URBAN CALCULATOR

User manual

version April 2022 (0.9.9.0)

Contents

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Introduction

Urban Calculator is a tool that allows to deliver better and smarter urban projects in the future that sustain socially inclusive, vibrant neighbourhoods and are more resilient to unforseen changes. The tool helps you to test how new or transformed neighbourhoods will perform from a social perspective (generating more pedestrian flows, safe urban environments, and public spaces for people to meet) and from an economic perspective (providing conditions for urban diversity, allowing for commercial markets to emerge).

It is a design support tool that gives urban designers without any prior GIS knowledge access to advanced spatial analysis. It lets you test different design ideas quickly using the similar advanced tools as GIS experts use that run at the backend of the tool. It is based on the Space Syntax theory and the GIS-based tool PST (Place Syntax Tool) developed at KTH and Chalmers, in cooperation with Spacescape AB (https://github.com/SMoG-Chalmers).

UC is a stand-alone tool, easy and user-friendly, which can bridge the separate phases of the design process – from the concept formulation, to the testing of different design alternatives and evaluation of design proposals.

It can be used as an evaluation tool after the design has taken shape, but more importantly, it can be used as part of the design process. During the first explorative sketches feedback is given to make informed decisions, revise the design and rerun the analysis until the project's ambitions are met.

The main functionalities of the Urban Calculator include (i) modifying the map to test design proposals, (ii) analysing the existing situation or plan proposal. These functionalities depend on good base maps and data that are integrated in the tool and presented below.

Maps and data

The different map layers that may be included in the Urban Calculator are:

- **Editable maps**: motorised and non-motorised street network where the non-motorised map includes all streets and paths that are accessible for people walking or cycling, including those that are shared with vehicles. All

streets where walking or cycling is forbidden, such as motorways, highways, or high-speed tunnels, are not included, but are part of the motorised map. The motorised map in turn excludes pedestrian paths where vehicle movement is not possible.

- **Additional non-editable maps:** buildings, plots, water bodies, schools (primary schools and kindergartens), local markets (e.g. daily services, retail stores, cafes, restaurants), public transport stops, population.

Map data is tailored to each particular project but always covers the project area plus surroundings within a 5km radius to ensure correct results of the analyses. A larger extended area can be agreed upon with the client.

Editing the map

The street maps allow editing in order to test different design alternatives. This means that one is able to add, move, change and remove streets. The tool is developed so that one does this in a manner that ensures correct analyses. For instance, new lines are always linked to existing lines, so the tool "snaps" your new line always to an existing one. Once the new streets are drawn, the tool also creates unlinks, assuming that new streets are under- or overpasses. Unlinks can then be removed by the user, if the intention is to create real level crossing.

Analysing the map

Urban Calculator allows to analyse both the current situation and the modified map. The output gives, besides results on the map, a description in text of what the specific analyses mean, which will help the user to interpret the results and draw correct and informative conclusions.

Four types of spatial analyses are included in the Urban Calculator: street centrality, accessible built density, accessibility and proximity to services. These four groups of analysis are acknowledged to be key for sustainable urban development (e.g. Cervero, 1997; Berghauser Pont et al. 2019b) and often reoccurring in design guidelines such as the global Sustainable Design Strategies of UN Habitat (2015) and the Swedish Indicators for Quality (Spacescape, 2017).

Theoretical background

To describe the urban environment as 'lived-space', we need to understand how the environment affects people's movement patterns and hence co-presence, which is central to all kinds of socioeconomic processes as is described in the theory of 'natural movement' (Hillier et al., 1993).

To do so, the city must be understood as a network of components, a system. The street network is thus understood as a system that because of its configurational properties, creates places with high centrality and places with low centrality. These variations in centrality have been proven very important for the number and diversity of people that are found in these places. In the same way, buildings are not described as objects, but their position in the system and accessibility are in focus.

Space syntax offers methods and theories to describe the built environment as 'lived-space'. To describe the distribution of people in the built environment, one needs to consider the whole street network and the distribution of attractions (activities and functions). The theory of 'natural movement' (Hillier et al., 1993) describes the primacy of the street network over attractions, because it is the configuration of streets that, through its impact on movement flows, drives a willingness to invest in a location that results in changes in land use and built density. At the same time, a higher density and more activities attract more people that, in turn, attract more investments and activities. This phenomenon is described with the concept 'multiplier effect'. Numerous studies have investigated this triangular relation between centrality (Hillier & Iida, 2005; Hillier et al., 1987; Hiliier, 1996; Peponis et al., 1989, Stavroulaki et al. 2019), attractions (Berghauser Pont & Marcus, 2015; Legeby, 2013; Netto et al., 2012; Ozbil et al., 2011, 2015; Peponis et al., 1997; Read, 1999; Ståhle et al., 2008) and pedestrian movement.

