VISUALISING ACCESSIBILITY: AN INTERACTIVE TOOL AND TWO APPLICATIONS TO EMPIRICAL CASE STUDIES OF URBAN DEVELOPMENT AND PUBLIC ENGAGEMENT

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1. INTRODUCTION

While a substantial body of literature exists on the theoretical definitions and measures of accessibility, the extent to which such measures are applied into practice to assess project alternatives is less frequent (Geurs and Van Wee, 2004). Recent studies affirm that one of the main barriers to the usability of accessibility measure is the lack of visualisation quality and mapping tool for accessibility representation (te Brömmelstroet et al, 2014), while visualisation tools are commonly recognised as the most effective methodology to facilitate knowledge sharing, particularly in those processes involving public stakeholders and non-experts with different expertise.

Starting form this consideration, this paper presents an application of the Interactive Visualisation Tool, named InViTo (Pensa and Masala, 2014a; 2014b; Pensa, et al., 2014; Pensa, Masala and Lami, 2013; Pensa, Masala and Marina, 2013) able to generate maps of the level of perceived accessibility (i.e. "desirability") of different urban areas. Desirability is here computed as the perceived level of access to different urban items as transport supply (metro and rail stations, public transport stops, parking) and urban activities such as hospitals, schools, museums. In this respect, the concept of desirability encompasses a measure of accessibility to several urban facilities, and the perception that residents of the study area have of such facilities.

The InViTo tool allows to build up maps of desirability interactively, by making selection of the chosen items and by giving differential weights to each items. This makes the tools powerful and very useful particularly when discussing and showing analysis results to stakeholders, who could have the opportunity to see in real time the results of different scenario alternatives and assumptions.

1

In the paper two applications are presented. The first one to the empirical case study of Rome, presents the steps to undertake in order to apply the tool: from data gathering, maps coding, and results representation. The second application aims at exploring the potential usability of the tool in engaging public stakeholders into the assessment of different urban development options. Furthermore, the results of a workshop held in Turin, in which public and private stakeholders were interactively involved, are discussed.

The paper is organised as follows. In section 2, an overview of the InViTo tool is given with a focus on its applicability formeasuring accessibility. In section 3 the results of the two InViTo applications are discussed. Conclusions are drawn in section 4, with an outlook to undergoing research issues.

2. APPROACHING SPATIAL ISSUES: INVITO AND THE ACTIVE EXPLORATION OF DATA

The latest version of the Interactive Visualisation Tool (InViTo) proposes a simple web interface conceived for supporting users in the interactive exploration of spatial data. The main task of the tool is providing a structured framework for facilitating users in accessing and interrogating a georeferenced spatial thematic database. Furthermore, the tool can be used for investigating the effects of decision makers' choices on urban and regional areas. In this respect, InViTo can be considered as a spatial Decision Support System (sDSS), which works with GIS data in order to analyse, manage and evaluate their spatial meaning on a territorial system.

InViTo is a platform, based on free and open web technologies such as Google Maps and Google Fusion Tables, for visually managing and exploring georeferenced data. Since its framework is very flexible, this platform can be used to study a wide variety of spatial issues, ranging from urban planning to transport, social and economic issues. It works in real time and create different kind of visualisations that aim at facilitating the comprehension of users on particular projects or case studies.

The structure of the tool is designed in order to consider a large number of variables on the basis of a spatial issue at the same time. Each variable has a spatial effect which is defined by a customised model that relates GIS data with a particular behaviour on spatial areas. Therefore, InViTo is suitable to multi-criteria analysis, offering a visual method for describing the localisation and

intensity of both the positive and negative effects on land due to specific planning choices.

