RESHAPE

Rapid forming and simulation system using unmanned aerial vehicles for architectural representation

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Abstract. As digital technology advances, multiple ways of repre-senting objects interactively in space, architects and designers begin to use Virtual Reality (VR) and Immersive Digital Environ-ments (IDE) to communicate their ideas. However, these technolo-gies are bounded with their spatial limitations. In responding to this issue, our paper introduces ReShape, a digital-physical spatial representation system supported by Unmanned Aerial Vehicle (UAV) swarm technology that allows a user to project their unbuilt design and interact with them in real space, unattached by headset, fixed cameras or screen. ReShape can be controlled by user orien-tation and gesture as an input, where the real-time feedback is provided by UAV spatial arrangement in space, augmented by computational simulation. Spatial data is transmitted between the UAV agents for the user to experience the digital model, creating a versatile and computationally efficient platform to edit and en-hance the design in real-space. This paper outlines four systems in ReShape, i.e., (1) detection system to identify and locate the user position and orientation; (2) task-arrangement system to provide spatial information to the UAV agents; (3) UAV's communicating system to control the UAV position and task in space; and (4) Physical-Digital forming system, to project digital simulation by the UAV agents.

Keywords. UAV system; Spatial representation; a detecting sys-tem; human-computation interaction.

1. Introduction

Since CAD origination in 1963 by Ivan Sutherland, digital representation in architecture has been advancing through various mediums, from on-screen to off-screen simulation, and from virtual simulation to physical fabrication. These conversions have brought different consequences and opportunities. For example, Virtual Reality (VR) and Immersive Digital Environments (IDE) have brought new ways of experiencing virtual space, but attachment to the device remains unsolved (Jung et al., 2015). VR technology is limited by its headset and IDE are bounded by the projector location. Moreover, while 3D printing allows for quick

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prototyping, the flow between designing and physical validation mostly occurs linearly, the physical prototype does not provide feedback to the digital model. The next reasonable step is to then reconsider ways to liberate spatial attachment and one-way simulation, by reconfiguring the relationship between virtual and physical representation in architecture.

This paper introduces *ReShape*: a rapid formation system with a physical user interface, an intelligent UAV system, and real-time feedback of multiple spatial simulations. Our preliminary experiments and case studies indicate a promising avenue by using ReShape to reduce the digital barriers by projecting virtual design and relevant information into a real environment. With ReShape, design information is no longer attached to a pair of eyes behind the headset or exclusive to people, who have access to fixed screen and projectors but instead offers ultra-mobility and openness to the surrounding observer. While programmable swarm drones have been widely applied to portray object in space, the main difference with ReShape is that each drone has a unique role in forming an object rather than following a uniform flight path program. This system allows users to manipulate the way in which each UAV system collaborates with each other as a bi-directional Tangible User Interface (TUI) (Ishii et al., 2012).

1.1. BACKGROUND

Inspiration for ReShape was drawn upon speculation about the evolution of User Interface (Ishii et al., 2012). Ishii outlines his research areas (e.g., shape dis-plays, swarm robotics and self-levitating user interfaces) in three main evaluation phases: [1. GUI - Graphic User Interface] where the user data is displayed fully on the screen, [2. TUI - Tangible User Interface] when the user accesses the data via a hybrid of a screen and mechatronic systems and [3. Radical Atom], where digital data is fully embodied in a physical object. ReShape responds to the latest challenge in Radical Atom.

There are growing interests aimed at developing interactive application for Radical Atom in the last few decades. Particularly, for controlling physical matter as a digital embodiment to produce interactive simulation in spaces. Some systems support discretized shapes to perform 2.5D surfaces i.e., a surface made of two-dimensional array of linear actuators, while others use continuous shapes with advanced materials, such as servo, pneumatic actuation (Yao et al., 2013) or shape-memory alloys (Poupyrev et al., 2004). For instance, *Lumen* explored individual control of shape and graphics by varying the height of a 5x5 array of light guides using shape-memory alloys. *Relief* (Leithinger and Ishii, 2010) investigated a set of common interactions for viewing and manipulating content on a 12x12 shape display. *Recompose* (Leithinger et al., 2011) implemented a framework that allowed for gestural and direct manipulation of an actuated surface. More Recently, *InForm* (Follmer et al., 2013) showcased a 30x30 shape display aimed at exploring the design space of dynamic physical affordances and constraints with shape-changing user interfaces. Nevertheless, boundary issues, as addressed in the introduction, remain in these projects. Lumen, Relief, Recompose and InForm are constrained by the surface area where the actuators are fixated.

Experiments in swarm robotics in the past ten years offer more flexibility than 2.5D surfaces. Recently, roboticists have started to develop methods for interacting with large collectives of robots that support either direct or gestural user interactions. Formation of tiny robots to mimic an object collectively was demonstrated with *Kilobot* by Rubenstein et al. (Rubenstein et al., 2012) with a dynamic programmable display method (Rubenstein et al., 2014). While Rubenstein robots did not respond to user input, hence, a one-way system, *Zooids* (Le Goc et al., 2016) extended this approach further, focusing on direct manipulation of tangible robots. In another case, Alonso-Mora et al. (Alonso-Mora et al., 2012) proposed a swarm display in which each pixel is a robot of controllable color. Their system was recently extended to support interaction through sketching and mid-air gesture (Alonso-Mora et al., 2011) (Alonso-Mora et al., 2015). A common drawback with such system, however, is that they are inherently limited to two-dimensional configurations.

A natural extension to swarm user interfaces is that of self-levitating tangible user interfaces, self-propelled robots that can arrange spatially to assemble a complex three-dimensional structure on the fly. Such systems were exemplified with *Flight Assembled Architecture* (D'Andrea, 2013) and Termite Inspire construction (Justin et al., 2014). While these examples provide exciting technical innovations, there has been little focus on interaction among those systems. Researchers have explored the concept of levitating displays via flying robots equipped with projectors and high-resolution displays (Nozaki, 2014) (Scheible et al., 2013) (Schneegass et al., 2014) (Gomes et al., 2016). While these explorations have enabled user interaction, they were limited to a single drone that primarily acted as a visual information display. An exception to the above work is Drone 100 ("spaxels® research initiative - Swarms of the Future," 2017), a platform comprising of 100 quadcopters that act synchronously to display images. Another example of quadcopters working together to represent 3D structures can be found in *BitDrones* (Gomes et al., 2016) and *GridDrones* (Braley et al., 2018). Nevertheless, the scale of this large operation prevents user from directly interact with them, and only few of these applications were related to form and space creation.

It is for such constraints and opportunities, i.e., fixation on 2.5D actuators, 2D swarm robots, and 3D drone formation, that this research aims to extend the swarm logic with self-levitating agents. ReShape system took advantage of tangible interfaces and UAV systems to expand the limitations of traditional architectural representations (restricted by 2D surface and only visual effect.) into space simulations. To investigate ReShape's capacity, the scope of this study is limited to architectural representation in the real world for one user.

2. Methodology

2.1. DESIGN OF RESHAPE

The ReShape system has User Inputs, Connections and Outputs to simulate space and to display spatial information (we refer to the drone as UAV system from this page onward). To let the UAV agents perform a correct formation based on the users' or clients' perspective view, ReShape tracks users' location and orientation.

The user's data is then analyzed and aligned with the UAV position which carrying a set of apparatus (e.g., projector, panel) to simulate the digital design in physical space. The spatial information would be transferred into the physical apparatus, for example, rendering information or heat map of the space.

The UAV that is used in this project is *Tello*, which installed with one normal camera and two infrared cameras. Using this UAV, the ReShape system is divided into four sub-systems: [1] a task arrangement system, [2] a detecting system, [3] a communication system and [4] a physical-digital system. (Figure 1). The relationship between the input-connection-output system with the four subsystems outlined as follows:

1) **Users Input**: Any information or data that is sent to a computer for processing is considered user input. For example, in the ReShape system, the first input is the pre-designed model that is required to be imported into the Task Arrangement System before operating the rest of the system. The second input uses the users' spatial values that are perceived by detecting system, for example, the users' orientation in connection to the users' visual field and position values. After obtaining those two kinds of data, the next step requires sending it into the next process, connection.

2) **Connection**: The connection process acquires data from the User Input and exports data to the Output. In the ReShape system, the users' value (input) is provided to the Task Arrangement System, where the task of the UAV system would be calculated based on the users' imported value. After generating the spatial organization data of UAV, ReShape system then transfers the data into the UAV system (output) in the physical world to simulate space.

3) **Output**: The expected output in the ReShape system requires UAV spatial simulation to correspond to the spatial analysis information. Thus, in the following procedure, the UAV system attached with pre-installed boards will begin to perform the designed space based on the data from the communication system. Also, due to one of the UAV systems carrying projectors, the spatial analysis information simulated in computers would be projected into boards carried by the UAV system.

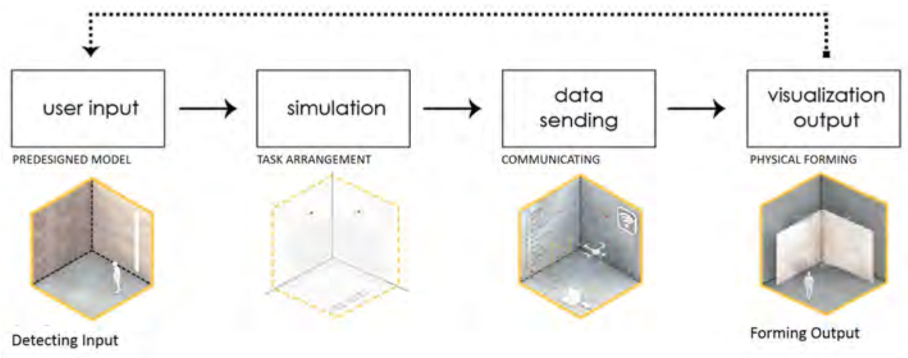

Figure 1. System structure of ReShape System.

2.2. TASK ARRANGEMENT SYSTEM

To control UAV system to perform particular spatial simulation, there are several UAV system's tasks need to be considered, firstly, the flying path of UAV system based on imported model with users' visual field need to be calculated before simulating in physical world (Figure 2-top). Secondly, the collision problems of UAV system need to be avoided. Thirdly, the safety of users' needs to be taken into account. Thus, these flying paths of UAV system need to be arranged before exporting those spatial data into Output part.

Figure 2. The UAV agents, carrying the projector and panel, follow user's orientation to perform corresponding space.

While the UAV agent is commonly regarded as a single point in the physical world (e.g., in displaying shape as a point could), in ReShape, we augmented the UAV agent's point-based representation into higher dimensional shapes by having them carry certain apparatus (e.g., string, panels or boards). With this apparatus, a surface, for example, does not have to be simulated with an array of many UAV systems as point cloud, but rather by carrying a 2D surface apparatus itself. Different UAVs have unique roles, and hence, carrying different apparatus.

Firstly, the digital model information is imported to simulate those tasks of the detecting system and physical-digital forming system, before the Task Arrangement System starts to divide the UAV into three parts: [1] carrying the UAV system, [2] detecting the UAV system and [3] projecting the UAV system based on the digital model's outline (Figure 3). Carrying UAV systems focuses on spatial organization, which is carrying portable material to perform designed space. For detecting-UAV system, the main task is to detect the users' spatial information. Lastly, projecting - UAV system needs to follow carrying the UAV system to project simulated data into a specific area (Figure 3). To simulate the space correctly, the task arrangement system needs to maintain the spatial relationship between these three types of UAV systems precisely. For example, during an experiment, we can see how the left drone would change its orientation to follow the right one to maintain the relative position (Figure 4-top). Also, in Figure 4-bottom, those tow drones are designed to fly as a rectangle together. Thus, task arrangement system could be regarded as one of the bridges between designed space and the physical world.

Figure 3. Task Arrangement: the process of designing flying path based on shortest walk.

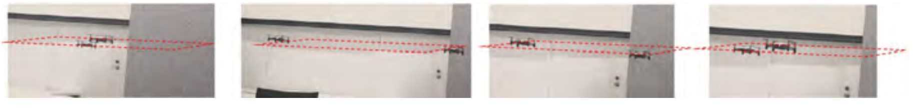

Figure 4. Demonstration: Two Carrying UAVs perform a certain task (flying as rectangle).

2.3. DETECTION SYSTEM

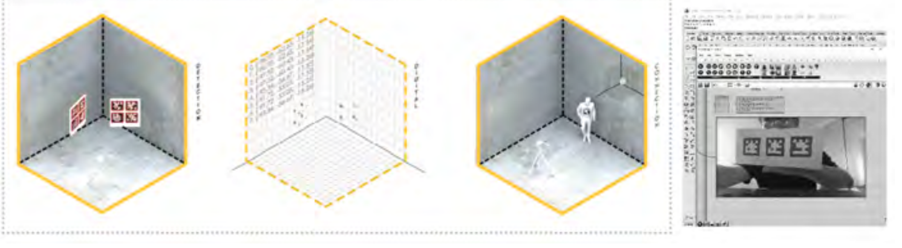

Figure 5. Task Arrangement System: (left) maintaining the relationship between Carrier, Projec-tor, and Detector; (far right) Figure 12. Demonstration (top) tag recognizing platform (extracting video from detecting drone with Arduino and Processing) in Grasshopper with AprilTag .

The detecting-orientation system serves one of the key roles in ReShape system: to simulate what the user would see in a real space based on their location in physical space. Therefore, the user's position and orientation will determine the UAV position in the spatial simulation task (Figure 5). ReShape detects the user position and orientation based on camera sensor devices, which is used to connect the physical and digital world. A tag called AprilTag needs to be attached to users so that camera would be able to recognize users' orientation and location value.

