# The State of the Art in Visual Analytics for 3D Urban Data

Fabio Miranda, Thomas Ortner, Gustavo Moreira, Maryam Hosseini, Milena Vuckovic, Filip Biljecki, Claudio Silva, Marcos Lage, Nivan Ferreira

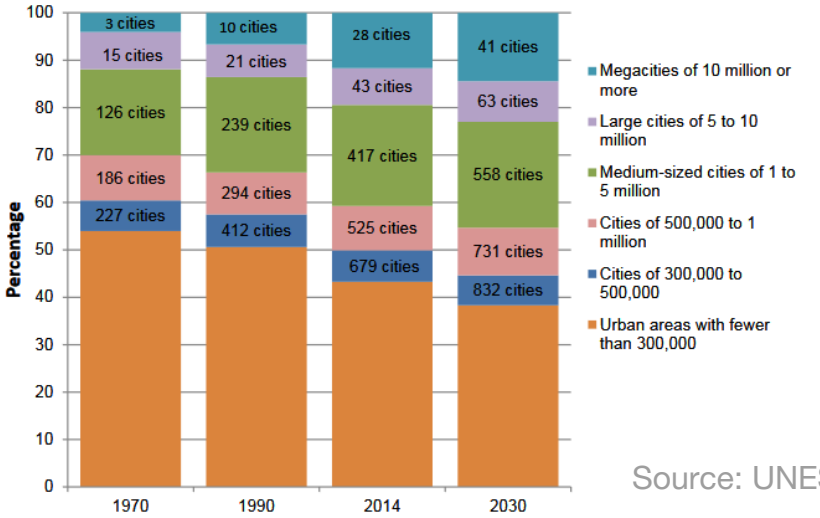







*EuroVis 2024 STARs*

# Urbanization




Source: UNESCO

**2050**

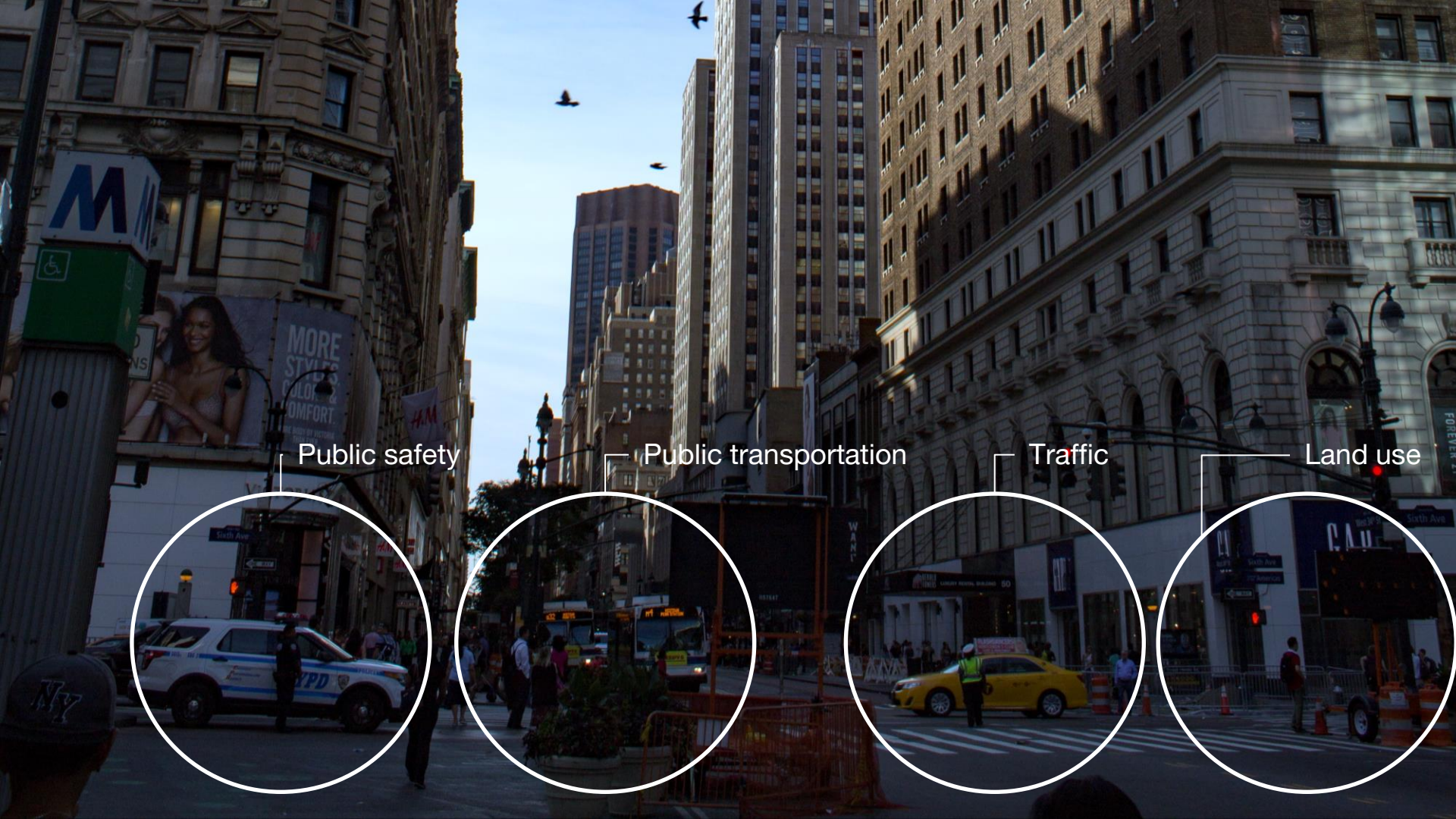
**68%**

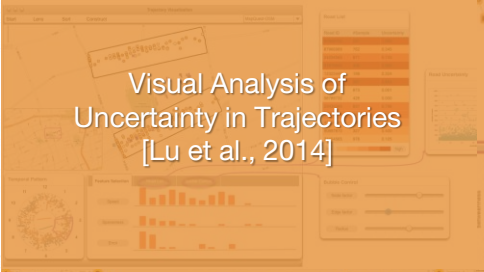
Source: UN

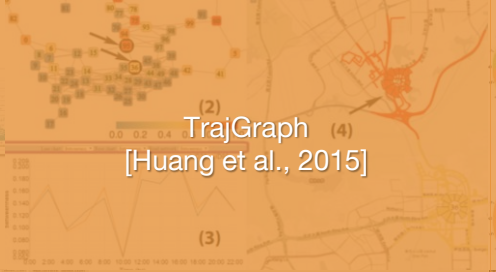
# Urban data

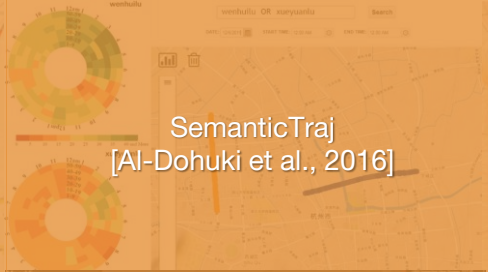
# Urban data

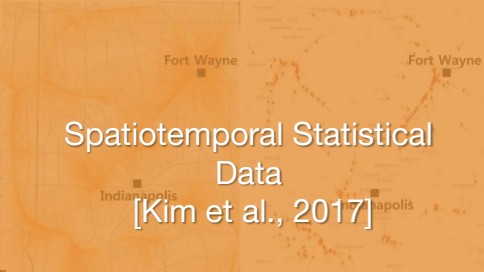

# Urban data



Public safety
Public transportation
Traffic
Land use

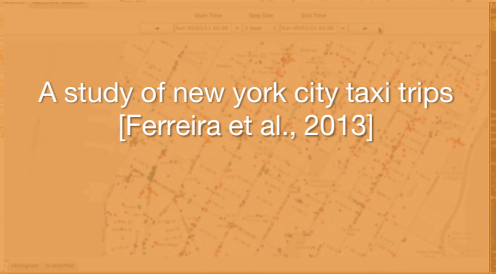

Visual Analysis of Uncertainty in Trajectories [Lu et al., 2014]


TrajGraph [Huang et al., 2015]


SemanticTraj [Al-Dohuki et al., 2016]


Spatiotemporal Statistical Data [Kim et al., 2017]


Forecasting Road Traffic Congestion [Lee et al., 2019]


A study of new york city taxi trips [Ferreira et al., 2013]


MaraVis [Li et al., 2020]

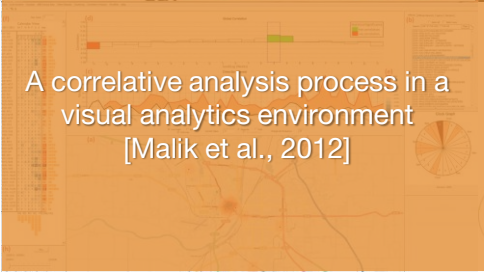

SEEVis [Li et al., 2020]


Air Pollution Problem in Hong Kong [Qu et al., 2007]

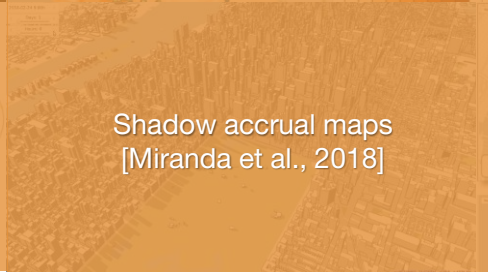

Air Temperature [Gautier et al., 2020]


Urban Mosaic [Miranda et al., 2020]


Location2vec [Zhu et al., 2019]

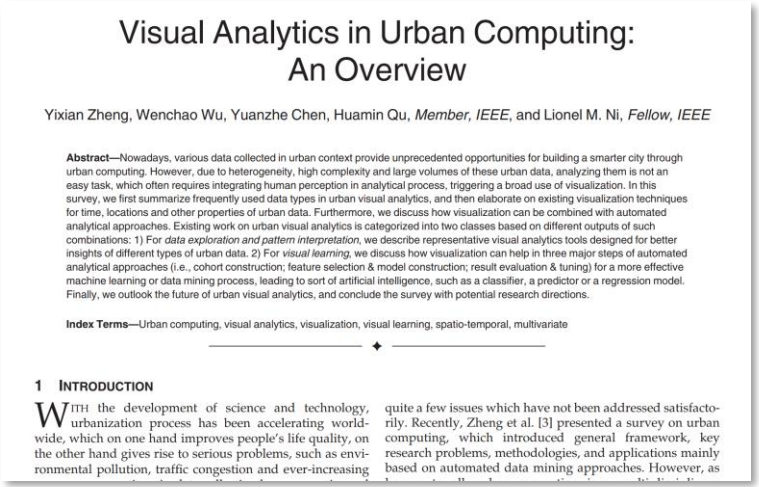

A correlative analysis process in a visual analytics environment [Malik et al., 2012]


HydroQual [Accorsi et al., 2014]


Shadow accrual maps [Miranda et al., 2018]


Urban Pulse [Miranda et al., 2016]

# Urban visual analytics surveys



Visual Analytics in Urban Computing: An Overview

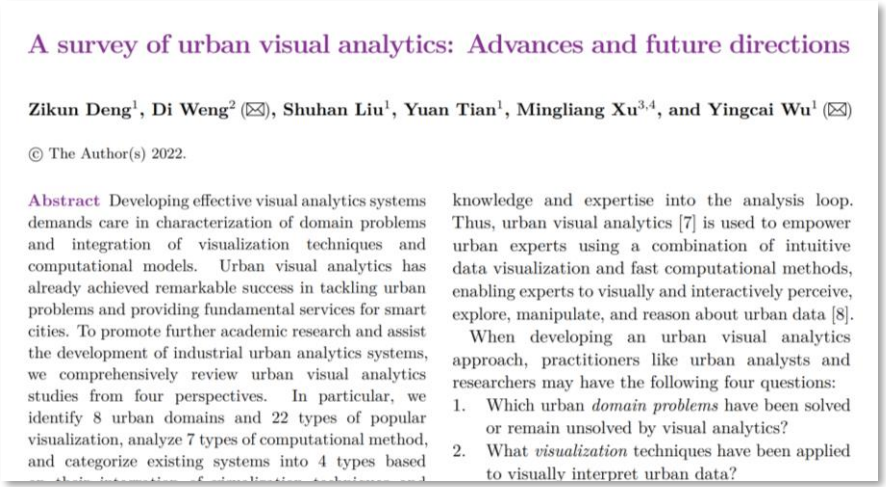
Yixian Zheng, Wenchao Wu, Yuanzhe Chen, Huamin Qu, *Member, IEEE*, and Lionel M. Ni, *Fellow, IEEE*

**Abstract**—Nowadays, various data collected in urban context provide unprecedented opportunities for building a smarter city through urban computing. However, due to heterogeneity, high complexity and large volumes of these urban data, analyzing them is not an easy task, which often requires integrating human perception in analytical process, triggering a broad use of visualization. In this survey, we first summarize frequently used data types in urban visual analytics, and then elaborate on existing visualization techniques for time, locations and other properties of urban data. Furthermore, we discuss how visualization can be combined with automated analytical approaches. Existing work on urban visual analytics is categorized into two classes based on different outputs of such combinations: 1) For *data exploration and pattern interpretation*, we describe representative visual analytics tools designed for better insights of different types of urban data. 2) For *visual learning*, we discuss how visualization can help in three major steps of automated analytical approaches (i.e., cohort construction; feature selection & model construction; result evaluation & tuning) for a more effective machine learning or data mining process, leading to sort of artificial intelligence, such as a classifier, a predictor or a regression model. Finally, we outlook the future of urban visual analytics, and conclude the survey with potential research directions.

**Index Terms**—Urban computing, visual analytics, visualization, visual learning, spatio-temporal, multivariate

1 Introduction

With the development of science and technology, urbanization process has been accelerating worldwide, which on one hand improves people's life quality, on the other hand gives rise to serious problems, such as environmental pollution, traffic congestion and ever-increasing quite a few issues which have not been addressed satisfactorily. Recently, Zheng et al. [3] presented a survey on urban computing, which introduced general framework, key research problems, methodologies, and applications mainly based on automated data mining approaches. However, as



A survey of urban visual analytics: Advances and future directions

Zikun Deng[1], Di Weng[2] (✉), Shuhan Liu[1], Yuan Tian[1], Mingliang Xu[3,4], and Yingcai Wu[1] (✉)

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Abstract Developing effective visual analytics systems demands care in characterization of domain problems and integration of visualization techniques and computational models. Urban visual analytics has already achieved remarkable success in tackling urban problems and providing fundamental services for smart cities. To promote further academic research and assist the development of industrial urban analytics systems, we comprehensively review urban visual analytics studies from four perspectives. In particular, we identify 8 urban domains and 22 types of popular visualization, analyze 7 types of computational method, and categorize existing systems into 4 types based

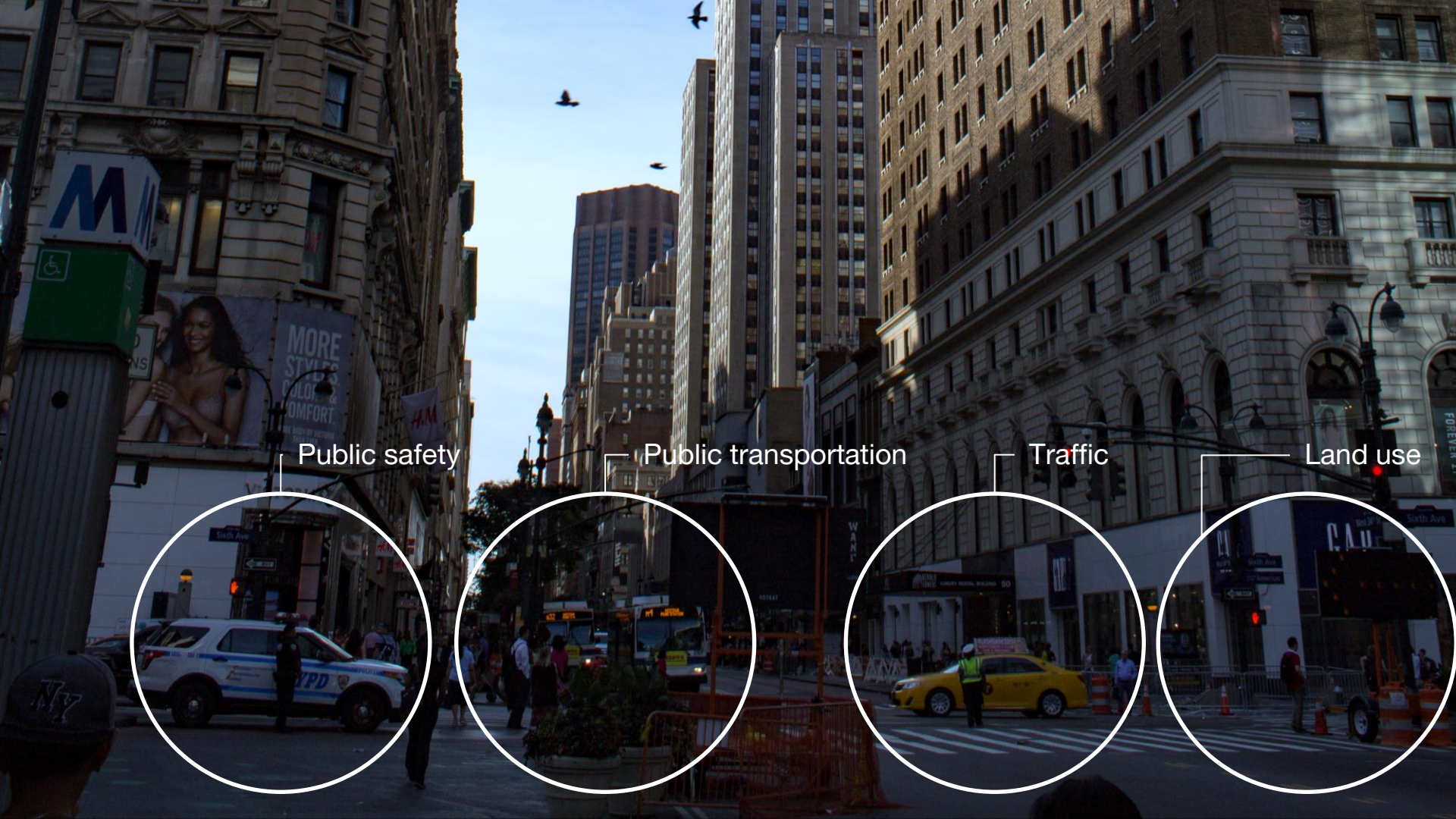
knowledge and expertise into the analysis loop. Thus, urban visual analytics [7] is used to empower urban experts using a combination of intuitive data visualization and fast computational methods, enabling experts to visually and interactively perceive, explore, manipulate, and reason about urban data [8].

When developing an urban visual analytics approach, practitioners like urban analysts and researchers may have the following four questions:

1. Which urban *domain problems* have been solved or remain unsolved by visual analytics?
2. What *visualization* techniques have been applied to visually interpret urban data?

> 150 papers (Zheng et al., 2016)

> 200 papers (Deng et al., 2022)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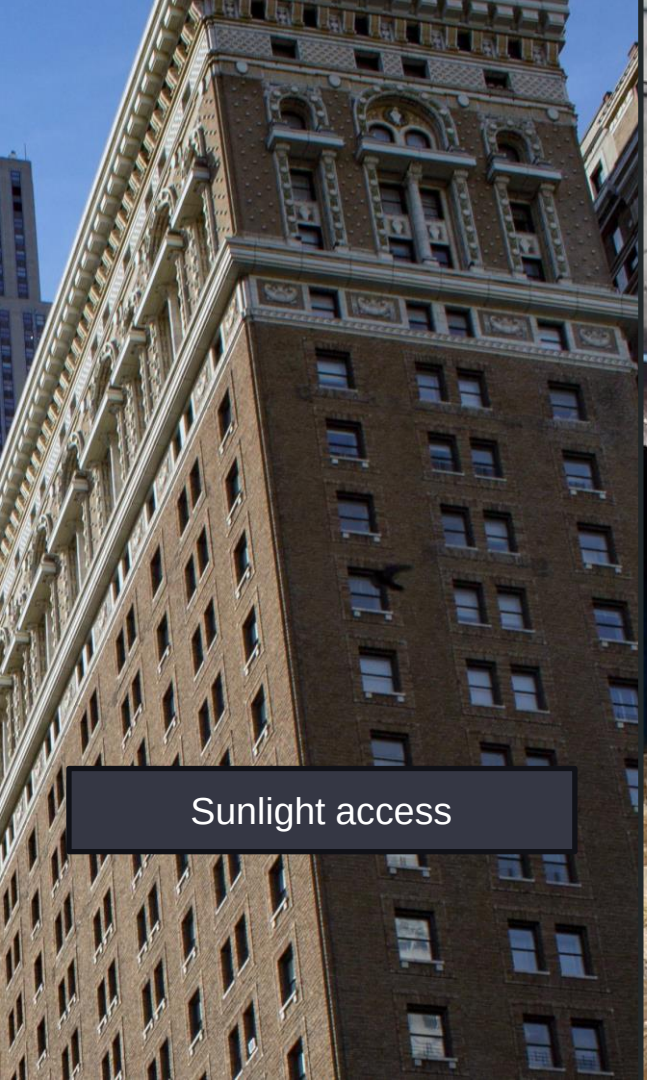
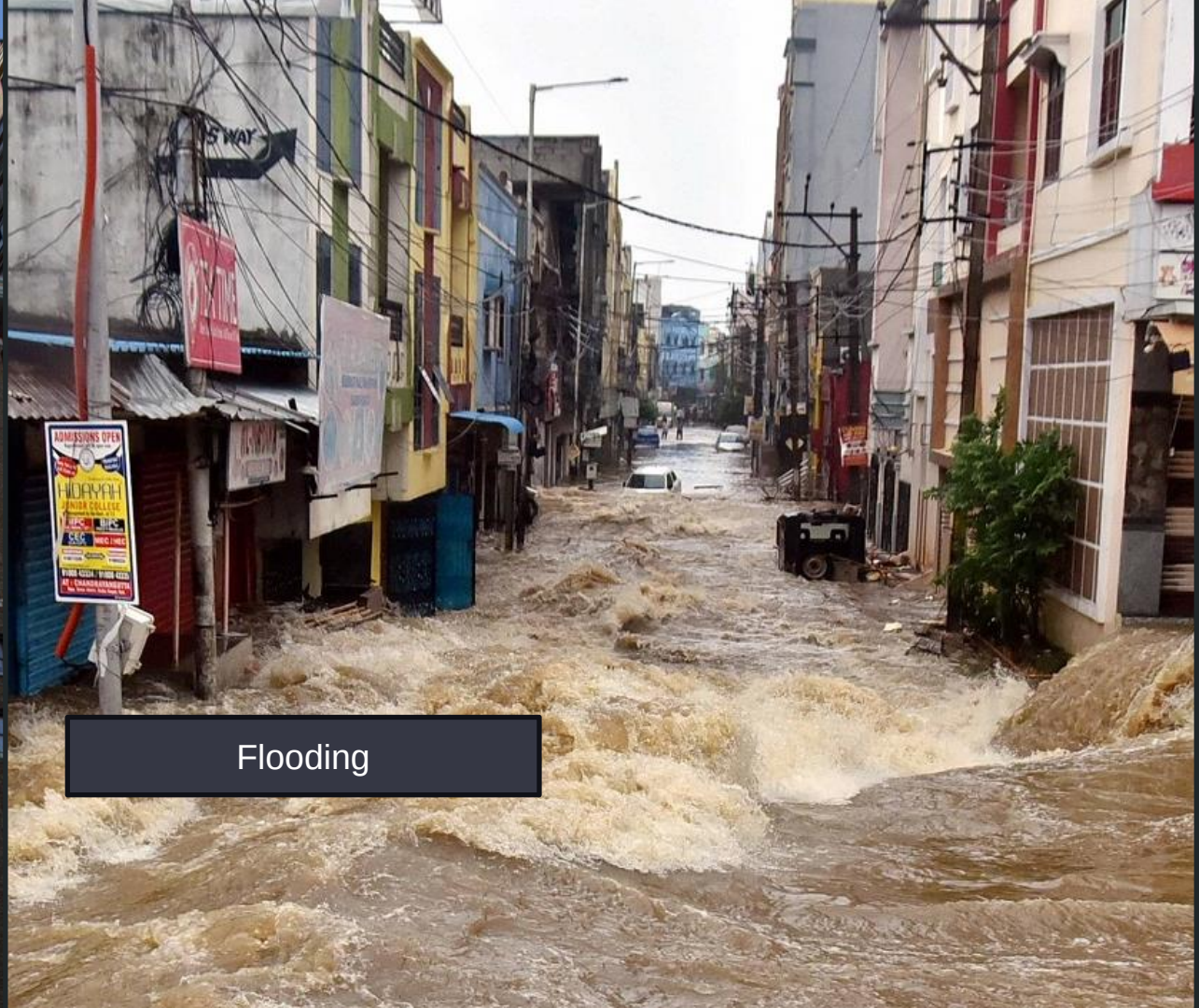
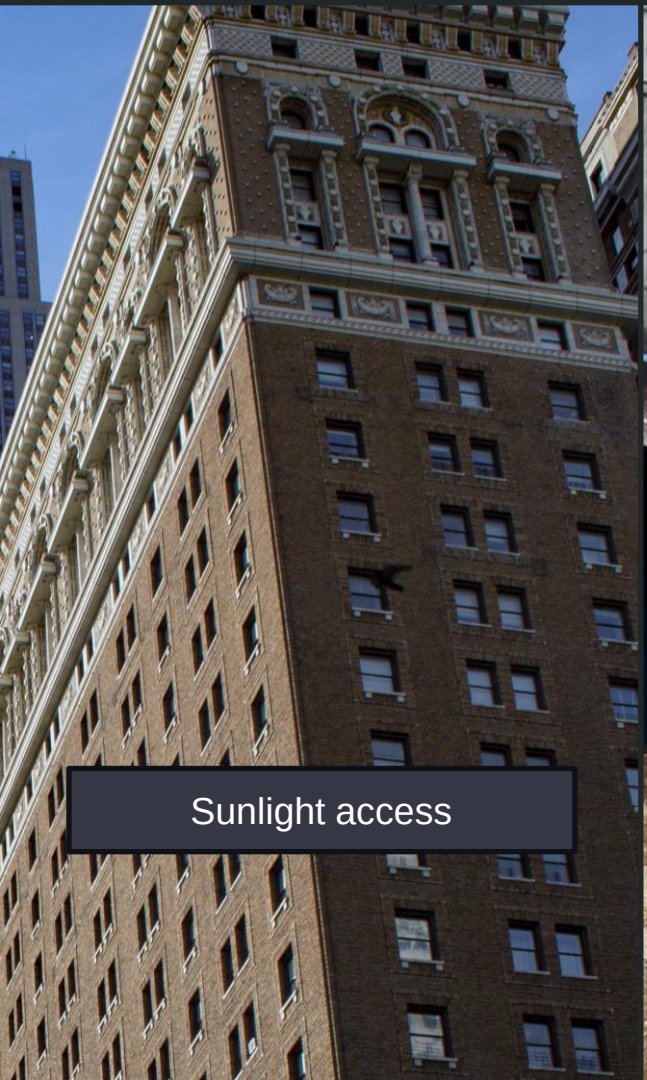
Public transportation
Traffic
Land use



