# Space Modeler User Guide Analyzing a space model

March 29, 2023

**Tutorial project description** 

#### Overview

Building type Apartment building

Architects Kaden Klingbeil Architects, Berlin

Location Esmarchstrasse 8, Berlin, 2008

#### Use

Mixed use: 6 floors residential, ground floor commercial (architectural office)

#### Construction

Wood columns/walls, composite wood/concrete ceilings, concrete technical infrastructure shafts, concrete external stairs

#### **Project organisation**

Private owner association Participatory design process





















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#### Ground floor



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#### First floor



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#### Second floor



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### Third floor



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## Fourth floor



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#### Fifth floor



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#### Sixth floor



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#### **Elevations**





#### **Construction details**



Wandaufbau Putz 8 mm Steinwolle 70 kg/m<sup>3</sup> 100 mm Fermacell 12,5 mm Stütze dazwischen Brettstapelwand 160 mm Fermacell 2 x 18 mm







Kaden Klingbeil Architects, e\_3, Berlin, 2008 Zuschnitt (2009)





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#### References

Architects Kaden Klingbeil Architects, Berlin

**Clients** Baugruppe e3, Berlin

Structural design Julius Natterer with Tobias Linse, Munich

**Timber construction** projekt holzbau merkle. k.o.m. GmbH, Bissingen-Teck

Images Bernd Borchardt

#### Articles

D. Kleilein 2008, Kritische Verkapselung, Bauwelt 15:18-23

T. Kaden, 2008, Sieben aus Holz. Siebengeschossiges Wohnhaus als Holzkonstruktion, Deutsche Bauzeitung 6:83

C. Käpplinger, 2009, Lückenfüller mit Distanz, Eine Bauinitiative am Prenzlauer Berg, Zuschnitt 9:33:6-9

# Spatial analysis

## Modeling workflow



#### Source space data (input layout)



Kaden Klingbeil Architects, e\_3, Berlin, 2008 Heckmann and Schneider (2011)

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Room

51

Room

52

Room

48 0 0

Room

Room

45

# Source space data (input layout)





Space Modeler User Guide – Analyzing a space model


Kaden Klingbeil Architects, e\_3, Berlin, 2008 Heckmann and Schneider (2011)

# Source space data (input layout)



Space Modeler User Guide – Analyzing a space model

Kaden Klingbeil Architects, e\_3, Berlin, 2008 Heckmann and Schneider (2011)

# Source space data (input layout)



Space Modeler User Guide – Analyzing a space model

Kaden Klingbeil Architects, e\_3, Berlin, 2008 Heckmann and Schneider (2011)



Element properties: Whole space, primary space property Spatial relations: None Spatial relation network properties: Number of components = 45 Number of cycles = 0 Number of whole spaces = 14 Number of subspaces = 0 Number of space elements = 31



# 'Map' web app http://spacepatterns.com/sp/map/html/viewer.html



# 'Visualize' web app



Element properties:

Whole space, primary space property

Spatial relations:

None

Spatial relation network properties:

Number of components = 45

Number of cycles = 0

Number of whole spaces = 14

Number of subspaces = 0

Number of space elements = 31

# Architectural view:

- Spaces (rooms)
- Windows, doors, openings, stairs
- Furnishing elements, sanitary elements







Element properties: Whole space, primary space property Spatial relations:

None

Spatial relation network properties: Number of components = 45 Number of cycles = 0 Number of whole spaces = 14 Number of subspaces = 0 Number of space elements = 31

Summary of sub-view's spatial relation network properties



Element properties: Whole space, primary space property Spatial relations: None Spatial relation network properties: Number of components = 45 Number of cycles = 0 Number of whole spaces = 14 Number of subspaces = 0 Number of space elements = 31



Element properties: Whole spaces, internal, area: Maximum = 48.39m<sup>2</sup> Mean = 14.52m<sup>2</sup> Minimum = 0.57m<sup>2</sup> Spatial relations: None Spatial relation network properties: Number of components = 45 Number of cycles = 0 Number of whole spaces = 14 Number of subspaces = 0 Number of space elements = 31



**Element properties:** Whole spaces, internal, area: Maximum = **48.39m**<sup>2</sup>  $Mean = 14.52m^2$ Minimum =  $0.57m^2$ Spatial relations: None Spatial relation network properties: Number of components = 45 Number of cycles = 0Number of whole spaces = 14 Number of subspaces = 0Number of space elements = 31



# Comparison with reference housing projects

- The tutorial project is compared with a sample of 13 housing projects selected from the Space Patterns project database
- Selection criteria
  - Architect
  - Location
  - Country

Analysis categories:

- Facilitate formulation of qualitative, natural language statements about results
- Results from each project are (currently rather informally) mapped to categories
- Adjectives are used to categorize results (e.g. 'large', 'medium', 'small' for areas)



# Projects

#### Residential: max. bedroom area



Projects

Element properties: Whole spaces, degree: Maximum = 10Mean = 2.85Minimum = 0Space elements, degree: Maximum = 2Mean = 1.29Minimum = 0Spatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 5Number of cycles = 8Number of whole spaces = 14 Number of subspaces = 0Number of space elements = 23



**Element properties:** Whole spaces, degree: Maximum = 10Mean = 2.85Minimum = 0Space elements, degree: Maximum = 2Mean = 1.29Minimum = 0Spatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 5Number of cycles = 8 Number of whole spaces = 14 Number of subspaces = 0Number of space elements = 23

> Space enclosure network: Determine space connectivity through windows, doors, openings



