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Estimating and visualizing perceived accessibility to transportation and urban facilities

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Abstract

In this paper we present some estimated functions of residential location utility, perceived by individuals, varying with the distance from selected transportation and urban facilities, such as metro and train stations, highway and road junctions, as well as hospitals, green spaces and leisure centres. By summing up such functions we get a measure of the overall convenience of residing in different zones of a given study area, that we call "perceived accessibility". The functions, estimated by means of SP-surveys, have been implemented into an accessibility Interactive Visualisation Tool (i.e. InViTo) and applied to case study of Rome (Italy). The application allows to validating the use of interactive visualization tools to measure accessibility and its potential usability to produce easy-to-read accessibility maps of urban scenarios of urban development.

Keywords: geo-visualisation, dynamic accessibility maps, Planning Support Systems (PSS), SP-surveys.

1. Introduction

While a substantial body of literature there exists on the theoretical definitions and measures of accessibility (Geurs and Van Wee, 2004), the extent to which such measures are applied into practice to assess project alternatives is less frequent (Hull et al., 2012). Recent studies affirm that one of the main barriers to the usability of accessibility measure is, among others, the lack of mapping tool for accessibility representation (Papa et al., 2017), whereas visualisation tools are commonly recognized as the most effective methodology to facilitate knowledge sharing, particularly in those processes involving public stakeholders with different expertise (Brömmelstroet et al., 2014).

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Starting form this consideration, this paper presents an application of the Interactive Visualisation Tool, named InViTo (Pensa and Masala, 2014a; 2014b) able to generate interactive and dynamic maps of accessibility. Accessibility is here defined as the overall location utility, perceived by individuals, computed as a function of proximity to different transportation and urban facilities, such as metro and rail stations, public transportation stops, parking, as well as hospitals, schools, museums. With respect to the approaches proposed in the literature (see for instance, Coppola and Nuzzolo, 2011; Ibeas et al, 2012) which introduce a zoning of the study area and compute the attributes for each zones, InViTo allows to assuming a continuous space representation and computing attributes at a micro-level. To this aim, the utility functions include attributes varying with the distance to the considered facilities. In fact, accessibility is computed by summing up some the attributes of the residential location utility, expressed as a function of the distance from a given facility. Such curves are estimated by means of disaggregate SP-surveys.

The paper is organized as follows. In section 2, an brief overview of the InViTo tool is given with a focus on its capability of building up maps of accessibility interactively, by making selection of chosen facilities and by giving differential weights to each of them. 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. In section 3, the estimated curves of the (utility) attributes varying with distance are presented and an application to the empirical case study of Rome is presented focusing on the three steps to operationalize the tool: data gathering, maps coding, and results representation. Conclusions are drawn in section 4, with an outlook to undergoing research issues.

2. InViTo: an interactive and dynamic tool for visualizing accessibility

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 (Pensa and Masala, 2014b). 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 customized 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 (Pensa and Masala, 2014a).

The tool can be used for building a spatial model of a given study area. To this aim, the first step is to import the GIS data of the relevant variables into a specific WebGIS tool, and organise the data based on the objective of the analysis. Each analysis variable needs to be geo-referred.

In addition, to each variable a specific functions which spatially describe its influence on the area, have to be specified. For instance, in order to describe the spatial influence on residential location of a train station, a curve has to be set up to describe positive impacts (e.g. high connectivity) as well as the negative ones (.g. those due to induce traffic or congestion) in the proximity of the station. In fact, the influence of a transportation or urban facility (e.g. a rail station) may have typically a radial positive effect that decreases with the distance to zero at a given distance threshold, where its benefits are no more perceived (Fig. 1, left-hand side graph). On the other hand, there are cases (e.g. a road junction) in which the facility can generate congestion or traffic-related externalities, such that it is perceived negatively in the immediate proximity and positively after a given distance threshold (Fig. 1, fight-hand side graph). In order to specify such functions, the InViTo tool allows for including basic functions as well as complex models taking into accounts also railways scheduled services in the station (see, for instance, Cascetta and Coppola, 2016).

