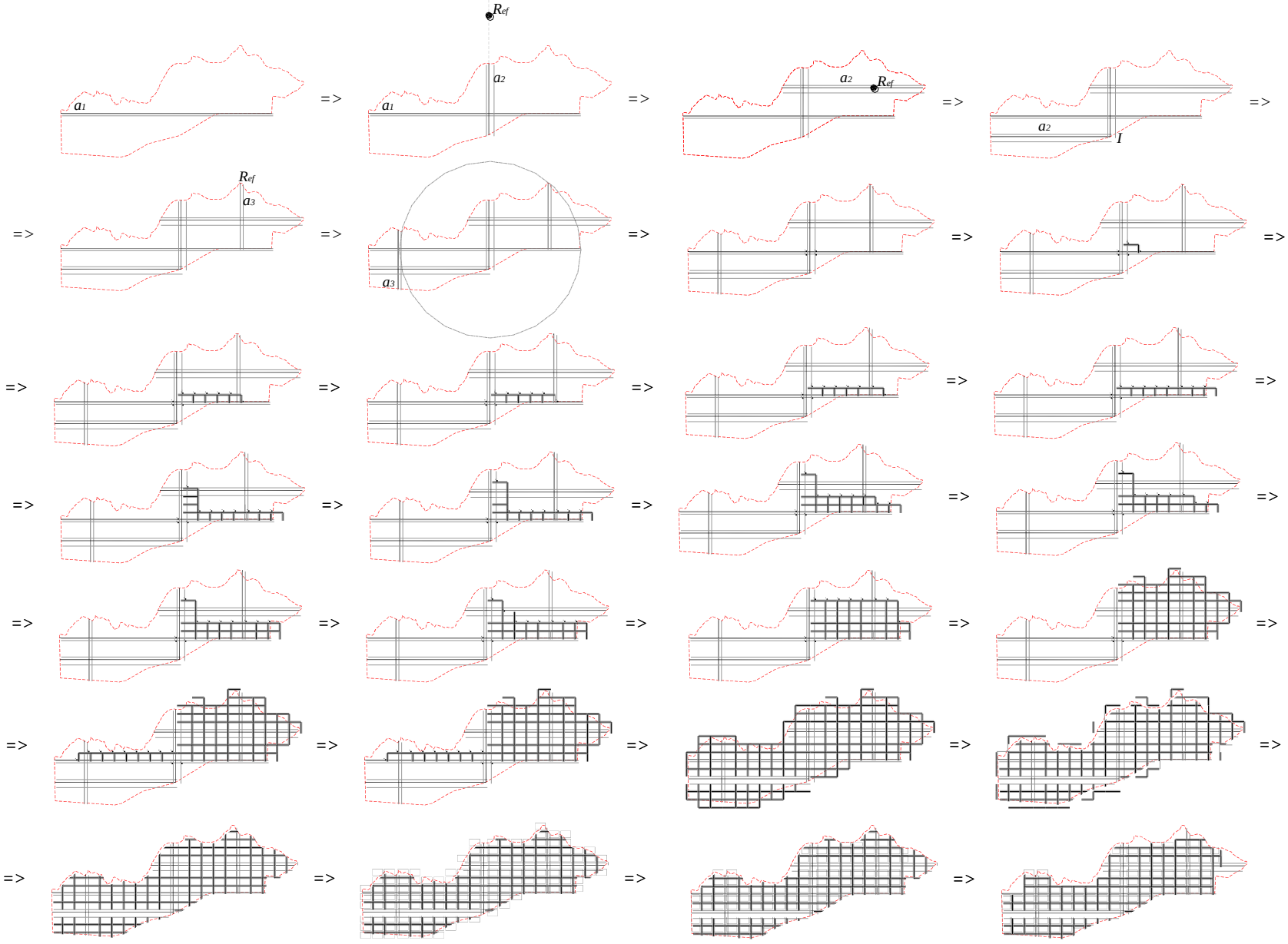
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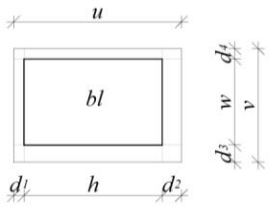
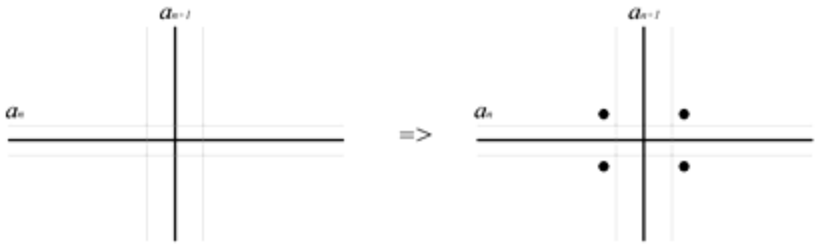


$$u = d_1/2 + h + d_2/2$$
$$v = d_3/2 + w + d_4/2$$

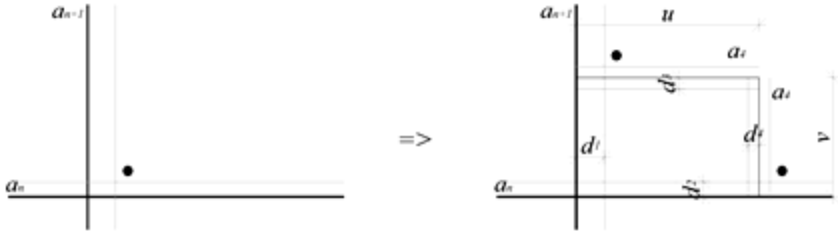
UIP 003 - Rules for adding cells one by one – *AddingBlockCells*

Rule 1 - places 4 ● labels in the crossing of a_n and a_{n+1} axes to start the generation process; it chooses the least n value, i.e. it takes an a_1 if present in the bounded area where it applies otherwise searches for the smallest n value.



$n \in \{1,2,3\}$

Rule 2 - erases ● label next to a crossroads defined by two axes of the type a_n and a_{n+1}, inserts a block with two a_4 axis segments and places two more ● labels to continue the generation



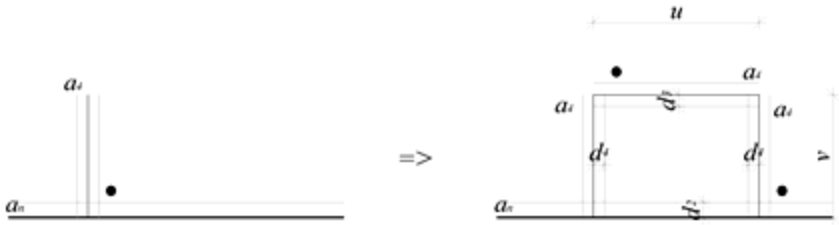
$d_1 = a_{n\_width}/2$ $\quad d_2 = a_{n+1\_width}/2$ $\quad n \in \{1,2,3\}$

$d_3 = a_{4width}/2$ $\quad d_4 = a_{4width}/2$

$u = d_1 + h + d_4$ $\quad v = d_2 + w + d_3$

l and h are respectively the block length and width

Rule 3 - erases ● label next to a crossroads defined by two axes of the type (horizontal) a_n and (vertical) a_4, inserts a block with two a_4 axis segments and places two more ● labels to continue the generation



$d_2 = a_{n\_width} / 2 \qquad n \in \{1,2,3\}$

$d_3 = a_{4width} / 2 \qquad d_4 = a_{4width} / 2$

$u = h + 2d_4 \qquad v = d_2 + w + d_3$

l and h are respectively the block length and width

Rule 4 - erases ● label next to a crossroads defined by two axes of the type (vertical) a_n and (horizontal) a_4, inserts a block with two a_4 axis segments and places one more ● label to continue the generation

$d_1 = a_{n\_width} / 2 \qquad n \in \{1,2,3\}$

$d_3 = a_{4width} / 2 \qquad d_4 = a_{4width} / 2$

$u = d_1 + h + d_4 \qquad v = w + 2d_3$

l and h are respectively the block length and width

Rule 5 - erases ● label next to a (vertical) a_4 axis, inserts a block with two a_4 axis segments and places one more ● label to continue the generation

$d_3 = a_{4width} / 2 \qquad d_4 = a_{4width} / 2$

$u = h + 2d_4 \qquad v = w + 2d_3$

l and h are respectively the block length and width

Rule 6 - erases ● label next to a (horizontal) a_4 axis, inserts a block with two a_4 axis segments and places one more ● label to continue the generation

$d_3 = a_{4width} / 2$ $\quad$ $d_4 = a_{4width} / 2$

$u = h + 2d_4$ $\quad$ $v = w + 2d_3$

l and h are respectively the block length and width

Rule 7 - erases ● labels falling outside the bounded area or intervention site limit.

$\forall \bullet \not\subset I_s$

where I_s is the Intervention Site Limit

Rule 8 - Trims axes outside the intervention site. The label I_s indicates the inside side of I_s polygon.

$\forall a_4 \cap I_s$

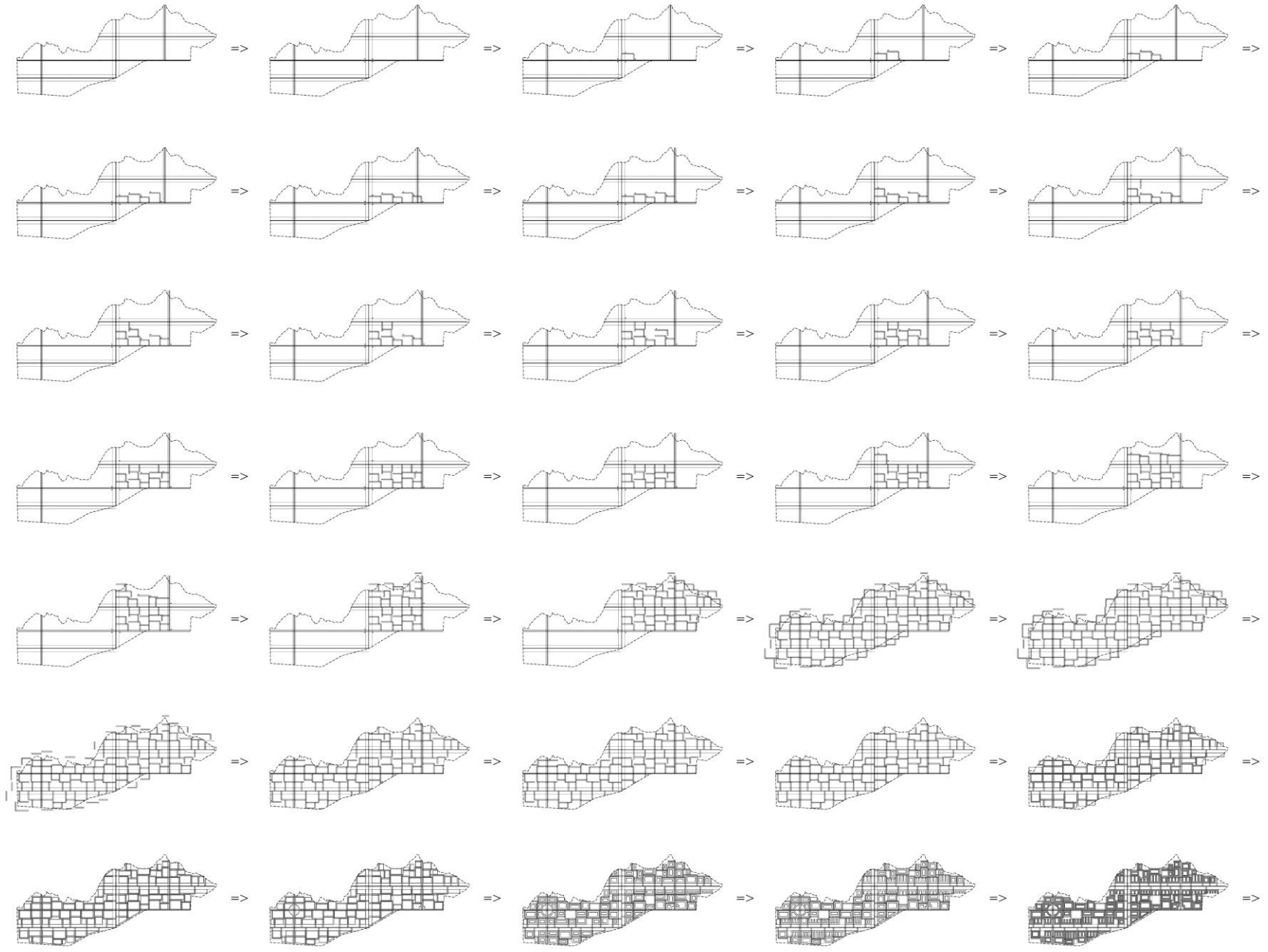
where I_s is the Intervention Site Limit

Rule 9 - Erases axes outside the intervention site.

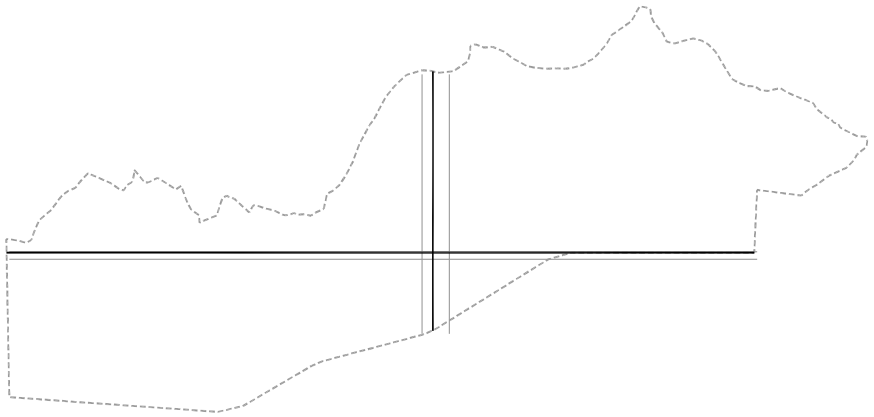
$\forall a_4 \not\subset I_s$

where I_s is the Intervention Site Limit

All symmetrical rule arrangements may be applied.



