Royal College of Art

LAHP | The LONDON ARTS & HUMANITIES PARTNERSHIP

RIBA

Creation Through Variation: Cross-Disciplinary Practices in Architectural Design

EST 1892 LSBU

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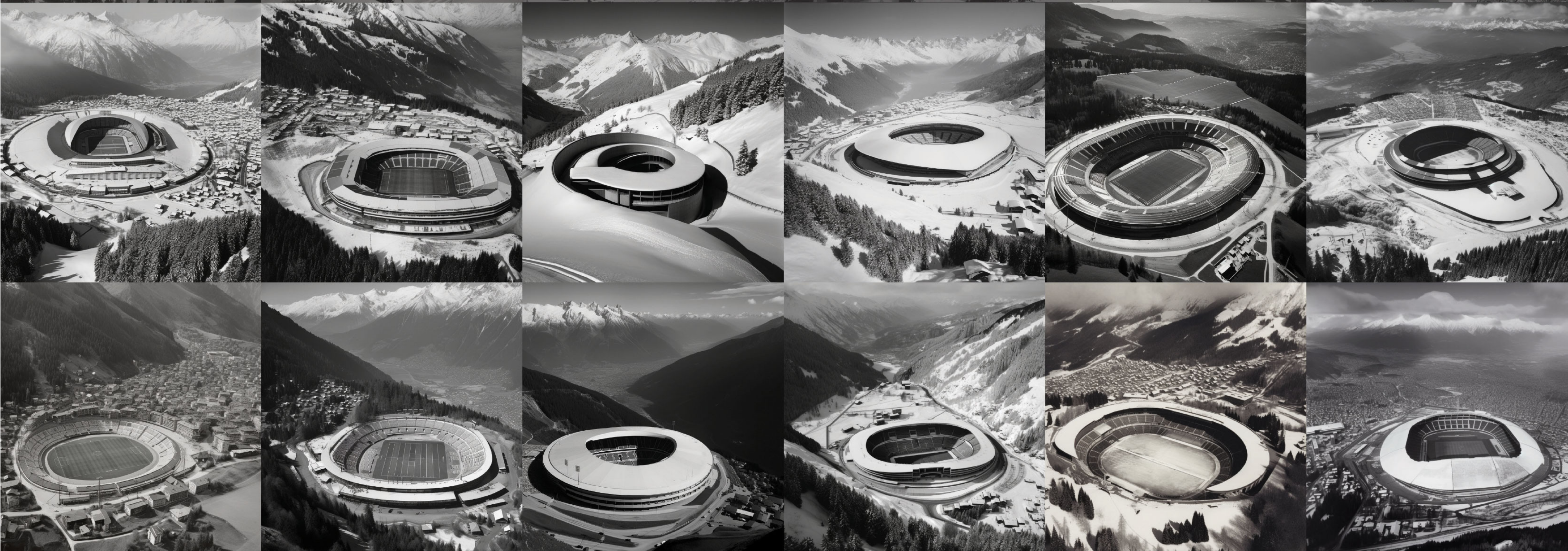
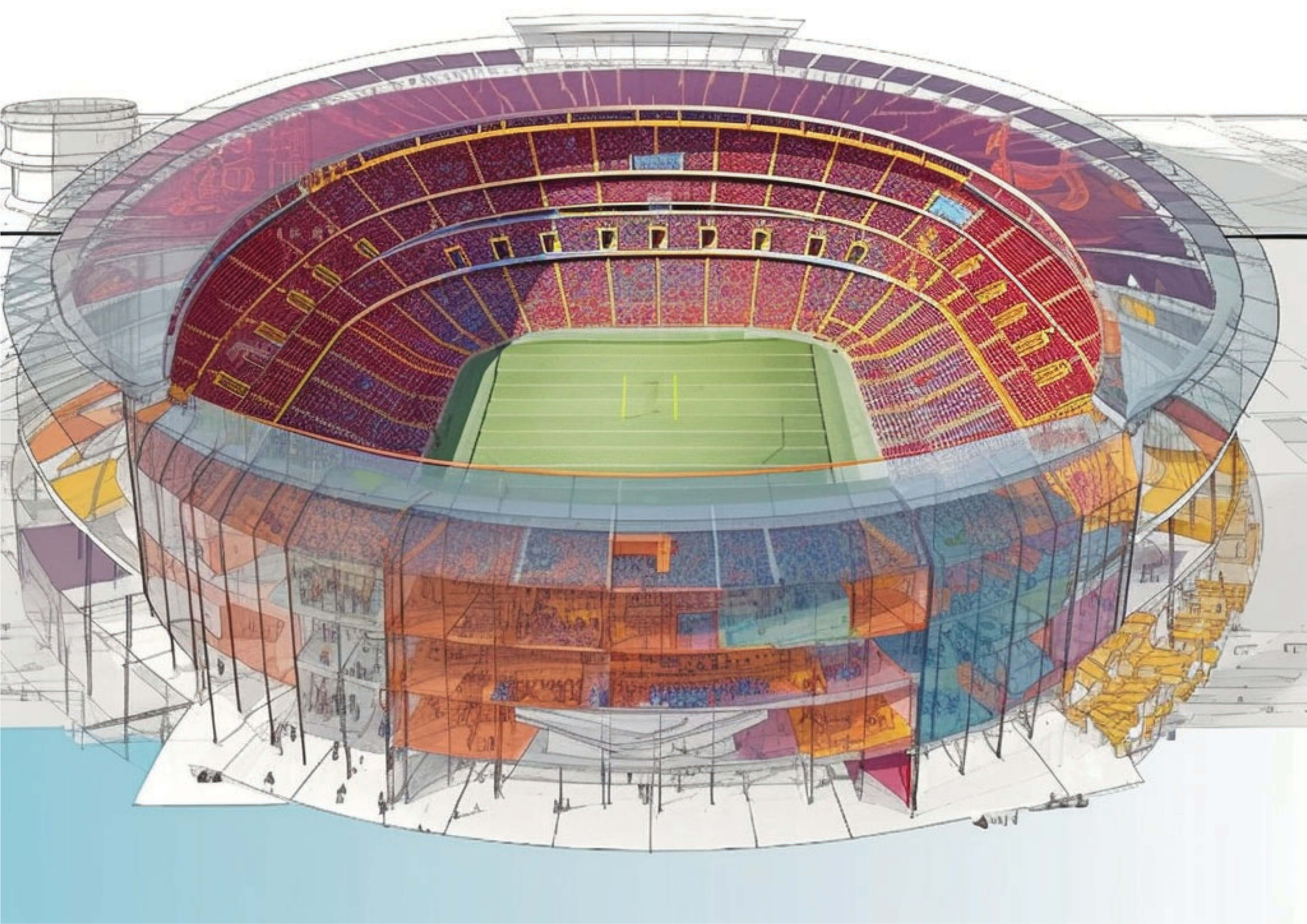
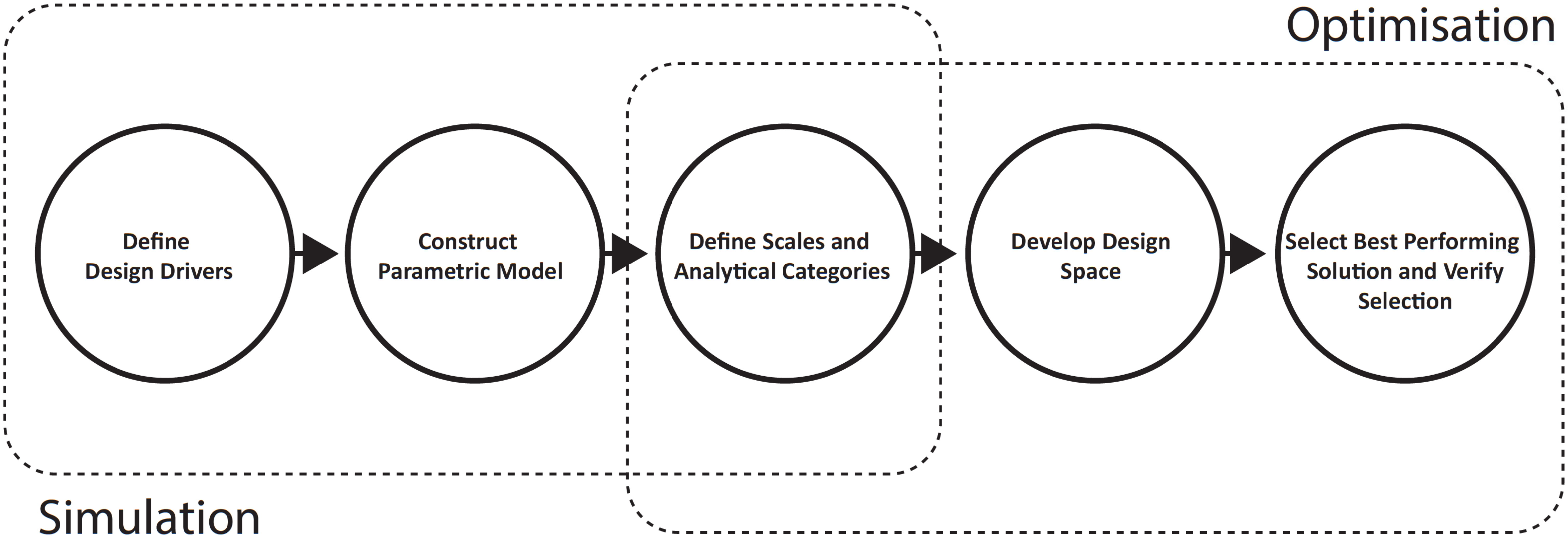
PhD Candiadate Royal College of Art

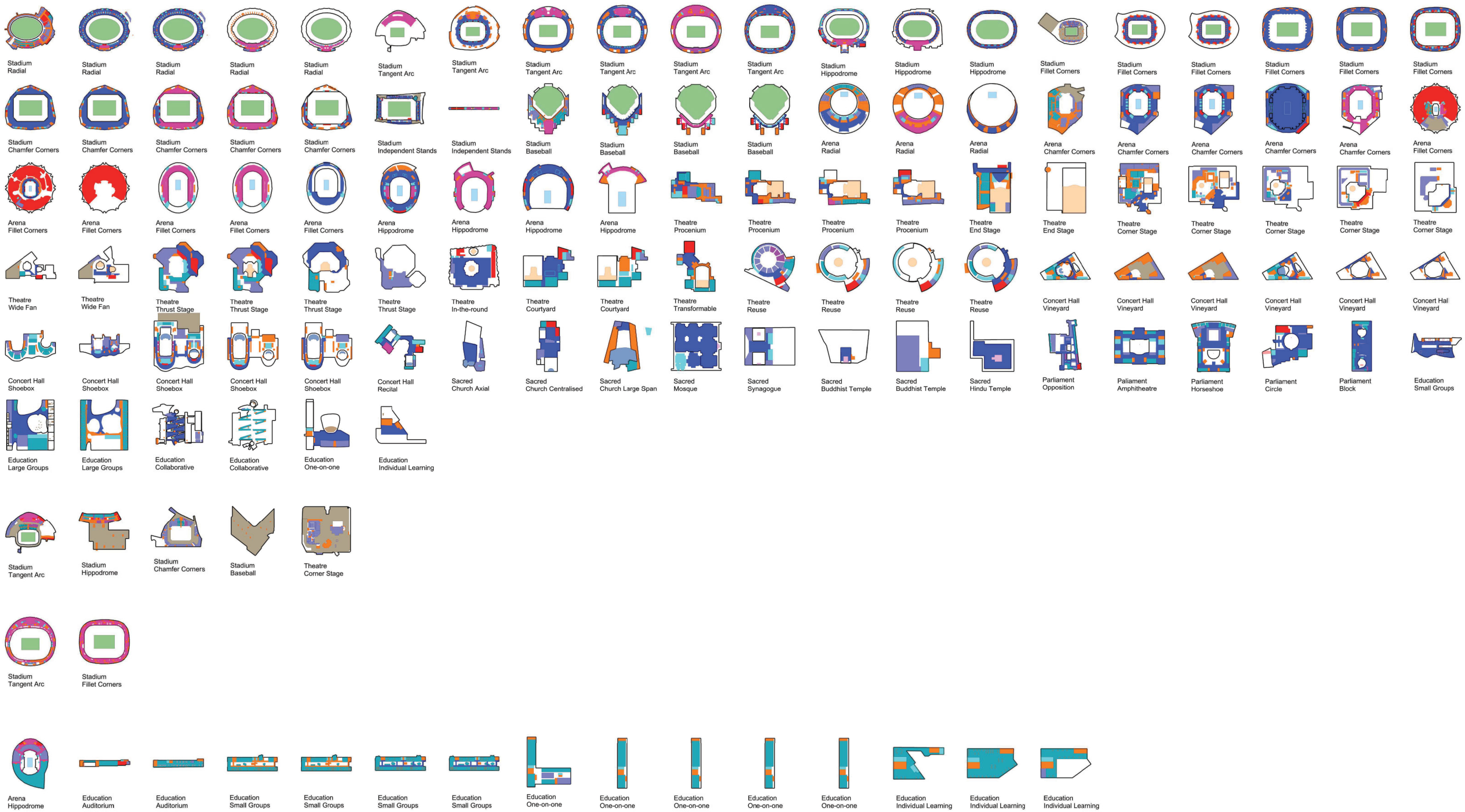
If I distinguish the text from the book, I shall say that the destruction of the book, as it is now under way in all domains, denudes the surface of the text. That necessary violence responds to a violence that was no less necessary.

Derrida, Jacques, Of Grammatology, 1st American ed (Baltimore: Johns Hopkins University Press, 1976)



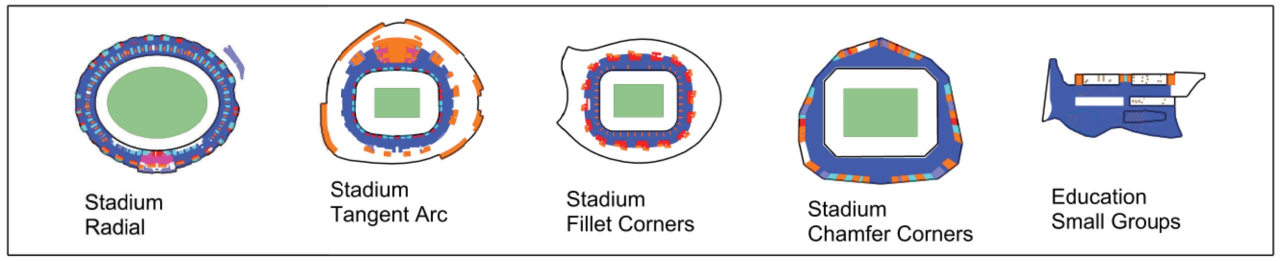


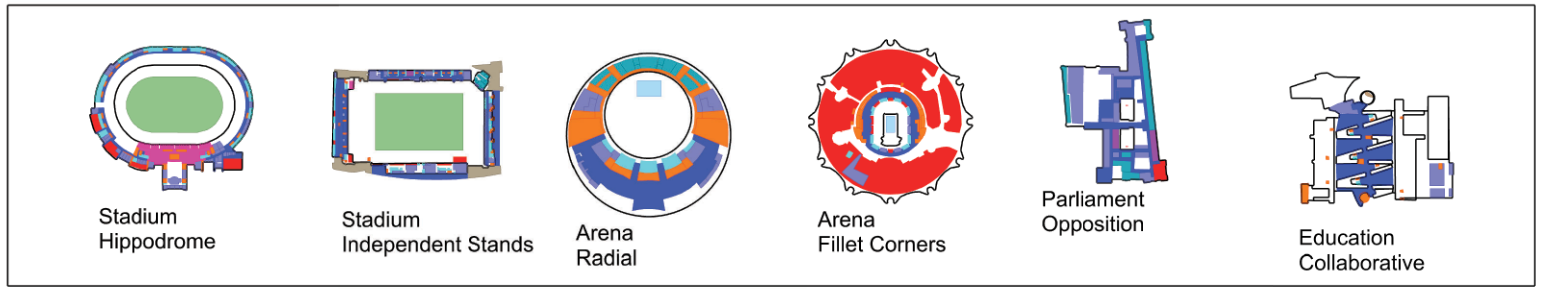

Optimisation
Define
Design Drivers
Construct
Parametric Model
Define Scales and
Analytical Categories
Develop Design
Space
Select Best Performing
Solution and Verify
Selection
Simulation

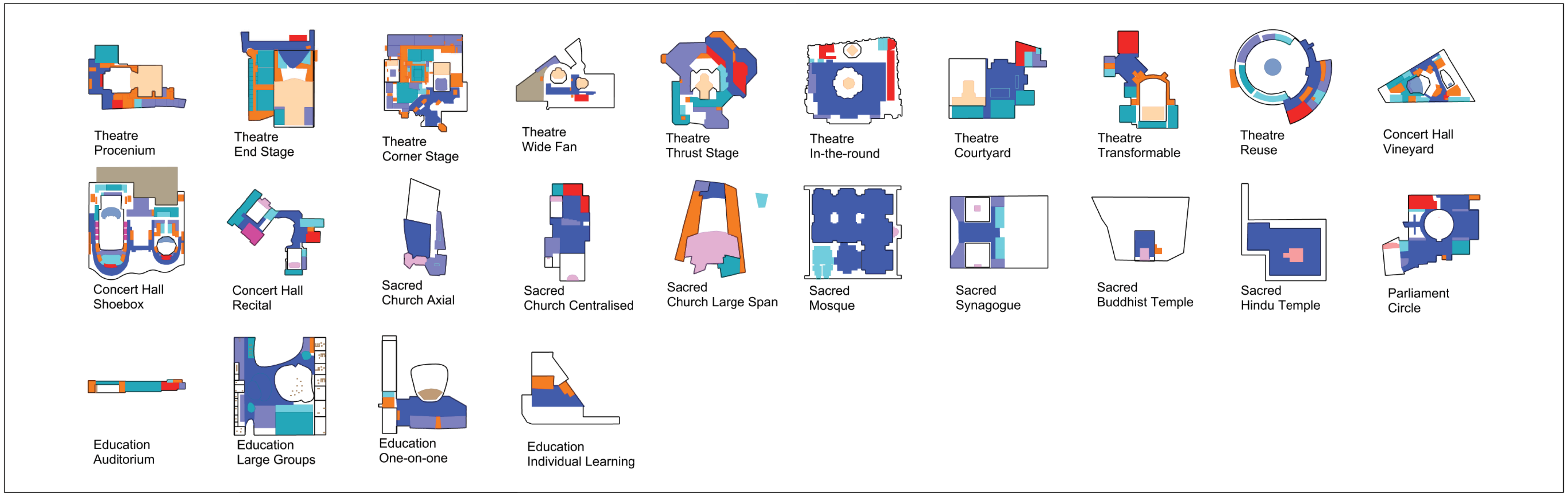

Stadium Radial
Stadium Radial
Stadium Radial
Stadium Radial
Stadium Radial
Stadium Tangent Arc
Stadium Tangent Arc
Stadium Tangent Arc
Stadium Tangent Arc
Stadium Tangent Arc
Stadium Tangent Arc
Stadium Hippodrome
Stadium Hippodrome
Stadium Hippodrome
Stadium Fillet Corners
Stadium Fillet Corners
Stadium Fillet Corners
Stadium Fillet Corners
Stadium Fillet Corners
Stadium Fillet Corners
Stadium Chamfer Corners
Stadium Chamfer Corners
Stadium Chamfer Corners
Stadium Chamfer Corners
Stadium Chamfer Corners
Stadium Independent Stands
Stadium Independent Stands
Stadium Baseball
Stadium Baseball
Stadium Baseball
Stadium Baseball
Arena Radial
Arena Radial
Arena Radial
Arena Chamfer Corners
Arena Chamfer Corners
Arena Chamfer Corners
Arena Chamfer Corners
Arena Chamfer Corners
Arena Fillet Corners
Arena Fillet Corners
Arena Fillet Corners
Arena Fillet Corners
Arena Fillet Corners
Arena Fillet Corners
Arena Hippodrome
Arena Hippodrome
Arena Hippodrome
Arena Hippodrome
Theatre Procenium
Theatre Procenium
Theatre Procenium
Theatre Procenium
Theatre End Stage
Theatre End Stage
Theatre Corner Stage
Theatre Corner Stage
Theatre Corner Stage
Theatre Corner Stage
Theatre Corner Stage
Theatre Wide Fan
Theatre Wide Fan
Theatre Thrust Stage
Theatre Thrust Stage
Theatre Thrust Stage
Theatre Thrust Stage
Theatre In-the-round
Theatre Courtyard
Theatre Courtyard
Theatre Transformable
Theatre Reuse
Theatre Reuse
Theatre Reuse
Theatre Reuse
Concert Hall Vineyard
Concert Hall Vineyard
Concert Hall Vineyard
Concert Hall Vineyard
Concert Hall Vineyard
Concert Hal Vineyard
Concert Hall Shoebox
Concert Hall Shoebox
Concert Hall Shoebox
Concert Hall Shoebox
Concert Hall Shoebox
Concert Hall Recital
Sacred Church Axial
Sacred Church Centralised
Sacred Church Large Span
Sacred Mosque
Sacred Synagogue
Sacred Buddhist Temple
Sacred Buddhist Temple
Sacred Hindu Temple
Parliament Opposition
Paliament Amphitheatre
Parliament Horseshoe
Parliament Circle
Parliament Block
Education Small Groups
Education Large Groups
Education Large Groups
Education Collaborative
Education Collaborative
Education One-on-one
Education Individual Learning
Stadium Tangent Arc
Stadium Hippodrome
Stadium Chamfer Corners
Stadium Baseball
Theatre Corner Stage
Stadium Tangent Arc
Stadium Fillet Corners
Arena Hippodrome
Education Auditorium
Education Auditorium
Education Small Groups
Education Small Groups
Education Small Groups
Education Small Groups
Education One-on-one
Education One-on-one
Education One-on-one
Education One-on-one
Education One-on-one
Education Individual Learning
Education Individual Learning
Education Individual Learning

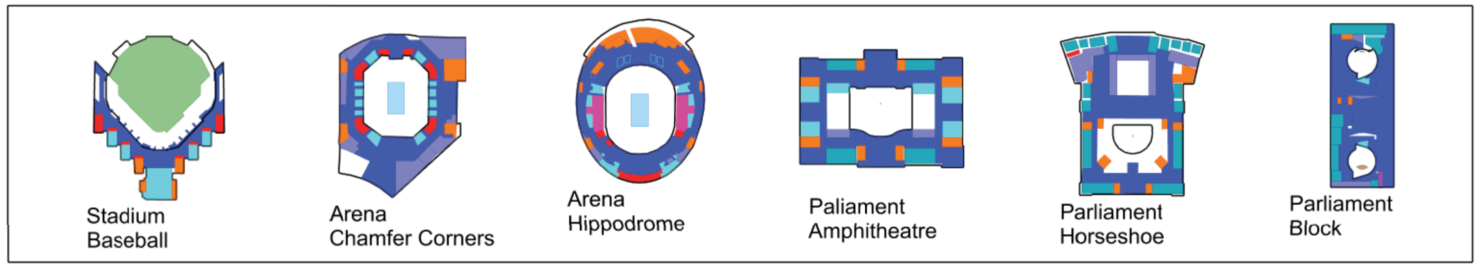
Building Scale :
Ground floor footprint

Evaluation parameters:
GA Concourse area
Level footprint area





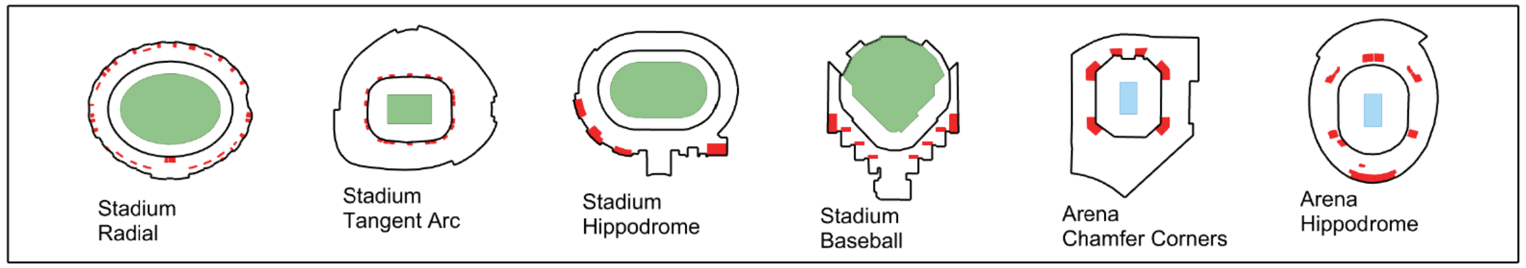


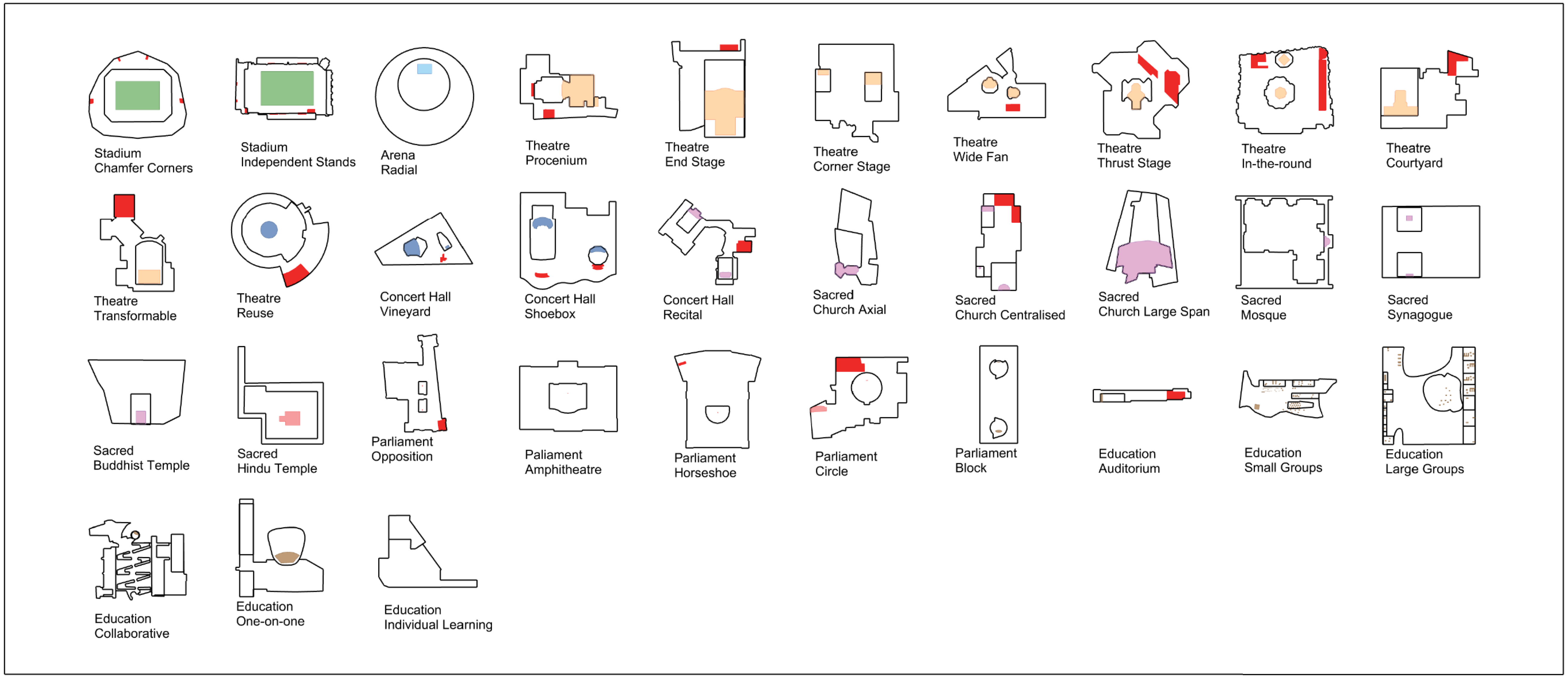


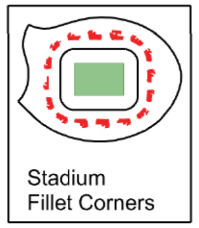
- Commercial
- Circulation
- GA Concourse
- Hospitality
- Media
- Parking
- Performers` spaces
- Podium
- Service
- Toilets