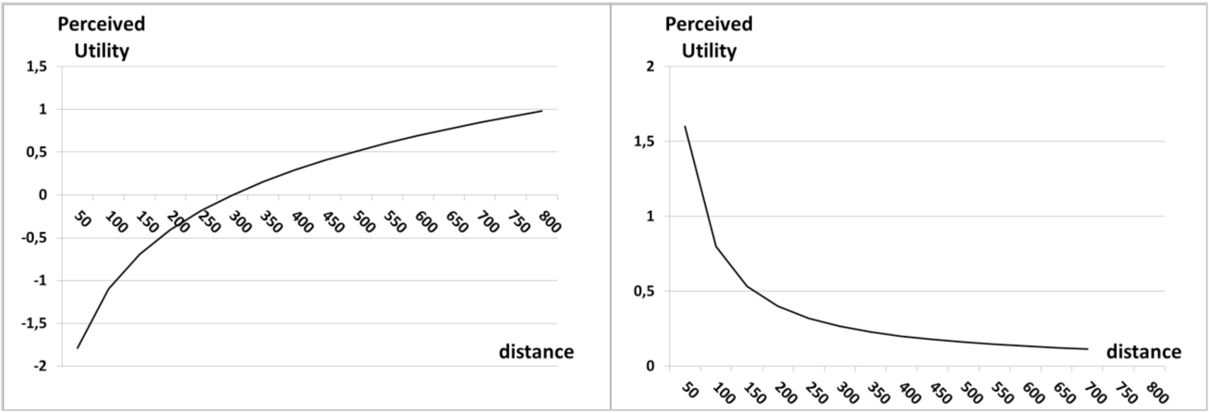

Fig. 1 - Examples of perceived utility functions varying with distance, w.r.t. given transportation and urban facilities.

All the above settings are edited on a single web page interface, organized into two vertical frames (Fig. 2). The frame on the left-hand side contains the menu and the model settings, whereas the frame on the right-hand 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.