AddingAxes



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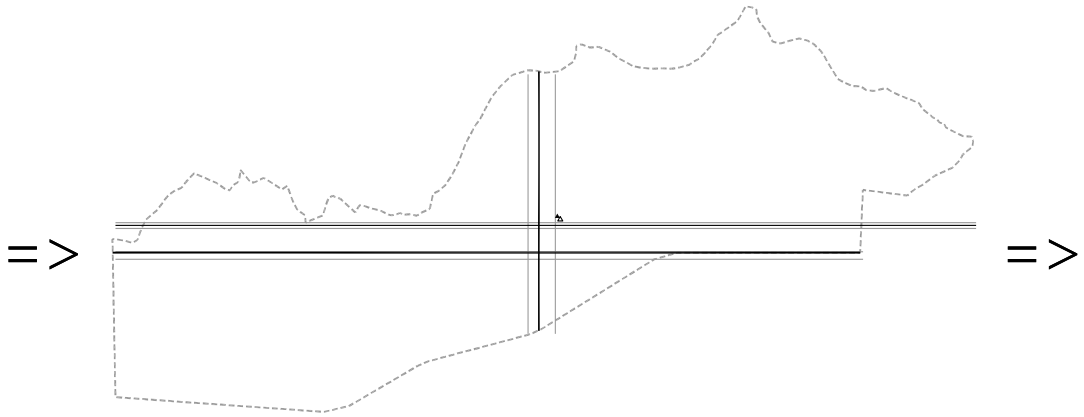

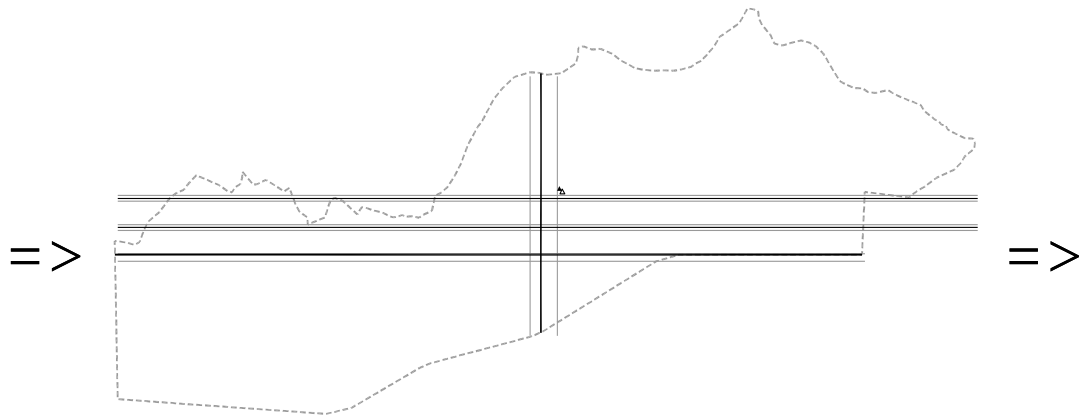

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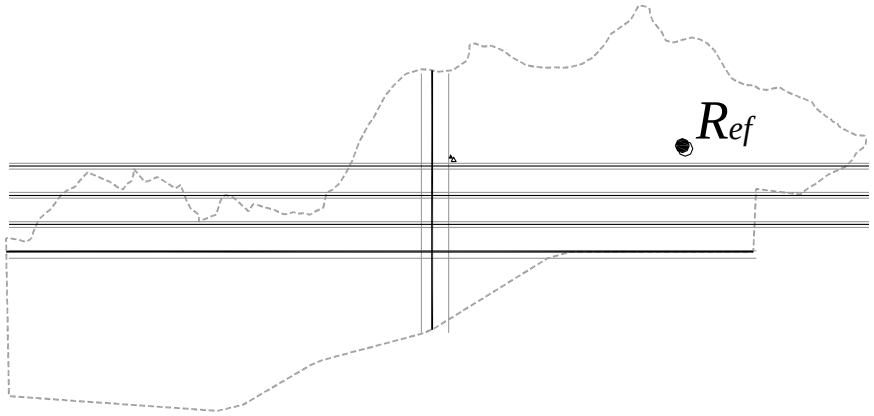
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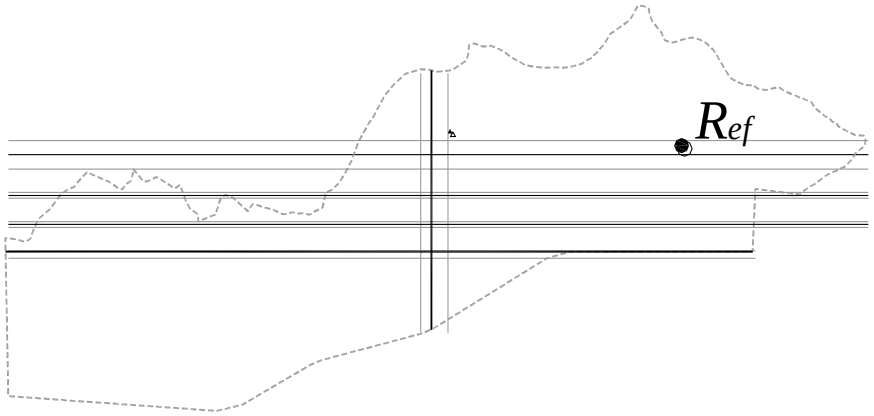
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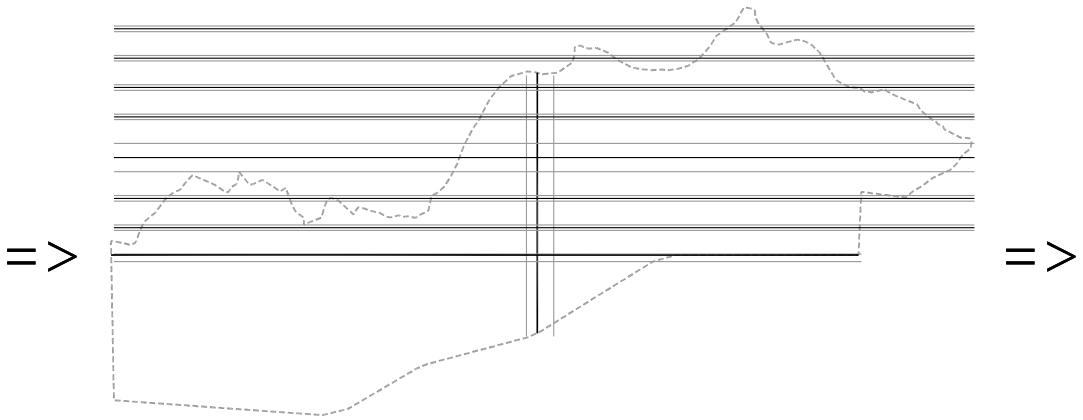
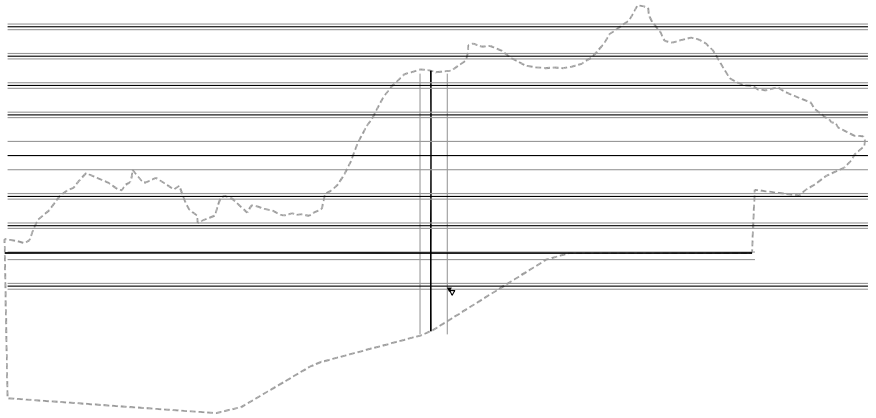
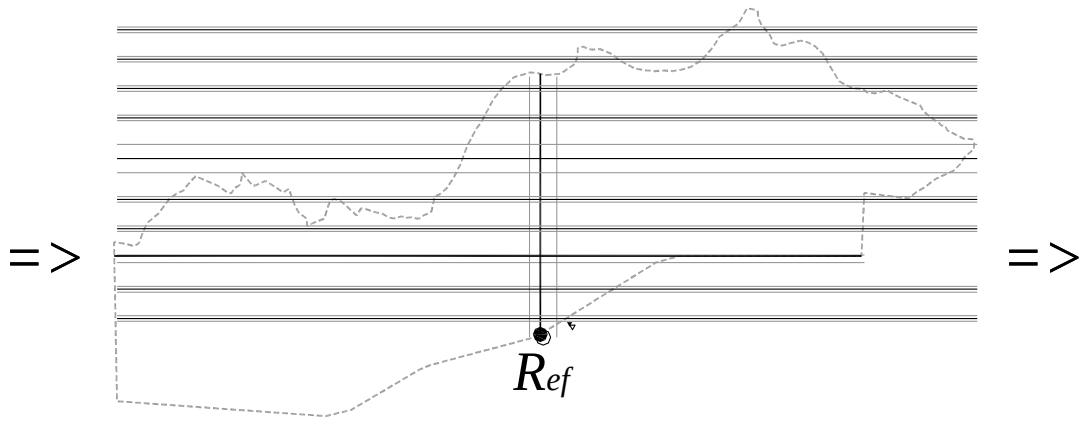


=>  =>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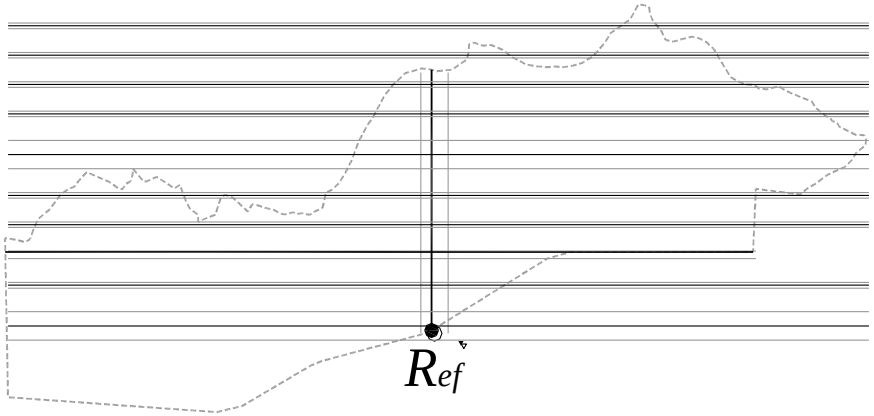
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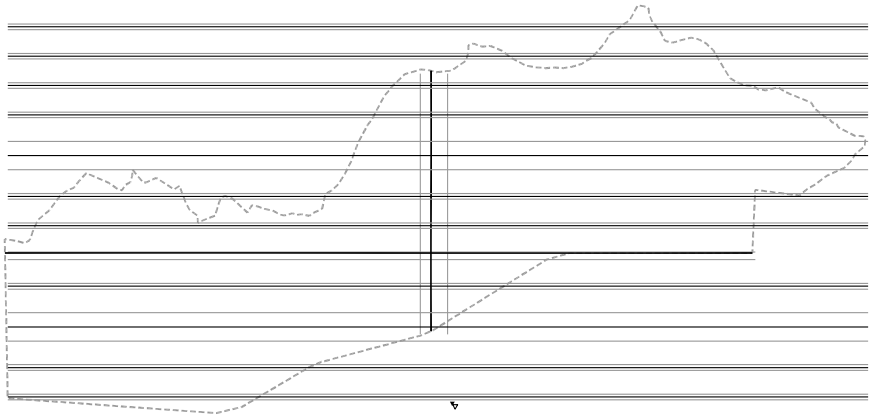

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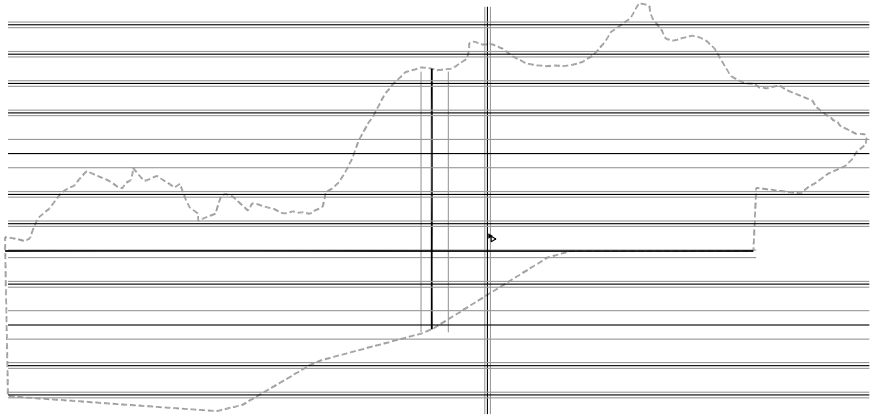

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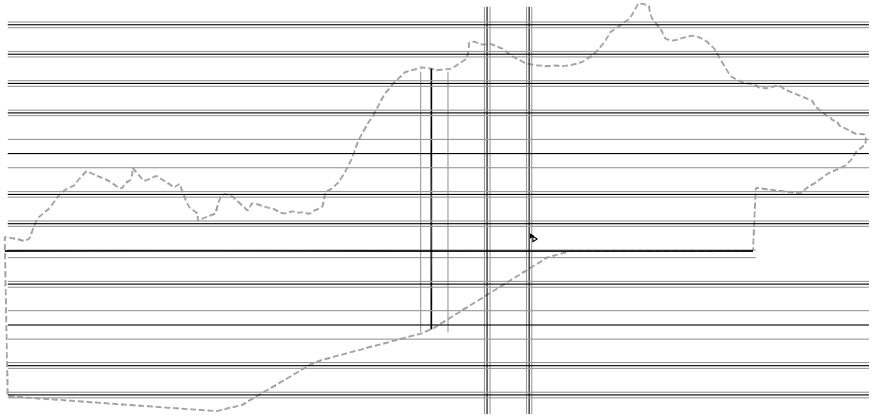

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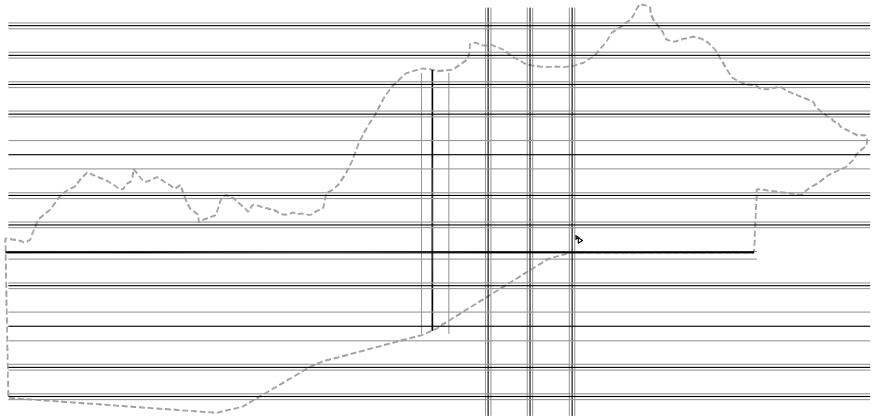