**Element properties:** Whole spaces, degree: Maximum = 10Mean = 2.85Minimum = 0Space elements, degree: Maximum = 2Mean = 1.29Minimum = 0**Spatial relations:** - Space element partially enclosing whole space Spatial relation network properties: Number of components = 5Number of cycles = 8 Number of whole spaces = 14 Number of subspaces = 0Number of space elements = 23

> Max. degree = 10: → Living room is by far the most connected space

6

External space degree = 2:

7

10

3

2

→ Fewer windows and doors are oriented to street than to courtyard or stair



```
Element properties:
  Whole spaces, distance nearest:
   Maximum = 3
   Mean = 2.60
   Minimum = 1
  Space elements, distance nearest:
    Maximum = 2
   Mean = 1.80
   Minimum = 0
Spatial relations:
- Space element partially enclosing whole space
Spatial relation network properties:
  Number of components = 5
  Number of cycles = 0
  Number of whole spaces = 14
  Number of subspaces = 0
  Number of space elements = 10
```



# 'Map' web app http://spacepatterns.com/sp/map/html/viewer.html



http://spacepatterns.com/sp/charts/html/charts.html?tags=Kaden\_Klingbeil;chart=number\_of\_units\_by\_primary\_function;proj=KK08-4

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 $\diamond$   $\diamond$  select 2 projects  $\checkmark$  = =  $\Rightarrow$   $\square$  ?

- Spaces
- Pedestrian circulation view
- Space elements for pedestrian circulation: doors, openings, stairs, ...

3

 $\infty$ 

2

2

 $\infty$ 

 $\infty$ 

3

3/

3

- Element properties: Whole spaces, distance nearest: Maximum = 3 Mean = 2.60 Minimum = 1 Space elements, distance nearest: Maximum = 2 Mean = 1.80
  - Minimum = 0
- Spatial relations:
- Space element partially enclosing whole space Spatial relation network properties:
  - Number of components = 5 Number of cycles = 0 Number of whole spaces = 14 Number of subspaces = 0 Number of space elements = 10

Space access network: Determine space access properties

#### Distance nearest metric: Path length (number of edges)

# Pedestrian circulation view

**Element properties:** Whole spaces, distance nearest: Maximum = 3Mean = 2.60Minimum = 1Space elements, distance nearest: Maximum = 23 Mean = 1.802 Minimum = 0**Spatial relations:** 2 - Space element partially enclosing whole space Spatial relation network properties: Number of components = 5 $\infty$ Number of cycles = 0Number of whole spaces = 14 Number of subspaces = 0Number of space elements = 10 **Destination nodes:** Unit doors

3 3/ 3  $\infty$ Source nodes: Space elements and spaces

 $\infty$ 

Element properties:

Whole spaces, distance nearest

- Maximum = 3
- Mean = 2.60

Minimum = 1

Space elements, distance nearest:

- Maximum = 2
- Mean = 1.80
- Minimum = 0

Spatial relations:

- Space element partially enclosing whole space Spatial relation network properties:

```
Number of components = 5
Number of cycles = 0
Number of whole sp ces = 14
Number of subspace = 0
Number of space e<sup>1</sup> nts = 10
```

# No cycles:

- $\rightarrow$  Space access network is a tree
- → Typical for access to private spaces

Space with min. distance nearest (depth) = 1 and no cycles:

→ Living room controls access to all other spaces



Several spaces in unit with max. distance nearest (depth) = 3 (2 spaces):
 → Space access network in unit is balanced, i.e. access to bedrooms and service rooms seems equally convenient

**Element properties:** Whole spaces, distance nearest: Maximum = 3Mean = 2.60Minimum = 1Space elements, distance nearest: Maximum = 2Mean = 1.80Minimum = 0Spatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 5Number of cycles = 0 Number of whole spaces = 14 Number of subspaces = 0Number of space elements = 10

Distance nearest (depth) =  $\infty$ :

3

 $\frac{1}{2}$ 

2

 $\infty$ 

 $\infty$ 

 $\infty$ 

 $\infty$ 

3

3/

3

- → Shaft is separated from the rest of the space access network
- $\rightarrow$  Inaccessible space

## Max. distance nearest (depth) = 3: $\rightarrow$ Very shallow space access network



#### Max. distance to unit door, by number of edges

Path length [-]

**Element properties:** Whole spaces, distance nearest: Maximum = 3Mean = 2.60Minimum = 1Space elements, distance nearest: Maximum = 2Mean = 1.80Minimum = 0**Spatial relations:** - Space element partially enclosing whole space Spatial relation network properties: Number of components = 5Number of cycles = 0Number of whole spaces = 14 Number of subspaces = 0Number of space elements = 10

# Paths from entrance

Entrance - Kitchen → Direct (living room) Entrance - Living room

 $\rightarrow$  Direct

Entrance - Bedrooms  $\rightarrow$  Via living room

(Direct access or access via hallways is preferred)



**Element properties:** Whole spaces, distance nearest: Maximum = 3Mean = 2.60Minimum = 1Space elements, distance nearest: Maximum = 2Mean = 1.80Minimum = 0**Spatial relations:** - Space element partially enclosing whole space Spatial relation network properties: Number of components = 5Number of cycles = 0Number of whole spaces = 14 Number of subspaces = 0Number of space elements = 10

# **Functional paths**

Kitchen - Dining area  $\rightarrow$  Direct (living room)

Bedrooms - Bathroom  $\rightarrow$  Via living room

(Direct access or access via hallways is preferred)



**Element properties:** Subspaces, internal, distance nearest: Maximum = **12.42m** Mean = 8.07m Minimum = 0.72mSpace elements, distance nearest: Maximum = 11.59mMean = 8.03m Minimum = 0mSpatial relations: - Subspace adjacency - Subspace/space element proximity Spatial relation network properties: Number of components = 4Number of cycles = 21Number of whole spaces = 0Number of subspaces = 50 Number of space elements = 11



# 'Map' web app http://spacepatterns.com/sp/map/html/viewer.html



http://spacepatterns.com/sp/charts/html/charts.html?tags=Kaden\_Klingbeil;chart=number\_of\_units\_by\_primary\_function;proj=KK08-4





 $\diamond$   $\diamond$  select 2 projects  $\checkmark$  = =  $\Rightarrow$   $\square$  ?