2.1 InViTo potential users

InViTo can be used by two different typologies of users: "power user" and end-user. The first one can use the tool for building a spatial model in the back-end of the tool. In this case, the user has to import GIS data into a specific WebGIS tool, and organise the data on the basis of the case study goal. The power user has to decide which are the possibilities left to end-users, i.e. the second typology of user. Therefore, the power user has to define the data analysis pattern, the data typology and the cluster the data have to be grouped in. The tool requires geo referenced data for each item, then missed localisation should be restored or provided. In addition, the power user can decide the mathematical functions needed for processing the variables, so that he/she has to assign to each analysis data a specific function which could spatially describe its influence on the area. For instance, in order to describe the spatial behaviour of a bus stop, a curve has to be set to describe the positive influence of a bus stop on the calculation of urban accessibility to public transport. In some urban areas, this influence can be processed as a radial positive effect, that decreases with the distance until reaching a radius of 500m, where the bus stop does not present any more benefit.

All these settings generate a spatial model which can be used to analyse and evaluate a specific spatial issue. The results of power user's settings are then edited on a single web page. The web page is the interface for the second typology of user, the final user, who works only on the front end. This user interacts with the already built model through a menu of the web page, but he/she cannot modify the spatial model.

The interface of InViTo is organised on two vertical frames (Figure 1).
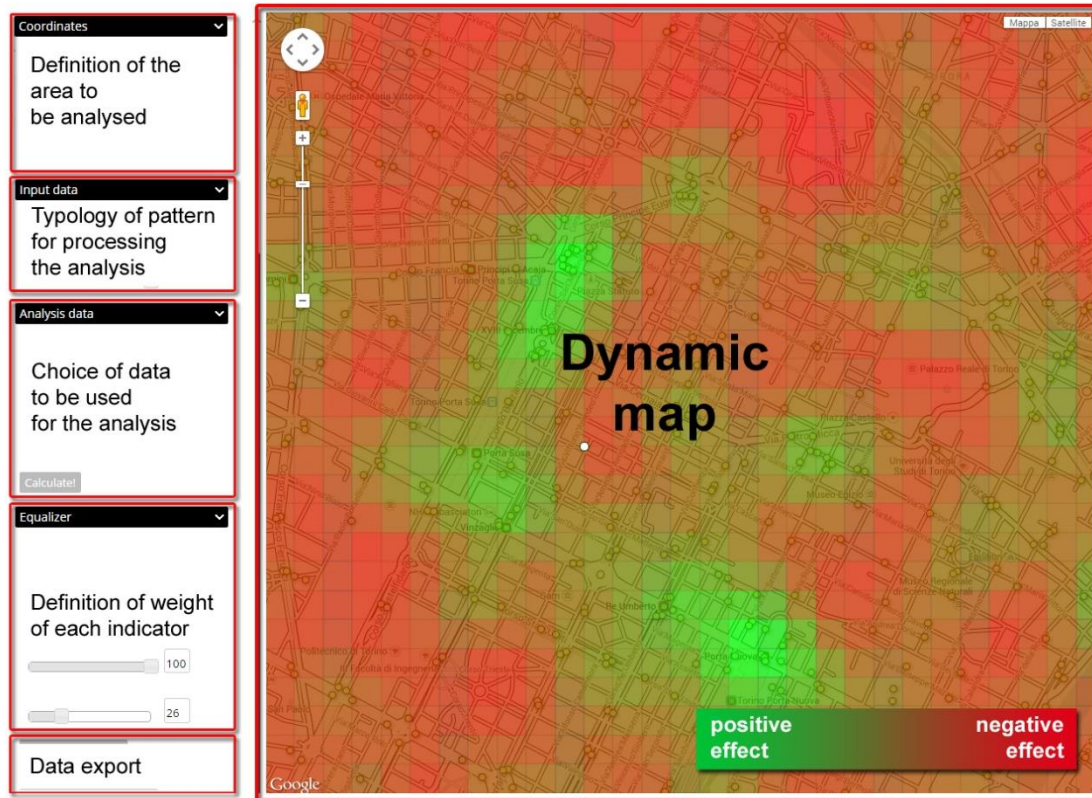
Figure 1: Web interface of InViTo organised in two main frames: the menu on the left side, a dynamic map based on Google Maps on the right side.

The frame on the left side contains the menu and all the settings of the model, while the frame on the right side is larger and displays a dynamic map based on Google Maps. The menu frame works as a guideline for users, who have to follow a sequence of actions.