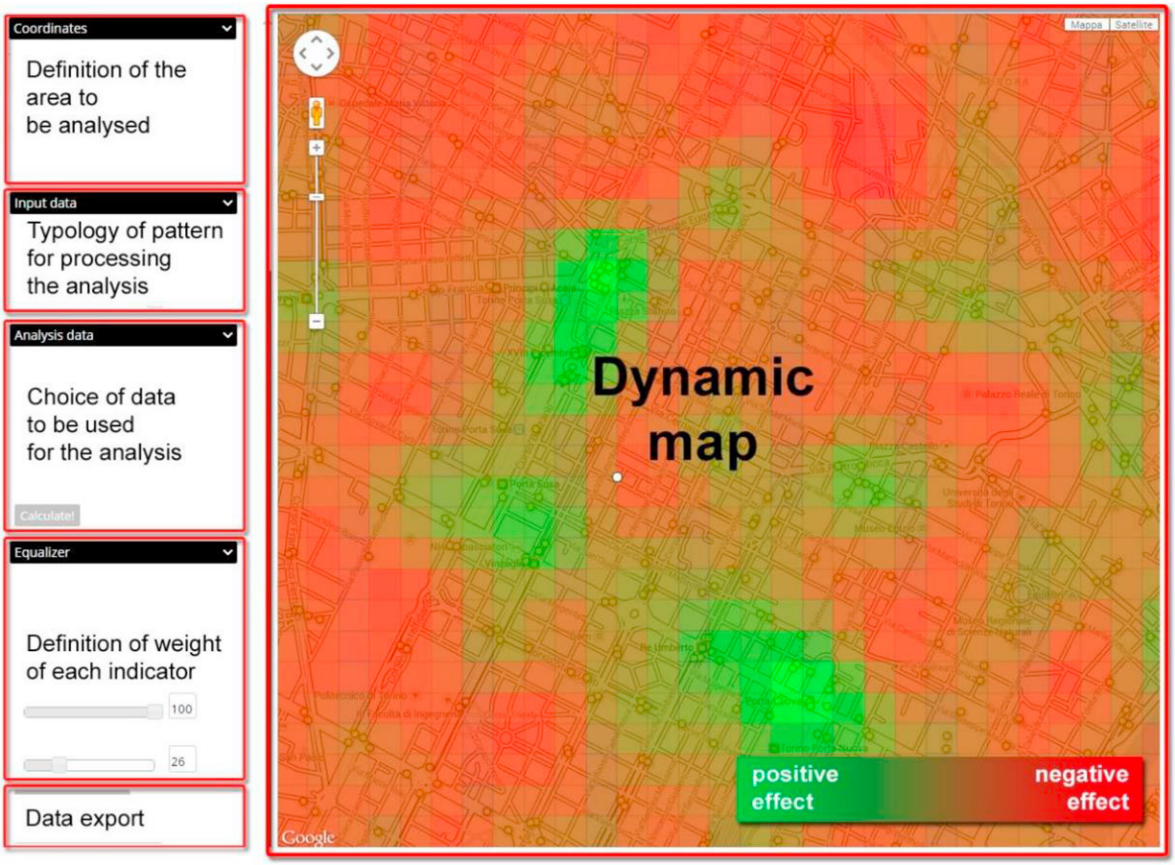

Fig. 2 - Web interface of InViTo (source: Pensa and Masala, 2014a).

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 and other specific patterns at different sizes, depending on the case study.

The third step consists in choosing which kind of data are to be used in the analysis. The model considers several input data related to urban facilities, such as green and pedestrian areas, school and universities, hospital or shopping malls, and to transport supply, such as metro and railway stations, motorways junctions or parking facilities. Each item is studied singularly, in order to estimate its perceived utility as function of the distance. The utility functions are related to each data or family of data, based on the settings of the model. For a given cell, accessibility is computed by summing up the utilities or dis-utilities as defined by the mathematical curves.

Final users are enabled 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 facilities. Thus, through a checklist, the final user can select the input data useful for achieving the goal of the planning issue. 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 (Pensa and Masala, 2014a)..

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 based on a distance. Therefore, InViTo can be used to study spatial issues such as environmental assessments, transport infrastructures impacts or land use zoning effects. While tool developers need some technical knowledge on GIS management, the final user does not need any specific expertise or skills. Even non-expert people can use the front-end interface of the tool, this makes it suitable for improving communication value in multidisciplinary meetings, where different actors with different expertise and backgrounds are called to confront and express their opinion.

3. Application to the urban case study of Rome

This application is finalized 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:

- Transportation supply and urban facilities identification;
- Database collection and geocoding;
- Perceived accessibility functions estimation;
- Implementation.

3.1. Facilities identification

Facilities represent those elements of the urban environment whose proximity can affect accessibility (in either positive or negative way) and thus the utility perceived by individuals to live there (Coppola and Nuzzolo, 2011; Ibeas et al., 2012). Facilities are related to both the transportation supply and urban amenities. The following facilities 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.

Figure 3 shows the web interface of InViTo for the model built up to study accessibility in the city of Rome. On the left-hand side the list of input data that can be observed, i.e. pedestrian areas, motorways, railway surface tracks, shopping malls, monuments, tram stops, hospitals, public gardens, railway stations, underground stations, motorways access points, universities.