Sunlight access

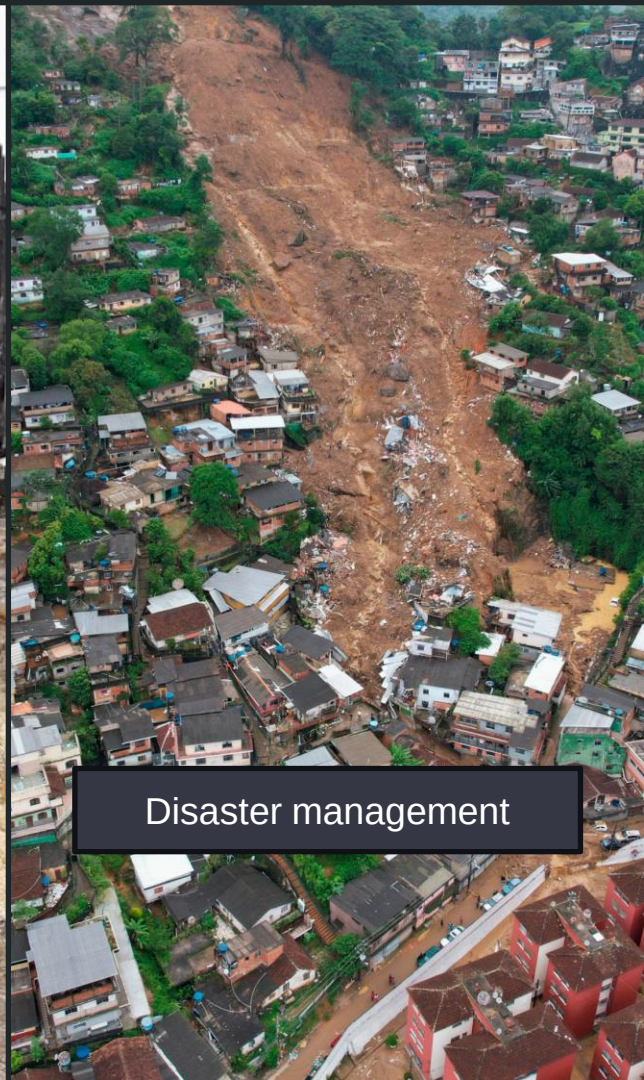



Flooding



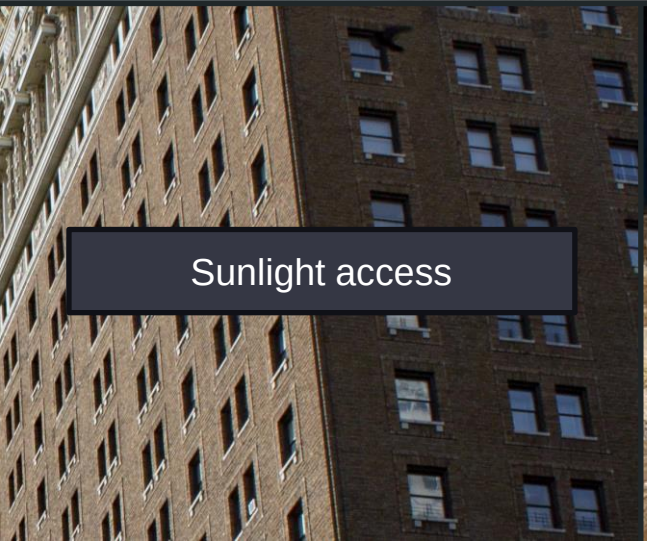
Sunlight access


Flooding



Disaster management

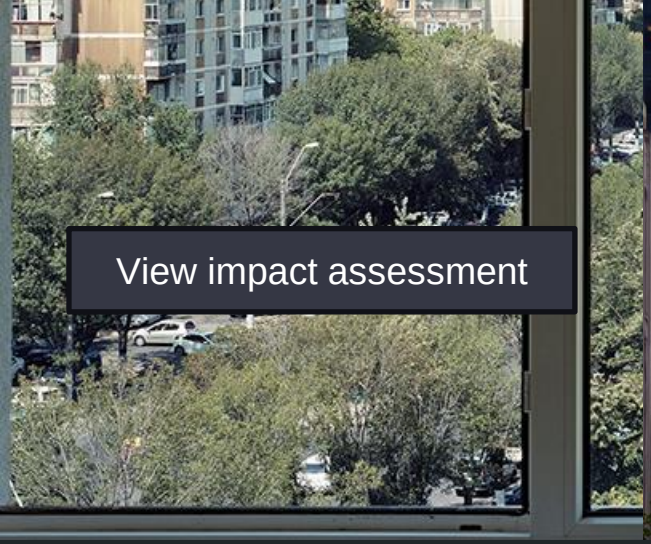
View impact assessment

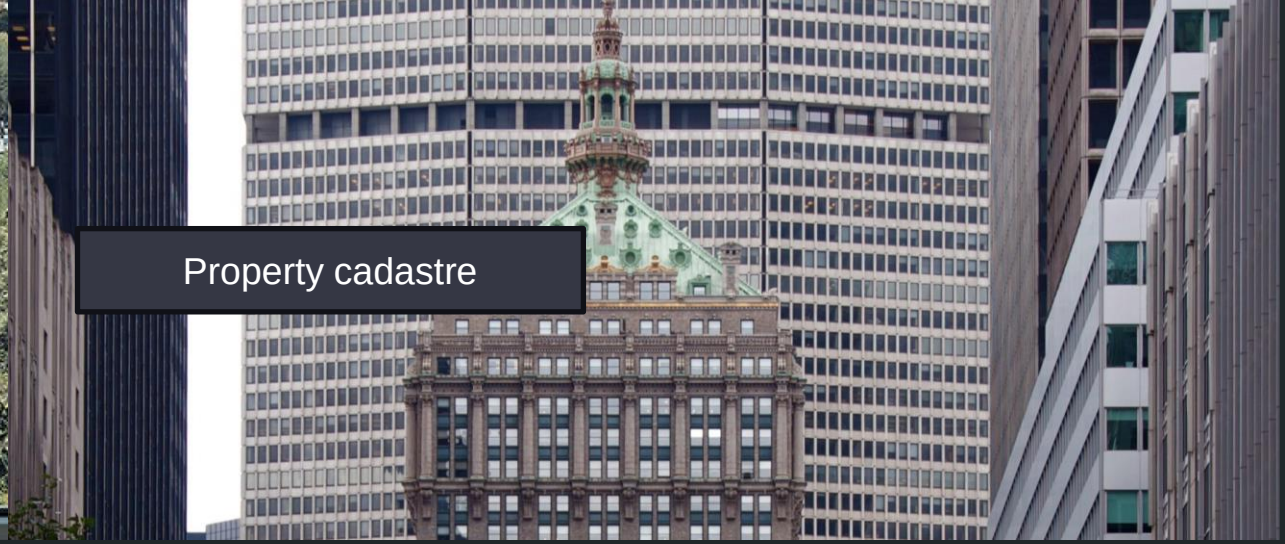


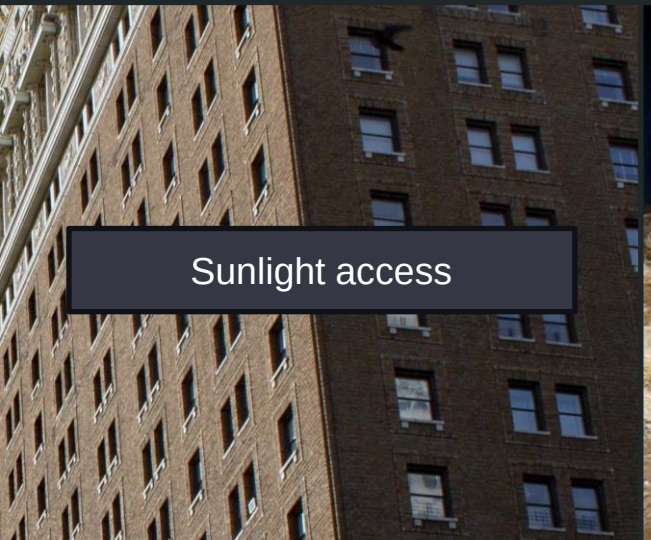
Sunlight access

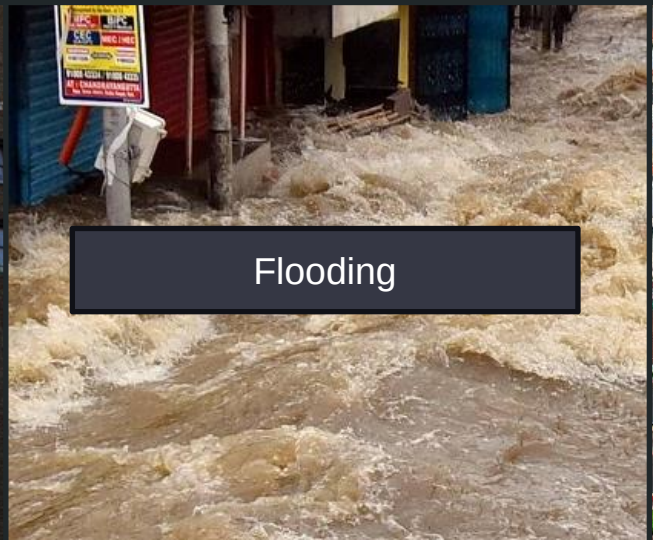
Flooding

Disaster management

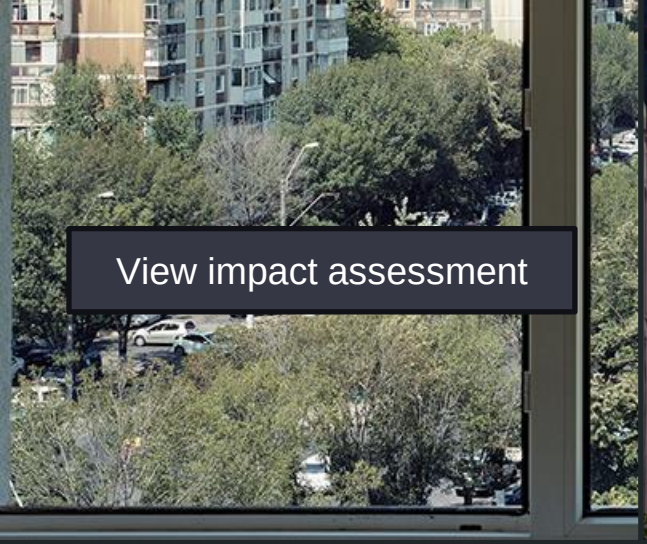

View impact assessment

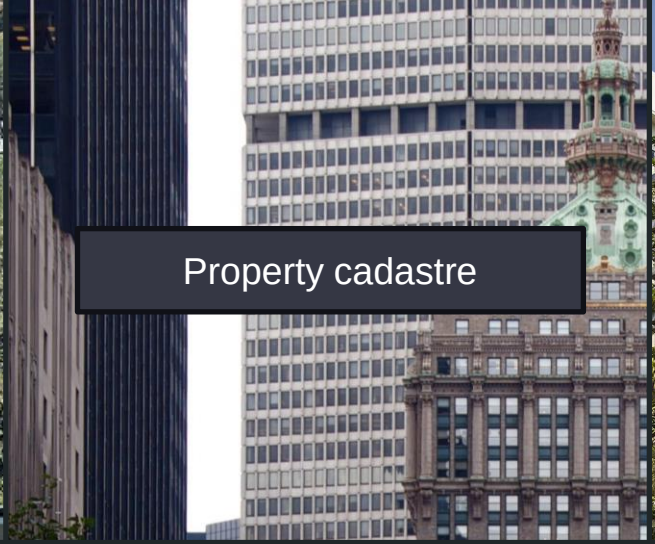

Property cadastre


Sunlight access

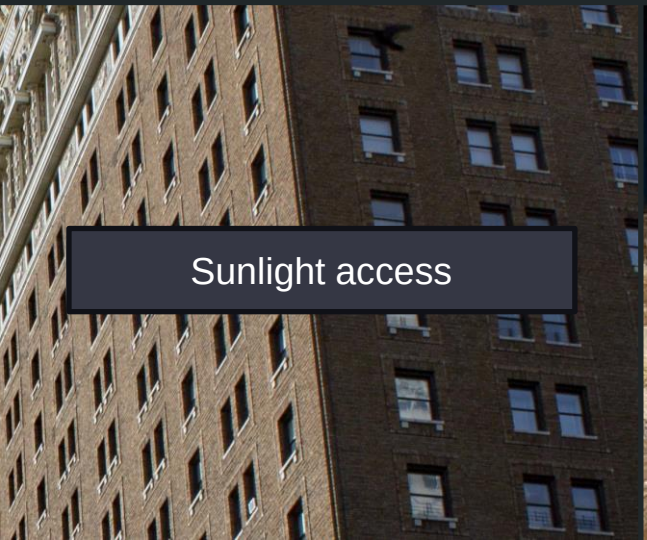

Flooding


Disaster management


View impact assessment


Property cadastre

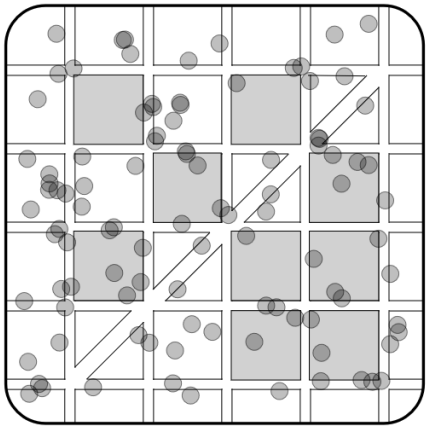

Urban farming


Sunlight access


Flooding


Disaster management

# 3D Urban Data



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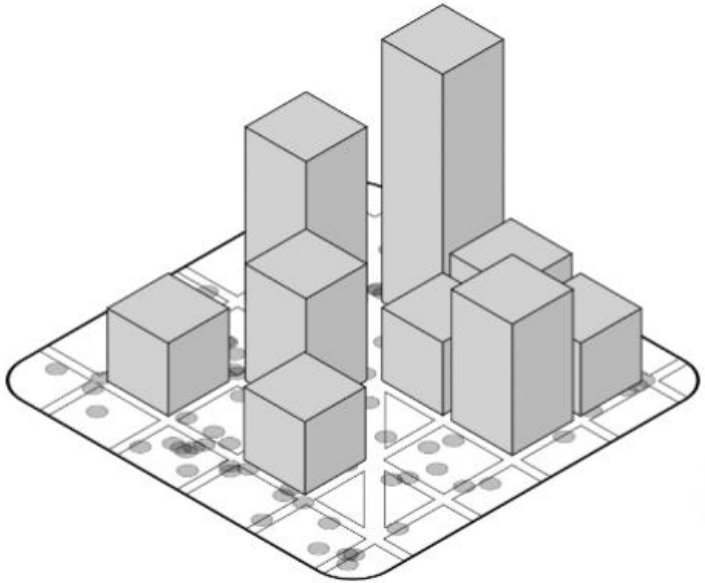
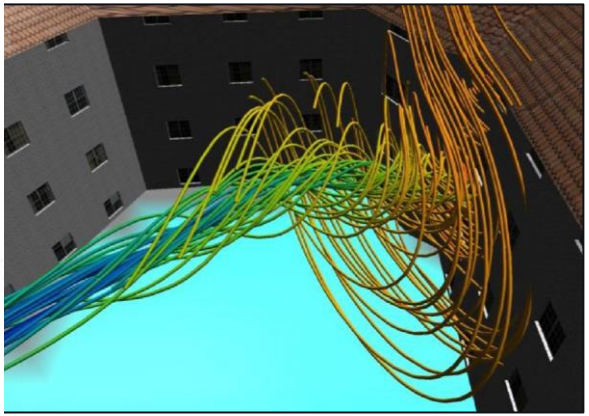
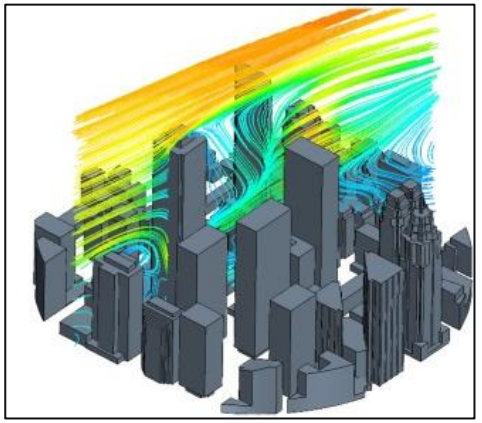


Wind & weather simulations





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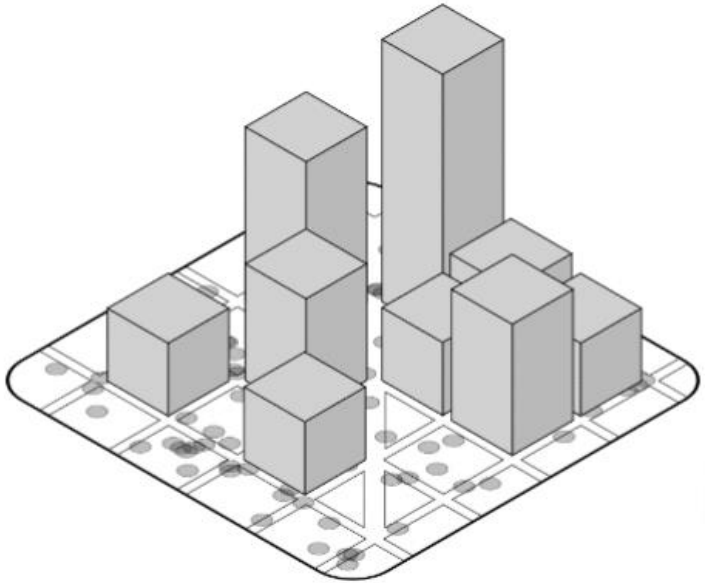
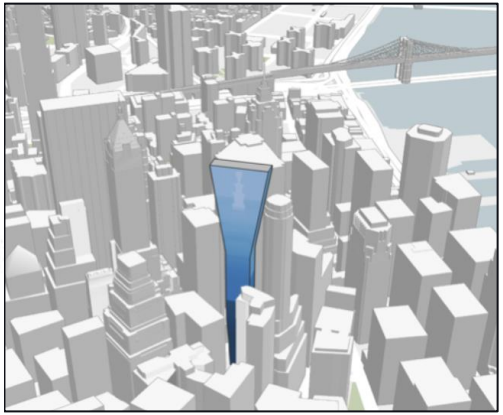
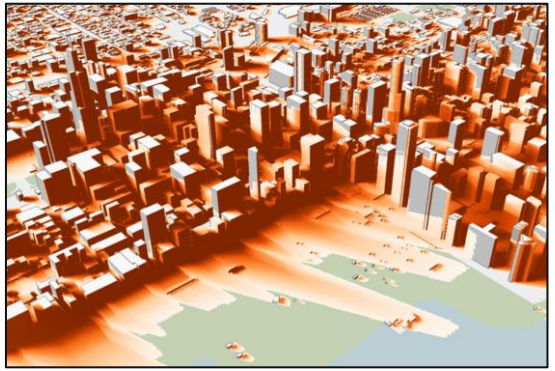