These configurational properties of the built environment are important also for social processes that depend on the presence and distribution of people in the environment (their co-presence). Olsson (1998) describes three reasons why this is important. First, it relates to the need people have to be seen and to see others and, in a city, public space and social infrastructure (such as libraries, schools but also shopping malls) are important places for people to meet. The second reason is related to tolerance that is the result of different

FIG.1 *Same urban form can perform differently depending on its location in the street system of the city*

kinds of ongoing negotiating processes for which interaction is needed, in cities, taking place in public space. Third, urban life improves cohesion in society at large, a phenomenon that refers to a kind of civic spirit where people are willing to do things for the common society (Vaughan 2007).

Movement patterns of people are also an important driver for economic concentration of retail, restaurants and other activities that are dependent on people passing by or vice versa, dependent on remoteness (e.g. Scoppa et al. 2015, Marcus et al. 2017). A shift in centrality or density can cause changes in flows that can have big impact on these processes and in turn, on land prices and land uses (e.g. offices, housing, shopping malls).

The spatial analyses that are included in the Urban Calculator are street centrality, accessibility and proximity to services and accessible built density. In all four, network analysis is central.

Multiple scales of analysis

Changes in the network have impact on centrality at different scales. This has in turn consequences for the patterns of movement and the earlier described social and economic processes. For example, a change can take place at regional, urban or neighbourhood scale with different consequences. For example, a change in local centrality might impact the local community, while a change in regional centrality can cause regional redistributions of economic activities.

All analysis discussed here can be calculated at different radii to describe configurational characteristics at different scales from global to local.
Metric radii have been shown to be effective in capturing different modes of movement. Higher radii correspond to vehicular movement and lower radii corresponds to pedestrian movement. These measures can be overlapped to identify spaces with multi-modal and multi-scale movement potential (Space Syntax Methodology, UCL).

Types of analyses

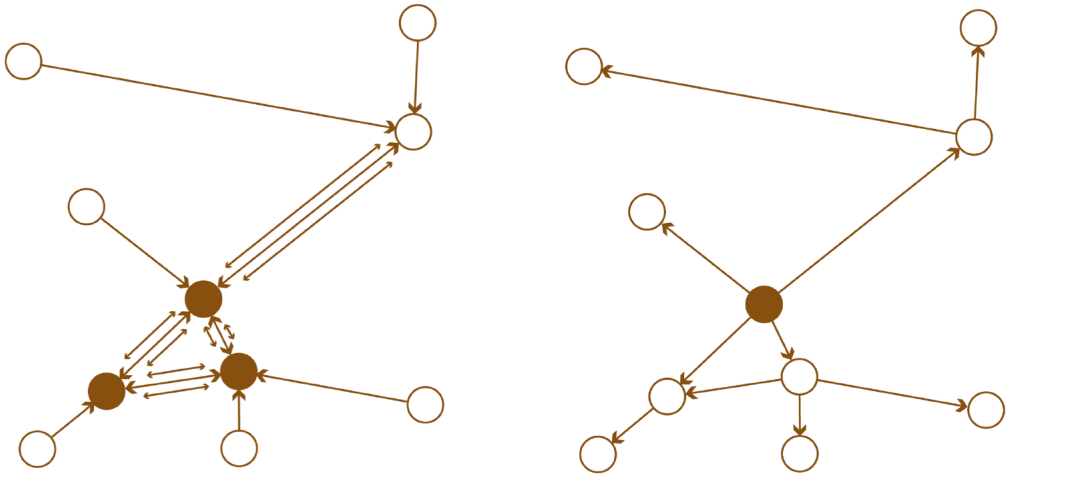
Centrality

Centrality can be measured in several ways, but the most commonly used measures are closeness centrality and betweenness centrality.

Closeness centrality measures the connectivity of each street with all other streets. Higher values indicate that the street is spatially better integrated. Betweenness centrality measures the role of the street when moving between areas. Higher values indicate the importance of that street as a path connecting different parts of the city.

Closeness centrality highlights centrality areas and betweeness centrality highlights centrality paths. Both measures have great influence on the movement patterns in cities.

A segment with high closeness centrality is one that is highly connected to other streets and is highly accessible in few angular turns, as for example the clusters of the well-connected streets in the city center. On the other end, a segment with low closeness centrality has only a few connections to other streets, it is deep in the structure and requires a lot of turns to reach it, making it less accessible and segregated. Such examples are the clusters of



Betweenness Centrality: which location is the part of the most transit trips

Closeness Centrality or Integration: Distance from place A to all other places

FIG.2 *Conceptual difference between betweenness and closeness centrality*

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the inner meandering streets of the modernistic estates. In a global scale, the measure distinguishes between the integrated and segregated areas in the city. Both measures have been shown to correlate to traffic and pedestrian flows, where high centrality in the motorised network is related to high vehicular traffic whereas high centrality in the non-motorised network is related to high pedestrian flows (e.g. Serra and Hillier, 2018; Stavroulaki et al. 2019; Hillier and Iida, 2005).