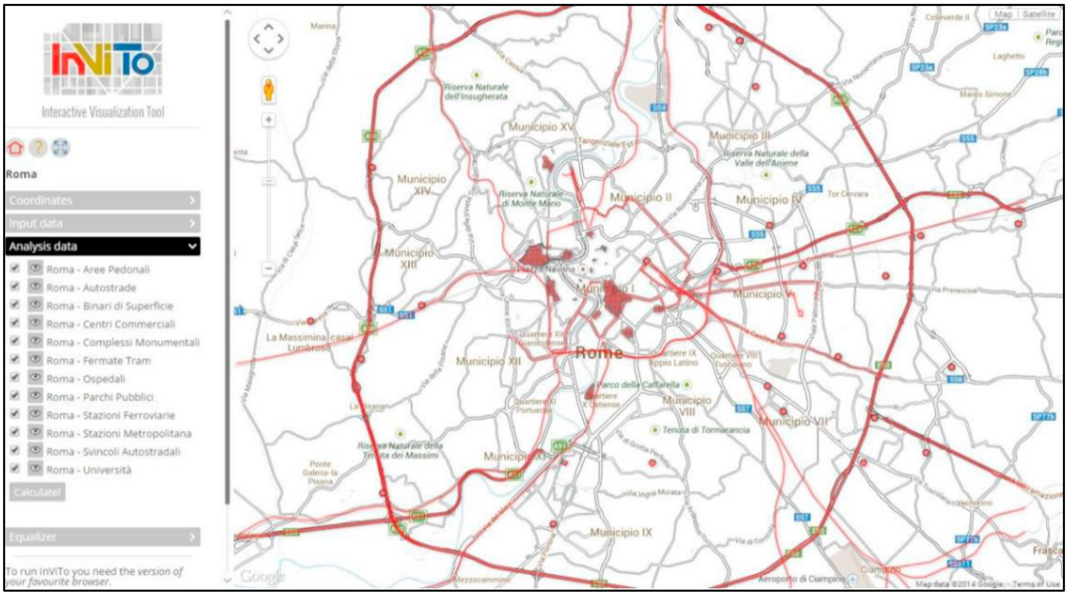

Fig. 3- The InViTo web interface of for the model built up for the urban area of Rome.

3.2. 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, but this is not true for specific urban facilities that, for some particularity of form, function or age, have not a correspondent shape file. In such case, specific map elements as monuments, pedestrian areas, and so on need to be drawn as polygons, axis or single points (Fig. 4) on geo-referenced shape files and uploaded onto InViTo.

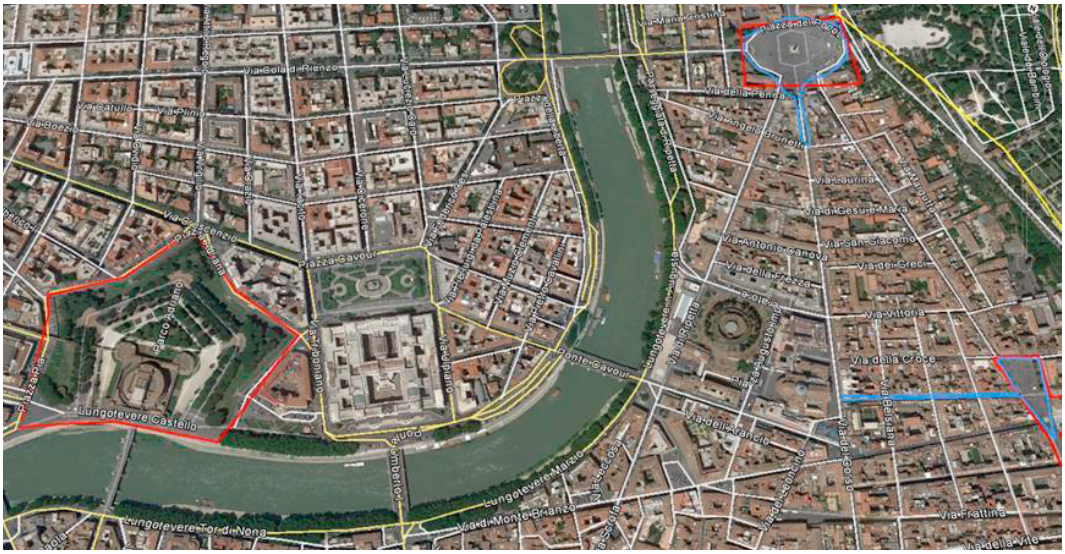

Fig. 4 - Example of geocoding pedestrian area (blue polygons) and monumental complexes (red polygons) in the city centre.