As first step, users have to set up the area to analyse. Thus, the centre and the radius of a geo-positioned circle have to be drawn on the map. The second step consists on defining the pattern by which the studied area should be divided and processed: users can choose between a regular squared grid or another specific patterns depending on the case study. The third step consists in choosing which kind of data are to be used in the analysis. Thus, through a checklist, the final user can select the input data useful for achieving the goal of the planning issue. At this moment, input data need to be processed and the final user has to run their calculation, a process which can range from few seconds to some minutes, depending on the number of record selected. When the calculation is finished, a new window on the menu appears for allowing users to set the weight of each spatial element. Accordingly to user's settings,

the map change its shape in real time, thus illustrating where effects are higher or lower. As final step, the user can export the dataset relative to the chosen setting and reuse it in other tools for the management of GIS or database data.

InViTo presents as an easy tool which aims at simplifying the process of analysis and evaluation of spatial data. For this reason, while the back-end user needs some technical knowledge on GIS management, the final user does not need any specific expertise or skills. The front-end interface of the tool can be used by non-expert people, so that InViTo appears suitable for improving the communication value in multidisciplinary meetings, where different actors with multiple capabilities are called to express their opinion and interest.

## 2.2   Application of InViTo to study urban accessibility

InViTo is a tool that can be used for approaching different spatial problems. Its framework is very flexible and can be adapted to study whatever spatial data that work on the basis of a distance. Therefore, InViTo can be used to study spatial issues such as environmental assessments, transport infrastructures impacts or land use zoning effects. In this paper, InViTo is applied as a tool for studying urban accessibility to public facilities.

 InViTo is here used to measure accessibility and it uses and combines spatial data to show in real-time the outcomes of an accessibility model which is based on functions related to the distance. The set up model can be run on the basis of a regular grid pattern which is composed by a cells grid available at different sizes. The model considers several input data that relate, urban facilities, such as green and pedestrian areas, school and universities, hospital or shopping malls, to data referring to transport supply, such as underground and railway stations, motorways junctions or parking facilities. Figure 2, for instance,shows the web interface of InViTo for the model built to study the accessibility to public facilities in the city of Rome, Italy. The figure shows on the left side the list of input data that can be used to analyse the case study: pedestrian areas, motorways, railway surface tracks, shopping malls, monuments, tram stops, hospitals, public gardens, railway stations, underground stations, motorways access points, universities.

Accessibility is here defined as the perceived utility (by urban agents, such as individuals, households or business owners) of living in a given area, depending on the proximity to selected urban items. Each item is studied singularly, in order to estimate the curves of their perceived utility as a function of the distance from each of the considered items. To this aim, disaggregate SP-

surveys need to be carried on, asking residents of the study area to rank the levels of utility (in a Likert scale from -7 to +7) of several urban items located at pre-defined intervals of distance (e.g. 100-250 meters, 250-500 m, etc.).
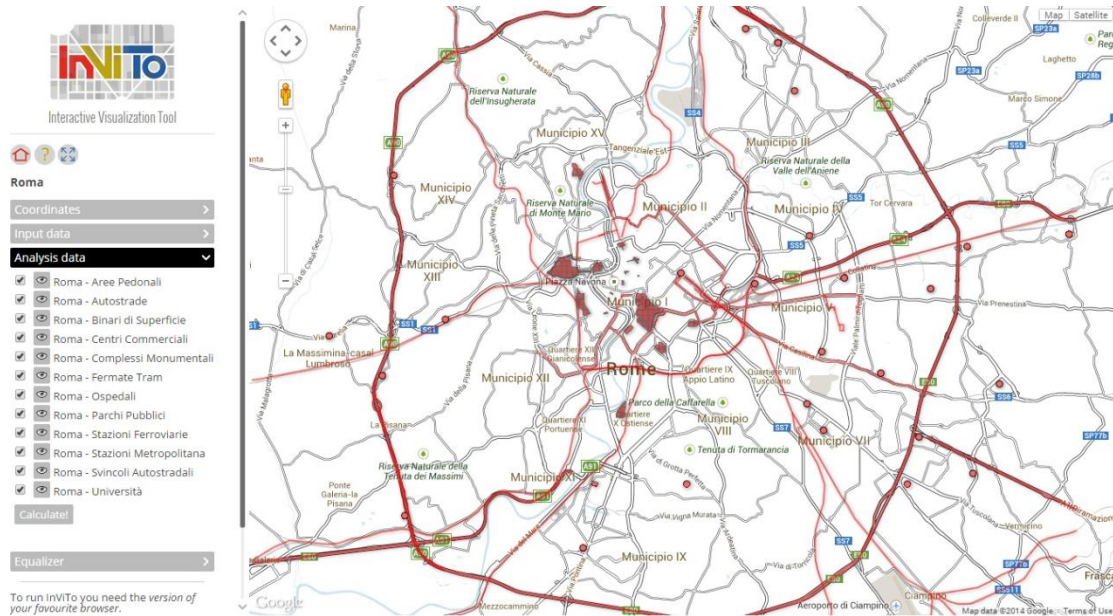
Figure 2: The web interface of InViTo for the model built to study the accessibility to public facilities in the city of Rome, Italy.