Built density

The concept of density is important for urban design and planning, but the definitions and the use of the concept has varied greatly through modern history. In its essence it is rather simple and can be described with the expression A/B where the nominator A can be population, number of dwellings or floor area and the denominator B is the plan area for which density is calculated (i.e. plot or neighbourhood). Berghauser Pont and Haupt (2010) developed a multi-variable method to measure urban density that is able to describe urban form through density metrics. This is what is referred to as the Spacematrix method. The variables included are Floor Space Index (FSI), compactness (GSI), number of floors (L) and spaciousness (OSR).

This set of four variables (FSI, GSI, L and OSR) can be represented in a scatterplot where typical building types have shown to group with each other into a unique density profile described by the combination of FSI, GSI, OSR and the number of floors. Two variables are enough to define the position in the scatterplot and thus, to know what building type dominates an area. In the Urban Calculator, density is calculated using the measures of accessibility. The total amount of built up area (buildings' footprint) and the total amount of gross floor area (GFA or BTA in Swedish) is calculated. This value is used as nominator A in the simple fraction A/B. The area of land that can be reached is used as denominator B.

Accessibility to services

Besides the characteristics of the network itself, streets also give access to people and services. Accessibility within a distance threshold answers the question how many shops, park area or people one can reach within 500 meter walking distance, – a distance that people are more inclined to walk (Gehl,

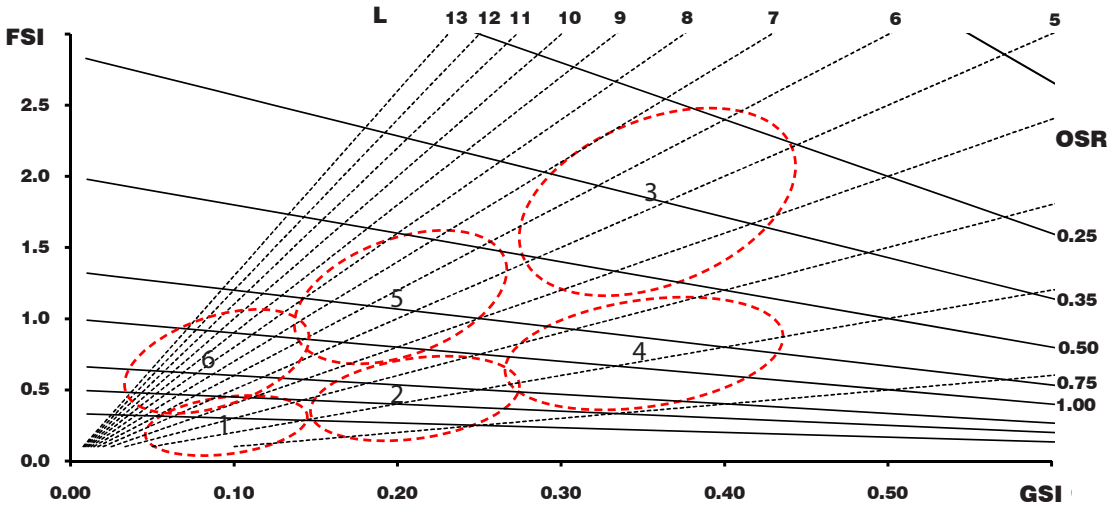

FIG.3 *Spacematrix with clusters of building types: 1. spacious low-rise (mostly villas); 2. compact low-rise (rowhouse); 3. dense mid-rise (closed building blocks); 4. dense low-rise; 5. compact mid-rise; 6. spacious mid-rise (strip and point buildings). See Berghauser Pont et al. 2019a, 2019b and the Fusion Point report ´Teorier om stadsform för att mäta städer´ for more details.*

2010) . This is an important indicator for the customer base for stores, but also for the freedom of choice. The map with the distribution of accessibility also gives insight in the equality of access to services.

Proximity

Proximity calculates the distance from A to B based on the actual street network that is used to reach the service (walking distance). This analysis answers the question of how far it is to for instance the nearest primary school, park or bus stop. This is important, because we know that distance plays an important role for people's willingness and ability to access the service. If the bus stop is too far, less people will choose to walk to the bus and might choose to take the car instead.

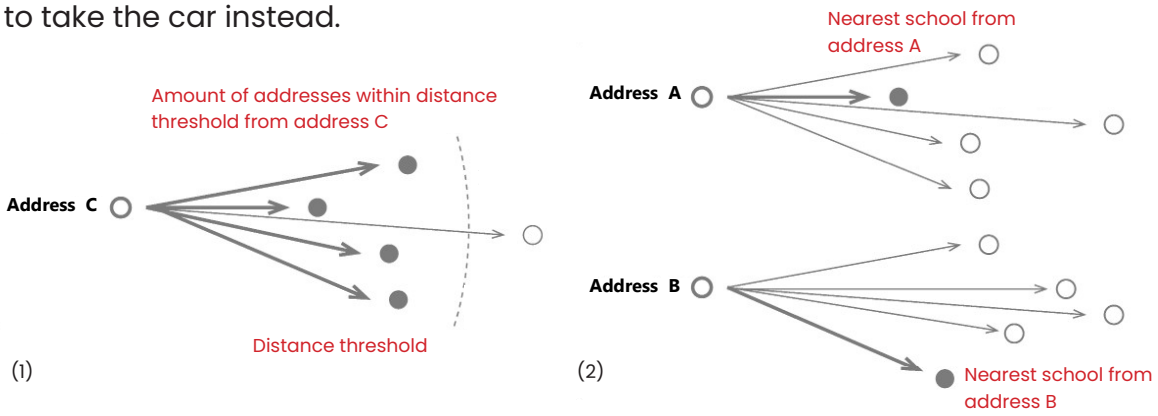

FIG.4 *Accessibility to services (1) and Proximity analysis(2); attraction can be of different kind, e.g.local markets, schools or public transport stops*