3.3. Accessibility function estimation

Accessibility is here defined as the overall location utility, perceived by individuals, computed as a function of proximity to different transportation and urban facilities. The estimation is achieved by summing up attributes expressed as function of distance to the considered transportation supply and urban facility.

The functions are estimated by means of disaggregate SP-surveys, where a sample of residents in the study area was asked to rank, for each given facility, the relative levels of perceived utility at varying distances.

The survey consisted of three sections. In the first section, for a selected facility, respondents were asked to assign a value of utility (expressed in a numerical Likert scale from -7 to +7) to that attribute 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. In the second section of the survey, respondents assigned a qualitative value to the importance they perceive for each specific facility: 'very important', “important”, “slightly relevant”, “indifferent”. The facilities evaluated as “important” and “very important” were then ranked in order of preference. The questionnaire concluded with the 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 allowed to profiling respondents and create a subdivision into subgroups to better interpretation of data and estimation results.

Data collected were filtered in order to obtain a better estimate of the curves of desirability. For each attribute 115 questionnaires were collected . 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 expressed by respondents were normalized with respect to the maximum and minimum rate assigned to each interval of distance.

Figures 5 shows some examples of the estimated attributes functions for the considered transportation supply facilities.

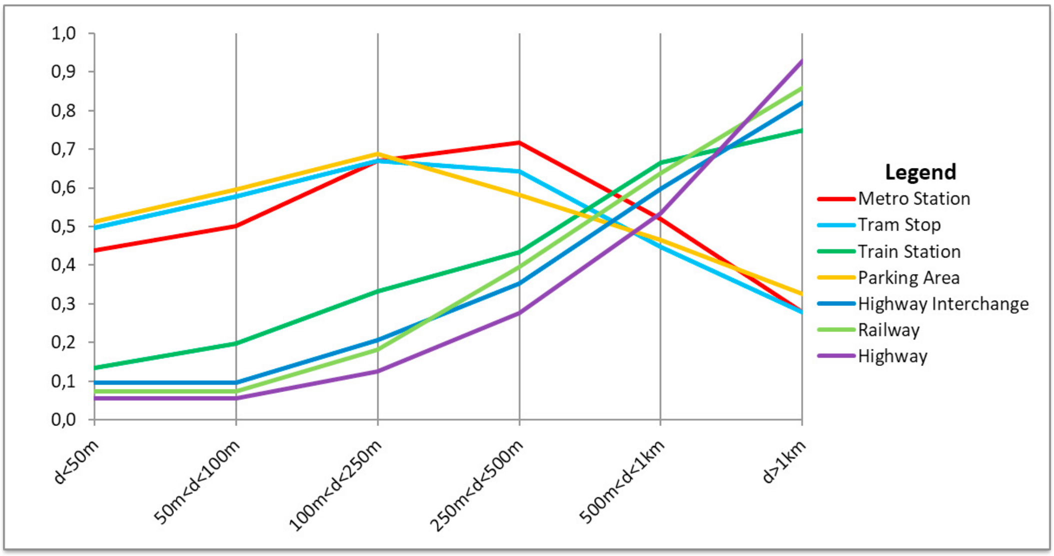

Fig. 5 – Perceived utility of transportation facilities varying with distance.

It can be observed that, within a range of 1 Km, the value of utility related to highways and railways is increasing with distance, meaning that proximity to such transportation infrastructures is negatively perceived by individuals in terms of residential location utility. This happens also for Train station, however this results is very case specific, provided that the areas around the main train station in Rome are very congested and present a spoiled urban texture. On the other hand, facilities such as metro stations and tram stops and parking facilities show an optimal perceived distance from home in a range of 100-500 meter.

Figures 6 shows some examples of the estimated attributes functions for the considered urban facilities. It can be observed that, within a range of 1 Km, the value of utility related to monumental complexes is increasing with distance, meaning that proximity to such urban facilities is negatively perceived by individuals, possibly due to the high level of congestion and flows of tourists they generate. On the other hand, facilities such as public green areas show an optimal perceived distance from home in a range of 0 to 500 meter, whereas hospitals university shopping centers shows an optimal perceived distance from home in a range of 500 meters to 1 km.