**Element properties:** Subspaces, internal, distance nearest: Maximum = 12.42mMean = 8.07mMinimum = 0.72mSpace elements, distance nearest: Maximum = 11.59mMean = 8.03mMinimum = 0mSpatial relations: - Subspace adjacency - Subspace/space element proximity Spatial relation network properties: Number of components = 4Number of cycles = 21Number of whole spaces = 0Number of subspaces = 50 Number of space elements = 11

#### Walking network:

- Determine walking distances between spaces and unit doors
- Consider obstructing space boundaries

12.42m

Element properties: Subspaces, internal, distance nearest: Maximum = 12.42m Mean = 8.07m Minimum = 0.72m Space elements, distance nearest: Maximum = 11.59m Mean = 8.03m Minimum = 0m Spatial relations: - Subspace adjacency - Subspace/space element proximity

Subspace adjacency
Subspace/space element proximity
Spatial relation network properties: Number of components = 4 Number of cycles = 21 Number of whole spaces = 0 Number of subspaces = 50 Number of space elements = 11

# Distance nearest metric:

- Path weight
- Edge weights correspond to Euclidean distance between related layout elements



**Element properties:** Subspaces, internal, distance nearest: Maximum = 12.42mMean = 8.07m Minimum = 0.72mSpace elements, distance nearest: Maximum = 11.59mMean = 8.03mMinimum = **Om** Spatial relations: - Subspace adjacency - Subspace/space element proximity Spatial relation network properties: Number of components = 4Number of cycles = 21Number of whole spaces = 0Number of subspaces = 50 Number of space elements = 11


# Max. distance nearest = 12.4 m: $\rightarrow$ Short distance



#### Max. distance to unit door, by edge lengths

Path length [m]

- Short escape routes and external (thus smoke-free) main circulation part of concept to ensure fire safety of 7 story wood construction
- Austrian fire safety code (OIB-300.2-007/07-001): max. 40 m walking distance to nearest internal or external stair case or safe external location

Element properties: Whole spaces, degree: Maximum = 8Mean = 1.35Minimum = 0Space elements, degree: Maximum = 2Mean = 1.81Minimum = 1Spatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 5Number of cycles = 0Number of whole spaces = 14 Number of subspaces = 0Number of space elements = 10



```
Element properties:
  Whole spaces, degree:
   Maximum = 8
   Mean = 1.35
   Minimum = 0
                                                                                  0
  Space elements, degree:
    Maximum = 2
   Mean = 1.81
    Minimum = 1
Spatial relations:
- Space element partially enclosing whole space
Spatial relation network properties:
  Number of components = 5
  Number of cycles = 0
                                                         3
  Number of whole spaces = 14
                                                                                       8
  Number of subspaces = 0
  Number of space elements = 10
                                                                       0
               Space access network
```

**Element properties:** Whole spaces, degree: Maximum = 8Mean = 1.35Minimum = 0Space elements, degree: Maximum = 2Mean = 1.81Minimum = 1Spatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 5Number of cycles = 0 Number of whole spaces = 14 Number of subspaces = 0Number of space elements = 10



### 'Visualize' web app





Element properties: Whole spaces, degree: Maximum = 1Mean = 0.28Minimum = 0Space elements, degree: Maximum = 2Mean = 2Minimum = 2Spatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 6Number of cycles = 0Number of whole spaces = 7 Number of subspaces = 0Number of space elements = 1



# 'Map' web app http://spacepatterns.com/sp/map/html/viewer.html



## 'Chart' web app http://spacepatterns.com/sp/charts/html/charts.html



Number of main circulation spaces [-]

1.5



 $\bigstar$   $\checkmark$  [%] select 2 projects  $\checkmark$   $\Box$  = =  $\bigtriangleup$   $\Rightarrow$   $\square$  ?

**Element properties:** Whole spaces, degree: Maximum = 1Mean = 0.28Minimum = 0Space elements, degree: Maximum = 2Mean = 2Minimum = 2Spatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 6Number of cycles = 0Number of whole spaces = 7Number of subspaces = 0Number of space elements = 1

> Unit access network Determine type of access to units

Pedestrian access zones view:
Spaces not separated by unit or external doors are merged

0

0

1

0

Element properties: Whole spaces, degree: Maximum = 8 Mean = 1.35 Minimum = 0 Space elements, degree: Maximum = 2 Mean = 1.81 Minimum = 1 Spatial relations: - Space element partially enclosing whole space Spatial relation network properties:

Number of components = 5 Number of cycles = 0 Number of whole spaces = 14 Number of subspaces = 0 Number of space elements = 10

Derivation of pedestrian access zones: Spaces in the 'Pedestrian circulation' view that belong to the same component in the space access network - after the removal of unit and external doors - are merged to form pedestrian access zones



Element properties: Whole spaces, degree: Maximum = 1Mean = 0.28Minimum = 0Space elements, degree: Maximum = 2Mean = 2Minimum = 2Spatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 6Number of cycles = 0Number of whole spaces = 7 Number of subspaces = 0Number of space elements = 1