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Modifying the street network

After starting the tool, the user can open a base map (Figure 5), which is either the motorised or the non-motorised street network map of the project area. Be aware that the choice for the base map (motorized or non-motorised) effects all analysis done later. The screen is divided in three panels: the map, the layer panel, and the street info. A short description of function and an overview of map layers is given in Figure 5, but for a more complete overview, see 'List of Functions'.

The user can add new streets to the network layer, which are visible through the distinct red colour (Figure 6). The existing streets are shown in black, removed streets in grey and new streets in red. When streets are added and they cross an existing street, unlinks are automatically created. This means that

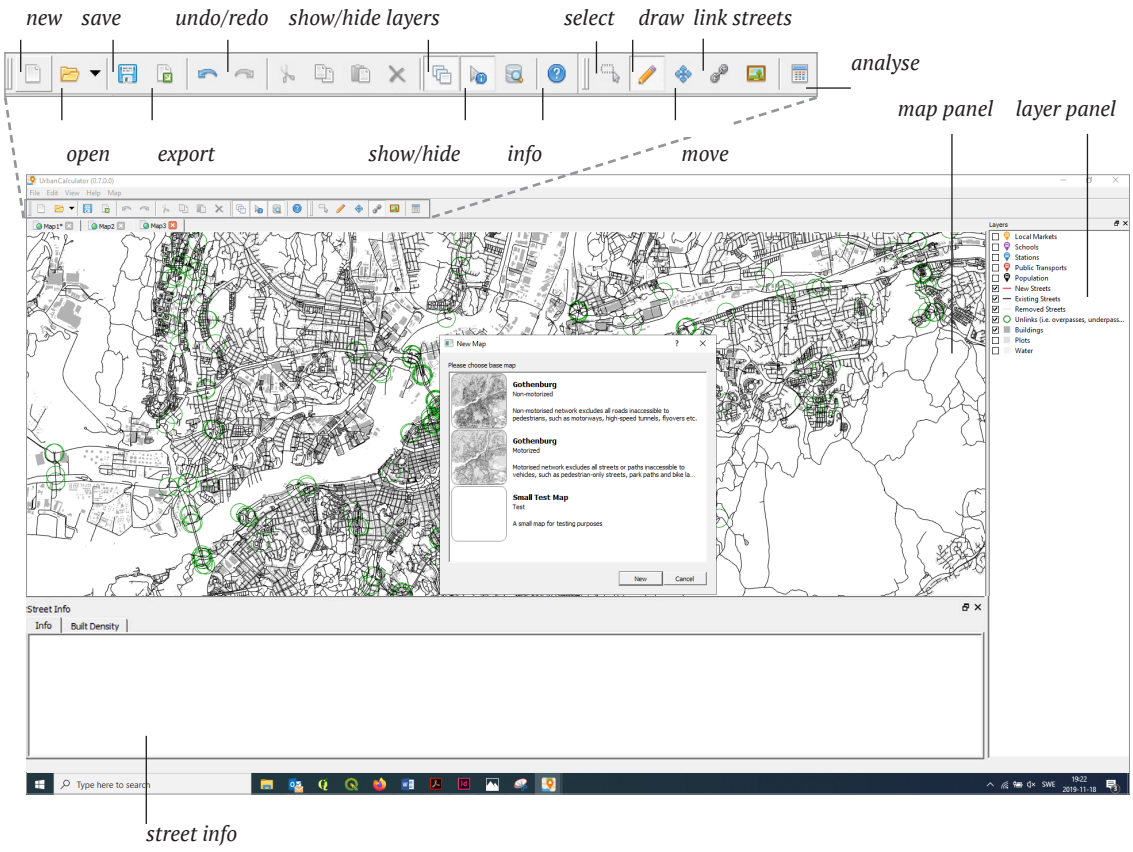

FIG.5 *Urban Calculator, opening panel to choose between motorised and non-motorised map of Gothenburg and overview of panels and functions (see for details 'List of functions')*

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FIG.6 *Adding new streets and removing unlinks*

it is assumed that these new streets do actually not cross, but are under- or overpasses. The user has to actively remove the unlinks in case the intention is to connect the streets at the crossing and create a regular level intersection.

