# D5.3 Analysis Module: User-Friendly Visualisation Tool

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</tbody>
</table>
# Table of Contents

EXECUTIVE SUMMARY ........................................................................................................... 1

1. **INTRODUCTION** .................................................................................................................. 3

2. **MATSIM VISUALISATIONS** ................................................................................................. 4
   2.1 MATSIM OUTPUTS .................................................................................................................. 4
   2.2 VIA VISUALISATION TOOL ................................................................................................. 6

3. **VISUALISATION PROPOSAL** ............................................................................................... 7

4. **SOFTWARE SOLUTION** ....................................................................................................... 8

5. **EUNOIA VISUALISATION** ................................................................................................... 10
   5.1 INPUT ...................................................................................................................................... 10
   5.2 INTERFACE ELEMENTS ........................................................................................................ 12
      5.2.1 Maps ................................................................................................................................. 13
      5.2.2 Zone analysis ................................................................................................................... 14
      5.2.3 Trip analysis ..................................................................................................................... 16
   5.3 USER CONTROLS .................................................................................................................. 18
      5.3.1 Time selection ................................................................................................................... 18
      5.3.2 Number of trips filter ....................................................................................................... 19
      5.3.3 Animation ........................................................................................................................ 19
      5.3.4 City selection .................................................................................................................... 20
Executive Summary

Visualisation and visual analysis contributes to facilitating the interpretation of data and the understanding of complex relationships, the evaluation of the impact of (a set of) policies in a more effective way, or the communication between citizens and policy makers. One of the objectives of EUNOIA is to develop user-friendly visualisation tools to interact and ease the interpretation of the MATSim simulation results. MATSim (http://www.matsim.org/) is the agent-based transport simulation tool that will be used to conduct the EUNOIA case studies in the cities of Barcelona, London and Zurich. MATSim provides some plots to visualise the simulation results, such as travel distance statistics or the comparison between simulated and real data counts, and there exists a visualisation tool called VIA (http://senozon.com/products/via) that provides additional visualisation features. Most of these visualisations are mainly focused on disaggregated information (agent trips, link road analysis, etc), being the analysis and the interaction with aggregated data developed to a lesser extent. The objective of the EUNOIA visualisation is to contribute to the improvement of the manner in which aggregated data are analysed, focusing on generation and attraction of trips by zones and the distribution of these trips between zones.

The EUNOIA visualisation consists of a web solution constructed using three core web technologies: HTML, CSS and JavaScript. Two JavaScript libraries (jQuery and D3) and a JavaScript API to Google maps are being used.

The visualisation has four main interface elements:

- The map of the city, where the mobility patterns are represented.
- The zones, represented by their geometric centroids as coloured circles.
- The links (or trips) between zones, represented as lines connecting the zones.
- The messages when hovering over a zone or tabulated at the bottom left corner when clicking on a zone.

In order to represent the generation and attraction of trips per zone, we use coloured circles of different sizes located at the centroid of the zone. The colouring differentiates between areas that generate a lot of trips (bright green colour) and the ones that attract a lot of trips (bright red colour) passing through the ones that are balanced (blue colour). There are also some zones that might generate or attract some trips but not a lot (darker green and darker red respectively). When clicking on a zone, a bar graph containing all the departures and arrivals per hour for that zone is displayed at the bottom right corner of the screen.

The distribution of trips is represented by means of coloured lines connecting zones. The colouring gives information about the predominant direction of the trips, indicating whether there are a lot of trips from the selected zone to the other one (bright green colour) or a lot of trips from the other zone to the selected zone (bright red colour) passing through the balanced situation (blue colour). There are also some zones that might generate or attract some trips from or to the selected zone, but not a lot (darker green and darker red respectively). The size of the lines is proportional to the total number of trips in both directions, being a greater number a thicker line. When hovering over a line, information about the link is displayed through a modal text area. The information represented is the total number of trips between the two zones and the departures and arrivals from and to the selected zone.
The user controls allow the user to tune or adjust the way the visualisation is presented. The main user controls in our visualisation are:

- The city selector, which allows the selection of the city to be visualised.
- The time picker, to select the hour range to visualise.
- The number of trips filter, which allows the restriction of the zones to be visualised to the ones over a certain number of trips.
- The animation button, which starts an animation of the whole day visualisation.