View & sunlight models





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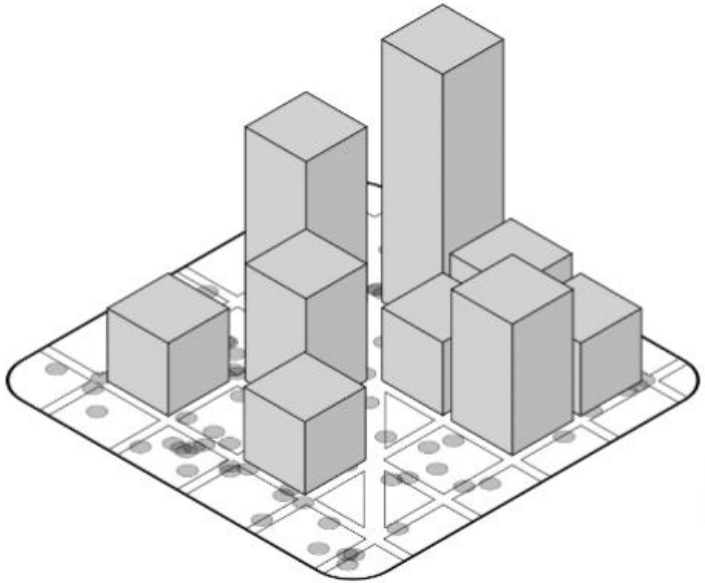
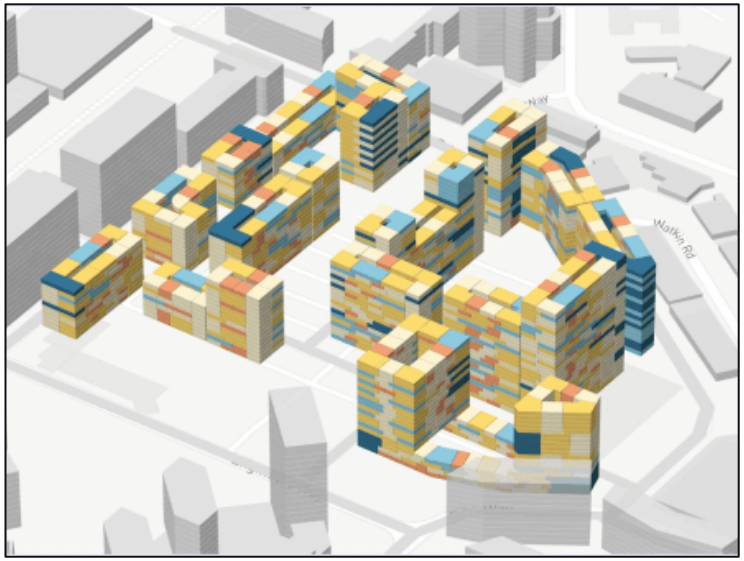
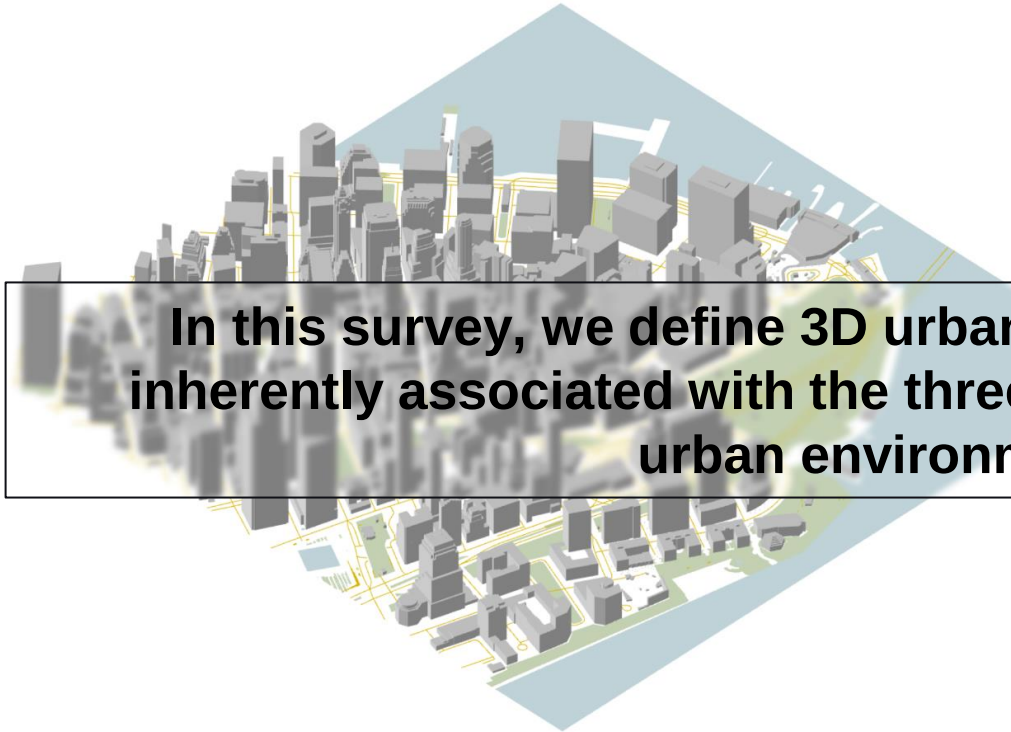


Surveyed data



# What is 3D Urban Data?



**In this survey, we define 3D urban data as the information inherently associated with the three-dimensional structure of urban environments.**

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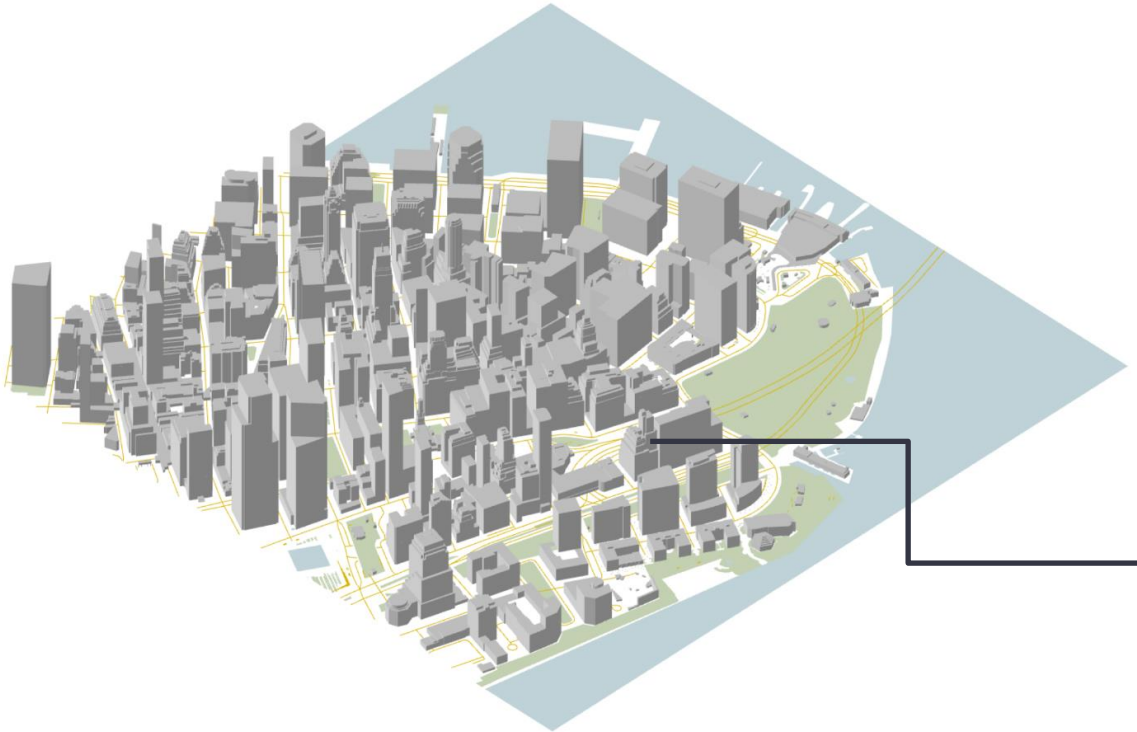
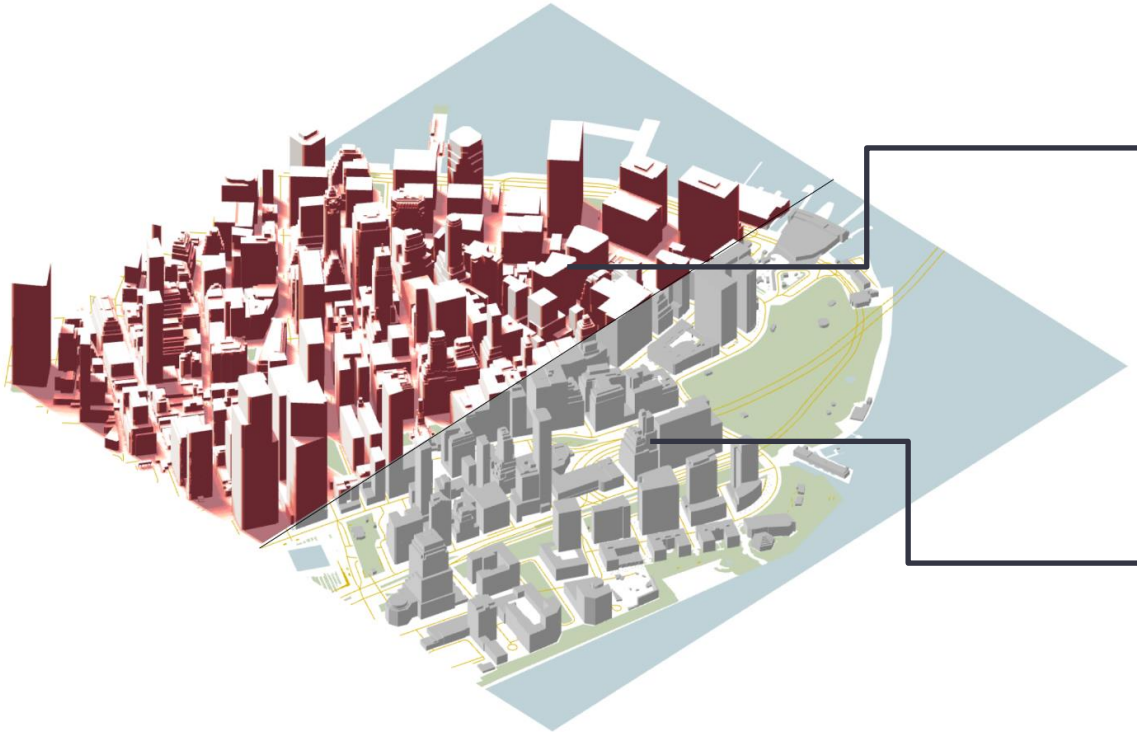


Physical layers:
- Buildings
- Streets
- Parks
- Water bodies

# What is 3D Urban Data?



Thematic layers:
- Simulation outputs
- Survey results
- Sensed data

Physical layers:
- Buildings
- Streets
- Parks
- Water bodies

# Why this survey?

- **Growing availability of 3D urban datasets & visual analytics tools leveraging them.**
- Inclusion of this additional dimension increases the difficulty in addressing the various challenges involved in designing effective GIS and VA tools:
  - Visual strategies to support analysis of the data referent to the city's geometry.
  - Navigation to learn the structure of the environment.
  - Integration of the information from different points of view, while avoiding occlusion and viewpoint changes.

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*Tackling these challenges can be fundamental to uncovering features valuable for decision-making and problem-solving in several domains.*

# Survey scope

We included papers that:

1. Made visualization contributions leveraging 3D urban data or facilitating 3D urban analytics.
2. Made domain-specific contributions generating or analyzing 3D urban data.

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1. Made visualization contributions leveraging 3D urban data or facilitating 3D urban analytics.
2. Made domain-specific contributions generating or analyzing 3D urban data.

Venue selection process involved:

6 visualization researchers

3 domain experts

# Survey scope

| | |
|---|---|
| CFG | Computer Graphics Forum |
| CG | Computers & Graphics |
| CGA | IEEE Computer Graphics and Applications |
| IV | Information Visualization |
| TOG | ACM Trans. on Graphics |
| TVCG | IEEE Trans. on Visualization and Computer Graphics |
| TVCJ | The Visual Computer |
| VI | Visual Informatics |
| CHI | ACM Conf. on Human Factors in Computing Systems |
| EuroVis | Eurographics Conference on Visualization |
| PacificVis | IEEE Pacific Visualization Symposium |
| SIGGRAPH | ACM SIG on Comp. Graphics and Inter. Techniques |
| VIS | IEEE Visualization Conference |
| BE | Building and Environment |
| CEUS | Computers, Environment and Urban Systems |
| EPB | Env. and Planning B: Urban Analytics and City Science |
| IJAC | Int. Journal of Architectural Computing |
| IJGIS | Int. Journal of Geographical Information Science |
| P&RS | Journal of Photogrammetry and Remote Sensing |
| ISPRS Ann. | ISPRS Ann. of the Phot. Rem. Sens. and Spat. Inf. Sci. |
| JUD | Journal of Urban Design |
| LUP | Landscape and Urban Planning |
| SCS | Sustainable Cities and Society |
| SimAUD | Symp. on Sim. for Architecture and Urban Design |
| UC | Urban Climate |

Collaborative effort to select venues that publish works within the scope of the survey.
Over 20 venues (journals, conferences, symposiums).

# Survey scope

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| CFG | Computer Graphics Forum |
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| TVCG | IEEE Trans. on Visualization and Computer Graphics |
| TVCJ | The Visual Computer |
| VI | Visual Informatics |
| CHI | ACM Conf. on Human Factors in Computing Systems |
| EuroVis | Eurographics Conference on Visualization |
| PacificVis | IEEE Pacific Visualization Symposium |
| SIGGRAPH | ACM SIG on Comp. Graphics and Inter. Techniques |
| VIS | IEEE Visualization Conference |
| BE | Building and Environment |
| CEUS | Computers, Environment and Urban Systems |
| EPB | Env. and Planning B: Urban Analytics and City Science |
| IJAC | Int. Journal of Architectural Computing |
| IJGIS | Int. Journal of Geographical Information Science |
| P&RS | Journal of Photogrammetry and Remote Sensing |
| ISPRS Ann. | ISPRS Ann. of the Phot. Rem. Sens. and Spat. Inf. Sci. |
| JUD | Journal of Urban Design |
| LUP | Landscape and Urban Planning |
| SCS | Sustainable Cities and Society |
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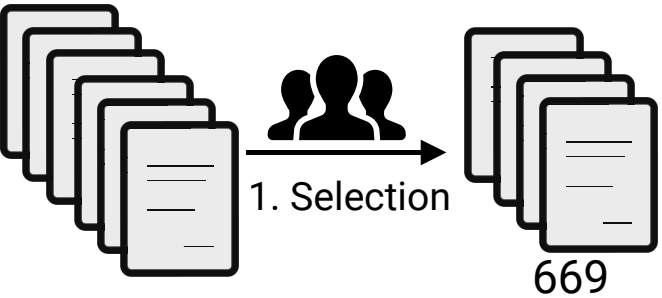
Visualization venues

Urban-specific venues

# Survey methodology: Four-stage process

1. **Selection:**
   a. Each venue was assigned to two co-authors;
   b. Review of published works and selection of works within scope.
2. **Filtering:**
   a. Each selected paper was assigned to two co-authors;
   b. In-depth review of works. Papers were included if both co-authors agreed that it fell within the scope of the survey.
   c. Meetings to create dimensions and tags.
3. **Tagging:**
   a. Each filtered paper was assigned to two co-authors for tagging.
4. **Consolidation:**
   a. One co-author merged tags, resolving eventual conflicts.



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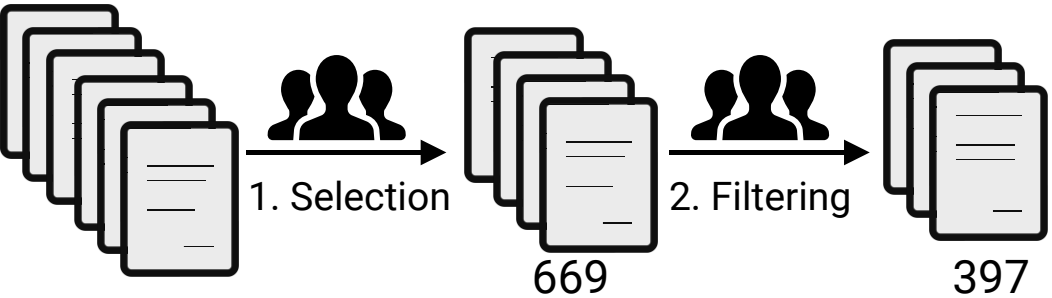

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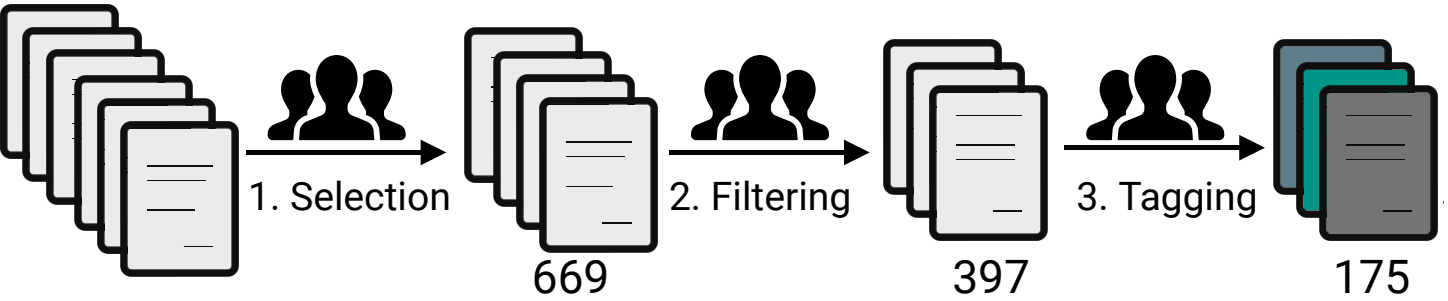

# Survey methodology: Four-stage process

1. **Selection:**
   a. Each venue was assigned to two co-authors;
   b. Review of published works and selection of works within scope.
2. **Filtering:**
   a. Each selected paper was assigned to two co-authors;
   b. In-depth review of works. Papers were included if both co-authors agreed that it fell within the scope of the survey.
   c. Meetings to create dimensions and tags.
3. **Tagging:**
   a. Each filtered paper was assigned to two co-authors for tagging.
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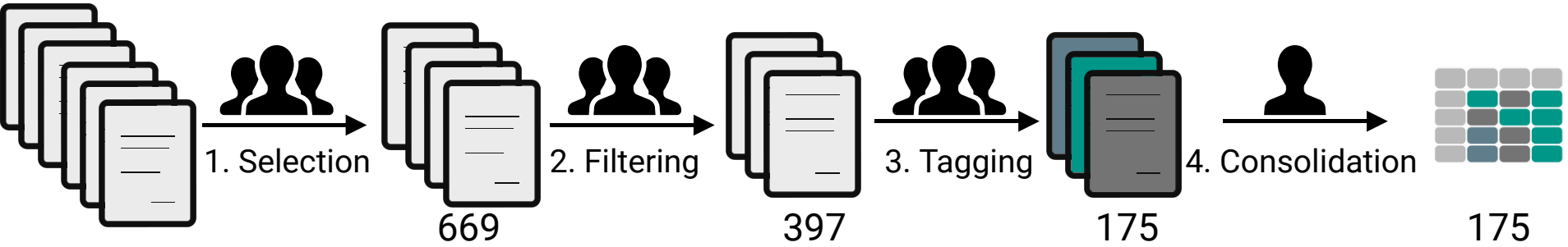

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4. **Consolidation:**
   a. One co-author merged tags, resolving eventual conflicts.

**Survey corpus: 175 papers**

54 visualization papers

121 domain-specific papers

# The State of the Art in Visual Analytics for 3D Urban Data

HOME WIZARD

## About

This is a companion website for our survey paper on visual analytics for 3D urban data

**Authors:** Fabio Miranda, Thomas Ortner, Gustavo Moreira, Maryam Hosseini, Milena Vuckovic, Filip Biljecki, Claudio T. Silva, Marcos Lage, Nivan Ferreira

Urbanization has amplified the importance of three-dimensional structures in urban environments for a wide range of phenomena that are of significant interest to diverse stakeholders. With the growing availability of 3D urban data, numerous studies have focused on developing visual analysis techniques tailored to the unique characteristics of urban environments. However, incorporating the third dimension into visual analytics introduces additional challenges in designing effective visual tools to tackle urban data's diverse complexities. In this paper, we present a survey on visual analytics of 3D urban data. Our work characterizes published works along three main dimensions (why, what, and how), considering use cases, analysis tasks, data, visualizations, and interactions. We provide a fine-grained categorization of published works from visualization journals and conferences, as well as from a myriad of urban domains, including urban planning, architecture, and engineering. By incorporating perspectives from both urban and visualization experts, we identify literature gaps, motivate visualization researchers to understand challenges and opportunities, and indicate future research directions.

Use our wizard to browse through a corpus of more than 150 papers covering a period of more than ten years and almost 20 venues.

Feel free to get in touch if you have any questions or comments.

## Use the Wizard

Use the wizard tab to navigate and filter the surveyed papers. We summarize previous visualization and domain-specific contributions using an interrogative method that categorize the papers concerning three questions:

**Why** is 3D urban data being analyzed
**What** data is being analyzed
**How** it is being analyzed

## Read the Survey

**The State of the Art in Visual Analytics for 3D Urban Data**
Fabio Miranda, Thomas Ortner, Gustavo Moreira, Maryam Hosseini, Milena Vuckovic, Filip Biljecki, Claudio T. Silva, Marcos Lage, Nivan Ferreira
Computer Graphics Forum (EuroVis 2024)

Email GitHub

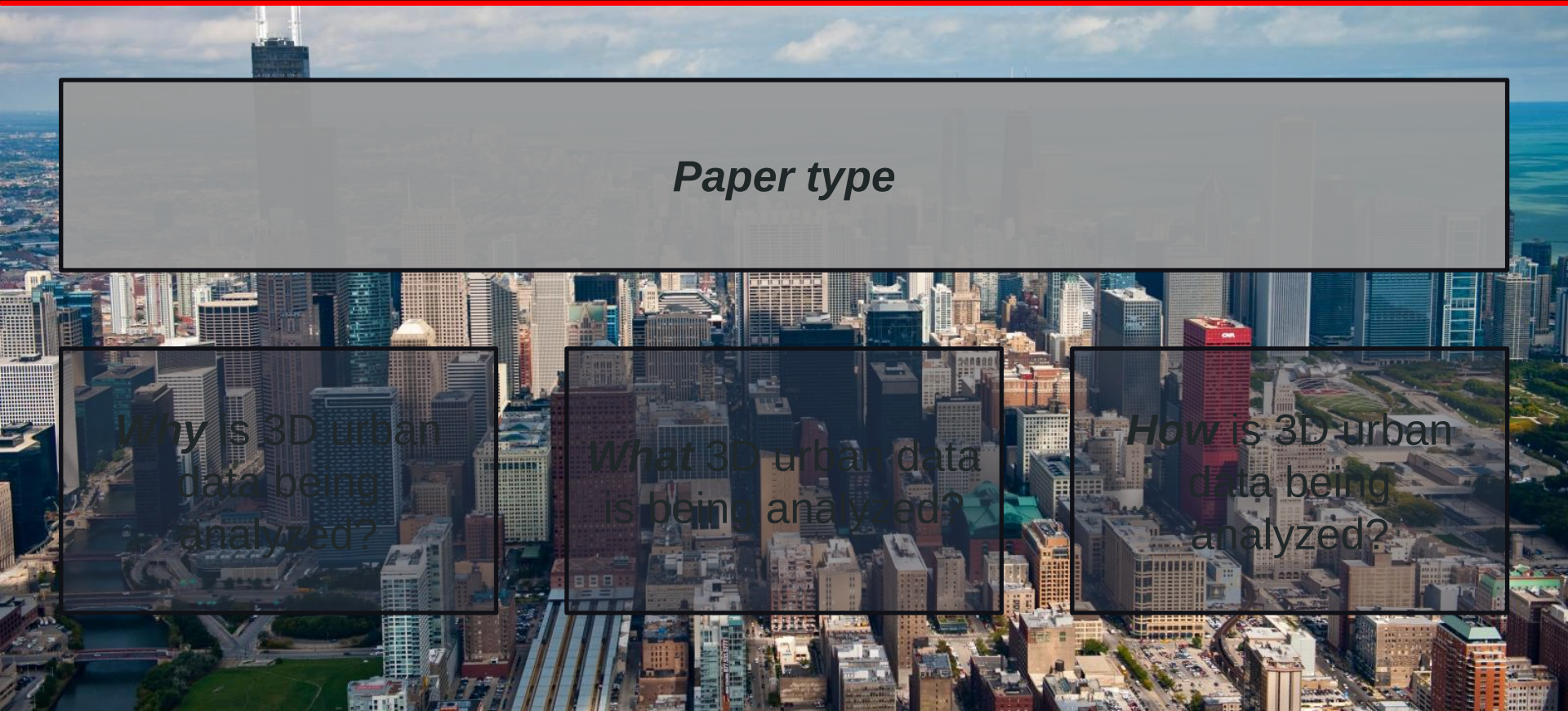


urbantk.org/survey-3d

# Survey contributions

1. We establish a common characterization that allows us to organize contributions from a multitude of domains, including visualization, architecture, engineering, and urban planning.
2. We introduce a comprehensive survey on 3D urban visual analytics, reviewing 175 papers.
3. We report a series of research directions and open problems in 3D urban visual analytics.