Building Scale :
Ground floor footprint

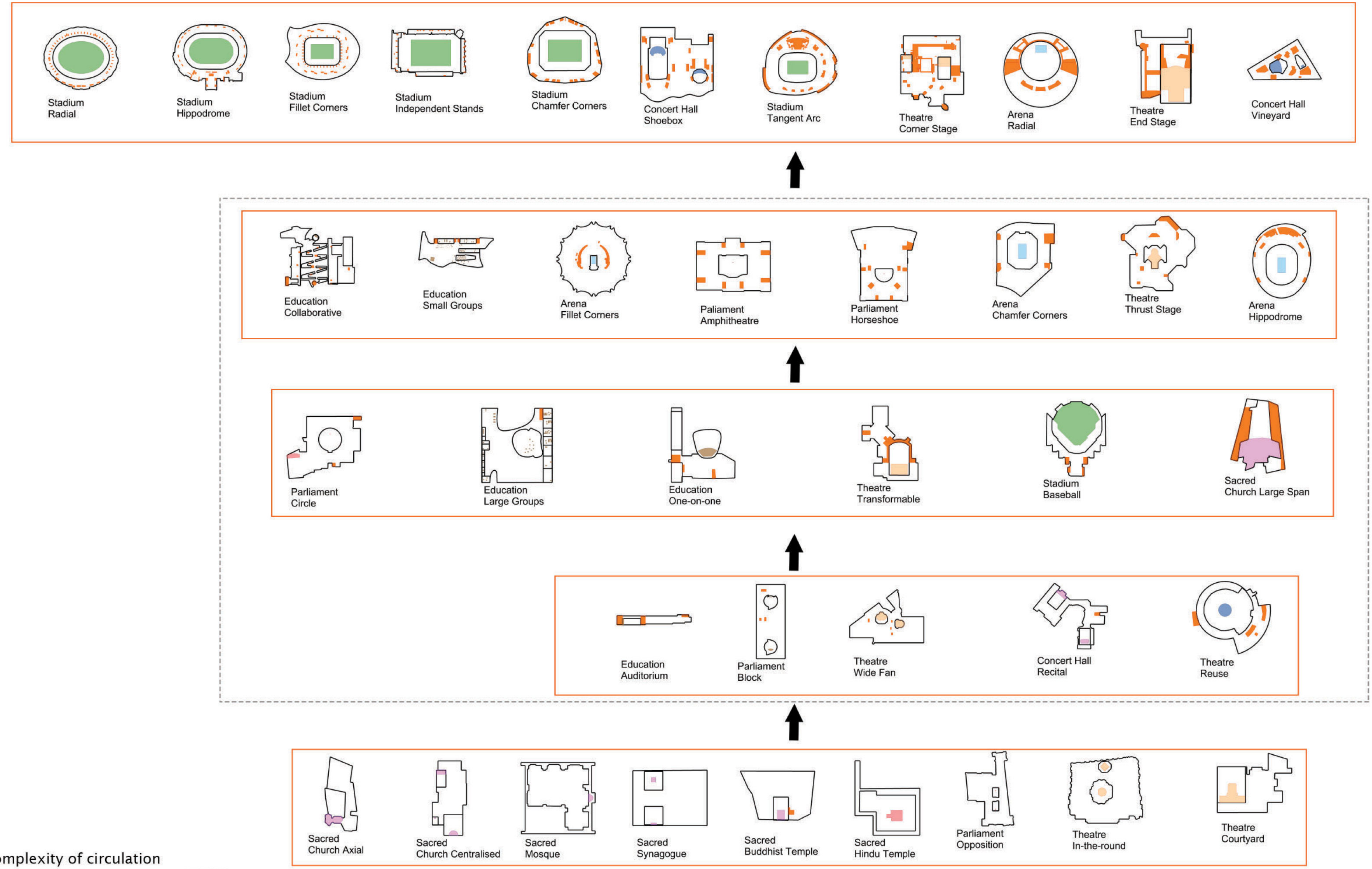
Evaluation parameters:
Level footprint
Commercial spaces area



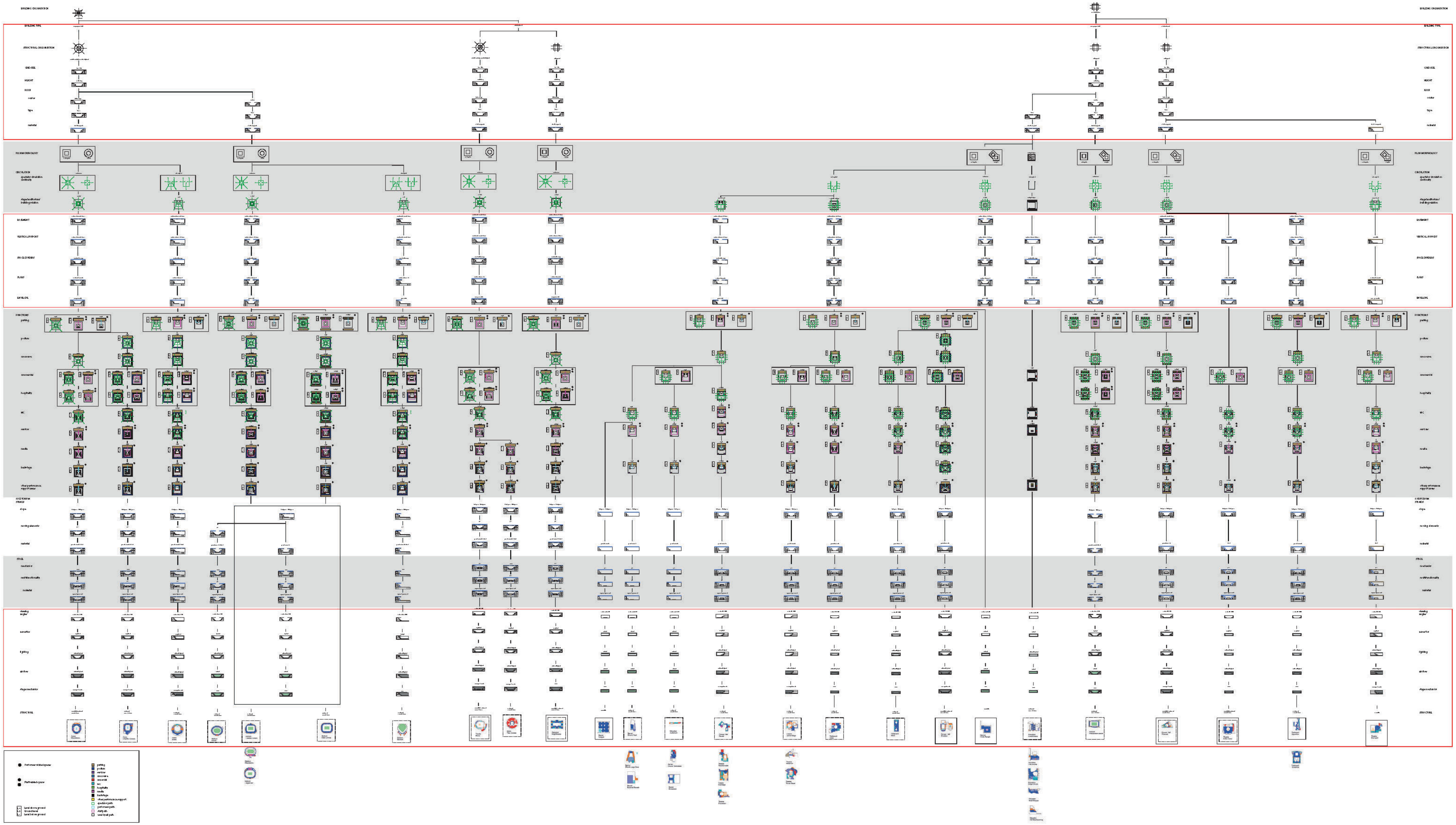


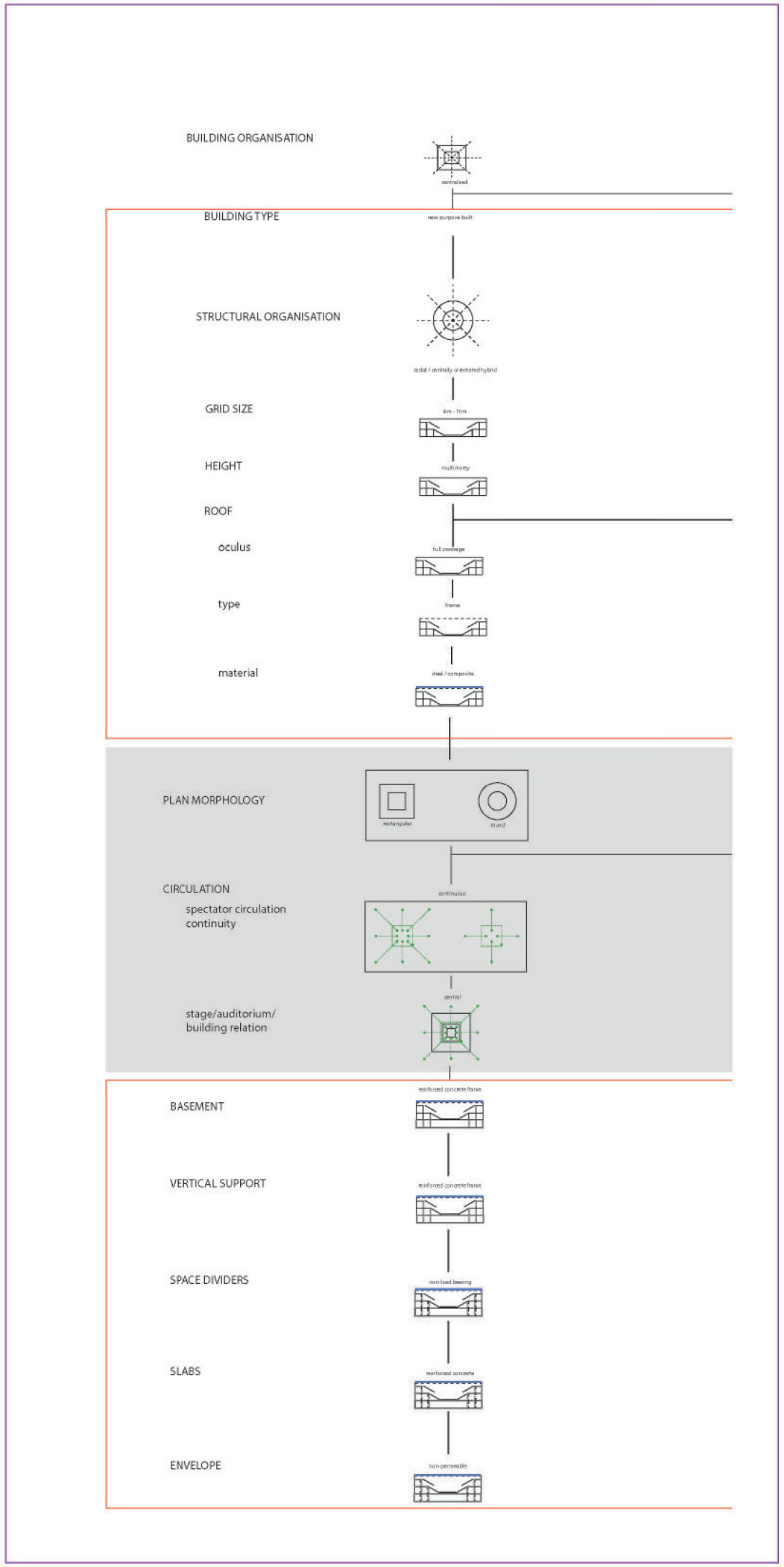


- Commercial
- Circulation
- GA Concourse
- Hospitality
- Media
- Parking
- Performers` spaces
- Podium
- Service
- Toilets

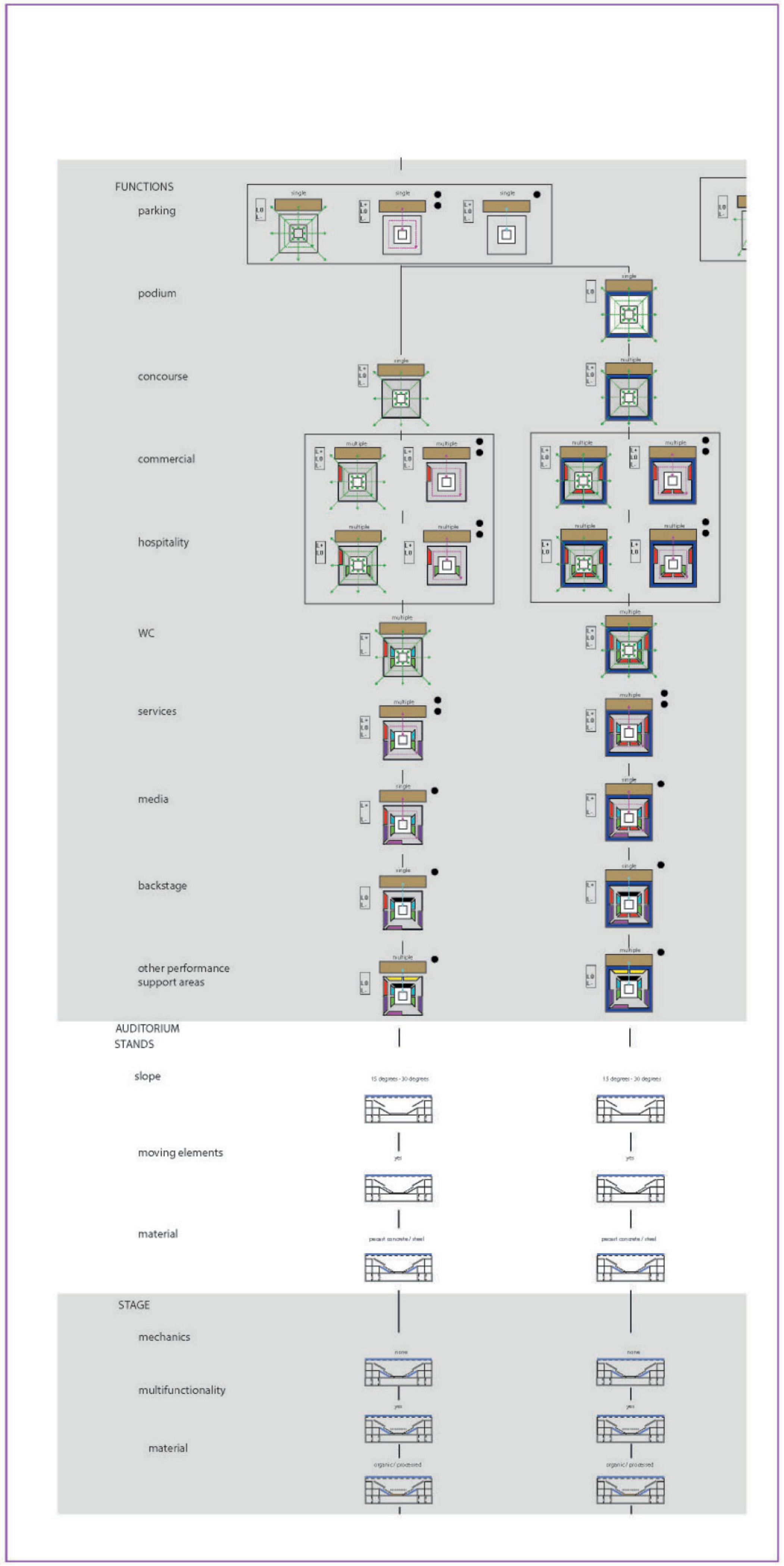


Complexity of circulation
not directly related to entering the
auditorium

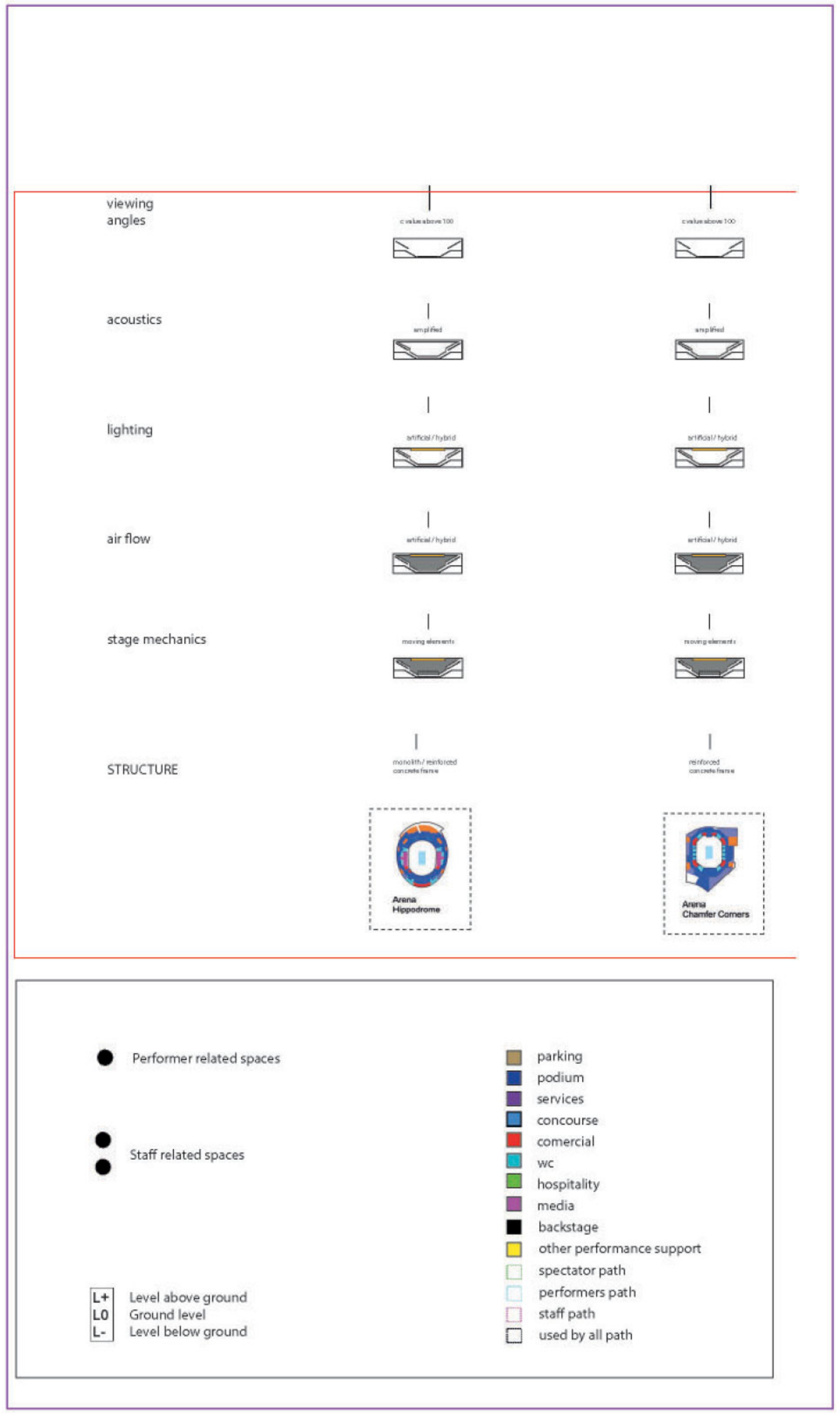

BUILDING ORGANISATION
BUILDING TYPE
STRUCTURAL ORGANISATION
GRID SIZE
HEIGHT
ROOF
type
material
PLAN MORPHOLOGY
CIRCULATION
spectator circulation continuity
stage/auditorium/ building relation
VERTICAL SUPPORT
SPACE DIVIDERS
SLABS
ENVELOPE
FUNCTIONS
parking
podium
concourse
commercial
hospitality
WC
media
backstage
other performance support areas
slope
moving elements
material
STAGE
mechanics
multifunctionality
material
viewing angles
acoustics
lighting
air flow
stage mechanics
STRUCTURE
Performer related spaces
Staff related space
Level above ground
Ground level
Level below ground
parking
podium
concourse
commercial
wc
hospitality
media
backstage
other performance support
spectator path
performer path
staff path
used by all path



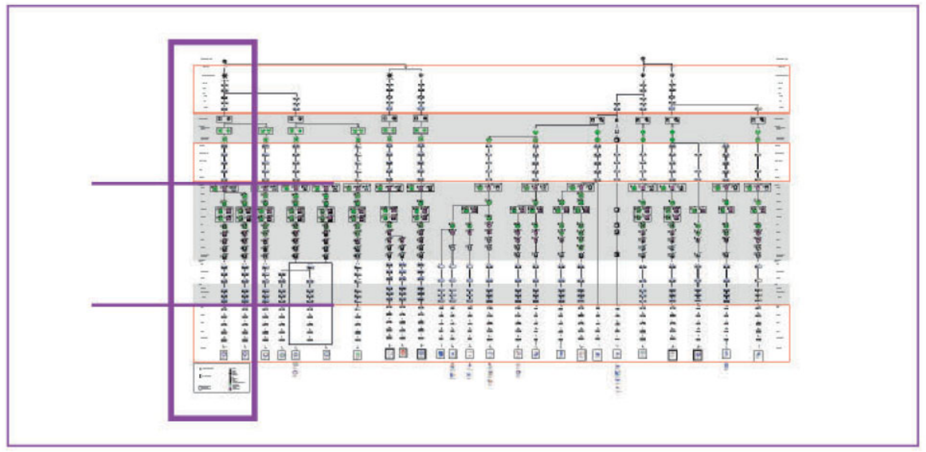
BUILDING ORGANISATION
BUILDING TYPE
STRUCTURAL ORGANISATION
GRID SIZE
HEIGHT
ROOF
oculus
type
material
PLAN MORPHOLOGY
CIRCULATION
spectator circulation continuity
stage/auditorium/ building relation
BASEMENT
VERTICAL SUPPORT
SPACE DIVIDERS
SLABS
ENVELOPE

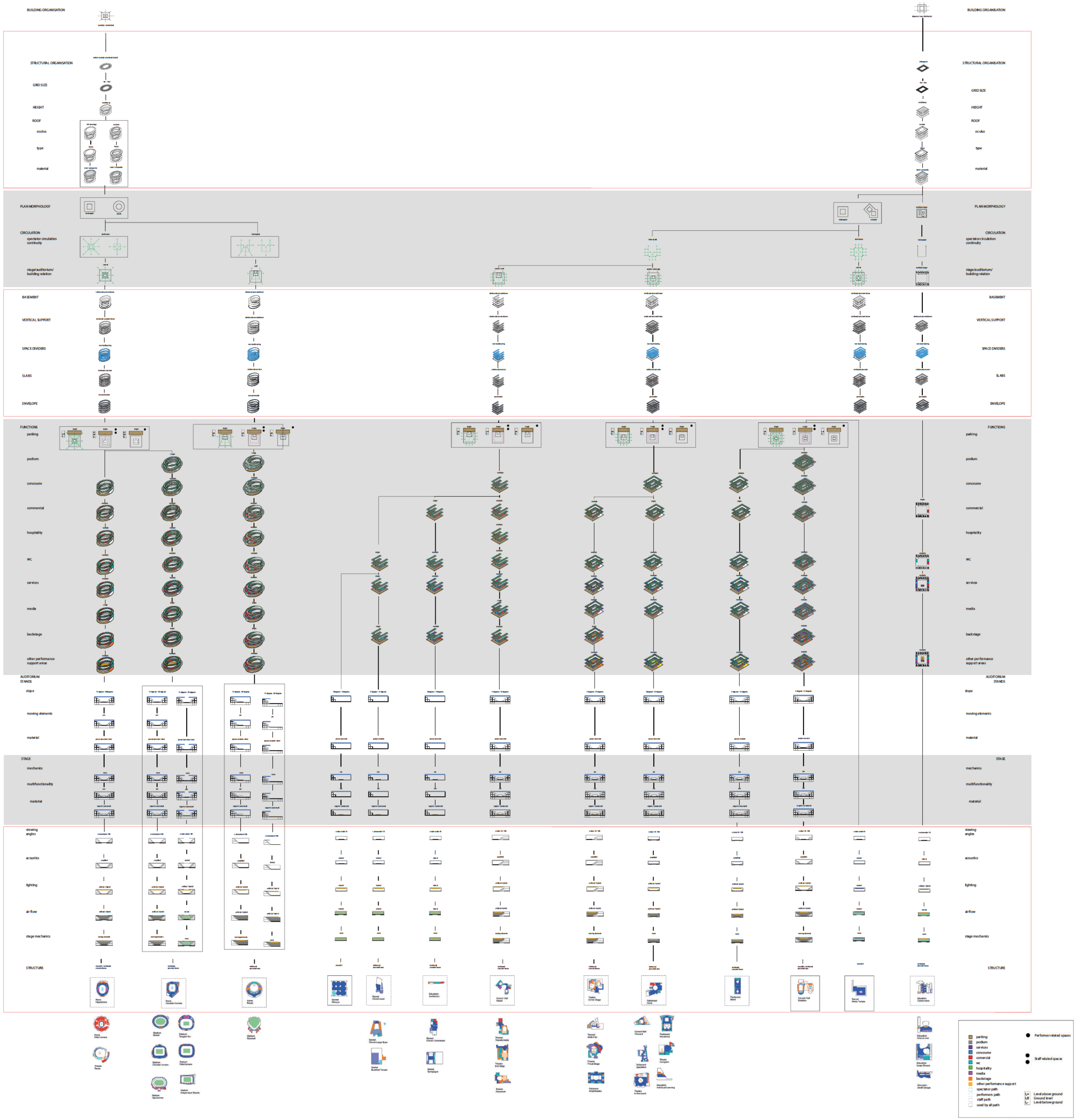


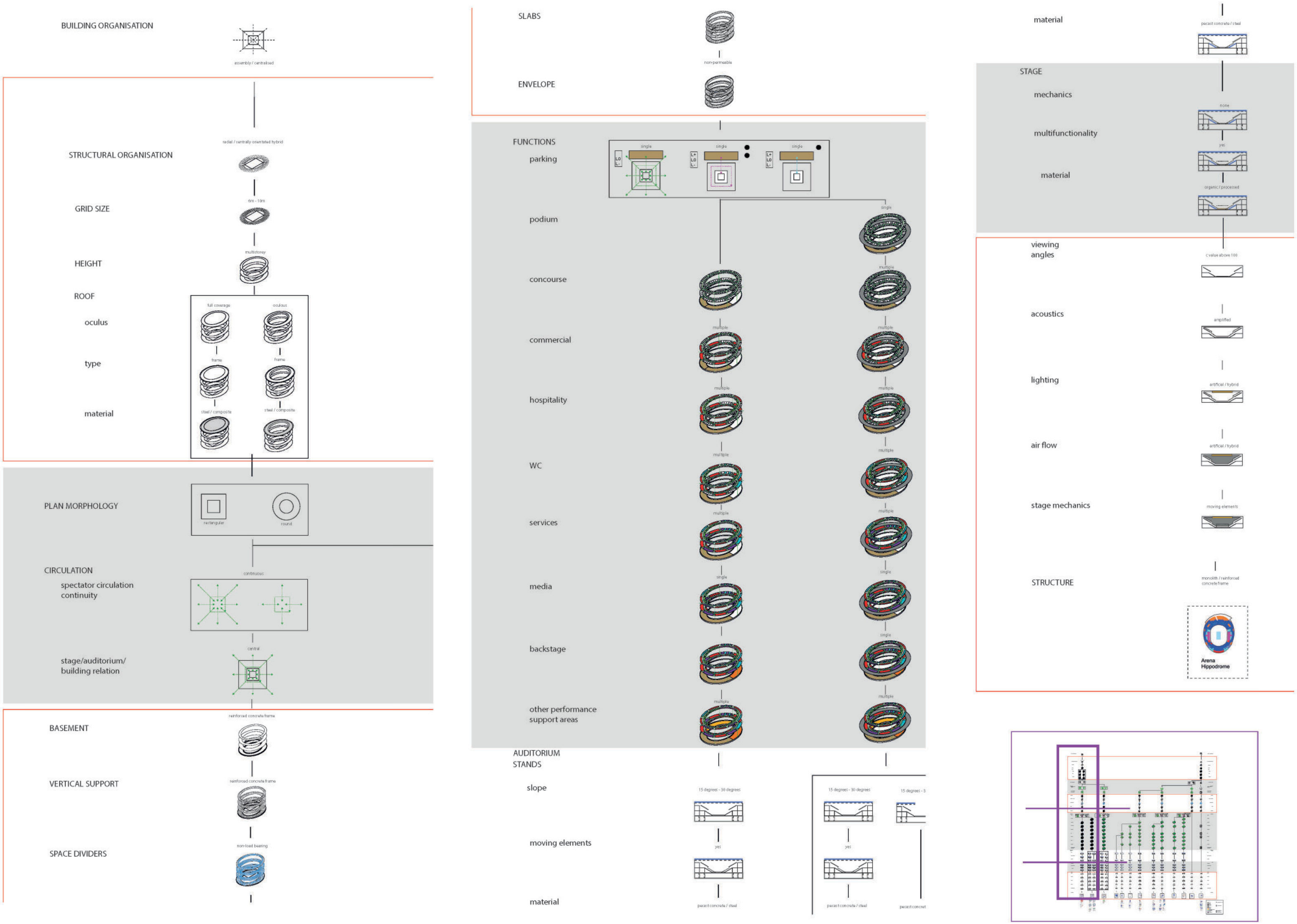
FUNCTIONS
parking
podium
concourse
commercial
hospitality
WC
services
media
backstage
other performance support areas
AUDITORIUM STANDS
slope
moving elements
material
STAGE
mechanics
multifunctionality
material



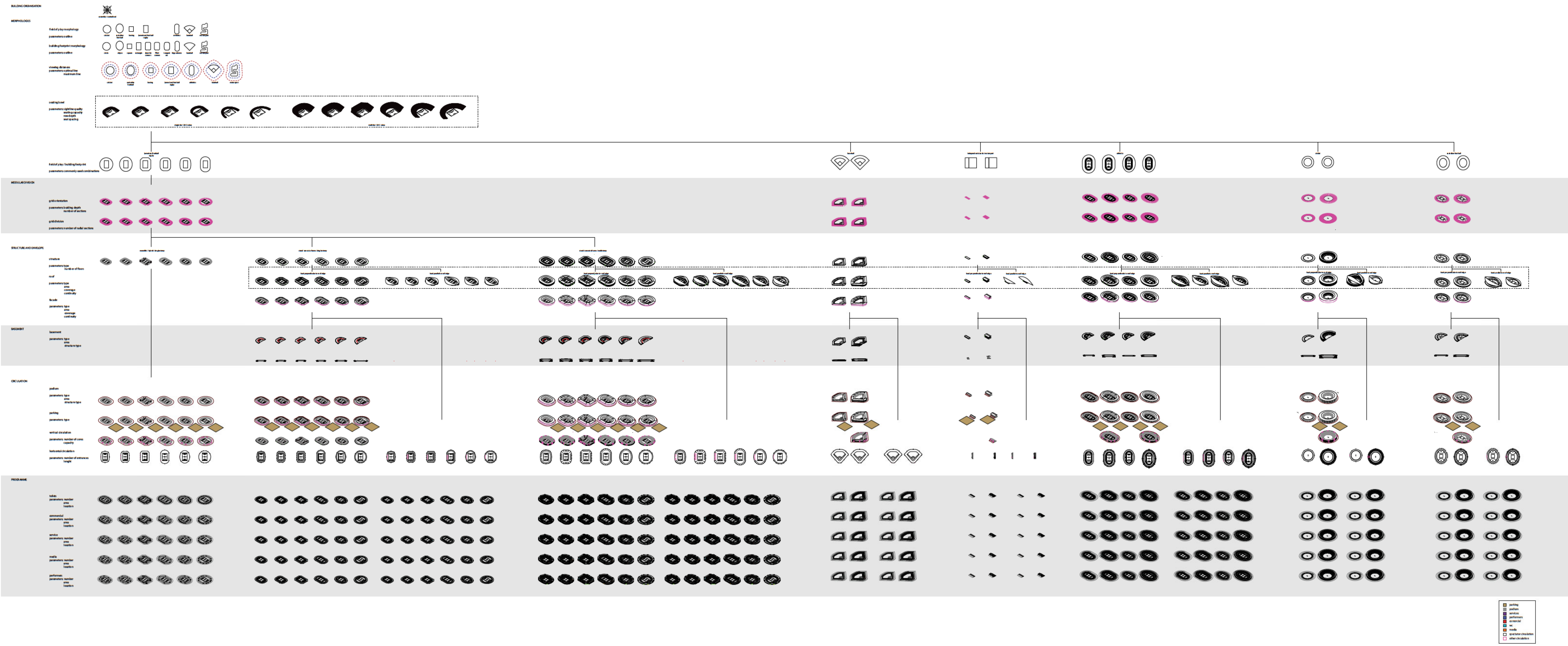
viewing angles
acoustics
lighting
air flow
stage mechanics
STRUCTURE
Arena Hippodrome
Arena Chamber Corners
Performer related spaces
Staff related spaces
L+ Level above ground
L0 Ground level
L- Level below ground
parking
podium
services
concourse
comercial
wc
hospitality
media
backstage
other performance support
spectator path
performers path
staff path
used by all path