Element properties: Whole spaces, internal, area: Maximum = 153.32m<sup>2</sup> Mean = 39.94m<sup>2</sup> Minimum = 0.57m<sup>2</sup> Spatial relations: None Spatial relation network properties: Number of components = 8 Number of cycles = 0 Number of subspaces = 7 Number of subspaces = 0 Number of space elements = 1



Element properties: Whole spaces, internal, area: Maximum = 153.32m<sup>2</sup> Mean = 39.94m<sup>2</sup> Minimum = 0.57m<sup>2</sup> Spatial relations: None Spatial relation network properties: Number of components = 8 Number of cycles = 0 Number of whole spaces = 7 Number of subspaces = 0 Number of space elements = 1

> Apartment usable areas, SMART subsidized housing program, City of Vienna:

- 1 Room: max. 40 m<sup>2</sup>
- 2 Rooms: max. 55 m<sup>2</sup>
- 3 Rooms: max. 70 m<sup>2</sup>
- 4 Rooms: max. 80 m<sup>2</sup>
- 5 Rooms: max. 100 m<sup>2</sup>

#### Residential unit area = 153.32 m<sup>2</sup> (5 rooms)

- $\rightarrow$  Assuming 80% usable area due to construction areas (worst-case) = 122 m<sup>2</sup>
- $\rightarrow$  Spacious floor plan





**Element properties:** Whole spaces, distance nearest: Maximum = 2Mean = 0.75Minimum = 0Space elements, distance nearest: Maximum = 1 Mean = 1Minimum = 1Spatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 11Number of cycles = 3Number of whole spaces = 18 Number of subspaces = 0

Number of space elements = 11



# 'Map' web app http://spacepatterns.com/sp/map/html/viewer.html



### 'Chart' web app

http://spacepatterns.com/sp/charts/html/charts.html?tags=Kaden\_Klingbeil;chart=number\_of\_units\_by\_primary\_function;proj=KK08-4





 $\wedge$   $\checkmark$  [-] select 2 projects  $\checkmark$   $\equiv$  =  $\Rightarrow$   $\bigtriangleup$  ?



Small external spaces:

- Support detailed modeling of space orientations
- Useful in the analysis of 'Natural lighting', 'Natural ventilation', and 'Orientation zone' views





Element properties: Whole spaces, distance nearest: Maximum = 2 Mean = 0.75 Minimum = 0 Space elements, distance nearest: Maximum = 1 Mean = 1 Minimum = 1 Spatial relations:

- Space element partially enclosing whole space Spatial relation network properties:

Number of components = 11 Number of cycles = 3 Number of whole spaces = 18 Number of subspaces = 0 Number of space elements = 11







Direct, indirect, no daylight [%]

- Well-lit spaces requested by occupants
- Occupants opted for a white color scheme for improved daylight reflection of façade surfaces

**Element properties:** Whole spaces, internal, distance must pass: Maximum = 2Mean = 2Minimum = 2Space elements, distance must pass: Maximum = 2Mean = 2Minimum = 2Spatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 11Number of cycles = 3Number of whole spaces = 18 Number of subspaces = 0

Number of space elements = 11

 $\infty$  $\infty$  $\infty$  $\infty$  $\infty$  $\infty$ 

```
Element properties:
  Whole spaces, internal, distance must pass:
    Maximum = 7
    Mean = 2
    Minimum = 2
  Space elements, distance must pass:
    Maximum = 2
    Mean = 2
    Minimum = 2
Spatial relations:
- Space element partially enclosing whole space
Spatial relation network properties:
  Number of components = 11
  Number of cycles = 3
  Number of whole spaces = 18
  Number of subspaces = 0
  Number of space elements = 11
```

Must-pass distance:

- Length of shortest path that passes through a given internal space (must-pass node) and connects two distinct external spaces (source/destination nodes)
- Metric: path length (number of edges)
- First and last edge in a path are not counted as they are external edges



**Element properties:** Whole spaces, internal, distance must pass: Maximum = 2Mean = 2Minimum = 2Space elements, distance must pass: Maximum = 2Mean = 2Minimum = 2**Spatial relations:** - Space element partially enclosing whole space Spatial relation network properties: Number of components = 11 Number of cycles = 3Number of whole spaces = 18 Number of subspaces = 0Number of space elements = 11 Source node Path example: (a, b, c, d, e) 2 internal edges



**Element properties:** Whole spaces, internal, distance must pass: Maximum = 2Mean = 2Minimum = 2Space elements, distance must pass: Maximum = 2Mean = 2Minimum = 2Spatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 11 Number of cycles = 3Number of whole spaces = 18 Number of subspaces = 0Number of space elements = 11

Daylight orientation:

- Multilateral
   (natural light from 2 or more external spaces):
- Unilateral (natural light from 1 external space):

Must-pass distance > 2:

1 (17%)

5 (83%)

→ Space does not receive natural light from 2 or more external spaces

Must-pass distance = 2:

 $\infty$ 

 $\infty$ 

→ Space receives natural light from 2 or more external spaces

 $\infty$ 

 $\infty$ 

 $\infty$ 

 $\infty$ 

### Natural ventilation view



#### Natural ventilation view

**Element properties:** Whole spaces, internal, distance must pass: Maximum = 22.04mMean = 13.00mMinimum = 4.88mSpace elements, distance must pass: Maximum = 19.80mMean = 11.38m Minimum = 4.88mSpatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 8Number of cycles = 7 Number of whole spaces = 18 Number of subspaces = 0Number of space elements = 18



# 'Map' web app http://spacepatterns.com/sp/map/html/viewer.html



http://spacepatterns.com/sp/charts/html/charts.html?tags=Kaden\_Klingbeil;chart=number\_of\_units\_by\_primary\_function;proj=KK08-4

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 $\bigstar$   $\checkmark$  select 2 projects  $\checkmark$   $\Box$   $\overline{\bigtriangledown}$   $\Rightarrow$   $\bigtriangleup$  ?