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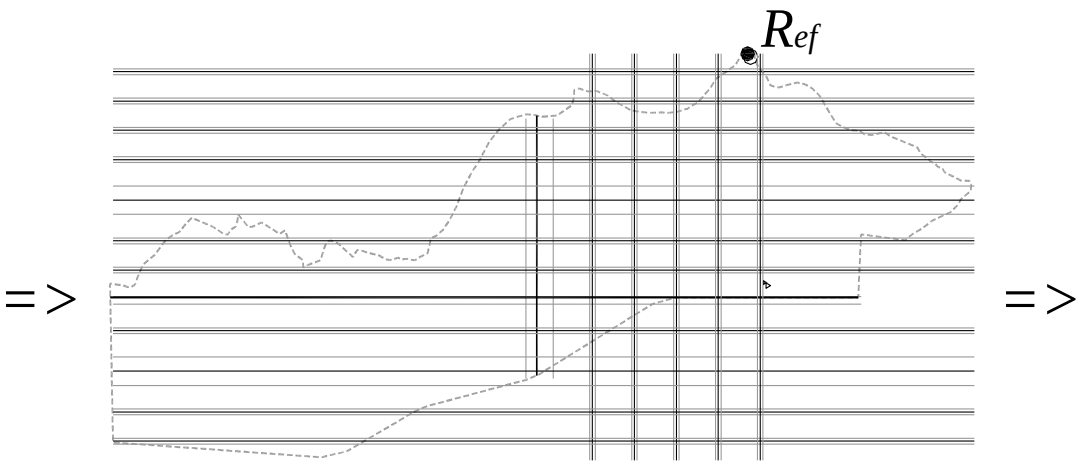
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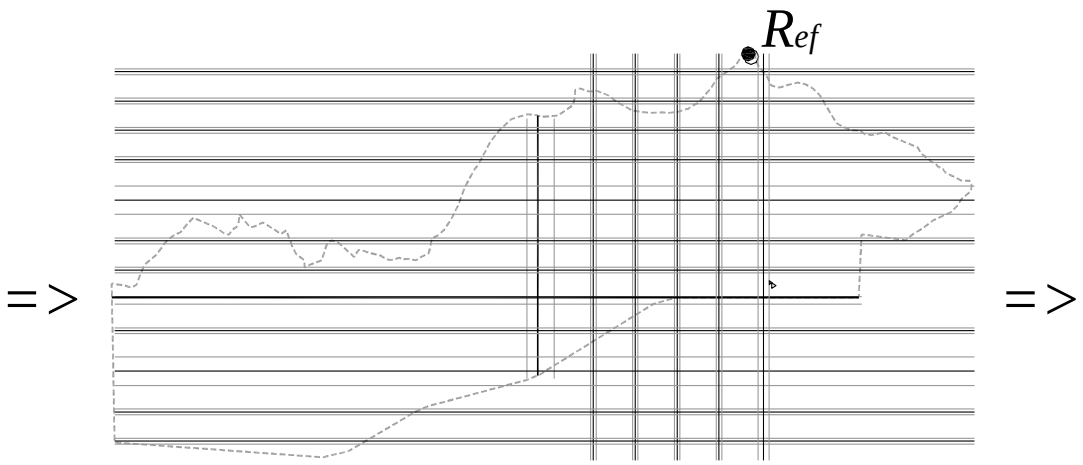
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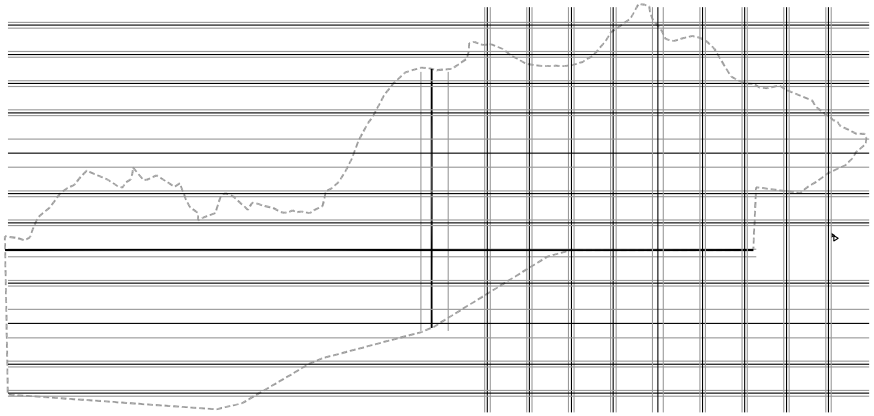

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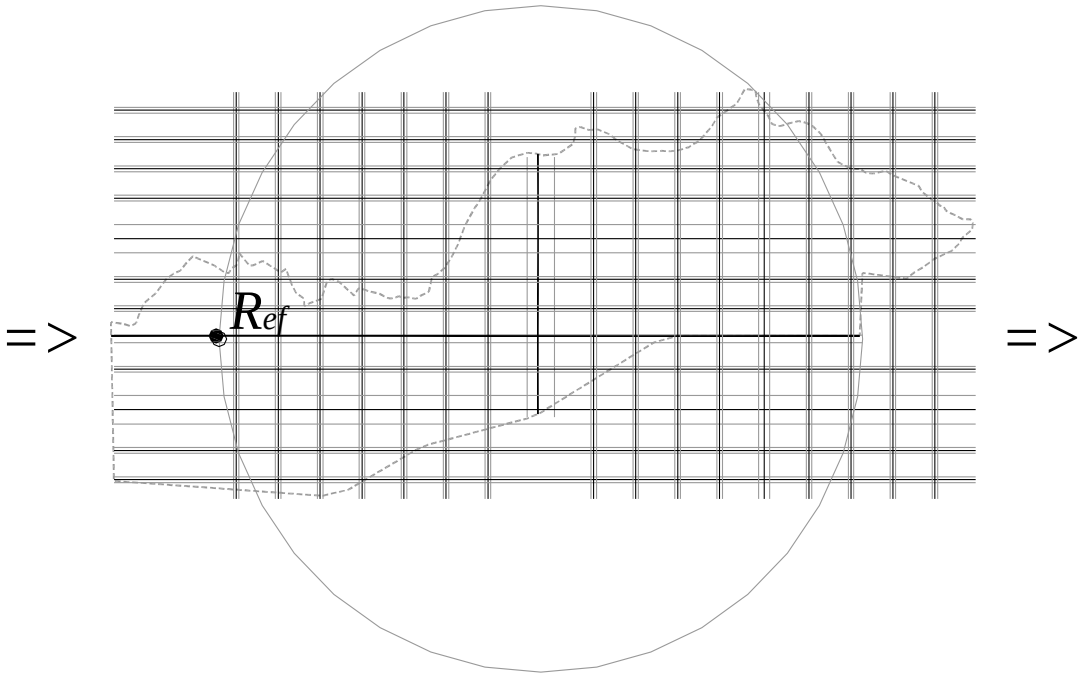
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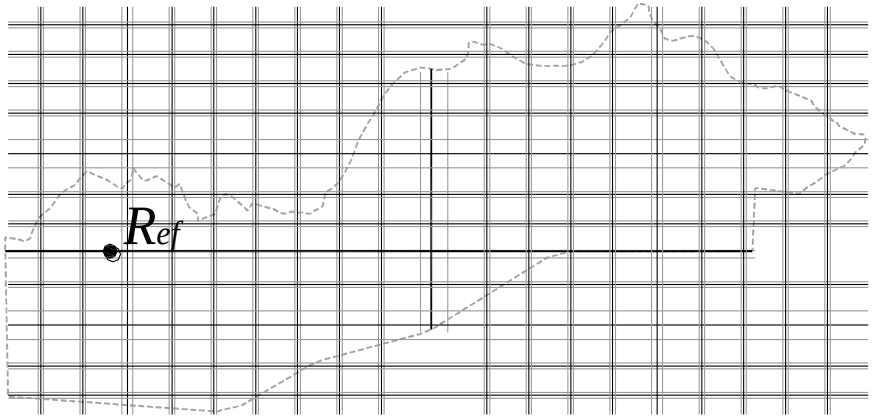
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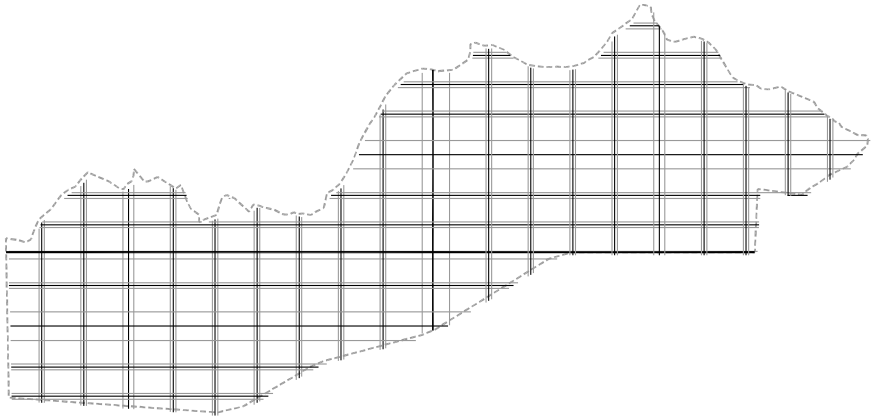

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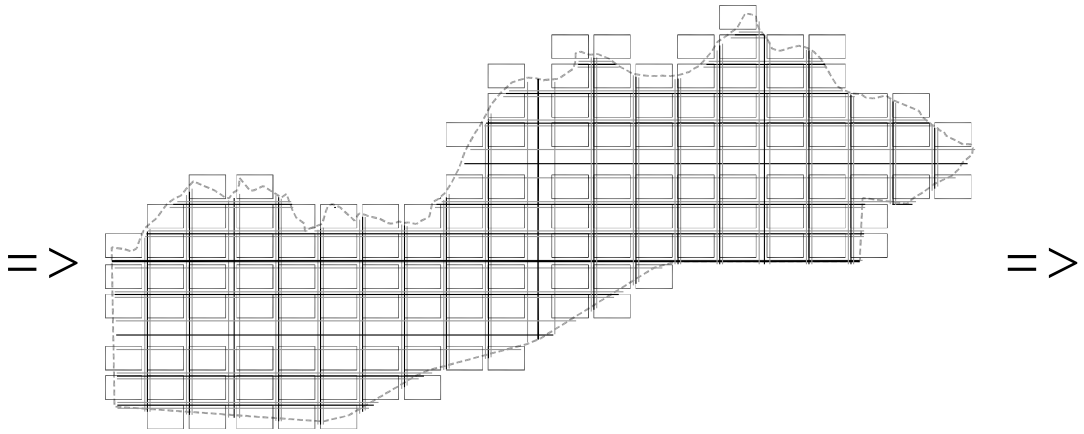

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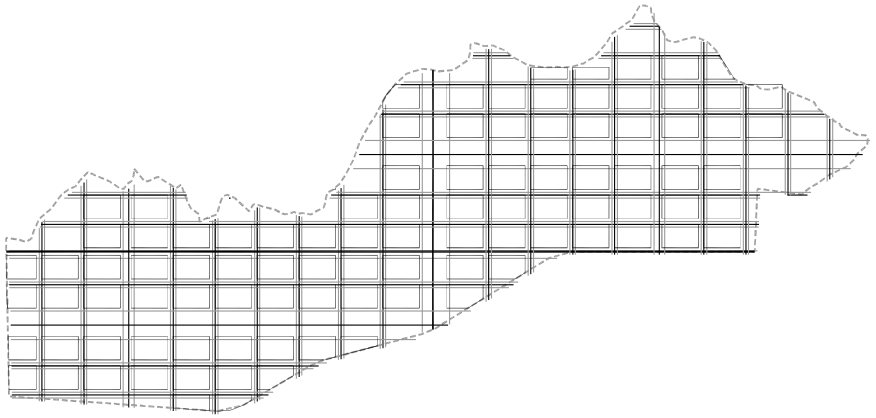