The results of these surveys are collected and used to define the curve which describe the influence of each spatial item on achieving the goal of the case study. The curves represent the perceived utility as a function of distance, and allow to analyse the relative importance of items as well as the utility trends with respect to the distance. For example, the utility of residing in a given area results to be decreasing with distance from underground stations or from green areas, whereas it increases with distance for items like motorway junctions, railway tracks, etc., that typically spoil the urban environment due to noise and pollutant emissions, visual intrusion and so on.

For a given cell, accessibility is computed by summing up the utilities or dis-utilities as defined by the mathematical curves. The utility functions are related to each data or family of data, on the basis of the settings of the model. According to multi-criteria methods, InViTo enables final users to assign specific weights to each urban item so to allow the exploration of different scenarios and alternative options. A slider cursor for each urban item allows the weight to be set by the final user. At the same time, weighting the importance of each urban item causes a change in the map, which visualises the results of

the sum of all selected items. Figure 3, for instance, shows the InViTo interfaces for setting weights to be assigned to a number of spatial elements used in the evaluation of the accessibility to urban facilities in the city of Rome, Italy. Each spatial element influence the accessibility map according to its weight, which is set up with a slider cursor on the left side of the page. The visualisation works on a two contrasting colour map, where the green indicates higher values and the red shows where are the lower values. In this way, the visualisation offers a quick way to identify the areas included within specific ranges.

Figure 3:   InViTo interfaces: setting weights and output accessibility maps (red colour = areas with lower values of accessibility; green colour = areas with higher values of accessibility).

3. APPLICATIONS

Two applications of InViTo are presented in this section. The first one aims at showing the steps to undertake in order to apply the tool to an empirical case study. The second application aims at exploring the potential usability of the tool in engaging public stakeholders into the assessment of different urban development options.

3.1   Applicability for urban accessibility analysis: the case study of Rome

This application is finalised to create maps showing levels of accessibility of different urban areas in the city of Rome, as perceived by residents. To this aim the following steps have been undertaken:

- items identification

- database collection and geocoding

- perceived accessibility (or desirability) function estimation

- implementation

3.1.1 Items identification

Items represent those services and facilities of the urban environment whose proximity can affect the accessibility (in either positive or negative way) of a given zone in the study area, and thus the desirability for individuals to live there.

Items are related to both the transport infrastructures and urban facilities. The following items are considered for this application:

- Transport infrastructures: metro and tram stop; train stations, rail tracks,multi-storey parking facilities, urban highways sections, urban highways ramps.

- Urban facilities: green area, pedestrian area, university, monumental complex, hospital, markets and shopping mall.

3.1.2 Data collection and geocoding

Since InViTo works on a geo-referenced system, all data needs a geocoding. Generally, when facing a new case study, many data are available already geo-referenced, but this is not true for specific urban items that, for some particularity of form, function or age, have not a correspondent shape file. In that case, the power user needs to draw or correct some map (Figure 4).

Figure 4: example of geocoding pedestrian area (blue polygons) and monumental complexes (red polygons) in the city centre

By the use of common GIS tool, a GIS technician can draw new polygons, axis or points on geo-referenced maps, so to use the shape files for inputting in InViTo specific items as monuments or new projects.