# Survey structure



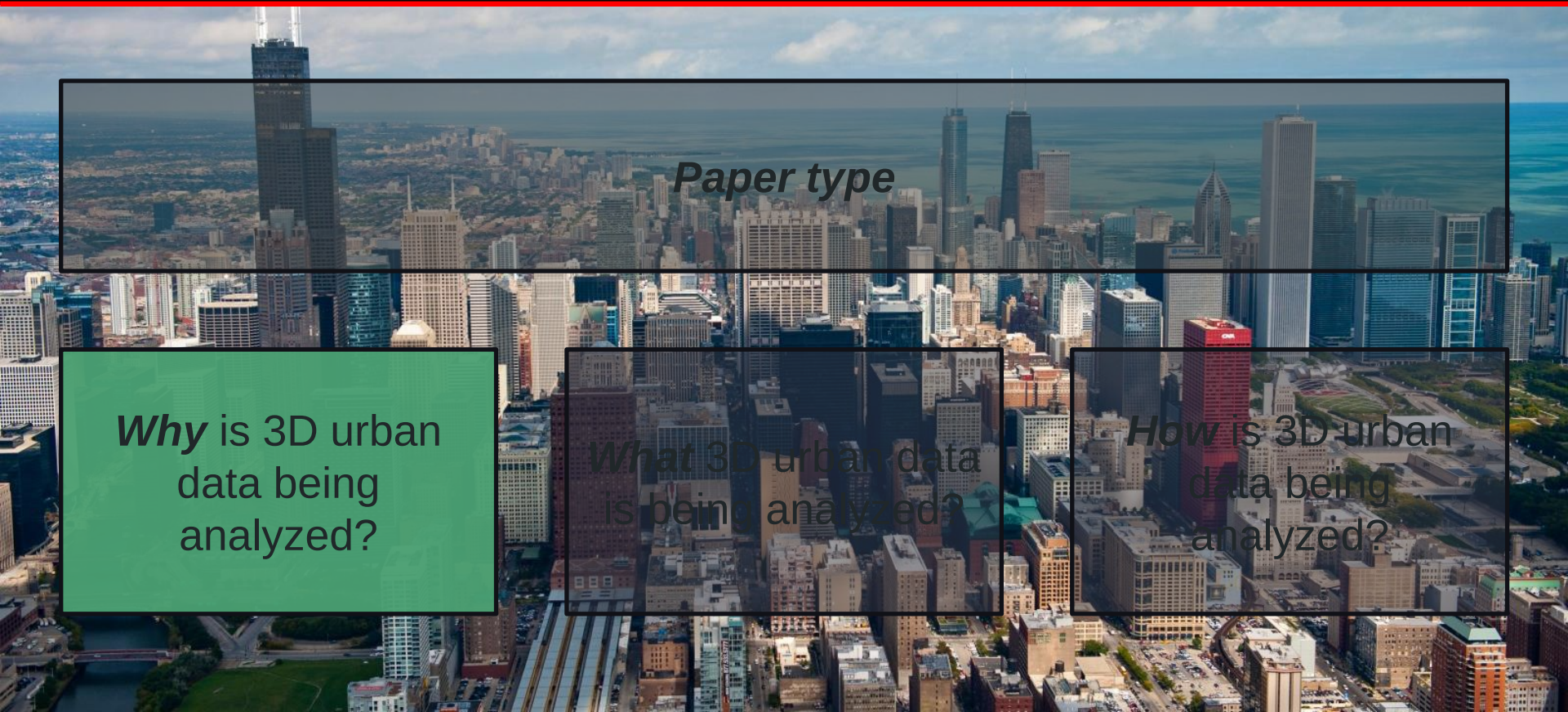
***Paper type***

***Why*** is 3D urban data being analyzed?

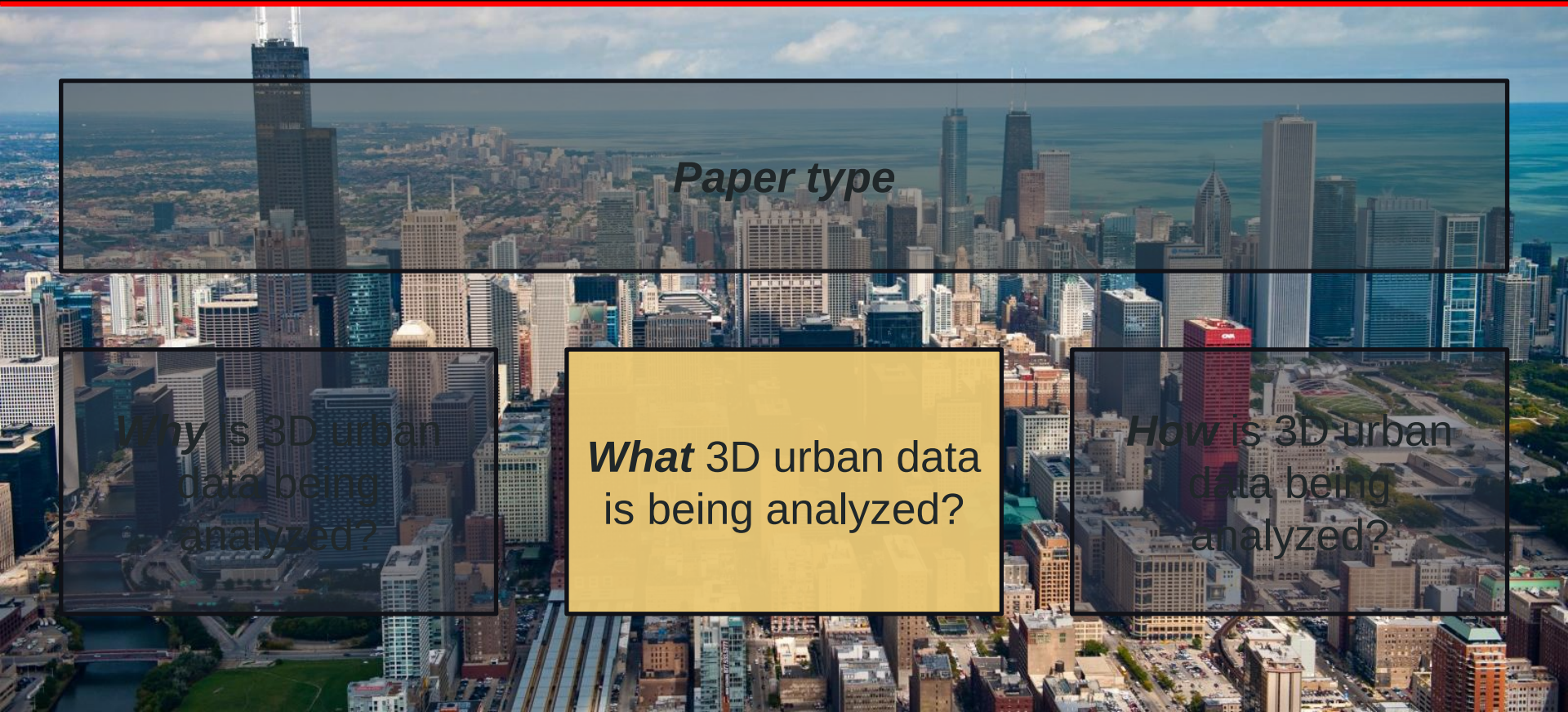
***What*** 3D urban data is being analyzed?

***How*** is 3D urban data being analyzed?

# Survey structure



# Survey structure



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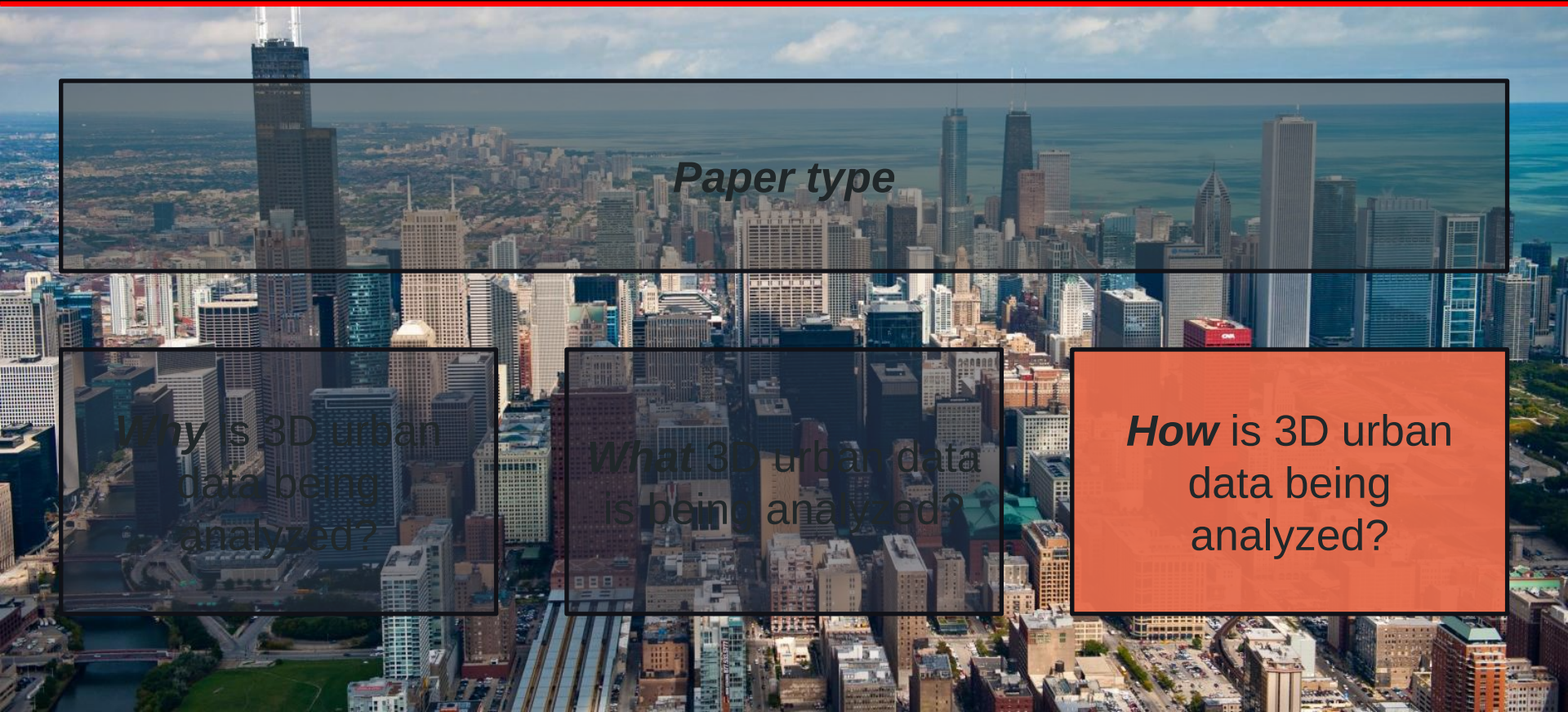
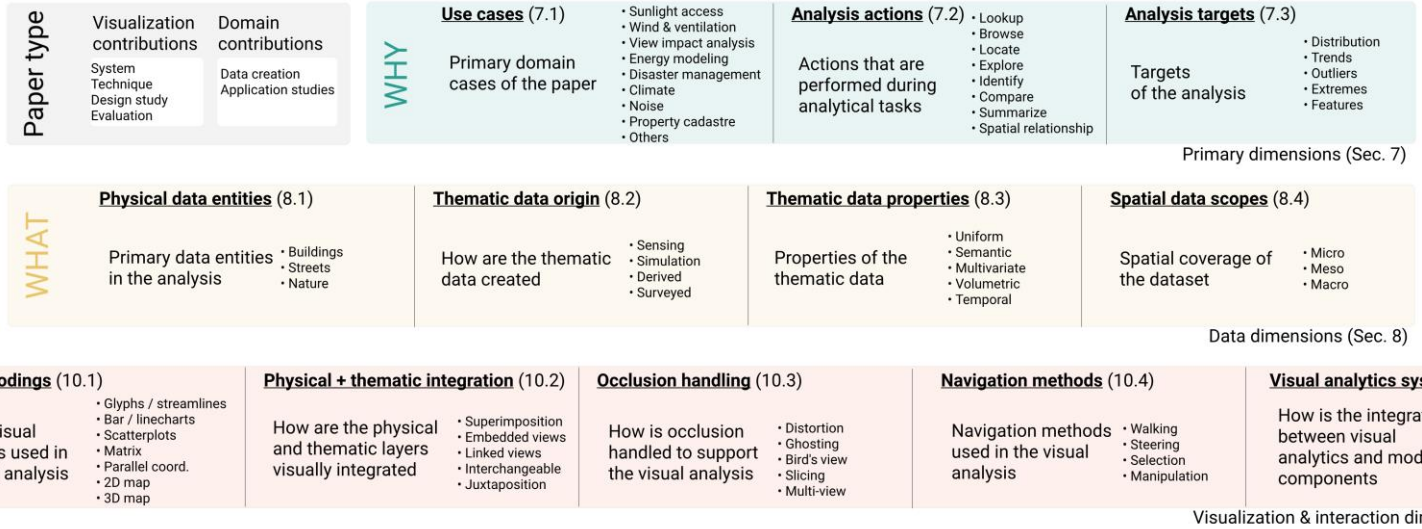


# Survey structure



# Paper type

| System | Technique | Design study | Evaluation | Data creation | Application study |
|---|---|---|---|---|---|
| Visualization contributions | | | | Domain contributions | |

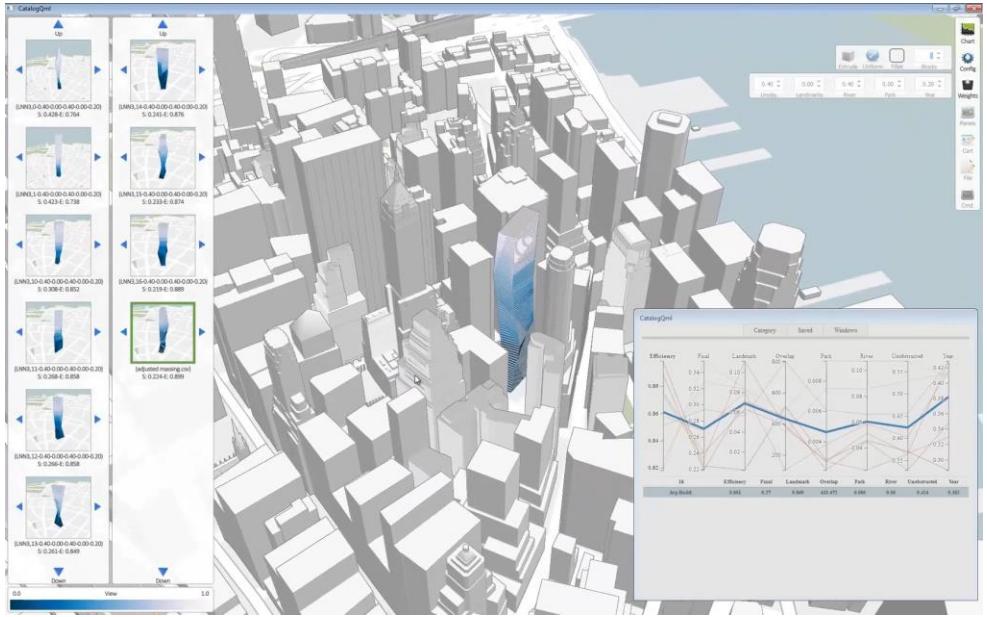
# Paper type

| **System** | **Technique** | **Design study** | **Evaluation** | **Data creation** | **Application study** |
|---|---|---|---|---|---|
| *New infrastructure, framework, or toolkit (27)* | *New visualization algorithms (16)* | *New visualization for a particular domain problem (5)* | *Assessing how systems or techniques are used by users (5)* | *Methodologies to create new 3D data (13)* | *Analytical studies using 3D urban data (109)* |

Visualization contributions

Domain contributions

# Paper type



[Doraiswamy et al., 2015]

**System**
*New infrastructure, framework, or toolkit (27)*

**Technique**
*New visualization algorithms (16)*

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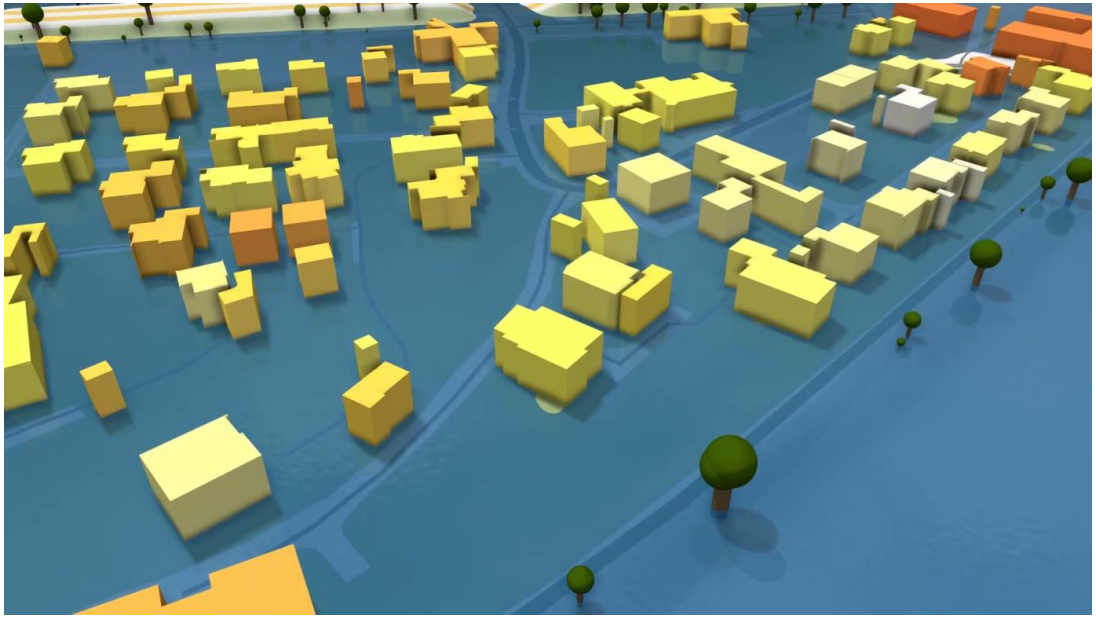

[Cornel et al., 2019]

**System**
*New infrastructure, framework, or toolkit*
*(27)*

**Technique**
*New visualization algorithms*
*(16)*

**Design study**
*New visualization for a particular domain problem*
*(5)*

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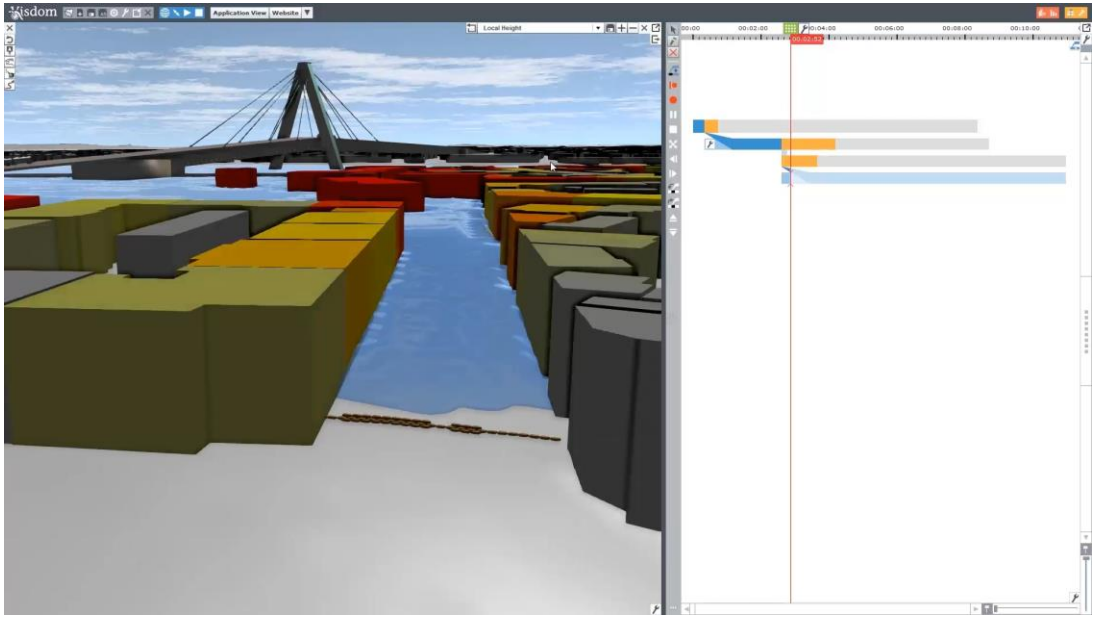
*Analytical studies using 3D urban data*
*(109)*

# Primary dimension: Paper type



[Waser et al., 2014]

**System**
*New infrastructure, framework, or toolkit*
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**Technique**
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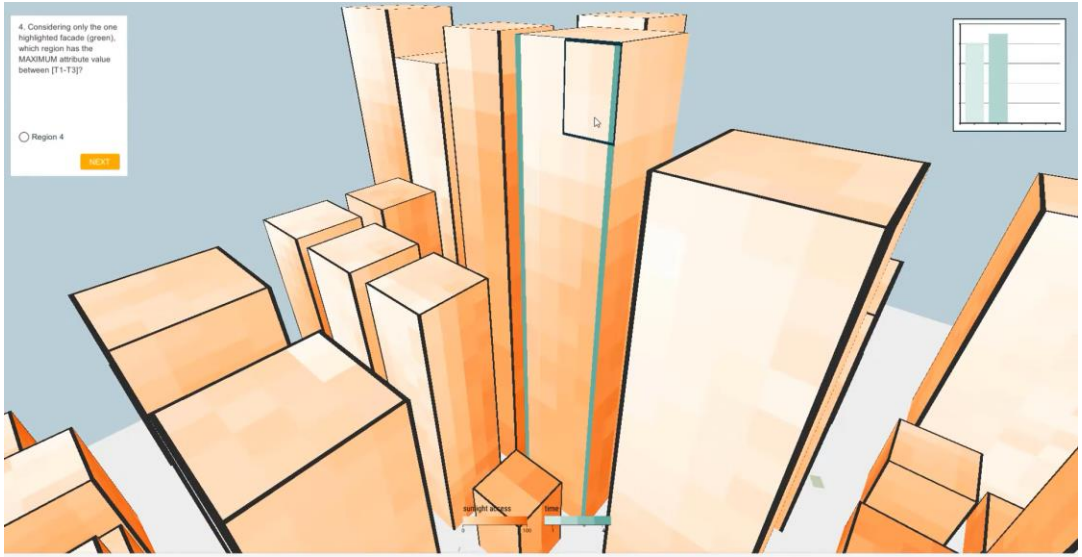