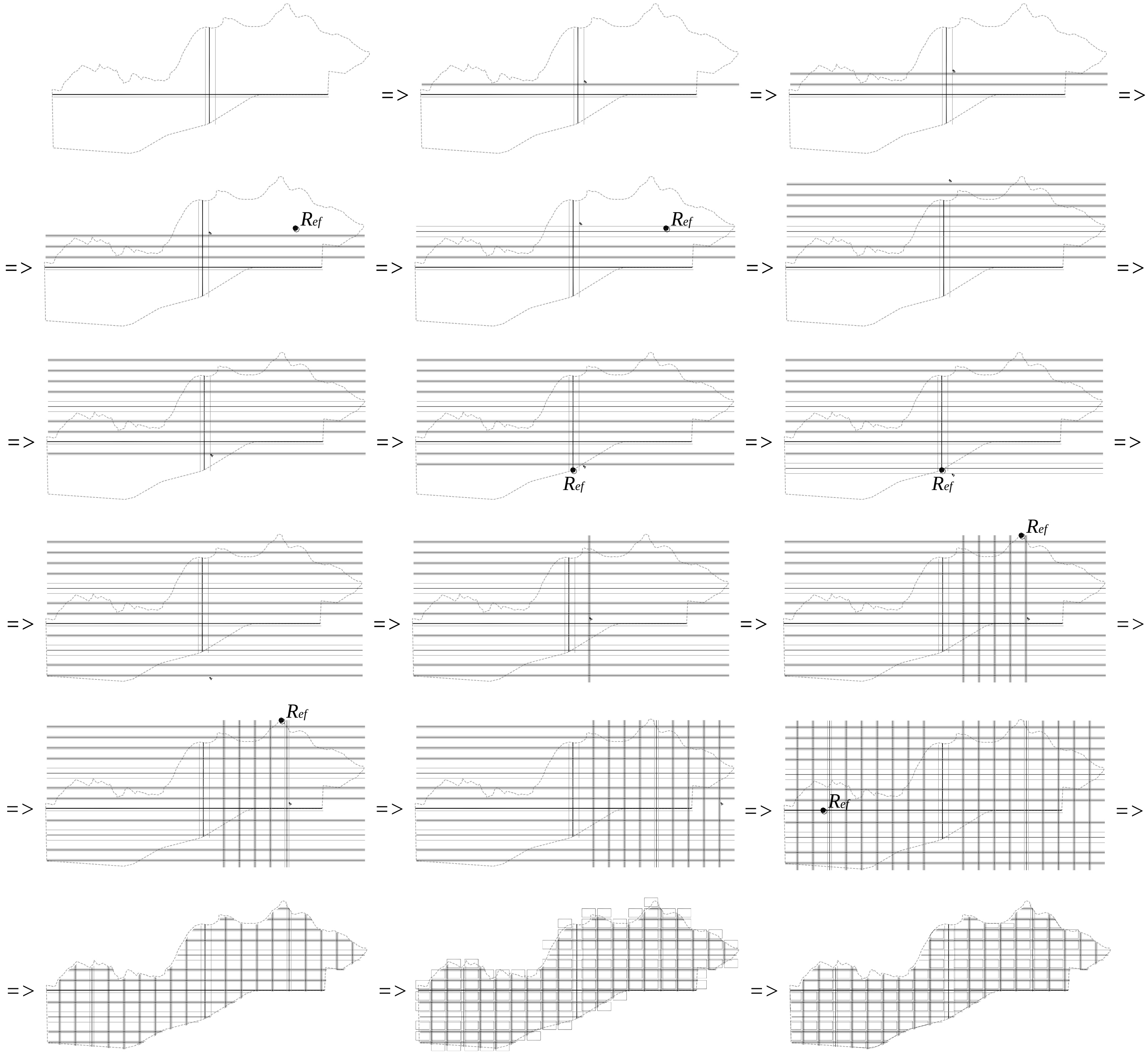

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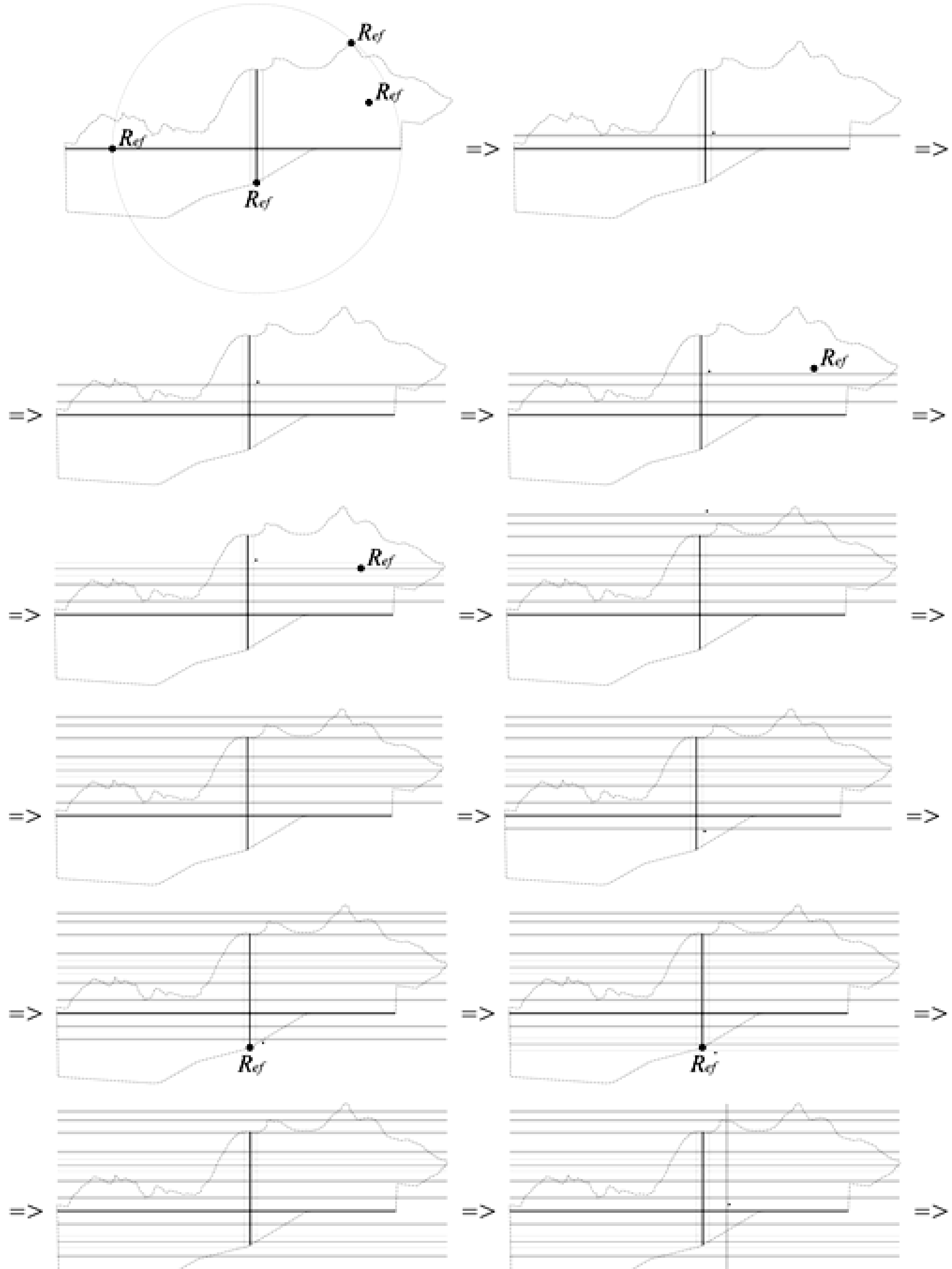
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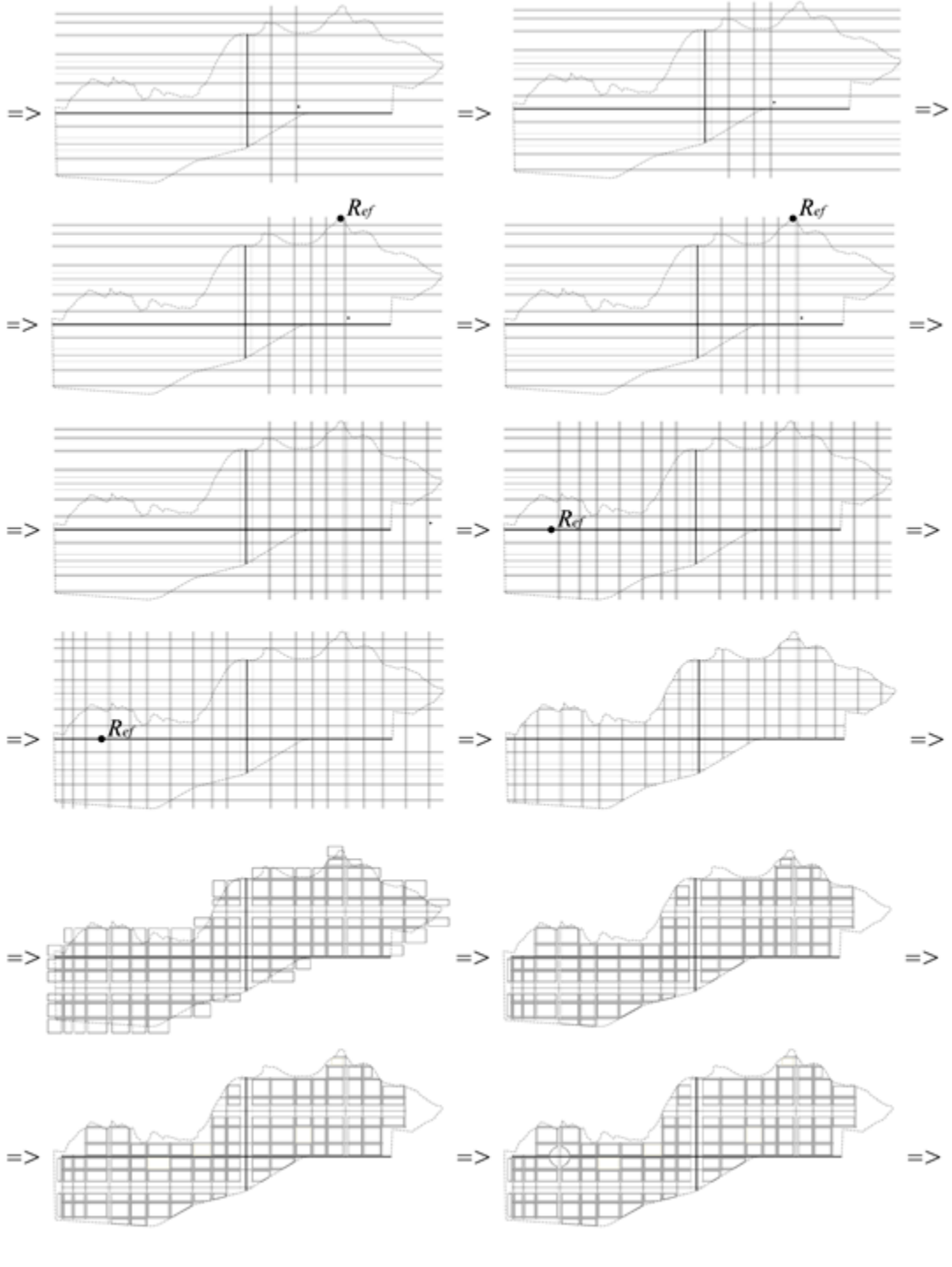
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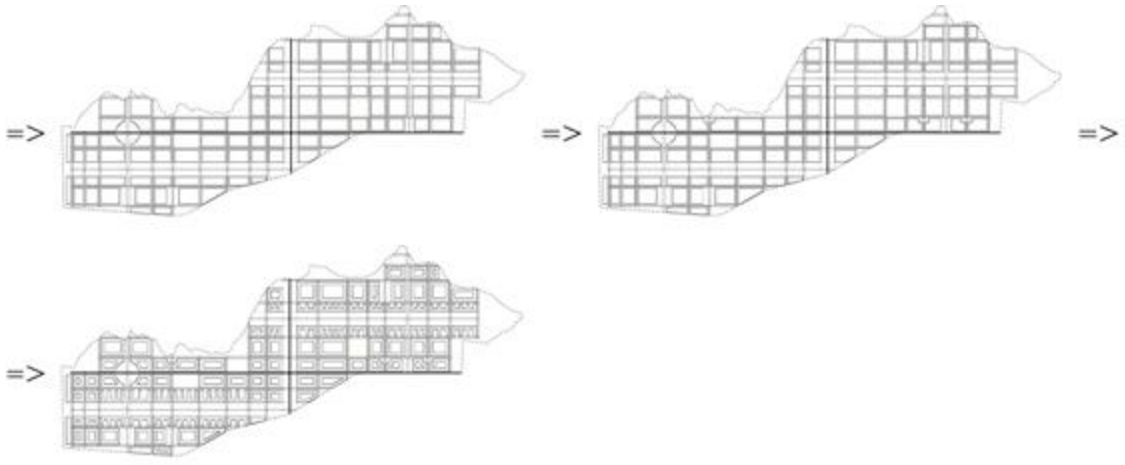
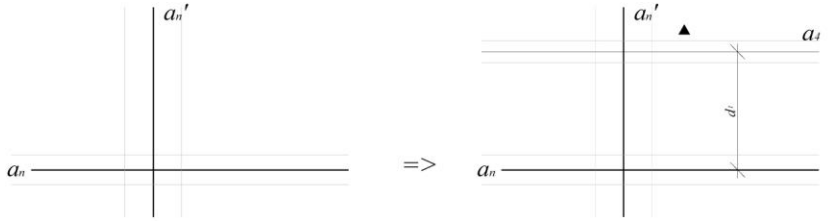


Rules for UIP

AddingAxes

Rule 3a



$a_4, a_n, a_n' \in \mathbf{AN}$, $n \in \{1,2,3\}$

$d_1 = w + a_{4\_width}/2 + a_{n\_width}/2$

w is the block width

$|a_4| = |\min x, \max x|$

Rule 4a

While $y<\max_y$

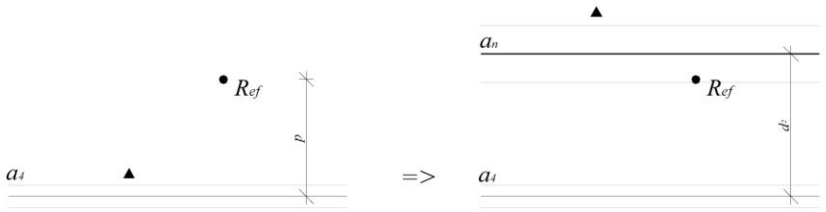
$a_4 \in \mathbf{AN}$

$d_2 = w + a_{4\_width}$

w is the block width

$|a_4| = |\min x, \max x|$

Rule 4c



If $\frac{1}{2}w - a_{4\_width} < p < \frac{3}{2}w + a_{4\_width}$

While $y<\max_y$

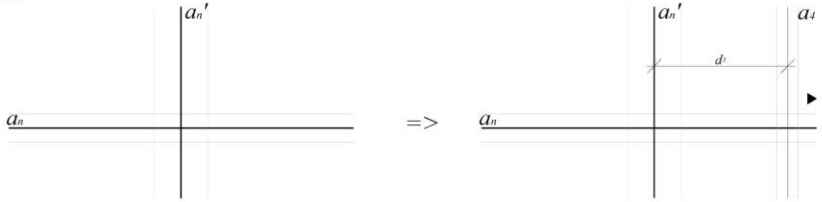
$a_4, a_n \in \mathbf{AN}$, $n \in \{1,2,3\}$

$d_2 = a_{4\_width}/2 + w + a_{n\_width}/2$

w is the block width

$|a_4| = |\min x, \max x|$

Rule 5a



$a_4, a_n, a_n' \in \mathbf{AN}$, $n \in \{1,2,3\}$

$d_3 = h + a_{4\_width}/2 + a_{n\_width}/2$

h is the block length

$|a_4| = |\min y, \max y|$

Rule 6a

While x<$\max_x$

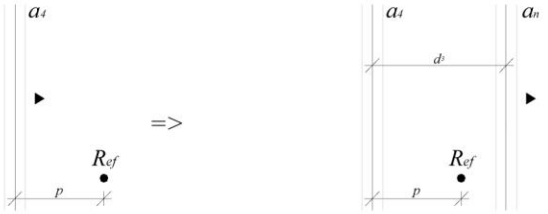
$a_4 \in \mathbf{AN}$, $n \in \{1,2,3\}$

$d_3 = h + a_{4\_width}$

h is the block length

$|a_4| = |\min y, \max y|$

Rule 6c



If $\frac{1}{2}h - a_{4\_width} < p < \frac{3}{2}h + a_{4\_width}$

While y<$\max_y$

$a_4, a_n \in \mathbf{AN}$, $n \in \{1,2,3\}$

$d_4 = a_{4\_width}/2 + h + a_{n\_width}/2$

h is the block length

$|a_4| = |\min x, \max x|$

Rule 8

$\forall a_n \in \mathbf{AN}$, $n \in \{1,2,3,4\}$

$a' = a_n \cap A_{site}$

Rules for UIP

AddBlockstoCells

Rule 1

$d_1 = a_{n\_width} / 2$ $d_2 = a_{n'\_width} / 2$ $d_3 = a_{n''\_width} / 2$ $d_4 = a_{n'''\_width} / 2$

Rule 2

$d_1 = a_{n\_width} / 2$ $d_2 = a_{n'\_width} / 2$ $d_3 = a_{n''\_width} / 2$

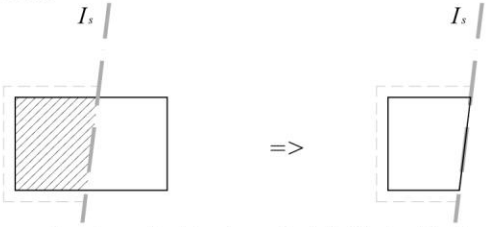
AdjustingBlockCells

UIP 005 - Rules for adjusting blocks that fall outside the boundary – *AdjustingBlockCells*

Rule 1 - Reduces the size of a block so that it fits inside the bounded area giving an additional buffer area corresponding to the width of the street a_n which is coincident with the border.