The developed visualisation has been successfully tested with different city representatives to analyse different datasets (e.g. measured and simulated use of the Barcelona’s bike sharing scheme), and has been proved to be a simple and meaningful way of representing generation and attraction of trips by zones and the distribution of these trips between zones.
1. Introduction

Visualisation is a process to communicate content through different pictorial techniques in order to allow users to get information and gain knowledge on a specific topic or process. In the past, research efforts mainly focused on information visualisation, i.e. on the development of effective visualisation techniques for abstract data as a function of the data type (e.g., numerical, relationship, hierarchy...). A more recent research area, visual analytics, aims at extending the role of visualisation to data analysis. The adoption of visualisation and visual analysis methodologies has several benefits, such as facilitating the interpretation of data and the understanding of complex relationships even by non-technical users; the evaluation of the impact of (a set of) policies in a more effective way; or the communication between citizens and policy makers.

One of the objectives of the EUNOIA project is to develop user-friendly visualisation tools to interact with MATSim. MATSim is the agent-based transport simulation tool that will be used to conduct the EUNOIA case studies in the cities of Barcelona, London and Zurich (detailed information about MATSim can be found at http://www.matsim.org/). The visualisation tools developed by EUNOIA will be used to: i) explore mobility 'raw' data, ii) ease the analysis of MATSim results, and iii) facilitate the communication of simulation results to relevant stakeholders. There already exist some visualisation tools around MATSim that help analyse the simulation outputs; EUNOIA will focus on providing new visual information not considered by the current tools.

This deliverable contains information about the main characteristics (software, interface and user controls) of the visualisation tool developed. The document is structured as follows:

- section 2 briefly summarises the visualisation tools already available for the analysis of MATSim results,
- section 3 presents the new visualisations proposed by EUNOIA;
- section 4 describes the software solution chosen;
- section 5 presents the main characteristics of the visualisation tool developed.
2. MATSim visualisations

2.1 MATSim outputs

MATSim provides different types of outputs. The main ones are:

- Events file: provides information about the different actions performed by the agents
- Log file: provides information about the different steps of the simulation.
- Plots and text files: MATSim creates several plots and text files during a simulation run, which can be used to analyse the results.
- Counts: provides information by comparing real with simulated counts.

For some of these outputs, MATSim provides plots and visualisations that facilitate the interpretation of the results, specifically from 'plots and text files' and 'counts'.

Regarding 'plots and text files', MATSim provides the following plots:

- Score Statistics: the score statistics are available as picture (scorestats.png). They show the average best, worst, executed and average of all plans of an agent for every iteration (see Fig. 1a)
- Leg Travel Distance Statistics: the leg travel distance statistics is comparable to the score statistics, but instead of the score, the travel distance is plotted (see Fig. 1b)
- Leg Histogram: a leg histogram depicts the number of agents that arrive, depart or are en route per time unit. Histograms are created for each transport mode and, additionally, for the sum of all transport modes. (See Fig. 1c)

With respect to 'counts', MATSim returns a .kmz file that allows the visualisation of the comparison between real and simulated data in Google Earth. Additionally, the visualisation contains a slider at the top left side of the screen that allows the modification of the time interval in which results are shown. Fig. 2 shows a count comparison in Switzerland for the time period between 11:00 and 12:00.

More detailed information about MATSim outputs available at: http://www.matsim.org/
Figure 1. MATSim plots: (a) Score Statistics, (b) Leg Travel distance statistics and (c) Leg Histogram for all modes at iteration 100.

Figure 2. Counts comparison analysis provided by MATSim
2.2 VIA visualisation tool

In addition to the plots and Google Earth visualisations provided by MATSim, there exists a specific tool called VIA that was developed to easily visualise and analyse results of MATSim simulations. VIA is a visualisation tool developed by Senozon, a spin-off of the Swiss Federal Institute of Technology (ETH) Zurich, one of the institutions (together with TU Berlin) that are leading the development of MATSim.

VIA takes the outputs of MATSim and provides different kinds of visualisations, allowing the interaction with the data visualised. VIA shows how agents perform their activities and trips along the day (see Fig. 3). It is possible to conduct different analyses focusing on specific elements of the visualisation, such as tracking a single agent, analysing traffic on specific road links or comparing simulated and real counts. For more information about VIA, visit: http://senozon.com/

![VIA visualisation. Agents performing their daily trips.](image)

Some videos of the use of VIA to visualise MATSim outputs are shown below.