While the accuracy of the detection system would be higher via a fixed camera, the camera position will limit the user's movement and spatial orientation. To anticipate this, ReShape's liberates their users to spatial experience by capturing their movement with a camera attached to the UAV agent. The detecting UAV system can follow users' position to provide relatively flexible detecting range (Figure 5-far right). Video's from the camera is then streamed to another UAV agent that project the digital design aligned to the user visual field in real time.

Note that the distance between user and detecting UAV in our project is limited by four meters. To get the relative location value of user, we use two key algorithms. The first one is for 'following.' Based on the April Tag attached to user, a detecting UAV would detect the tag and send their coordinate value to the computer. The computer will then calculate the value between the last and the latest value of user, to get the user's movement. Based on this information, the detecting UAV will execute command to follow user (e.g., by rotating, translating, etc.). Secondly, in order to get the absolute coordinate of user based on the relative coordinate read by detecting UAV, the location value of the detecting UAV when taking off need to be recorded to get the location value of user during experiment process.

2.4. UAV COMMUNICATION SYSTEM

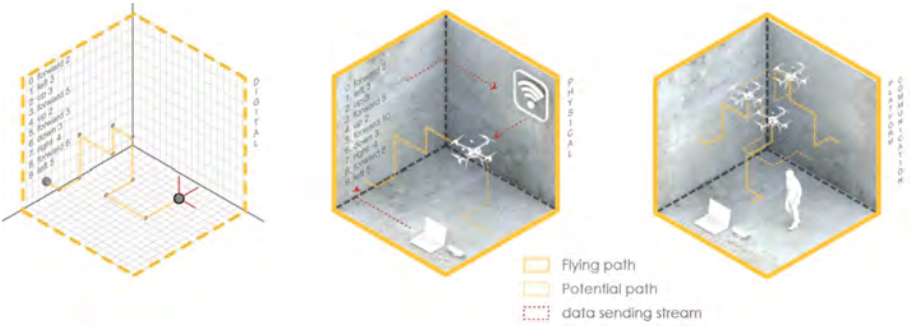

Figure 6. Communicating system: the procedure of data transferring in communicating system. (Left) Simulated in host computer; (Middle) The stream of data would transmit from computer to Wifi Hotspot, then to UAV system; (Right) The digital simulating information is projected into physical world.

The communication system connects the task arrangement system with UAV simulation in the physical world. Firstly, the data generated from the task arrangement system is based on the Cartesian coordinates system. This value is then transferred into a series of command lines to propel the UAV agent, e.g., 'forward 1', 'back 1', 'left 1', 'right 1', 'up 1', 'down 1' and so on. Secondly, these command lines are transmitted through WIFI signals to the UAV agent that would allow them to perform what has been simulated in digital work in real-time (Figure 6).

2.5. PHYSICAL AND DIGITAL FORMING SYSTEM

2.5.1. Physical simulation

After receiving data through a communication system, UAV system would start to carry pre-attached material to perform the designed space. The formation of UAV's system is updated in real time based on the users' orientation and visual field in real space. Due to the budget and amount of time, the materials in this study were limited to flat panels, and fabric yet could still simulate a certain amount of various shapes and space. For example, two portable boards could be carried by UAV system to form a corner space (Figure 7). Fabric could also be used to simulate space bounded with flexible form.

The simulated data are transferred into a projector attached to one of the UAV systems, which is called a projecting- drone. This system would provide users with a different spatial experience compared with traditional sample space via overlaying various information. The physical-digital forming system allows users to experience the designed space in multiple layers of information, such as photorealistic rendering or environmental, structural and spatial analysis (Figure 8).

Figure 7. Demonstration: carrying different objects to perform different tasks (e.g., frame, layer, and holders).

2.5.2. Digital Simulation

While experiencing space formed by ReShape, designers can adjust the spatial organization by gesture controlling mechanism. For example, to quickly test certain ideas for shape modification (Figure 8) or testing different material (Figure 9). The user controlling gesture can be detected and sent into computers to simulate through task arrangement system. The adjusted design will be then recorded for further steps in the design process.

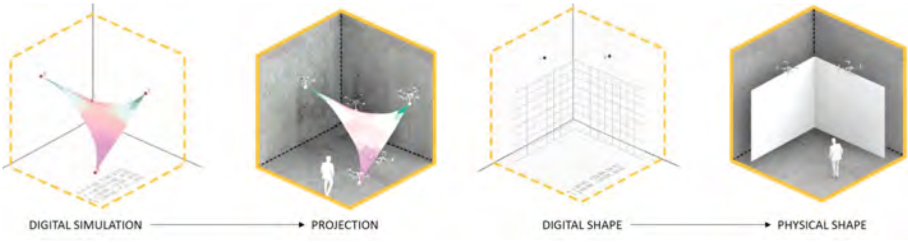

Figure 8. Examples of projecting digital simulation into physical world: (top) Structural analysis with flexible shape; (bottom) Material information on rigid shape; (bottom-right) a portable shelter.

3. Conclusion

This paper has outlined a method to integrate a user's input into the UAV system with multiple drones, each with their own task. The system creates new opportunities on the way in which a designer interacts with their design rapidly. There are three contributions of this prototype system design:

1) Evidence-Based Decision Making: The ReShape System equipped with database to accommodate evidence-based decision-making process between architects and clients.

2) Rapid Physical Simulation Tools: Using ReShape, information from designers can be mapped onto the physical world rapidly to the users and allow them to participate in the design process.

3) UAV Human-Oriented Control System: Compared to regular drone applications, such as surveying or aerial photographing, ReShape focuses on how users interact with UAV systems directly to accomplish complex design tasks in real time.

With ReShape, design iterations and refinements happen in real time, allowing for live mockups that do not require manual assembly and dis-assembly. Due to the flexible boundaries offered by the UAV system, ReShape has the potential to expand the architectural field by providing a more realistic approximation of volume form that can be easily ad-justed in life size rather than constrained by specific area, for example, fixed camera or fixed motion tracking system.

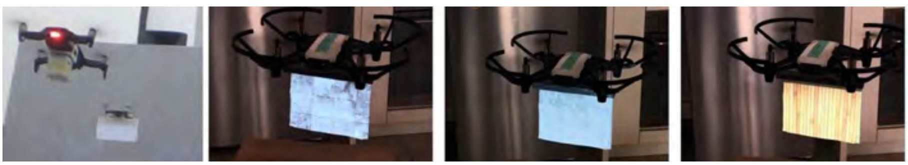

Figure 9. Demonstration: Project UAV projecting different materials into the Carrying UAV.

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2. UrbanXTools

CAUPDxUrbanXLab / **UrbanXTools** Public

Based on the design logic, UrbanXTools could generate urban design automatically in a very short period of time, and evaluated from the view of sustainability, with the help of algorithms. While gradually bridging the gap between urban design and sustainable systems, the toolbox could improve the efficiency of design.

GPL-3.0 License

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main

alphonse-lin … on 16 Dec 2021

View code

README.md

UrbanXTools

Language

中文 [Engilish]

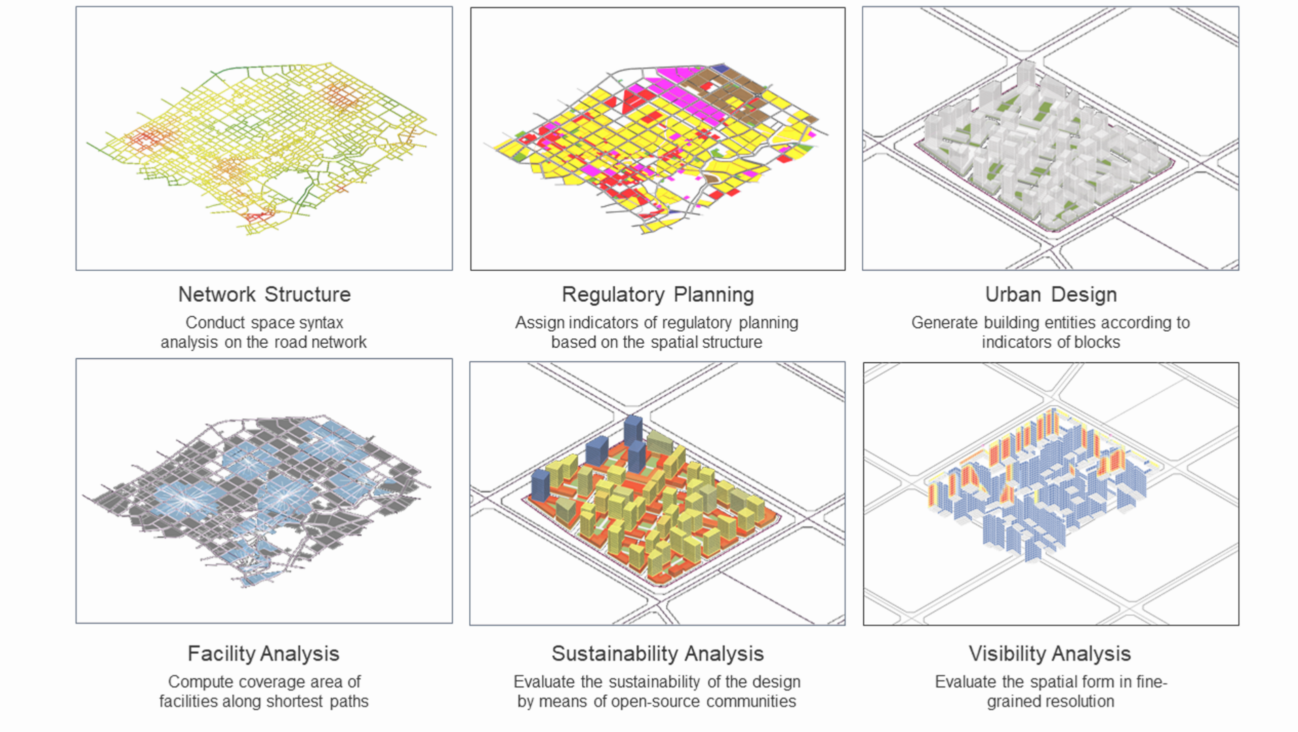
Content

- Add curve boundary in Exposure Rate 3D
- Improve the efficiency of network analysis 3D

Content

- License

Introduction



1. Main Functions

- **Autogeneration of spatial models**: by integrating urban planning logics and computer algorithms, UrbanXTools can rapidly generate rudimentary spatial models for urban design projects. The spatial model will be complied with superior plans and regulations.
- **Assessment of urban design projects**: UrbanXTools can provide instant assessment of urban design projects based on multi-disciplinary features and sustainable development goals.
- **Construction of a feedback loop**: by using parametric design methods, we aim to construct a mechanism for regulatory plans and urban design projects to get instant assessments, feedbacks and modifications. With this mechanism, the efficiency and quality of urban design could be enhanced

2. Objectives

- High quality
- Sustainable urban development

3. Developers

- Tao Yang, Weizhen Luo, Xuhui Lin, Chengru Deng, Yufei Dong

4. Translating Contributor

- Yihan Zhang

5. Notifications

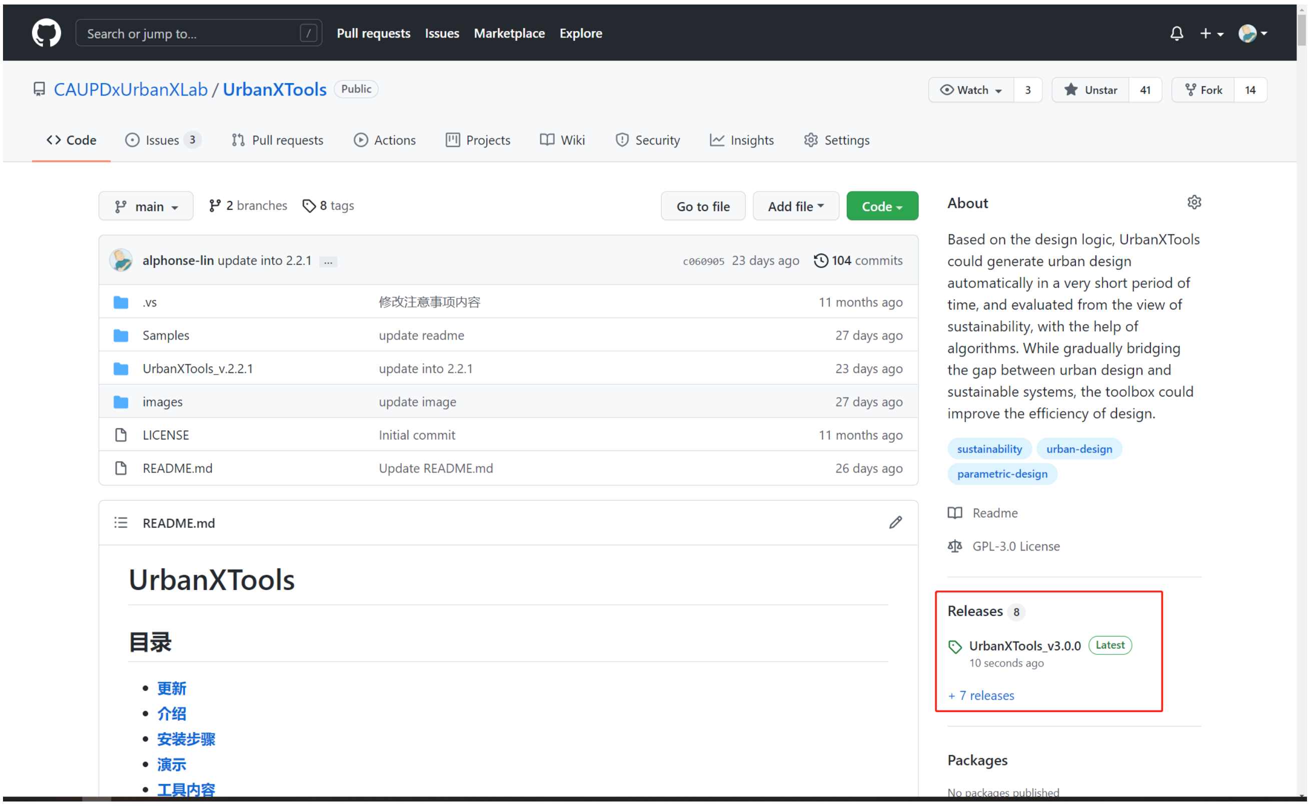
- Rhino version 6.9 and above are recommended.
- Model unit MUST BE METER, and models cannot be generated if your model unit is millimeter (mm)
- Please put your geometric objects, such as roads and land parcels, near the origin of coordinates (0, 0, 0). Confined by computation accuracy of geometric objects in RhinoCommon, the geometric Boolean operation might go wrong if you put your model too faraway from the origin point.
- If you encounter any other problems or have any demands and suggestions, please let us know via Github Issues. We'll try our best to help.