Running analyses

Next, the user can analyse the existing map or the modified map by activating the "Analyse map" icon. The analysis panel appears where a selection can be made of relevant analysis (Figure 7). All can be selected at the same time, but be aware that the centrality analysis on the scale 5 km can take some time (still, only a few minutes).

The results of two analyses in Figure 8 show how a new bridge in Gothenburg increases Betweenness values for the added bridge and better links Järntorget (2) with Lindholmen (1). This strong line continues all the way to Kvillebäcken in the North (3) and Lundby in the West (4). Besides these long and strong connections, more locally, Sannegårdsskajen (5) as well as Första till Tredje Långatan (2) increase its betweenness values.

Besides facts of the street itself, the user receives information about its values in relation to all streets in the city (the difference between the black and

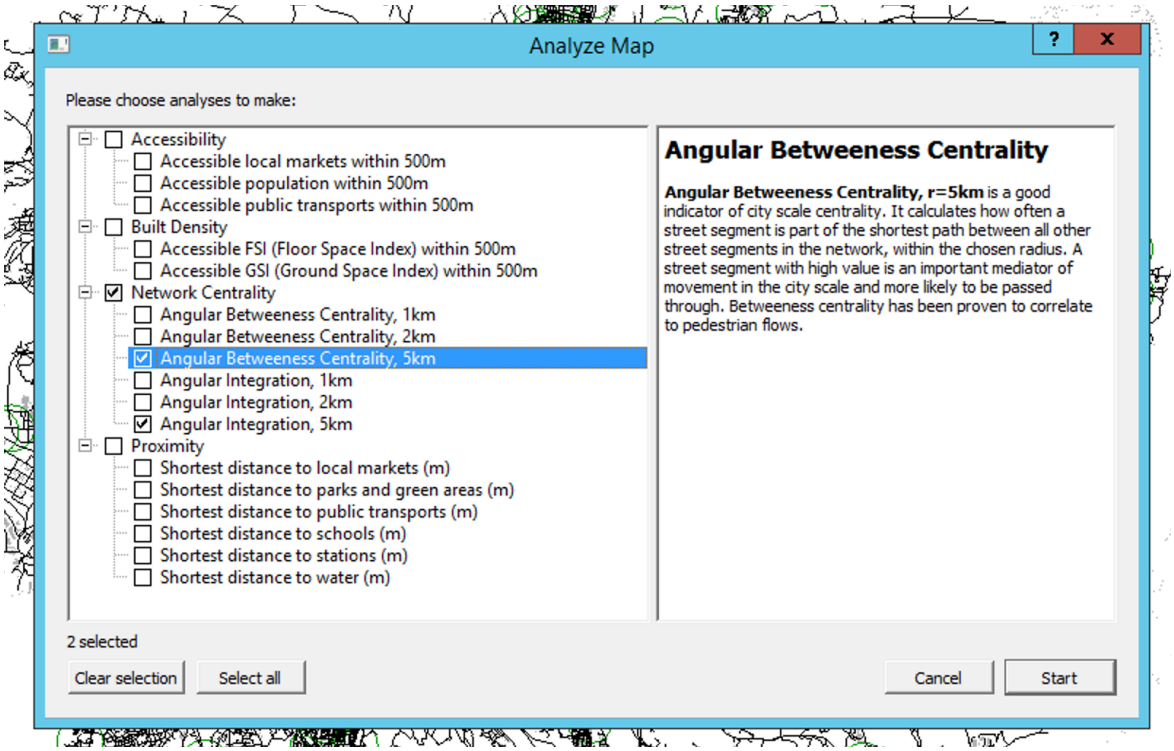

FIG.7 *Overview of all the analysis possible to perform in Urban Calculator*

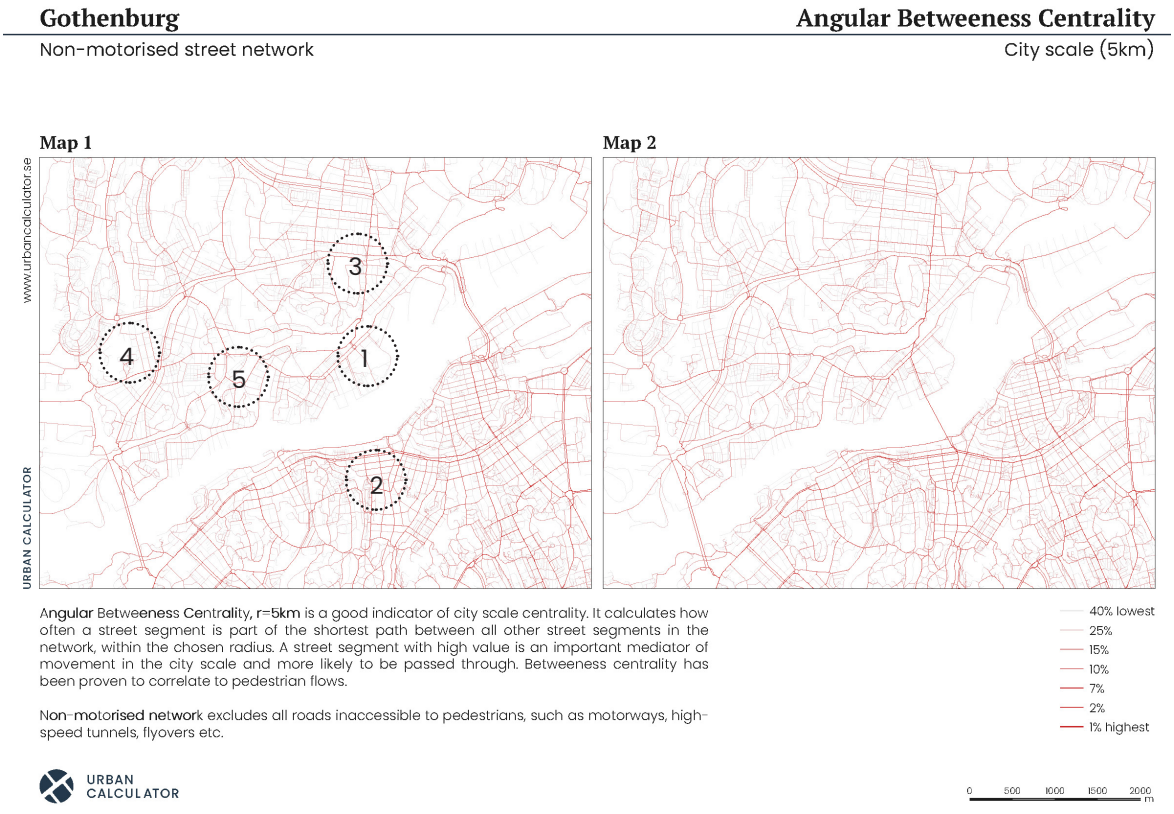