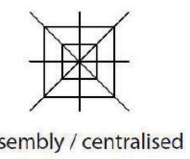

BUILDING ORGANISATION
STRUCTURAL ORGANISATION
GRID SIZE
HEIGHT
ROOF
oculus
type
material
PLAN MORPHOLOGY
CIRCULATION
spectator circulation continuity
stage/auditorium/ building relation
BASEMENT
VERTICAL SUPPORT
SPACE DIVIDERS
SLABS
ENVELOPE
FUNCTIONS
parking
podium
concourse
commercial
hospitality
WC
services
media
backstage
other performance support areas
AUDITORIUM STANDS
slope
moving elements
material
STAGE
mechanics
multifunctionality
material
viewing angles
acoustics
lighting
air flow
stage mechanics
STRUCTURE
Arena Hippodrome
parking
podium
services
concourse
comercial
wc
hospitality
media
backstage
other performance support
spectator path
performers path
staff path
used by all path
Performer related spaces
Staff related spaces
L+ Level above ground
L0 Ground level
L- Level below ground



BUILDING ORGANISATION
assembly / centralised
STRUCTURAL ORGANISATION
GRID SIZE
HEIGHT
ROOF
oculus
type
material
PLAN MORPHOLOGY
rectangular
round
CIRCULATION
spectator circulation continuity
stage/auditorium/ building relation
BASEMENT
VERTICAL SUPPORT
SPACE DIVIDERS
SLABS
ENVELOPE
FUNCTIONS
parking
podium
concourse
commercial
hospitality
WC
services
media
backstage
other performance support areas
AUDITORIUM STANDS
slope
moving elements
material
material
STAGE
mechanics
multifunctionality
material
viewing angles
acoustics
lighting
air flow
stage mechanics
STRUCTURE
Arena Hippodrome


BUILDING ORGANISATION
MORPHOLOGIES
field of play morphology
parameters: outline
building footprint morphology
parameters: outline
viewing distances
parameters: optimal line
maximum line
seating bowl
parameters: sightline quality
seating capacity
row depth
seat spacing
field of play / building footprint
parameters: commonly used combinations
MODULAR DIVISION
grid orientation
parameters: building depth
number of sections
grid division
parameters: number of radial sections
STRUCTURE AND ENVELOPE
structure
parameters: type
number of floors
roof
parameters: type
area
coverage
continuity
facade
parameters: type
area
coverage
continuity
BASEMENT
basement
parameters: type
area
structure type
CIRCULATION
podium
parameters: type
area
structure type
parking
parameters: type
vertical circulation
parameters: number of cores
capacity
horizontal circulation
parameters: number of entrances
lenght
PROGRAMME
toilets
parameters: number
area
location
commercial
parameters: number
area
location
service
parameters: number
area
location
media
parameters: number
area
location
performers
parameters: number
area
location
parking
podium
services
performers
comercial
wc
media
spectator circulation
other circulation

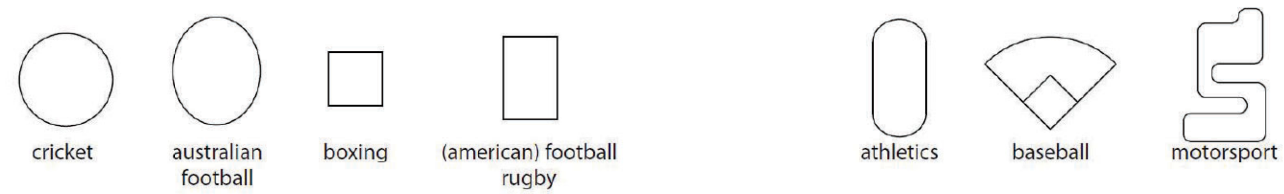
BUILDING ORGANISATION



MORPHOLOGIES

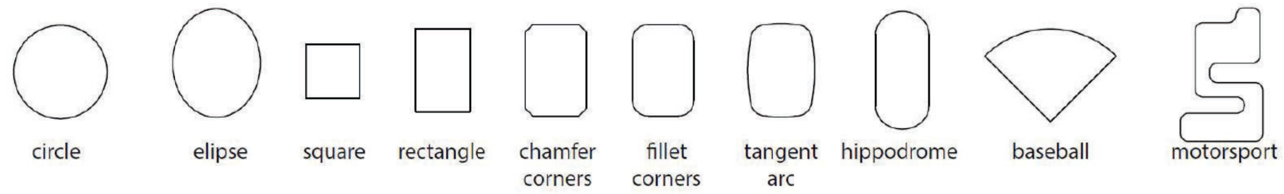
field of play morphology

parameters: outline



building footprint morphology

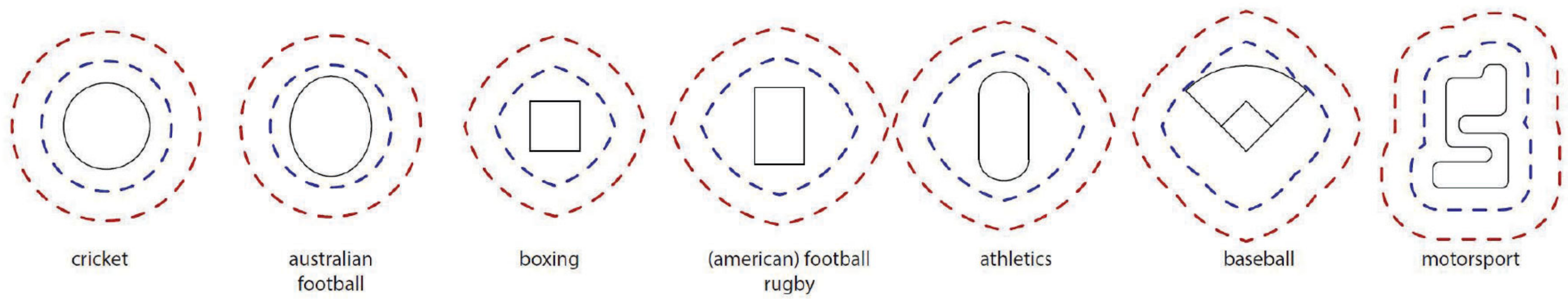
parameters: outline



viewing distances

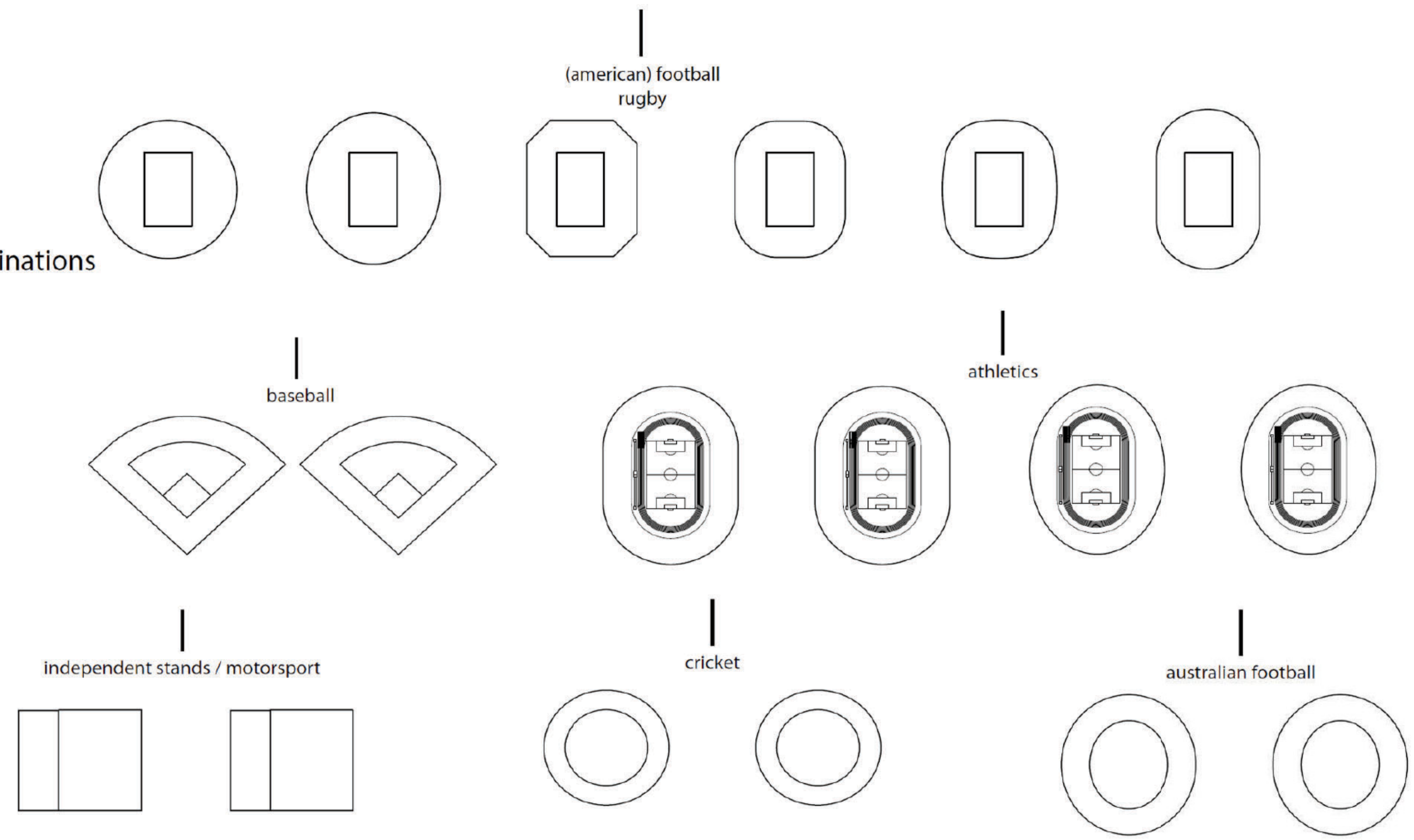
parameters: optimal line

maximum line



field of play / building footprint

parameters: commonly used combinations



seating bowl

parameters: sightline quality
seating capacity
row depth
seat spacing

single tier 120 C-value

multi-tier 120 C-value

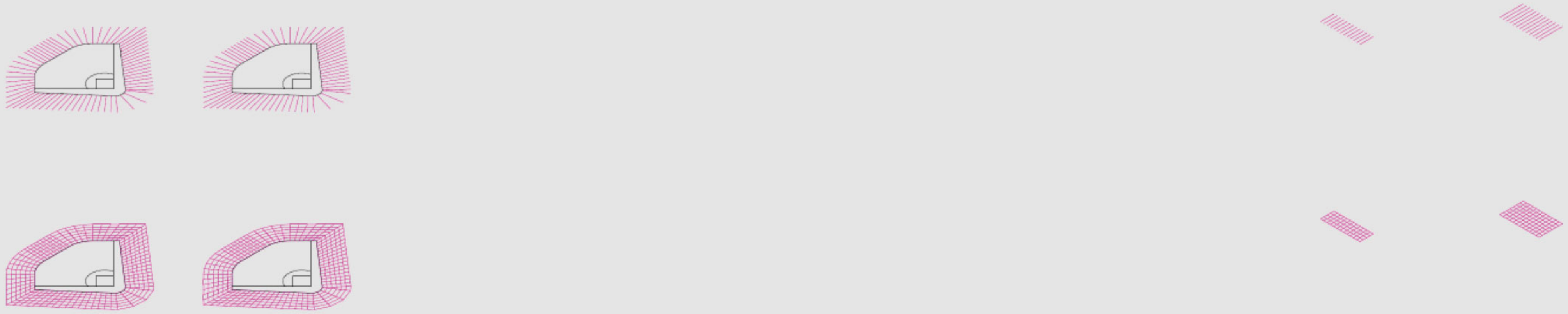
MODULAR DIVISION

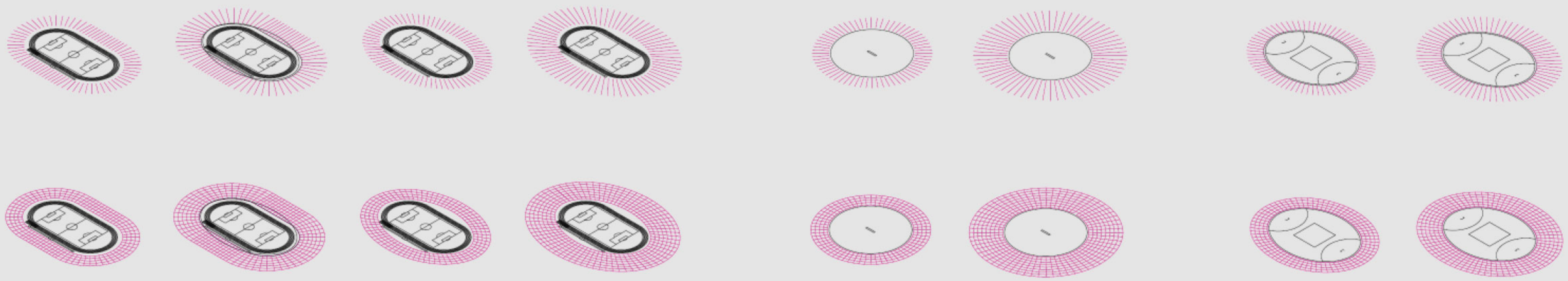
grid orientation

parameters: buiding depth
number of sections

grid division

parameters: number of radial sections





STRUCTURE AND ENVELOPE

structure

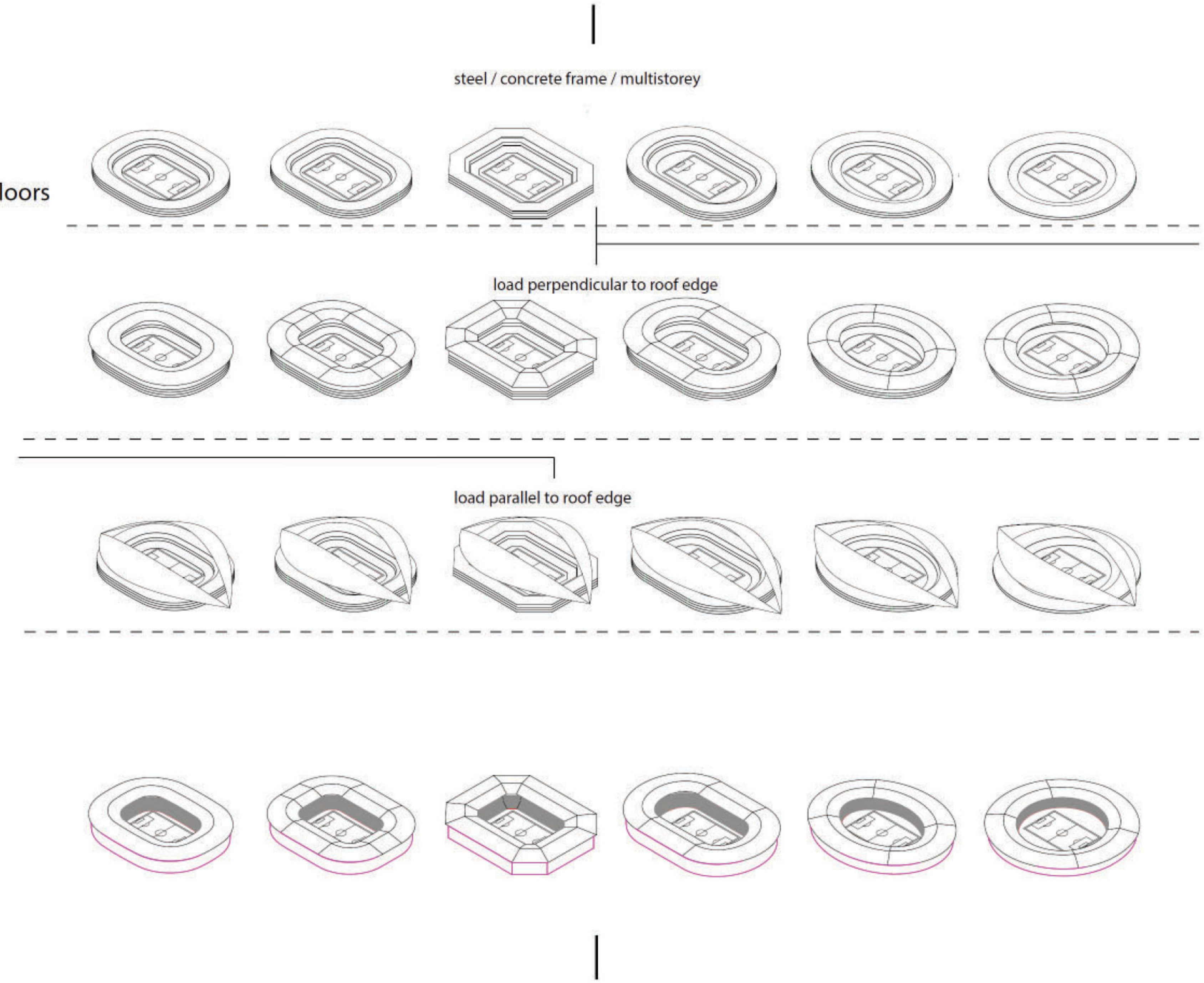
parameters: type
number of floors

roof

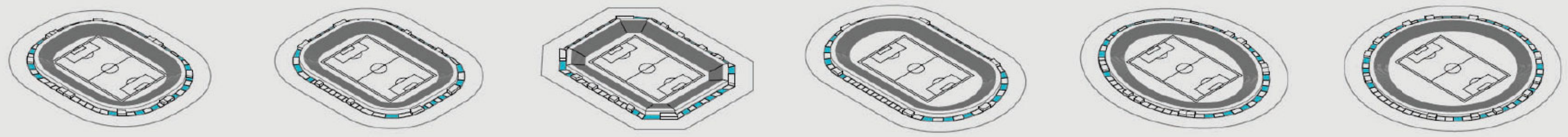
parameters: type
area
coverage
continuity

facade

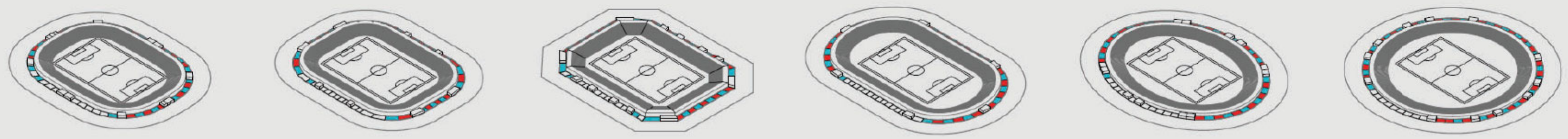
parameters: type
area
coverage
continuity



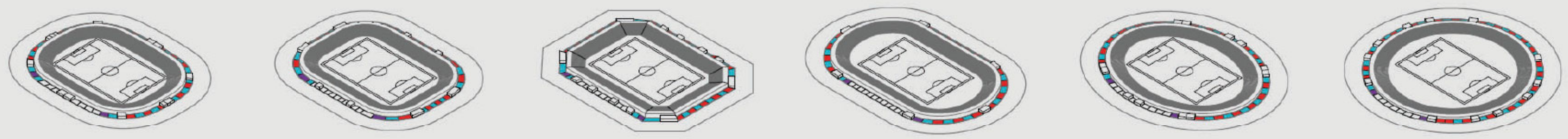
toilets
parameters: number
area
location



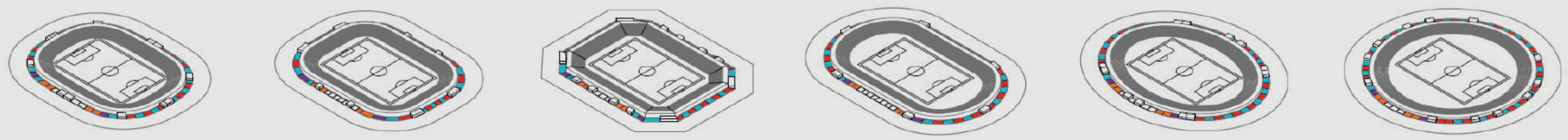
commercial
parameters: number
area
location



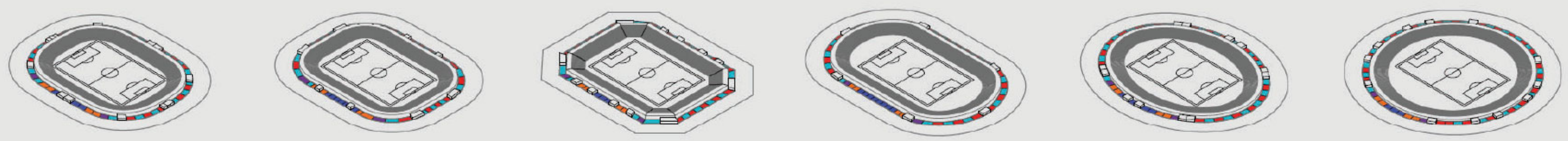
service
parameters: number
area
location



media
parameters: number
area
location



performers
parameters: number
area
location

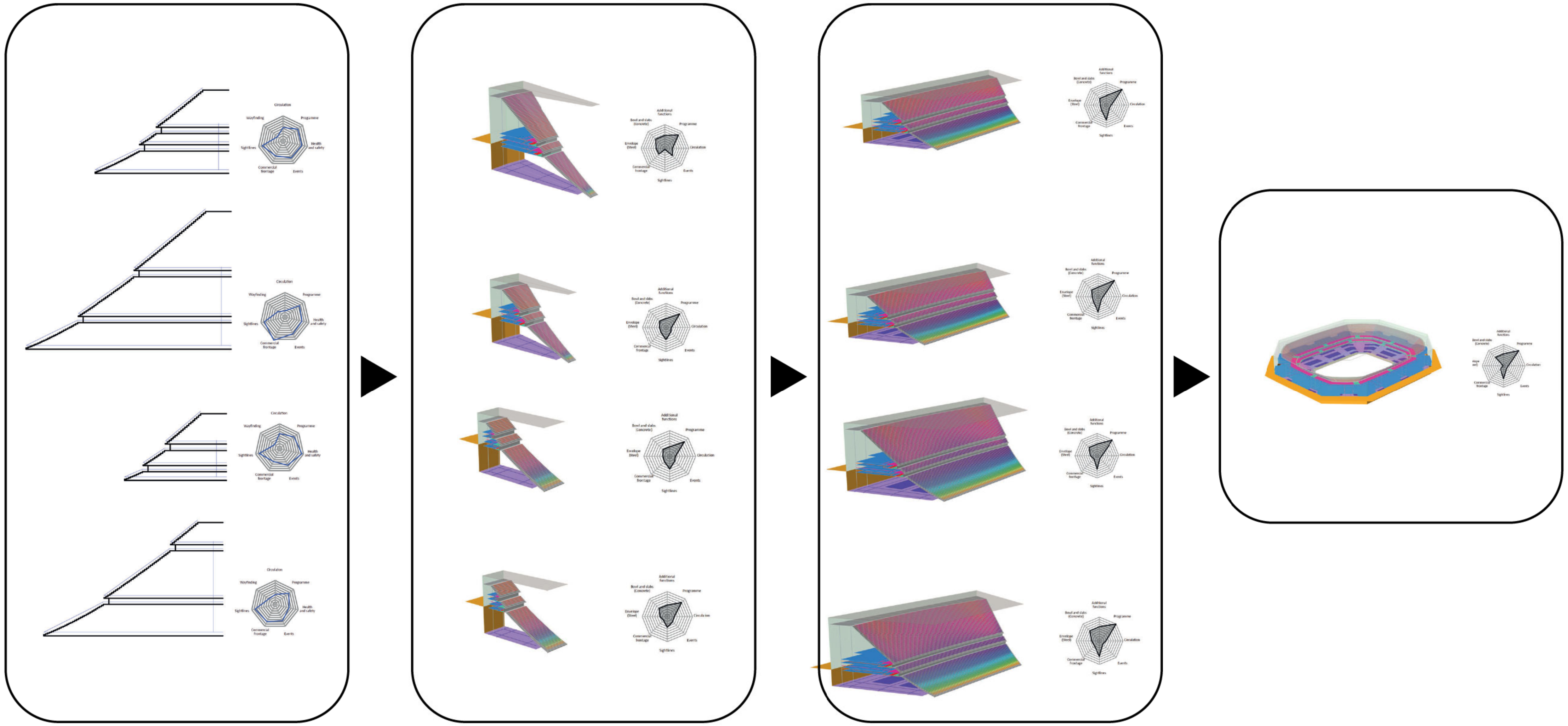


Generate 2d section

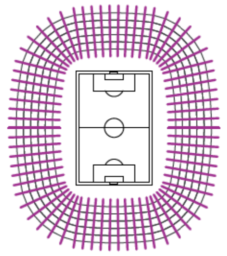
Generate Bay

Combine Bays to generate Stand

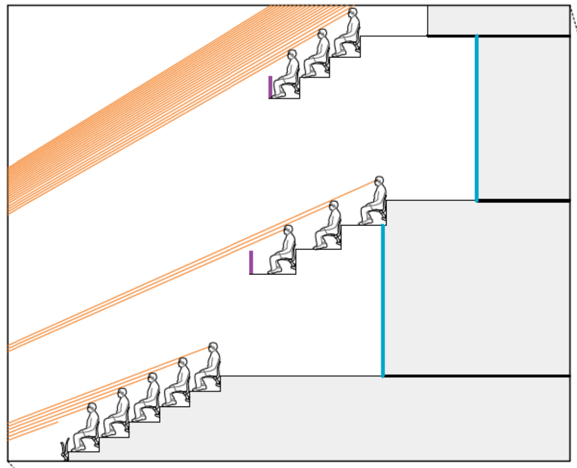
Combine Stands to generate Stadium



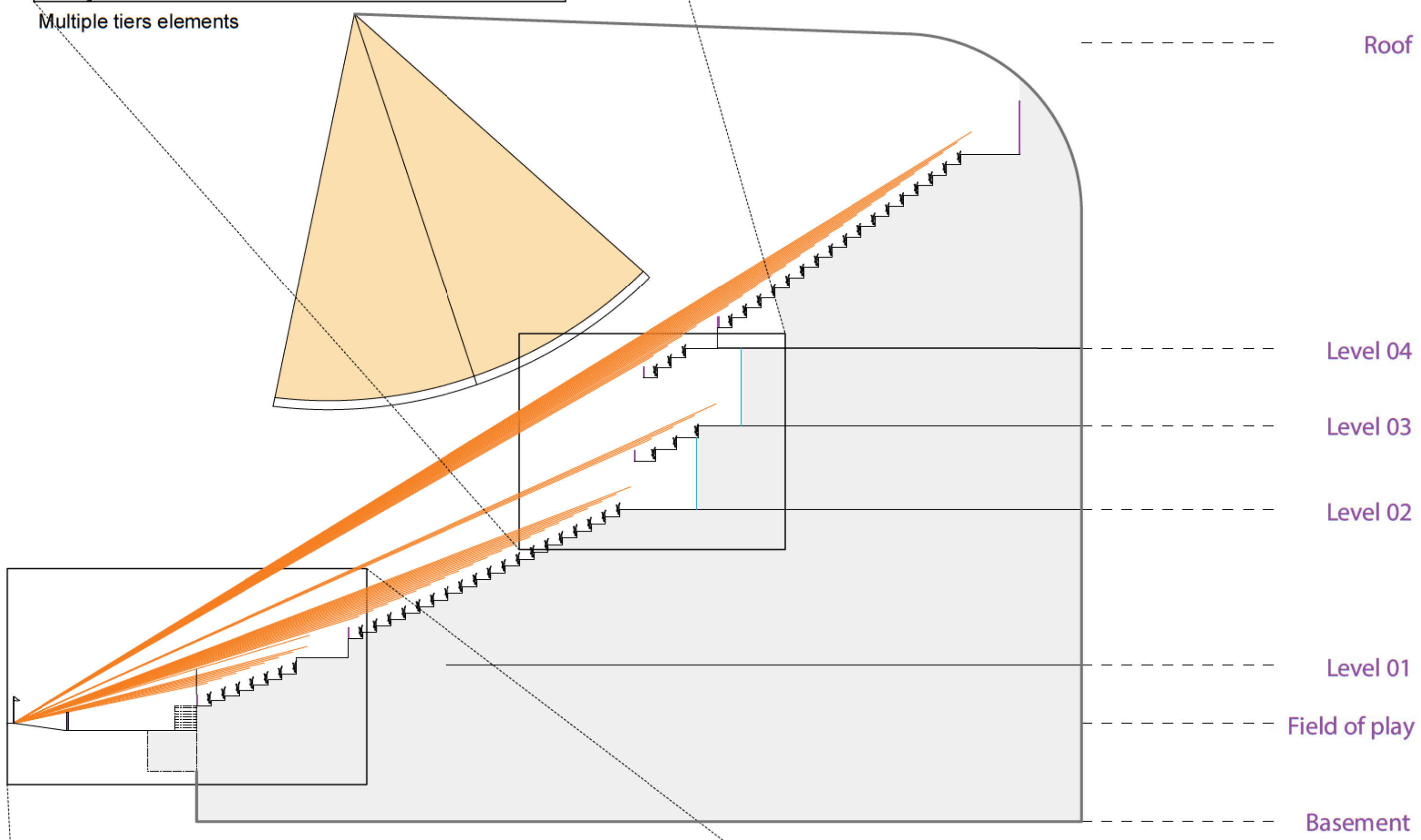
2d Section

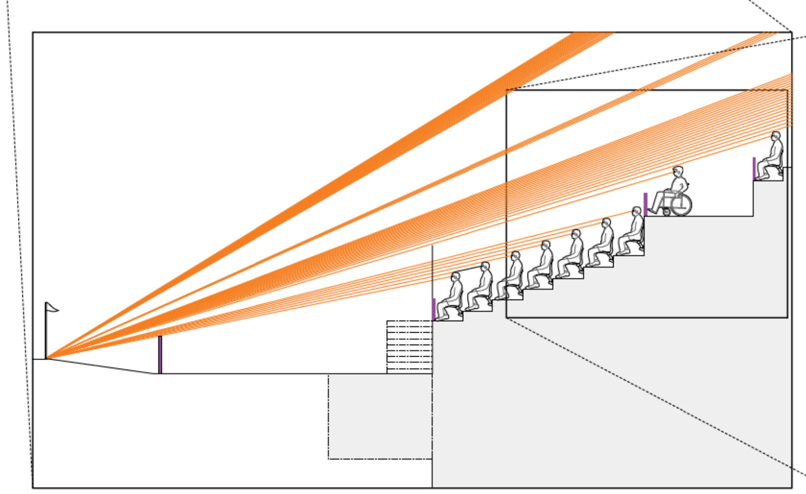


Field of play	Type *[natural - artificial - hybrid]*
	Height *[-500mm - 1500mm]*
Advertising boards	Location relative to touchline*[1500mm - 3500mm]*
	Building level *[-5 – 10]*
Seats	C-Value *[0 - ∞]*
	Depth *[400mm - 500mm]*
	Location on row *[back - mid -front]*
Rows	Depth *[700mm - 1200mm]*
	Superiser *[0-1]*
Tiers	Number *[0-10]*
	Number of rows per tier *[0-60]*
	Cantilever *[0mm - 12000mm]*
	Landing *[0mm - 12000mm]*
	Starting point *[-2500mm-5000mm]*
	Security features *[trap, wall, barrier]*
	Scoreboard Location *[x;y;z]*
	Scoreboard Dimensions *[x,y,z in mm]*
Slabs	Height *[-2500mm-60000mm]*
	Depth *[10mm-3000mm]*
Facade	Location relative to touchline *[-7200mm-90000mm]*
Roof	Location from ground *[-7200mm-90000mm]*
	Fillet to facade *[0mm-50000mm]*
Podium	Location from ground *[0mm-30000mm]*
	Width *[0mm-70000mm]*