Installation

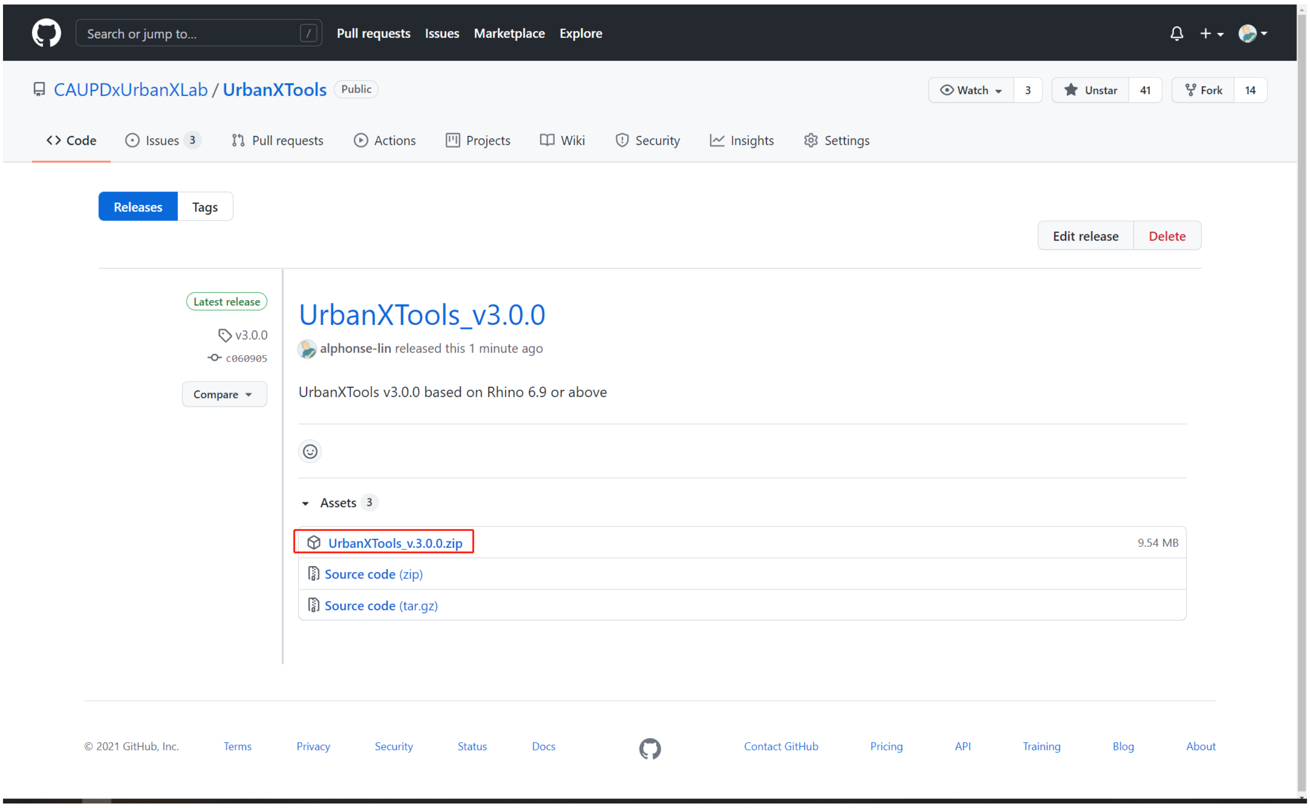
- Download UrbanXTools：
  - Lanzou NetDisk
    - Link：https://wwe.lanzoui.com/b01tqy68f
    - Password: h5d8
  - Baidu NetDisk
    - Link：https://pan.baidu.com/s/1acBnxjOD2pCm4wnlYHIOzg
    - Password： gz4u
  - Github
    - Link：https://github.com/CAUPDxUrbanXLab/UrbanXTools/releases

1. Enter Releases, choose a compatible version, download the zip file and extract (please choose the latest version)

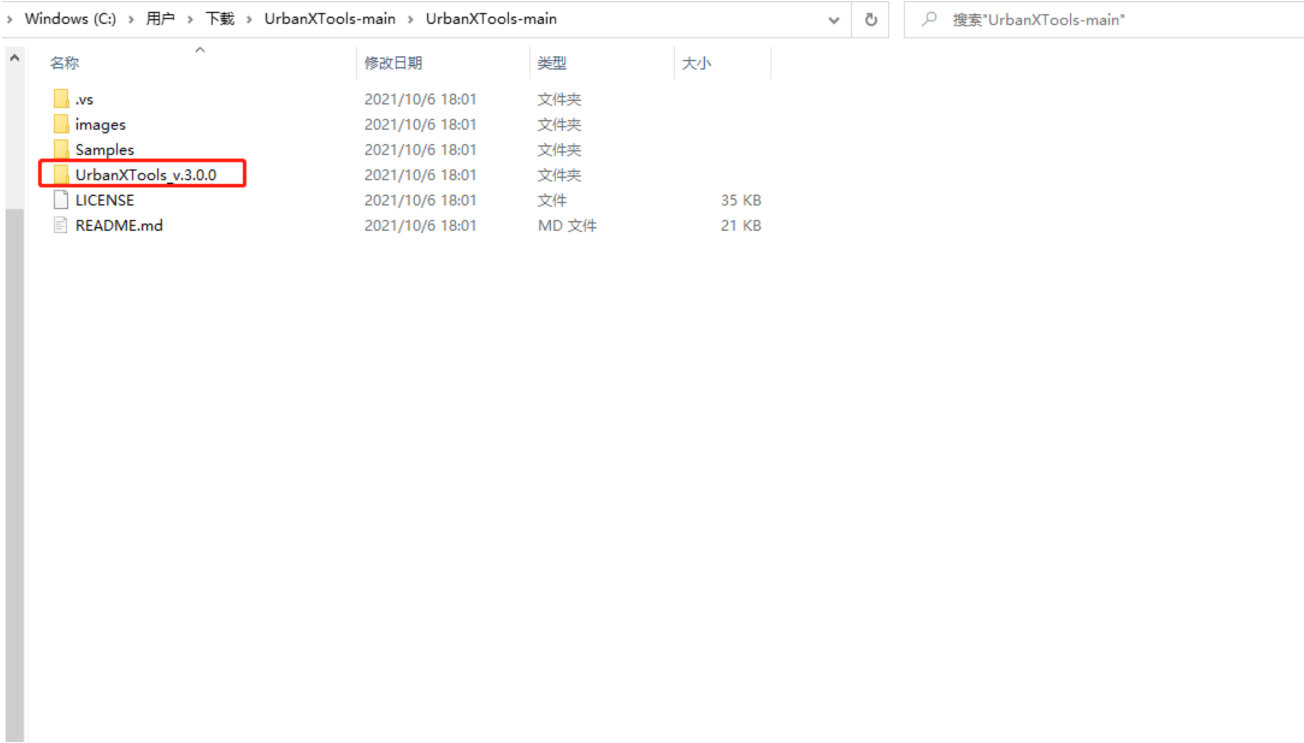
- Click to enter Releases



- Within the Releases page, please download:
  - Full version: UrbanXTools_v3.0.1 is recommended

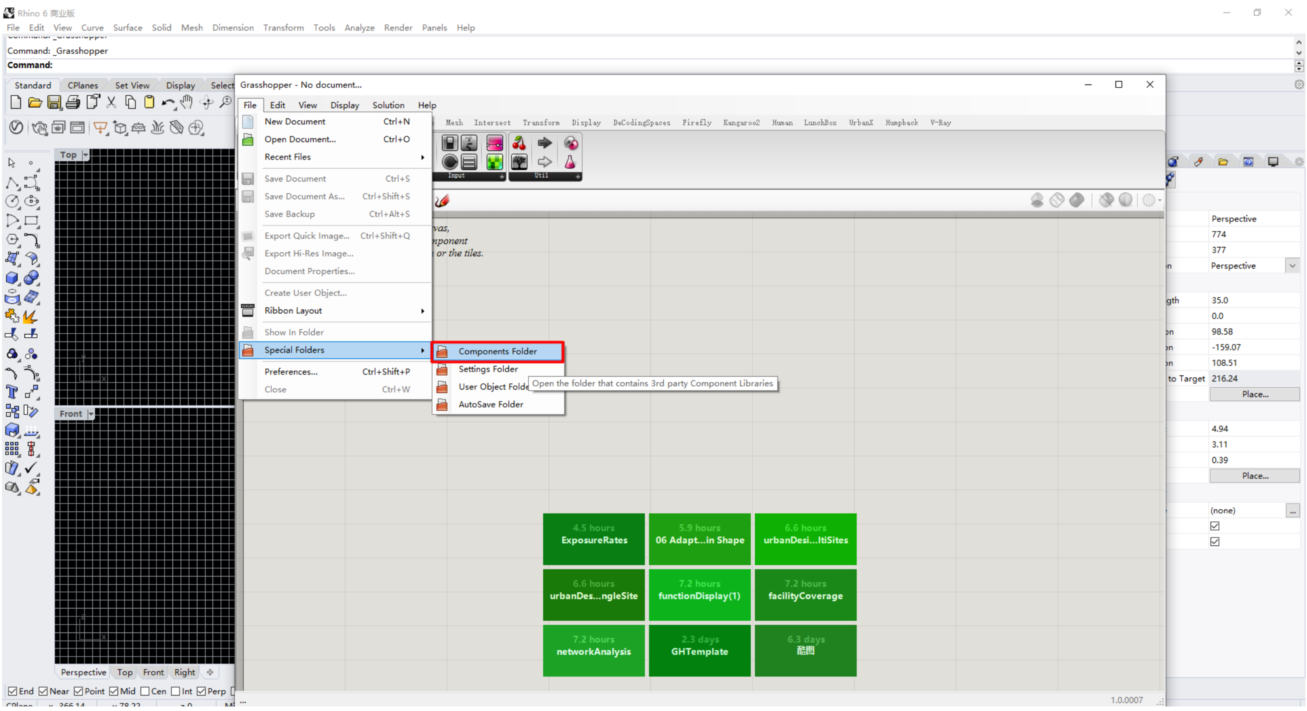


- Extract the zip file: UrbanXTools_v3.0.1

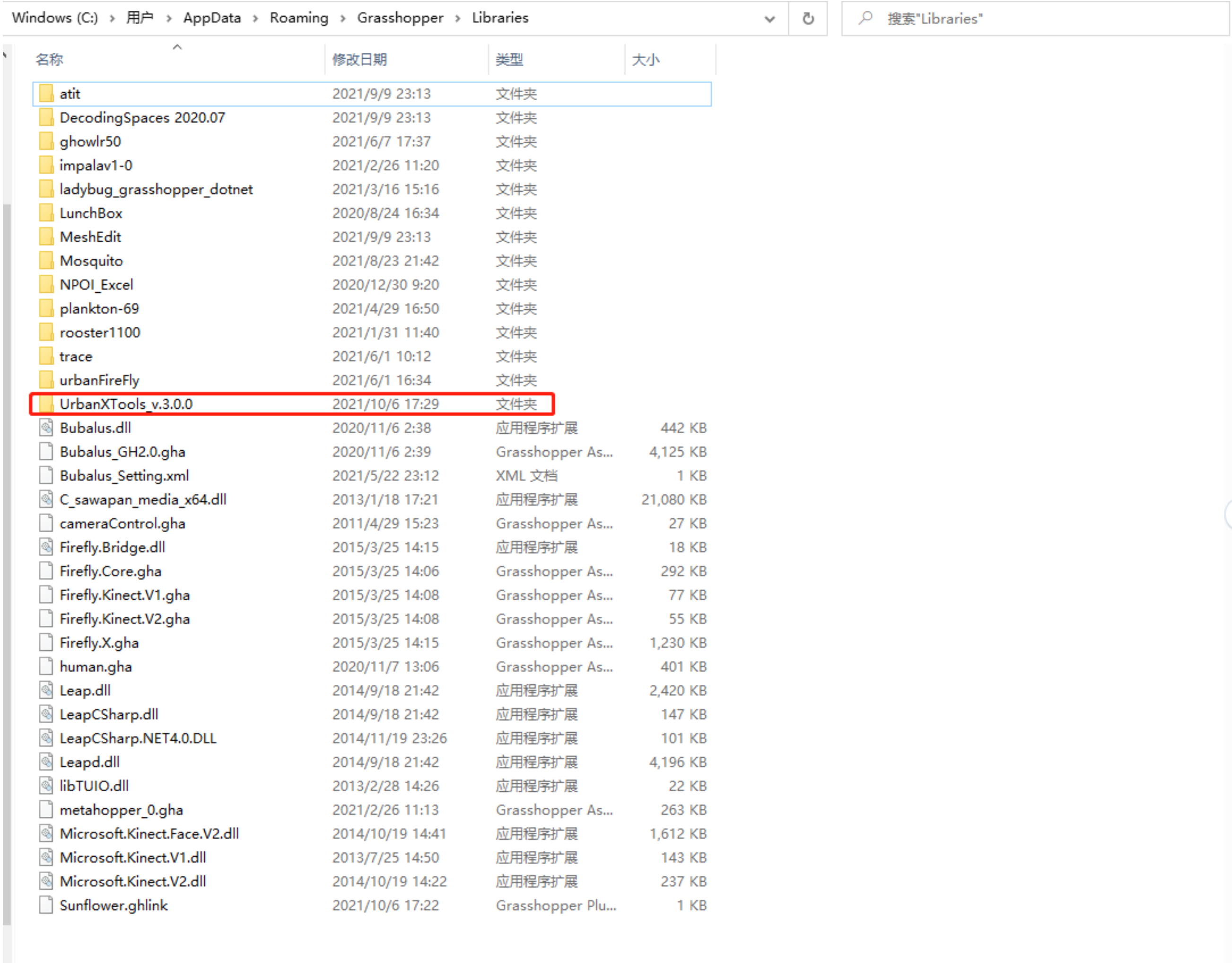


2. Open Grasshopper in Rhino, enter Components Folder

- Open Rhino and then Grasshopper, open File --> Special Folders --> Components Folder