FIG.8 *Urban Calculator analysis output (betweenness centrality 5 km) of current sitation (Map 1) and with the new bridge (Map 2)*

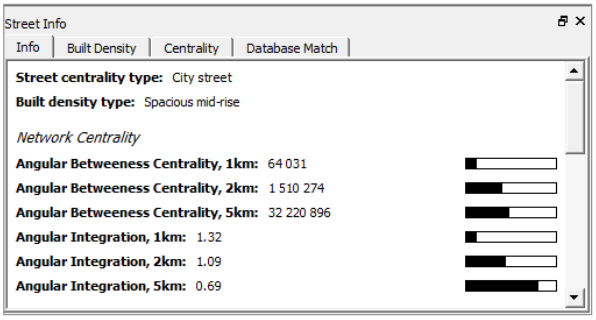

FIG.9 *Street info: measures. Information is provided for centrality, accessibility and density.Both absolute values and relative values in comparison to the rest of the city are given*

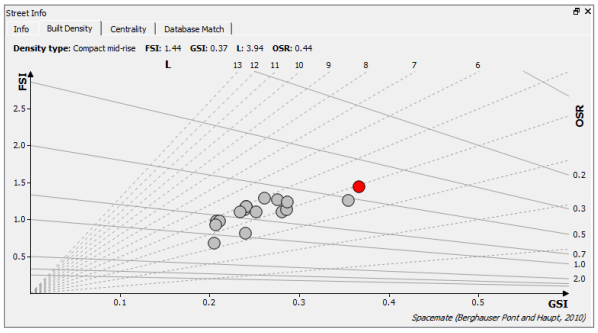

FIG.10 *Street info :Spacematrix. Density is shown in the Spacemate scatterplot where the red dot shows the value of the selected street.*

white bars in Figure 9). Furthermore, the density values are depicted in the Spacematrix scatterplot (Figure 10). Be aware that the density of the street means the density of the street surrounding defined by the 500 meter walking distance as discussed in the former section.

Output

All analysis can be exported as PDF. The output maps include the map, information about the type of analysis and scale as well as a legend and scale bar. In Figure 11 the accessible density (FSI) analysis output and accessibility to local markets are shown correspondingly.

In order to better compare before/after situation or several design alternatives, one can export two or three analysis maps at the same time.