#### Must-pass distance nearest metric: Path weight (Euclidean distance)

#### Natural ventilation view

**Element properties:** Whole spaces, internal, distance must pass: Maximum = 22.04mMean = 13.00mMinimum = 4.88mSpace elements, distance must pass: Maximum = 19.80mMean = 11.38mMinimum = 4.88mSpatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 8Number of cycles = 7 Number of whole spaces = 18 Number of subspaces = 0Number of space elements = 18


#### Natural ventilation view

**Element properties:** Whole spaces, internal, distance must pass: Maximum = 22.04mMean = 13.00mMinimum = 4.88mSpace elements, distance must pass: Maximum = 19.80mMean = 11.38m Minimum = 4.88mSpatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 8Number of cycles = 7 Number of whole spaces = 18 Number of subspaces = 0Number of space elements = 18







#### Avg. natural ventilation path length, by edge lengths

Path length [m]

# Projects

#### Natural ventilation view

Element properties: Whole spaces, internal, distance must pass: Maximum = 8 Mean = 4.75 Minimum = 2 Space elements, distance must pass: Maximum = 6 Mean = 4 Minimum = 2 Spatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 8 Number of cycles = 7 Number of whole spaces = 18

Number of subspaces = 0

Number of space elements = 18



# 'Map' web app http://spacepatterns.com/sp/map/html/viewer.html



http://spacepatterns.com/sp/charts/html/charts.html?tags=Kaden\_Klingbeil;chart=number\_of\_units\_by\_primary\_function;proj=KK08-4

 $\equiv$ 



Avg. natural ventilation path length, by number of edges



^ ? select 2 projects v — 20 m \$

# 'Chart' web app

http://spacepatterns.com/sp/charts/html/charts.html?tags=Kaden\_Klingbeil;chart=number\_of\_units\_by\_primary\_function;proj=KK08-4





 $\wedge$   $\checkmark$  [-] select 2 projects  $\checkmark$   $\Box$   $\overline{\bigtriangledown}$   $\stackrel{\frown}{=}$   $\stackrel{\frown}{=}$ 

#### Must-pass distance nearest metric: Path length (number of edges)

#### Natural ventilation view

Element properties: Whole spaces, internal, distance must pass: Maximum = 8 Mean = 4.75 Minimum = 2 Space elements, distance must pass: Maximum = 6 Mean = 4 Minimum = 2 Spatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 8

- Number of cycles = 7 Number of whole spaces = 18 Number of subspaces = 0
- Number of space elements = 18

Source/destination nodes: External spaces 8

8

#### Natural ventilation view

```
Element properties:
  Whole spaces, internal, distance must pass:
    Maximum = 8
    Mean = 4.75
    Minimum = 2
  Space elements, distance must pass:
   Maximum = 6
    Mean = 4
   Minimum = 2
Spatial relations:
- Space element partially enclosing whole space
Spatial relation network properties:
  Number of components = 8
  Number of cycles = 7
  Number of whole spaces = 18
  Number of subspaces = 0
  Number of space elements = 18
```

Must-pass distance = 2: → Space is oriented to 2 or more external spaces

#### Must-pass distance = 4:

→ Space is oriented to 1 external space and related to another space which is oriented to an external space

Must-pass distance = 6 or greater:

8

8

→ Space is oriented to 0 or 1 external space

#### Natural ventilation view

Element properties:

- Whole spaces, internal, distance must pass:
  - Maximum = 8
  - Mean = 4.75

```
Minimum = 2
```

Space elements, distance must pass:

- Maximum = 6
- Mean = 4

```
Minimum = 2
```

Spatial relations:

- Space element partially enclosing whole space Spatial relation network properties:

Number of components = 8 Number of cycles = 7 Number of whole spaces = 18

# Min. must-pass distance = 2:

- $\rightarrow$  Space is the only internal space in the path
- → Space is on a short path, which suggests high natural ventilation (cross ventilation) potential

#### Natural ventilation potential of spaces:

- High (must-pass distance = 2 or 4):
- Medium (must-pass distance = 6):
- Low (must-pass distance >= 8):

Mean must-pass distance = 4.75:  $\rightarrow$  On average, there are 2.4

internal spaces in a path

6 (75%)

2 (25%)

0 (0%)

Max. must-pass distance = 8:

- $\rightarrow$  4 internal spaces in the path
- → Space is on a long path, which suggests low natural ventilation (cross ventilation) potential

8

8



#### Avg. natural ventilation path length, by number of edges

Path length [-]

Avg. natural ventilation path length = 4.75:  $\rightarrow$  Short path length



High, medium, low [%]



## What are perimeter and core zones?

### **Perimeter zone**

- Adjacent to external spaces
- Created by merging connected perimeter spaces in the Architectural view

## Core zone

- Not adjacent to external spaces (e.g. in compact buildings with high depth)
- Created by merging connected core spaces in the Architectural view

## **General properties**

- Perimeter spaces interact with outdoor climate through building enclosure (e.g. solar irradiance)
- Core zones:

How provide daylight?

How provide fresh air?

How extract heat?