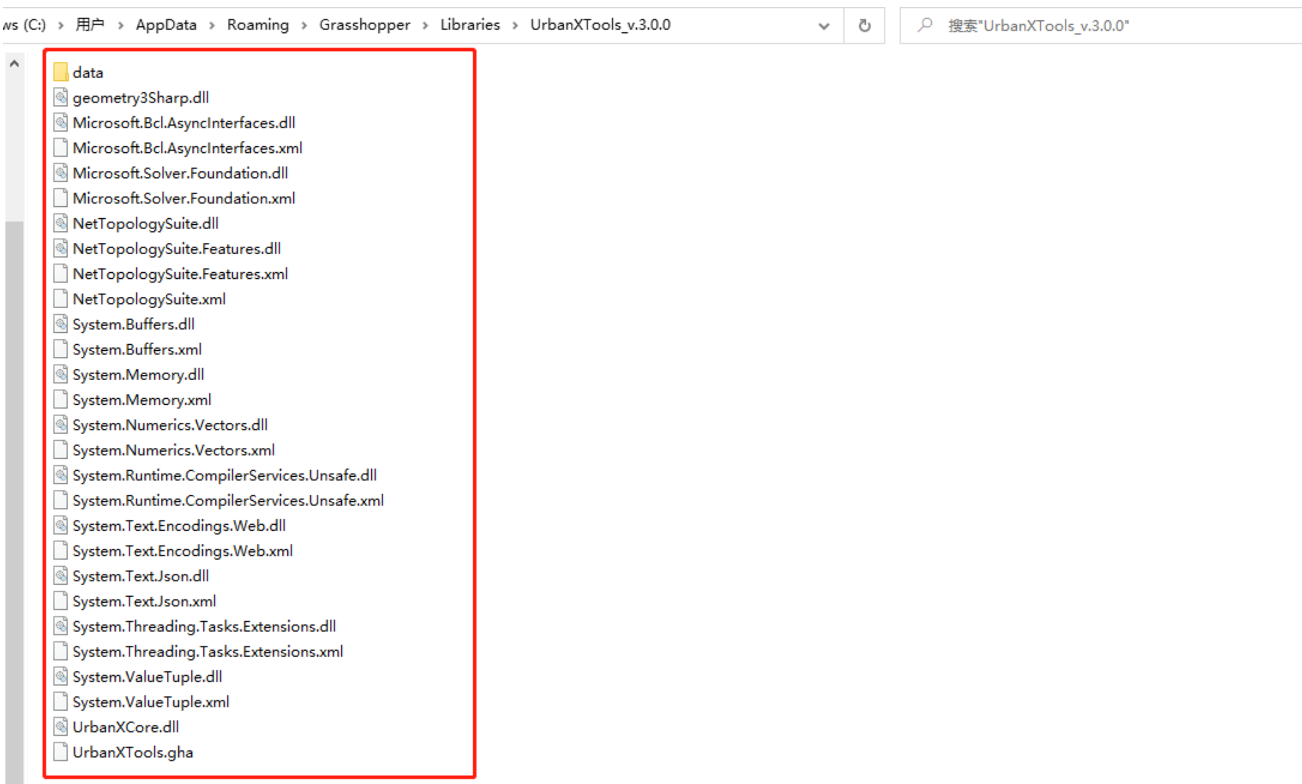


- Copy and paste the whole UrbanXTools_v3.0.1 folder here
- If you already have UrbanXTools_v.1.0.0 or UrbanXTools_v.2.0.0 in this folder, please delete them in advance.



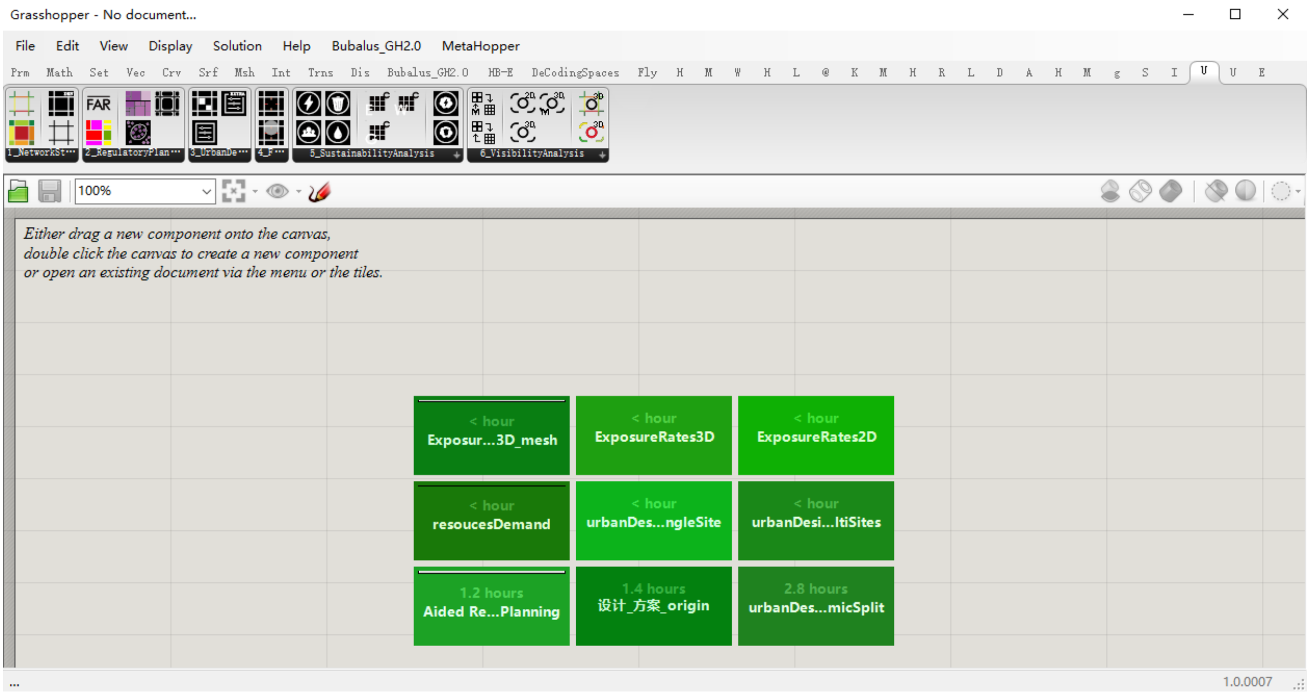
3. Check your UrbanXTools_v3.0.1 folder and then restart Rhino

- Make sure every file listed below are also in your UrbanXTools_v3.0.1 folder



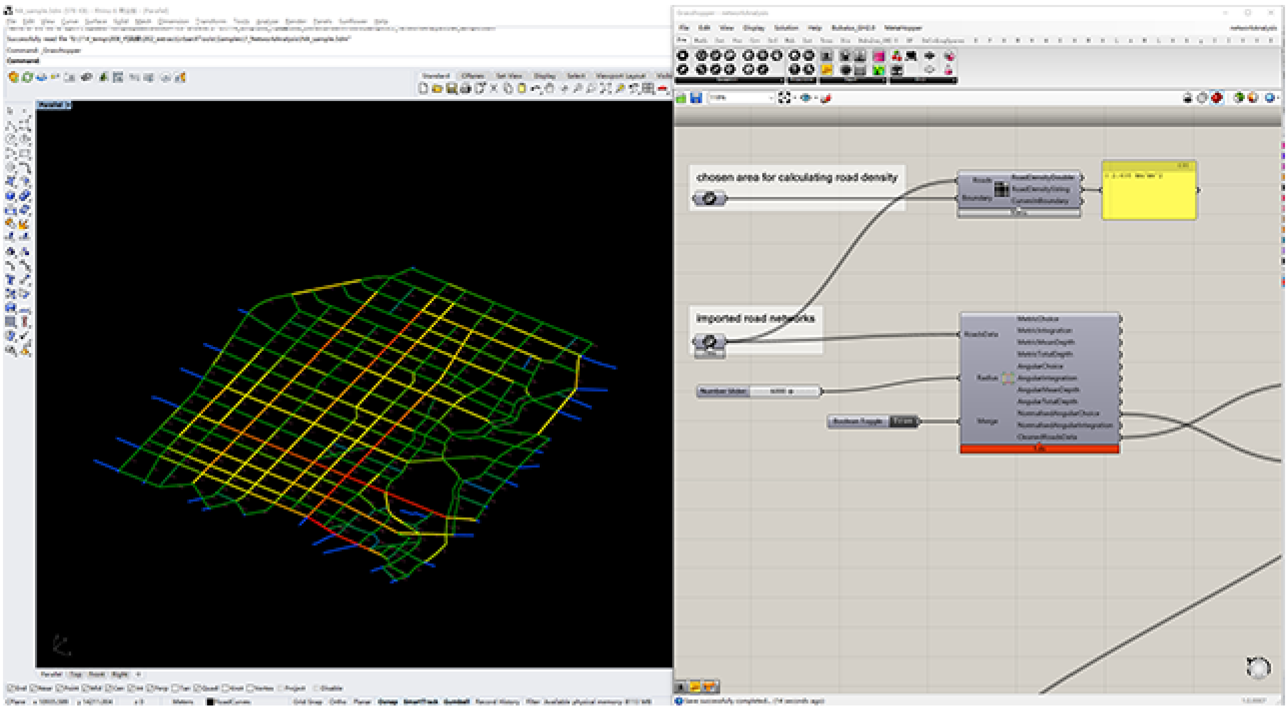
4. Finish

- If you have successfully installed UrbanXTools, you'll get this in your Grasshopper