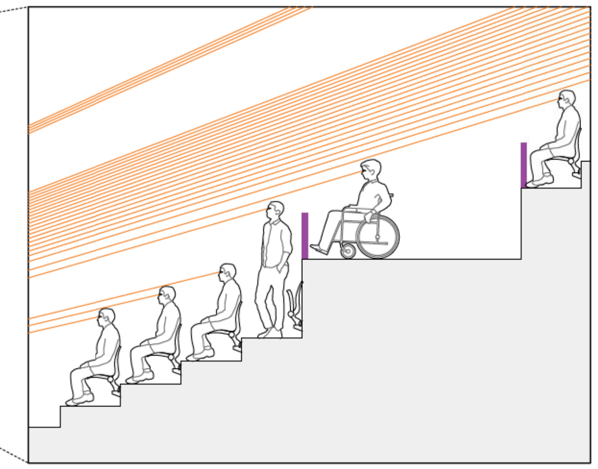


Multiple tiers elements



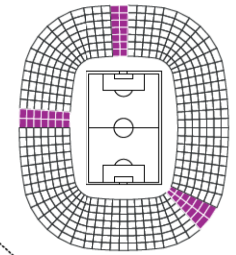


Parabolic section and safety features

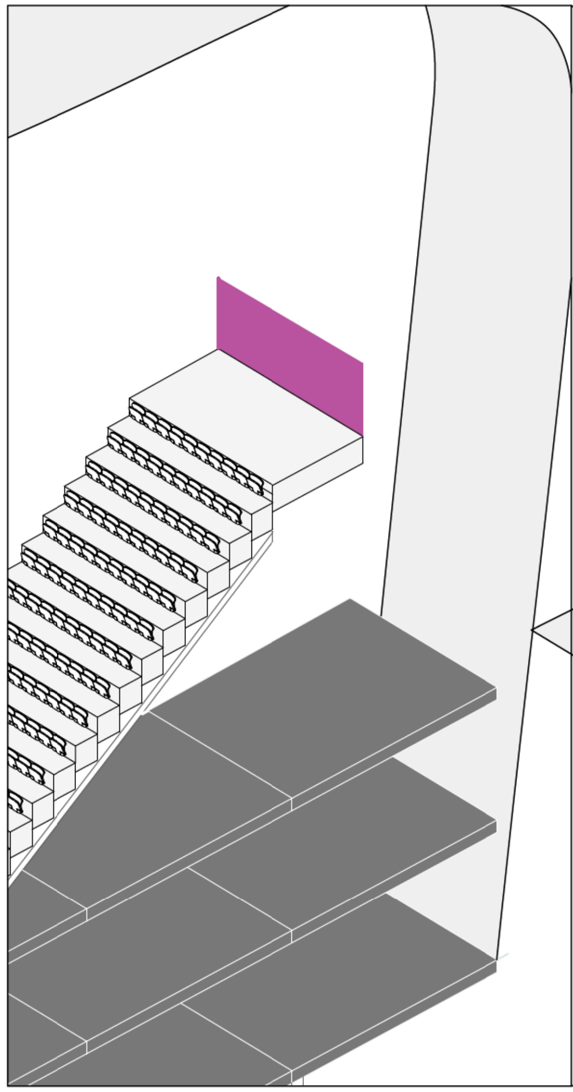


Super risers and accessibility

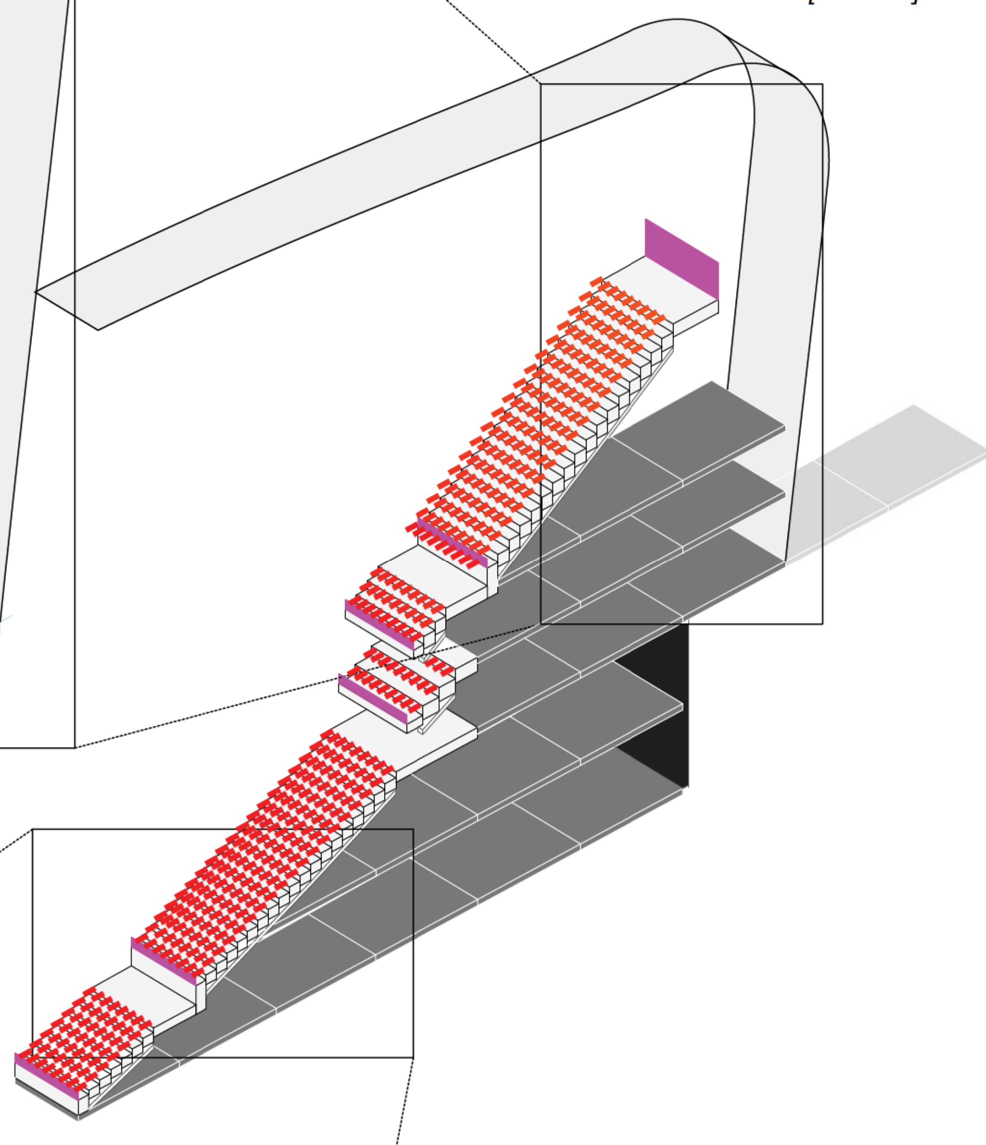
Bay

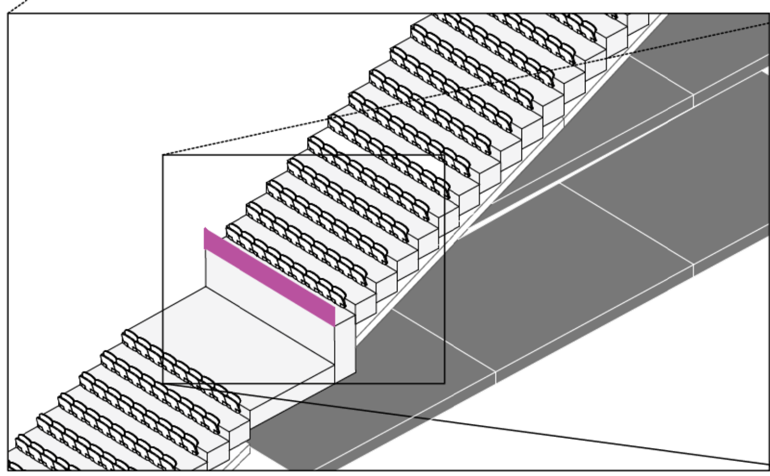


Seats	Width *[400mm - 600mm]*
	Spacing *[400mm - 700mm]*
Slabs	Panelisation U *[0 - 100]*
	Panelisation V *[0 - 100]*
Columns	Section *[20mm - 1500mm]*
Facade	Coverage *[0 % - 100%]*
	Panelisation U *[0 - 100]*
	Panelisation V *[0 - 100]*
	Roof fillet *[0mm - 30000mm]*
Roof	Percentage *[0 % - 100%]*
	Panelisation U *[0 - 100]*
	Panelisation V *[0 - 100]*

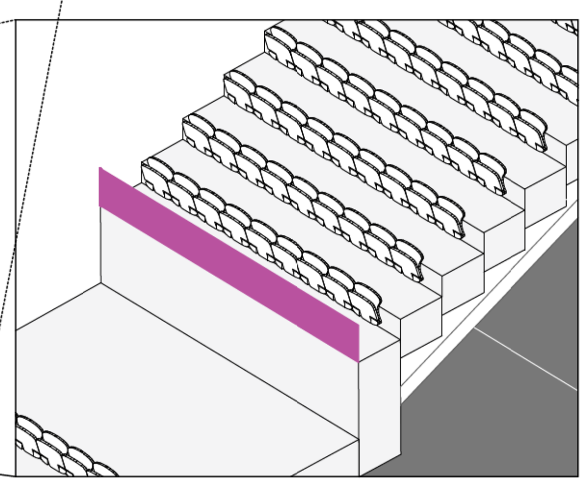


Slab, envelope, seating bowl modules





Bowl row, raker, super riser modules



Seat spacing and safety feature modules

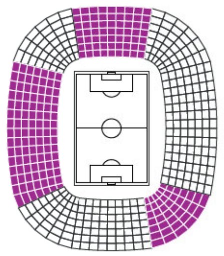
Vomitories
Bay number *[0 -∞]*
Height *[number of rows]*
Width *[1200mm - 1800mm]*
Building level *[-5 – 10]*

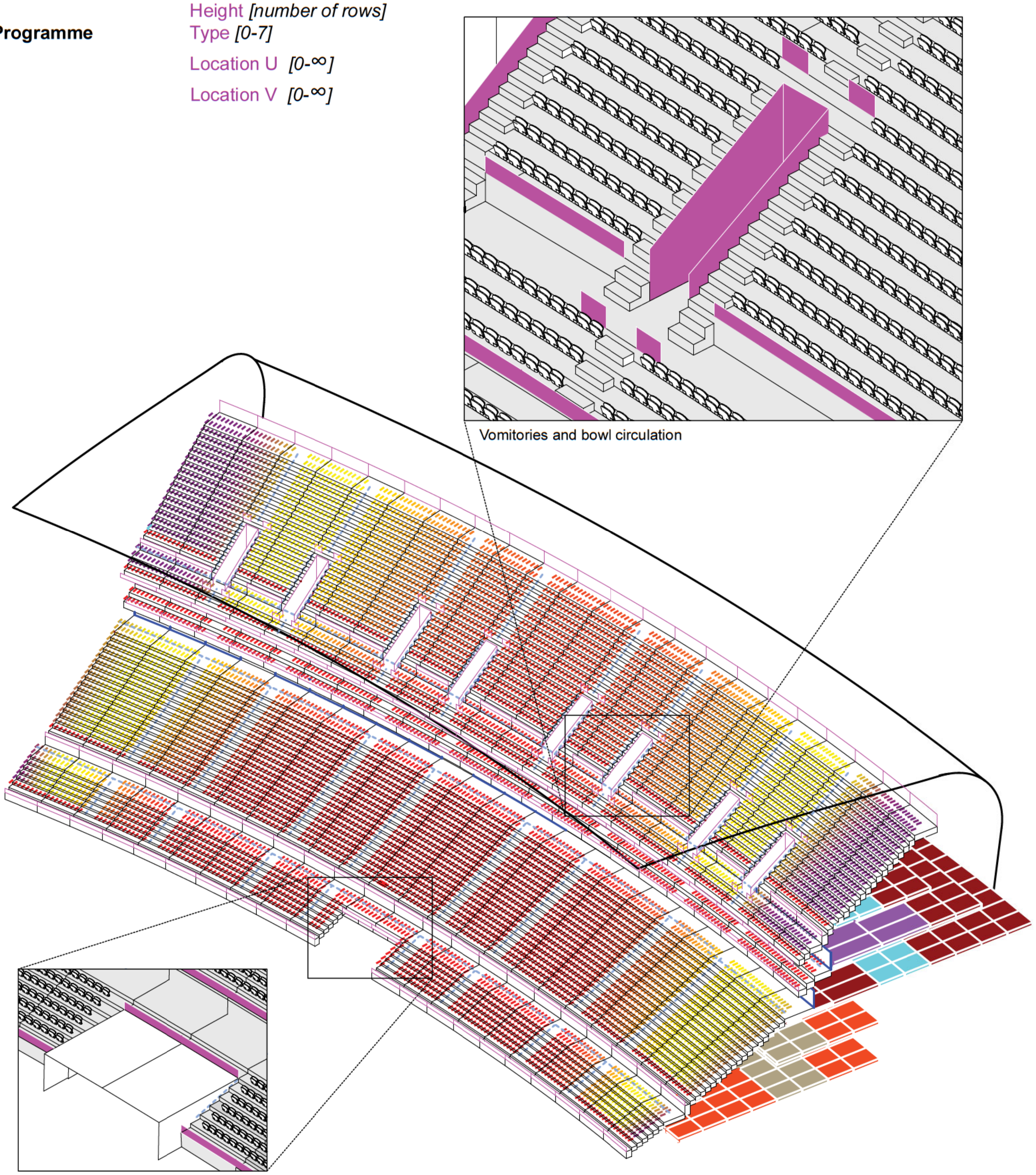
Gangways
Width *[1200mm - 1800mm]*
Bay number *[0 -∞]*
Location on row *[back - mid -front]*

Tunnels
Bay number *[0 -∞]*
Height *[number of rows]*

Programme
Type *[0-7]*
Location U *[0-∞]*
Location V *[0-∞]*

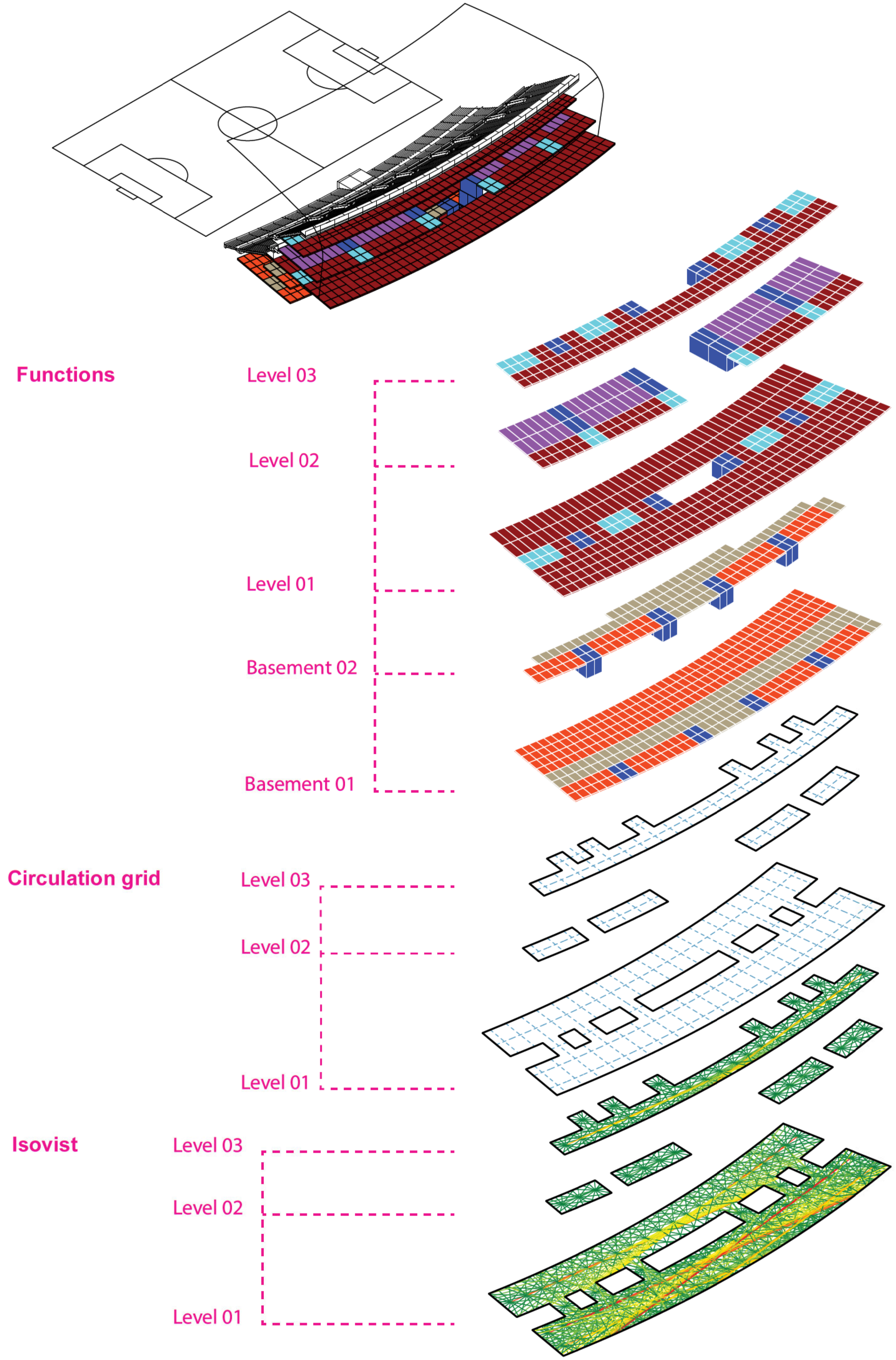
Sector





Vomitories and bowl circulation

Tunnels

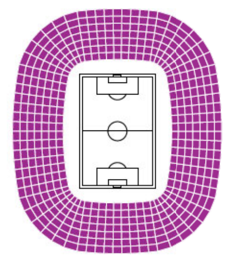


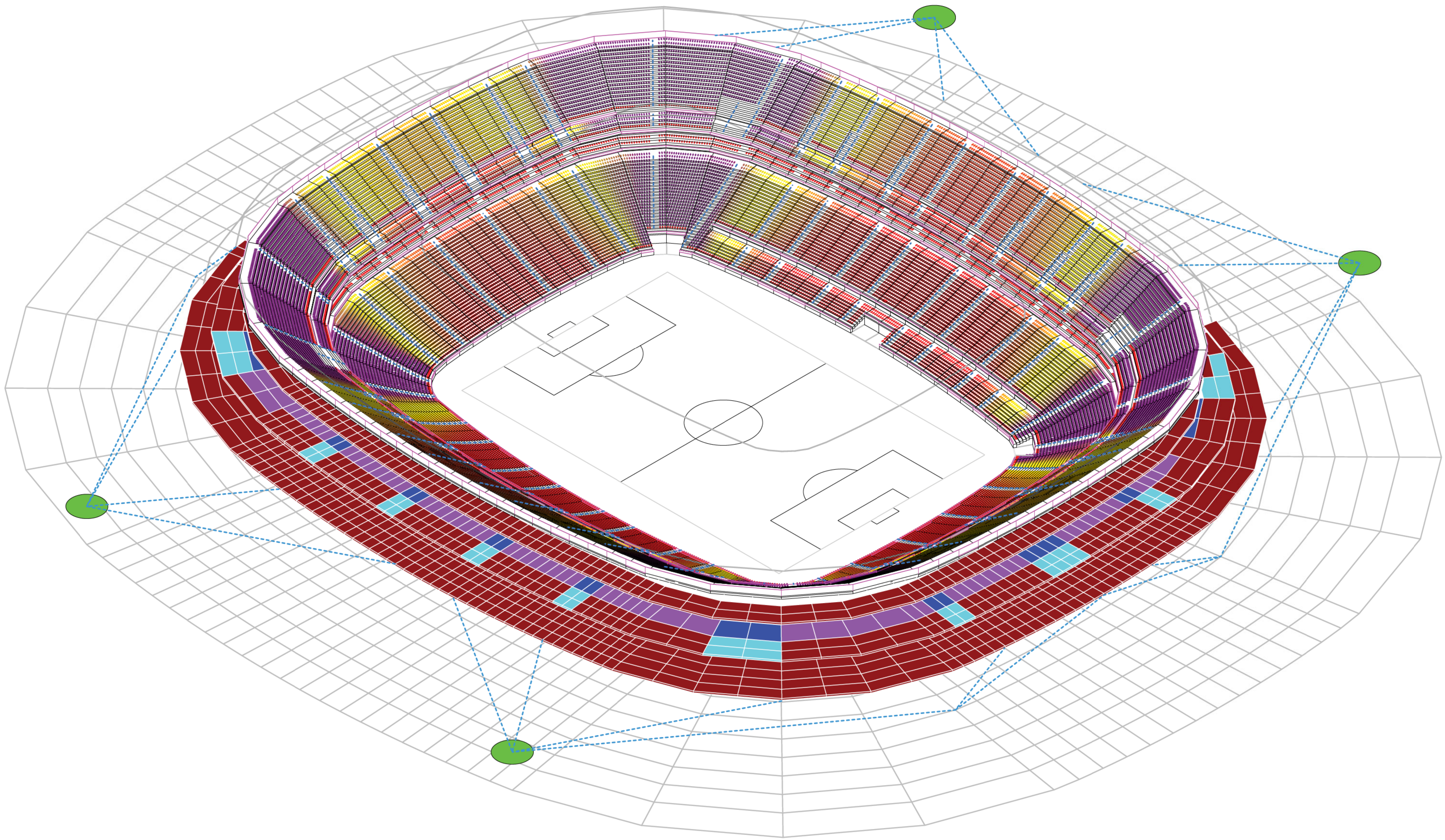
Masterplan entries location relative to centre of playing field

Level *[0 -∞]*

Orientation Relative to North *[-22º - 22º]*

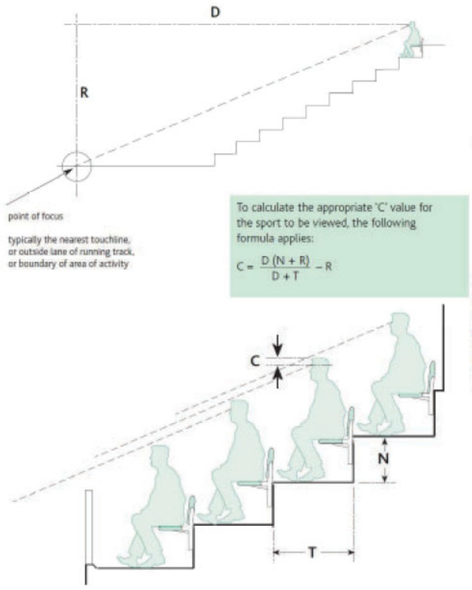
Stadium



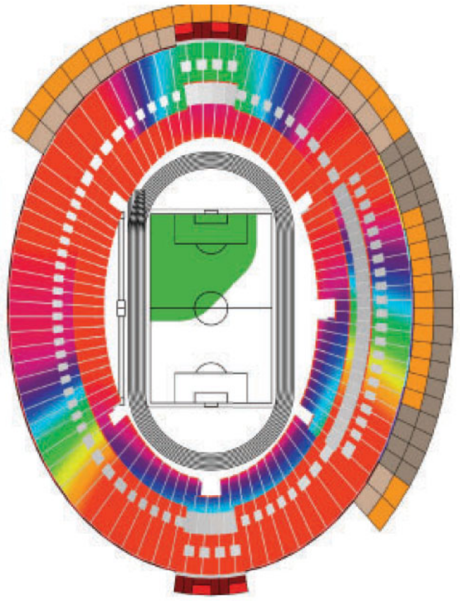


Sightline quality

measurement



point cloud output



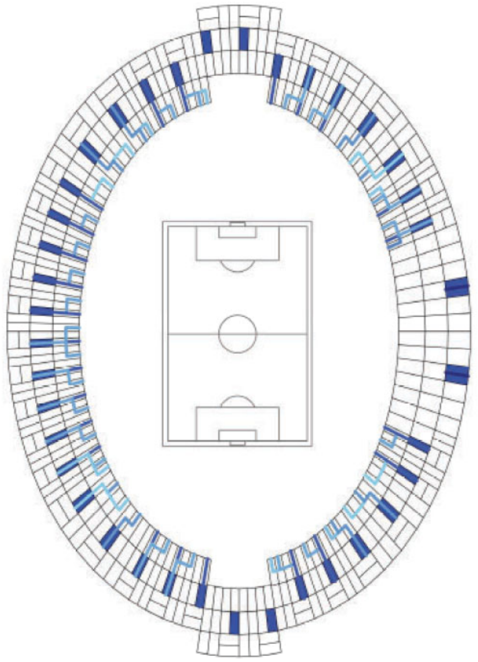
Sightline quality is measured with formulas:
c-value
a-value
physical properties
restricted views

Optimisation target:
Maximise number of high quality sightlines

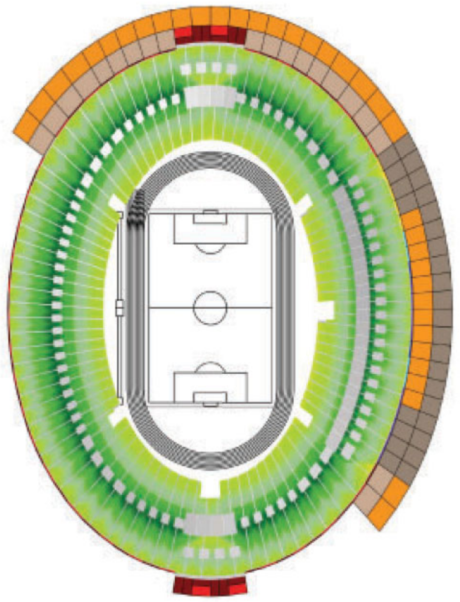
Benchmarks from case studies:
c-value: Allianz Riviera, Nice, 70% above 100mm
a-value: Allianz Riviera, Nice, 65% above 12
physical properties: Allianz Riviera, Nice, 75% above the average estimate
restricted views: all cases except Craven Cottage, London - 100%

Circulation

measurement



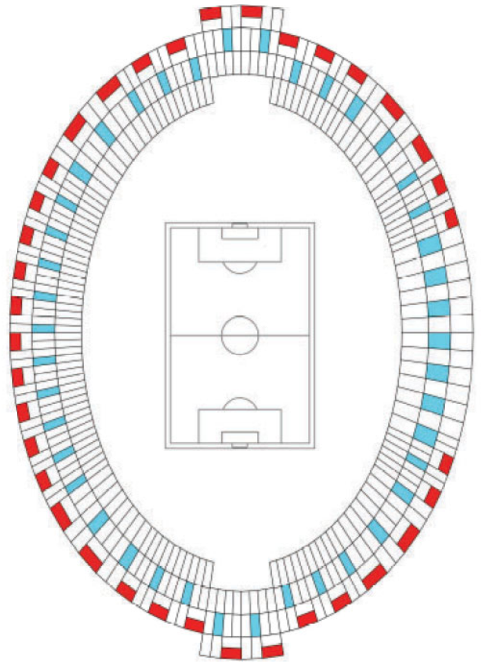
point cloud output



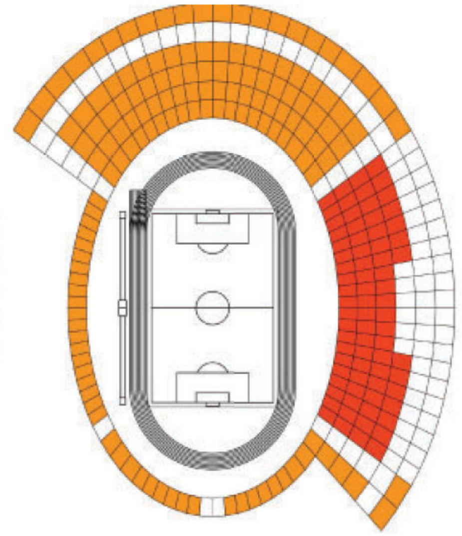
Circulation distance measured by:
Direct distance from seat to centre of gangway
Distance to vomitory is also direct.
Pathfinding on the concourse is based on a grid, and using shortest path component in Grasshopper shortest path on the grid is identified.
The length of that path is then added to the groups of distances coming from the bowl exit.
Optimisation target:
Minimise number of seats further than 38m to exit
Minimise number of seats further away than average from functional element
Benchmark from legislation:
Department for Culture, Media and Sport, 2008. Guide to safety in sports grounds. The Stationery Office, London. - more than 7.5m distance seat to gangway and more than 38m seat to exit

Layout functional relationships

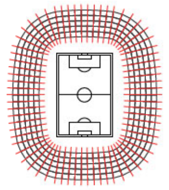
measurement / numeric output



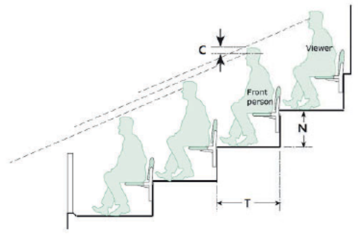
measurement / numeric output



Layout functional relationships measured by:
Area per seat for WC, commercial, and concourse
Ratios of different functions
Optimisation target:
Maximise area per seat
Ratios are on case by case basis
Benchmark from legislation:
Department for Culture, Media and Sport, 2008. Guide to safety in sports grounds. The Stationery Office, London. -
more than 1sqm concourse area per seat
more than 2 sqm WC per 600 seats
Benchmarks from case studies:
Dependent on designer/client requirements, then best fitting case study ratios become target

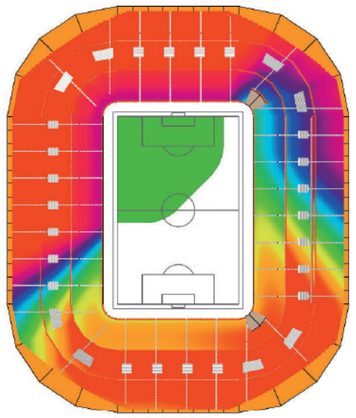


C-value football



Cvalue

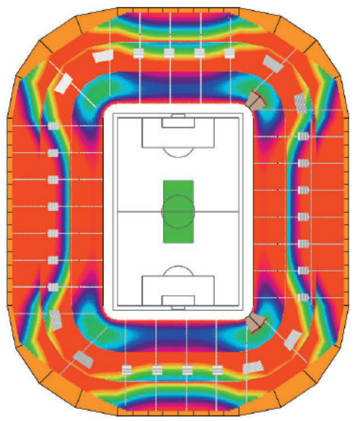
Department for Culture, Media and Sport, Guide to Safety in Sports Grounds (London: The Stationery Office, 2008)



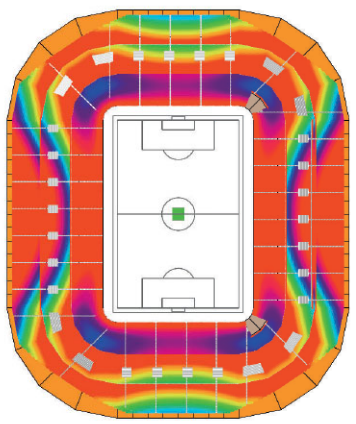
C-value baseball

Point cloud of seat locations with individual sightline quality value based on the unobstructed view above the head of the spectator on the lower row. The sampling is based on the full capacity of the stadium and each value is based on the spectator looking towards the closest point on the field of play touchline.