- MATSim Model of New York: [https://www.youtube.com/watch?v=5rrn01Auqkg](https://www.youtube.com/watch?v=5rrn01Auqkg)
- MATSim Model of Berlin: [https://www.youtube.com/watch?v=dNaBIBWKEcQ](https://www.youtube.com/watch?v=dNaBIBWKEcQ)
3. Visualisation proposal

As it was presented in the previous section, VIA is one of the most powerful tools to visualise MATSim results. Although VIA focuses mainly on the analysis of disaggregate data and the study of route/link information (e.g., congestion), it also allows the analysis of aggregated information, such as the number of agents that cross a specific area or the trips between two areas (Fig. 4). However, the information provided as well as the interaction with the visualisation is limited.

The objective of the EUNOIA visualisation is to contribute to the improvement of the manner in which aggregated data is analysed, focusing on generation and attraction of trips by zones and the distribution of these trips between zones. The new visualisation will improve the interaction with the data and will provide extra information facilitating the interpretation of the results.

![Figure 4. VIA - Aggregation of trips into hexagonal zones](image)

Figure 4. VIA - Aggregation of trips into hexagonal zones
4. Software solution

The EUNOIA visualisation uses a web solution to present graphical information about the number and direction of trips between zones.

This web solution is constructed by using the three core web technologies:

- **HTML** (HyperText Markup Language) - HTML is the standard markup language for web page creation. HTML documents are usually pairs of angle brackets enclosed tags (<html> and </html>) that hierarchically conform a structured document. These tags can be interpreted by a web browser to represent web pages. HTML allows embedding objects such as images and scripts to define a dynamic behaviour of the web pages.

- **CSS** (Cascading Style Sheets) - CSS is a style sheet language used for describing the format and design of a markup language written document. The main goal of CSS is to allow the separation of the document presentation from the document content. CSS allows colours, fonts and layouts definition.

- **JavaScript** - JavaScript is a dynamic programming language. It is found frequently in web pages and web browsers to allow users to have a more reactive and rich experience. JavaScript programs are run on the client side and can alter the page content that is being displayed. Its name and syntax might induce to think that is related to the Java programming language, but they are completely unrelated. There is a vast array of JavaScript libraries and frameworks that allow building complex and rich web applications and behaviours.

For the EUNOIA visualization, two JavaScript libraries (jQuery and D3) and a JavaScript API (Application Programming Interface) to a Google service (Google maps) are being used.

- **jQuery** - jQuery is a JavaScript library designed to simplify the client-side scripting in HTML. jQuery makes it easier to manipulate the DOM (Document Object Model) of a document. This object holds all of the nodes/elements of a web page in a tree structure. Making changes on this structure allows dynamic changes on the document (such as adding, removing or manipulating elements on some user action). It also simplifies event handling (clicking, mouse hovering, zooming, etc.) and allows the construction of rich and powerful widgets (like advanced input box, tables or calendar controls).

- **D3** (Data Driven Documents) - D3 is a JavaScript library that uses SVG (Scalable Vector Graphics), JavaScript and CSS standards to create advanced interactive data visualisations that run within web browsers.

- **Google Maps** - One of the most successful services and technologies provided by Google. Through Google's API it is possible to embed Google Maps in external sites, configuring what to be shown, the presentation style and overlay specific information on top of it. The API also provides geocoding and elevation profiles and uses a close variant of the Mercator projection (which avoids showing accurate information on areas around the poles).

The input data to be represented in the visualisation will be in a **JSON** (JavaScript Object Notation) format, which allows for a light structured data representation.
The system architecture is a HTML web page which holds a Google Map with an overlay on top of it where all of the interface elements are drawn using D3, and a few jQuery controls to allow for user interaction. In order to make the visualisation available to web browsers, a simplified Apache web server instance is installed to hold all the previously mentioned elements. All the modern web browsers should be able to access the visualisations without any troubles, but although there shouldn't be any cross platform issues, it has been observed that Google Chrome provides the best performance.