3.1.3 Accessibility function estimation

The accessibility functions represents how proximity to a given item is perceived by an individual. This is achieved by means of estimated curves where on the x-axis there are several distance ranges from the item, and on the y-axis a proxy of the perceived level of utility provided by that item for each distance range.

The curves are estimated by means of disaggregate SP-surveys, where a sample of residents in the study area are asked to rank, for a given item, the relative levels of utility they perceived (in a Likert scale) at varying item distance ranges (e.g. between 100-250 meters, between 250-500 m, …).

The survey consisted of two parts. In the first part, for a selected item, respondents are asked to assign a value of utility to that item for the following distance ranges: less than 50 meters, between 50 and 100 m, between 100 and 250 meters, between 250 and 500 meters, between 500 meters and 1 kilometre, more than 1 km. The values of such utility can be expressed in a numerical scale, e.g. from -7 to +7.

In the second part of the questionnaire, respondents assign a qualitative value to the importance they perceive for each specific item (i.e. 'very important', "important", "slightly relevant", "indifferent"). The items evaluated as "important" and "very important" are then ranked in order of preference. The questionnaire concludes with collection of socio-economic information of the respondent such as age, gender, professional condition, zone of residence, private vehicles ownerships (cars, motorcycles and bicycles), individual attitudes to daily trips, such as trip- frequency by car and Public transport, number of walking trips and their average duration. This allows to profiling respondents and create a subdivision into subgroups to better interpretation of data and estimation results.

The data collected are filtered in order to obtain a better estimate of the curves of desirability. 115 questionnaires were collected for each item. To improve the estimates, outliers were drop out of the estimation. In total 82 observations were available to estimate the accessibility functions. To take into consideration heterogeneity among respondents, the values of utility for each item expressed by respondents, were normalised with respect to the maximum and minimum rate assigned to each interval of distance.