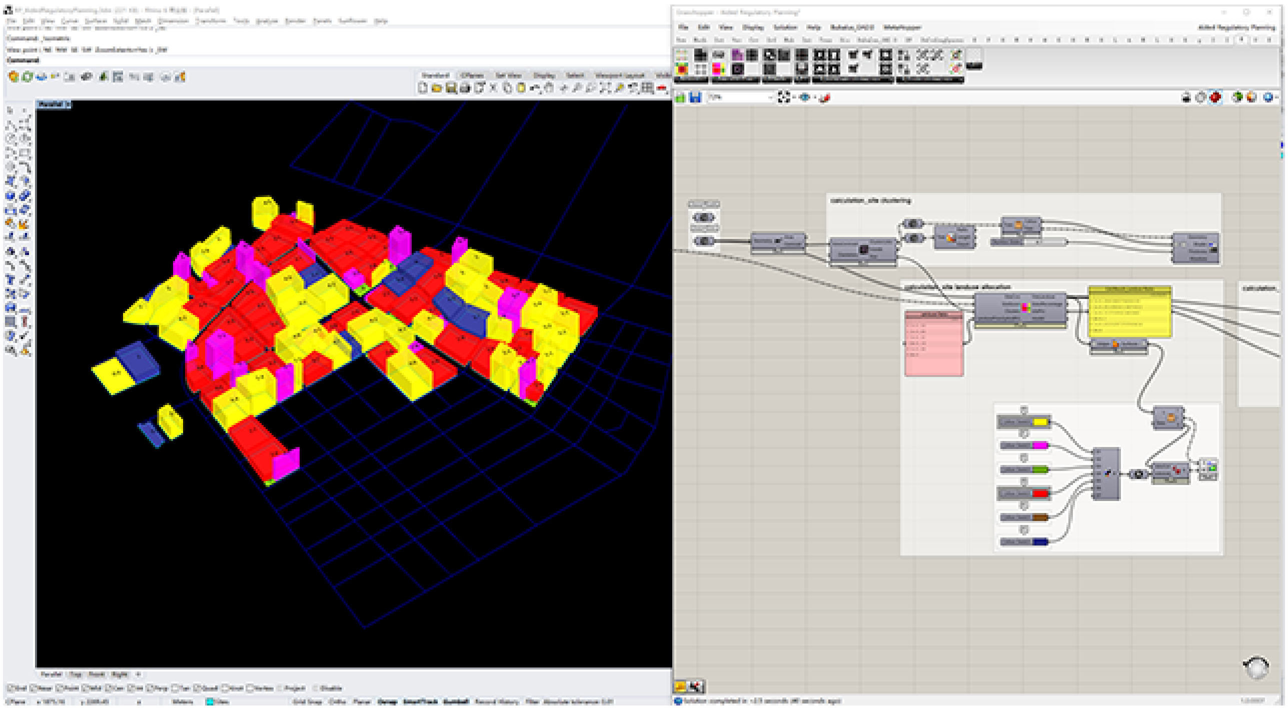
Samples

1. Network Structure



Sample: NetworkAnalysis

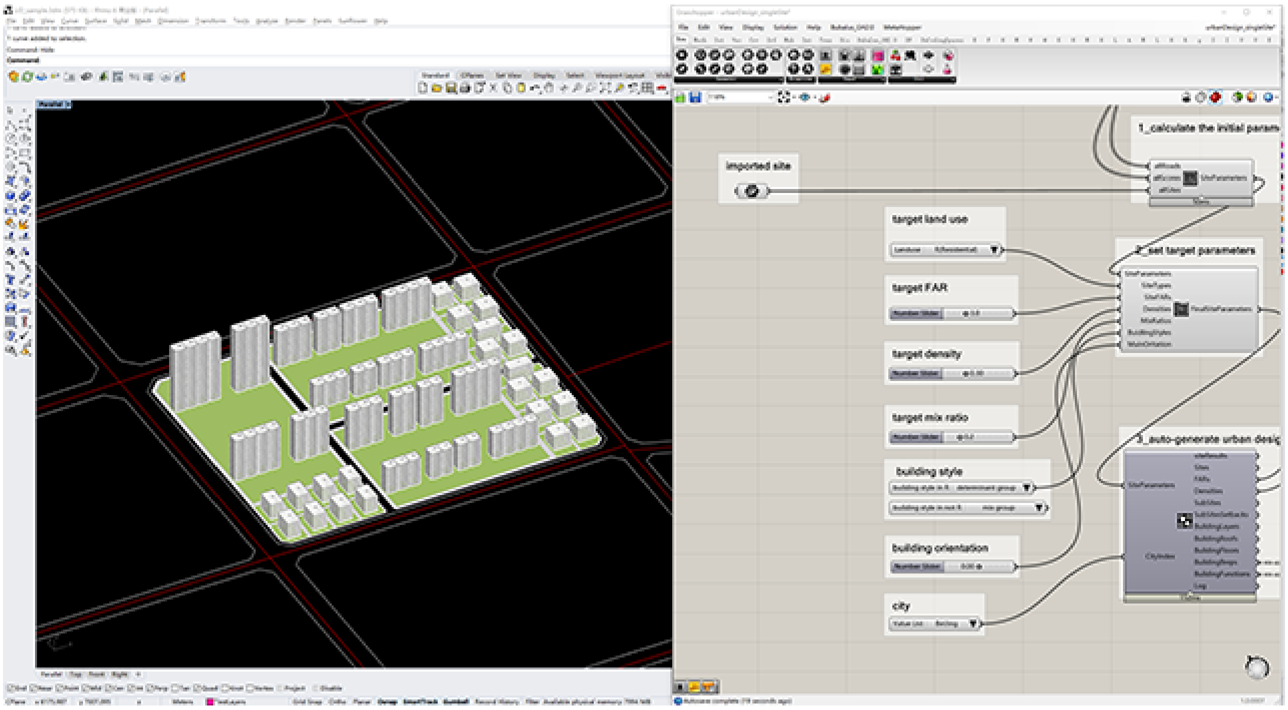
2. Aided Regulatory Planning



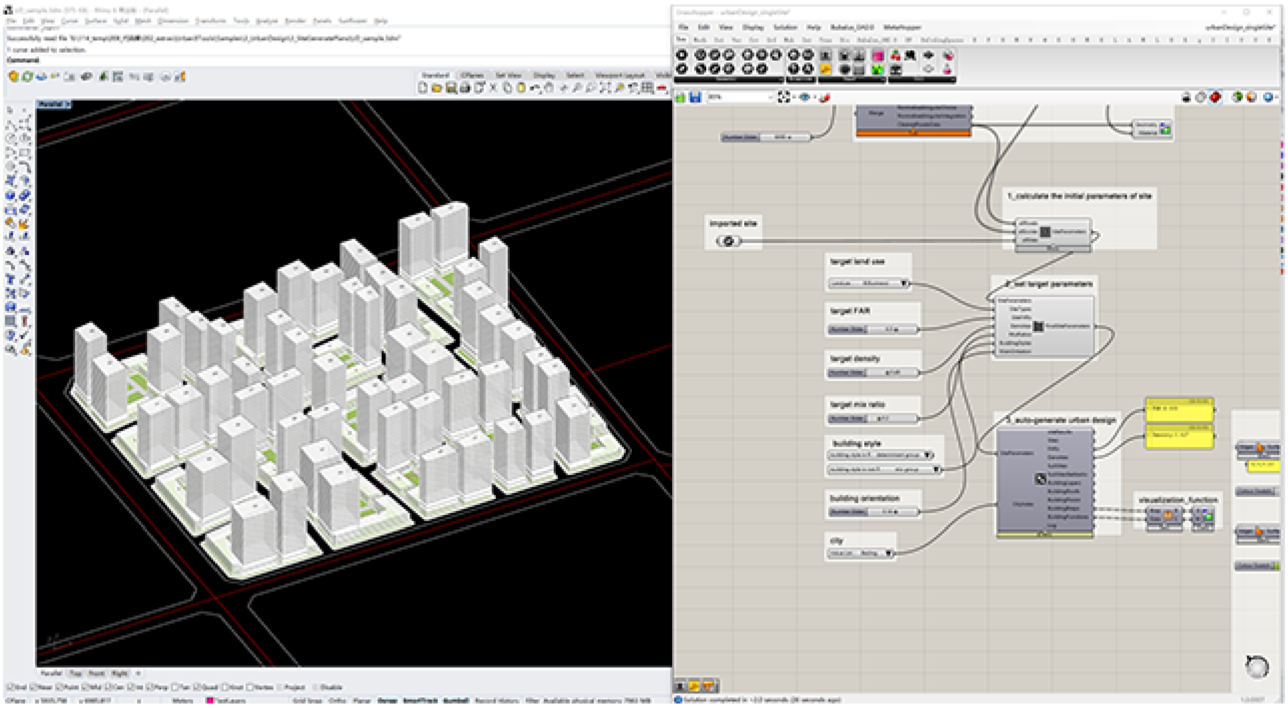
Sample: AidedRegulatoryPlanning

3. Urban Design Autogeneration

- Residential buildings



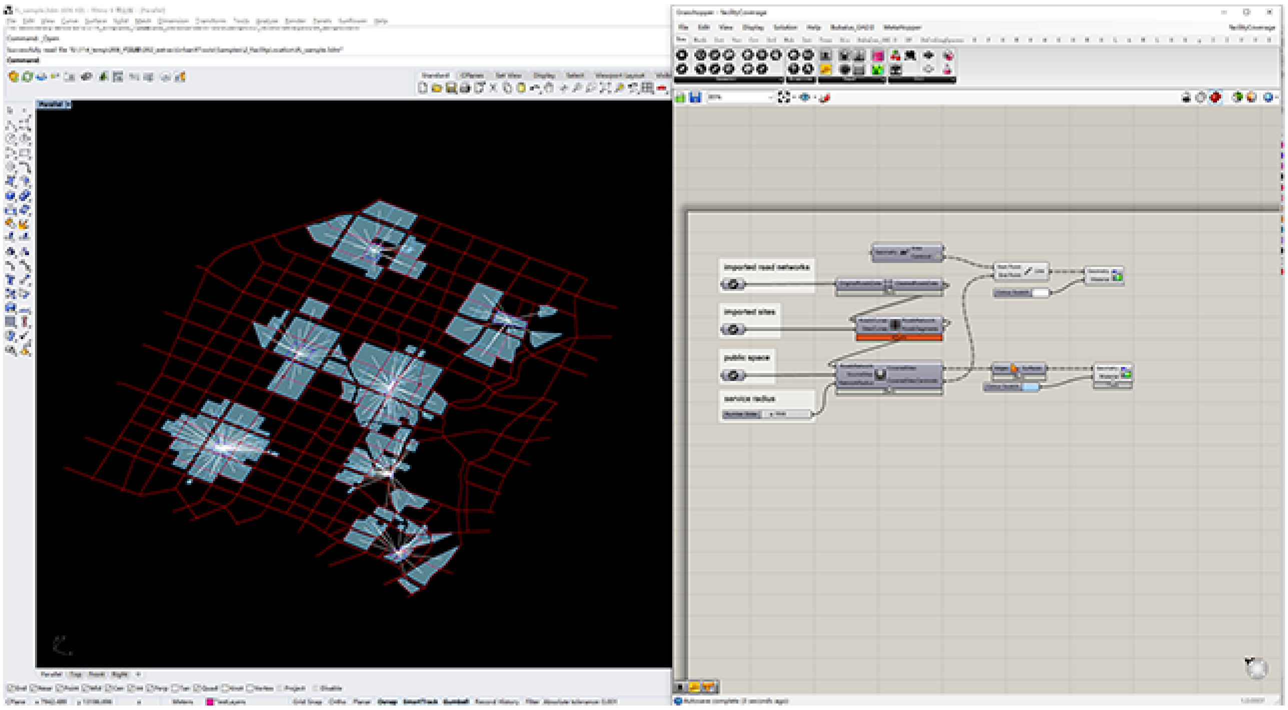
- Commercial buildings + Warehouses + Factories