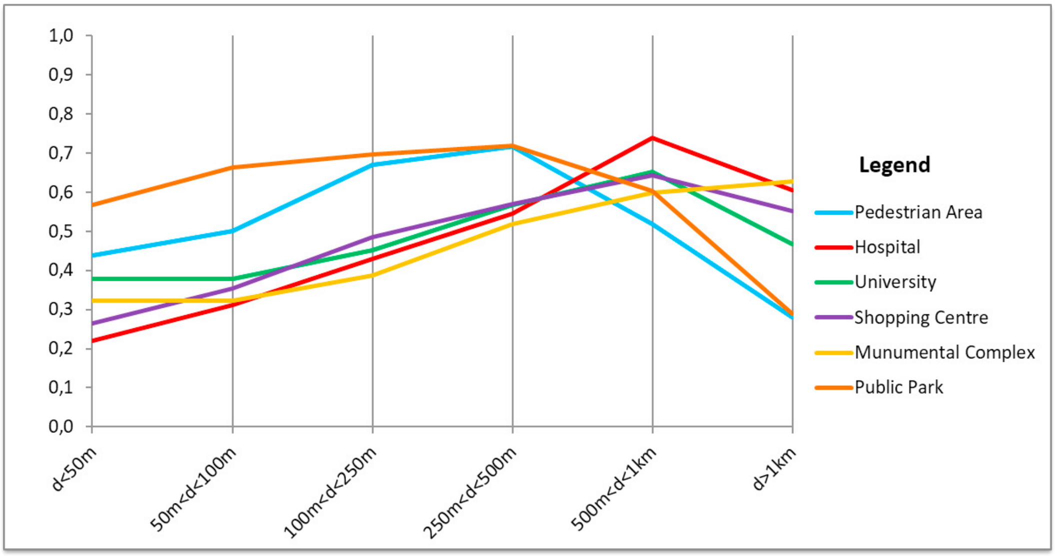

Fig. 6 - Perceived utility of urban facilities varying with distance.

Moreover, different attributes functions were estimated for different clusters of residents (e.g. students, employees) with respect to a given specific facility. For instance, Figure 7 shows different curves of the perceived utility of proximity to a metro station for different clusters of individuals, segmented according to trip frequency by car:

1. never use the car;
2. use the car once per week;
3. use the car few days per week;
4. daily use of the car.

It can be observed that the higher car use the lesser users value proximity to a metro station: travellers that never use the car show an optimal perceived distance from home in a range of 50 to 250 meters, whereas travellers that use the car more frequently show an optimal perceived distance from home in a range of 250-500 meters.