![Diagram](image)

Figure 5. VIA - Aggregation of trips into hexagonal zones
5. **EUNOIA visualisation**

5.1 **Input**

The input data for the EUNOIA visualisation are files in the json (JavaScript Object Notation) and csv (Comma Separated Values) format. They hold the details of the position of the different zones in a map and the number of trips between such zones.

For every city there are 24 json files, one for each hour and as many csv files as zones defined for that city.

Each of the 24 json files holds a list of zones that have information regarding its position, some of its attributes and the number of trips from/to this zone to/from other zones:

- "lat": Holds the latitude of the centroid of the represented zone.
- "long": Holds the longitude of the centroid of the represented zone.
- "clustered_id": Id assigned to the zone. Some zones are too small or very close to others. In order to simplify the network, these zones have been clustered in just one with this ID.
- "original_ids": This ID identified the zones that form a cluster. Most zones will have a unique "original_id" meaning they haven’t been clustered with any other zones, but some (the ones that have been clustered) will show multiple IDs in this field.
- "total_trips": Total number of trips made from and to this zone.
- "exits/departures": Number of trips with this zone as an origin.
- "entries/arrivals": Number of trips with this zone as a destination.
- "trips": List of interaction elements. Each of these elements holds the "clustered_id" of a zone that is an origin or a destination for trips between itself and the current zone, the number of departures and the number of arrivals.
- "extra parameter": Additional parameters that define attributes specific to the zone or the mean of transport.

For example, in the case of a bike-sharing mobility network, we would have something like in Fig. 6a. This structure represents two bicycle clusters in a given hour of stations with ID 0 and 25. The first cluster is formed by only one station and the second one by two different stations. They both have their longitude and latitude (of the cluster center) and trips between them and other station clusters, with information on how many of those trips were an arrival (entries) or a departure (exits). Also the number of bicycle slots for each of the clusters and the height above sea level of the cluster are given as a particular attribute of a bicycle transport system.

For every zone in our visualisation, we have a csv file that holds information for that particular zone during the whole day, such as the number of trips made from and to the zone. For example we could have something like in Fig. 6b. It shows the number of arrivals and departures per hour during the day for a particular zone.
Figure 6. Example of json (a) and csv (b) input files

```
a) [...
   {
   "lat": 41.407411,
   "long": 2.192819,
   "clustered_station_id": 0,
   "original_station_ids": [133],
   "total_trips": 5,
   "exits": 1,
   "entries": 4,
   "trips": [[49,0,1],[65,0,1],[71,1,0],[158,0,1],[368,0,1]],
   "num_slots": 18,
   "height": 16
   },
   {
   "lat": 41.578932,
   "long": 2.259836,
   "clustered_station_id": 25,
   "original_station_ids": [43,57],
   "total_trips": 20,
   "exits": 10,
   "entries": 10,
   "trips": [[42,0,1],[23,3,1],[97,2,5],[136,1,2],[368,4,1]],
   "num_slots": 12,
   "height": 10
   }
   ...
```

b) Hour, Arrivals, Departures
   00,4,1
   01,1,0
   02,0,0
   03,0,0
   04,0,0
   05,2,2
   06,1,2
   07,13,8
   08,30,32
   09,16,15
   10,5,7
   11,5,5
   12,3,3
   13,17,13
   14,15,22
   15,7,15
   16,7,10
   17,17,16
   18,13,12
   19,7,10
   20,14,12
   21,10,13
   22,11,8
   23,11,8
5.2 Interface elements

The interface elements are the elements that represent the data that we are trying to visualise in a graphical manner. These elements don’t include user controls to tune or adjust the visualisation in any way.

The main interface elements in our visualisation are:

- The map of the city where we are representing the zone mobility patterns.
- The zones, represented by their geometric centroids as coloured circles.
- The links (or trips) between zones, represented as lines connecting the zones.
- The messages when hovering a zone or tabulated on the bottom left corner when clicking on a zone.

![Figure 7. Interface elements](image-url)
5.2.1 Maps

EUNOIA's visualisation uses a background map to represent the cities where the mobility between zones is being studied. On top of the map there is an overlay where all the elements of the visualisation are drawn, maintaining the relative position when dragging or doing zoom in the map. The map provider is Google Maps, which is a web mapping service provided by Google that has a powerful API that allows interaction with the map (searching, zoom in/out, etc.) along with geolocation and elevation services. It also allows the configuration of the style that the map will show and the level of detail (showing cities, places, roads, boundaries, etc.).