Figure 5 and 6 give examples of estimated accessibility curves respectively for the considered transportation systems and urban facilities items.
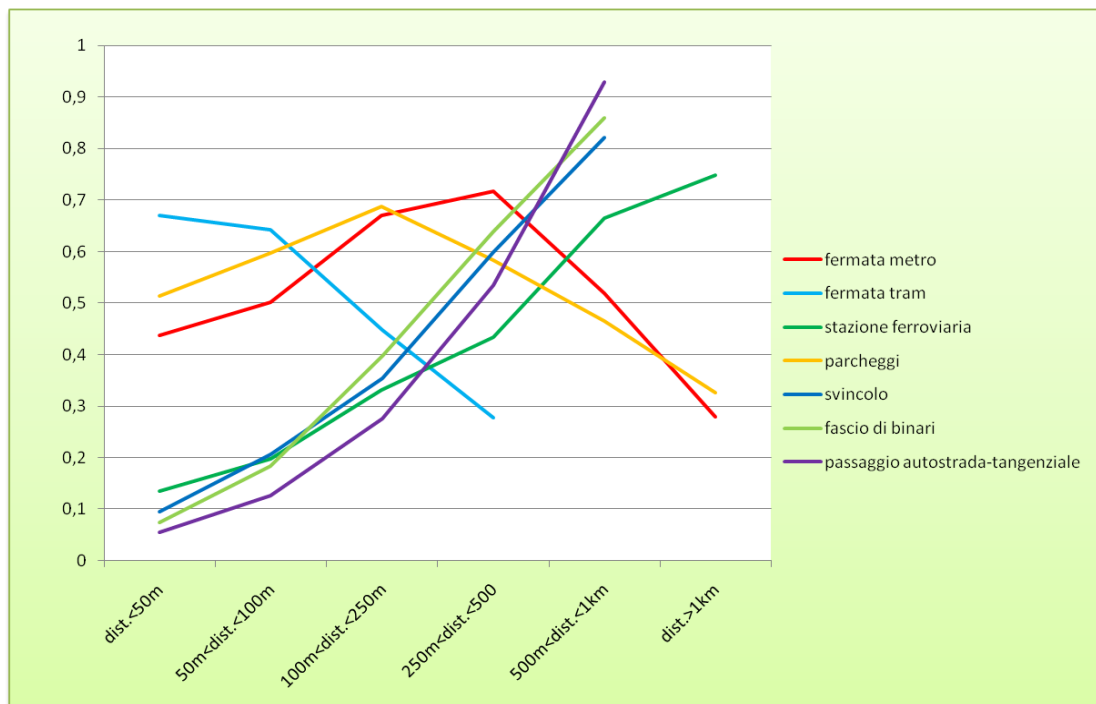
Figure 5:   perceived accessibility curves for transportation systems items.
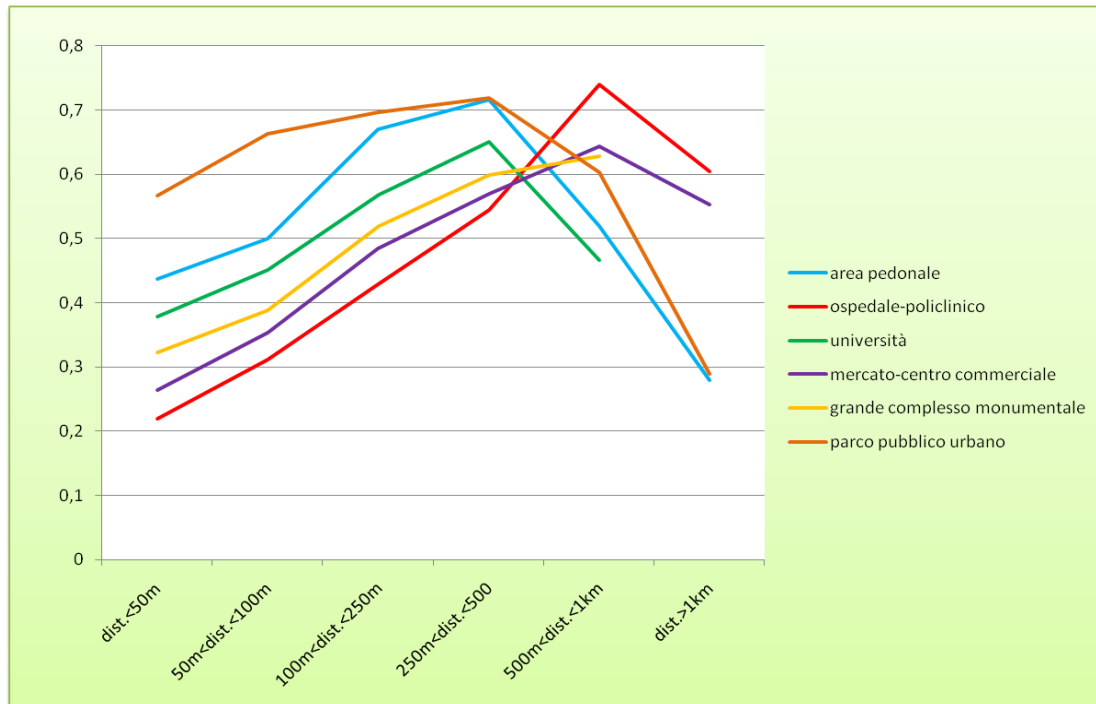
Figure 6: perceived accessibility curves for urban facilities items

Different curves of the perceived accessibility for each item, are estimated for different clusters of residents (e.g. students, employees).

3.1.4 Implementation

In the last step of the application, data collected by the survey are included in the back-end platform of InViTo as mathematical curves that describe the behaviour of urban items. These curves generate a dynamic map which is visible in the InViTo web page. Based on the Google Maps viewer, the map can be zoomed and moved so to allow final users to explore the outcomes of the calculation.

Accordingly to the weights given to each urban item, the map changes in real time, showing the localisation of different values, ranging from the lowest (in red) to the highest (in green). The weights are chosen by the final user either under a collective or individual perspective. In doing so, maps represent the outcome of a specific planning choice and can be used to evaluate if the effect of this choice is coherent with pursued goals.