## **Properties in residential buildings**

- Circulation spaces located in core zones Main stair cases, hallways, elevators Internal hallways and stairs
- Service spaces located in core zones

Element properties: Whole spaces, distance nearest: Maximum = 2 Mean = 1.19 Minimum = 0 Spatial relations: - Whole space adjacency Spatial relation network properties: Number of components = 1 Number of cycles = 0 Number of subspaces = 5 Number of subspaces = 0 Number of space elements = 0



# 'Map' web app http://spacepatterns.com/sp/map/html/viewer.html



# 'Chart' web app

http://spacepatterns.com/sp/charts/html/charts.html?tags=Kaden\_Klingbeil;chart=number\_of\_units\_by\_primary\_function;proj=KK08-4





 $\bigstar$   $\checkmark$  select 2 projects  $\checkmark$   $\Box$   $\bigtriangledown$   $\bigtriangleup$   $\bigstar$   $\checkmark$   $\square$  ?

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• Connected spaces with the same distances to external spaces are merged

0

Perimeter core zones view Element properties: Whole spaces, distance nearest: Maximum = 2 Mean = 1.19 Minimum = 0 Spatial relations: - Whole space adjacency Spatial relation network properties: Number of components = 1 Number of cycles = 0 Number of whole spaces = 5

- Number of subspaces = 0
- Number of space elements = 0

Space adjacency network: Determine core zone levels

#### Architectural view

Derivation of perimeter and core zones: Spaces with same distance to external spaces (distance metric: path length) in the space adjacency network of the 'Architectural' view are merged into perimeter core zones



Element properties: Whole spaces, distance nearest: Maximum = 2 Mean = 1.19 Minimum = 0 Spatial relations: Whole space adjacency Spatial relation network properties: Number of components = 1 Number of cycles = 0 Number of whole spaces = 5 Number of subspaces = 0 Number of space elements = 0 Single-space zone (not merged) 0

#### Distance nearest metric: Path length (number of edges)

Element properties: Whole spaces, distance nearest: Maximum = 2 Mean = 1.19 Minimum = 0 Spatial relations: - Whole space adjacency Spatial relation network properties: Number of components = 1 Number of cycles = 0 Number of whole spaces = 5 Number of subspaces = 0 Number of space elements = 0







Projects

Depth [-]

Element properties: Whole spaces, internal, area: Maximum = 142.77m<sup>2</sup> Mean = 39.94m<sup>2</sup> Minimum = 0.57m<sup>2</sup> Spatial relations: None Spatial relation network properties: Number of components = 31 Number of cycles = 0 Number of subspaces = 5 Number of subspaces = 0 Number of space elements = 26



# 'Chart' web app

http://spacepatterns.com/sp/charts/html/charts.html?tags=Kaden\_Klingbeil;chart=number\_of\_units\_by\_primary\_function;proj=KK08-4





 $\bigstar$   $\checkmark$  [m<sup>2</sup>] select 2 projects  $\checkmark$   $\Box$   $\overline{\bigtriangledown}$   $\doteq$   $\sim$   $\square$  ?

Element properties: Whole spaces, internal, area: Maximum = 142.77m<sup>2</sup> Mean = 39.94m<sup>2</sup> Minimum = 0.57m<sup>2</sup> Spatial relations: None Spatial relation network properties: Number of components = 31 Number of cycles = 0 Number of subspaces = 5 Number of subspaces = 0 Number of space elements = 26





Area [%]

# Projects

## Functional zones view



## What is a functional zone?

### Connected spaces with similar functional properties in the architectural view are merged

## **General properties**

Functional zoning typically facilitates

- Activity separation,
- Sound control,
- Internal/external accessibility,
- Provision of technical services (heating/cooling, electrical, water)
- ...

## **Properties in residential buildings**

Minimize interferences between joint and individual activities

- Separate communal (living room, dining room, kitchen) from private rooms (bedrooms, bathrooms)
- Often in combination with hallways serving as buffer zones and providing separate access to communal and private rooms

Avoid functional zoning to ensure privacy (e.g. separate private rooms in large shared apartments)

#### Functional zones view

Element properties: Whole space, primary space property Spatial relations: None Spatial relation network properties: Number of components = 38 Number of cycles = 0 Number of whole spaces = 8 Number of subspaces = 0 Number of space elements = 30



# 'Map' web app http://spacepatterns.com/sp/map/html/viewer.html



http://spacepatterns.com/sp/charts/html/charts.html?tags=Kaden\_Klingbeil;chart=number\_of\_units\_by\_primary\_function;proj=KK08-4

3

≡





 $\diamond$   $\diamond$  select 2 projects  $\checkmark$   $\Box$   $\overline{\bigtriangledown}$   $\triangleq$   $\simeq$   $\square$  ?

#### Functional zones view

Element properties:

Whole space, primary space property

Functional zones view:

Connected spaces with similar functional

Spatial relations:

None

Spatial relation network properties:

Number of components = 38

Number of cycles = 0

Number of whole spaces = 8

Number of subspaces = 0

Number of space elements = 30



#### Architectural view

Derivation of functional zones: Spaces in the 'Architectural' view which have similar functional properties and are connected in the space adjacency network are merged into functional zones





#### Functional zones view

Element properties: Whole space, primary space property Spatial relations: None Spatial relation network properties: Number of components = 38 Number of cycles = 0 Number of whole spaces = 8 Number of subspaces = 0 Number of space elements = 30

3 multi-space functional zones<sup>1</sup>:

- 1 Bedroom zone
- 1 Service zone
- 1 Main circulation zone

3 single-space functional zones:

- 1 Living room
- 1 Bedroom
- 1 Shaft

Avg. size of functional zones (number of functional spaces in 'Architectural' view / number of functional zones):  $\rightarrow 12/6 = 2$  spaces

<sup>1</sup> Functional space/zone: a space/zone whose primary space property is not 'ext air'


#### Large functional zones:



based on their functions



Element properties: Whole spaces, internal, area: Maximum = 56.45m<sup>2</sup> Mean = 34.12m<sup>2</sup> Minimum = 0.57m<sup>2</sup> Spatial relations: None Spatial relation network properties: Number of components = 38 Number of cycles = 0 Number of subspaces = 8 Number of subspaces = 0 Number of space elements = 30



Element properties: Whole spaces, internal, area: Maximum = 56.45m<sup>2</sup> Mean = 34.12m<sup>2</sup> Minimum = 0.57m<sup>2</sup> Spatial relations: None Spatial relation network properties: Number of components = 38 Number of cycles = 0 Number of subspaces = 8 Number of subspaces = 0 Number of space elements = 30



Element properties: Whole spaces, degree: Maximum = 10Mean = 4.75Minimum = 0Space elements, degree: Maximum = 2Mean = 1.26Minimum = 0Spatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 4Number of cycles = 12 Number of whole spaces = 8 Number of subspaces = 0Number of space elements = 22



**Element properties:** Whole spaces, degree: Maximum = 10Mean = 4.75Minimum = 0Space elements, degree: Maximum = 2Mean = 1.26Minimum = 0Spatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 4Number of cycles = 12Number of whole spaces = 8Number of subspaces = 0Number of space elements = 22

> Space enclosure network: Determine zone connectivity through space enclosures



**Element properties:** Whole spaces, degree: Maximum = 10Mean = 4.75Minimum = 0Space elements, degree: Maximum = 2Mean = 1.26Minimum = 0Spatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 4Number of cycles = 12Number of whole spaces = 8Number of subspaces = 0Number of space elements = 22

> Max. degree = 10: → Although it is a single-space zone, the living room is the most connected zone (compare with 'Architectural' view)





# Connected spaces in the architectural view with openings oriented to the same external spaces are merged

# **General properties**

- Large orientation zones typical for buildings with few main orientations (unilateral, bilateral) planar enclosures
- Small orientation zones typical for buildings with multiple orientations (multi-lateral) protrusions or recesses

# **Properties in residential buildings**

- Large orientation zones typical for row houses
- Small orientation zones typical for detached and semi-detached houses loggias, bay windows attached main circulation

Element properties: Whole space, primary space property Spatial relations: None Spatial relation network properties: Number of components = 48 Number of cycles = 0 Number of whole spaces = 17 Number of subspaces = 0 Number of space elements = 31





#### Natural lighting view

Derivation of orientation zones: Internal spaces in the 'Natural lighting' view whose openings are oriented to the same exterior spaces and which are connected in the space adjacency network are merged into orientation zones



Element properties: Whole space, primary space property Spatial relations: None Spatial relation network properties: Number of components = 48 Number of cycles = 0 Number of whole spaces = 17 Number of subspaces = 0 Number of space elements = 31



Element properties: Whole space, primary space property Spatial relations: None Spatial relation network properties: Number of components = 48 Number of cycles = 0 Number of whole spaces = 17 Number of subspaces = 0 Number of space elements = 31

1 multi-space zone oriented to exterior:

• 1 Bedroom zone (3 Bedrooms)

3 single-space zones oriented to exterior:

- 1 Living room
- 1 Bedroom
- 1 Bathroom

#### 2 zones **not** oriented to exterior:

- 1 Shaft
- 1 Service (Shaft, Laundry room, Bathroom)

**Avg. size of orientation zones** (number of spaces with direct daylight / number of zones oriented to exterior):

 $\rightarrow$  6 / 4 = **1.5** spaces





Projects

Element properties: Whole spaces, internal, area: Maximum = 56.45m<sup>2</sup> Mean = 22.82m<sup>2</sup> Minimum = 0.57m<sup>2</sup> Spatial relations: None Spatial relation network properties: Number of components = 48 Number of cycles = 0 Number of subspaces = 17 Number of subspaces = 0 Number of space elements = 31



Element properties: Whole spaces, internal, area: Maximum = 56.45m<sup>2</sup> Mean = 22.82m<sup>2</sup> Minimum = 0.57m<sup>2</sup> Spatial relations: None Spatial relation network properties: Number of components = 48 Number of cycles = 0 Number of whole spaces = 17 Number of subspaces = 0 Number of space elements = 31



Element properties: Whole spaces, degree: Maximum = 5Mean = 1.23Minimum = 0 Space elements, degree: Maximum = 2Mean = 1.90Minimum = 1Spatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 12Number of cycles = 5Number of whole spaces = 17 Number of subspaces = 0Number of space elements = 11



# 'Map' web app http://spacepatterns.com/sp/map/html/viewer.html



# 'Chart' web app http://spacepatterns.com/sp/charts/html/charts.html

6





 $\wedge$   $\checkmark$  [%] select 2 projects  $\checkmark$   $\Box$   $\overline{\bigtriangledown}$   $\triangleq$   $\Rightarrow$   $\square$  ?