Sample: UrbanDesign_SingleSite

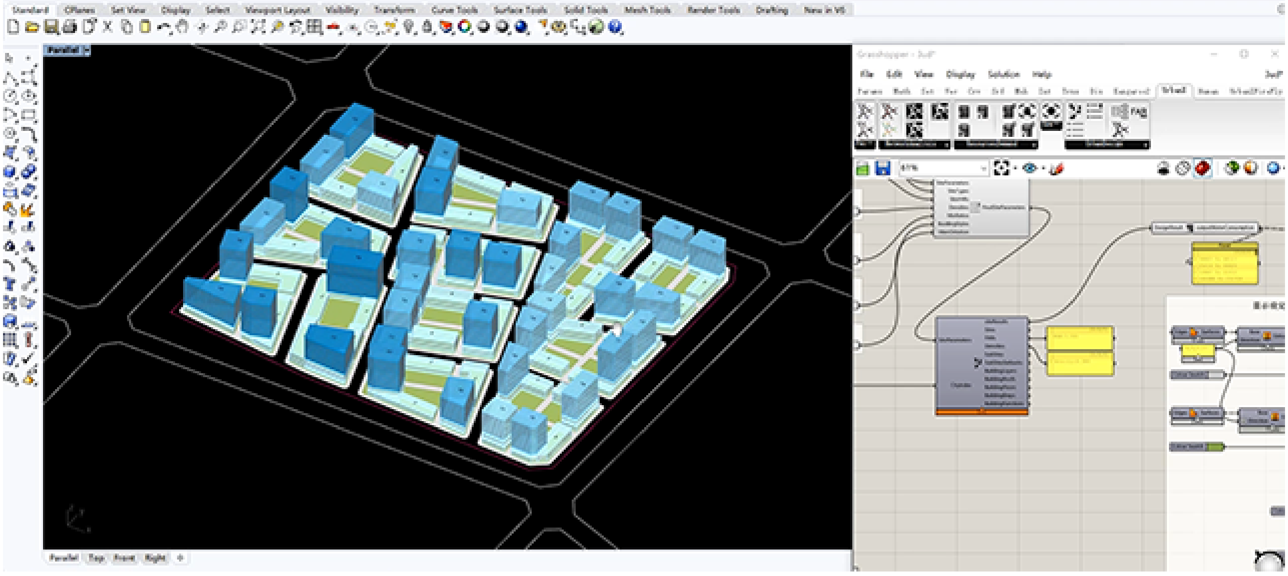
Sample: UrbanDesign_MultiSitesSites

4. Coverage Analysis of Public Facilities



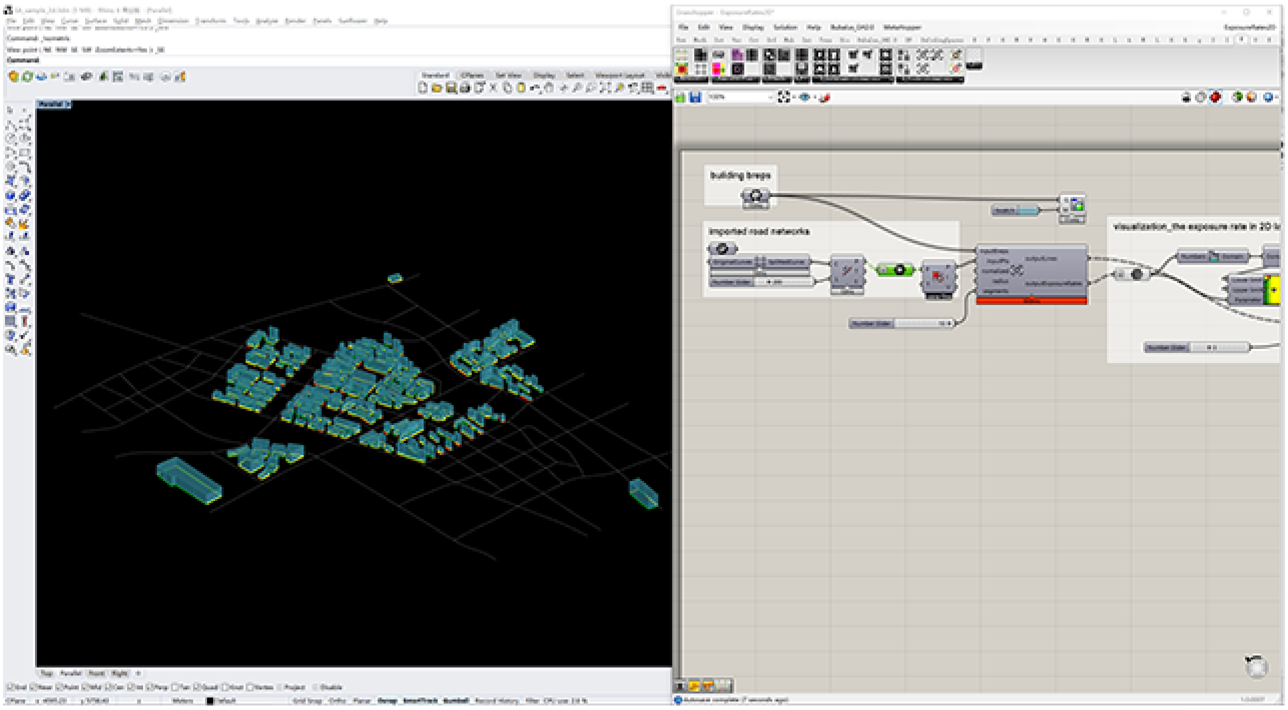
Sample: FacilityLocation

5. Sustainability Analysis of Urban Design Projects



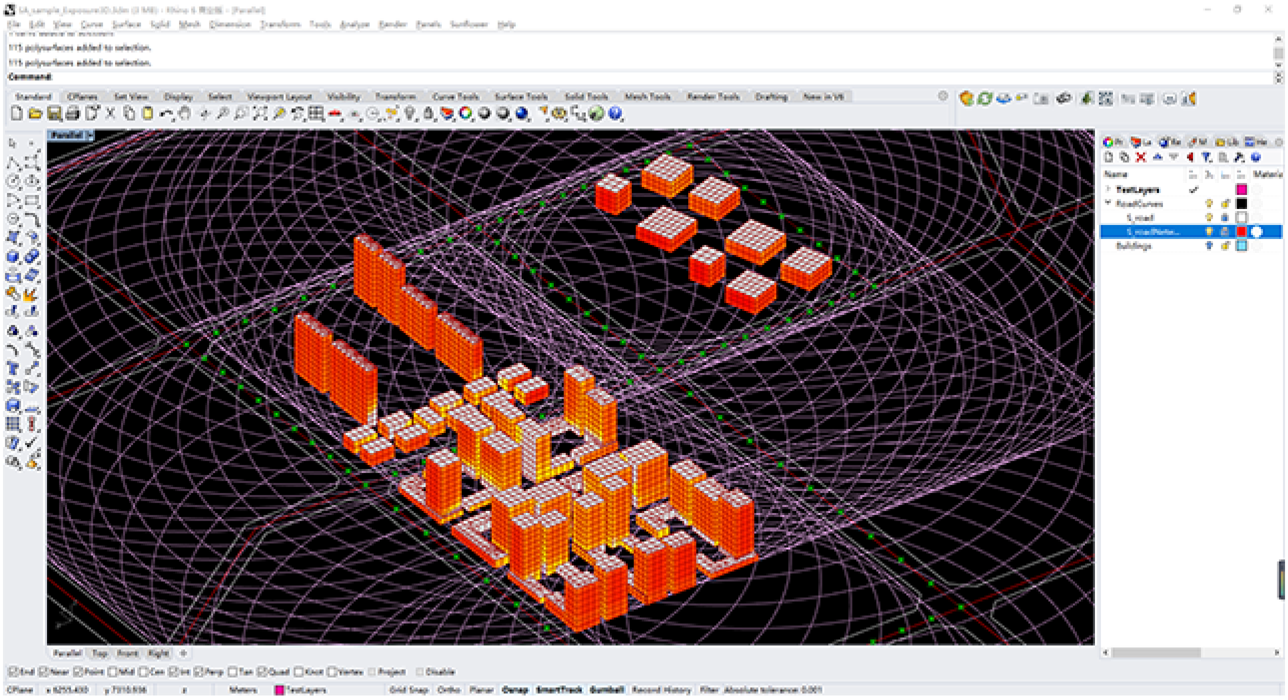
Sample: Resources Demand

6. Exposure Rate Analysis of Urban Design Projects (2D)



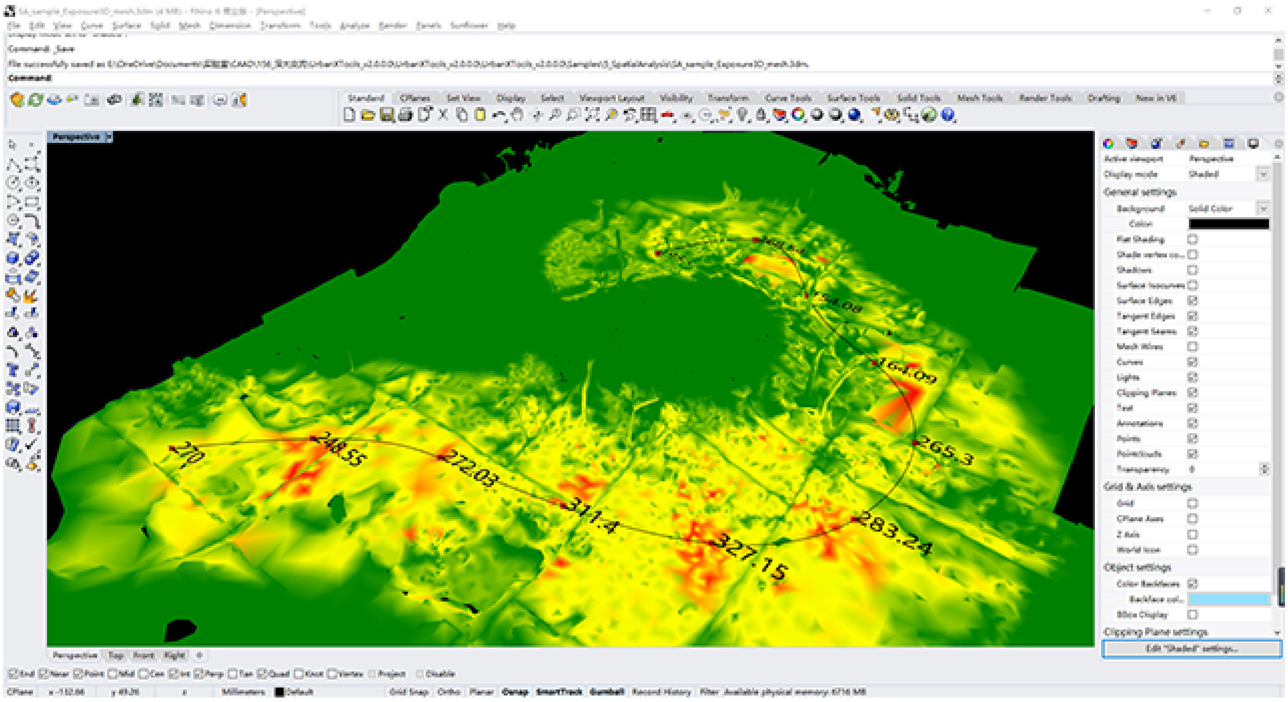
Sample: ExposureRates2D

7. Exposure Rate Analysis of Urban Design Projects (3D)



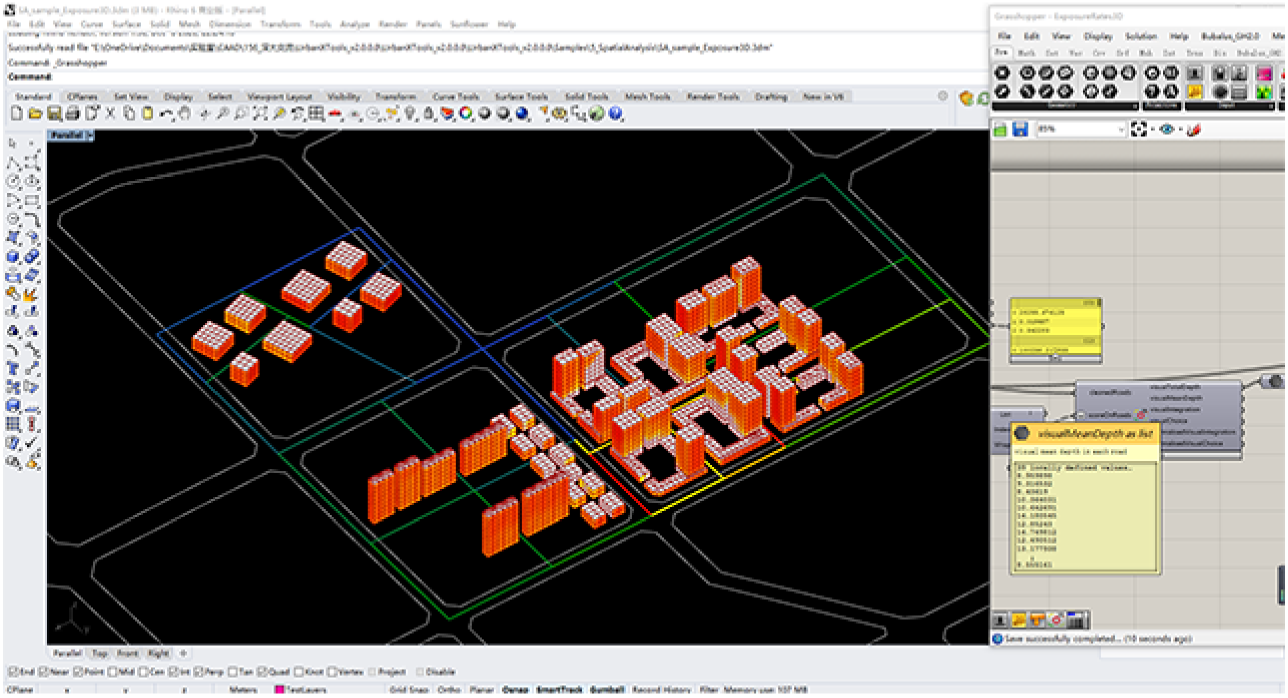
Sample: ExposureRates3D

8. Exposure Rate Analysis of Urban Design Projects (3D_Mesh)



Sample: ExposureRates3D_mesh

9. Visual Graph Network Analysis of Urban Design Projects



Sample: ExposureRates3D_visualGraphNetwork

Tools

1. Network Structure

> Network_RoadsSplitter

- **Purpose**:
  - Clean and split the curves to handle degeneracies, such as overlaps, identical shapes, invalid curves, etc.
- **Input**:
  - Original curves
- **Output**:
  - Cleaned and split curves
- **Sample**:

> NetworkStructure_Computing3D

- **Purpose**:
  - This command computes network properties, including angular distance and metric distance in space syntax. You may choose different radius for calculation.
  - Betweenness: Within a certain distance, this command finds the shortest paths between any pair of points and counts the number of times each road segment is passed.

  - Closeness: Within a certain distance, compute the average distance from this point to a specified destination point along the shortest paths.
- **Input**:
  - Road network of 2D or 3D geometries
  - Radius
  - Merging or not
- **Output**:
  - Metric choice
  - Metric integration
  - Metric mean depth
  - Metric total depth
  - Angular choice
  - Angular integration
  - Angular mean depth
  - Angular total depth
  - Normalized angular choice(NACH)
  - Normalized angular integration(NAIN)
  - Cleaned road-segments
- **Sample**:

NetworkStructure_SiteAccessibility

- **Purpose**:
  - This command computes the accessibility scores of sites
- **Input**:
  - Cleaned road segments
  - Accessibility scores of each road segment
  - Curves of site boundaries
- **Output**:
  - Polygons generated by site boundaries
  - Accessibility scores of sites, with the same sequence as polygons above
- **Sample**:

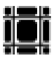
NetworkStructure_RoadDensity

- **Purpose**:
  - Compute road density within the given boundary

- **Input**:
  - Roads to be computed
  - Boundary
- **Output**:
  - Road Density (numeric data)
  - Road Density (unit: km/km²)
  - Road segments "cookie-cut" (intersected) by the given boundary
- **Sample**:

2. Regulatory Planning RegulatoryPlanning_GeneratingSites

- **Purpose**:
  - Automatically generate sites polygon based on the input road network
- **Input**:
  - A list of primary roads
  - A list of secondary roads (optional)
  - A list of tertiary roads (optional)
  - A list of branch roads (optional)
  - Width of roads in the order from primary roads to branch roads
  - Radius for rounding the site corners
  - The boundary within which sites will be generated
- **Output**:
  - All generated site polygons
- **Sample**:



RegulatoryPlanning_ClusteringBlocks

- **Purpose**:
  - Clustering a set of sites based on the shortest-path distance matrix by using Hierarchical Agglomerative Clustering (HAC) algorithm
- **Input**:
  - Roads
  - Sites
  - Diameters for each clustering levels
- **Output**:
  - Links for visualizing the hierarchical relationships among the clusters
  - Id for each site in the tree structure to represent the hierarchy of all clusters

  - An object containing all the information of the clustering results to be used in the RegulatoryPlanning_LanduseAllocation component
- **Sample**:

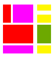
RegulatoryPlanning_ClusteringPoints

- **Purpose**:
  - Clustering a set of sites based on the euclidean distance matrix among all centroids of the sites by using Hierarchical Agglomerative Clustering (HAC) algorithm
- **Input**:
  - Centroids of each site
  - Diameters for each clustering levels
- **Output**:
  - Links for visualizing the hierarchical relationships among the clusters
  - Id for each site in the tree structure to represent the hierarchy of all clusters
  - An object containing all the information of the clustering results to be used in the RegulatoryPlanning_LanduseAllocation component
- **Sample**:

RegulatoryPlanning_LanduseAllocation

- **Purpose**:
  - Automatically allocating landuse to each of the sites
- **Input**:
  - Sites
  - Accessibility scores with different radius for each site (Recommended: 3 branches)
  - The object containing all the information of clustering results, which is obtained from the RegulatoryPlanning_ClusteringBlocks component
  - Landuse structure, with the order representing their priority, and their values indicating their proportion of area among all the sites respectively (Format: R:0.2)
- **Output**:
  - Sites, wihch may be split after the landuse allocation to fulfill the requirement of landuse structure
  - Allocated landuse for each site, with the same sequence as the sites above
  - Actual landuse structure
  - The object containing all the results of landuse allocation, which is useful for the RegulatoryPlanning_FarAllocation component

- **Sample**:

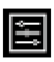


RegulatoryPlanning_FarAllocation

- **Purpose**:
  - Automatically allocating floor area ratio (FAR) to each of the sites
- **Input**:
  - The object containing all the results of landuse allocation, obtained from the RegulatoryPlanning_LanduseAllocation component
  - Total building area for the overall urban design
  - Building area structure, represented by the percentage of building area of each category of landuse
- **Output**:
  - Allocated FAR for each site
- **Sample**:

3. Urban Design UrbanDesign_SiteParameter

- **Purpose**:
  - This command autogenerates site parameters based on roads, accessibility scores and site info.
- **Input**:
  - Cleaned roads
  - Accessibility scores for each road segment
  - Curves of site boundaries
- **Output**:
  - Initial parameters for all the sites
- **Sample**:



UrbanDesign_SiteParameterExtra

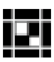
- **Purpose**:
  - This command allows you to adjust site parameters, such as FAR and building density
- **Input**:
  - Initial parameters of all sites, obtained from the UrbanDesign_SiteParameter component

- Landuse Type (R:0, C:1, GIC:2, M:3, W:4)
- FAR
- Density
- Mixed Ratio
- Building Styles
  - For residential buildings: 0-Rows, 1-Dots
  - For non-residential buildings: 0-Dots, 1-Groups, 2-Mixed
- Orientation of buildings (Unit: Radians)

- **Output**:
  - Adjusted parameters for each site
- **Sample**:

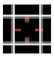
UrbanDesign_SiteGeneratePlans

- **Purpose**:
  - This command autogenerates building entities.
- **Input**:
  - Adjusted parameters for all sites, obtained from UrbanDesign_SiteParameterExtra component
  - City ID
- **Output**:
  - The object containing results of the design, which is useful for the Sustainability Analysis module
  - Curves of original site boundaries (not split)
  - FARs
  - Building densities
  - Subsite boundaries
  - Setback boundaries for each site
  - Outline curves of the floor layer of each building
  - Outline curves of each building roof
  - Numbers of levels of each building
  - Brep geometries of each building
  - Functions of each brep of each building, corresponding to building breps
- **Sample**:



4. Facility Analysis FacilityAnalysis_ConnectToNetwork

- **Purpose**:
  - Connect all sites to their nearest road segments
- **Input**:
  - Cleaned road network
  - Sites
- **Output**:
  - Generic parameters, which is useful for the FacilityAnalysis_CoverageArea component
  - New road segments after computing the connection
- **Sample**:



FacilityAnalysis_CoverageArea

- **Purpose**:
  - Compute facilities' coverage area by shortest-path distances in the road network based on a given radius
- **Input**:
  - Generic parameters, obtained from the FacilityAnalysis_ConnectToNetwork component
  - Sites where public facilities locate
  - Service radius of the facilities, which is defined as shortest paths within the road network
- **Output**:
  - Sites within facilities' coverage area
  - Centroids of all covered sites
- **Sample**:

5. Sustainability Analysis SustainabilityAnalysis_Energy

- **Purpose**:
  - Compute the energy consumption for each building in the autogenerated plan
- **Input**:
  - Generic parameters containing the original results of the design, obtained from UrbanDesign_SiteGeneratePlans component
- **Output**:
  - Energy consumption of each building
- **Sample**:

SustainabilityAnalysis_EnergyCarbonEmissions

- **Purpose**:
  - Compute the carbon emissions for generating the given amount of energy
- **Input**:
  - Energy consumption (Unit: kWh/year)
- **Output**:
  - Carbon emissions for generating the given amount of energy (Unit: tCO2/year)
- **Sample**:

SustainabilityAnalysis_Water

- **Purpose**:
  - Compute the water consumption for each building in the autogenerated plan
- **Input**:
  - Generic parameters containing the original results of the design, obtained from UrbanDesign_SiteGeneratePlans component
- **Output**:
  - Water consumption of each building
- **Sample**:

SustainabilityAnalysis_Waste

- **Purpose**:
  - Compute waste production for each building in the autogenerated plan
- **Input**:
  - Generic parameters containing the original results of the design, obtained from UrbanDesign_SiteGeneratePlans component
- **Output**:
  - Waste production of each building
- **Sample**:

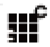
SustainabilityAnalysis_WasteCarbonEmissions

- **Purpose**:
  - Compute the carbon emissions for waste treatment

- **Input**:
  - Domestic waste generation which requires further treatment (Unit: tons/year)
  - Method of waste treatment (0-"waste_landfill", 1-"waste_incineration", 2-"waste-composting")
- **Output**:
  - Carbon emissions for waste treatment (Unit: tons CO2/year)
- **Sample**:

SustainabilityAnalysis_EnergyCustom

- **Purpose**:
  - Compute energy consumption of buildings based on the custom input
- **Input**:
  - Building breps
  - Building functions of each brep
- **Output**:
  - Energy consumption for each building
- **Sample**:



SustainabilityAnalysis_WaterCustom

- **Purpose**:
  - Compute water consumption of buildings based on the custom input
- **Input**:
  - Building breps
  - Building functions of each brep
- **Output**:
  - Water consumption for each building
- **Sample**:

SustainabilityAnalysis_WasteCustom

- **Purpose**:
  - Compute waste production of buildings based on the custom input
- **Input**:
  - Building breps
  - Building functions of each brep

- **Output**:
  - Waste production for each building
- **Sample**:

SustainabilityAnalysis_Population

- **Purpose**:
  - Estimated population of each residential building
- **Input**:
  - Building breps
- **Output**:
  - Estimated population of each building
- **Sample**:

6. Visibility Analysis VisibilityAnalysis_ExposureRate2D

- **Purpose**:
  - By analyzing its relationship to road intersections, this command returns 2D exposure rate for ground floor commerce, which could be a quantified spatial feature considered in commercial site selection process.
- **Input**:
  - Building breps
  - Preset view points
  - Normalize or not
  - Radius of viewshed
  - Subdivision (higher value will lead to higher accuracy but also longer runtime)
- **Output**:
  - Outlines of building breps
  - Exposure rate for brep outlines
- **Sample**:

VisibilityAnalysis_GenerateMeshBuilding

- **Purpose**:
  - Convert buildings from Rhino Brep to DMesh according to subdivision. This command aims to improve computational efficiency.
- **Input**:

- Rhino Brep of buildings
- Subdivision (default as -1) (higher value will lead to higher accuracy but also longer runtime)

- **Output**:
  - GenerateMesh Class
- **Sample**:

VisibilityAnalysis_GenerateMesh

- **Purpose**:
  - Convert geometry from Rhino Mesh to DMesh. This command aims to improve computational efficiency.
- **Input**:
  - Mesh
- **Output**:
  - GenerateMesh Class
- **Sample**:

VisibilityAnalysis_ExposureRate3DBuildings

- **Purpose**:
  - By analyzing its relationship to view points, this command returns 3D exposure rate for buildings, which could be a quantified spatial feature considered in commercial site selection process.
- **Input**:
  - Preset view points
  - GenerateMesh Class
  - View range in each point as radius (default as 300)
- **Output**:
  - Colored side mesh of each building
  - Uncolored top mesh and bottom mesh
  - Count of each mesh got intersected
  - Exposure rates for each view point
- **Sample**:

VisibilityAnalysis_ExposureRate3DMesh

- **Purpose**:
  - By analyzing its relationship to view points, this command returns 3D exposure rate for mesh entities which could be a quantified spatial feature considered in commercial site selection process.
- **Input**:
  - Preset view points
  - GenerateMesh Class
  - View range in each point as radius (default as 300)
- **Output**:
  - Colored Mesh
  - Count of each mesh got intersected
  - Exposure rates for each view point
- **Sample**:

VisibilityAnalysis_VisualCalc

- **Purpose**:
  - Compute the visibility of road network by interpolating points in 3D context
- **Input**:
  - Preset road network
  - GenerateMesh Class
  - Subdivision of roads to be divided (Unit: meter, default: 500m)
  - View range in each point as radius (default as 300)
  - Output Mesh or not
- **Output**:
  - Cleaned roads, which is useful in the VisibilityAnalysis_VisualSyntaxComputing component
  - Viewpoints on roads
  - Visibility properties of each road
  - Colored mesh (depending on whether you choose to output mesh)
- **Sample**: 

VisibilityAnalysis_VisualSyntaxComputing

- **Purpose**:
  - Compute visual graph network analysis by input road network and corresponding scores in 3D context
- **Input**:
  - Cleaned roads, obtained from the VisibilityAnalysis_VisualCalc component

- Corresponding scores of each road
- Radius (default as -1, which leads to global calculation)

- **Output**:
  - Visual total depth
  - Visual mean depth
  - Visual integration
  - Visual choice
  - Normalized visual integration
  - Normalized visual choice
- **Sample**:

6. WaterPipeNetwork_Calculation（Coming Soon)

▶ WaterPipeNetwork Parameters

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Releases 9

UrbanXTools_v3.0.1 Latest
on 16 Dec 2021

+ 8 releases

Packages

No packages published
Publish your first package

3. Production driven logistical performance integrating with urban transportation

1. Provisional Title

Production driven logistical performance integrating with urban transportation

2. Background:

Resilience has been widely accepted as a critical concept in monitoring and navigating the complexities of human and environment system (Li, Kappas, and Li 2018). As a complex environment that combined human and environment, cities frequently experience situations that interfere in travelling activities such as the occurrence of emergency delivery or recurrent events, such as inefficient urban freight which low driving speed and accidents (Leobons, Gouvêa Campos, and Mello Bandeira 2019). Any decrease in the transportation system's performance could jeopardize many city sectors' operation, causing great inconvenience to the population and economic loss('Resilient Urban Mobility a Case Study of Integrated Transport in Ho Chi Minh City - Arup' n.d.). Thus, a new way of resilience strategies that focus on urban freight needs to be considered in order to reduce the effect on transportation systems. In this context, improving resilience through strategies includes various prevention, mitigation and restoration activities(Adams, Bekkem, and Toledo-Durán 2012).

In urban transportation, the goal of resilience is to reduce impact by maintaining or restoring a normal level of mobility in the shortest time possible (Leobons, Gouvêa Campos, and Mello Bandeira 2019), considering bother passengers and freight transportation. According to the World Bank report in 2009, urban freight transport represents between 20 to 25% of road space contributing to between 10 to 20 % of urban road traffic. Especially after covid-19, although physical contact among people has progressively decreased during this period, it is hard to reduce the need for daily supplies. In May, the volume of express delivery business in China reached 7.3 billion units, which increased by 39.6% compared to last month(Zhou 2020). The movement of goods happens in every urban area nowadays. Thus, simulating how logistics evolve in the urban area in advanced could be a possible method to mitigate urban freight congestion and improve urban resilience. However, such urban goods movements have not received the same attention than people's movements (Wang, Liu, and Shang 2014). Those factors that would affect urban logistics deserve the careful attention of urban-transportation planners.

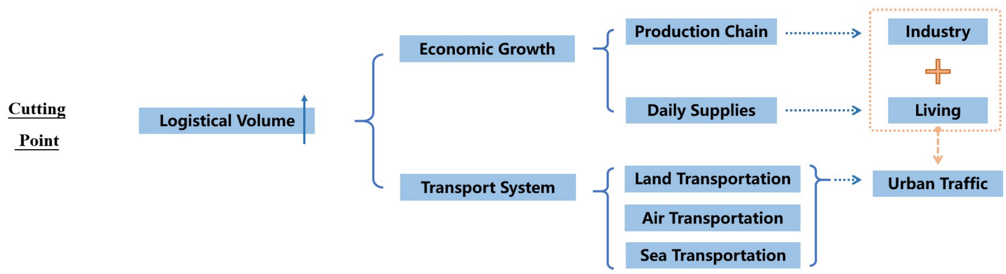
Researchers found that the spatial layout of urban logistics service node and urban road network topology structure will influence the urban logistics service supply capacity. Traditionally, logistics analysts divide decisions level into strategic, tactical and operational, respectively. Each level is considered separately for modelling purpose. Miranda and Garrido(2006) combined these three levels based on urban spatial structure and present a cross-level model designed to analyze inventory control and facility location decisions. Wang(2005) raised an index system of logistics centre location based on the factor analysis method, including selecting the section and location genes, the analytic hierarchy process and the cluster analysis method. Urban logistics network is not only about nodes, but also links. Yan, Yang, Liu and Kang(2007) incorporated the location model and genetic algorithm in their study to connect the logistics centre and road network as an integrated city logistics network.

Fu(2016) established an extended and weighted Barabasi Albert model for the agglomeration and dispersion of logistics network in her research project and claimed that the evolution of urban logistics network has the potential to optimize the allocation of urban resources and urban spatial structure, especially for land use. Thus, urban spatial planning and design could be regarded as an essential part of the urban-transportation early design phase.

There are also many studies illustrate that economic growth and increase consumption level have great influence on the urban freight system. Narayanaswami claimed that the increasing economics and population would increase business and household demand for general freight across the urban area(2016). From the angle of macro-economic, Modern theory of logistics in China was introduced in the 1980s. Since its economic reformed and opened up in 1978, China's economy keeps booming, with a growth rate of nearly 10% in annual GDP, which has become a global manufacturing centre(Li & Fung Research Centre 2008). China's logistic industry has been experiencing fast growth because of sustainable economic growth. According to the logistics industry reported, the average annual growth rate of the logistics industry in China was 22.2%, added value reached RMB 1.4 trillion in 2006 up 13.9% over 2005; and in 2007, the added value even reached near 1.7 trillion up 20% over 2006. It is expected that China's logistics market value will continue to maintain annual growth of 20% in 2010('Development of Logistics Industry in China' n.d.).