**Linked View**: multi-viewpoint one location + time interval [task 4]

[Mota et al., 2022]

| System | Technique | Design study | **Evaluation** | Data creation | Application study |
|---|---|---|---|---|---|
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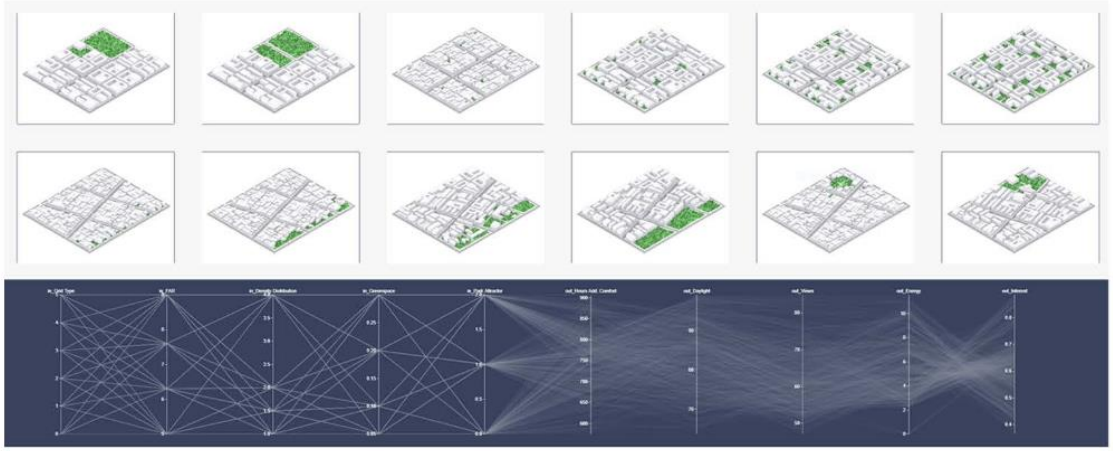


[Wilson et al., 2019]

**System**
*New infrastructure, framework, or toolkit (27)*

**Technique**
*New visualization algorithms (16)*

**Design study**
*New visualization for a particular domain problem (5)*

**Evaluation**
*Assessing how systems or techniques are used by users (5)*

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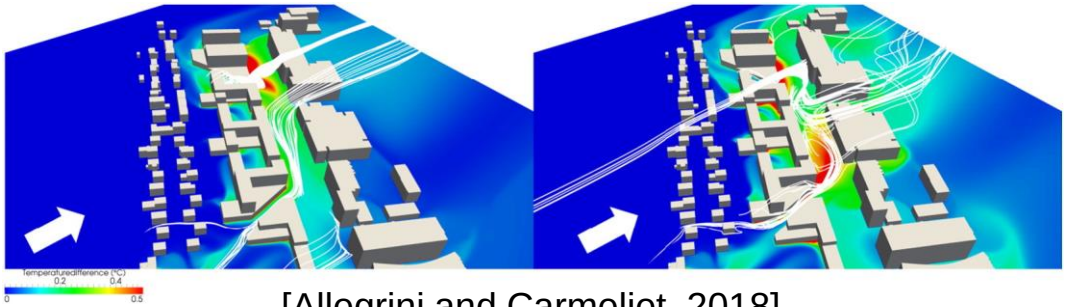
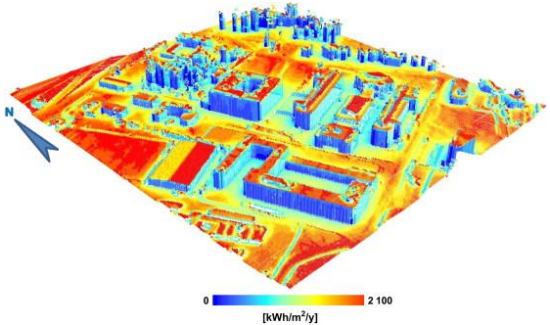


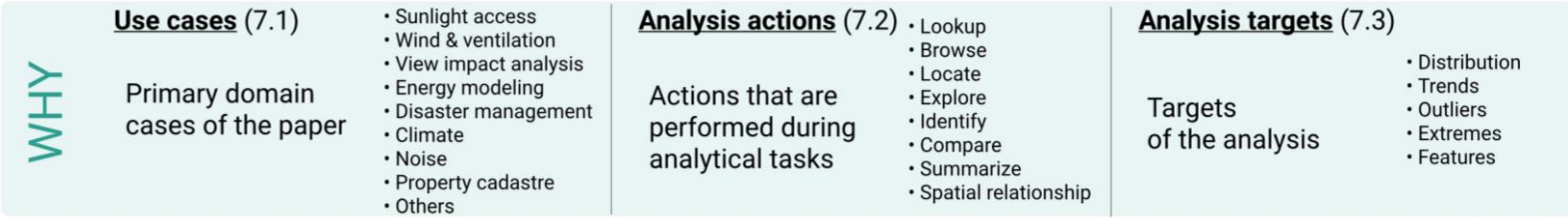
[Allegrini and Carmeliet, 2018]



[Catita et al., 2014]

| System | Technique | Design study | Evaluation | Data creation | **Application study** |
|---|---|---|---|---|---|
| *New infrastructure, framework, or toolkit (27)* | *New visualization algorithms (16)* | *New visualization for a particular domain problem (5)* | *Assessing how systems or techniques are used by users (5)* | *Methodologies to create new 3D data (13)* | *Analytical studies using 3D urban data (109)* |

# *Why* is 3D urban data being analyzed?




Primary dimensions (Sec. 7)

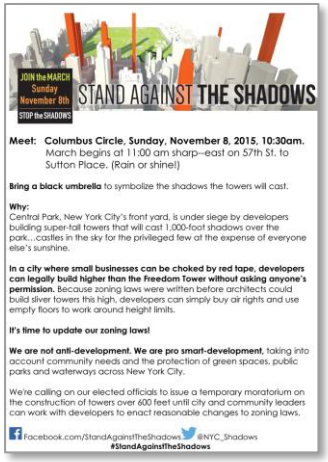
# *Why*: Use cases

Primary domain cases of the paper:

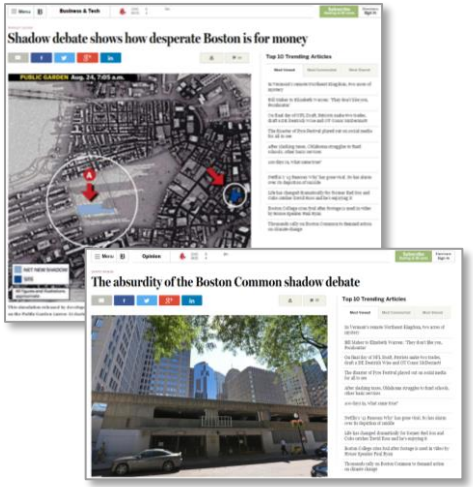
- Sunlight access
- Wind & ventilation
- View impact analysis
- Energy modeling
- Disaster management
- Climate
- Noise
- Property cadastre
- Others

# ***Why*: Use cases**

***Sunlight access:*** works that study the impact of the built environment on “right to light” or “right to sunshine.”







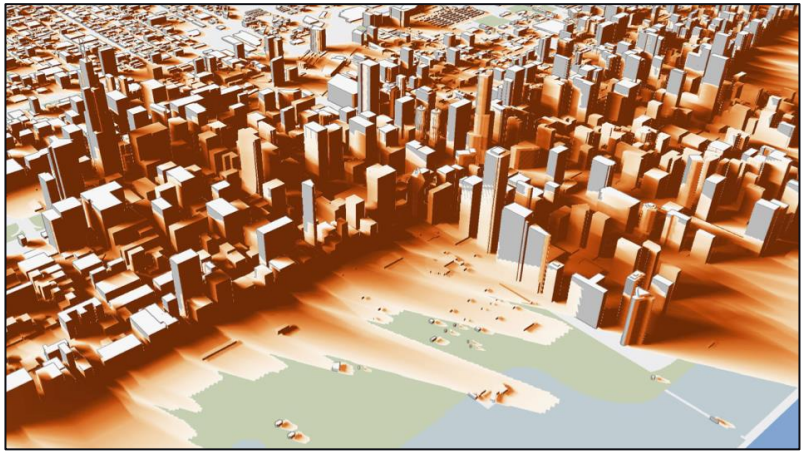

Sunlight access | Wind & ventilation | View impact | Energy modeling | Disaster management | Climate | Noise | Property cadastre

# ***Why*: Use cases**

***Sunlight access:*** works that study the impact of the built environment on “right to light” or “right to sunshine.”

Total of 39 papers:

- 3 visualization systems
- 3 visualization techniques
- 2 evaluation studies
- 5 data creation
- 25 analysis studies

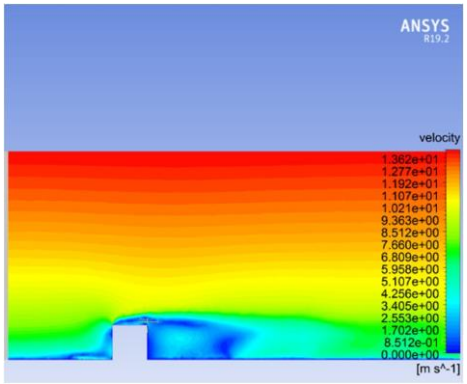


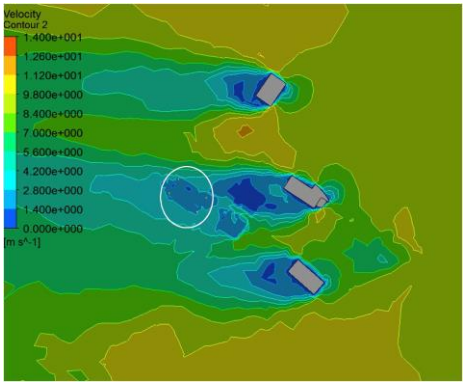
[Miranda et al., 2018]

# ***Why*: Use cases**

***Wind & ventilation:*** works that study the interplay between built environment and wind.

Total of 43 papers:
- 2 data creation
- 41 application studies



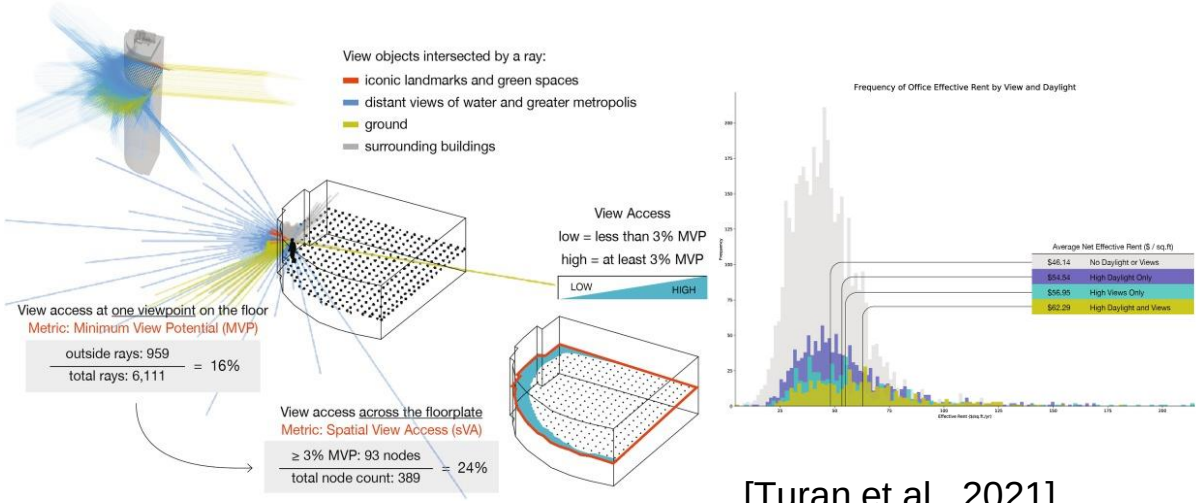

[Shiraz et al., 2020]

# *Why*: Use cases

***View impact analysis:*** works that use scores computed on the surface of buildings summarizing the visibility of certain geographical features (e.g., landmarks, parks, waterfronts).

Total of 14 papers:

- 3 visualization systems
- 1 design study
- 10 application studies




[Turan et al., 2021]

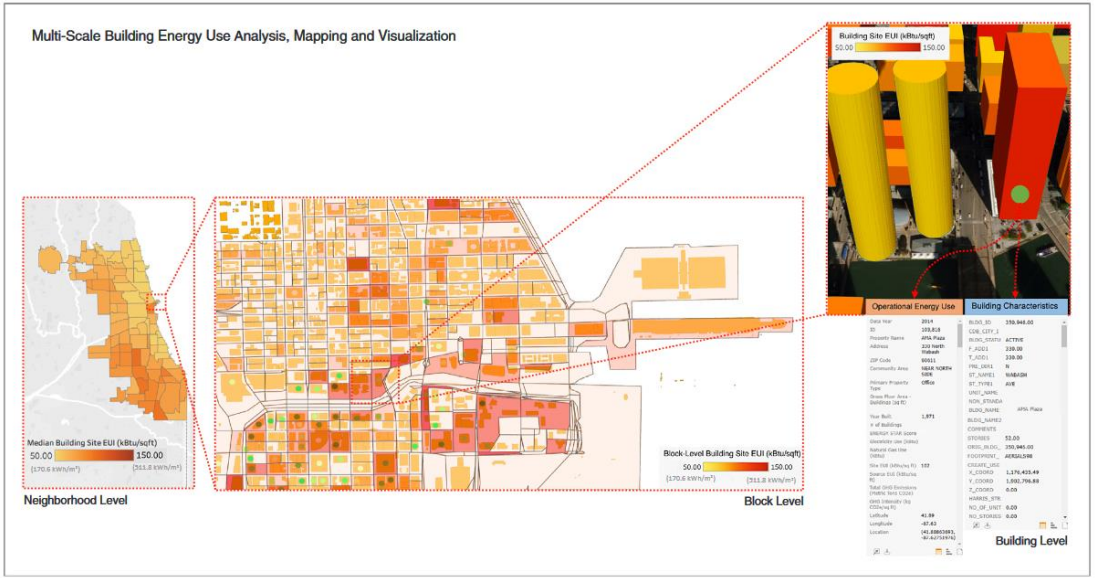
Sunlight access | Wind & ventilation | View impact | Energy modeling | Disaster management | Climate | Noise | Property cadastre

# ***Why*: Use cases**

***Urban building energy modeling:*** works that model building energy consumption.

Total of 23 papers:

- 2 visualization systems
- 4 data creation
- 17 application studies




[Abbasabadi et al., 2019]

Sunlight access | Wind & ventilation | View impact | **Energy modeling** | Disaster management | Climate | Noise | Property cadastre

# *Why*: Use cases

***Noise & sound propagation:*** works that focus on the relationship between noise and the built environment.

Total of 8 papers:
- 1 visualization system
- 1 design study
- 6 application studies


[Tang et al., 2022]

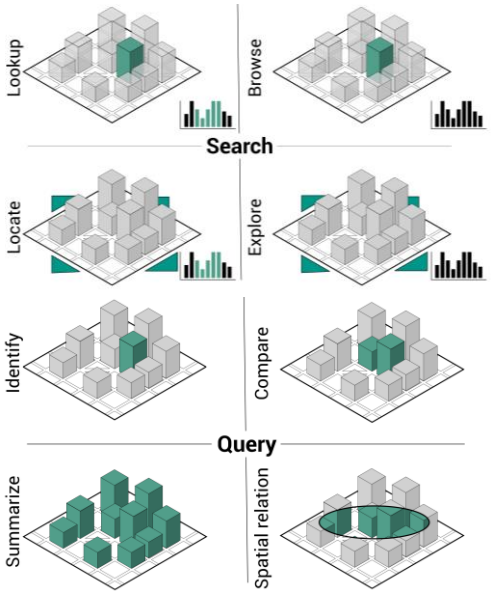
# *Why*: Use cases

Other works include:

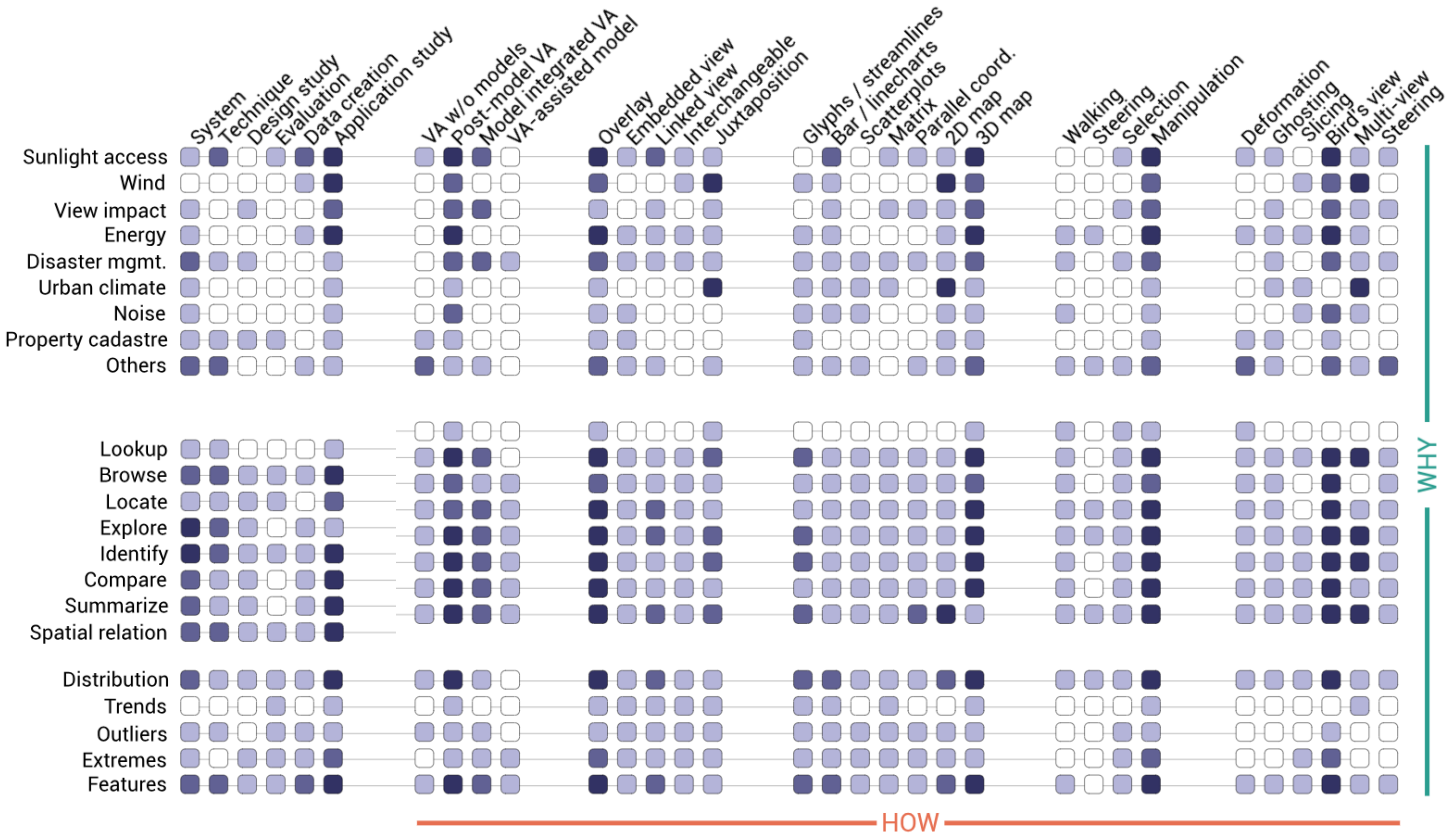
- Walkability considering 3D footpath networks
- Simulation of radio propagation
- Enclosure assessment
- Urban design plans
- Urban vitality

# ***Why*: Analysis actions**

- Actions that are performed during analytical tasks
  - Mid-level (search) actions:
    - Lookup
    - Browse
    - Locate
    - Explore
  - Low-level (query) actions:
    - Identify
    - Compare
    - Summarize
    - Spatial relationship

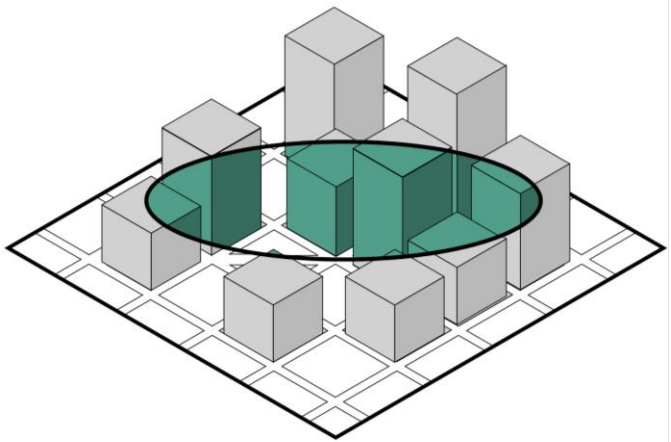


# *Why*: Analysis actions



# ***Why*: Analysis queries: Spatial relation**

Spatial relation

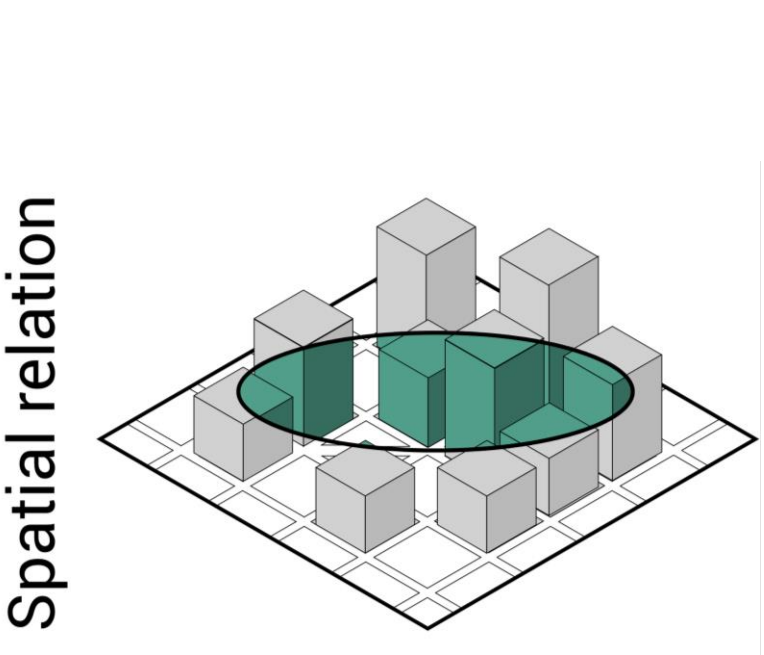


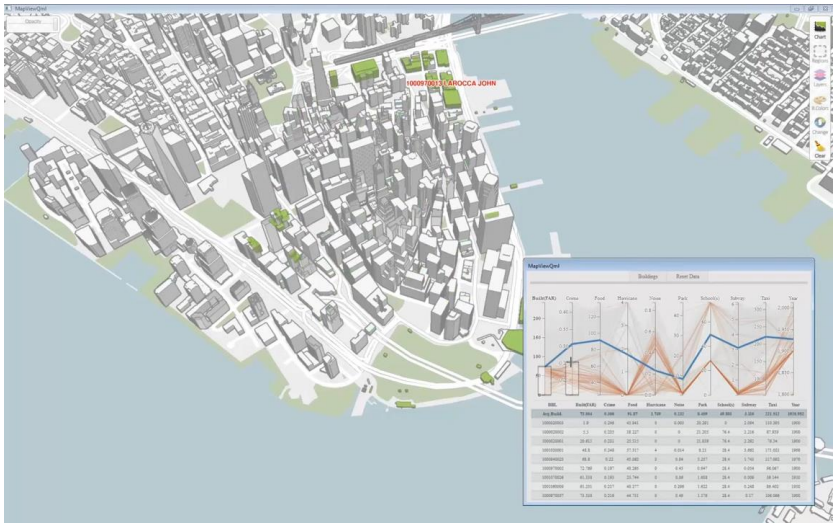
**Is the user interested in the relation of spatial properties of a target and its context?**

Looked for the use of keywords such as “context”, “neighborhood”, and “vicinity” in the description of the requirements, methodology, or analysis.