$s = a_{n\_width} / 2 \qquad n \in \{1,2,3,4\}$

Rule 2a - Reduces the size of a block so that it fits inside the bounded area - when no street is coincident with the border line



Rule 2b - Reduces the size of a block so that it fits inside the bounded area and creates an a_4 street

$s = a_{4\_width}$

Rule 3 - Reduces the size of a block so that it fits inside the bounded area giving an additional buffer area corresponding to the width of the street an which is coincident with the border

$s = a_{n\_width} / 2 \qquad n \in \{1,2,3,4\}$

Rule 4 - Reduces the size of a block so that it fits inside the bounded - when no street is coincident with the border line

w_s>12m

This value is an open variable defined by the memory bank. 12m is the value used bv Chuva.

Next rules are optional. Some sets of rules are mandatory although only one of the rules in the set may be applied - in this sense those are options for a mandatory set of rules. Rules 5-7 are a mandatory set for eliminating very small blocks - below standard values.

Rule 5 - Erases small blocks

If block area is smaller than 10% of the regular block size or smaller than a prefixed minimum block area or w_s<12m

Instead of erasing them, small blocks can be joined with others through rules:

Rule 6 - Joining small blocks - joining below minimum block with another incomplete block

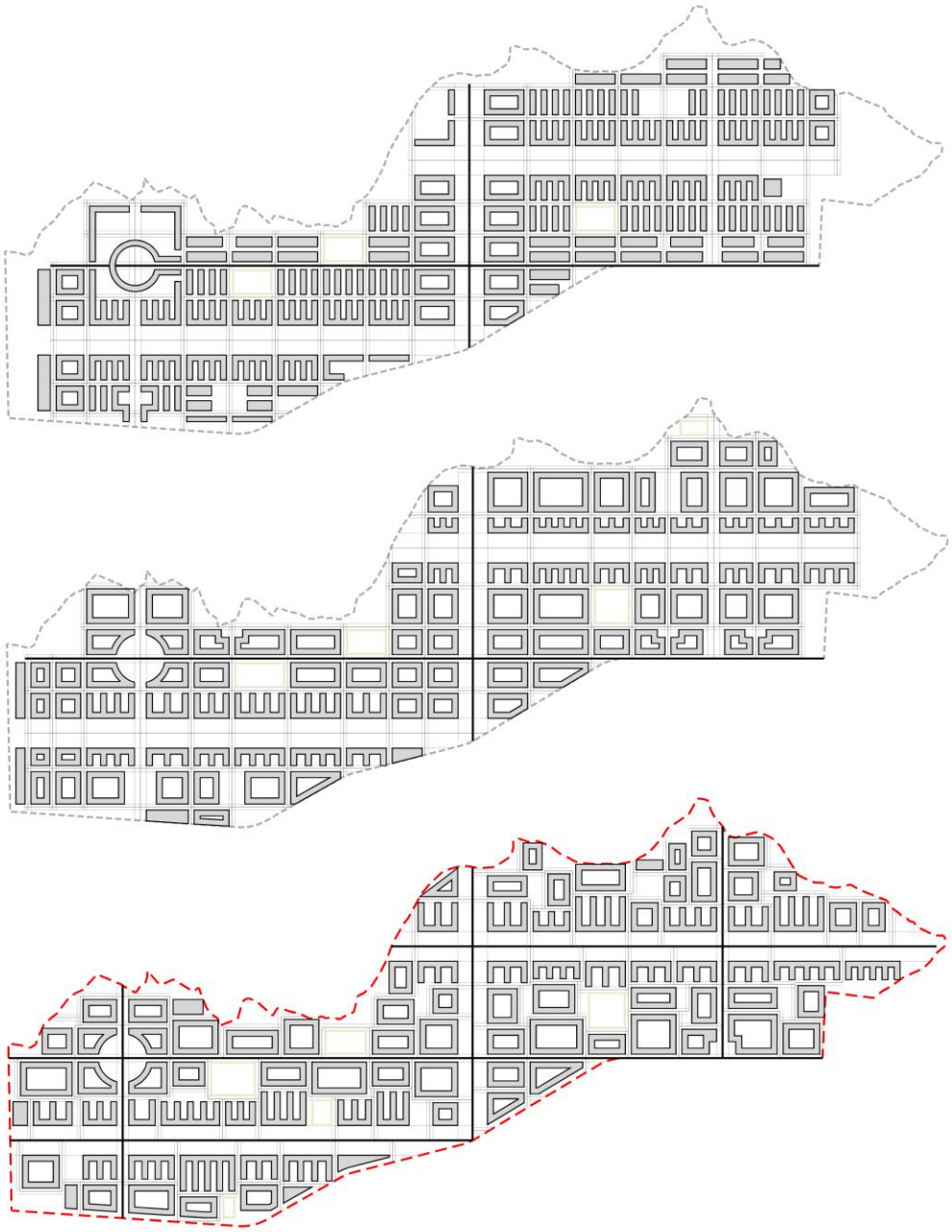
If block area is smaller than 10% of the regular block size or smaller than a prefixed minimum block area or w_s<12m

Rule 7 - Joining small blocks - joining below minimum block with complete block

If block area is smaller than 10% of the regular block size or smaller than a prefixed minimum block area or w_s<12m

Incomplete blocks can be joined together even when none of them is below the minimum block size.

Rule 8 - Joining small blocks - joining below minimum block with complete block



Contributions:

- The development of urban grammars along the urban design process by combining design patterns encoded as small grammars

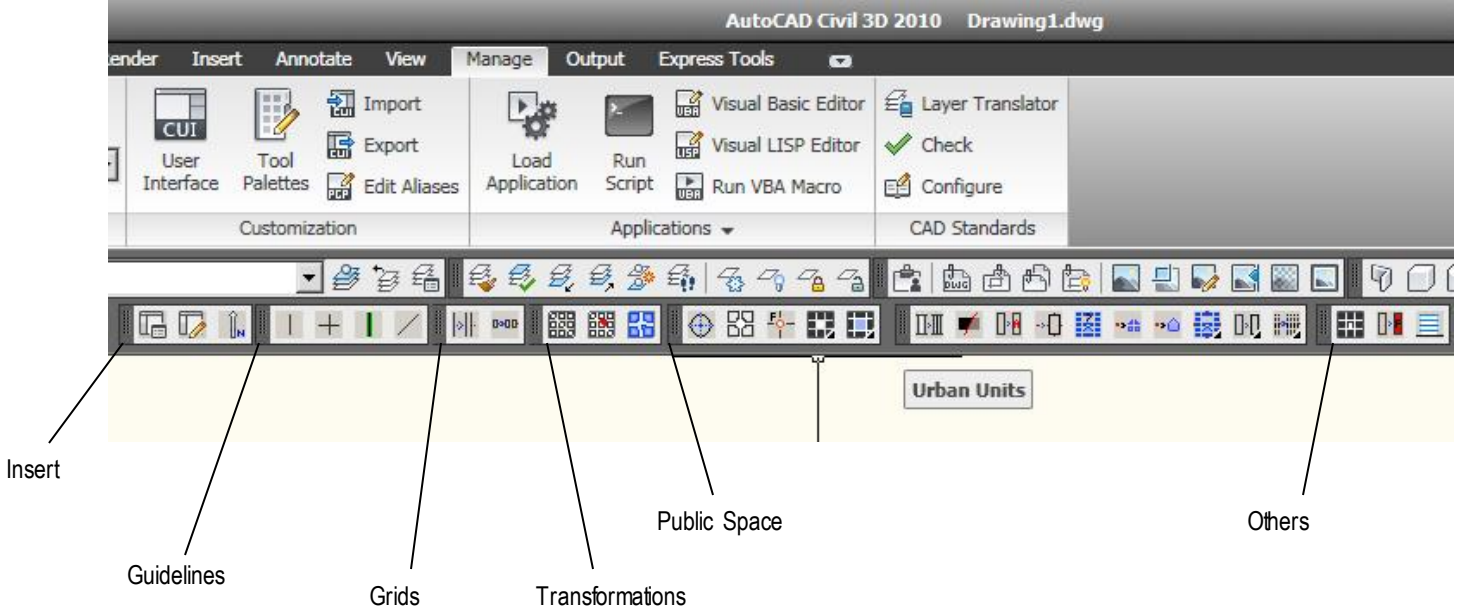
- The development of urban designs within a framework compatible with a GIS platform

The generation module

d. implementation

1 – in AutoCAD Civil3D

2 – Grasshopper in Rhinoceros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Tool Palettes
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Export
Edit Aliases
Customization
Load Application
Run Script
Visual Basic Editor
Visual LISP Editor
Run VBA Macro
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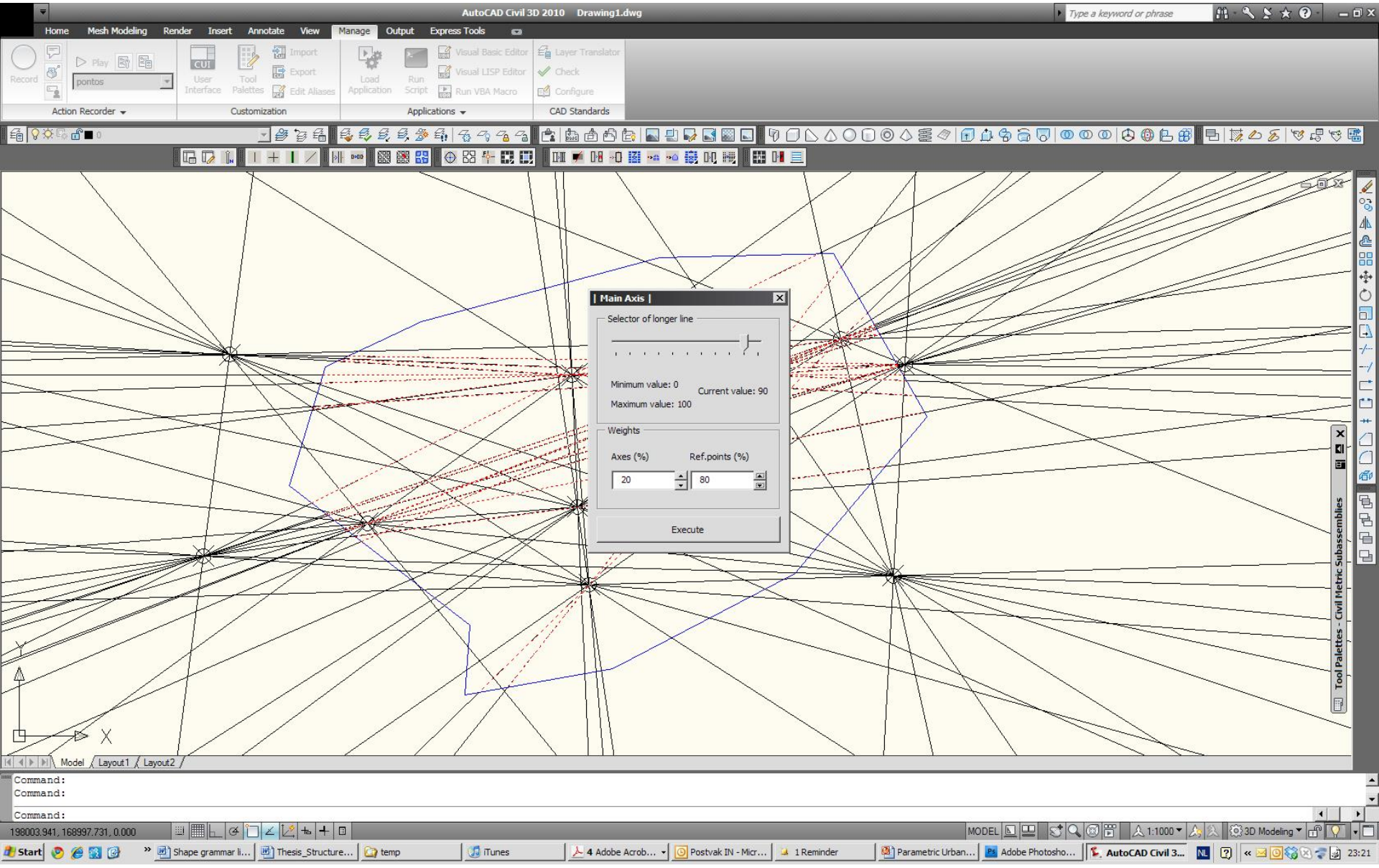
Layer Translator
Check
Configure
CAD Standards
Urban Units
Insert
Guidelines
Grids
Transformations
Public Space
Others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Maximum value: 100
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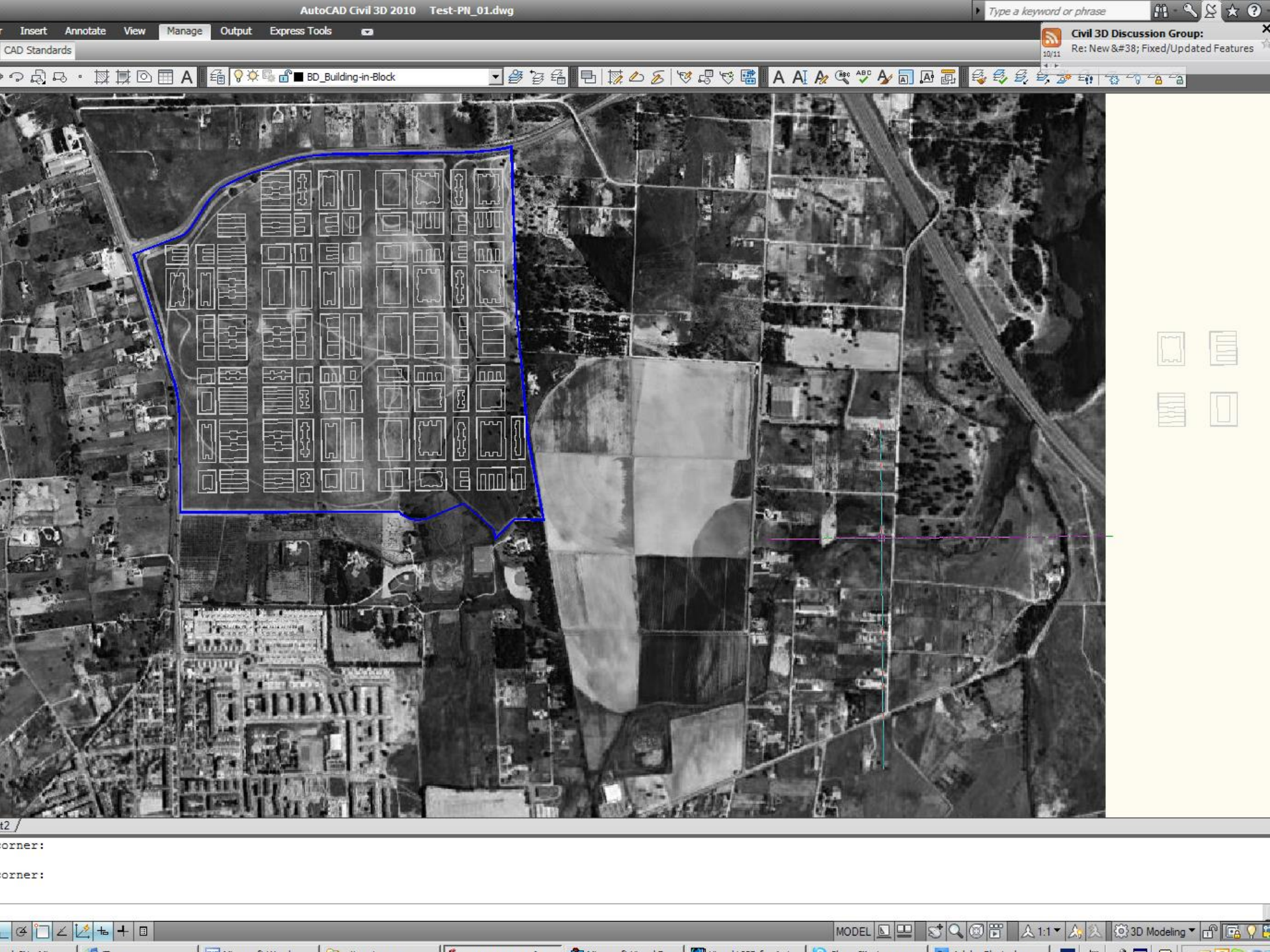
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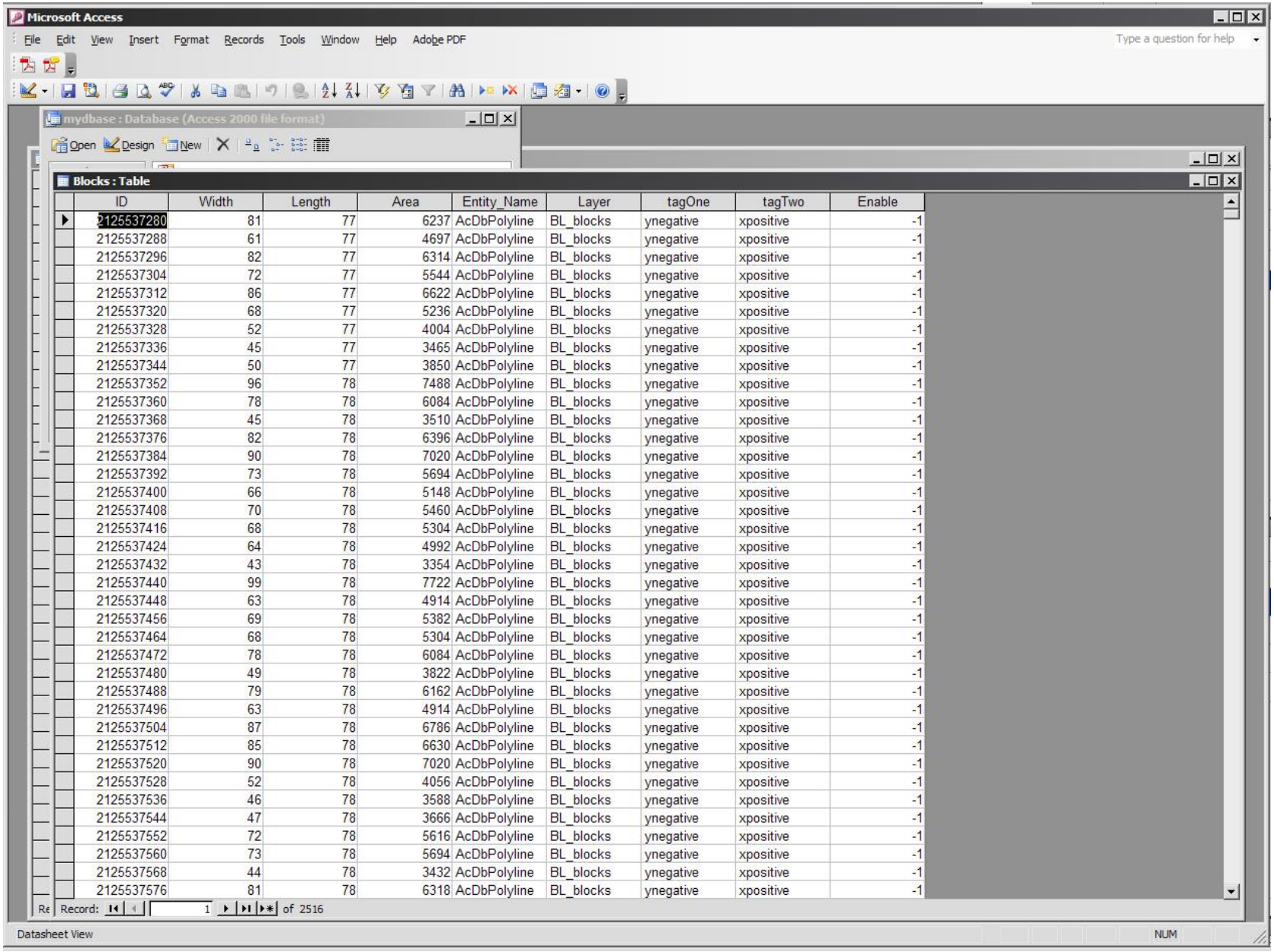
3D Modeling