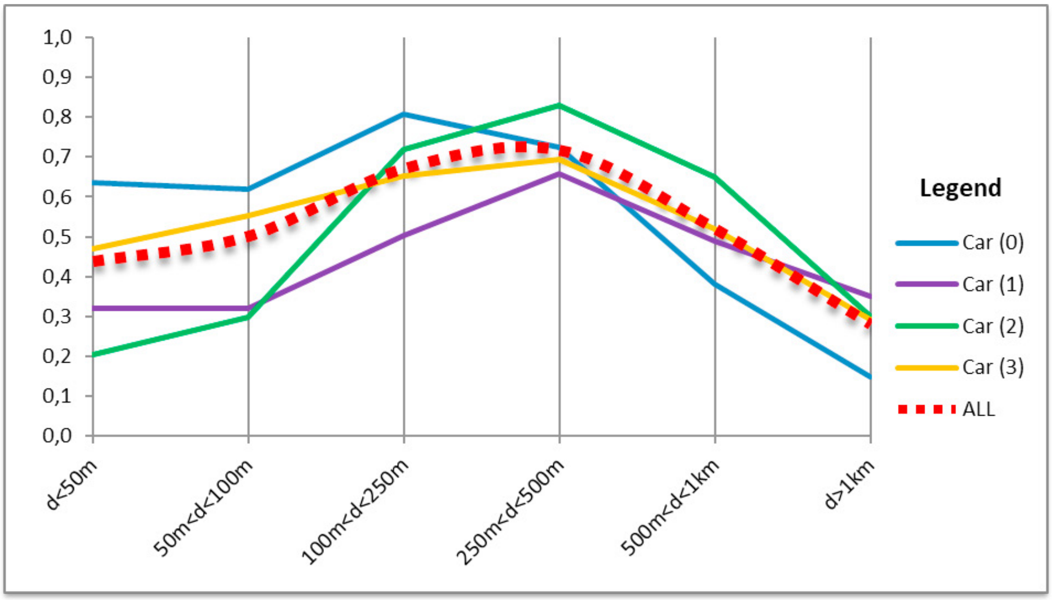

Fig. 7 - Perceived utility of a metro station varying with distance for different users clusters segmented on car use frequency: car (0) = never ; car (1) = once per week; car (2) = few days per week; car (3) = daily use of the car.

3.4. Implementation

In the last step of the application, the estimated function were included in the back-end platform of InViTo as mathematical curves that describe the behaviour of transportation and urban facilities. These curves generate a dynamic maps showing the perceived accessibility of different areas, ranging from the lowest (in red) to the highest (in green). Using Google Maps viewer, maps can be zoomed and be moved so to allow final users to explore the outcomes of the calculation. The generated maps can be modified real-time by changing the weights given to each of the considered facility. For the specific case study, two different grids centred in Porta Maggiore (i.e. approximately the geographic center of the urban area) with a regular grid of 100 m and by 50m by side.

The weights, ranging from 0 to 100, are chosen by the final user either under a collective or individual perspective. In doing so, the maps may represent the outcome of specific planning exercises and can be used either to assess the output of specific policies with respect to predefined strategic goals or in before and after analysis of specific intervention on the transportation networks (Cascetta et al., 2013; Cascetta and Coppola, 2015). Results show (Fig. 8), for instance, that for a specific set of assigned weights (Railways = 0; Shopping mall = 42; highway junctions = 28; Green public areas = 32; Hospitals = 46 ; Railways stations = 0; Metro station = 42; tram stops = 24; University = 41; Pedestrian areas = 0) the area of Rome perceived as more accessible lay between the Colosseum and Via Nomentana (Villa Torlonia).

Fig. 8- InViTo interfaces: setting weights and output accessibility maps (red colour = areas with low values of accessibility; green colour = areas with higher values of accessibility).

4. CONCLUSIONS

In this paper an applications of the Interactive Visualisation Tool, named InViTo, to generate maps of the level of perceived accessibility of different transportation and urban facilities, is presented. Accessibility is here defined as the overall location utility, perceived by individuals, computed as a function of proximity to different transportation and urban facilities, such as metro and rail stations, public transportation stops, parking, as well as hospitals, schools, museums. The estimation is achieved by summing up attributes expressed as function of distance to the considered transportation supply and urban facility.

The functions were estimated by means of disaggregate SP-surveys, where a sample of residents in the study area was asked to rank, for each given facility, the relative levels of perceived utility at varying distances.

Results showed that proximity to highways and railways infrastructures is negatively perceived by individuals in terms of residential location utility. This happens also for Train station, however this results is very case-specific, provided that the areas around the main train station in Rome are very congested and present a spoiled urban texture. Moreover, facilities such as metro stations and tram stops and parking facilities show an optimal perceived distance from home in a range of 100-500 meter. On the other hand, proximity to monumental complexes is negatively perceived due to the high level of congestion and flows of tourists they generate, whereas facilities such as hospitals university shopping centers shows an optimal perceived distance from home in a range of 500 meters to 1 km.

In the application to the empirical case study of Rome, InViTo shows its flexibility through the creation of dynamic maps of accessibility. This allowed validating the use of the tool to measure accessibility and produce accessibility maps of urban scenarios, easy to be managed and understood even by non-expert end-users.

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