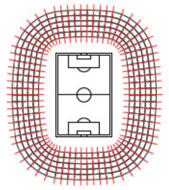
Higher value is better.

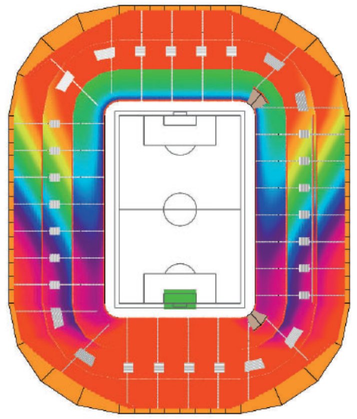


C-value tennis

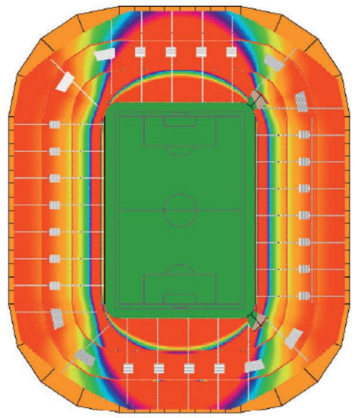


C-value boxing





C-value concert

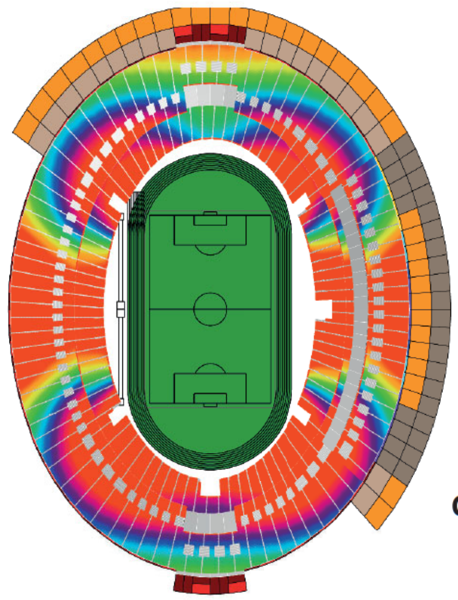


C-value athletics*

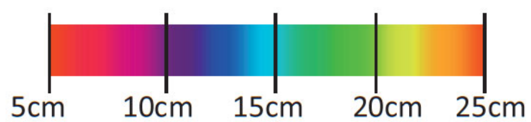
*

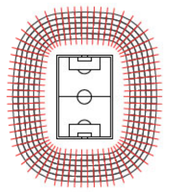
The calculation is for an athletics track that goes under the seating stand.

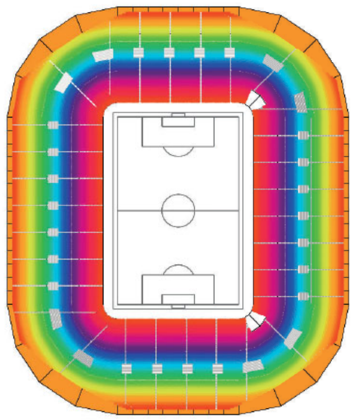
Below you can see the London stadium in athletics configuration.



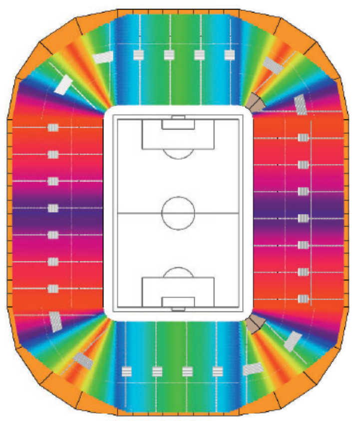
C-value athletics



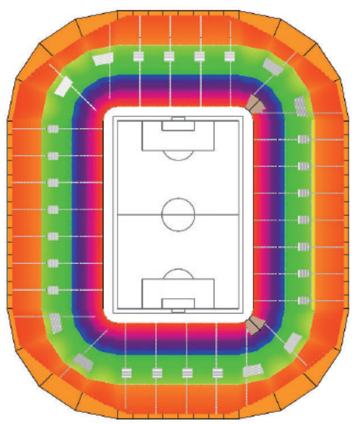




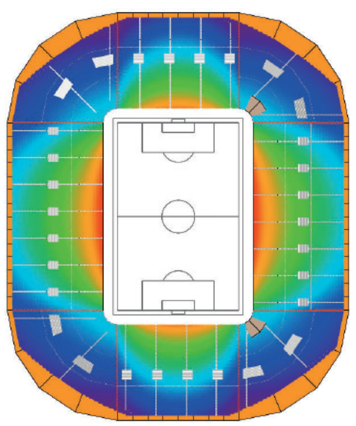
Distance seat to touchline



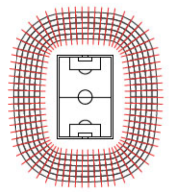
Horizontal angle

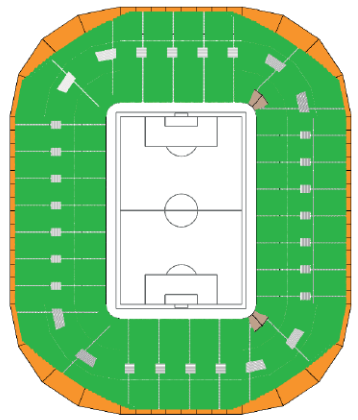


Vertical angle



Field of view

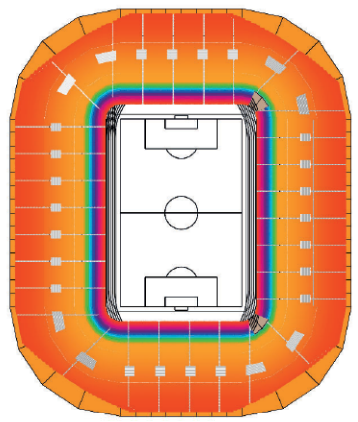




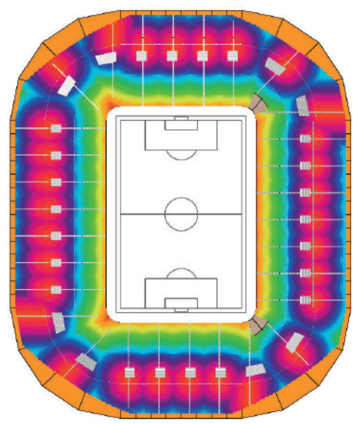
unobstructed views

restricted views

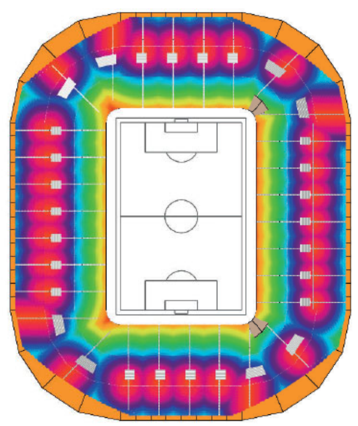
Restricted views



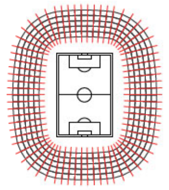
Weather protection

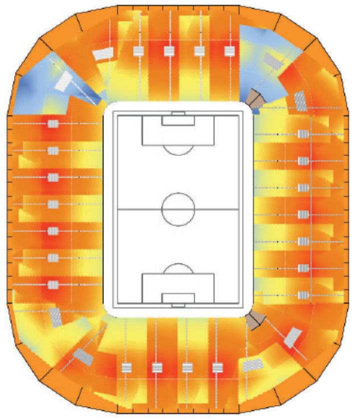


Distance seat to gangway

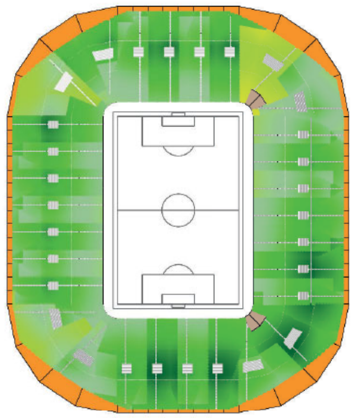


Distance seat to bowl exit

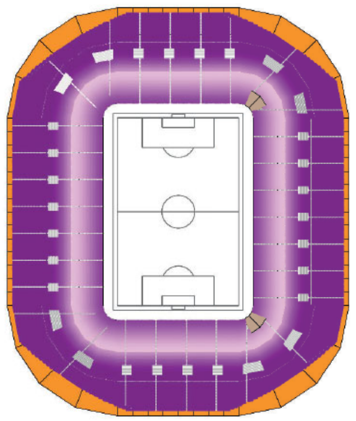




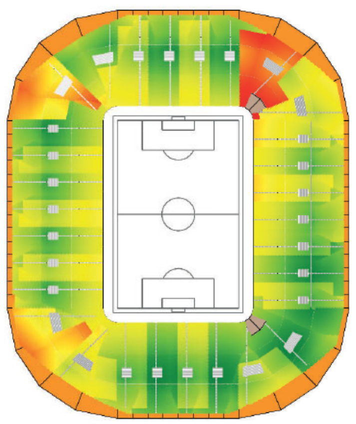
Distance seat to vertical circulation



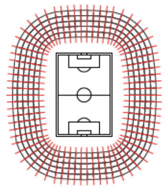
Distance seat to stadium entrance



Vertical distance seat to main entry level



Distance seat to masterplan entry



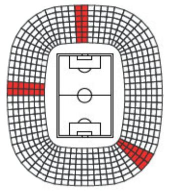
Numerical data:

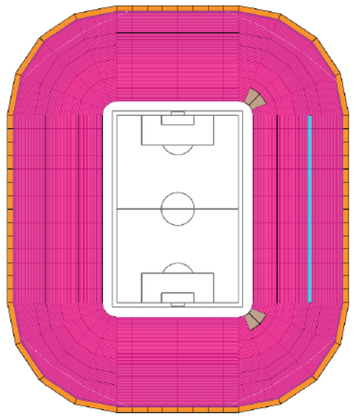
Feasable events = 4

Distance hospitality to stadium entrance =
57.311616 m

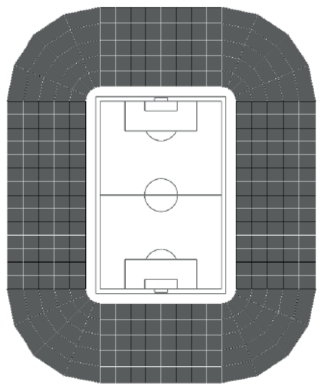
Distance performers to stadium entrance =
132.838819 m

Masterplan entrypoints per seat = 0.000074

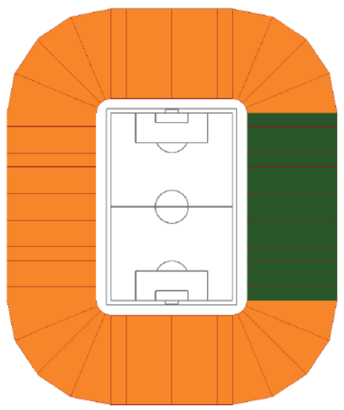




Row depth



Frame / monolith



Module type

Numerical data:

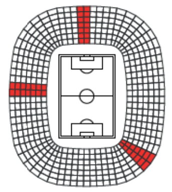
Moving elements area = 0 sqm

Moving elements number = 0

Rows maximum number = 73

Steps total = 8672

Steps highlight paint area total = 4995.072 sqm



Rakers total = 60

Bowl area = 33369.707645 sqm

Bowl material volume = 10010.912293 m3

Seats rail total lenght = 32917.405569 m

Gangway total area = 2336.07505

Gangway total number =246

Vomitories total area = 1452.483497

Vomitories total number = 76

Frame monolith ratio = 1

Number of columns total = 324

Columns length total = 5263.649914 m

Slab on ground total area = 23646.068102 sqm

Slab on columns total area = 91823.067082 sqm

Primary vertical circulation cores = 30

Vertical circulation area total = 12699.597987 sqm

Basement area total = 41272.659197 sqm

Basement walls area total = 8550.432296 sqm

Facade_area_total = 31115.368927 sqm

Facade height = 30.56794 m

Facade openings area = 1.238e-11 sqm

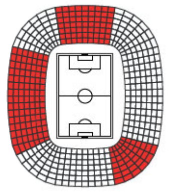
Roof area total = 69806.892608 sqm

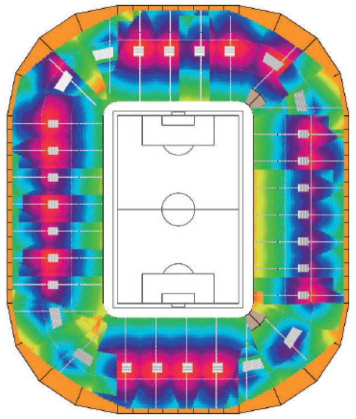
Roof span = 99.616322 m

Roof number of divisions = 60

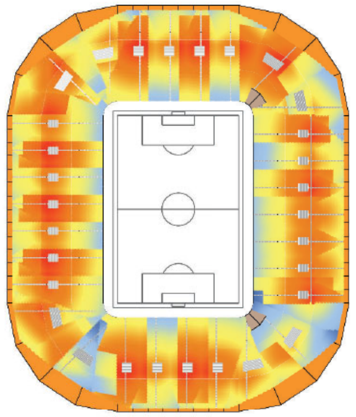
Podium area total = 10496.434079 sqm

Podium height = 8.4 m

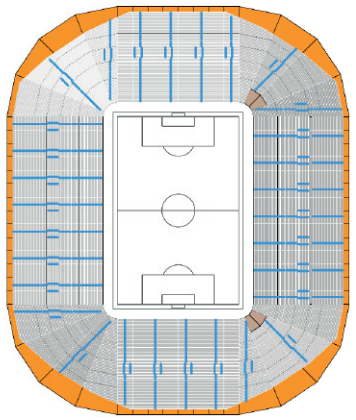




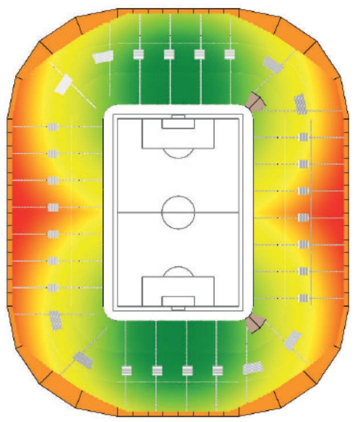
Distance seat to WC



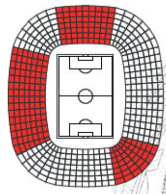
Distance seat to commercial

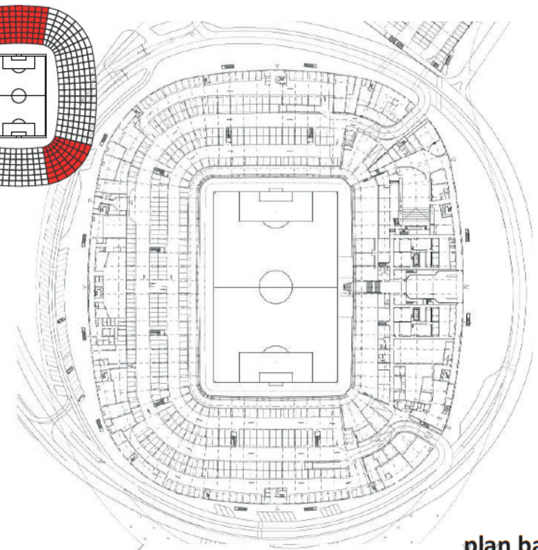


Bowl circulation

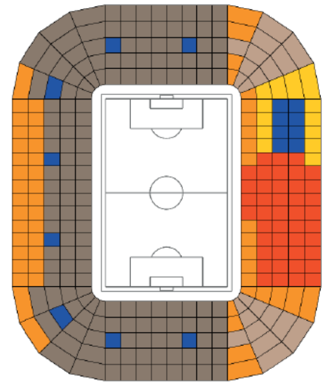


Distance seat to scoreboard

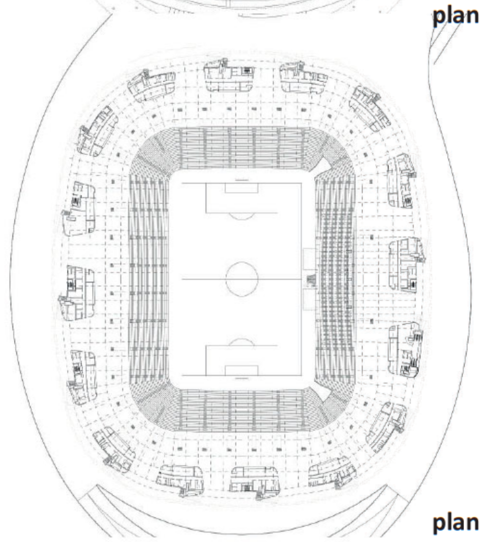




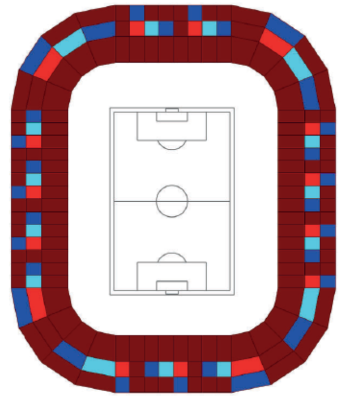
plan basement



parametric representation

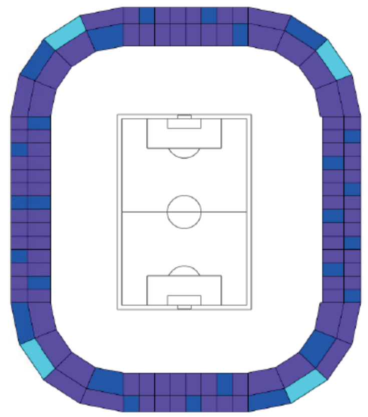


plan level 00
general admission concourse

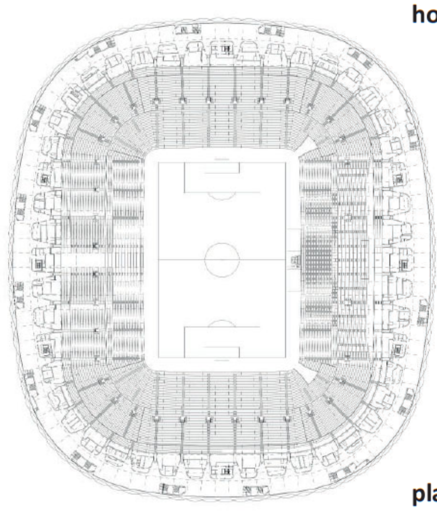


parametric representation

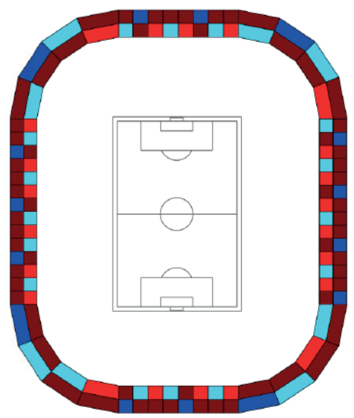
plan level 01
hospitality



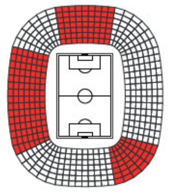
parametric representation

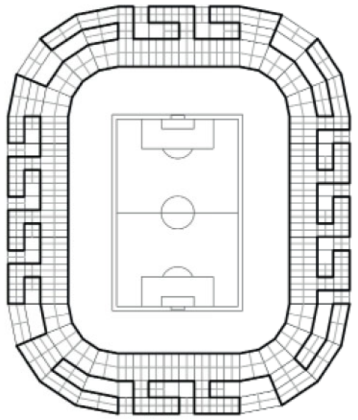


plan level 04
upper concourse

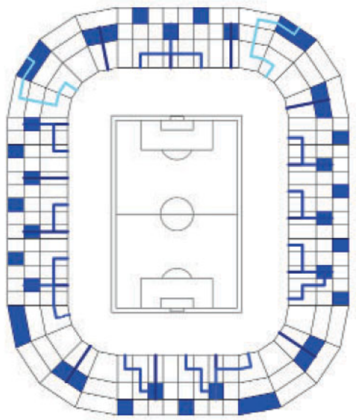


parametric representation

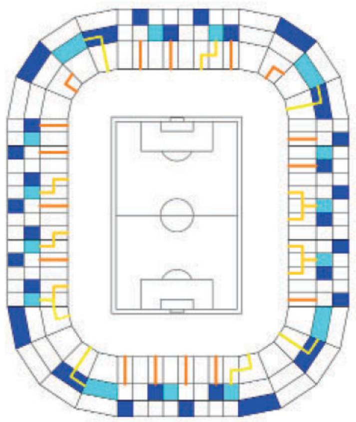




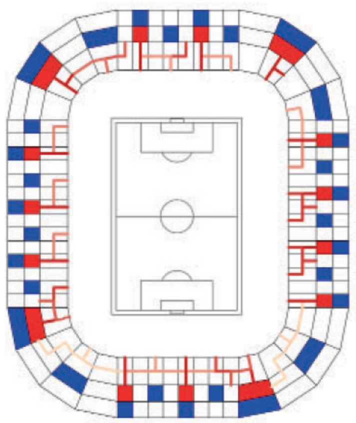
Concourse circulation analytical grid



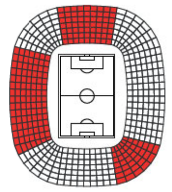
Vomitory to vertical circulation paths

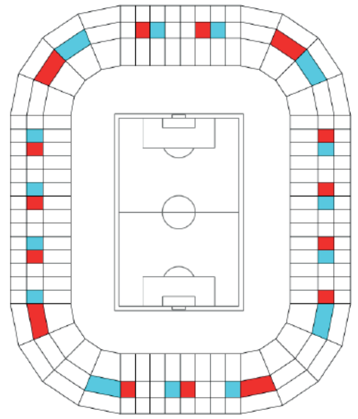


Vomitory to WC paths

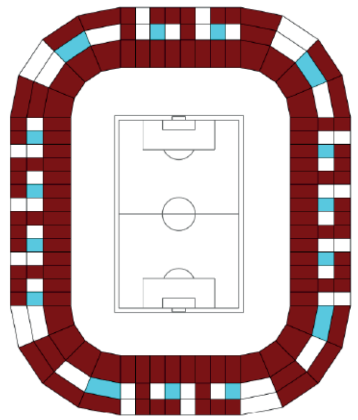


Vomitory to commercial paths

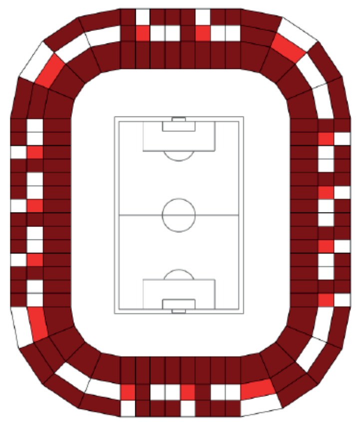




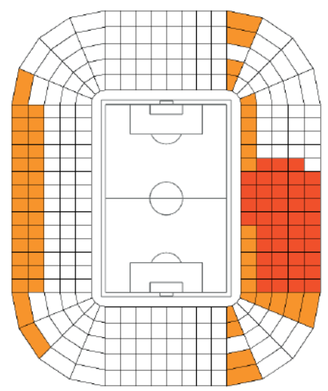
Spatial relationships WC - commercial



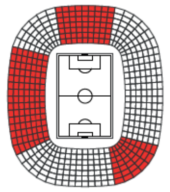
Spatial relationships WC - concourse

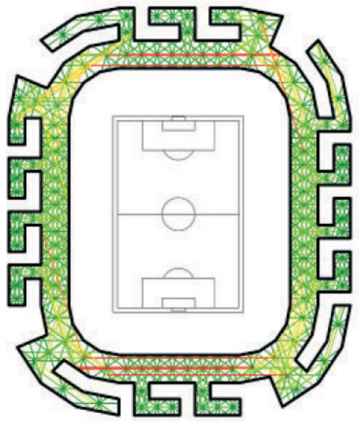


Spatial relationships commercial - concourse

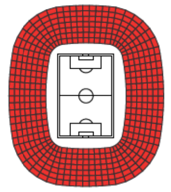


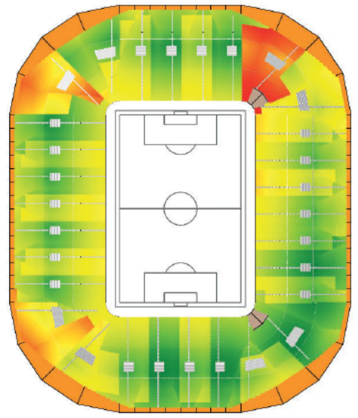
Spatial relationships service - performers





Isovist main concourse





Numerical data

Number of stadium entrance = 12
Number of masterplan entry points = 4
Distance podium entry to stadium entry = 8
Distance commercial to mastreplan entry = 186.125029 m
External programme variation = 4

Numerical data

Distance changing room to field of play = 5.6 m

Concourse area per seat = 0.367828

Vertical circulation to concourse area = 0.637609

Topological distance number of turns from bowl to vertical circulation = 1.466667

Angular distance angular change from bowl to vertical circulation = 14.20364

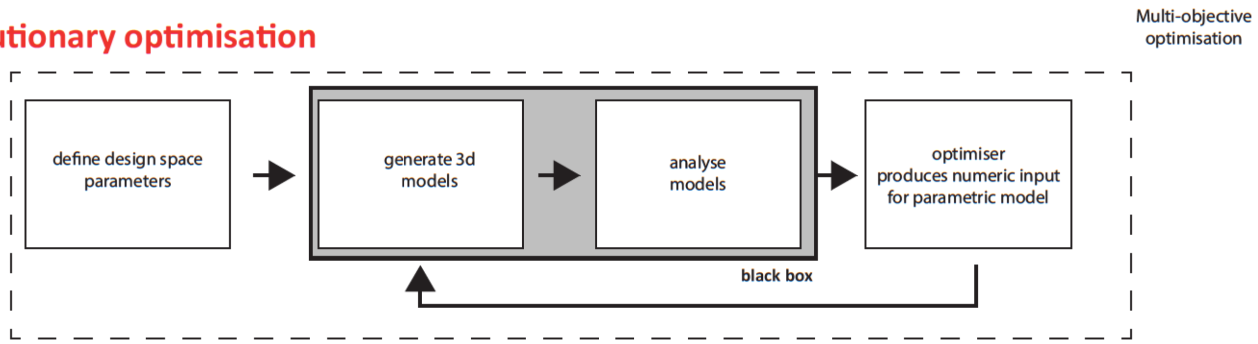
Average metric distance, Euclidean distance from bowl to vertical circulation = 34.588757