Element properties: Whole spaces, degree: Maximum = 5Mean = 1.23Minimum = 0Space elements, degree: Maximum = 2Mean = 1.90Minimum = 1Spatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 12Number of cycles = 5Number of whole spaces = 17 Number of subspaces = 0Number of space elements = 11

> Space enclosure network: **Determine orientation relations** between internal and external spaces



**Element properties:** Whole spaces, degree: Maximum = 5Mean = 1.23Minimum = 0Space elements, degree: Maximum = 2Mean = 1.90Minimum = 1Spatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 121 Number of cycles = 5Number of whole spaces = 17 Number of subspaces - 0 Nur Min. external space degree = 0:  $\rightarrow$  No apartment openings are directly oriented to spaces between stairs and apartment 0



Element properties: Whole spaces, degree: Maximum = 5Mean = 1.23Minimum = 0Space elements, degree: Maximum = 2Mean = 1.90Minimum = 1Spatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 12Number of cycles = 5Number of whole spaces = 17 Number of subspaces = 0Number of space elements = 11

2 main orientations (components):  $\rightarrow$  Courtyard

 $\rightarrow$  Loggia/street



Element properties: Whole spaces, internal, distance must pass: Maximum = 2 Mean = 2 Minimum = 2 Space elements, distance must pass: Maximum = 2 Mean = 2 Minimum = 2 Spatial relations: - Space element partially enclosing whole space Spatial relation network properties: Number of components = 12 Number of cycles = 5 Number of whole spaces = 17

Number of subspaces = 0

Number of space elements = 11



## Must-pass distance metric: Path length (number of edges)

 $\infty$ 

# Orientation zones view

Element properties:

Whole spaces, internal, distance must pass:

- Maximum = 2
- Mean = 2
- Minimum = <mark>2</mark>

Space elements, distance must pass:

Maximum = 2

Mean = 2

Minimum = 2

Spatial relations:

- Space element partially enclosing whole space Spatial relation network properties:

Number of components = 12 Number of cycles = 5 Number of whole spaces = 17 Number of subspaces = 0 Number of space elements = 11

> Source/destination nodes: External spaces

> > Must-pass nodes: Internal spaces

 $\infty$ 

 $\infty$ 

 $\infty$ 

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Spatial analysis summary

# Overview

- Project description
  - Context
  - Building
  - Source space data (input layout)
- Summary of key spatial analysis results for each space model view
  - Architectural view
    Pedestrian circulation view
    Pedestrian access zones view
    Natural lighting view
    Natural ventilation view
    Perimeter/core zones view
    Functional zones view
    Orientation zones view
- Side-by-side comparison of views
- Comparison with sample projects







#### Context

#### Address:

• Esmarchstrasse 3, Berlin

## Туре:

• Perimeter block development with multiple coutyards

# Building

Architects:

• Kaden Klingbeil Architects, Berlin

Year:

• 2008

Floors:

- 6 upper floors (residential)
- 1 ground floor (commercial)

Construction:

 Wood walls, composite wood/concrete ceilings, structural steel frame, concrete technical infrastructure shafts, concrete external stairs

Project organisation:

- Private owner association
- Participatory design

# Source space data (input layout)

Floor:

• 3



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1 Architectural view

- 2 Pedestrian circulation view
- 3 Pedestrian access zones view
- 4 Natural lighting view
- 5 Natural ventilation view
- 6 Perimeter/core zones view
- 7 Functional zones view
- 8 Orientation zones view

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## Architectural view

#### Use mix:

• 5 room apartment

Avg. living room area:

• 48.4 m<sup>2</sup> ( $\rightarrow$  medium to large)

Max. bedroom area:

• 22.7 m<sup>2</sup> ( $\rightarrow$  medium to large)

Most connected space(s):

• Living room



## Pedestrian circulation view

Number of cycles:

• 0 (balanced tree)

Max. depth from unit door:

- 3 levels ( $\rightarrow$  very shallow)
- 2 spaces

Access control:

• Living room controls access to all other spaces

Most connected space(s):

• Living room

Max. walking distance to unit door:

• 12.4 m ( $\rightarrow$  short)

Entrance paths:

- E K: direct (L)
- E L: direct
- E B: via L

Functional paths:

- K D: direct (L)
- B Br: via L

#### Pedestrian access zones view

Unit access:

Single-loaded access

#### Unit area(s):

• 153 m<sup>2</sup> (Residential unit)

Comparison with reference projects (if applicable)





#### Natural lighting view

Daylight access:

- 6 (75%) spaces have direct or indirect access to daylight
  - $(\rightarrow very high \%)$
- 2 (25%) spaces have no daylight
   (→ very low %)

Daylight orientation:

- 1 (17%) multilateral space
- 5 (83%) unilateral spaces

#### Natural ventilation view

Natural ventilation potential:

- 6 (75%) spaces have high or medium natural ventilation potential (→ high %)
- 2 (25%) spaces have low natural ventilation potential (→ low %)

Avg. natural ventilation path length:

- 13 m ( $\rightarrow$  very short)
- 2.4 spaces ( $\rightarrow$  short)







#### Perimeter/core zones view

Max. core zone depth:

• 2 levels ( $\rightarrow$  shallow)

Core/total area ratio:

• 7.3% ( $\rightarrow$  very small)

#### **Functional zones view**

Avg. size of functional zones:

• 2 spaces ( $\rightarrow$  *medium*)

Most connected zone(s):

• Living room

Largest zone(s):

- 56 m<sup>2</sup> (bedroom zone)
- 3 spaces (bedroom zone)

#### **Orientation zones view**

Main orientation(s):

- Courtyard
- Loggia/street

Largest zone(s):

- 56 m<sup>2</sup> (bedroom zone)
- 3 spaces (bedroom zone)

Avg. size of orientation zones:

• 1.5 spaces ( $\rightarrow$  medium)

Orientation types:

- 1 (25%) multilateral zone
- 3 (75%) unilateral zones