129 surveyed papers mention some type of spatial relationship.

# ***Why*: Analysis queries: Spatial relation**



[Ferreira et al., 2015]

Fereira et al. highlighted the need for *3D context models* and to *explore the view extent over the city*.

# *What* 3D urban data is being analyzed?

WHAT

**Physical data entities** (8.1)

Primary data entities in the analysis
- Buildings
- Streets
- Nature

**Thematic data origin** (8.2)

How are the thematic data created
- Sensing
- Simulation
- Derived
- Surveyed

**Thematic data properties** (8.3)

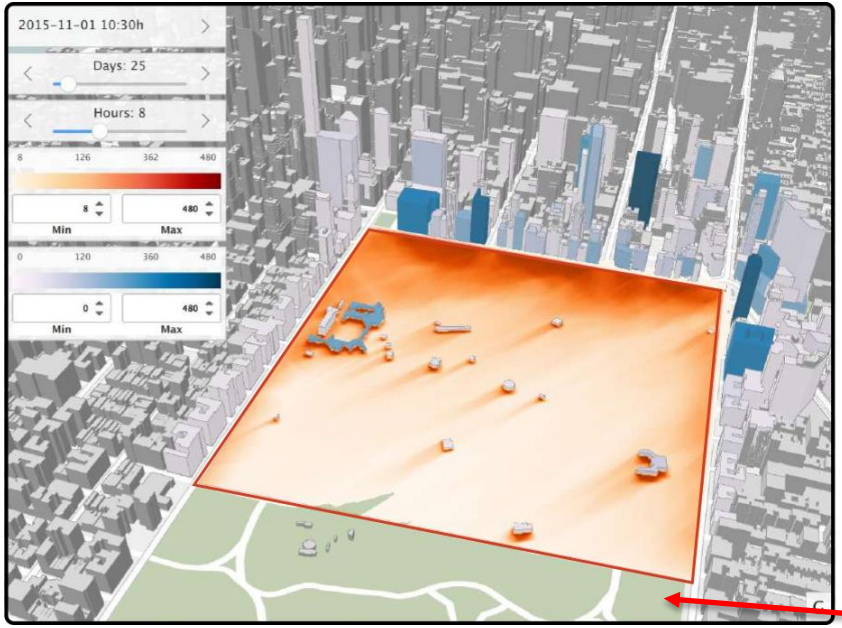
Properties of the thematic data
- Uniform
- Semantic
- Multivariate
- Volumetric
- Temporal

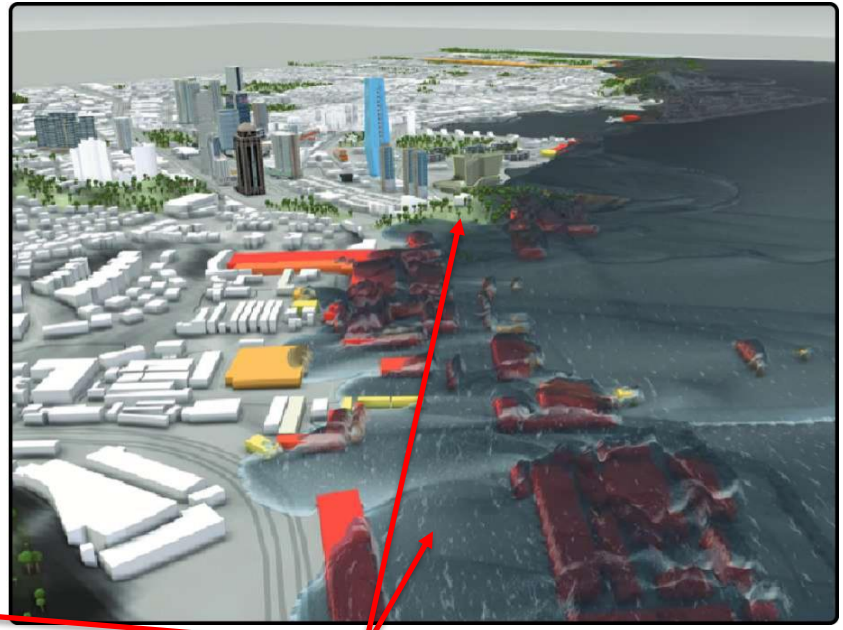
**Spatial data scopes** (8.4)

Spatial coverage of the dataset
- Micro
- Meso
- Macro

Data dimensions (Sec. 8)

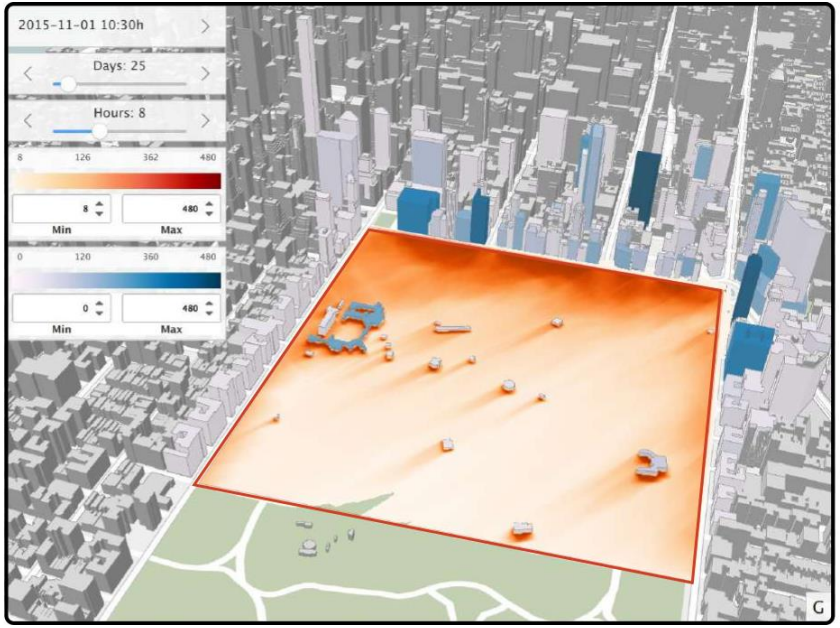
# ***What:*** Physical data entities

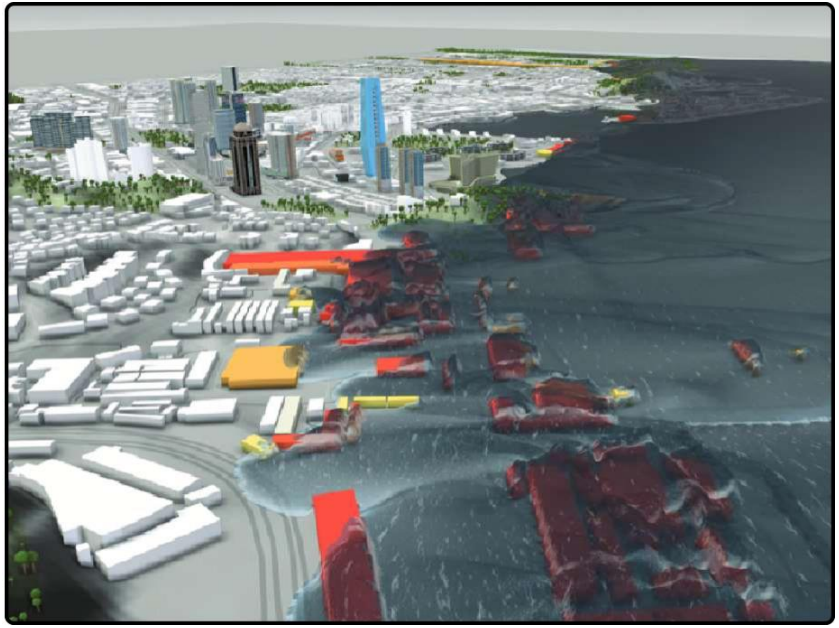


Buildings Streets Nature

# ***What:*** Physical data entities



Buildings — Streets — Nature

OpenStreeMap

Gov Agencies
OpenTopography

# ***What:*** Thematic data properties

Uniform

Structural

Volumetric

Temporal

Multivariate

# ***What:*** Thematic data properties

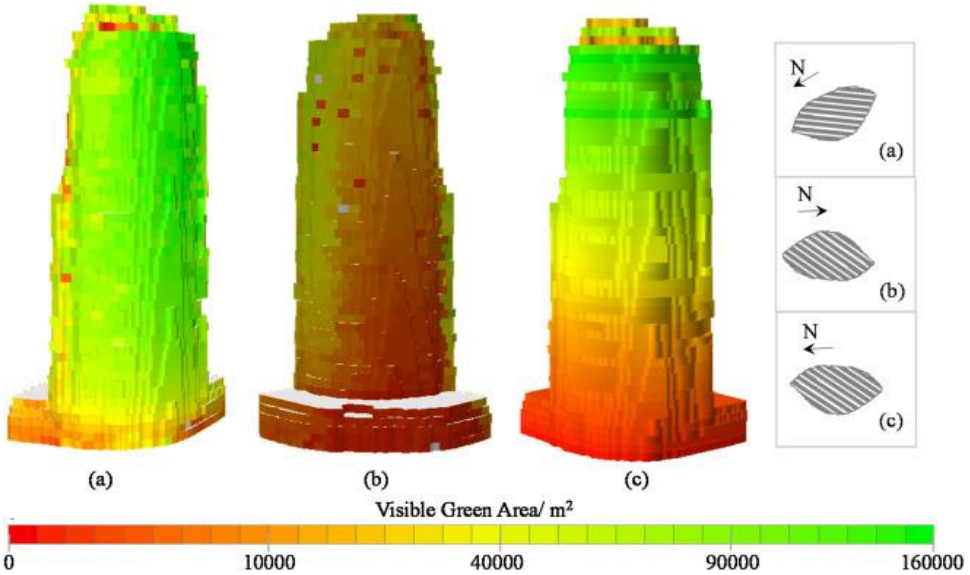
Uniform

Structural

Volumetric

Temporal

Multivariate




[Yu et al. 2016]

# ***What:*** Thematic data properties

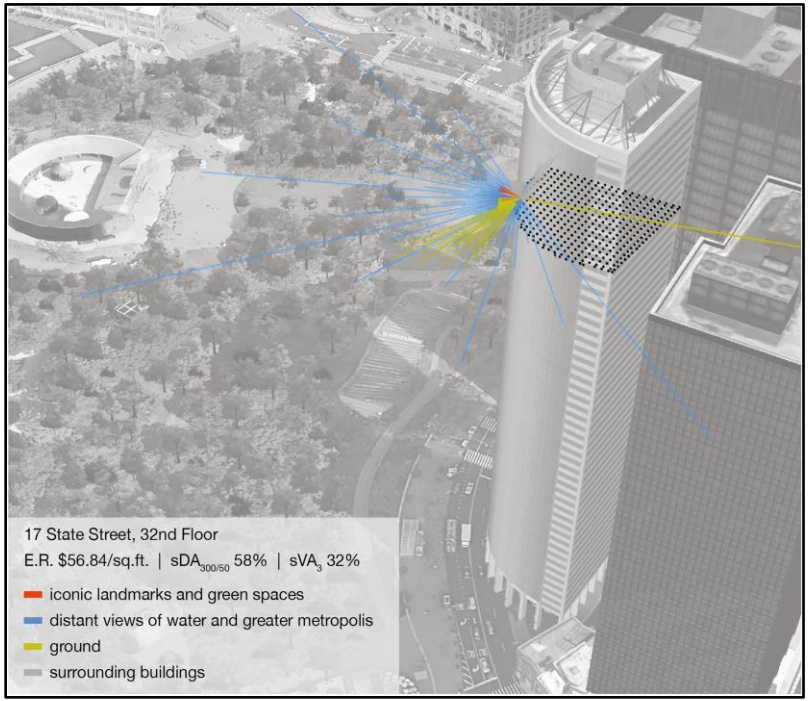
Uniform

Structural

Volumetric

Temporal

Multivariate




[Turan et al. 2021]

# ***What:*** Thematic data properties

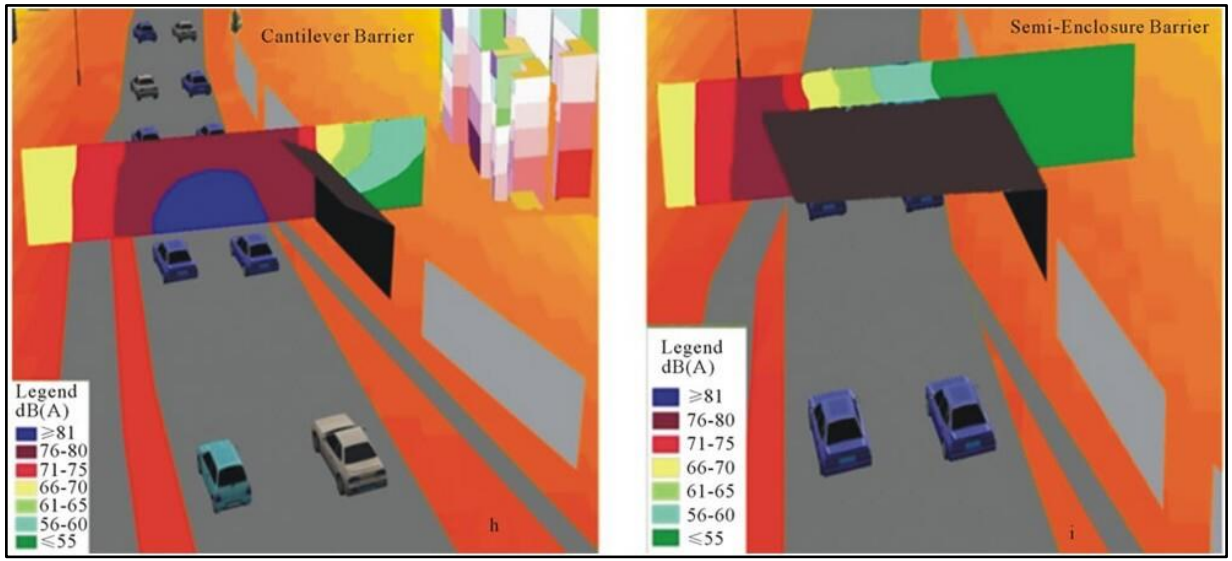
Uniform

Structural

Volumetric

Temporal

Multivariate




[Beran et al. 2021]

# ***What:*** Thematic data properties

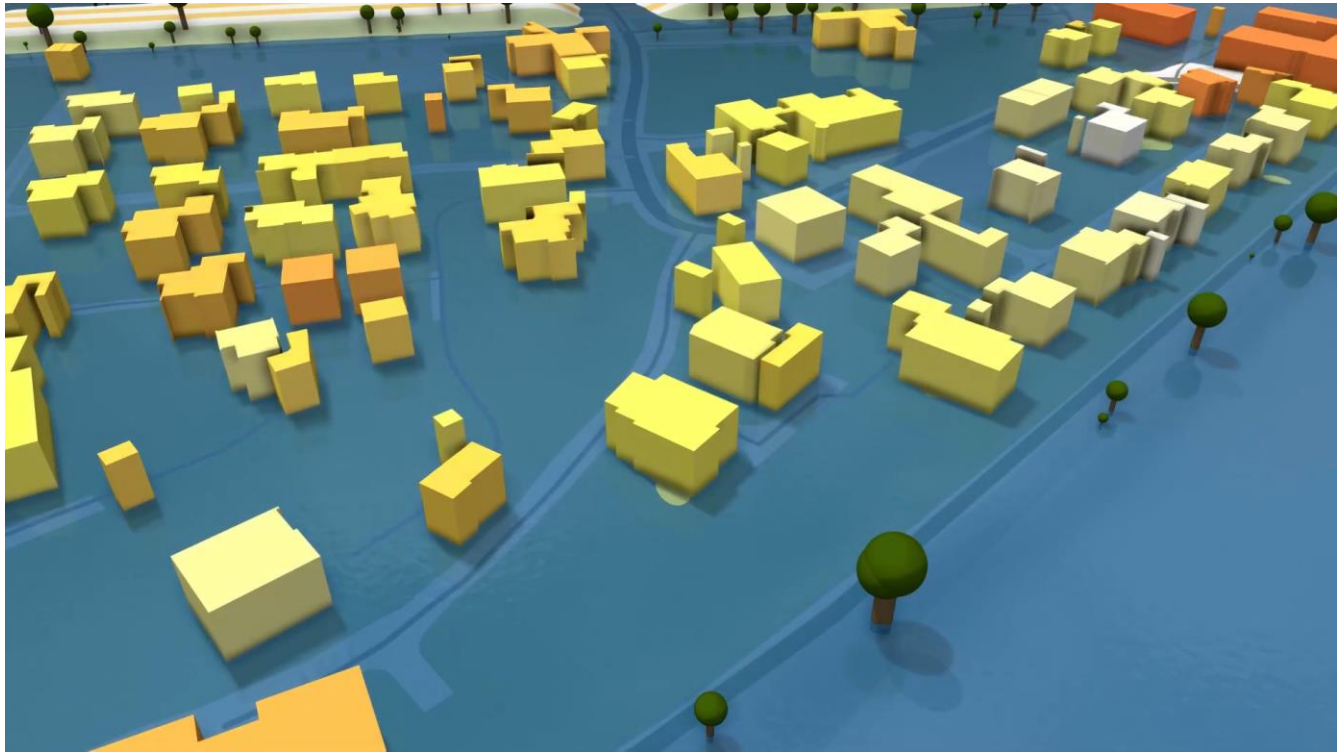
Uniform

Structural

Volumetric

Temporal

Multivariate



[Cornel et al. 2019]

# ***What:*** Thematic data properties

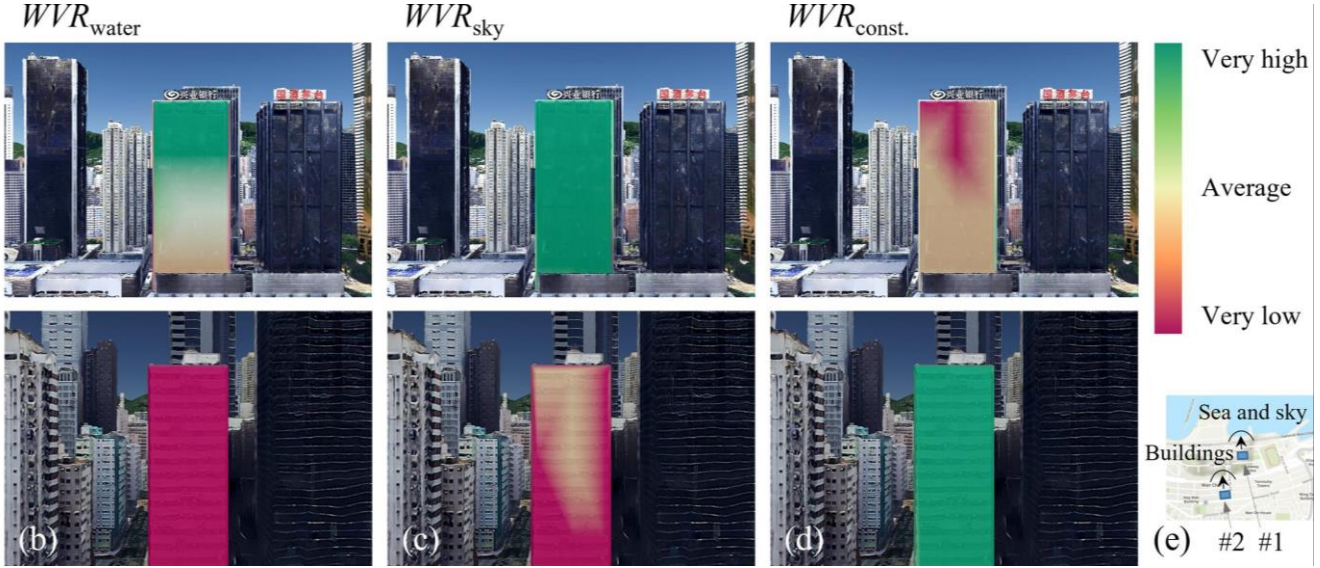
Uniform

Structural

Volumetric

Temporal

Multivariate




[Li et al. 2022]

# ***What:*** Thematic data properties

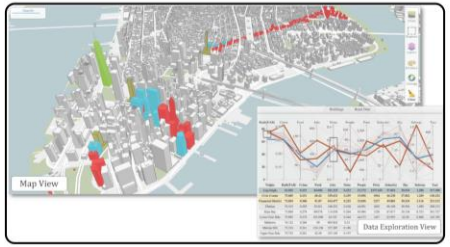
48 (~27%)
out of 175 papers
Volumetric

49 (~28%)
out of 175 papers
Temporal

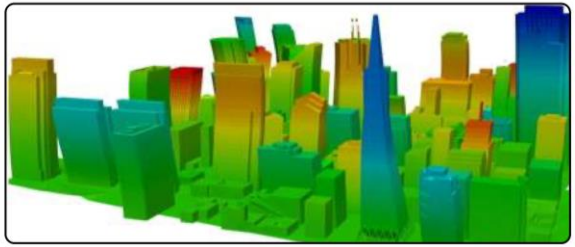
60 (~34%)
out of 175 papers
Multivariate

# ***What:*** Spatial data scopes

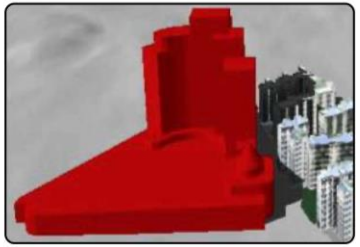
Macro




Meso



Micro



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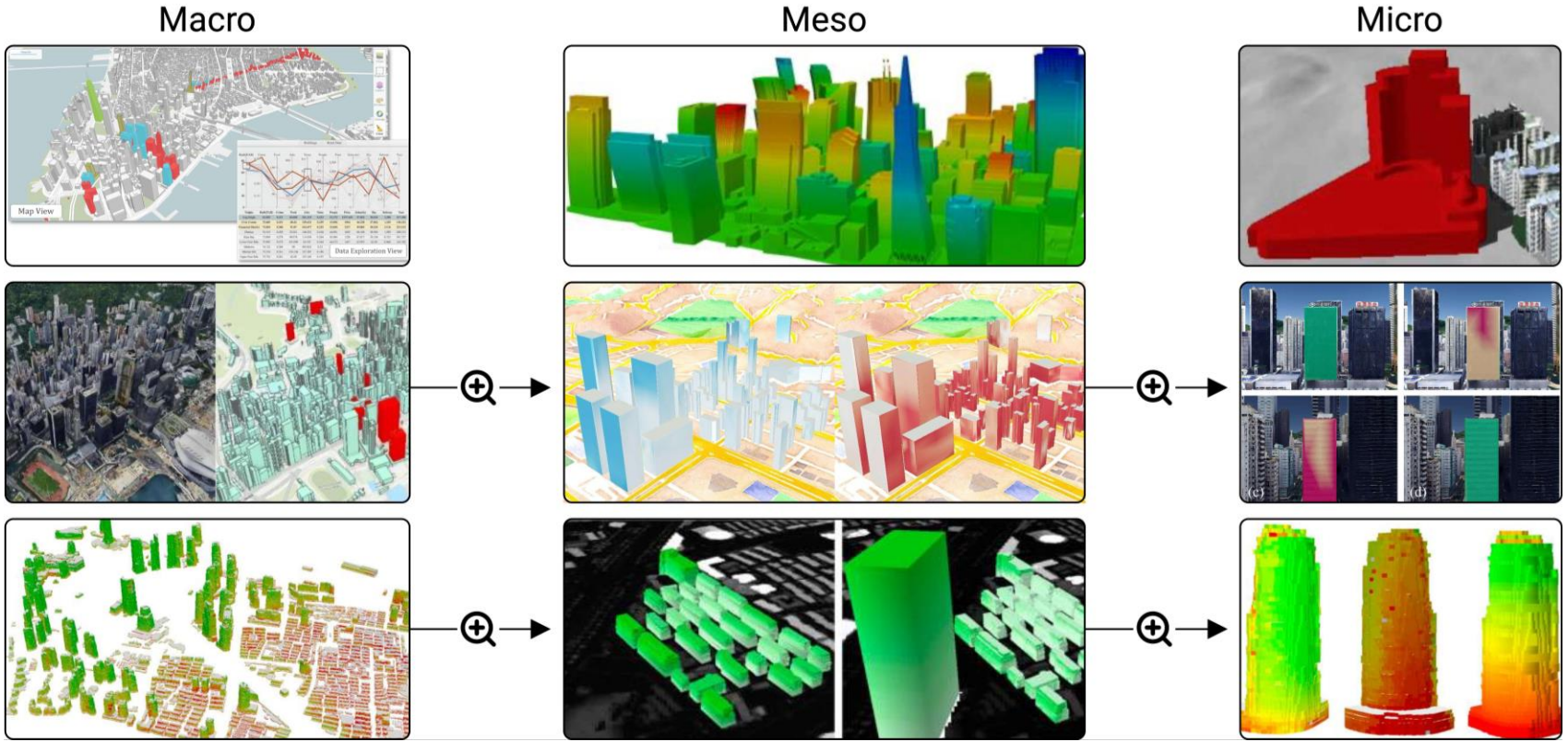