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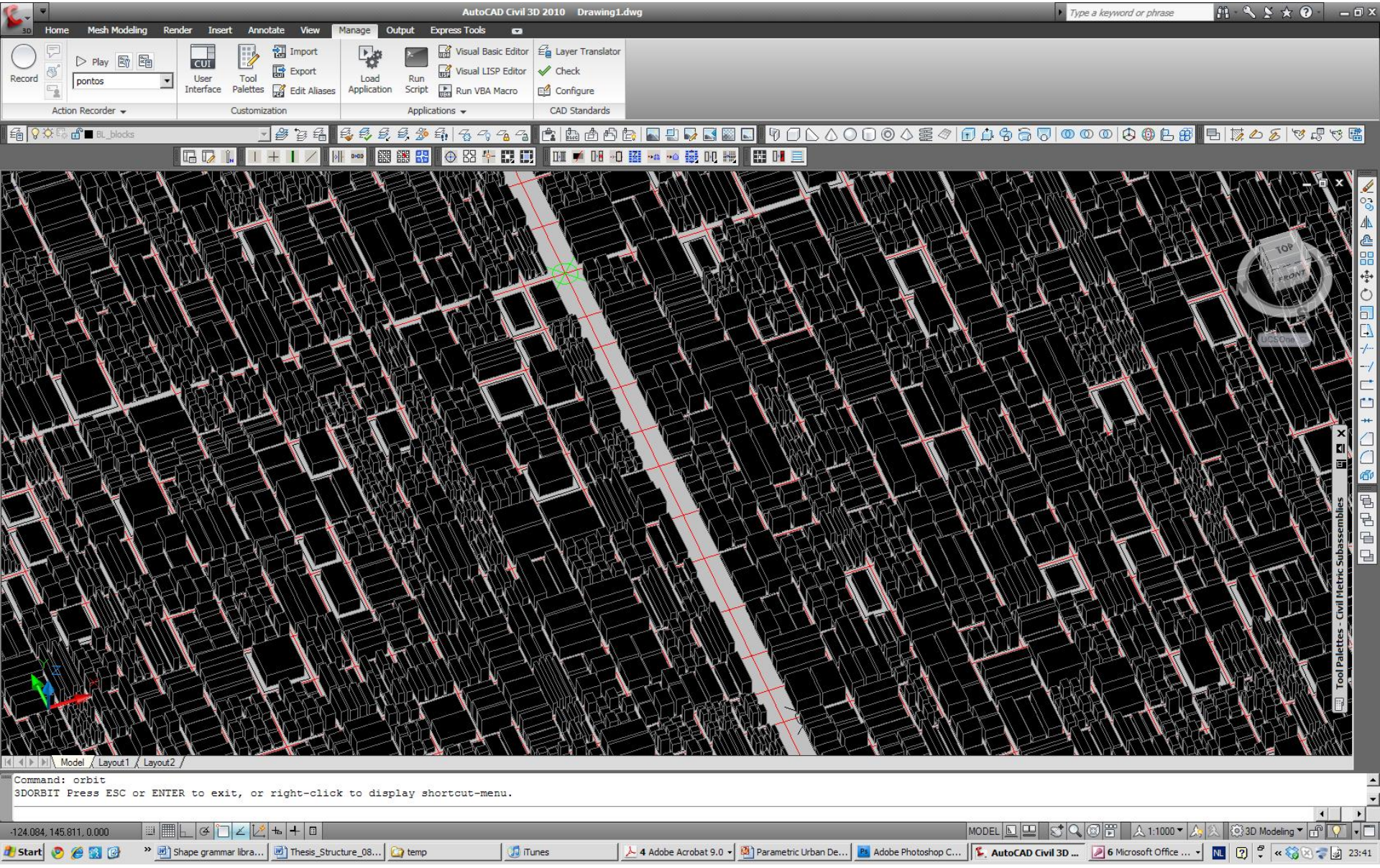
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Visual Basic Editor
Visual LISP Editor
Run VBA Macro
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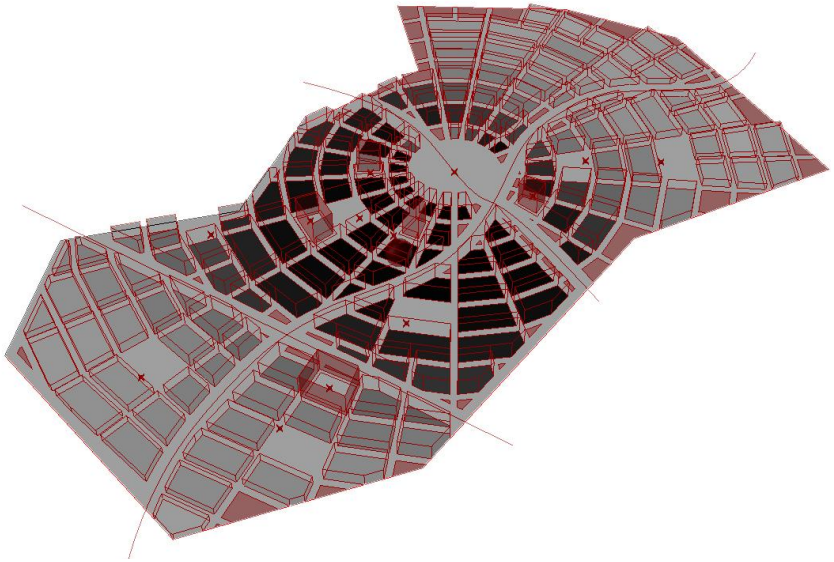
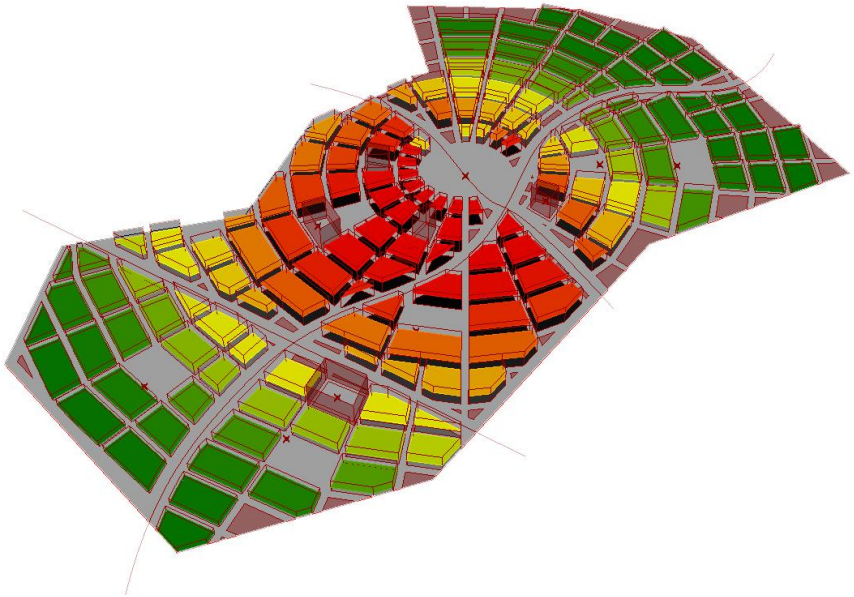




Part 2

Parametric Urban Design

an interactive Urban Design Tool

1. The opportunity

2. The concepts

3. The implementation

José Nuno Beirão (J.N.Beirao@tudelft.nl)
and
Pirouz Nourian (P.NourianGhadikolaee@tudelft.nl)

Bardia Mashhoodi (B.Mashhoodi@tudelft.nl)

1. The opportunity

2. The concepts

What is Parametric Urban Design?

It is design based on a support tool which:

- Adapts to the urban context.
- Is interactive. Responsive. Allows for continuous update on data and visualization.
- Informs the designer on morphology and data expressed by a set of indicators. The calculation of indicators is automatic.