On the other hand, using information gathered from some 30K surveys undertaken over the last 15 year (Allen et al. 2008), the findings indicate through micro urban level, the average High Street Business could expect to 10 core goods and 7.6 service visits per week, in non-peak trading period with 25% additional activity during the build-up to Christmas. With the economic level increase, urban freight starts to represent a higher ratio in urban space. Due to urban freight transports' economic importance over the last decade, it is important to focus far greater attention on freight transport efficiency and suitability. Thus, it is necessary to extract the connection between urban logistics system and citizens' demand estimated via the economic growth. Besides the urban spatial structure mentioned above, this model would provide planners with an understanding of road-based urban freight transport activity based on economic factors.

In conclusion, studies have shown that urban logistics is significantly related to urban spatial structure and economic performance. The current exploration of combining economic factors with logistics or combining urban spatial factors with urban freight has shown a great potential to improve the design/planning of urban transportation efficiency and it needs to be further developed. Thus, this research aims to build a mathematic model that would depict the spatial evolution of logistic in the urban area via extract those factors that would affect urban freight, and those affected by urban freight, then used to predict the evolution of logistics.



3. Keyword

Logistical System, Urban Freight, Production Logistics, Logistics Demand, Urban Spatial Structure, Land Use, Transportation Systems, Economic Production, Complex System

4. Hypothesis

According to the background research and literature review, this proposal raised a hypothesis that there is a novel way to describe the evolutional mechanism of logistics in the urban area via integrating with economic productions factors and transportation system.

To extract the evolutional mechanism of urban freight grows, the start point of this research is to estimate the logistical reflection on transportation system based on economic growth. The logistics system could be divided into four parts: logistics generation, logistics distribution, logistics chain selection, and logistics network assignment. As the image below describes, due to the logistics system's background, urban economic growth would increase the volume of logistics generation via industrial development or higher-level consumption. Logistics distribution would expand because of higher logistics demand. The transportation system would then be affected via logistics chain selection (land, air or sea) and logistics network assignment. Therefore, the potential solution of improving urban transportation resilience is to clarify the relationship between logistics evolution, urban space and economic production in order to solve this question.

The model can be used in two ways:
1. In the early planning stage, integrating urban spatial structure and economic production information with the evolution of logistics distribution, this model could predict the freight volume in urban area. Based on this value, urban transportation planners can minimize the impact of the rapid growth of urban logistics on urban traffic roads and maintain the accessibility of road network and the efficiency of urban goods movements.

2. In the process of urban operation, first, once the rapid economic rise is found, the pressure on road freight can be quickly predicted, temporary measures can be taken for specific areas of traffic congestion for maintaining transportation speed, for example, change transportation routes, adjust the order or time of delivery. Second, due to economic calculations and land use surveys being a long-term event, there is often no way to evaluate the data in a short period. However, urban freight data can be quickly obtained and analyzed. Thus, through these sensitive data, long-term data can be monitored in a short period. For example, a rapid

increase in urban freight might because of the abrupt changes in economic production. On the other hand, those data could be used to monitor whether the land use is violated.

Resilience definitions are conceptualized in two principal ways: one perspective recognizes resilience as the recovery time of the system to balance back to a formal stable state; another refers to the external disturbances a system can adapt to without losing its critical functions(). The theory of resilience explores a holistic way to interpret urban ecosystem dynamics related to interconnections of predominant factors affecting ecosystem balance and adaptability. It Holds that interconnections in human-environment systems help system to maintain its equilibrium or create the ability to adapt against disturbance. The dynamics of the human system influence the environmental system, and in turn, the response of the environment system trigger further changes in the human system ((Zhou 2020)). Thus, this model that combined economic production, logistics and urban transportation system might be a possible way to simulate how urban freight grows. Also, support urban-transportation planner to assess the consequences of optional actions or possible developments for the system's performance.

5. Aim & Objectives:

a. Aim

Based on this understanding, this research aims to explore the methodology of logistics network assignment in urban transportation system, based on economic growth, production chain, and land use.

b. Objectives:

- Obtain the current knowledge about production logistics, logistics demand, logistics distribution, logistics network assignment and transportation demand.
- Find impacts of economic growth on the production chain, also on logistics demand.
- Realize the procedure among logistics demand, logistics distribution, logistics chain selection and logistics network assignment.
- Realize the connection between logistics network assignment and urban transportation system.
- Develop the model of production driven logistics performance, integrating with urban transportation system

6. Research Questions

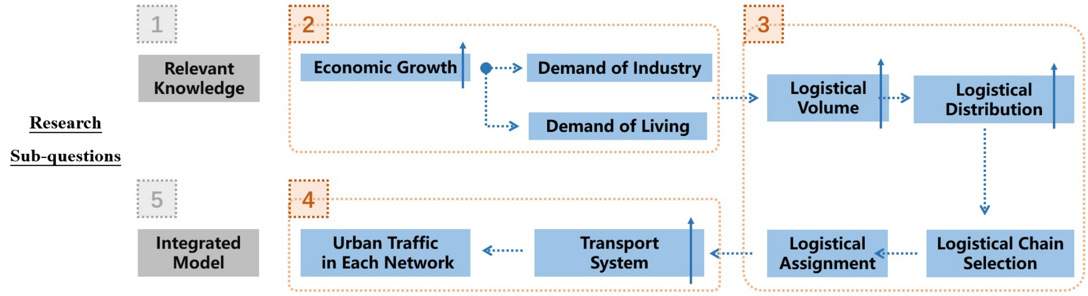
a. Main-Question

how to integrate transport system and logistics based on urban economic development?

b. Sub-Questions

This question could be divided into five sub-questions, as shown in the image below.

1) what is the relevant knowledge for this research?
2) how urban economic development would improve the volume of logistics?
3) how would logistical distribution expand based on increased logistical volume?
4) how would developed logistical distribution affect urban freight?
5) how to integrate the whole model among economic, logistics, and transportation?



i. *What is the relevant knowledge for this research?*

The relevant knowledge includes three aspects:
What is currently known about the relationship between economic production and logistics?
What is currently known about the development of logistical network and logistical centre?
What is currently known about the relationship between logistics and transportation system?

ii. *What is the proper estimation method for logistics distribution expanding based on increased economic production?*

Many studies mentioned that there are many economic factors that relevant to logistics distribution and logistics network structure. Currently, there are various logistics demand estimation methods based on macro-economics. However, those methods are challenging to locate logistics distribution into a specific area, Find out the algorithm to simulate how logistics centres locate and develop it is necessary for this research.

iii. *What are the impacts of logistics on urban transportation?*

There are some study shows that logistics can affect urban transportation, but how big the influence is, what is the mechanism behind logistics affecting transportation system, and what delivery parameters of urban freight can influence on is not clear.

iv. *How to integrate the whole model among economic, logistics, and urban transportation?*

It is necessary to discuss the qualitative and quantitative relationship between logistical distribution and urban freight to assign logistics pressure into urban road network. Besides, logistical distribution and urban freight both play an essential role in forecasting the performance of the urban spatial logistics system. The relationship among economic production, logistics demand, logistics distribution, logistics chain selection, and logistics network assignment will be further developed to realize the evolutional mechanism of logistics system and the reflection of urban freight on urban road network.

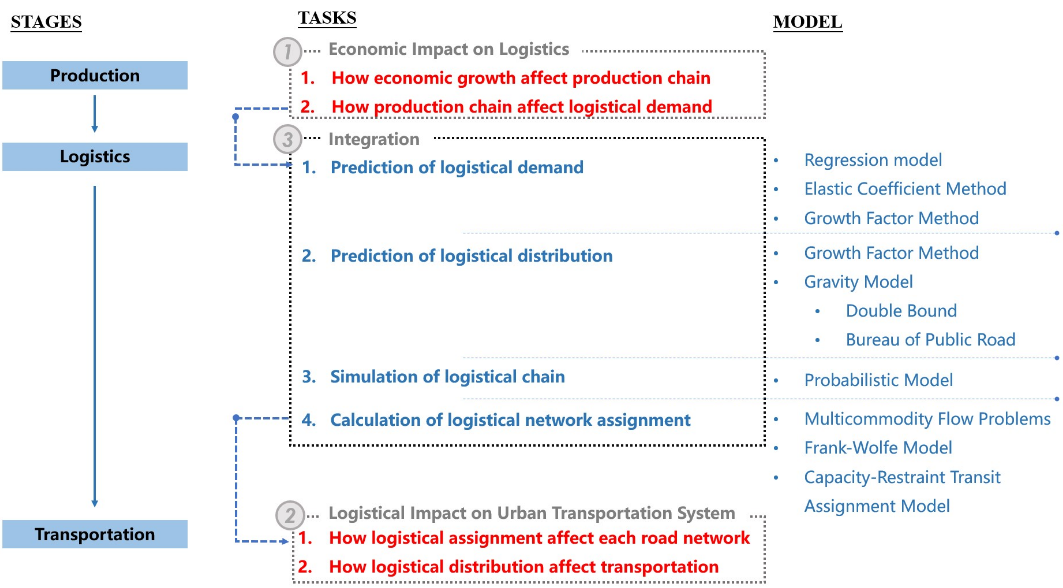
v. *how to realize the forecasting of production driven logistical performance integrating with urban transportation system*

A tool or model that can forecast the performance of urban logistics system is needed. It should include the integration of economic production and urban spatial structure for logistics evolutional model based on the outcomes of this research.

7. Methodology

The methodology includes five steps, i.e.

- literature review
- 1. Economic impact on logistics: develop the proper estimation method for logistics distribution based on increased economic production
- 2. Logistical impact on transportation: find the impacts of logistics on urban transportation
- 3. Integration: develop the model of forecasting production-driven urban freight integrating with the transportation system.



a. Literature Review

A Literature review is necessary to collect the basic information needed to answer the research questions. It includes four aspects of literature. Firstly, review the literature about the logistics demand prediction model based on economic growth to collect the method of quantity prediction as well as the general constraints for demand prediction. Secondly, review the literature about the approach to obtaining logistics network assignment to obtain the different allocation algorithm. Thirdly, review the literature about the relationship between logistics system and transportation system to get the logistics system variables. Fourthly, review the literature about the spatial typologies of the logistics system to obtain spatial evolution in logistics systems.

As 'background' and 'hypothesis' parts described those factors that are significantly related to urban logistics are land use as urban spatial structure, social economy as economic production. Thus, based on these factors with current logistics volume, the developing procedure of this model is forecasting the production volume of logistics, the distribution of logistics points, the selection of logistics chains, and the flow of logistics distribution in each network in the next few years and forecast its impact on traffic flow.

b. Develop the proper estimation method for logistics distribution based on increased economic production

To estimate how logistics distribution expand, the first step of this proposal is to calculate the logistics generation. Testing the existing different methods of logistics demand in order to obtain the pros and cons of current methods. Then, based on the conclusion, develop the proper estimation method which is suitable for the logistics demand prediction and develop it. Beside of this generation forecasting method, then distribution mechanism should also be simulated.

Logistics Generation

In the first stage: In order to forecast logistics production, the input data of this model are population, factory floor area, warehouse area, GDP, number of vehicles, per capita consumption level, per capita income level, etc.

The calculation method:

a. Regression prediction
b. Elasticity coefficient method
c. Growth coefficient method

Logistics Distribution

In the second stage: in the forecast of the distribution of logistics points, the main prediction is the amount of logistics exchange between each district. The input data is the current distribution of logistics, the occurrence and attraction of current logistics.

Calculation:

a. Growth coefficient model
b. Double restraint gravity model

c. Find the impacts of logistics on urban transportation

The relationship between logistics and urban transportation need to be developed, so testing the impact of logistics' influence on urban transportation is necessary. Firstly, find the parameters of logistics chain. Secondly, assess the impact of logistics chain selection on urban transportation. Thirdly, compare and analyze the outcomes of different logistics volume, logistics layout or chain selection. Fourthly, obtain impact of logistics on urban transportation.

Logistics Chain Selection

In the third stage: In the logistics chain selection, the main calculation is the possibility of the logistics chain selection, for example, railway, highway, aviation, water transportation, and integrated chain. Therefore, the probability model is used as the main selection decision calculation model. The input data is the distribution of logistics and the sharing rate of each logistics mode.

Calculation:

a. Probabilistic model

Logistics Network Assignment

In the fourth stage, in the process of logistics network assignment, the main calculation is the amount of logistics undertaken by each logistics facility. The main input data are the carrying capacity of the path logistics and the path logistics.

The calculation method is:

a. Multi-commodity flow model
b. Network allocation algorithm (Frank-Wolfe, capacity limitation method)

d. Develop the model of forecasting production-driven urban freight integrating with transportation system

This chapter is the final result of this research, aiming to obtain the model of economic production-driven logistical performance integrating with urban transportation system. All the previous outcomes will be concluded. Firstly, with the integrated evolutional model obtained by last step, find the proper method for predicting urban freight for this research. Secondly, connect urban spatial structure with the integrated evolutional algorithm, then build the spatial evolutional model prototype in logistics based on all the research outcomes and precedent study. Thirdly, find several proper cases for case studies. Fourthly, based on the result of case studies, modify the model.

8. Expected Research Products:

1) The relationship between economic growth, logistics demand, logistics network assignment and transport system.
2) The method for estimating logistics demand based on economic growth and production chain.
3) A model for logistics expansion, distribution, network assignment
4) A model for connecting logistics network assignment and transportation system.

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