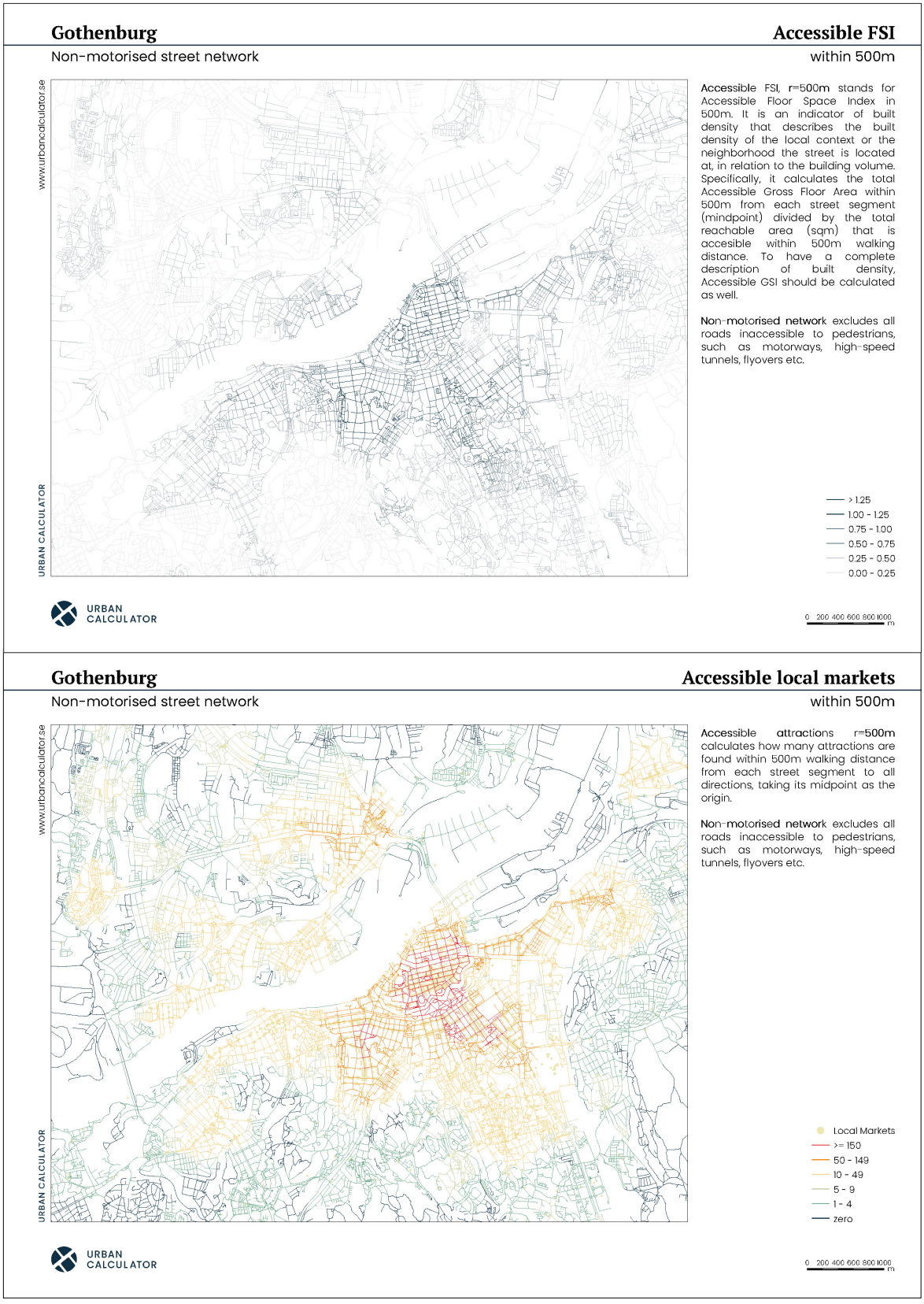

FIG.11 *Urban Calculator analysis output: accessible FSI (top) and accessible local markets within 500m walking distance (bottom)*

List of functions

Draw/Edit

 Add line

Snap (end point, mid points)	Implemented as “snap to closest line” or “snap to end point”. Unlinks are always added when two lines cross, except with endpoints. Hold “Ctrl” to disable snapping.
Delete	First “select”, then “Delete”.
Move line	Implemented so that the line always keeps its links to other lines; with “Ctrl” you can detach a line from existing lines.
Move endpoint	Use “Ctrl” and move end line, to snap back to an existing endpoint, switch off “Ctrl” function.
Move current selection	You can box select or click select separate lines and move them.

 Select line

Select end point	Using “Ctrl”.
Box select (more lines)	Select more than one line with same button as select line, with “Ctrl” you can add to the selection, with “shift” you remove selected lines.

 Link/Unlink

Removing unlinks one by one; you cannot manually add unlinks.

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Interface

Zoom	Scroll mouse wheel.
Pan	Press mouse wheel.

Basic functionalities

 Load/Save as	Format .ucmap
Quick access to recently opened files	See Load/Save as (also in drag down menu)
Export analysis to PDF	Choose if you want to export 1, 2 or 3 analyses maps. Only analyses deriving from the same basemap can be exported together in single PDF
 Undo/redo	

Analysis

 Analysis	
Visualisation/Colour ranges	One can choose Red-Grey, Blue-Grey or Spectral. The last chosen coloring mode will also be used as initially selected coloring mode for the next analysis you make. Method for showing ranges is fixed %
 Street info	Activates window with all the information about the selected street with an overview of all the analysis results for this street and its position in the Spacematrix scatterplot

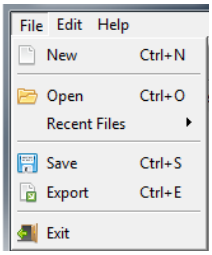
Layers

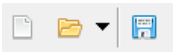
- Local markets (e.g. daily services, retail stores, cafes, restaurants)
- Schools (primary schools and kindergartens)
- Stations including train stations
- Public transport include all bus, tram and train stops
- Population including the residential population in cells of 100x100m
- New streets are streets added by the user
- Existing streets
- Removed streets are streets deleted by the user
- Unlinks define where two crossing streets are in reality a bridge or tunnel (underpasses or overpasses)
- Buildings
- Plots
- Water

HOW - TO

Urban Calculator currently only runs on Windows.