Concourse visibility isovist average lenght = 12.22707

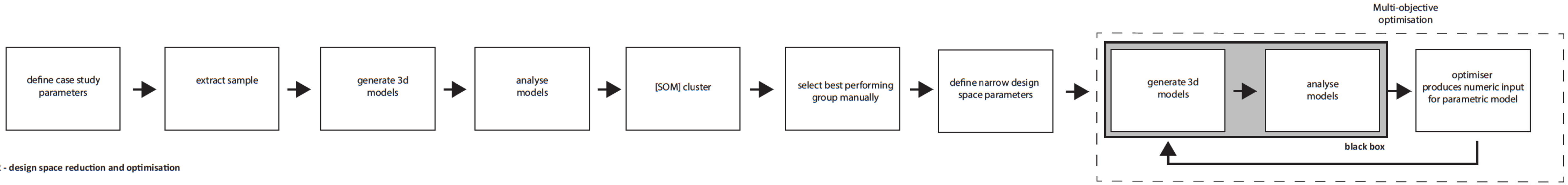
Isovist rays above 50m ratio = 0.027222

Other horizontal circulation area = 2259.724061 sqm
Vertical circulation area = 12699.597987 sqm
WC area = 4362.79534 sqm
Commercial area = 14376.172132 sqm
Service / Store area = 15770.50389 sqm
Performers = 2866.2961 sqm
Hospitality area = 17701.291461 sqm
Media area = 4089.569339 sqm
Other area = 21425.644933 sqm
Internal parking area = 19917.53994 sqm
Concourse area = 193397.372146 sqm

Evolutionary optimisation

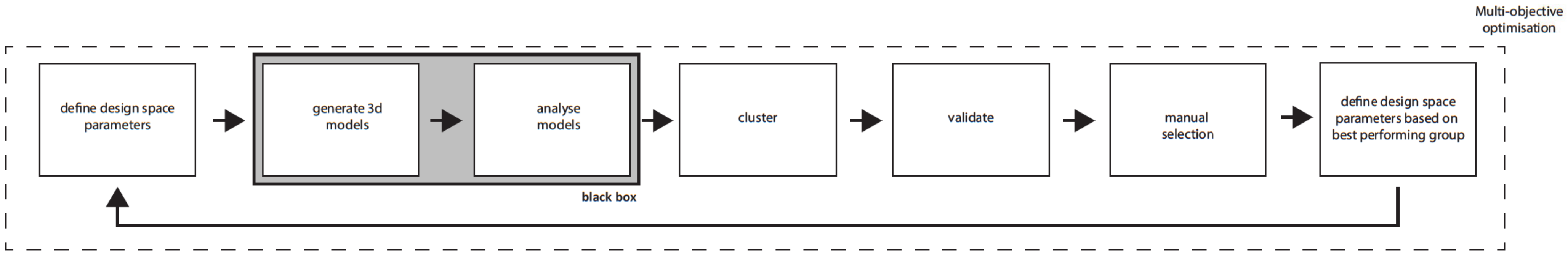


method 01 - optimisation

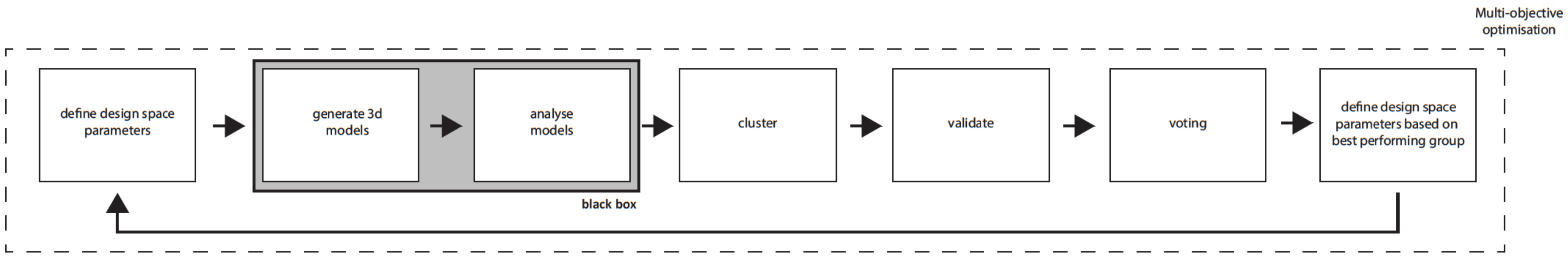


method 02 - design space reduction and optimisation

Unsupervised

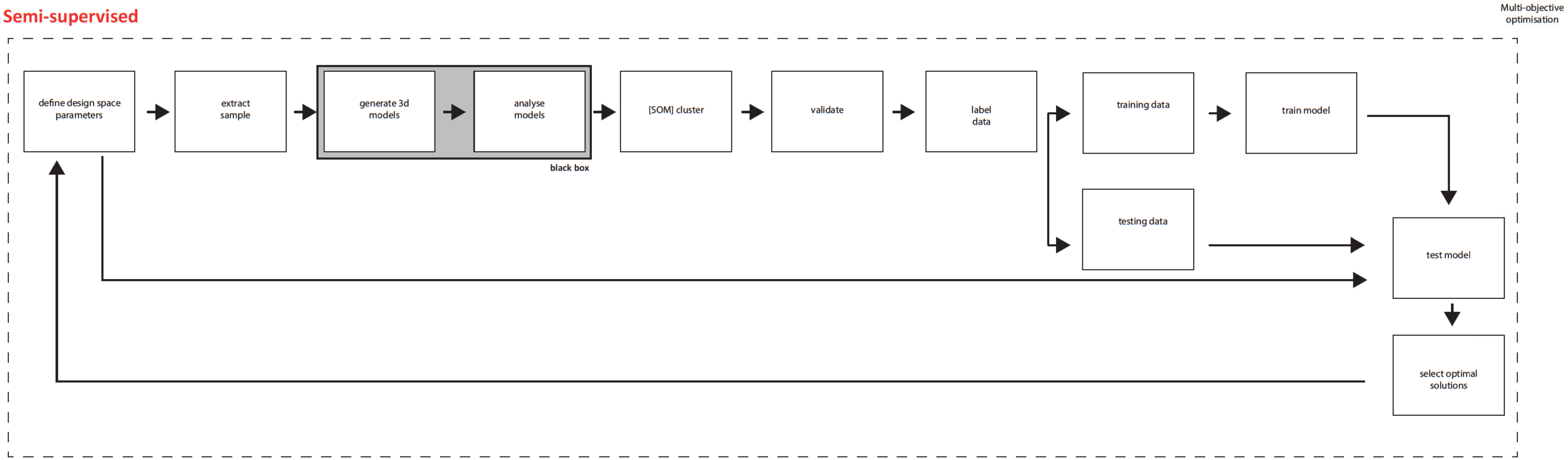


method 03 - clustering, manual selection of best performing group, use properties of cases in best performing group to define narrower design space



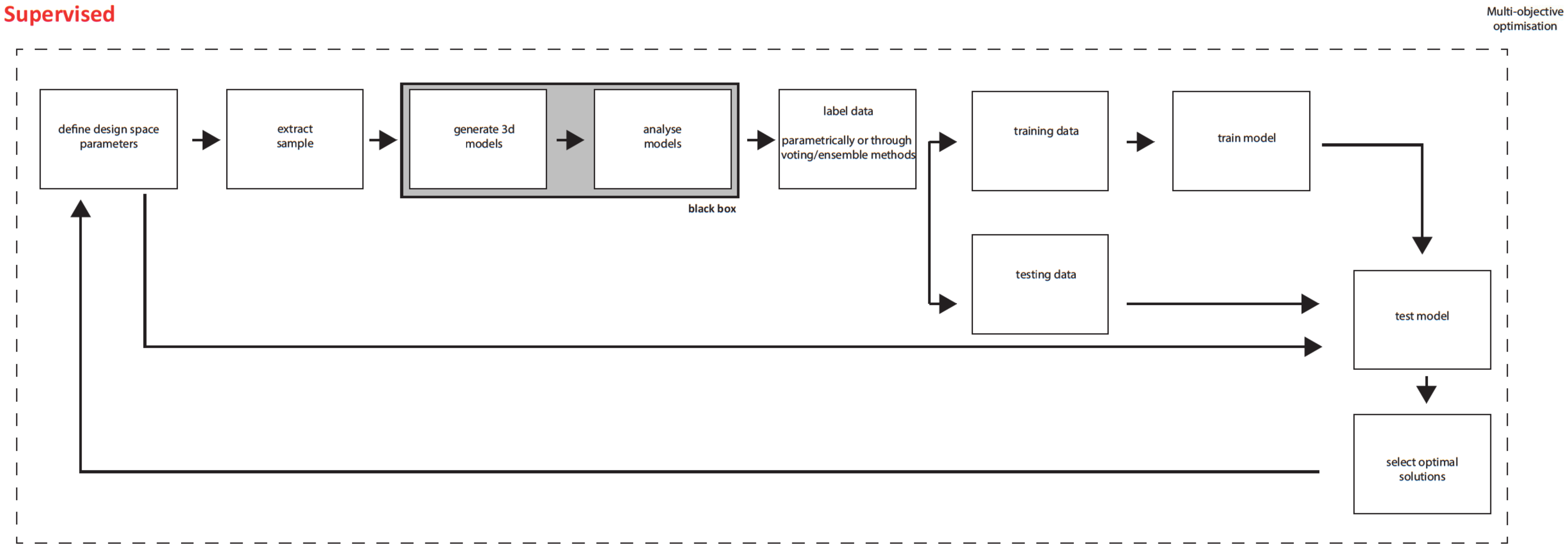
method 04 - clustering, selection of best performing group through voting, use properties of cases in best performing group to define narrower design space

Semi-supervised

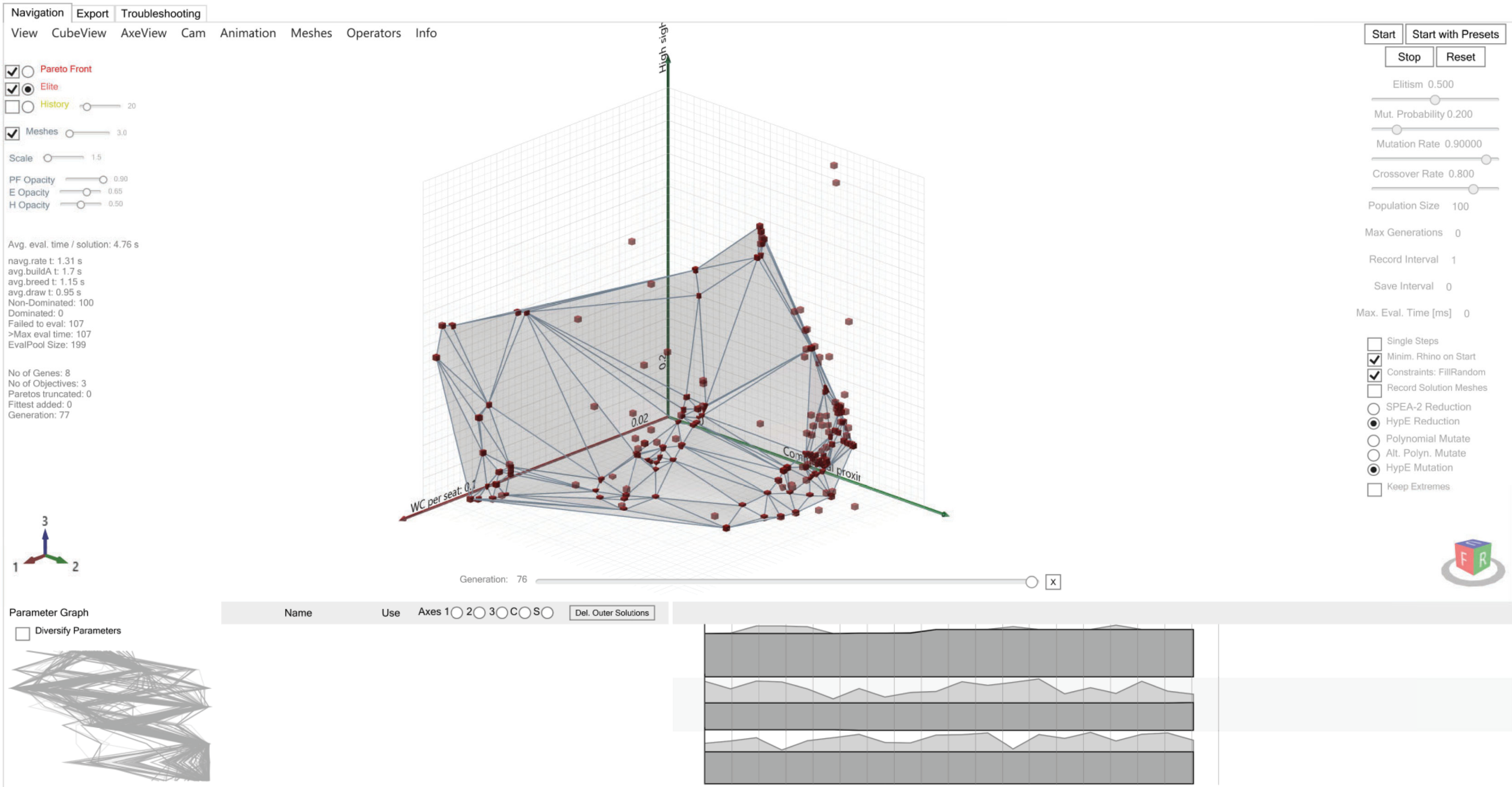


method 05 - clustering, data labelled, Classification algorithm to classify other case studies

Supervised



method 06 - data labelled in parametric model based on benchmarks, Regression algorithm to predict inputs for parametric model



Design space parameters:

Number of tiers [1 - 4]

Number of rows per tier [2 - 40]

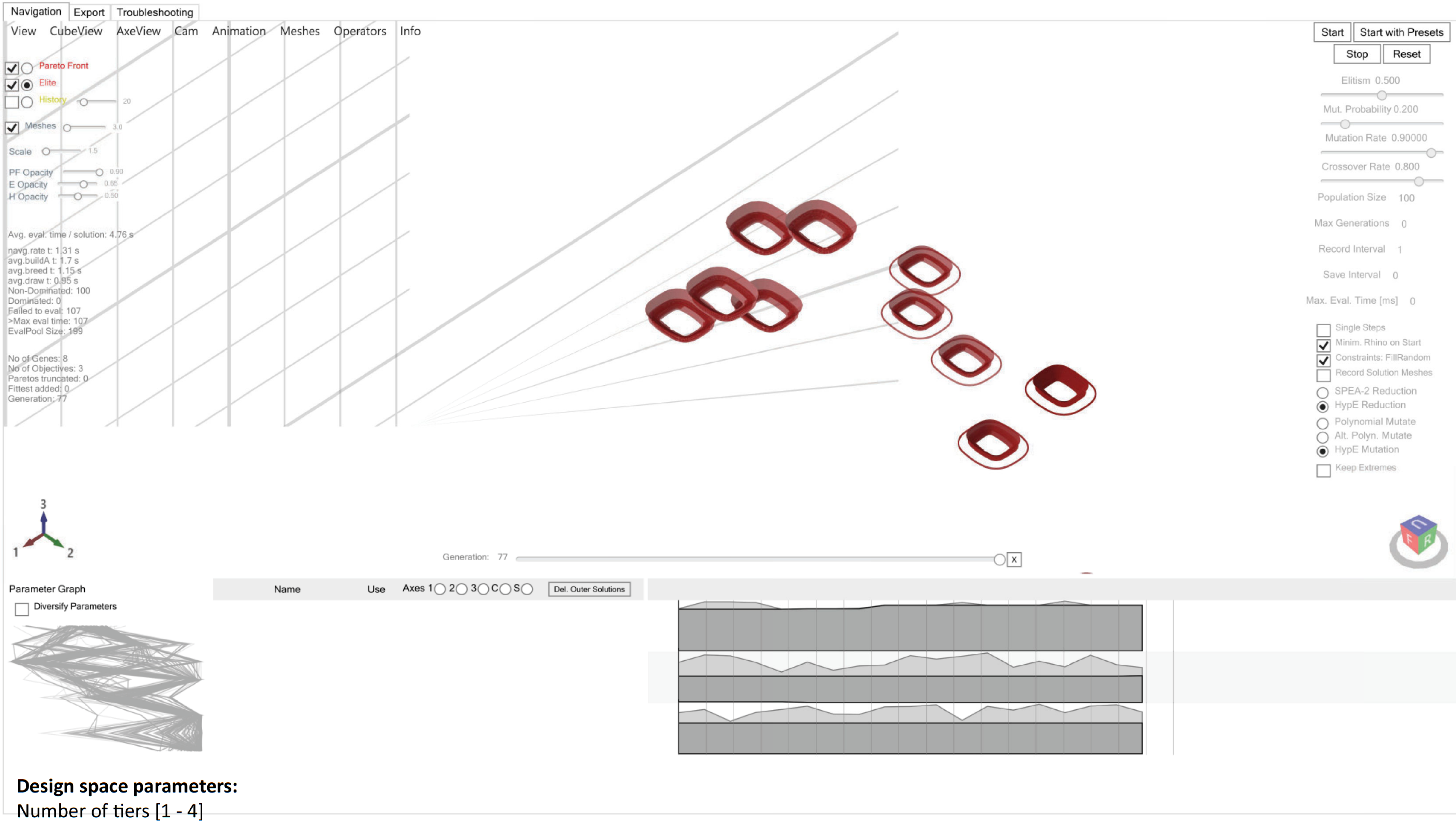
Central section C-value - [100 - 140]

Bowl and building morphologies [all types]

Bowl distance to touchline [2m - 12m]

Bowl start height [-1.5m - 2.5m]

Evolutionary multi-objective optimisation with Octopus and HypeE optimisation algorithm Pareto Front, this is the primary difference between linear optimisation and multi-objective blackbox optimisation - as there are no direct links betweeen the inputs and outputs, the optimisation algorithm explores the outer set of possible solutions which based on the Pareto Front theory 80% of the results are caused by 20% of the causes



Design space parameters:

Number of tiers [1 - 4]

Number of rows per tier [2 - 40]

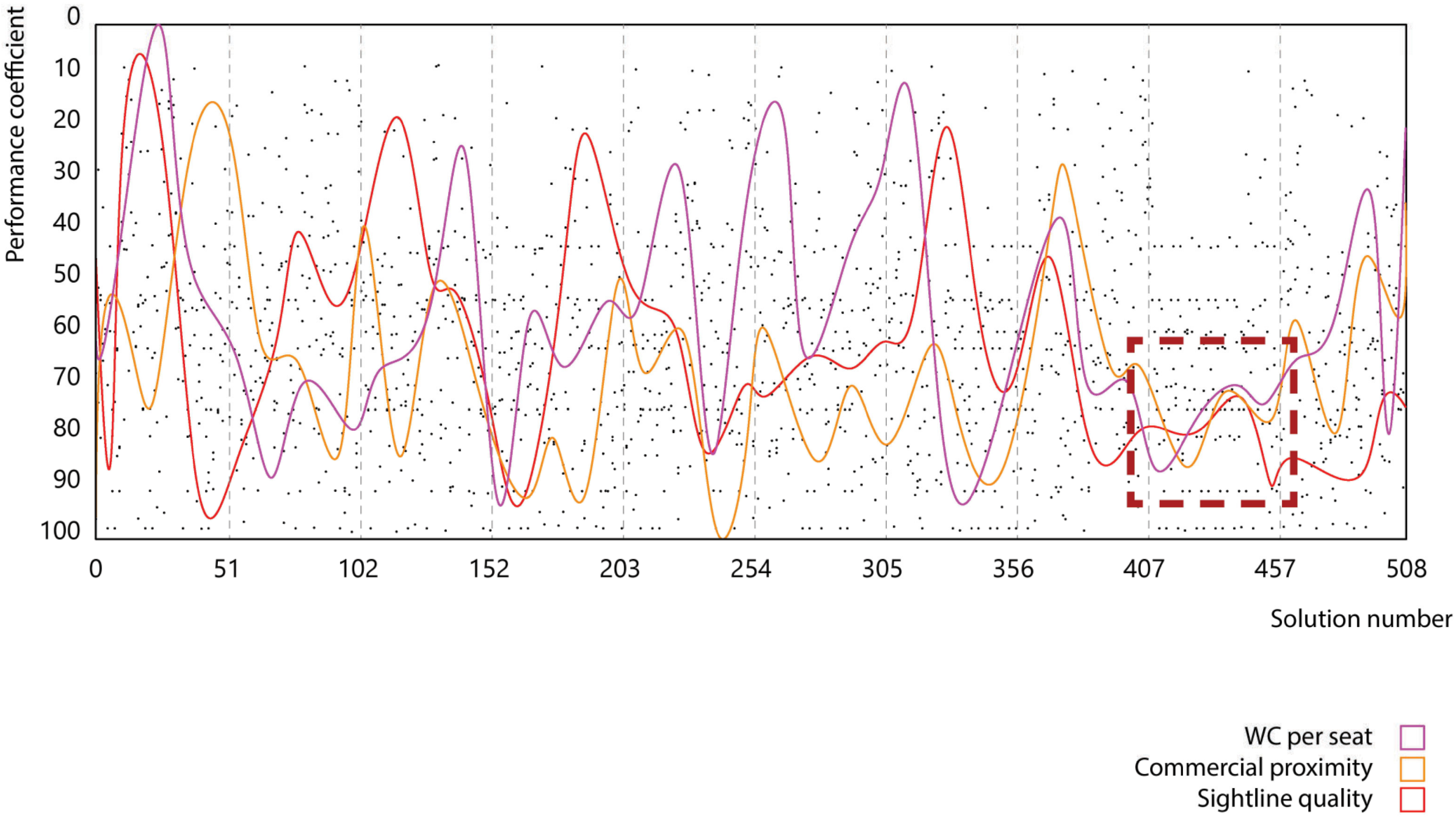
Central section C-value - [100 - 140]

Bowl and building morphologies [all types]

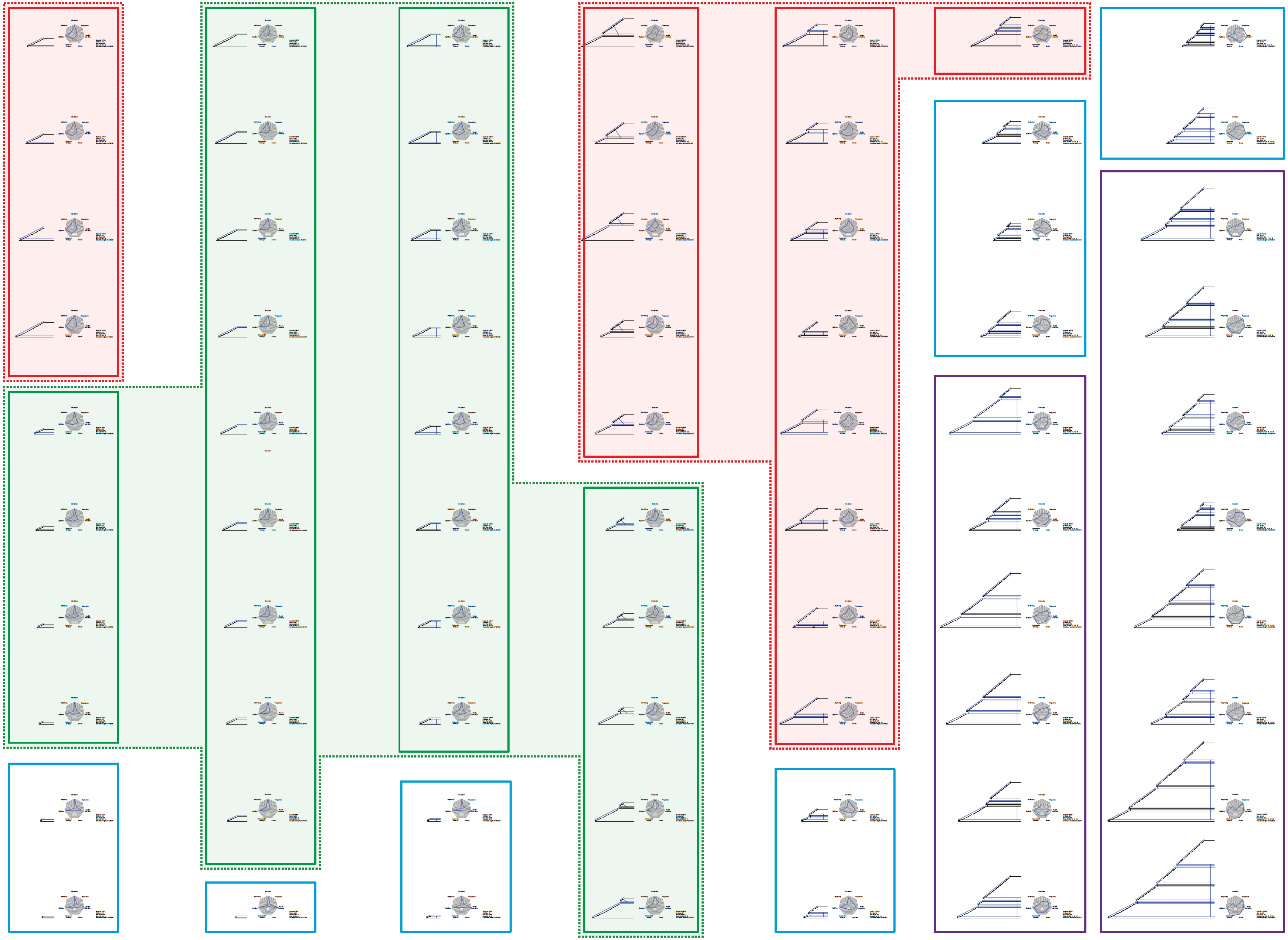
Bowl distance to touchline [2m - 12m]

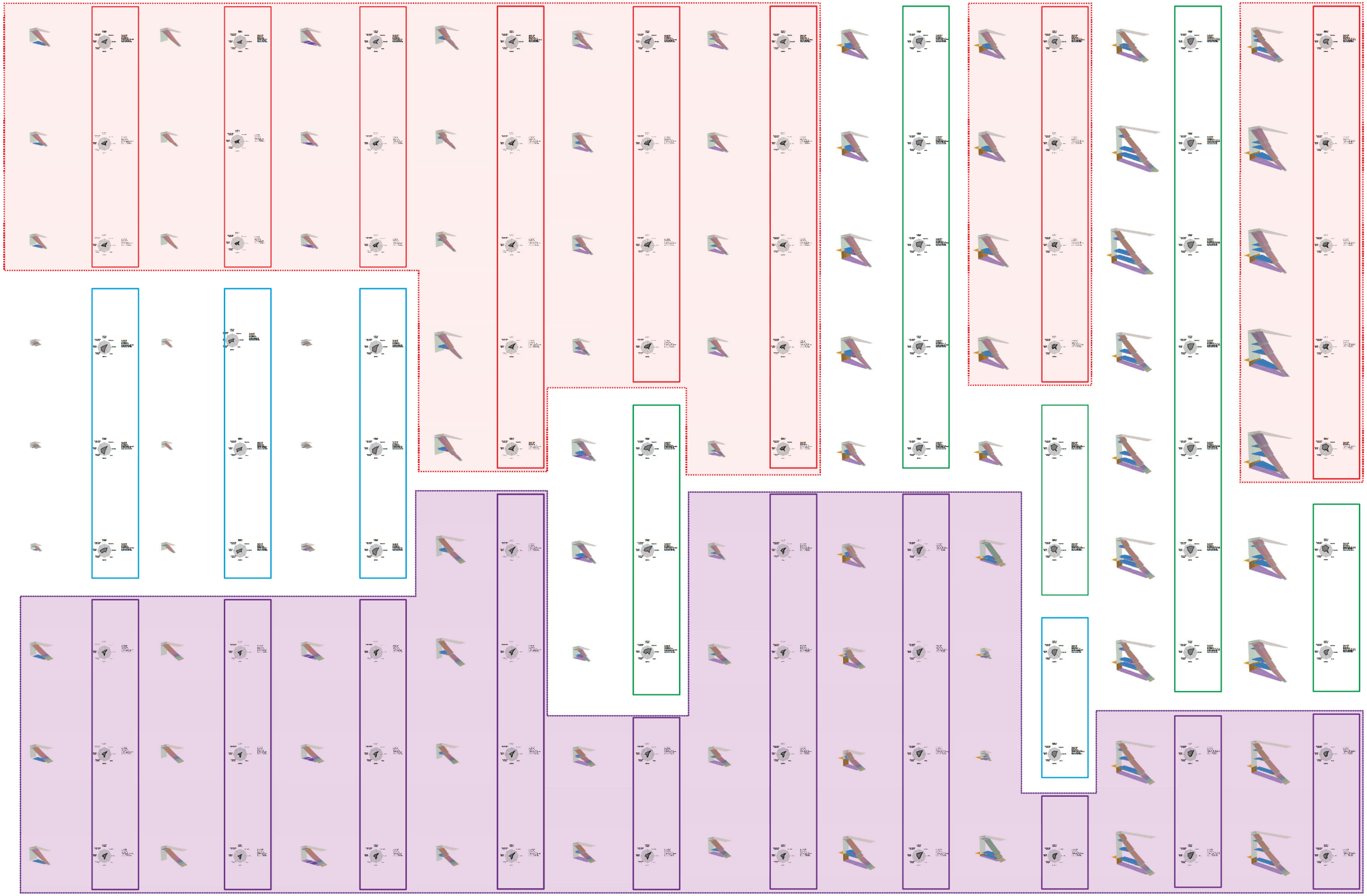
Bowl start height [-1.5m - 2.5m]