For EUNOIA we use a reduced style version of Google maps showing a less rich colour style and showing only city, neighbourhood and main road labels to keep the focus on the elements that will be overlaid on top of the map. The differences can be appreciated in Fig. 8.

![Figure 8. Comparison between Google maps completed and reduced style version.](image)

The Google Maps elements/controls that are available in our visualisation are:

- Map dragging - By clicking and maintaining the mouse's right button pressed and then moving the mouse we can move the map in any direction. When letting the button go, the map will stays in the position hold at the moment of releasing.

- The zooming control - The map can be zoomed out and in by using the mouse wheel or the zoom bar that can be found in the lower right corner (see Fig. 9).

- The scale legend - That indicates the map scale at every giving time (see Fig. 9).

![Figure 9. Scale legend (left) and zooming control (right)](image)
5.2.2 Zone analysis

One of the main interface elements in EUNOIA’s visualisation are the zones. The zones represent areas where trips are originated or ended. The way to represent these areas is by using coloured circles of different sizes which represent the centroid of the zone. By zooming in on the map, a closer view of the different zones can be achieved (see Fig. 10).

![Figure 10. Scale legend (left) and zooming control (right)](image)

Both the colours and the circles size give information about the zone.

The colouring differentiates between areas that generate a lot of trips (bright green colour) and the ones that attract a lot of trips (bright red colour) passing through the ones that are balanced (blue colour). There are also some zones that might generate or attract some trips but not a lot (darker green and darker red respectively). The colour assignment criterion is the following:

If there are more generated (outgoing) trips than attracted in a zone:

- If the difference between the generated and attracted trips is less than 20% of the total number of trips for that zone, the zone is considered balanced and will have a blue colour.
- If the difference between the generated and attracted trips is over the 20% of the total number of trips but less than 60% of the total number of trips for that zone, the zone is considered a generator and will have a dark green colour.
- If the difference between the generated and attracted trips is over than 60% of the total number of trips for that zone, the zone is considered a pure generator and will have a bright green colour.

On the other hand, if there are more attracted (incoming) trips than generated in a zone:

- If the difference between the attracted and generated trips is less than 20% of the total number of trips for that zone, the zone is considered balanced and will have a blue colour.
- If the difference between the attracted and generated trips is over the 20% of the total number of trips but less than 60% of the total number of trips for that zone, the zone is considered an attractor and will have a dark red colour.
• If the difference between the attracted and generated trips is over than 60% of the total number of trips for that zone, the zone is considered a pure attractor and will have a bright red color.

The size gives information about the total number of trips (both incoming or outgoing) generated at a zone, being a greater number a greater sized circle. There are five different sizes that are decided by using quantiles as border decision point. The way to calculate these quantiles is by ordering the list of the total number of trips for all the zones in the visualisation and then taking the points at regular intervals. The values at these points are the boundaries between consecutive subsets and circle sizes.

All this information about size and colour is summarized in the legend area, bottom left corner of the screen (see Fig. 11a). Additionally, when the mouse cursor is hovering over a zone, some information about the zone is made available through a modal text area (see Fig. 11b).

When clicking on a zone, all the links between that zone and all the other zones that have trips to or from the original zone are displayed (see Fig. 12). Additionally, a bar graph containing all the departures and arrivals per hour for that zone is displayed at the bottom right corner of the screen. Hovering over the bars of the graph will give the exact number of trips in a modal text area.

Figure 11. Legend (a) and zone information example for public-bike trips (b)

Figure 12. Clicking on a zone to display connections with other zones and trips per hour bar graph.
5.2.3 Trip analysis

When clicking on a zone, the trips between the selected zone and the rest are represented by using lines. Both the colour and the line's size give information about the trips. The colouring gives information about the predominant direction of the trips, if there are a lot of trips from the selected zone to the other one (bright green colour) or if there are a lot of trips from the other one to the selected zone (bright red colour) passing through the balanced situation (blue colour). There are also some zones that might generate or attract some trips from or to the selected zone but not a lot (darker green and darker red respectively). The colour assignment criterion is the following:

- if there are more trips from the selected zone to the other zone:
  - If the difference between the trips from the selected zone to the other zone and the ones in the opposite direction is less than 20% of the total number of trips for those two zones, the trip direction is considered balanced and will have a blue colour.
  - If the difference between the trips from the selected zone to the other zone and the ones in the opposite direction is over the 20% of the total number of trips for those two zones, but less than 60% of the total number of trips for those two zones, the trip direction is considered to go mostly from the selected zone to the other and will have a dark green colour.
  - If the difference between the trips from the selected zone to the other zone and the ones in the opposite direction is over the 60% of the total number of trips for those two zones, the trip direction is considered to go almost completely from the selected zone to the other and will have a bright green colour.