In the specific case study of Rome, the more desirable zone of Rome are those of the city center between the Colosseum and Nomentana (Villa Torlonia) as

depicted in the above Figure 3 representing the overall desirability (i.e. summing up zonal desirability of all the considered items) of the zones of the study area.

To implement the information provided by the maps, the final user can change the level of detail of the representation through modifying the pattern of analysis. For the case of Rome, three different grids have been set up to perform the analysis: the first is a regular grid 100m by side centred on Porta Maggiore in Rome; the second one is again centred in Porta Maggiore but the cell size is 50m by side; the third one is common to all the case studies in InViTo and is defined by the final user by drawing a circular area which can be divided in a number to base 4 (e.g. 4, 16, 64, 256, and so on), which size cell depends on the circle radius set up by the user.

3.2   Usability in a Public Engagement context: the case study of Turin

Although InViTo is not expressly created as a tool to measure accessibility, its characteristics have proved to be quite appropriate to this aim. In particular, it showed to be particularly suitable for supporting decision processes involving stakeholders with different level of knowledge. In this respect, during the COST Action TU1002 - "Accessibility Instruments for Planning Practices", in July 2013 InViTo was used by the Turin Work Unit for carrying out a workshop aimed at evaluating the real usability of the tool within planning and decision processes.

The workshop involved, in addition to the 4 members of the Turin Work Unit, a panel of 8 experts, 4 urban Planners and 4 transport Planners, with different backgrounds (such as academics, public administrations or consultants). The case study identified was the north-east quadrant of Turin, an area characterised by large brownfields, poor quality residential areas and existing or new mobility infrastructures in the process of redefining. The main topic proposed for the discussion was the route of the new subway line and its relationship with the urban context in which it is located. All invited participants were familiar or with the theme, if not directly involved in the process of transformation taking place, and were asked to discuss about the benefits of three different routes, in term of accessibility then considering land use as a key element in guiding the choices in infrastructure.

The aim of the workshop was to evaluate to what extent a complex and highly debated issue can be faced through the planning support tool. The workshop took place following a specific protocol, defined within the COST Action, which included the 4 following steps:

- Conceptualising accessibility;

- Collectively mapping, measuring, interpreting and analysing the conception of accessibility;

- Understanding changes in accessibility as a result of interventions;

- Designing integrated solutions/strategies.

By setting specific indicators on different scenarios concerning both transport infrastructures and urban transformation, participants created a number of maps, which described the effects on urban area for each main scenario.

The possibility of visualizing in real-time accessibility levels for changing scenarios was considered extremely positive. Some results were considered predictable from expert practitioners, who suggested that the instrument would be more indicated within participatory processes open to non-expert public. However, more than the outcomes produced, the most important result achieved during the workshop was the high level of involvement of participants in discussing the different scenarios. In fact, the main objective of the tool is not to provide one solution but to feed the debate around issues concerned the case study.

Another discussion produced interesting indications on how the tool could be implemented to be as useful as possible in supporting decision-making processes. Moreover, useful comments on usability of InViTo were collected, as well as useful suggestions on possible area of improvement, such as classification of public transport stops based on number of lines and their frequency, the possibility of considering urban quality in the model or the inclusion of bike sharing as a part of the transport system.

4. CONCLUSIONS

In this paper an application is presented of the Interactive Visualisation Tool, named InViTo, to generate maps of the level of perceived accessibility (i.e. "desirability") of different urban areas. Accessibility is here computed as the perceived level of access to different urban items as transport supply (metro and rail stations, public transport stops, parking) and urban activities such as hospitals, schools, museums.

In the application to the empirical case study of Rome, InViTo shows its flexibility to be adapted to different spatial issues, offering multiple uses. This allowed to validate the use of the tool to measure accessibility and produce accessibility maps of urban scenarios, easy to be managed and understood also by non-expert end-users.

Through the creation of dynamic maps, InViTo can offer visual supports for enhancing the discussion among transport and urban planners. In fact, visual meaning to the accessibility concepts has resulted to be effective, during a workshop carried out in the framework of the COST Action TU1002 on Accessibility Instruments usability. Here InViTo enabled the discussion and supported argumentations through the creation of shared knowledge.

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