- Indicators (Berghauser-Pont and Haupt, 2010):
    - FSI — building intensity — (at district and block level)
    - GSI — coverage — (at district and block level)
    - OSR — spaciousness — (at district and block level)
    - N — network density — (at district level)
    - PPI — parking performance index — (at district level)
    - B_d — total building footprint — (at district level)

3. The implementation

Method

Available parameters and controls

Initial geometries (drawn by the designer):

- Boundary
- Main Streets
- Main Square

Change and update:	Parameters:
• moving grip points	
• moving grip points	Street Width
• moving grip points	Size

Grid options:

Parameters:

- Rectangular grid
- Radial grid
- Rectangular dissection grid (recursive rectangular dissection rule)

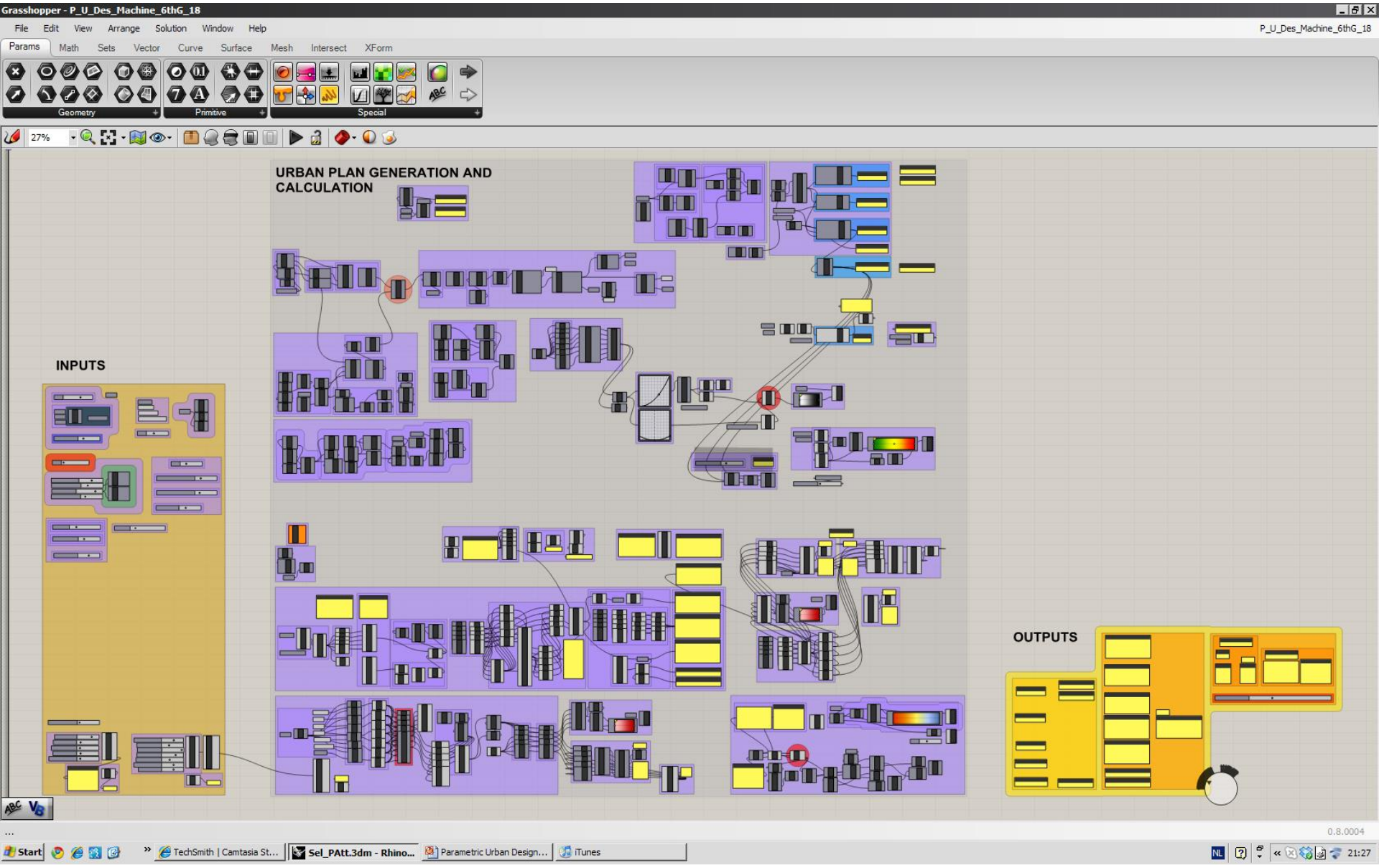
• Coordinates UV	Street Width
• Nr of Sectors / Nr of Rows	Street Width
• Maximum proportion / Minimum allowed area	Street Width

Local exceptions / filters:

- Local Squares
- Public Buildings
- Meaningless trimmed blocks

Local exceptions / filters:

- moving point
- moving point
- parameter controls the minimum accepted block size based on a percentage of the average block size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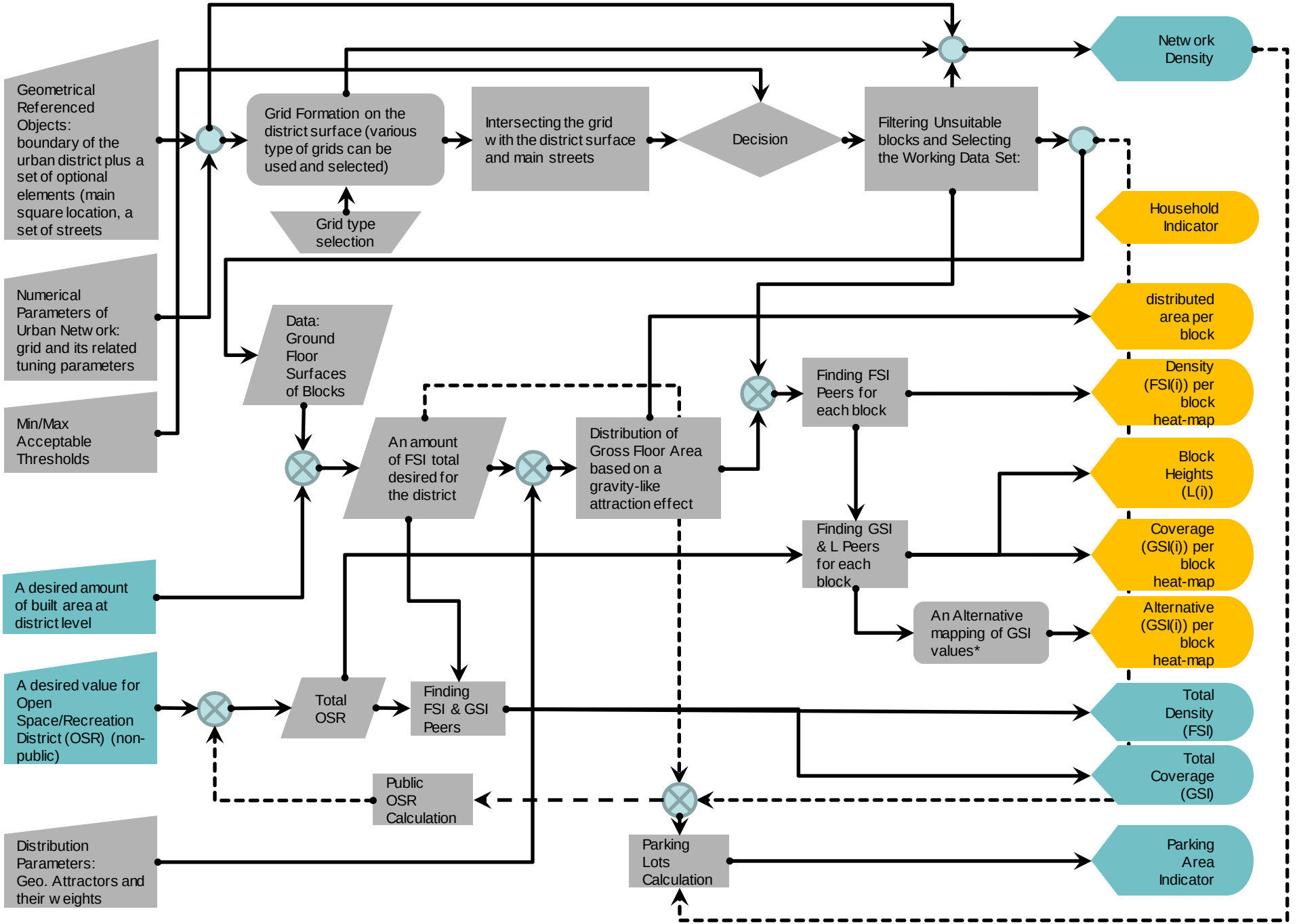
Flowchart of the Design System



Design Inputs (parameters)

Input geometry:

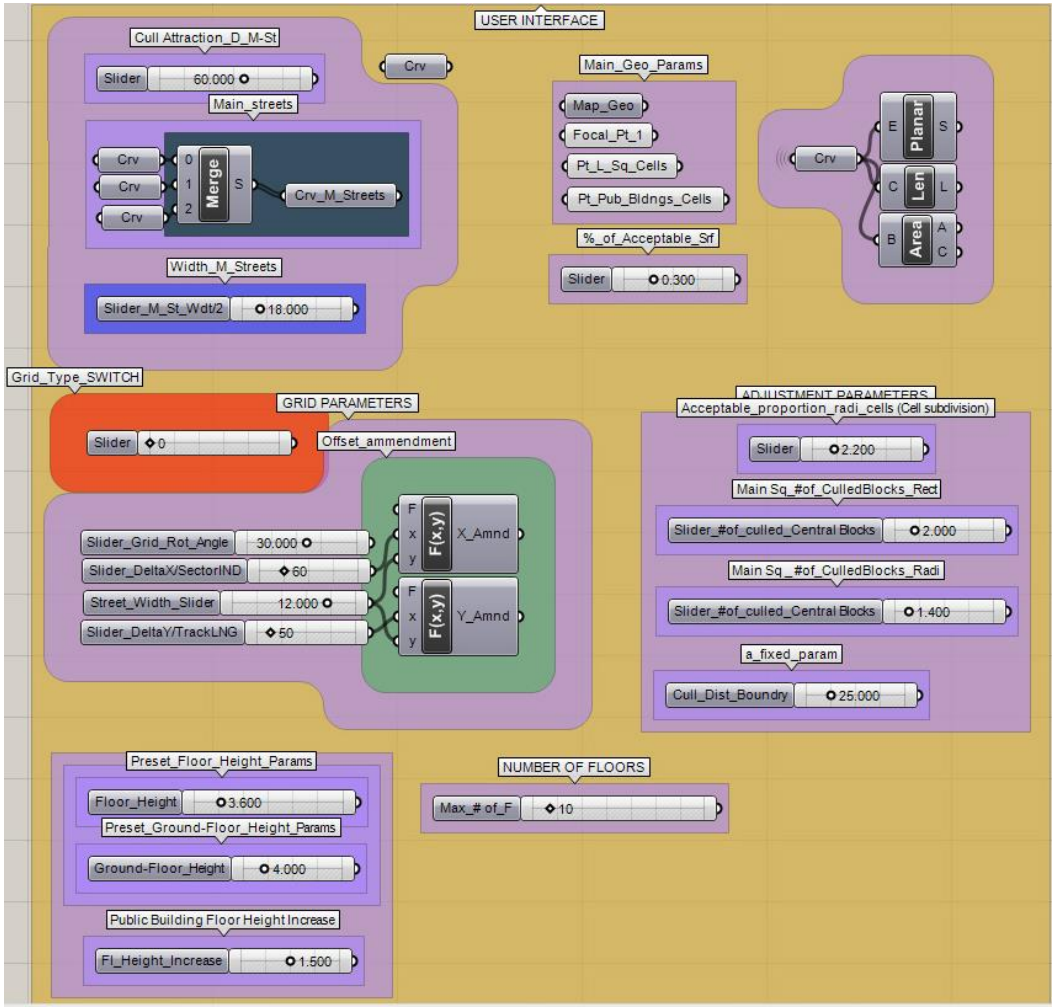
- Site Boundary (curve)
- Main Streets (curves)
- Squares (points)
- Public Buildings (points)

Grid Type

Grid Parameters

- Rotation
- Street width
- XY // Sector/Track

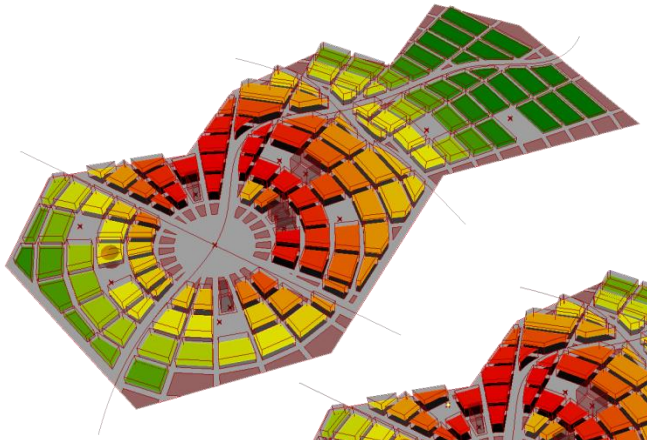
Number of floors and floor height



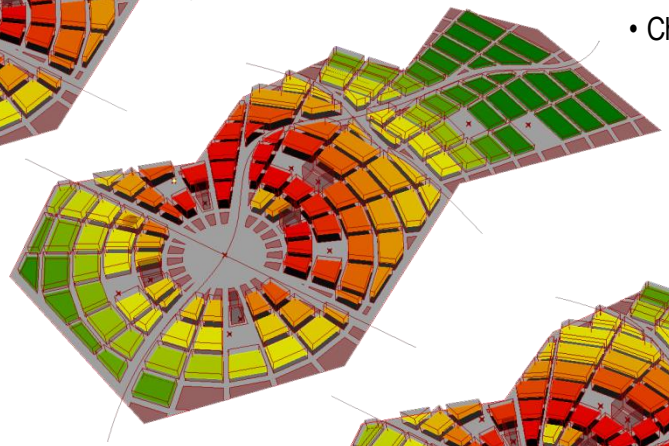
Adjustments:

to Boundary

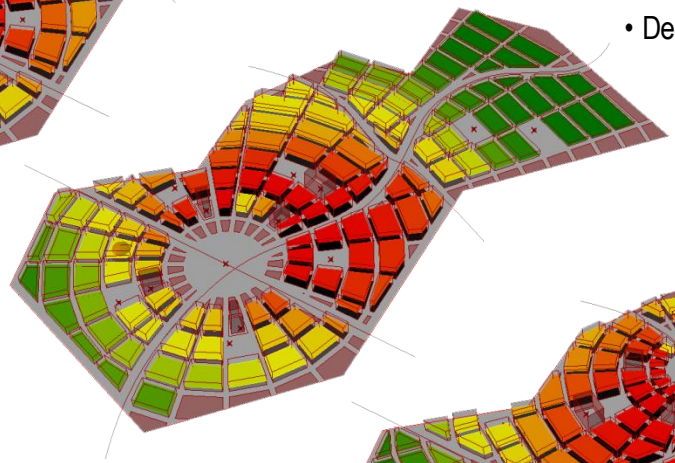
and Main Square



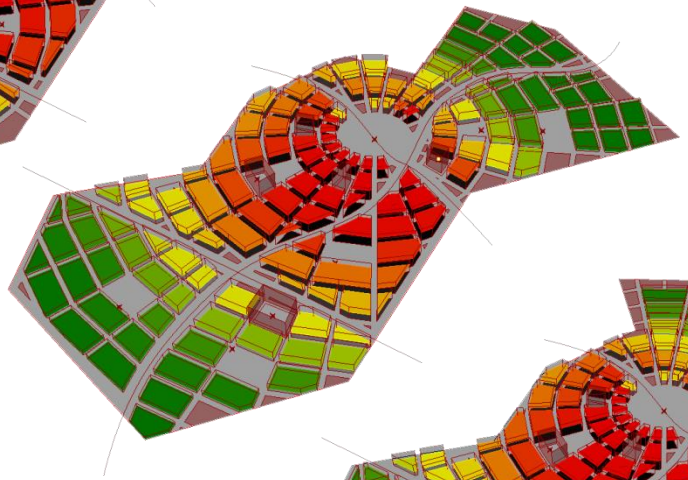
The design updates every time one of the geometrical entities is changed. It is possible to:



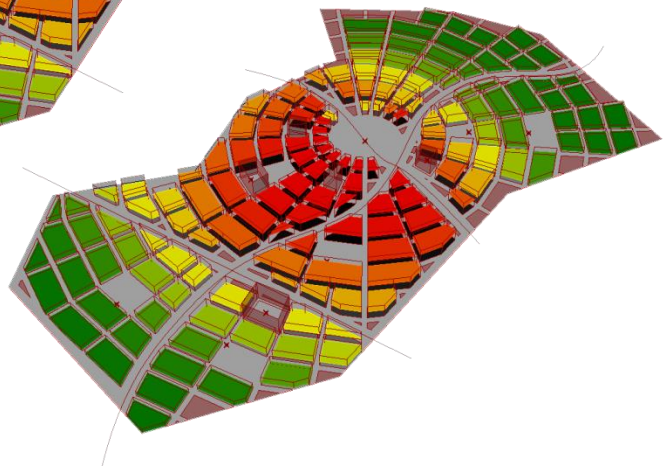
• Change the position of local squares and public buildings



• Deform or change the position of the main streets

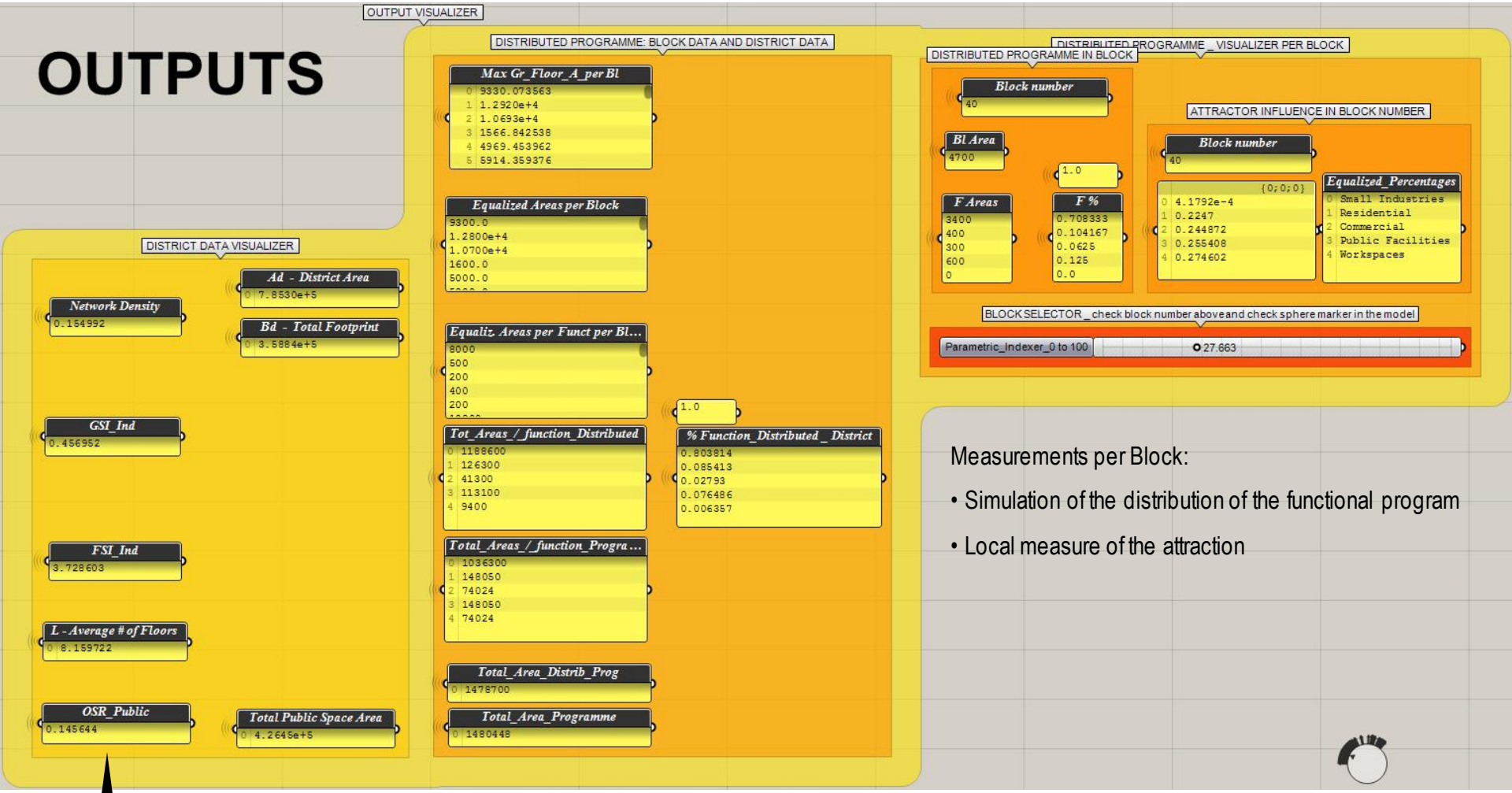


• Change the position of the main square



• Deform the boundary in order to adapt to different contexts or site definitions

OUTPUTS

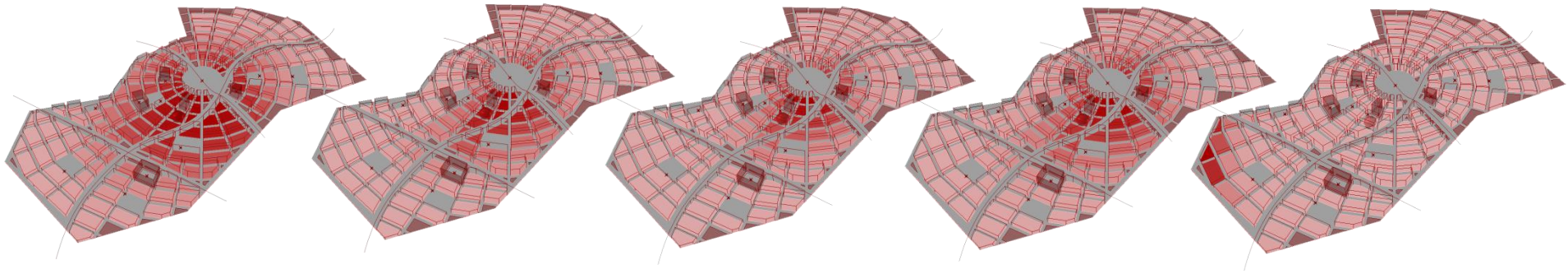


Measurements per Block:

- Simulation of the distribution of the functional program
- Local measure of the attraction

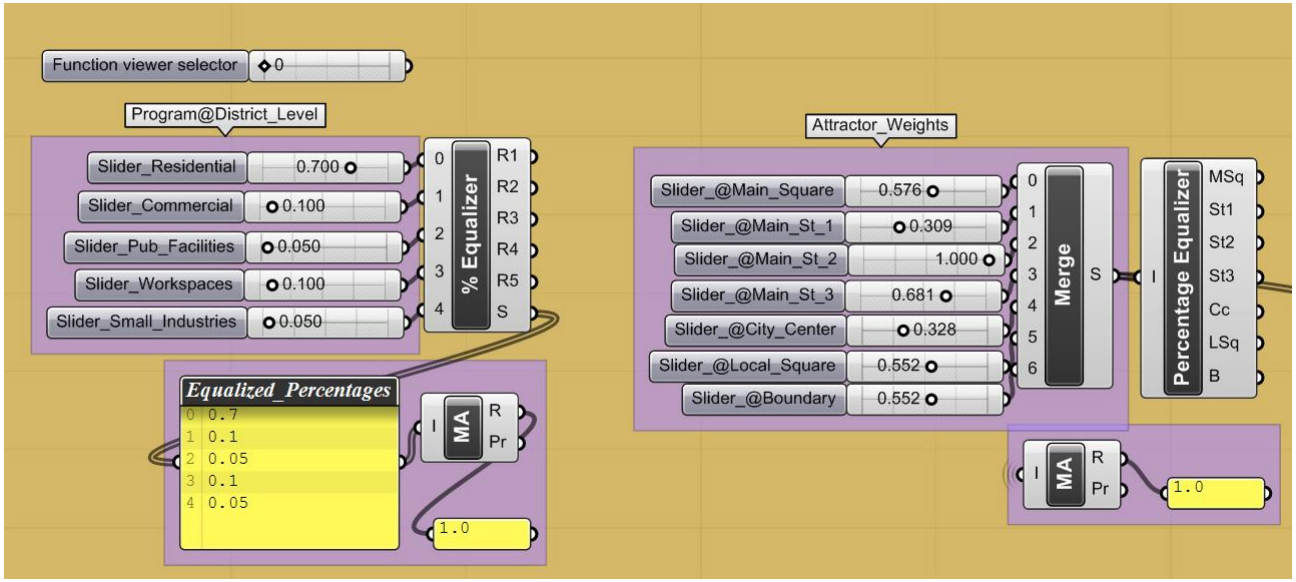
- Measurements at District scale

- Urban Indicators (according to Berghauser-Pont and Haupt, 2010)



Residential | Commercial | Public Facilities | Workspaces | Small Industry

Function distribution simulator

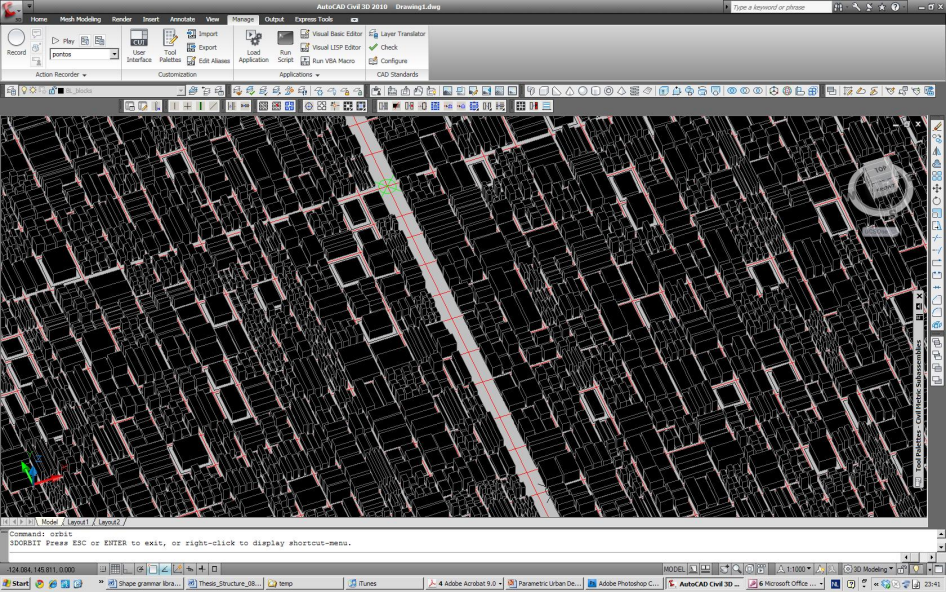


Outputs:

- A design layout
- A set of indicators and regulations at district level
  FSI; GSI; OSR; Nd (district level); PPI (fabric level)

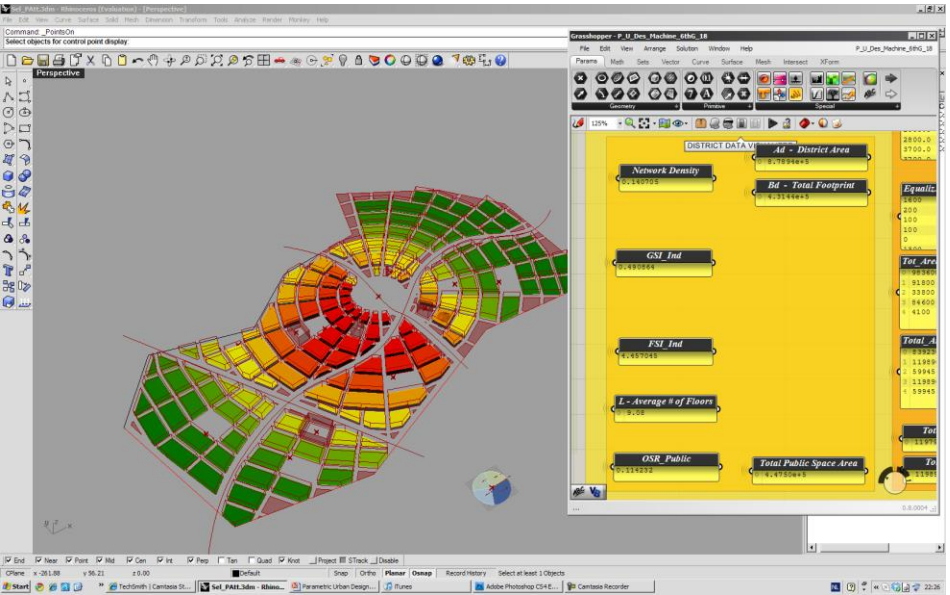
- Regulations per block:
  - max FSI (per block)
  - max GSI (per block)
  - min OSR (per block)

- Simulations of function distribution (scenarios) which might be used to set regulations



Part 3

Comparing models



José Nuno Beirão

CAD/GIS model

Integrates CAD/GIS functionalities in a single environment

It is extendible (extending the software using the API) – hard

Stores data in a database / adds data to the GIS database

Feedback loops imply re-generation

Direct integration with tools running in the GIS environment (any kind of assessment tools from simple queries to spatial analysis – e.g. space syntax, place syntax)

Parametric model

Lacks the integration with GIS platforms (possible but external)

It is extendible (extending program in Grasshopper) - easy

Provides all the generated data (possible to link with a database)

All inputs can be changed at any moment (model adapts in real time)

Integration with analytical tools and GIS tools still needs to be done

Thank you

City induction

Acknowledgements

The City Induction project is funded by Fundação para a Ciência e Tecnologia (FCT), Portugal (PTDC/AUR/64384/2006), hosted by ICIST at TU Lisbon, and coordinated by José P. Duarte.

J.N. Beirão, J. Gil and N. Montenegro also are funded by grants SFRH/BD/39034/2007, SFRH/BD/46709/2008 and SFRH/BD/45520/2008 from FCT. Beirão, Gil, and Montenegro are responsible for the generation, the evaluation, and the formulation modules, respectively.

I would like to thank Henco Bekkering, Sevil Sariyildiz, Frank van der Hoeven and Stephen Read for their readings, comments and support.

I am very much indebt to Pirouz Nourian for his extraordinary input and collaboration without whom my Parametric Model would not have been possible. Thank you.

We would like to thank architects Cândido Chuva Gomes, Frits Palmboom and Frits van Dongen for their kind support and for providing the data on the case studies.

Questions, proposals or comments:

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