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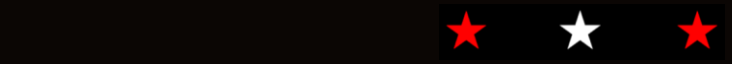


| Macro | Meso | Micro |
| --- | --- | --- |
|  |  |  |
| 52 (~30%)<br>out of 175 papers | 78 (~45%)<br>out of 175 papers | 106 (~61%)<br>out of 175 papers |
|  |  |  |

# *How* is 3D urban data being analyzed?

HOW

**Visual encodings** (10.1)

Primary visual encodings used in the visual analysis

- Glyphs / streamlines
- Bar / linecharts
- Scatterplots
- Matrix
- Parallel coord.
- 2D map
- 3D map

**Physical + thematic integration** (10.2)

How are the physical and thematic layers visually integrated

- Superimposition
- Embedded views
- Linked views
- Interchangeable
- Juxtaposition

**Occlusion handling** (10.3)

How is occlusion handled to support the visual analysis

- Distortion
- Ghosting
- Bird's view
- Slicing
- Multi-view

**Navigation methods** (10.4)

Navigation methods used in the visual analysis

- Walking
- Steering
- Selection
- Manipulation

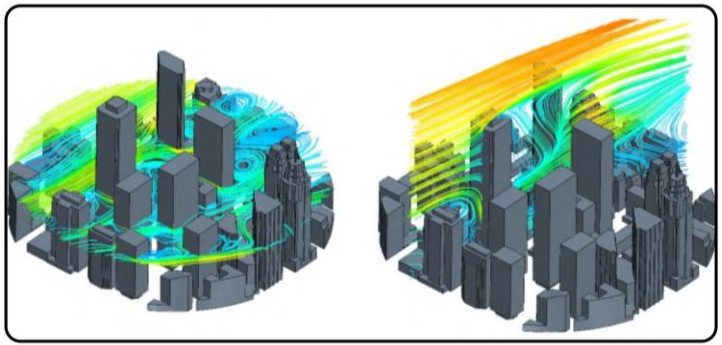
**Visual analytics systems** (10.5)

How is the integration between visual analytics and model components

- VA w/o models
- Post-model VA
- Model integrated VA
- VA-assisted model

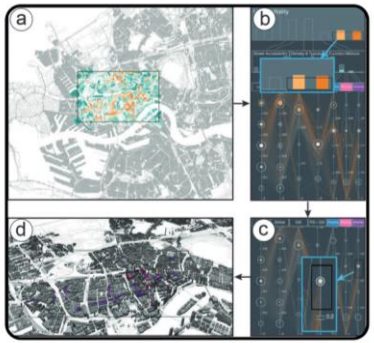
Visualization & interaction dimensions (Sec. 10)

# ***How:*** Physical & Thematic Visual Integration

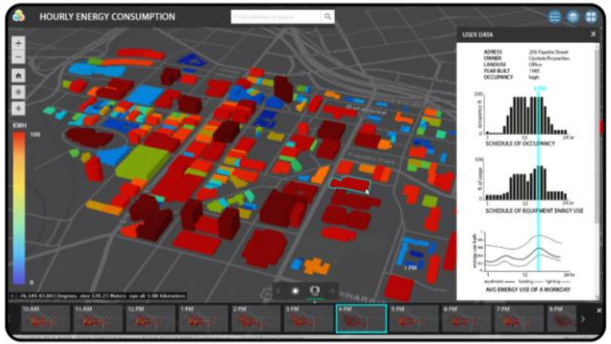


Superimposition

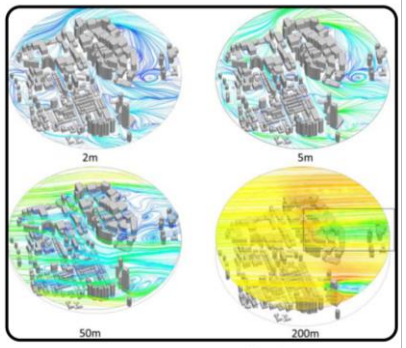

Embedded view




Linked view

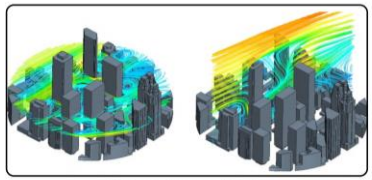



Interchangeable

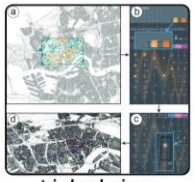


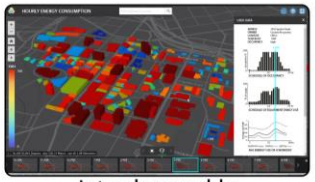

Juxtaposition

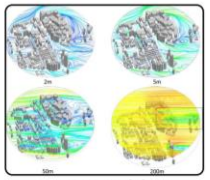
# **How:** Physical & Thematic Visual Integration

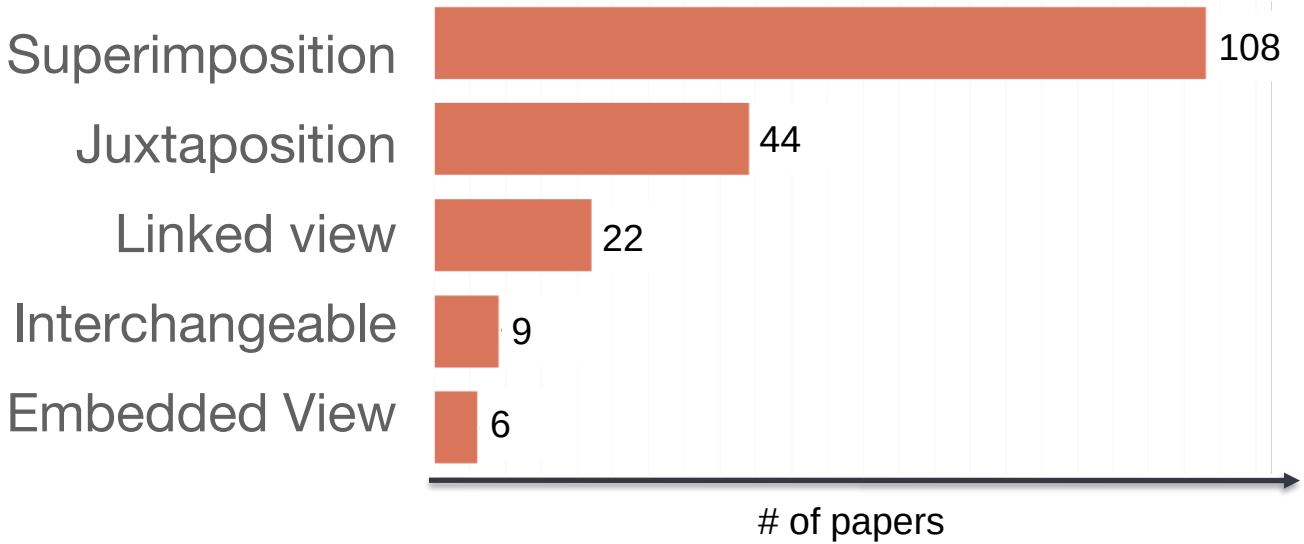

Superimposition


Embedded view


Linked view


Interchangeable


Juxtaposition



# *How:* Thematic Visual Encoding

- Spatial  Encodings
  - Mapping onto surfaces
  - 3D representations
- Non-spatial  Encodings
  - Line graphs
  - Bar Charts
  - Scatterplots
  - Parallel Coordinates
  - SPLOMs

# ***How:*** Thematic Visual Encoding

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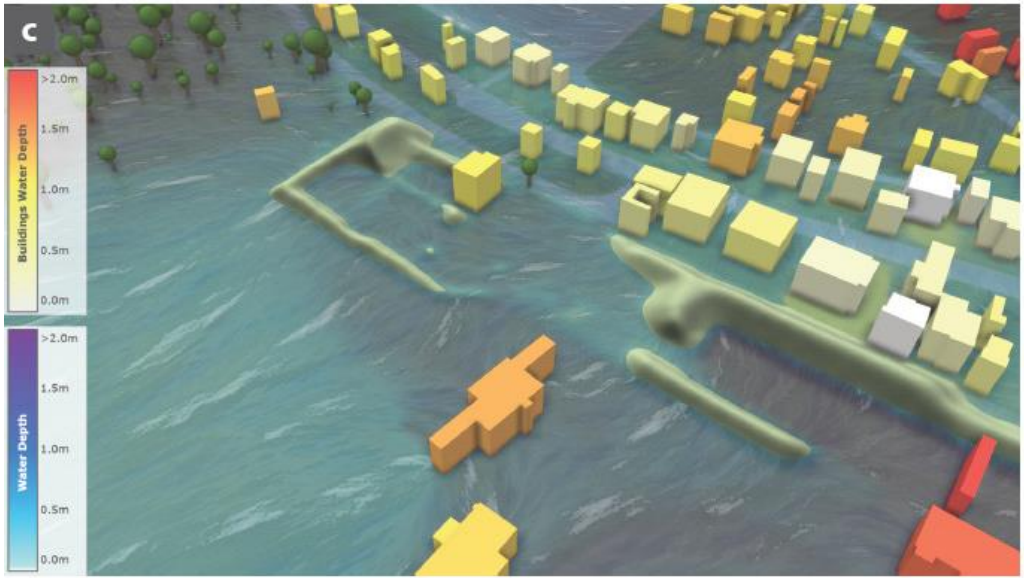


[Cornel et al. 2019]

# **How:** *Thematic Visual Encoding*

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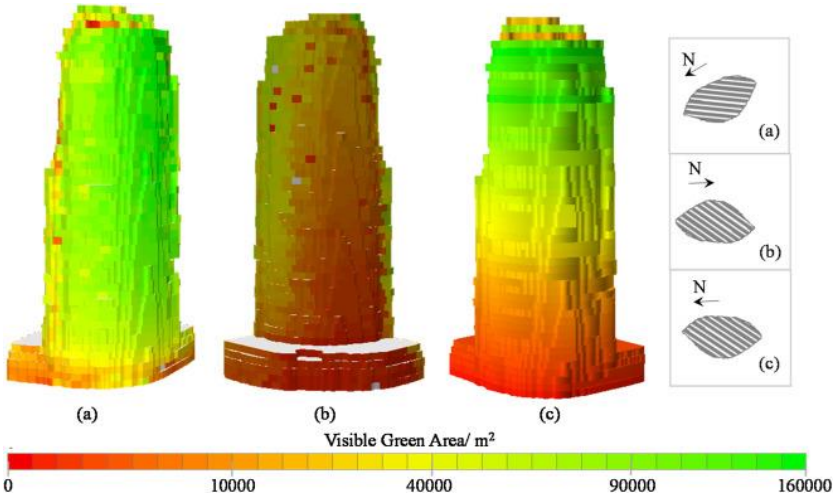


[Yu et al. 2016]

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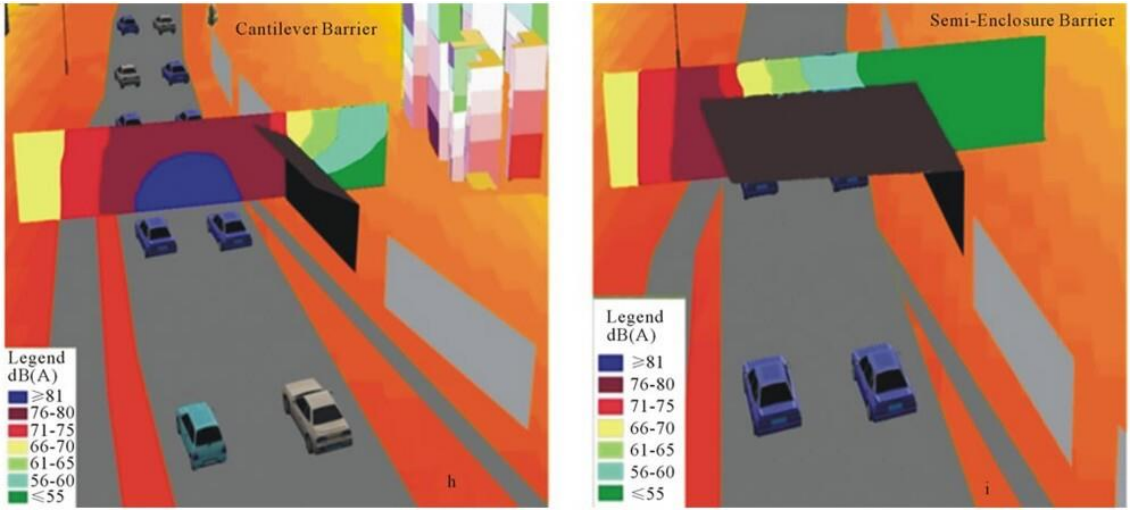


[Beran et al. 2022]

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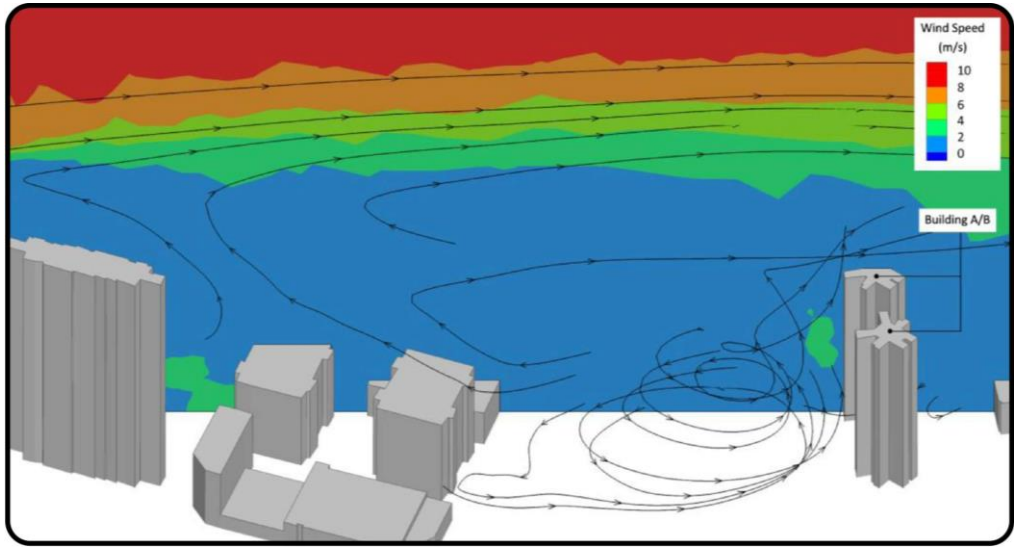


[Zhang et al. 2021]

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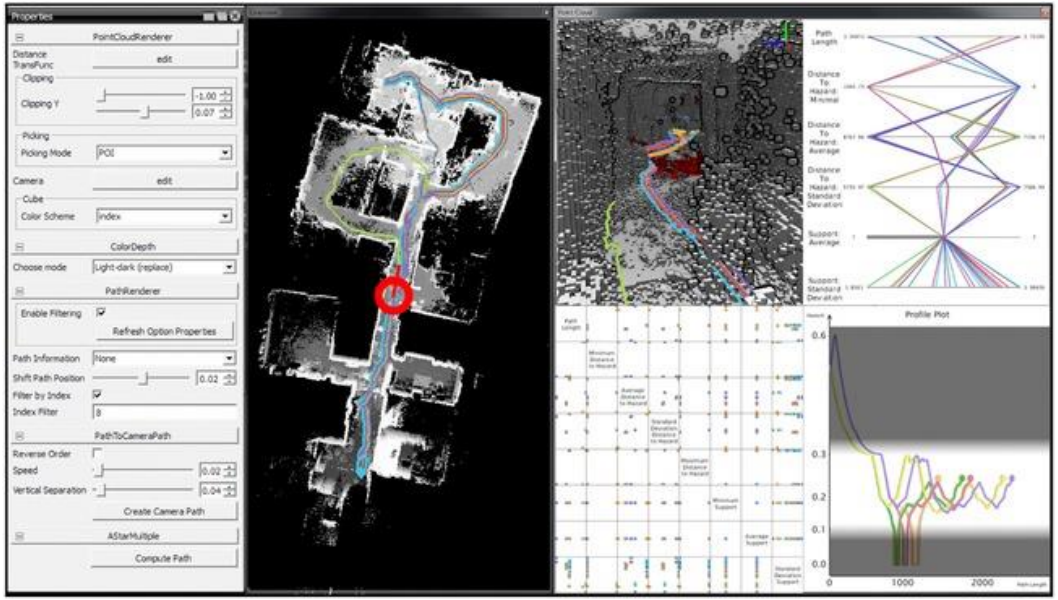
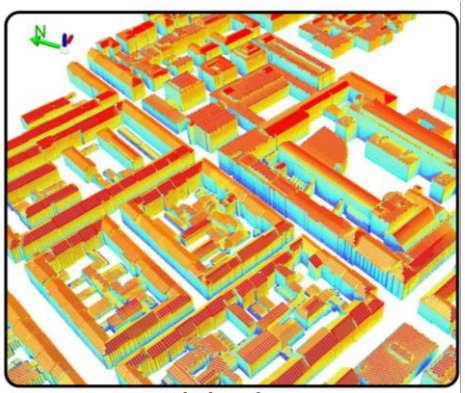
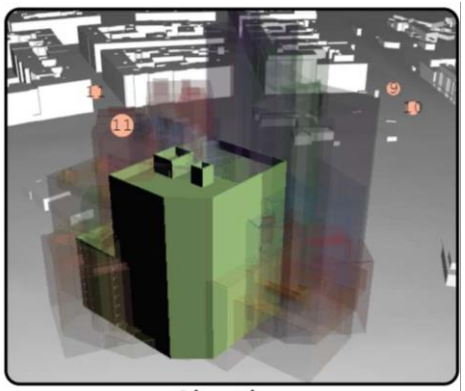



[Bock et al. 2016]

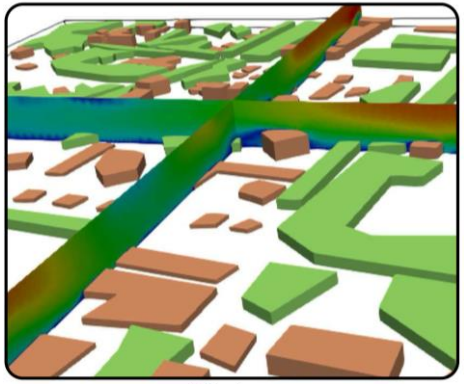
# *How:* Occlusion Handling



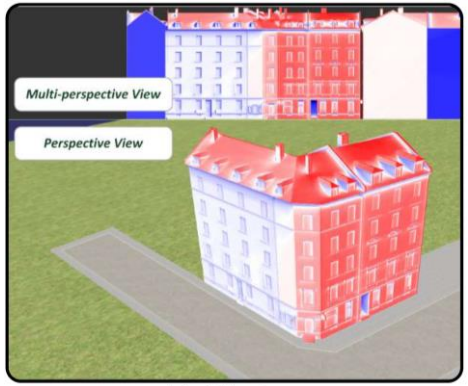
Bird's view



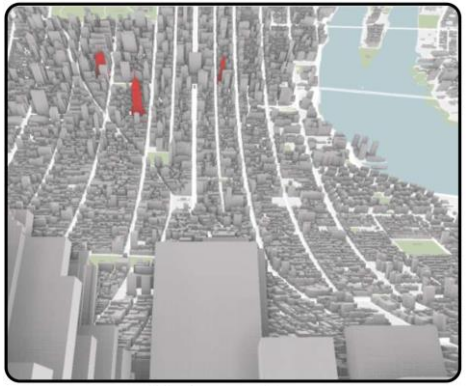
Ghosting



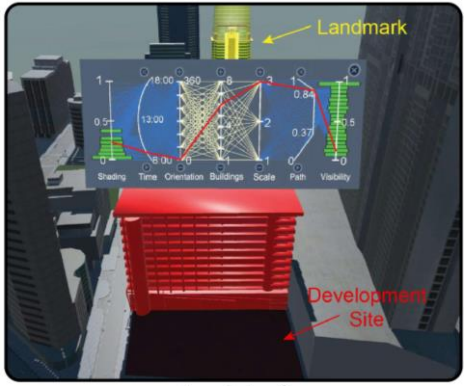
Slicing




Multi-view

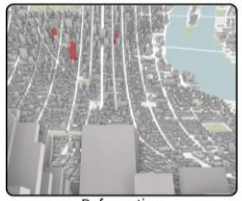


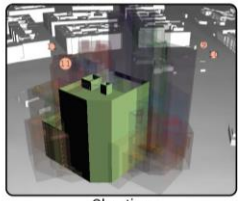
Deformation

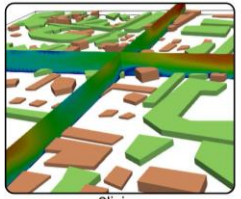



Assisted

# *How:* Occlusion Handling


Deformation


Ghosting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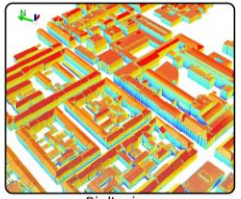
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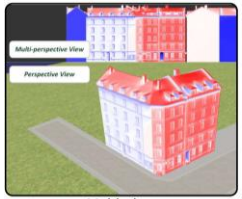
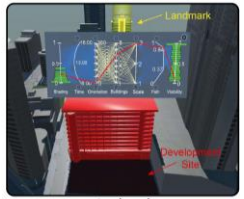
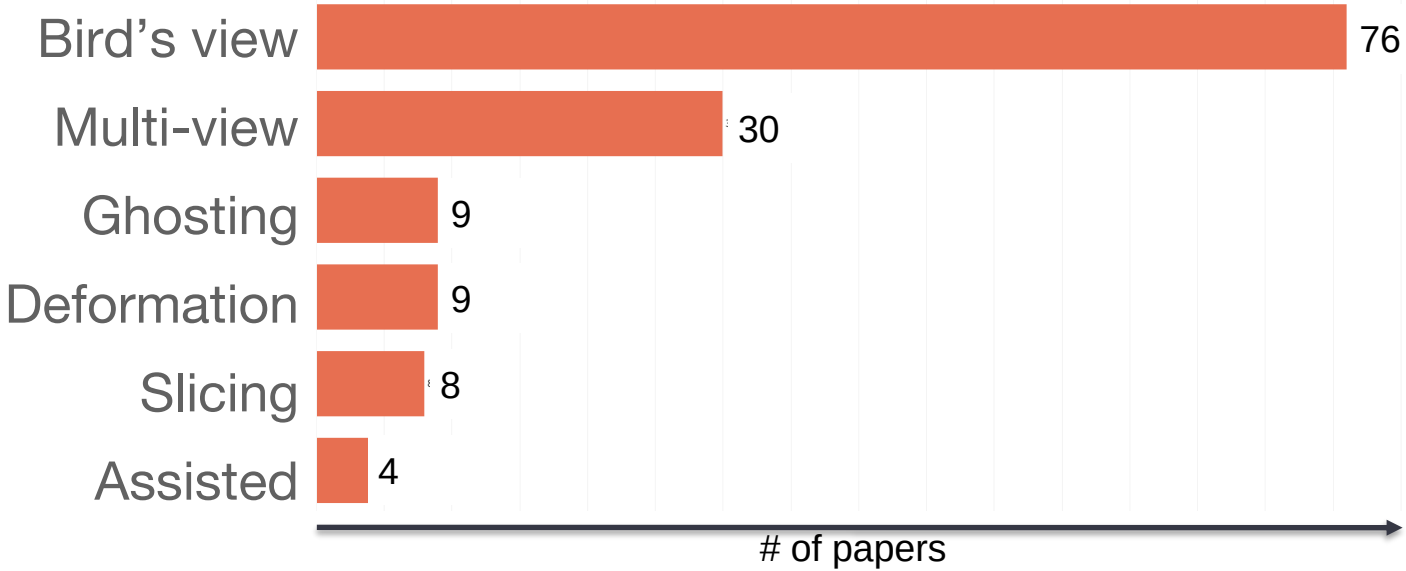