- if there are more trips from the other zone to the selected zone:
  - If the difference between the trips from the other zone to the selected zone and the ones in the opposite direction is less than 20% of the total number of trips for those two zones, the trip direction is considered balanced and will have a blue colour.
  - If the difference between the trips from the other zone to the selected zone and the ones in the opposite direction is over the 20% of the total number of trips for those two zones, but less than 60% of the total number of trips for that two zones, the trip direction is considered to go mostly from the other zone to the selected one and will have a dark red colour.
  - If the difference between the trips from the other zone to the selected zone and the ones in the opposite direction is over the 60% of the total number of trips for those two zones, the trip direction is considered to go almost completely from the other zone to the selected one and will have a bright red colour.

The size of the lines is proportional to the total number of trips in both directions, being a greater number a thicker line. There are five different sizes that are decided by using quantiles as border decision points. The way to calculate these quantiles is by ordering the list of total number of trips between the selected zone and all the other zones that connect to it in the visualisation and then taking the points at regular intervals. The values at these points are the boundaries between consecutive subsets and line sizes.

When hovering over a line, information about the link is made available through a modal text area. The information represented is the total number of trips between the two zones and the departures and arrivals from and to the selected zone.
Figure 13. Trip analysis visualisation
5.3 User controls

The user controls are the elements used to tune or adjust the way the visualisation is presented. The main user controls in our visualisation are:

- The city selector, which allows the selection of the city to be visualised.
- The time picker, to select the hour range to visualise.
- The number of trips filter, which allows the restriction of the zones to be visualised to the ones over a certain number of trips.
- The animation button, which starts an animation of the whole day visualisation.

5.3.1 Time selection

The visualisation has a time picker control to select the zones and trips for particular times (one hour ranges). When clicking on the watch button or on the text box area, a menu drops down where the desired hour range to visualise can be selected. One of the elements of the menu is the "full day" option, which allows the selection of the whole day activity instead of the hourly based. When a time range or the ‘FULL’ option is selected, the map overlay will change to represent the information for the zones and trips of the selection independently of the zoom level, zone selection or filters applied.
5.3.2 Number of trips filter

Another interface user control is the filter slider. This control allows the limitation of the number of zones that are visualised based on the total number of trips (both incoming and outgoing) per zone. The slider has a range that goes from zero to the maximum number of trips for the currently selected hour range. The visualisation will only show the zones that have a number of trips higher than that selected on the filter. When clicking and dragging the slider button holding the mouse button, the number of trips threshold (in orange colour) will change. Once the desired number of trips is reached, the mouse button can be released and the visualisation will change to only represent the zones that have a number of trips over that selected number. In Fig. 16 it is shown an example where it can be appreciated how the number of zones decreases when filtering the total number of trips per station to at least 40. The visualisation maintains the filter when using zoom or clicking on zones. However if the time picker control is used, the filter slider is reset to 1.

![Figure 16. Time selection](image)

5.3.3 Animation

The animation control plays the evolution of the visualisation over the 24 hours of the day, starting at 00:00 and ending at 23:00, with a 2 second delay between hour representations. To start the animation the "play" button needs to be pressed. Once pressed, the animation starts and the user controls are deactivated until it finishes. The animation can be launched at any zoom level and with the visualisation of all the zones or with a selected zone. Zooming and zone selection can also be performed while the animation is running.

![Figure 17. Animation](image)
5.3.4 City selection

Three cities are part of the EUNOIA project: Barcelona, London and Zurich. By clicking on the city selection bottoms each city results can be visualised. We can switch the city that we want to visualise by pressing the city buttons. By doing so, the visualisation will center the map in the selected city and represent its corresponding zones (see Fig. 18).

Figure 18. City selection options