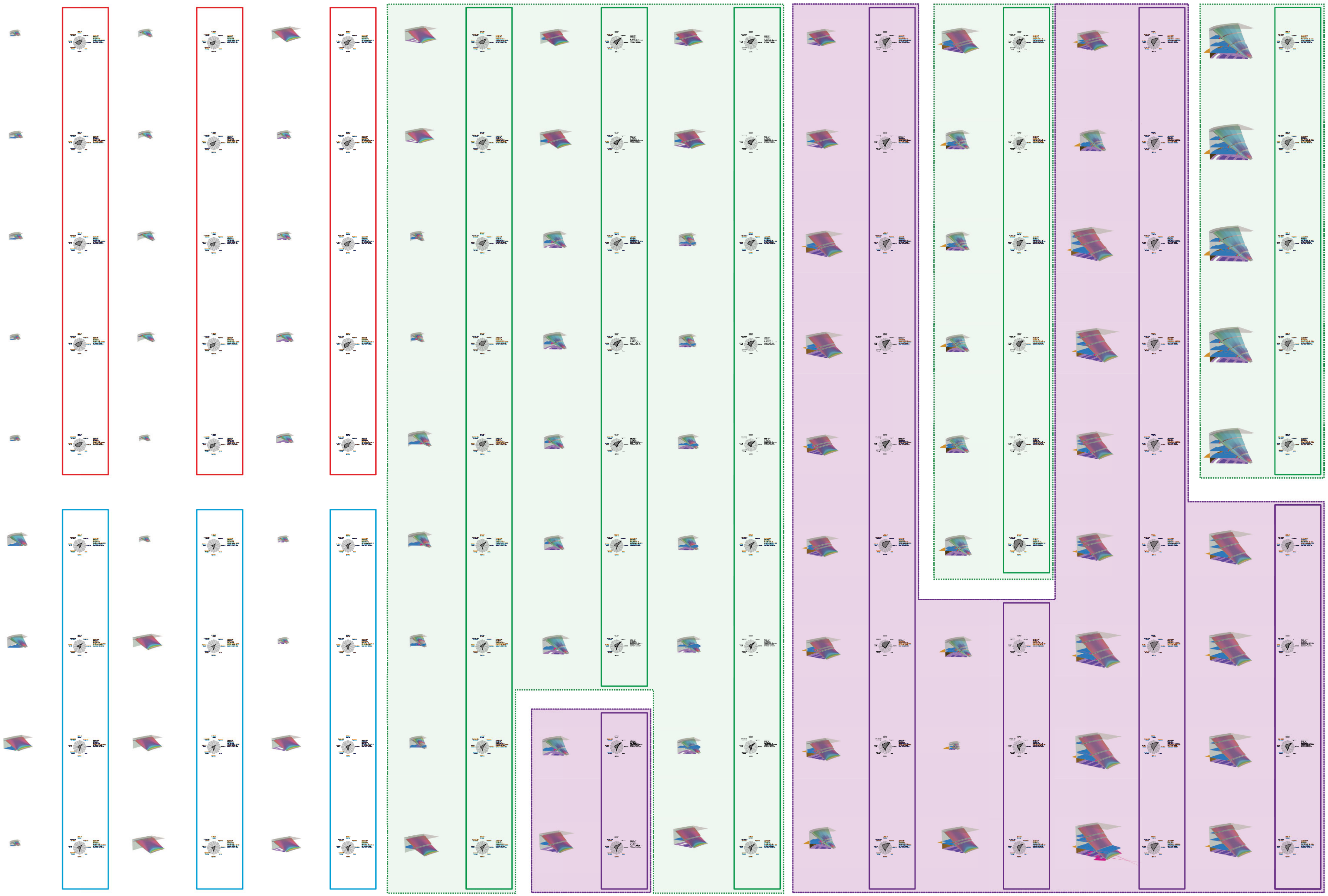
Evolutionary multi-objective optimisation with Octopus and HypeE optimisation algorithm selection of best performing solution after 77 generations, the design fits with the benchmarks from the case studies

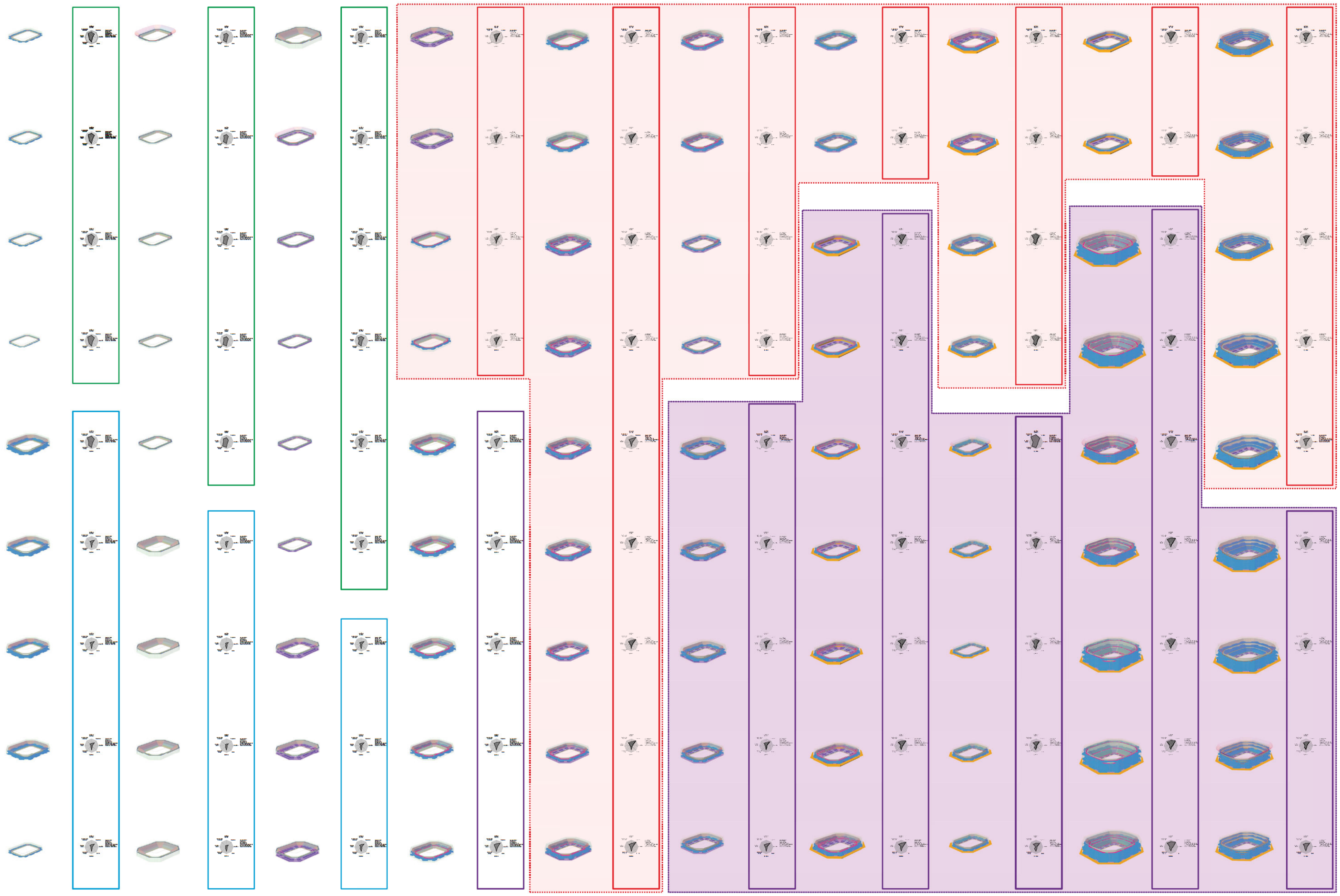


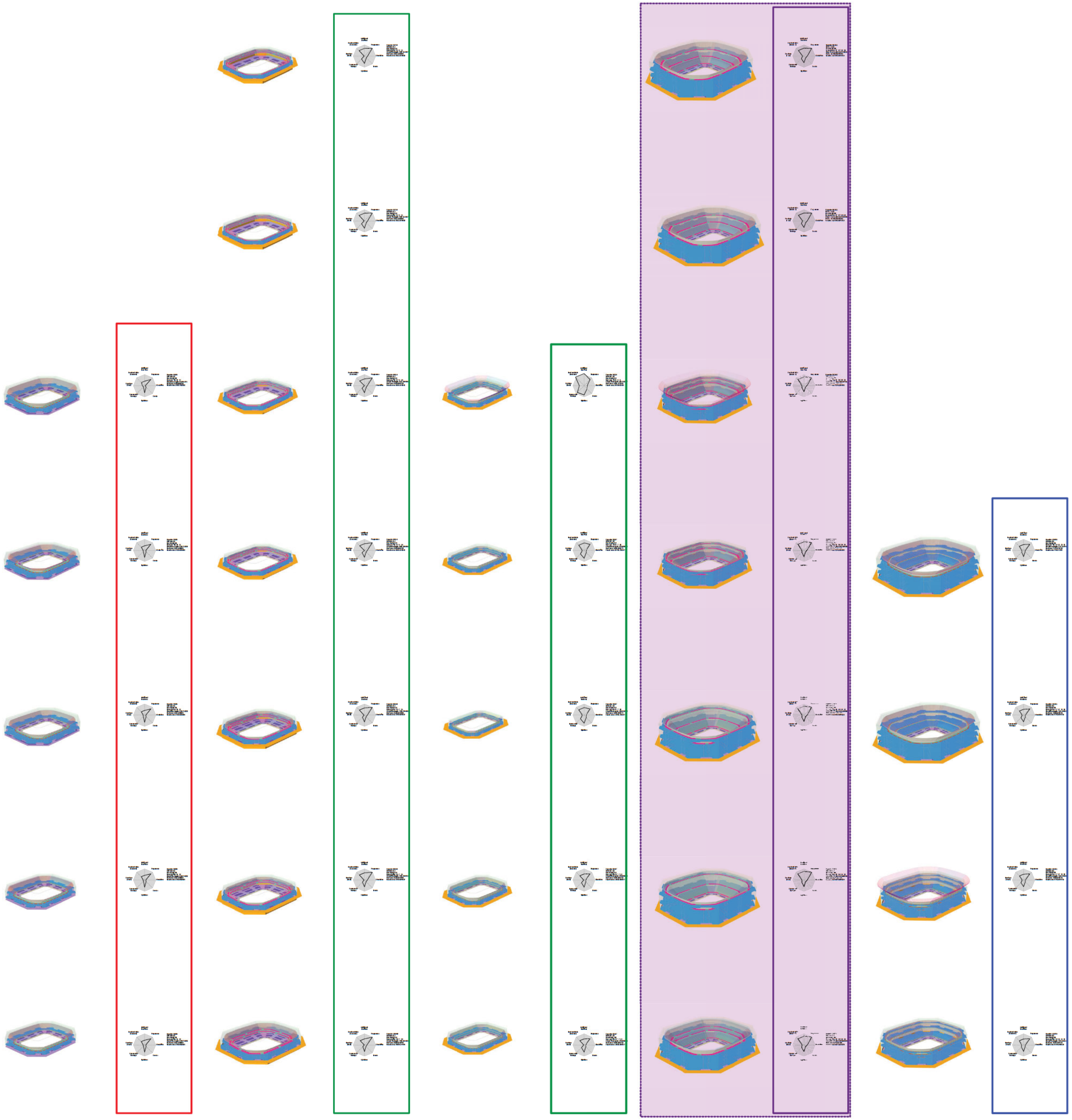
Evolutionary multi-objective optimisation with Octopus and HypeE optimisation algorithm selection of best performing solution after 77 generations and 508 solutions, higher performance coefficient is better, best performing solutions in overall are between 407 and 457

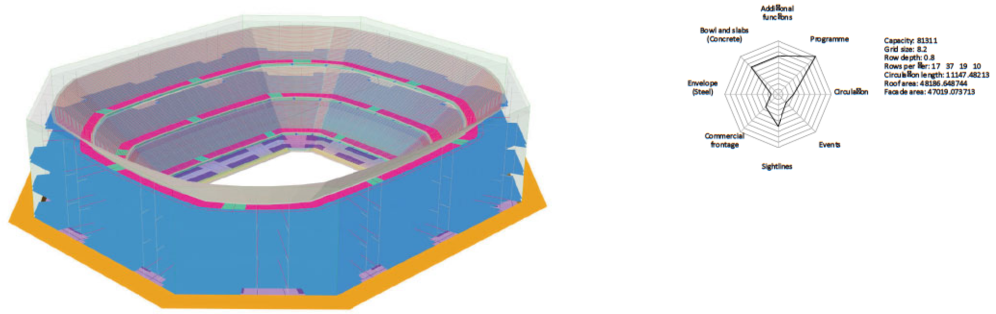


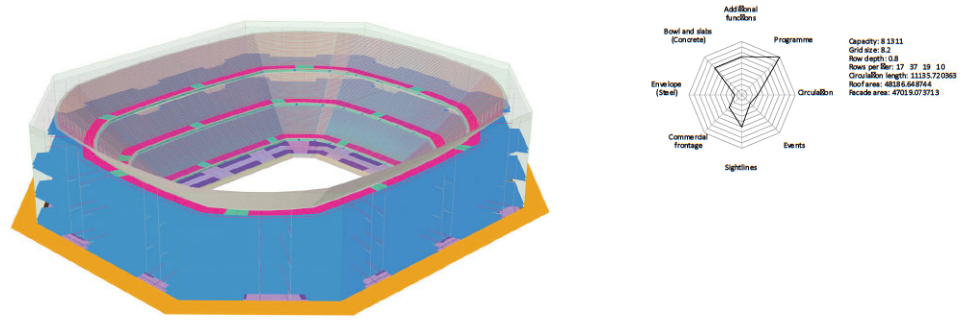


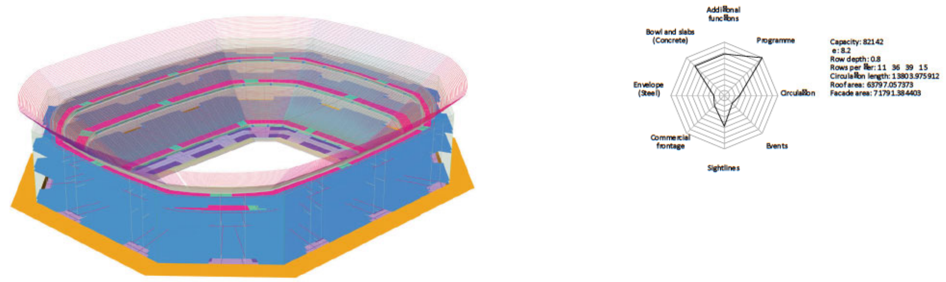


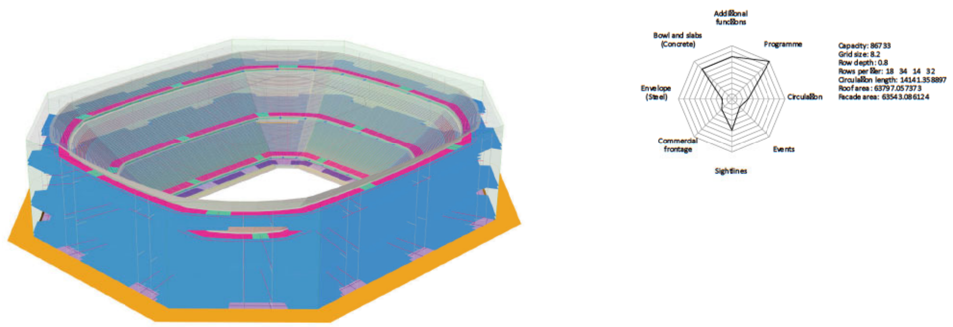


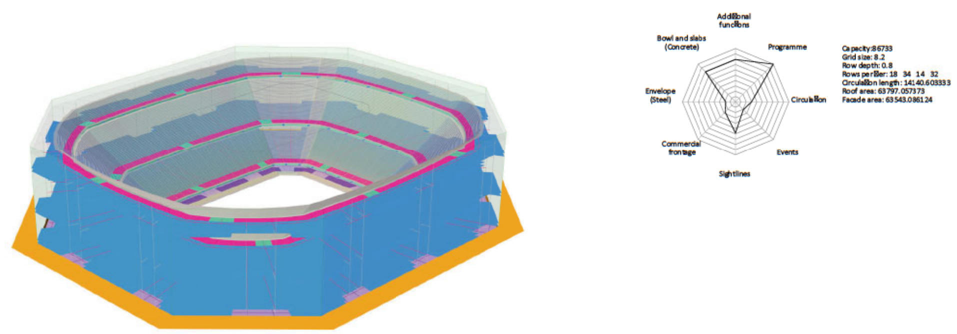


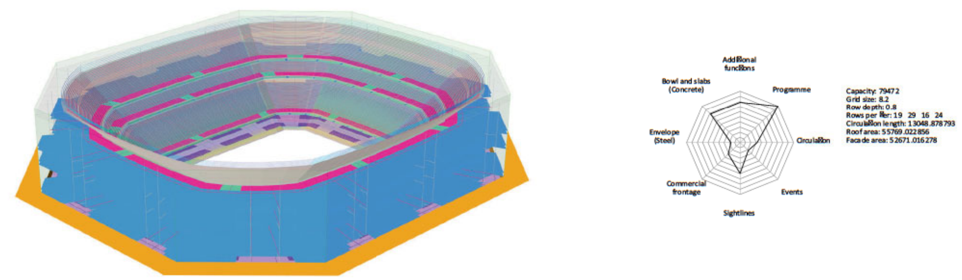

Additional functions
Bowl and slabs (Concrete)
Programme
Envelope (Steel)
Circulation
Commercial frontage
Events
Sightlines
Capacity: 81311
Grid size: 8.2
Row depth: 0.8
Rows per tier: 17 37 19 10
Circulation length: 11147.48213
Roof area: 48186.648744
Facade area: 47019.073713

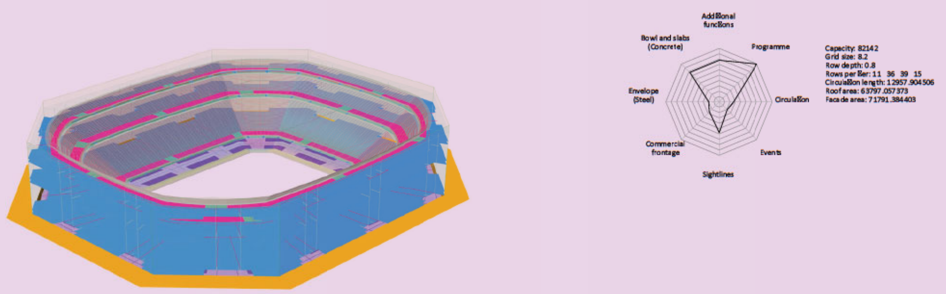

Additional functions
Bowl and slabs (Concrete)
Programme
Envelope (Steel)
Circulation
Commercial frontage
Events
Sightlines
Capacity: 81311
Grid size: 8.2
Row depth: 0.8
Rows per tier: 17 37 19 10
Circulation length: 11135.720363
Roof area: 48186.648744
Facade area: 47019.073713

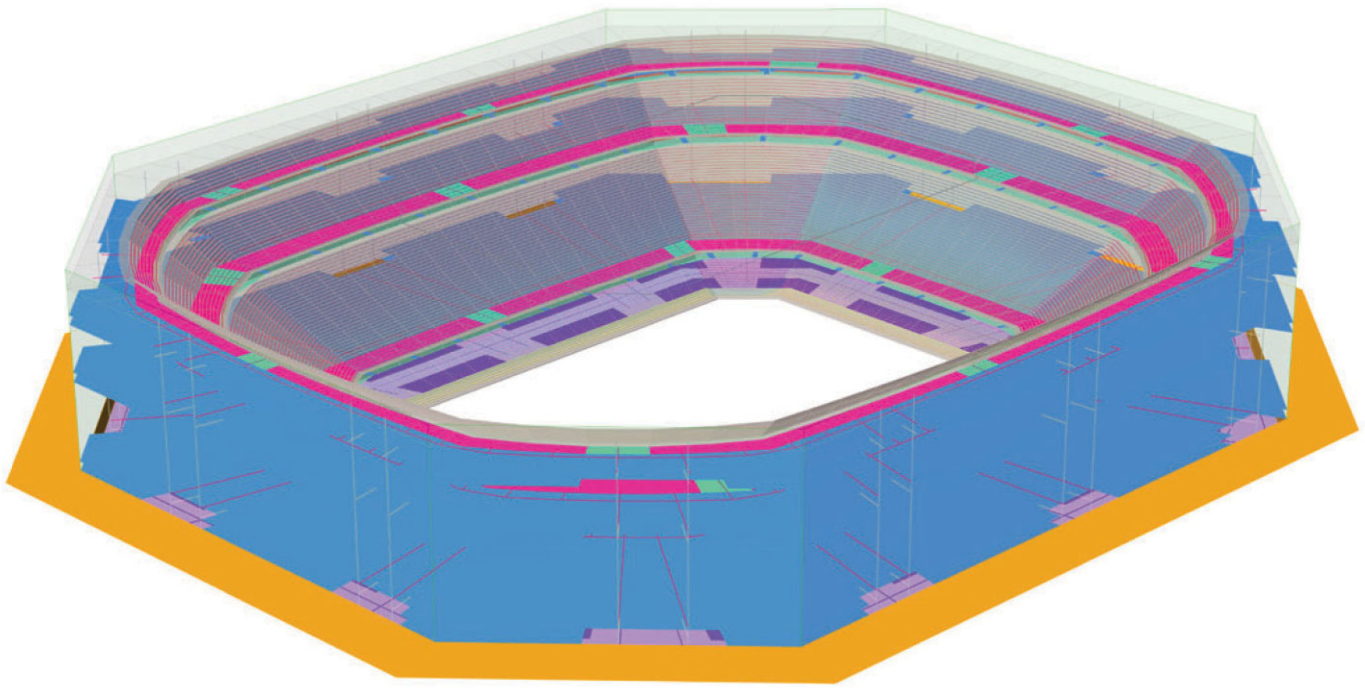

Additional functions
Bowl and slabs (Concrete)
Programme
Envelope (Steel)
Circulation
Commercial frontage
Events
Sightlines
Capacity: 82142
e: 8.2
Row depth: 0.8
Rows per tier: 11 36 39 15
Circulation length: 13803.975912
Roof area: 63797.057373
Facade area: 71791.384403

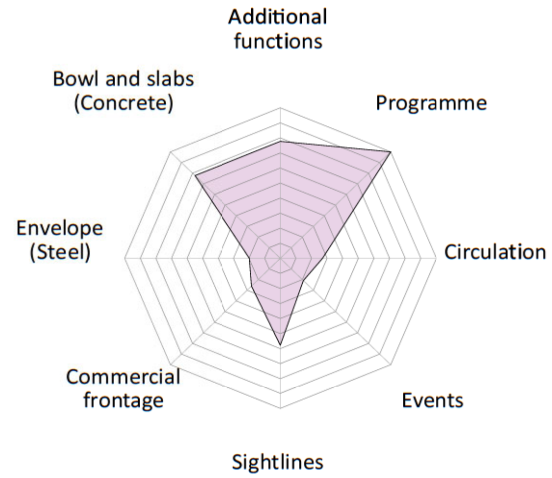

Additional functions
Bowl and slabs (Concrete)
Programme
Envelope (Steel)
Circulation
Commercial frontage
Events
Sightlines
Capacity: 86733
Grid size: 8.2
Row depth: 0.8
Rows per tier: 18 34 14 32
Circulation length: 14141.358897
Roof area: 63797.057373
Facade area: 63543.086124


Additional functions
Bowl and slabs (Concrete)
Programme
Envelope (Steel)
Circulation
Commercial frontage
Events
Sightlines
Capacity: 86733
Grid size: 8.2
Row depth: 0.8
Rows per tier: 18 34 14 32
Circulation length: 14140.603333
Roof area: 63797.057373
Facade area: 63543.086124

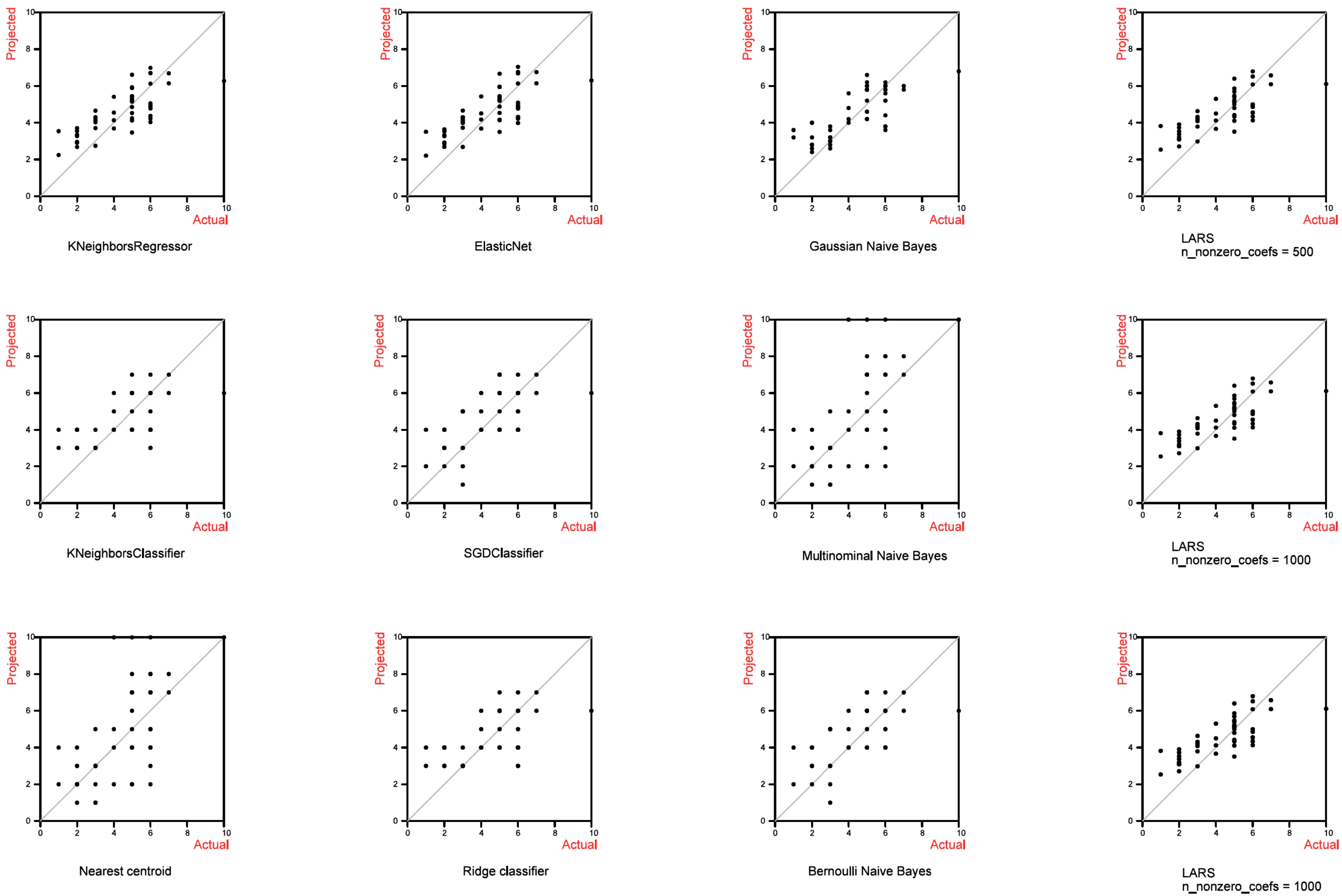

Additional functions
Bowl and slabs (Concrete)
Programme
Envelope (Steel)
Circulation
Commercial frontage
Events
Sightlines
Capacity: 79472
Grid size: 8.2
Row depth: 0.8
Rows per tier: 19 29 16 24
Circulation length: 13048.878793
Roof area: 55769.022856
Facade area: 52671.016278

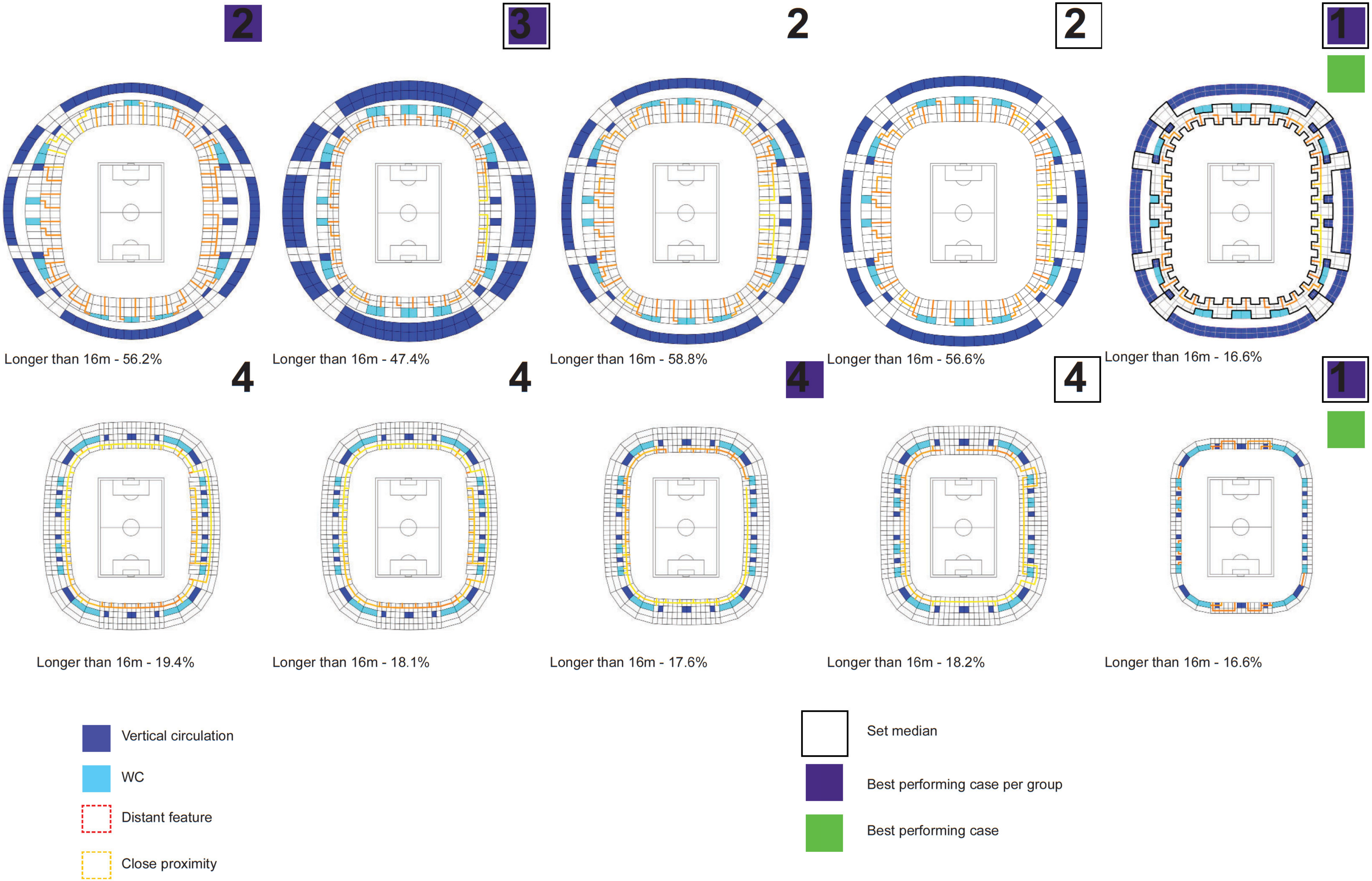

Additional functions
Bowl and slabs (Concrete)
Programme
Envelope (Steel)
Circulation
Commercial frontage
Events
Sightlines
Capacity: 82142
Grid size: 8.2
Row depth: 0.8
Rows per tier: 11 36 39 15
Circulation length: 12957.904506
Roof area: 63797.057373
Facade area: 71791.384403