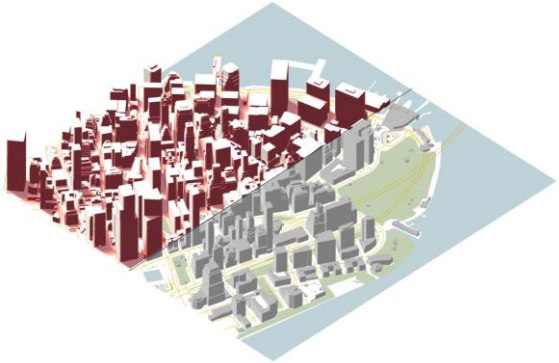
Multi-view



Assisted



# Research Challenges



Data Management

Thematic Data Representation

Navigation & Guidance

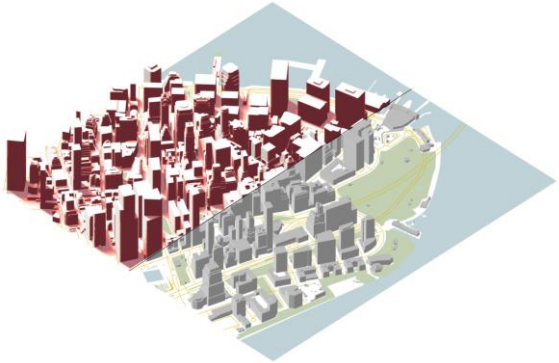
Empirical Validations

Visual Modalities

Open 3D Urban VA

Collaborative Analysis

# Research Challenges



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# Empirical Validations of Visual Designs

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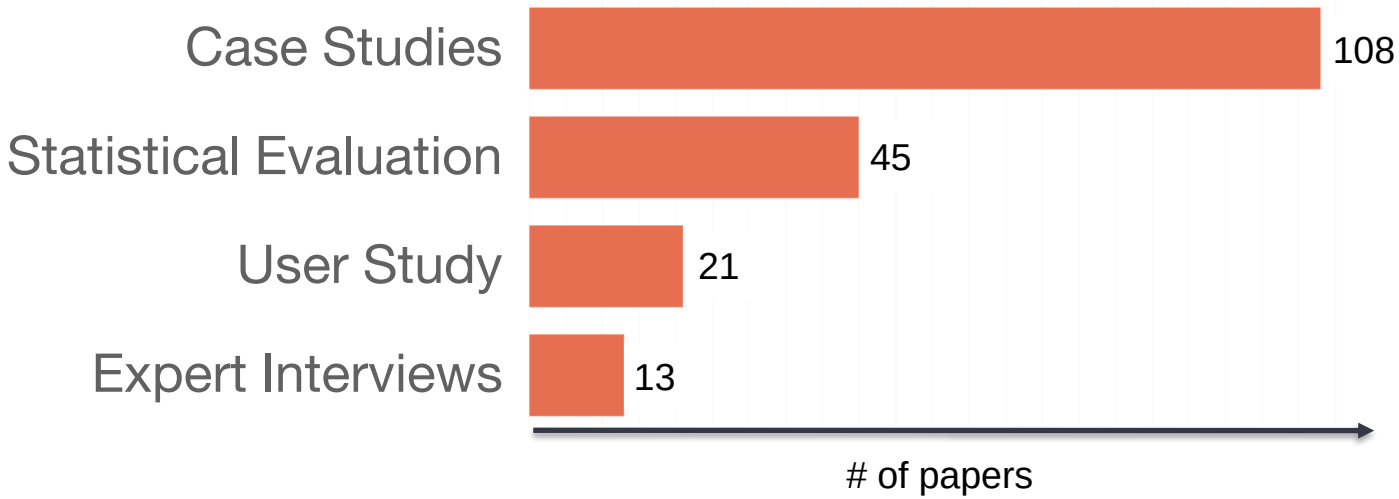
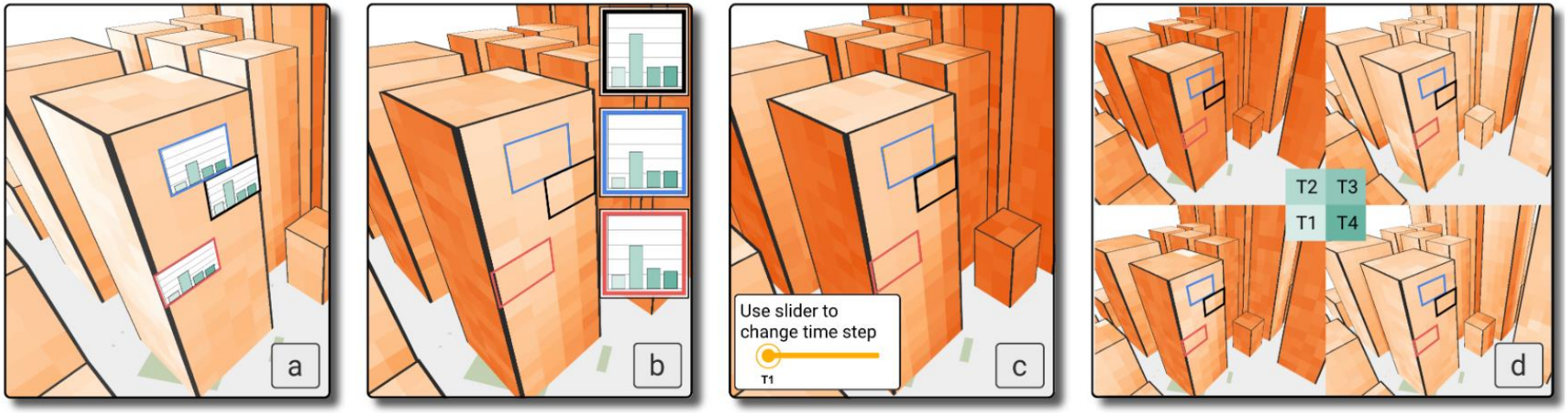
*"3D geovisualization is essential in urban planning as it assists the analysis of geospatial data and decision making in the design and development of land use and built environment. However,* ***we noted that 3D geospatial models are commonly visualized arbitrarily as current 3D viewers often lack of design instructions to assist end users****."*

[Neuville et al. 2019]

# Empirical Validations of Visual Designs



# Empirical Validations of Visual Designs




[Mota et al., 2022]

# Visual Metaphors for Thematic Dimensions

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3D Urban data is often complex

48 (~27%)
out of 175 papers
Volumetric

49 (~28%)
out of 175 papers
Temporal

60 (~34%)
out of 175 papers
Multivariate

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Furthermore, often include uncertainty

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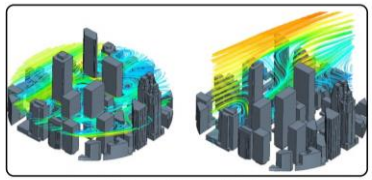
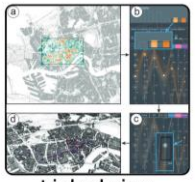
Multivariate

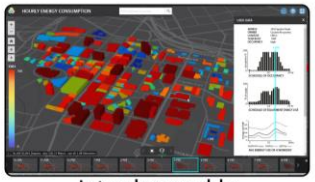
Furthermore, often include uncertainty
and analyzed at multiple scales

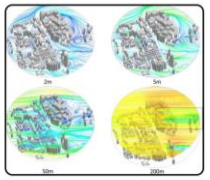
# Visual Metaphors for Thematic Dimensions

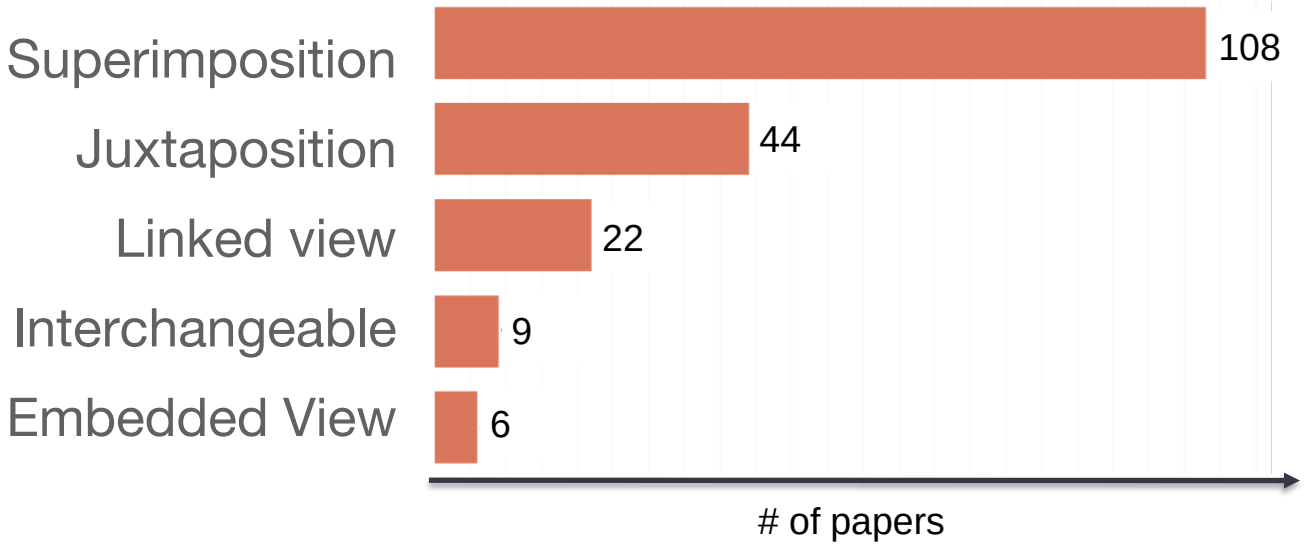

Superimposition


Embedded view


Linked view


Interchangeable


Juxtaposition



# Navigation and Guided Exploration

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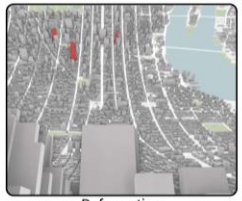
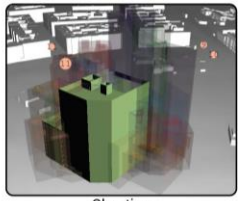
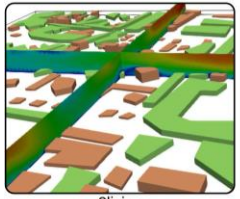
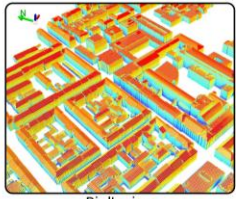
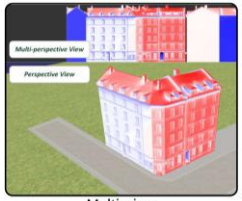

Deformation

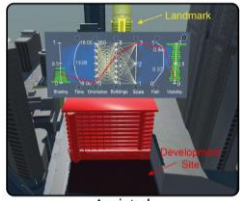

Ghosting


Slicing

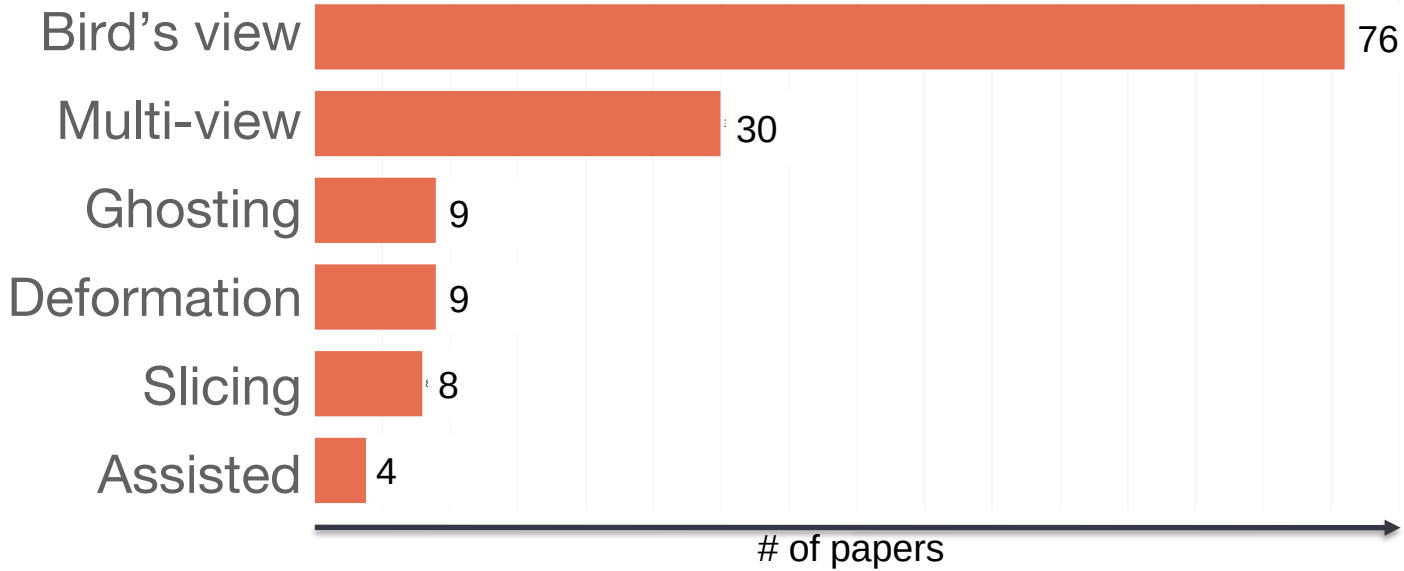

Bird's view



Multi-view



Assisted



# Navigation and Guided Exploration


Deformation


Ghosting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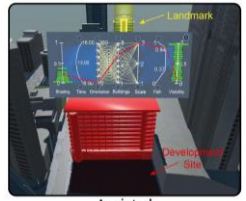
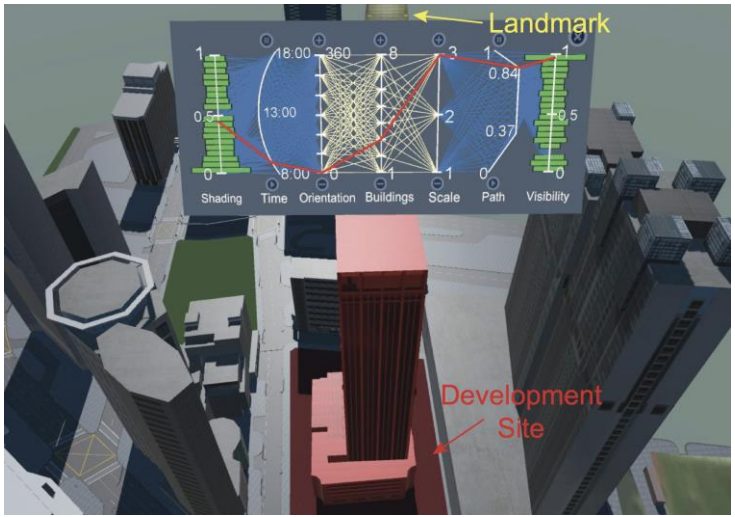


Assisted




[Zhang et al., 2021]

View Selection Criteria

- Camera Target Distance
- Camera Obstruction
- View Occlusion

# Navigation and Guided Exploration

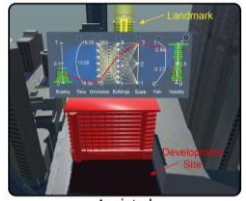

Deformation


Ghosting

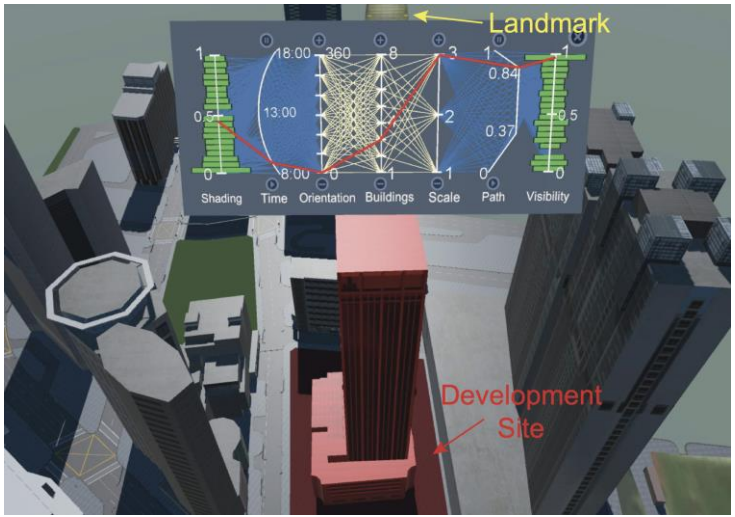

Slicing


Bird's view


Multi-view



Assisted




[Zhang et al., 2021]

View Selection Criteria

- Camera Target Distance
- Camera Obstruction
- View Occlusion

Does not take the thematic data into account

# Navigation and Guided Exploration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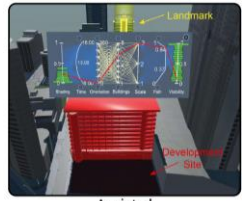

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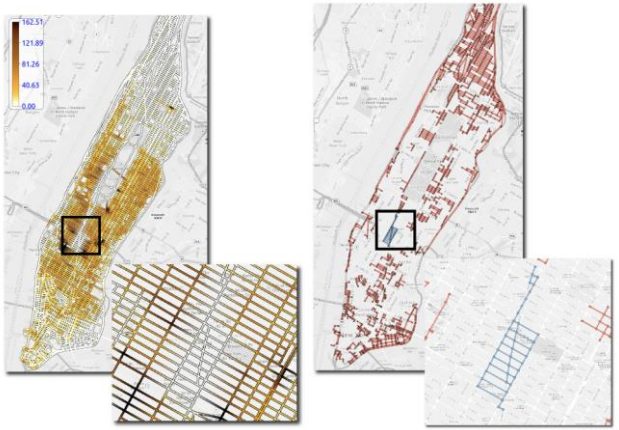
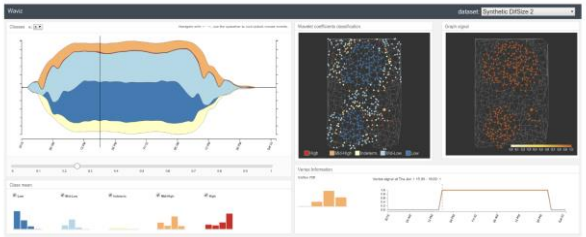

[Doraiswamy et al., 2014]

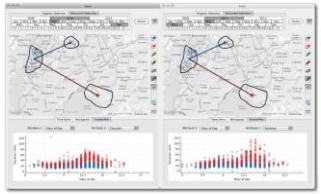

[Valdivia et al., 2015]

[Liu et al., 2018]

# Conclusion

- 3D Urban visual analytics is important tool with large potential of real impact in many domains.

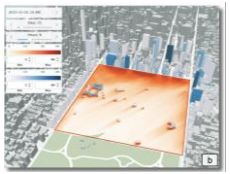
- A plethora of research opportunities
  - Large visual design space.
  - Lack of (open) toolkits.
  - Gap between vis researchers and domain experts.



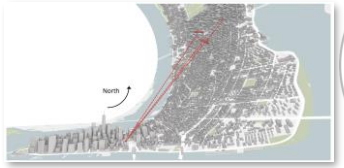
**TaxiVis**
(Ferreira et al., 2013)

**Urbane**
(Ferreira et al., 2015)

**Catalogue**
(Doraiswamy et al., 2015)



**Shadow Profiler**
(Miranda et al., 2019)

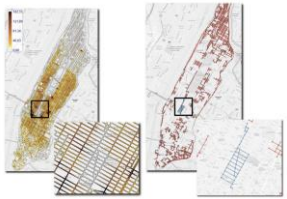



**UrbanRama**
(Chen et al., 2020)


**UTK**
(Moreira et al.,2023)

2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023

**Taxi Patterns**
(Doraiswamy et al., 2016)



**Urban Pulse**
(Miranda et al., 2016)

**Raster-Join**
(Doraiswamy et al., 2018)

**Urban Mosaic**
(Miranda et al., 2020)

**Urban Rhapsody**
(Rulff et al., 2022)

# The State of the Art in Visual Analytics for 3D Urban Data

HOME WIZARD

## About

This is a companion website for our survey paper on visual analytics for 3D urban data

**Authors:** Fabio Miranda, Thomas Ortner, Gustavo Moreira, Maryam Hosseini, Milena Vuckovic, Filip Biljecki, Claudio T. Silva, Marcos Lage, Nivan Ferreira

Urbanization has amplified the importance of three-dimensional structures in urban environments for a wide range of phenomena that are of significant interest to diverse stakeholders. With the growing availability of 3D urban data, numerous studies have focused on developing visual analysis techniques tailored to the unique characteristics of urban environments. However, incorporating the third dimension into visual analytics introduces additional challenges in designing effective visual tools to tackle urban data's diverse complexities. In this paper, we present a survey on visual analytics of 3D urban data. Our work characterizes published works along three main dimensions (why, what, and how), considering use cases, analysis tasks, data, visualizations, and interactions. We provide a fine-grained categorization of published works from visualization journals and conferences, as well as from a myriad of urban domains, including urban planning, architecture, and engineering. By incorporating perspectives from both urban and visualization experts, we identify literature gaps, motivate visualization researchers to understand challenges and opportunities, and indicate future research directions.

Use our wizard to browse through a corpus of more than 150 papers covering a period of more than ten years and almost 20 venues.

Feel free to get in touch if you have any questions or comments.

## Use the Wizard

Use the wizard tab to navigate and filter the surveyed papers. We summarize previous visualization and domain-specific contributions using an interrogative method that categorize the papers concerning three questions:

**Why** is 3D urban data being analyzed
**What** data is being analyzed
**How** it is being analyzed

## Read the Survey

**The State of the Art in Visual Analytics for 3D Urban Data**
Fabio Miranda, Thomas Ortner, Gustavo Moreira, Maryam Hosseini, Milena Vuckovic, Filip Biljecki, Claudio T. Silva, Marcos Lage, Nivan Ferreira
Computer Graphics Forum (EuroVis 2024)

Email GitHub



urbantk.org/survey-3d

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*EuroVis 2024 STARs*