BASIC INTERFACE



- Start a New project. Use **New** button or command  (or Ctrl+N)
    - Choose **Non-Motorised** (or **Motorised**)
- Open existing file. Use **Open** button or command (or Ctrl+O)
- Save your project. Use **Save** button or command (or Ctrl+S). Saves as **.ucmap** for the Map window and as **.ucanalysis** for the Analysis windows.
- Zoom: Scroll Mouse wheel or Use **Zoom** button 
- Pan: Press Mouse wheel or Use **Pan** button 

DRAW-EDIT

- Add Line: Use **Draw** button  (or D)
- **Link lines:** When you add a line a series of Unlink points are added (green circles) where the new line crosses existing lines. Use **Link** button  (or L) to remove the Unlinks and link lines. **Otherwise, the program will understand all new connections as bridges or tunnels**. As a rule of thumb, when the lines represent street segments that cross at a regular level intersection **Link** them. When the lines represent street segments that do not intersect but are in different levels (e.g. bridges, underpasses, tunnels, overpasses) leave them unlinked.
- Snap to Line/Points. Snapping is enabled by default. Use **Ctrl** to disable Snap.
- Delete line/s: First select with **Select** button  (or S), then **Delete** with Keyboard
- Move line: Use **Move** button 
- Move endpoint: Use **Move** button.  Hover over the endpoint and click to move.
- Move area: Box select area, then use Move button 

ADD LAYERS (if you want more information (e.g. water, green areas, buildings, attractions) to help you with you design) 

- Switch layers on and off. Use **Layers** button. You can select different layers (e.g. buildings, water, parks and green areas, local markets)

ADD BACKGROUND IMAGE (to help you tracing your project)

- click the icon on the Layers panel  or right-click on the Layers menu. After importing the image (.jpg), you can adjust its position and size using your mouse. You can remove the Background image using

ADD STUDY AREA (to re-visualise centrality analysis results and see variations of centrality in a smaller area)

- show "study areas view"  from top menu bar (if it is not ON by default). You will get Study areas menu.
- Add study area by clicking  and give it a name. You will see a rectangle appearing on the map view – adjust its size accordingly to you area of interest.
- You can remove study areas  , add few more  , zoom to study area  or rename them  .
- If you have a study area of interest, you should always add it **BEFORE** you start running any kind of analysis.

ANALYSE

- Use **Analyze map**  button. Select analysis and scales. You can select more than one analyses at once.
- If you want some of the background layers to be visible in the analysis/export view, then they must be switched ON in a map view (normally it is building layer, water, motorized map/non-motorized background network and/or railways)
- Once the analysis is finished, you can change between three visualization themes – go to main menu bar -> Analysis -> Themes. Choose between Spectral, Blue-Grey or Red-Grey.

  TIP: *Spectral theme normally works best for all the accessibility and proximity analyses, density analysis and angular integration. For betweenness centrality, spectral may work best for zoomed-in areas, and Blue-Grey or Red-Grey for zoomed-out visualizations.*

- **Visualizing analysis of study areas**: When in the analysis view, in the study areas panel, you can switch between Full map view or study area view. In the full map view, the analysis is visualized for the full map. In the study area view, analysis is only visualized within the selected study area, and the rest of the map will turn grey. Since centrality analyses are visualized with relative ranges, while all other analyses in absolute ranges, the difference between full map view and study area view is only visible in the visualization of centrality analysis.

STREET INFO

- Use the **Street info**  button and click on an existing street to get more information. See its spatial properties in **'Info'** and its Built density profile on the Spacematrix graph in **'Built density'**

SELECT AND SYNC VIEW between analysis windows

- In the **'Edit'** drop down menu select the **Copy viewport parameters**  button to copy a view from one window.
- In the same menu select the **Apply viewport parameters**  button to paste the selected view to another window.
  Synching views between analysis windows helps when Exporting before-after analyses (see next).

EXPORT ANALYSIS to PDF

- Use **Export** button  (or Ctrl+E). Select where to save the pdf. You can choose more than one analyses to combine (max 3). Use this option when you want to export before-after analyses to compare or if you want to compare analyses in different scales or in different zooms (zoom in area, zoom out in the context or city). Select your before-after exports wisely to showcase the impacts of your design interventions best.
- You can also export full map view or study area view – make sure you selected the relevant option in the Study area menu before exporting.

EXPORT ANALYSIS RESULTS IN GIS FORMAT

- Use **Export** button (or Ctrl+E). Select **GeoJSN** format and choose where to save it. This format can be further opened in regular GIS software (QGIS or ArcGIS). Be aware that coordinate system should be corrected in QGIS after the export.

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