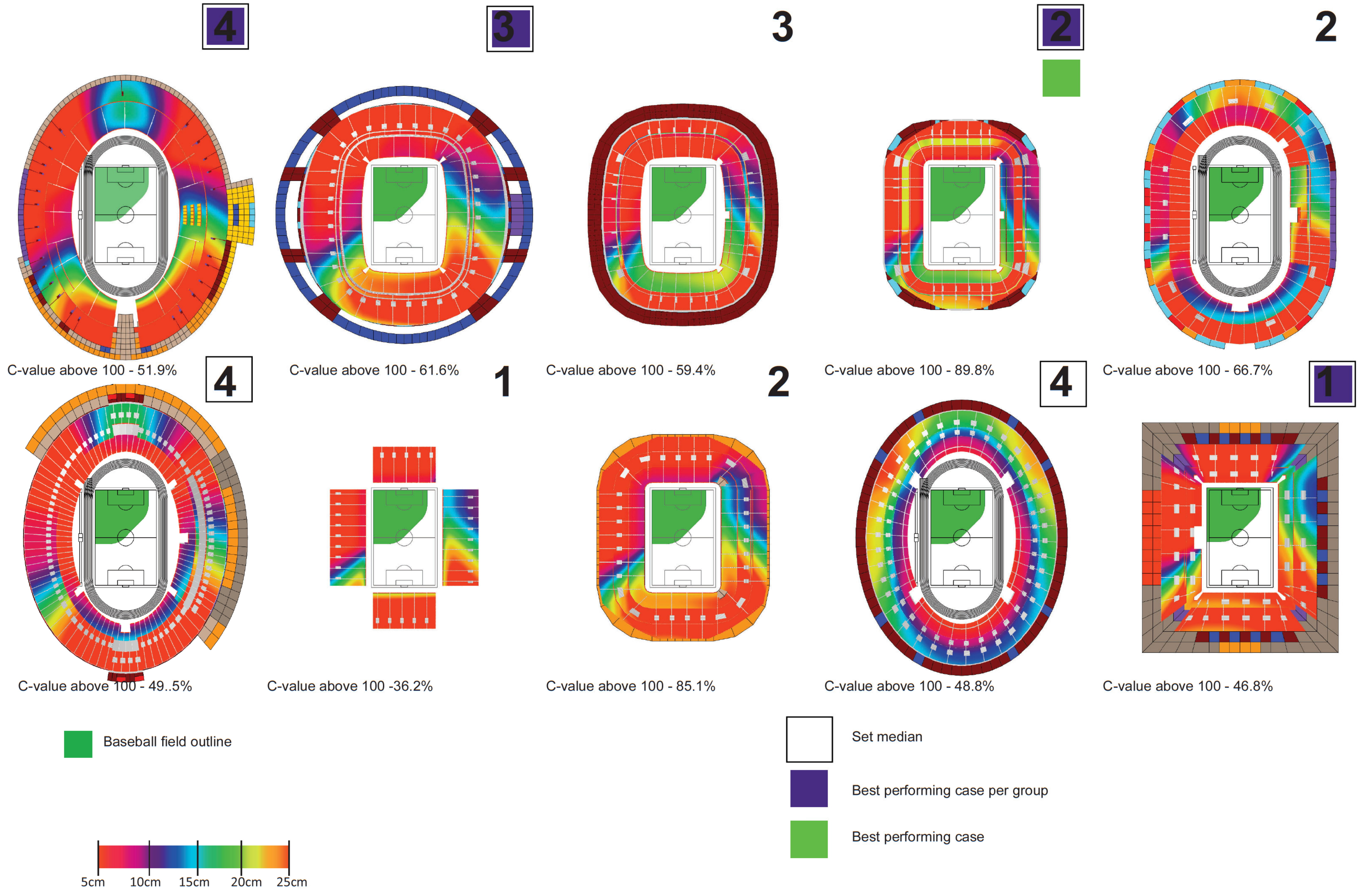




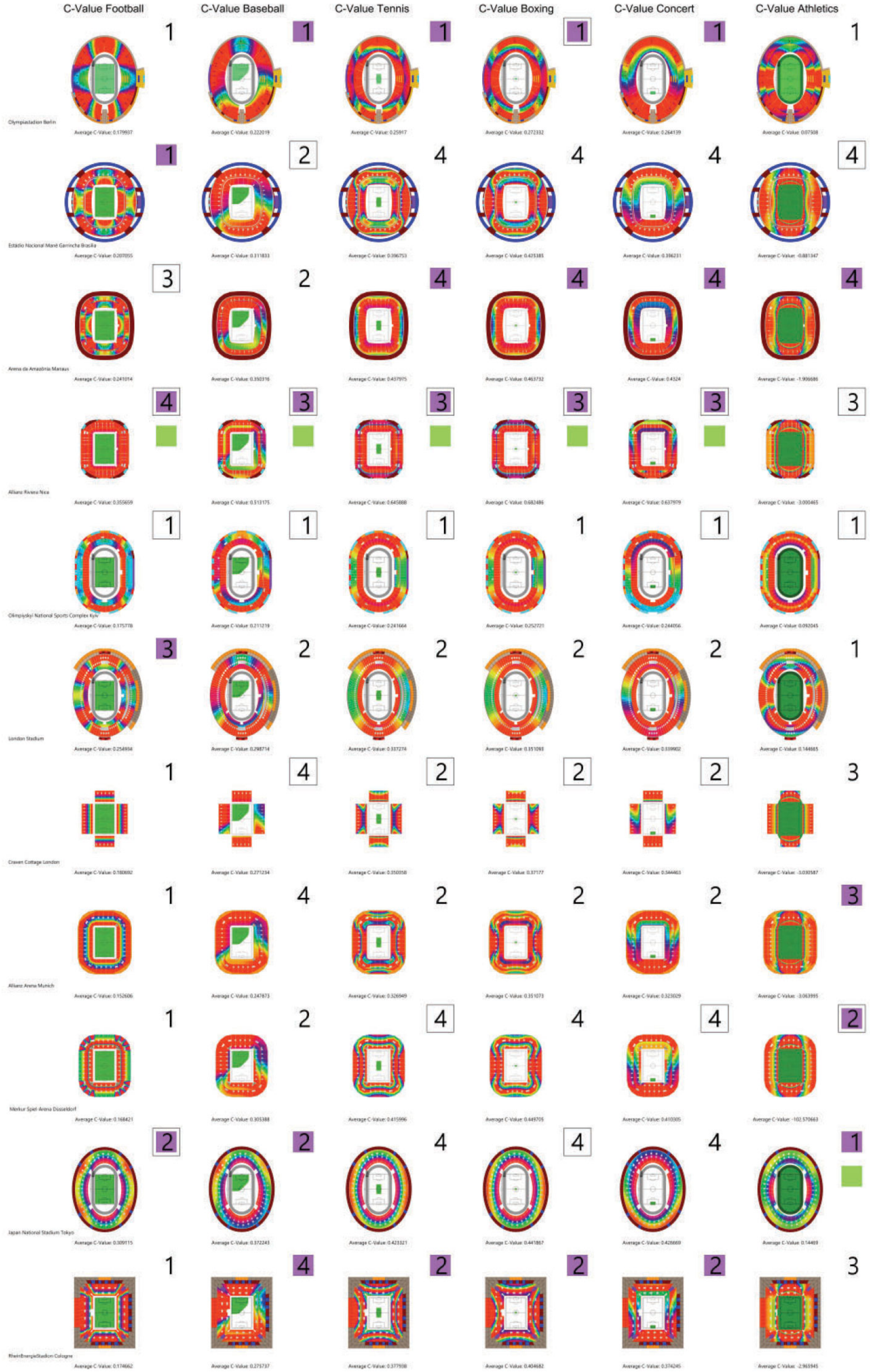
Capacity: 82142
Grid size: 8.2
Row depth: 0.8
Rows per tier: 11 36 39 15
Circulation length: 12957.904506
Roof area: 63797.057373
Facade area: 71791.384403


Projected
Actual
KNeighborsRegressor
ElasticNet
Gaussian Naive Bayes
LARS
n_nonzero_coefs = 500
KNeighborsClassifier
SGDClassifier
Multinominal Naive Bayes
LARS
n_nonzero_coefs = 1000
Nearest centroid
Ridge classifier
Bernoulli Naive Bayes
LARS
n_nonzero_coefs = 1000


2
3
2
2
1
Longer than 16m - 56.2%
Longer than 16m - 47.4%
Longer than 16m - 58.8%
Longer than 16m - 56.6%
Longer than 16m - 16.6%
4
4
4
4
1
Longer than 16m - 19.4%
Longer than 16m - 18.1%
Longer than 16m - 17.6%
Longer than 16m - 18.2%
Longer than 16m - 16.6%
Vertical circulation
WC
Distant feature
Close proximity
Set median
Best performing case per group
Best performing case

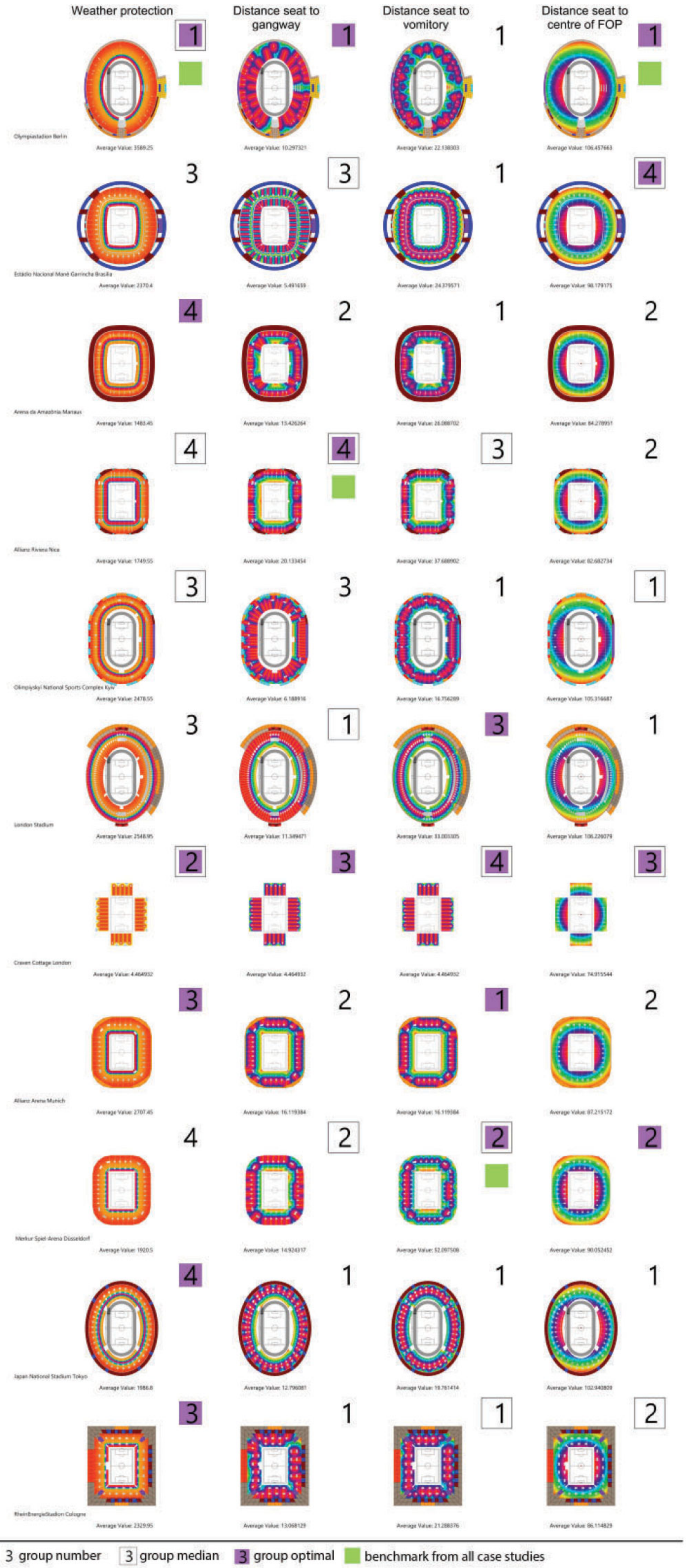


4
3
3
2
2
C-value above 100 - 51.9%
C-value above 100 - 61.6%
C-value above 100 - 59.4%
C-value above 100 - 89.8%
C-value above 100 - 66.7%
4
1
2
4
1
C-value above 100 - 49..5%
C-value above 100 -36.2%
C-value above 100 - 85.1%
C-value above 100 - 48.8%
C-value above 100 - 46.8%
Baseball field outline
Set median
Best performing case per group
Best performing case
5cm
10cm
15cm
20cm
25cm



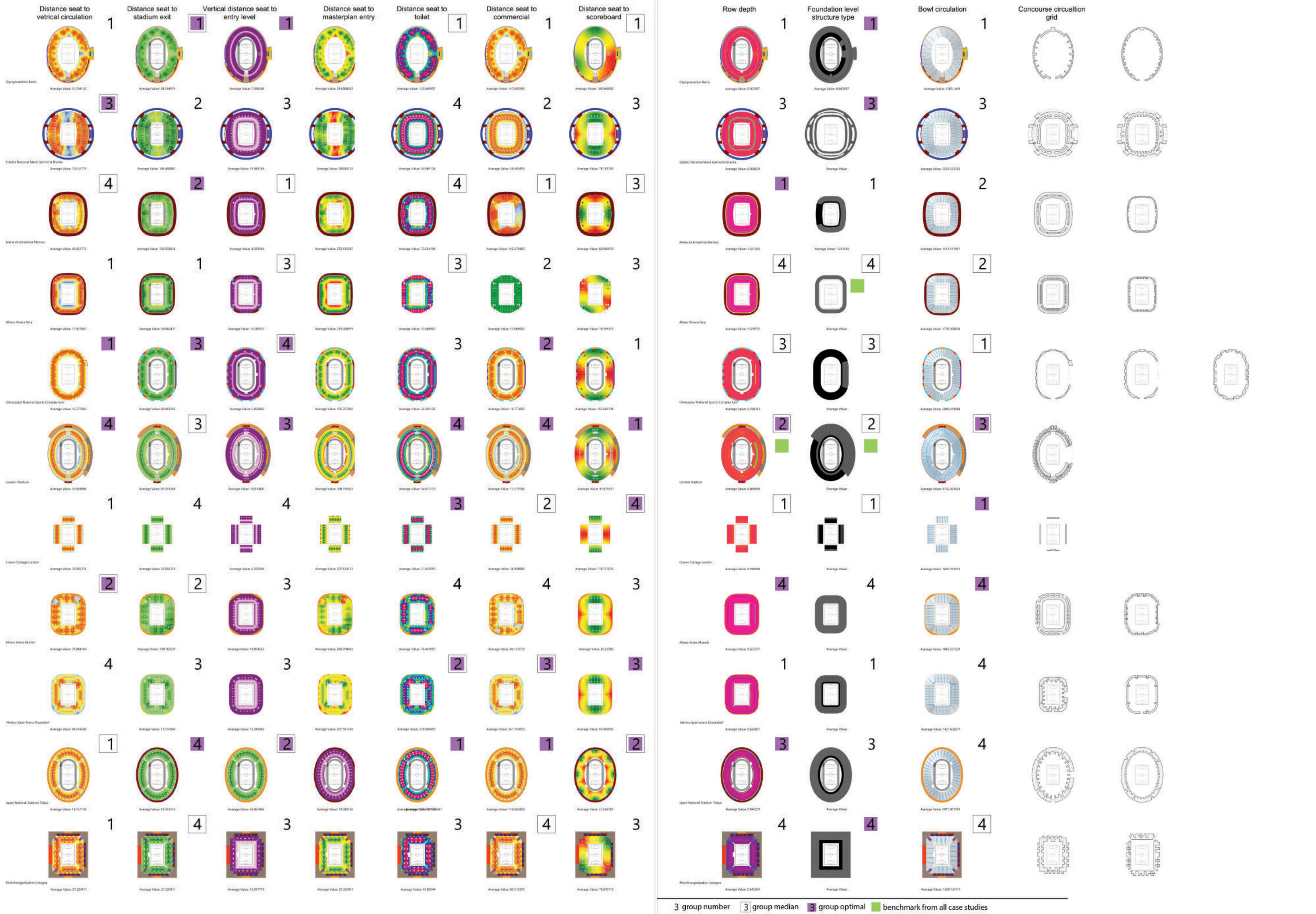
3 group number   3 group median   3 group optimal   benchmark from all case studies

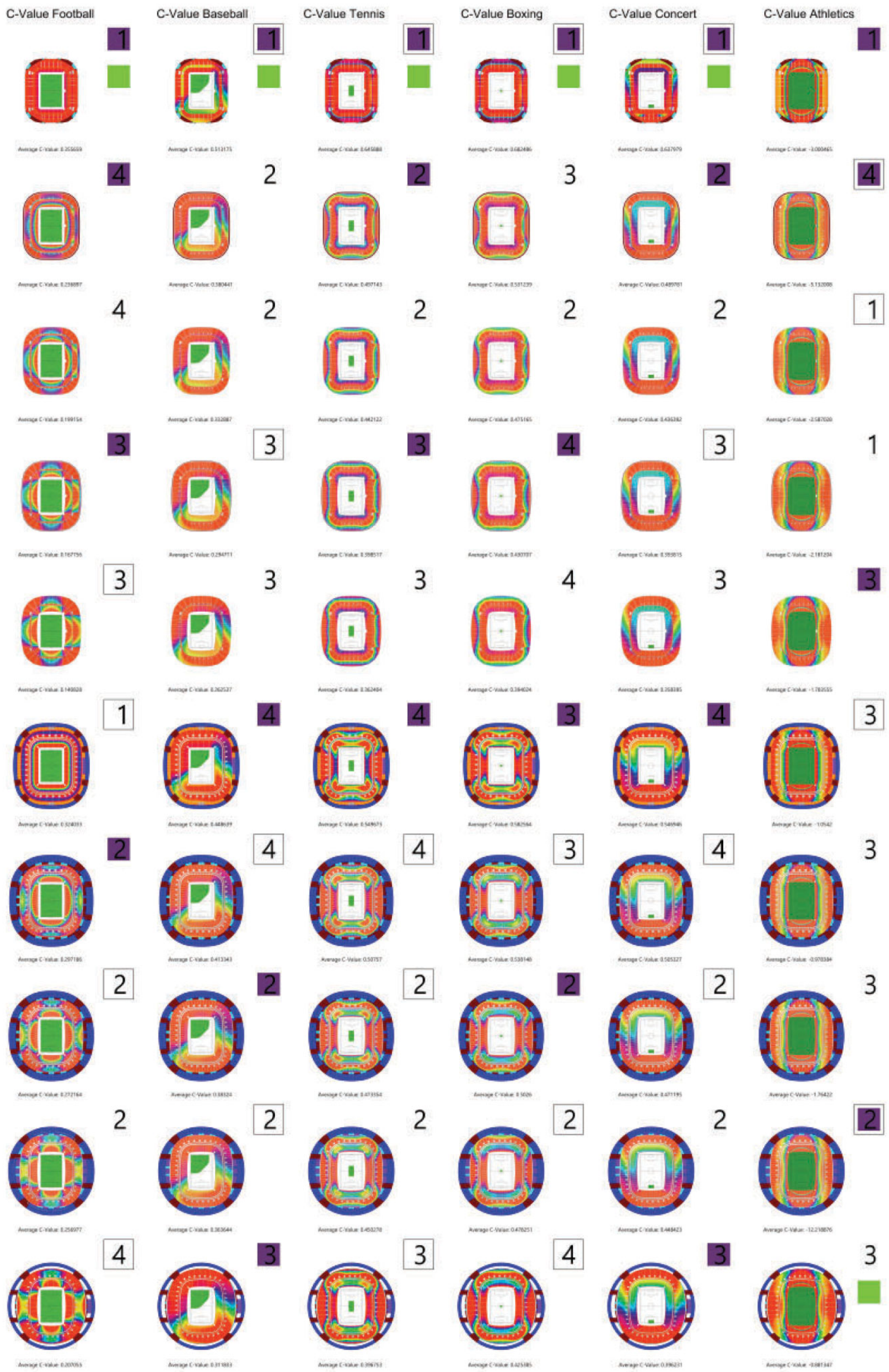
3 group number   3 group median   3 group optimal   benchmark from all case studies

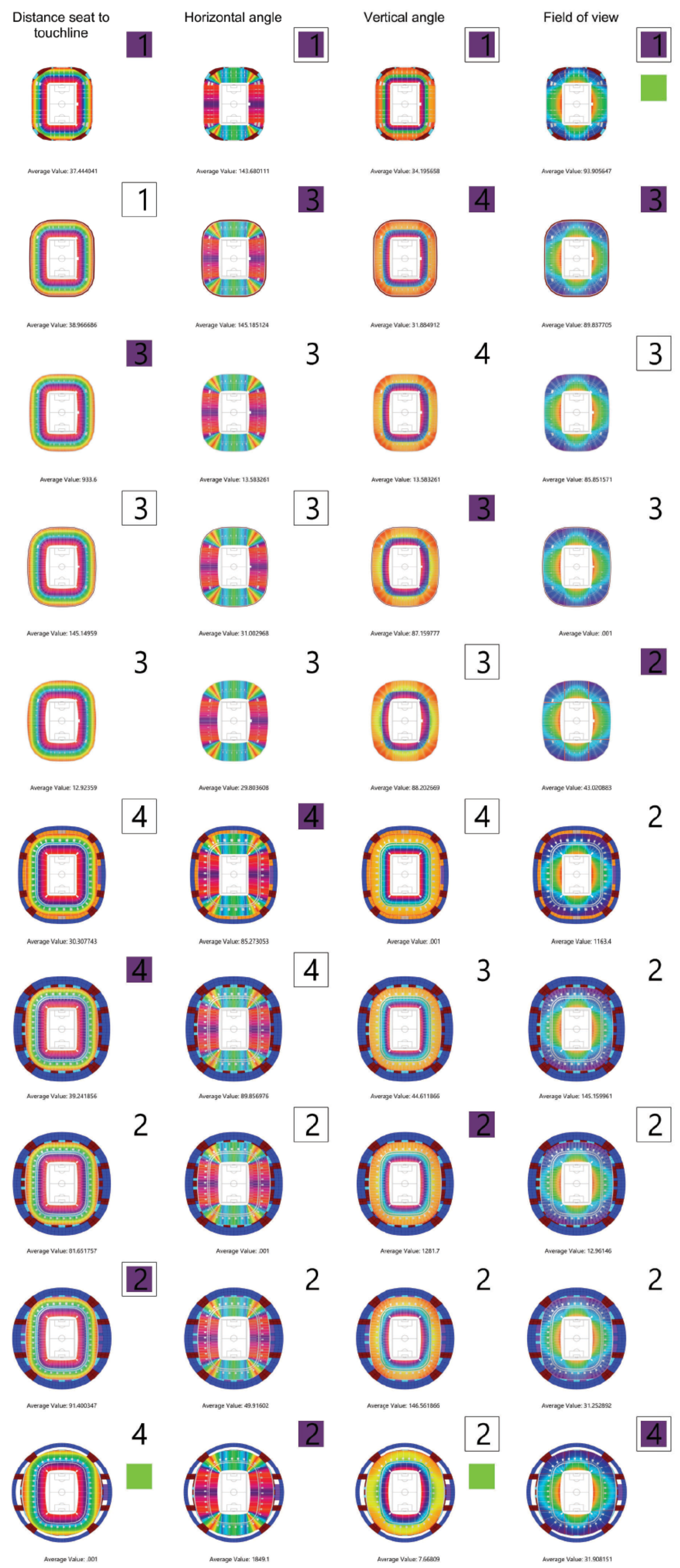


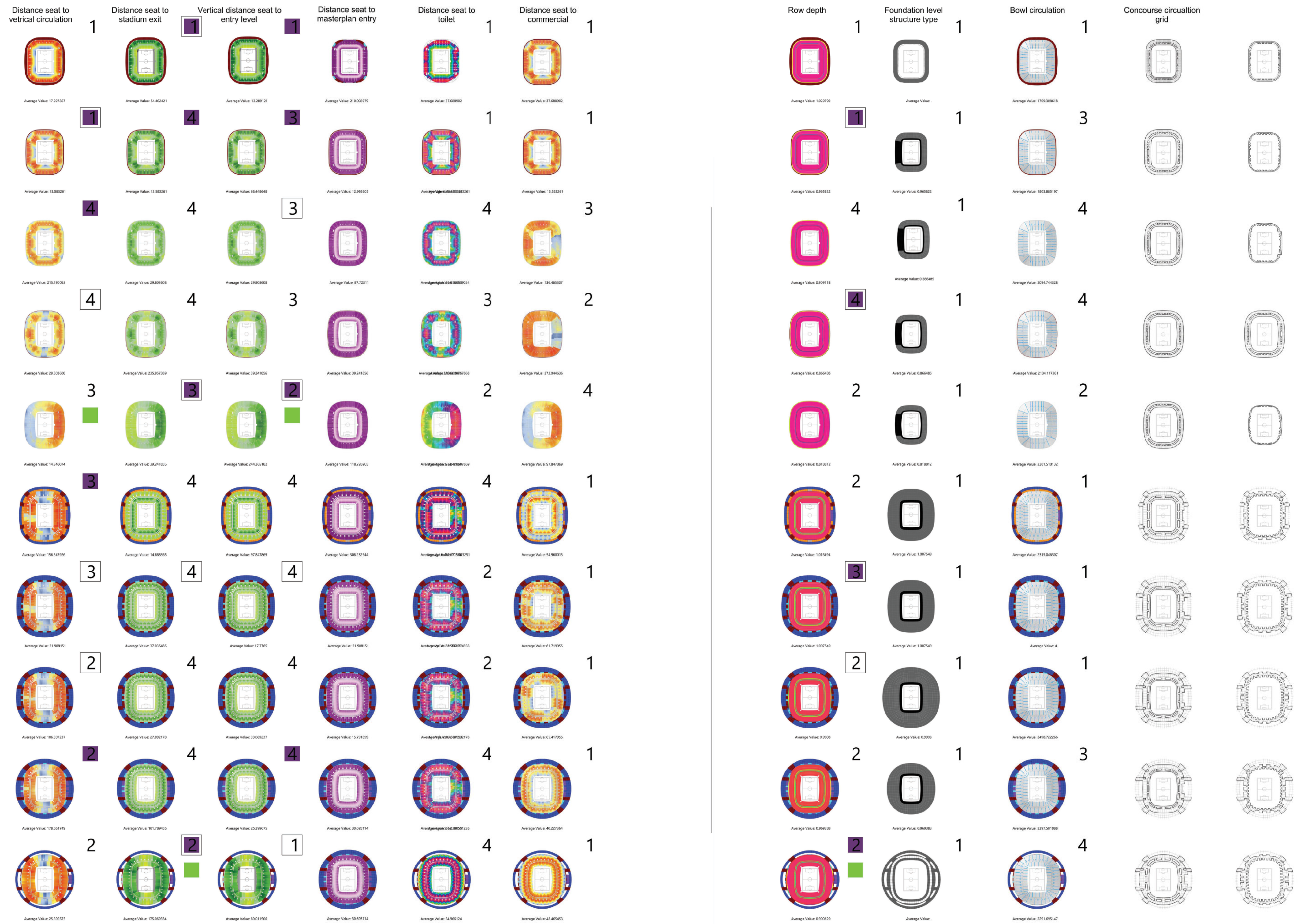
Weather protection
Distance seat to gangway
Distance seat to vomitory
Distance seat to centre of FOP
3 group number
3 group median
3 group optimal
benchmark from all case studies

Distance seat to vetrical circulation
Distance seat to stadium exit
Vertical distance seat to entry level
Distance seat to masterplan entry
Distance seat to toilet
Distance seat to commercial
Distance seat to scoreboard
3 group number
3 group median
3 group optimal
benchmark from all case studies


Distance seat to vertical circulation
Distance seat to stadium exit
Vertical distance seat to entry level
Distance seat to masterplan entry
Distance seat to toilet
Distance seat to commercial
Distance seat to scoreboard
Row depth
Foundation level structure type
Bowl circulation
Concourse circualtion grid
3 group number
3 group median
3 group optimal
benchmark from all case studies


C-Value Football
C-Value Baseball
C-Value Tennis
C-Value Boxing
C-Value Concert
C-Value Athletics


Distance seat to touchline
Horizontal angle
Vertical angle
Field of view



Distance seat to vetrical circulation
Distance seat to stadium exit
Vertical distance seat to entry level
Distance seat to masterplan entry
Distance seat to toilet
Distance seat to commercial
Row depth
Foundation level structure type
Bowl circulation
Concourse circualtion grid